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Taiwanese shouldered axes: its function, usage and chronology

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Li-Chi Chiang

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ABSTRACT

The origin of the Yuanshan Culture in Northern Taiwan has long been subjecting attracted major attention by archaeologist due to the particularity of its material culture. That particularity is not shown in the artefacts of other prehistoric cultures in Taiwan, instead, it can be found the similarity from the prehistoric culture(s) in neighbouring areas, such as southeast coast of China. For example, the shouldered axes, one of the artefacts with Yuanshan cultural characteristics. Various opinions of shouldered axe distributions across this area have been given by scholars, but no agreement so far has been drawn the issues of their source, function/usage and cultural significance.

Various scientific approaches have been applied to analyse 127 shouldered axes from twenty-two Yuanshan cultural sites and eight from unknown sites for learning the production techniques and usage/function of the shouldered axes. At the same time, 61 radiocarbon dating data of three material types collected from nine Yuanshan cultural sites have been reviewed to obtain the lower and upper chronological boundaries of the Yuanshan Culture. Analytical results are used to interpret the production technology and usage/function of shouldered axes, as well as the chronology and origin of the Yuanshan Culture.

The chronological analysis based on Bayesian modelling suggests that the date of the Yuanshan Culture is about *c.* 3600-2300 BP. There are two types of rock were

used as raw materials by the Yuanshan people by using pXRF experiments on shouldered axes. One is in the largest number of andesite of the total, the other is the sandstone which represents in three samples. However, the quarry of andesite raw material used by the Yuanshan peopled still cannot be confirmed that it was procured from the Tatun Volcano Group. The angles and forms of shoulders on the shouldered axes have no specific group as techno-typological production standard based on analytical results yielded by the PCA and typological analysis. Some of the types of the shouldered axes are similar to that discovered from the Pearl River Delta and the Indochina Peninsula where the appearance of the shouldered axes is about 6000-2000BP. The use-wear on the shoulder of the shouldered axe is the production marks which were evaluated by both use-wear analysis and replica experiments. Shouldered axes were most likely used as a hafted hoe with a handle in the agronomic activities.

Declaration of original authorship

I confirm that this is my own work and that the use of all material from other sources has been properly and fully acknowledged.

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Chapter 1_ITRODUCTION

1. Research Motivation

This research attempts to learn the possible origin of the Yuanshan Culture based on its distinctive shouldered axe as the beginning. First is to re-examine all the chronological data of Yuanshan Culture and apply the Bayesian chronological modelling to find a reasonable chronological range of Yuanshan Culture. The next step is to source the raw material of the shouldered axes for answering whether it is the andesite procured from the Tatun Volcano Group in northern Taiwan. Finally, it is to understand the production technology and usage/function of the shouldered axes and the purpose of the shoulder element. Several scientific methods and the ethnographic comparison will apply to this study for gathering the knowledge of the shouldered axe and the Yuanshan Culture.

The shouldered axe, also called the shouldered shovel, is a ground stone tool with a narrow head (upper part) and a broad flat blade (lower part) (Table. 1-1, Fig. 1-1). The shoulders, the unique features, are formed on both sides in-between the upper and lower part, and the edge of the blade is slightly curved usually. It is commonly presumed to have been used in turning the soil, coal or other materials upwards in the ground. The shouldered axe is widely found in the traditional rice farming regions around the South China Sea, including Taiwan, China, and Southeast Asia, and dated to 6000-2000 BP (Fu 1988).

Stone tool	Definition
axe	A tool for wood working. Normally has a cutting-edge parallel to the handle (if use handle).
adze	A tool similar to an axe for shaping wood. Normally has a cutting-edge perpendicular to the handle.
shovel	A tool for upturning the soil, coal, etc. Normally has a broad blade.

Table. 1-1 Glossary of the stone tools definition in this study.

Fig. 1-1 A shouldered axe of the Yuanshan Culture discovered in the Chanlugnshan site, 2013. (Jien and Kuo 2013)

In the early nineteenth century, the French orientalist Huber alleged that the shouldered axe is the representative stone implement of Southeast Asia, whilst Heine-Geldern (1932) considered that it is closely related to the ancient South Asian language ethnic group. Sung (1980) undertook morphological comparisons of shouldered axes and stepped adzes. He noticed that shouldered axes are mostly in the form of adze-like shapes in the Indo-China Peninsula, and gradually adopts the axe-form when it is found further to the north in China. The latter is also the pattern of shouldered axes found in Taiwan. The frequency of occurrence of shouldered axes descends in a northwards direction along the Southeast Coast China, and they completely disappear in Central China (Heine-Geldern 1932, Sung 1980). Various opinions of shouldered axe distributions across this area have been given by scholars, but no agreement so far have been drawn the issues of their source, function/usage and cultural significance. (Miyamoto 1939, Shi 1950, Kokubu 1981, Liu and Kuo 2000, Kuo 2014a)

The word shoulder refers to the zone between the upper and lower part of the object, and is deliberately shaped to resemble the shoulder of the human body. The shoulder shape of individual objects is not exactly the same however, shoulder angle or blade edge curvature both vary for instance (Fig. 1-2). In light of their distinctive appearance, it is generally believed among the academic community that the functions of shouldered tools were not just as an axe, and their usage as an adze, shovel and beater can be seen as well in East and Southeast Asia. (Matusmoto 1939, Shi 1950, Kokubu 1981, Wang 1987, Fu 1988, Liu and Kuo 2000) It will be seen from this that the shouldered axes vary in both their usage and morphology. Although there are sporadic, regional classification studies published, systematic studies covering all types of shouldered axes have not yet been established (Fu 1988). Therefore, this thesis will focus on the study of the production techniques, morphology and function of the shouldered axe.

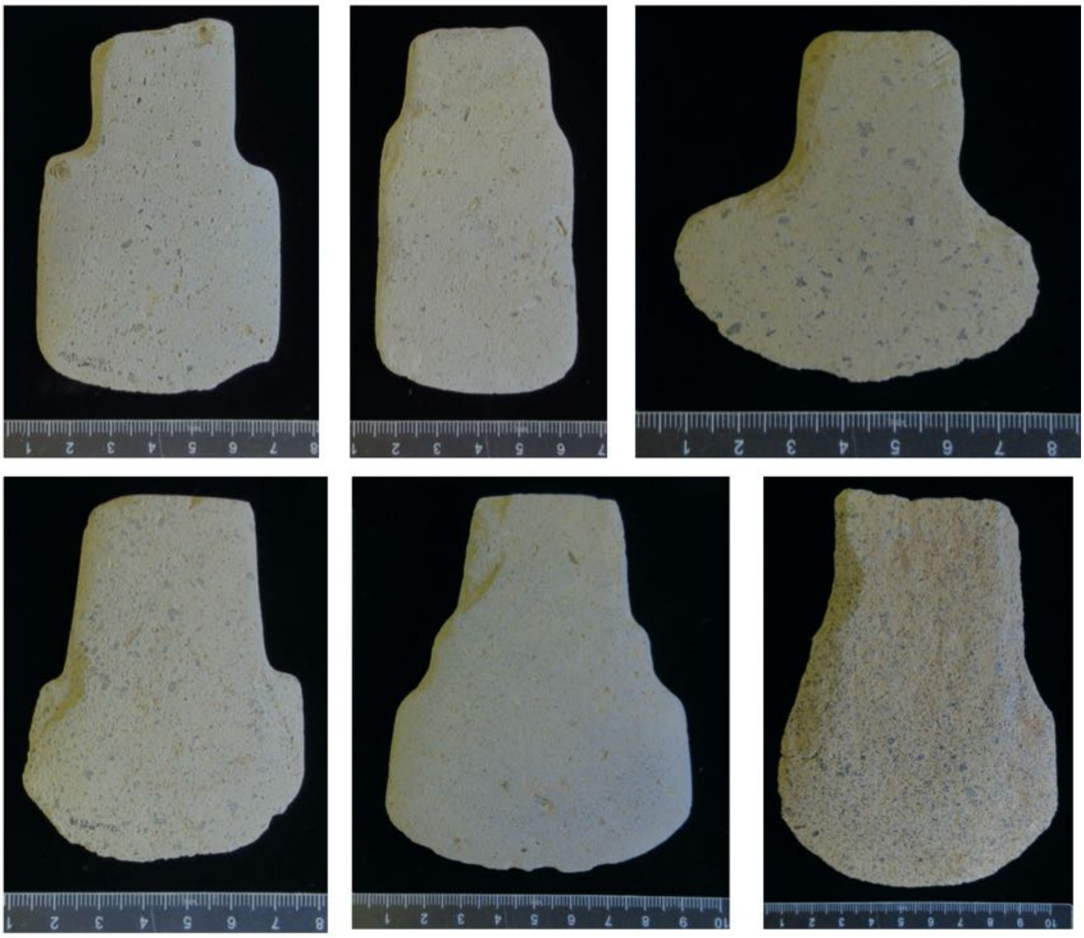


Fig. 1-2 The degree of the shoulder variability. (Shouldered axes from the Changlungshan site, Jien and Kuo 2013) (Photographed by Li-Chi Chiang)

There are not many shouldered axes that have been unearthed in Taiwan. Those that have are particularly concentrated in the prehistoric layers of the Yuanshan Culture, which only exists in Northern Taiwan. For that reason, the shouldered axe is regarded as one of the most unique stone implements of the Yuanshan Culture during the late Neolithic Age. Taiwanese Archaeologists in most cases assume that the usage of shouldered axes is possibly the most Northern boundary in Asia during

Neolithic Age for two reasons: the material culture is highly sophisticated and significantly different from the surroundings, and most of the sites found with shouldered axes are located near the coast or rivers (Huang, 1997), particularly in the Taipei basin area and the north coast region, whereas they are only sporadically found in other regions of Taiwan (Fig. 2-2-2). Because the Yuanshan material culture shows highly mature production techniques and lacks the visible evolutionary processes associated with the prehistoric cultures that occur before and after, it has been argued that the Yuanshan Culture was brought into Taiwan by the people who possessed such material culture from other regions, namely the prehistoric culture in South China. If so, the time of utilisation (1) and the place of origin of shouldered axes (2) have been identified as two of the most important issues in the archaeological studies of Neolithic Taiwan.

However, previous studies have failed to provide powerful explanations for (1) the type of stone used for the shouldered axes and (2) their function(s) of use, such as whether it was only used as an agricultural tool or had a multi-purpose feature. In the lithic studies of Taiwanese archaeology, the discussion of functional applications is mostly based on traditional typology (Ke 2016), and few other research methods have been employed to explore the possible usages of stoneware. Occasionally, experimental archaeological studies exploring the tool user's action or the equipment's performance have been undertaken, but have not been further developed. Shouldered axes, as an unique artefact of the Yuanshan Culture which only existed regionally and solely under the time-frame of prehistoric cultures in

Northern Taiwan, are therefore going to be studied in this thesis by employing multiple scientific-based methods for answering three fundamental questions:

1. its function,
2. its manufacturing technology, including raw material procurement,
3. its chronology

These questions will be addressed through analytical approaches including use-wear, pXRF and phytolith analysis, as well as the experimental archaeology for replicating functional uses. This thesis seeks to address the shortcomings of research in the past and apply the instrumental examination that has not been scientifically tested on any of the shouldered axes before. At the same time, with referencing the ethnographic records as the basis for linking research with analytical results, it is expected that the application of scientific and technological methodologies in this study can offer a foundation for furthering research on the provenance in ancient Taiwan.

2. Problem awareness

The origin of the Yuanshan Culture is a very important topic in the study of prehistoric culture in Taiwan, but the differences between the various discussions have never been resolved and persist in the literature (Table 2-2-3). The preliminary reasons for the scattered opinions may be generalised as follows: First, the misinterpretation of the radiocarbon data in the early days that caused misunderstanding of the chronology of the Yuanshan Culture and confused its relationships with other prehistoric cultures in Taiwan. Second, the inimitable material and cultural characteristics of the Yuanshan Culture are similar to those artefacts unearthed in neighbouring areas, such as Southeast Asia and East Asia. When speculating on the sources of the artefacts by focusing on morphological traits, it has been too easy to focus on the homogeneity and ignore the heterogeneity, for instance in their shapes, colours, dimensions, and weights. The latter data has the potential to reveal that a particular artefact has a specific temporal-spatial affinity. Third, the traditional morphological research system is insufficient: it is unable to construct a wide-ranging research database due to the large differentiations in artefacts from across the districts, which have been obstructing the study of similar objects at a regional scale for years. The shouldered axe is one of the artefact types whose study has been hindered by this kind of artefact research. Fourth, archaeological research is based on the collation and analysis of unearthed materials. The understanding of the Yuanshan Culture is still grounded in a general description of the archaeological materials. Further exploration of a single artefact or phenomenon and a comprehensive comparative study are yet to be developed, hindering understanding of their cultural significance. As one of the representative objects of the Yuanshan Culture, the shouldered axe is an opportunity to to solve the question of the source(s) of the Yuanshan Culture. The shouldered axe therefore forms the core of this thesis, with the key themes being a new investigation of its function/usage, production technology and raw materials procurement.

In the past, the means of usage and the function(s) of the shouldered axe were inferredon the basis of (1) morphological research and (2) their extensive appearances in the agricultural areas around the southeastern part of Asia during the Neolithic period. It is, therefore, a long-standing idea that the shouldered implement is related to the farming activity regionally (Mizuno 1933; Mastumoto 1939; Shih 1950; Obayashi 1982). The Taiwanese shouldered axe is currently supposed to have been used as a hoe for rice cultivation in agricultural activities. There are three grounds for this argument: First, all the prehistoric cultures in Northern Taiwan are viewed to have been engaged in agricultural production, on the basis of the material remains found at several archaeological sites, such as the sties of Chihshanyen and Yuanshan (Huang 1984, Huang 1999a, 1999b). Prior to the Yuanshan Culture period, agricultural activities had evidently occurred for two or three thousand years. Chang (1969, 1981) surmises on the basis of archaeological finds that people were capable of undertaking primitive farming, in the form of root crop cultivation, by using stone hoes and axes at the time around 6,000 B.P.

Second, most of these sites are unearthed with both rice remains and stone knives, while the normal type of axe and hoe also co-existed in the site layers, such as the Chihshanyen site (Huang 1984). Axe and hoe tools also found at the Yuanshan site while only a few rice remains uncovered. (Huang 1999a, 1999b). These artefacts are regarded as farm implements and include the shouldered axe. At the time of the Chihshanyen Culture, a large number of cereal crops, like carbonised rice remains, were unearthed, and all the archaeological items classified as farming tools accounted for a high proportion of the site utensils (Table 1-2). Although there are not many plants remains left in the Yuanshan site, a certain farming capacity of the Yuanshan people has being still believed (Huang 1996, 1999a, 1999b). It is consequently assumed that agricultural activities have been maintained for a considerable period of time in the prehistoric society of the Taipei Basin in Northern Taiwan. Among those tools, stone knives, which are commonly regarded as the tool for grain crop harvesting, are also found in the sites with rice remains, including the Yuanshan Cultural Sites. In addition, with the follow-up research on the shouldered axes employed in agricultural practises, a new theory has emerged due to the remnants of more cultivated crops unearthed from the Yuanshan Cultural Sites (Huang 1984, 1999a, b). That is, the idea suggests that the shouldered axe may be strongly related to rice cultivation activities and this hypothesis is seemly supported by further evidence after archaeological works around 1990s (Huang 1999a, 1999b).

Archaeological site	Prehistoric culture	Date (B.P.)
Chanlungshan site	Chihwuyuan Culture	2,800-1,800
	Yuanshan Culture	3,200-1,800
Chientang site	Shisanghang Culture	1,800-400
	Chihwuyuan Culture	2,800-1,800
	Yuanshan Culture	3,200-1,800
	Hsuntangpu Culture	4,500-3,500
Chihshanyen site	Chihwuyuan Culture	2,800-1,800
	Yuanshan Culture	3,200-1,800
	Chihshanyen Culture	3,800-3,200
	Hsuntangpu Culture	4,500-3,500
	Tapenkeng Culture	6,300-4,500
	Palaeolithic Culture (the late stage)	6,000 >

Chihwuyuan site	Shisanghang Culture	1,800-400
	Chihwuyuan Culture	2,800-1,800
	Yuanshan Culture	3,200-1,800
	Hsuntangpu Culture	4,500-3,500
	Chihwuyuan Culture	2,800-1,800
	Yuanshan Culture	3,200-2,800
	Chihshanyen Culture	3,800-3,200
	Tapenkeng Culture (the late stage)	5,000-4,500
Yuanshan site	Shisanghang Culture (the late stage)	1,800-400
	Chihwuyuan Culture	2,800-1,800
	Yuanshan Culture	3,200-1,800
	Chihshanyen Culture	3,800-3,200
	Hsuntangpu Culture	4,500-3,300
	Tapenkeng Culture	6,300-4,500
	Pre-pottery Culture	> 6,500

Table 1-2 Prehistoric culture(s) covered by individual Yuanshan Cultural Site with unearthed Shouldered Stone Tools in North Taiwan. (Liu *et al.* 2004)

*Each site has multi-cultural layers; therefore, the dates are varied. Besides, these dates are from 2004. These dates are the latest official record of each site in Taiwan if there is no updated data provided.

Thirdly, the function of the shouldered axe appears to be closer to the hoe, when inferred by reference to its morphology. Shi (1950) observed the types of shouldered axe and suggested that it does not appear to be like a typical stone axe that has the ability to supply powerful energy at hard materials to break or smash them; rather, it is more like the usage of a hoe, to rake downward into the ground then pull materials toward the user (Shi 1950). The category of stone implements of axe-hoe is acknowledged from characters as multiple uses in Taiwan; however, it is also could be used as an axe or hoe only. That is, the shouldered axe could be used as an axe, hoe. Thereupon, the shouldered axe is a generalised artefact name, for which the functions are mostly considered to be as an axe or hoe, or like a shovel sometimes (Liu and Kuo 2000; Kuo 2014a). This thesis attempts to address and define the differences in the use of shouldered axes: whether it is a multi-use axe-hoe tool, a single-purpose tool like an axe or hoe, or whether it was also used for other functions never previously discussed, such as weeding, wood-planing or woodworking (Shi 1950). This study will be the first to conduct experimental archaeology on the Taiwanese shouldered axe, and cross-reference the results with the agricultural evidence in the ethnographic documents to verify the possibility of the shouldered tools being used as a farming utensil in the Neolithic Age of Taiwan. This will provide a new direction to pursue the linking of shouldered artefacts and/or agricultural activities throughout the region.

That the shoulder of the shouldered axe is rather a practical function than a decorative design has been agreed by archaeologists in most cases (Shi 1950, Sung 1980). The shoulder is used by attaching the handle parallel to the blade edge of shouldered axe and binding it with a rope for the user to hold and perform tasks conveniently (Shi 1950, Sung 1980). Merely the idea of fastening the wooden handle for easily use faces the challenge by other archaeological materials. The Yuanshan Cultural Sites have also unearthed a large number of non-shouldered axe tools. As agricultural implements, such tools can be tied onto wooden handles and used without any trouble either. It is clearly the case that an axe or hoe with or without shoulders can both be used effectively for agricultural work. From this point of view, deliberately making a shoulder for the purpose of handle attachment and ease of use does not seem to be the whole answer: there may have been other, non-practical, considerations. Apart from the practical function considerations, whether the shoulder design has social and/or cultural implications has also been discussed by academics, such as the symbolic meaning of money, a popular culture in the region at the time, or the economic means of raw material control (Matsumoto 1939, Kuo 2014a, Boer-Mah 2008). For this reason it is necessary to clarify the purpose of shoulder production: whether it is related to the attachment of handles and the convenience of use.

Further, if the design of the shoulder is driven by practicality, the technique(s) of binding the handle with the shouldered axe needs to be explored. There are two ways to bind the wooden handles with shouldered or stepped stone tools whilst in use, which have been studied so far. One is the use of a wooden handle that provides a space for the head of a tool to fit into, another is using string or similar binding materials to tie the tool directly onto the wooden handle. Hung (2000) gives five further hafting methods in her study of the adzes in Taiwan, South China and Southeast Asia (Fig. 2-2-18, 2-2-19). The options of hafting techniques offered by Chen and Hung will be referenced within the shouldered axe hafting experiments developed in this thesis. On the other hand, the way(s) of making shouldered axes has not been systematically studied, except the general idea of knowing that shouldered tools are made by grinding, including Taiwanese shouldered axes. Usually, the method of stone grinding involves working directly on a larger grindstone or small portable grindstone. The raw material of the grindstone mostly is sandstone. It is not difficult to grind the raw rock on the grindstone. The shoulder manufacturing, however, is the main complicating issue of the grinding method. For example, the shoulder is created by grinding the tool blank on a small portable grindstone or holding the tool blank and working it on the grindstone at a specific angle, then grinding it into the specific shape of the shoulder form which is intended. This thesis will conduct new experiments on these two methods to elaborate on the producing technologies and binding methods of the shouldered axes.

Taiwanese archaeologists commonly believe that the stone tools of the Yuanshan Culture were made locally, and the stone raw materials were procured from the neighbouring area in Northern Taiwan. This implies that local manufacturing traditions were indeed dominant in stone tools' production. With regards to raw materials, many igneous rocks were used to produce stone tools. Studies notice that the shouldered tools in North Taiwan for example, are mostly produced in andesite that could be derived from the Tatun Volcano Group in the surrounding area of the Taipei basin (Huang 1996, Kuo 2014a) Yet, those studies do not provide any geochemical or petrological analysis results on the shouldered artefacts to verify the theory that the andesite used by the Yuanshan people was indeed collected from the Tatun Volcano Group (Huang 1997, Kuo 2014a). This research is therefore going to conduct pXRF analysis on sixteen Taiwanese shouldered axes borrowed from Dr Kuo, and on eight andesite raw materials from the Tatun Volcano Group area, in order to obtain trace element information on the andesite shouldered axes and the potential andesite sources. The thesis will also cross-reference the analytical results to those raw material sourcing data in the published works of literature (Chang and Chen 1979, Lo 1982, Chen and Lin 1982, Tsai *et al.* 2008, Fang 2011, Wan *et al.* 2012, Lai *et al.* 2014). The goal is to confirm the source of the andesite which Yuanshan people used to produce their shouldered axes.

Most of the Yuanshan Cultural Sites are located in the coastal area in Northern Taiwan or on both sides on the river banks of the inland basin (Fig. 1-3). The geographical environment of these sites is very similar to those sites where shouldered or stepped stone implements have been discovered in the south of China. The traditional house of the Yuanshan Culture is the stilt house, which is reflected in the posthole evidence found in sites. The Stilt house is the typical prehistoric dwelling type typically found in the archaeological sites along the eastern and southeast coast of China, as well as in Southeast Asia. The similarities in the geographical environments and architectural traditions of these sites indicate to some extent the archaeological and cultural connections between Taiwan, China and Southeast Asia in the prehistoric era. In the meantime, re-examining and modelling the Yuanshan Culture chronology, and comparing against the age data from the sites with shouldered axes in South China and Southeast Asia, will enhance understanding of the regional development and/or dispersal routes of the shouldered axe phenomenon.

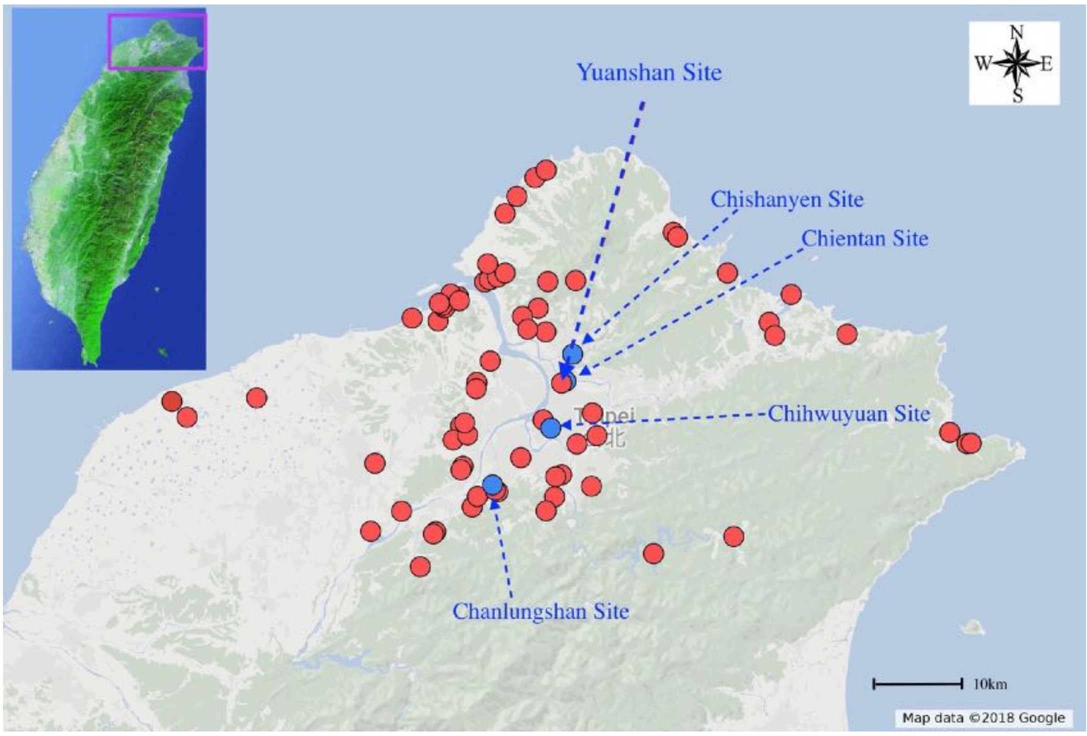


Fig. 1-3 Yuanshan Cultural Sites Distribution in Northern Taiwan. (Blue dots are the archaeological sites where the shouldered axes have been unearthed and examined scientifically in this dissertation.)

This thesis therefore attempts to address the following questions concerned with the current understanding of the Yuanshan Culture;1. Re-examining and constructing the chronology of the Yuanshan Culture. 2. Sourcing the raw materials of the shouldered axe. 3. Exploring the production techniques and the function(s)/usage(s) of the shouldered axe. 4. Understanding the purpose and use of the shoulder design. 5. Discussing the possible origin of the Yuanshan Culture.

3. Research methods

3.1 Radiocarbon chronology

The primary method for building Yuanshan cultural chronology in Northern Taiwan is radiocarbon dating. This study reviewed sixty-one samples of three material types were collected from nine Yuanshan sites of ^{14}C dating: Table 3-1-1 - cross-reference seven on shell (clam), one on wood and 53 charcoal samples were used to establish a chronology for Yuanshan Culture for ^{14}C dates. Using OxCal ^{14}C plotting software (Bronk Ramsey 2009) and the IntCal13 atmospheric calibration curve (Reimer *et al.* 2013) calibrated radiocarbon dates. Dates on marine-based organic material were calibrated using the IntCal13 atmospheric and Marine13 calibration curves (Reimer *et al.* 2013), using a ΔR regional offset from the CHRONO Marine Reservoir Database of 71±35 years (Yoneda *et al.* 2007). Interpreting the material culture by the Bayesian models of cultural phases generated in OxCal to obtain lower and upper chronological boundaries of the Yuanshan Culture.

3.2 pXRF analysis

Most of the Yuanshan shouldered stone objects have never been examined by geochemical methods to confirm the sources of the andesite. The shouldered tools of this study are not available for destructive tests. Nevertheless, this can be solved by using the non-destructive pXRF method. The portable XRF analysis is a non-destructive, high-resolution, multi-element experimental method, and has been successfully used to determine the source of archaeological stone implements over a number of years (Forster *et al.* 2011, Jia *et al.* 2010, Liu *et al.* 2012, Dussubieux *et al.* 2015, Frahm 2018,). Consequently, this is ideal method for clarifying the source(s) of andesite. Thus, the outcomes from these methods will broaden the knowledge of the exchange systems or networks involved in the acquisition and use of raw materials between the Yuanshan cultural sites in Northern Taiwan during the Neolithic age.

This study is going to inspect the trace elements in sixteen shouldered axes from the archaeological sites of Chanlungshan, Chihwuyuan, Chihshanyen and the raw material of andesite collecting from the Yangmingshan National Park. The results of the pXRF analysis will be compared with the trace element data of the andesite from the known literature in Northern Taiwan, in order to obtain the exact source of the andesite rocks.

3.3 PCA and typological analysis of shouldered axes

The definition and identification of style in shouldered technology is a key requirement in discussions of the usage and function of shouldered implements by a comparative analysis of the shoulder morphology. Shouldered objects from the Yuanshan Culture could be divided at least into three groups by shoulder type as stated in the following Chapter 2-2. The classification of the shoulder should concern the dimensions and manufacturing method as well as, for example, the hafting mode(s) and the objects upon which that shoulder type occurred. Consequently, the measurement data on the shoulder can assist in the quantitative analysis of the function and the usage of the associated implements. This study is going to examine the typology of the shoulder on 325 shouldered axes from 23 identified sites and 8 unknown sites in Taiwan, which can be utilised as the basis for determining the shouldered tools' appearance. And gradually expand the scope of the morphological comparison to those objects from the four museum collections in Taiwan, which are the Southern Taiwan Science-based Park Branch Museum of the National Museum of Prehistory in Tainan, National Museum of Prehistory in Taitung, the Museum of Institute of Ethnology, Academia Sinica and the Museum of Anthropology of the National Taiwan University in Taipei, as well as the literature of prehistoric lithic study in South China, Southeast Asia.

The shoulder type will be measured for each sample, and the position of the measurements is illustrated in Figure 1-4. The measurement data will be analysed statistically by SPSS, the outcome of the PCA will serve as reference material for experimental archaeology through the application of the typological and use-wear analysis.

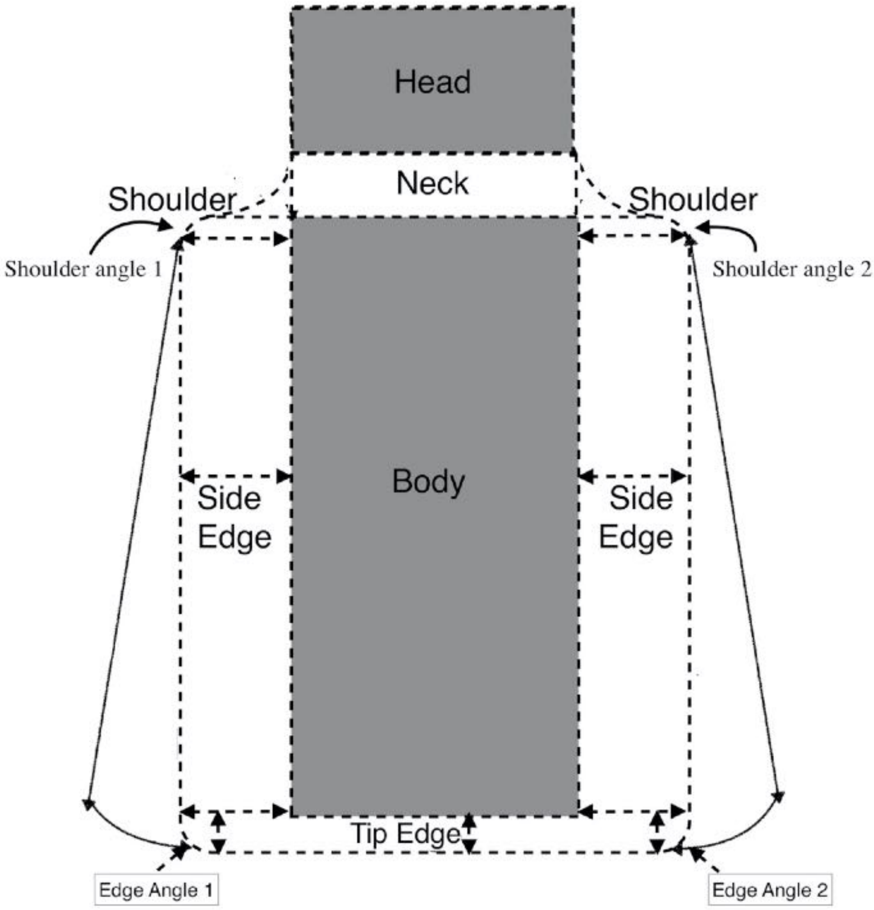


Fig. 1-4 Measurement positions on a shouldered axe.

3.4 Use-wear analysis

This study will focus on the wear traces on the shoulder and the blade edge on the shouldered artefacts, to assess the production methods and the use and function of the shoulder and the shouldered tools.

Currently, the study of surface wears on Taiwanese stone objects depends on the visual observation by microscopic examination. Hung (2000) has observed the use wear on the edge of stone adzes by conducting optical microscope and SEM-EDX analysis and found linear marks on the backside of the adze. Accordingly, Hung surmised that the most probable use for adzes is as a woodworking tool or, a planing tool for processing the animal skin to produce leather (Hung 2000). Kuo (2014b) has observed the striations of the annular notch on quartz sandstone, which is suspected as a stone burin, by optical microscope. Kuo, then, proposes a theory on the rotating cutting technology and rotating machinery movement for the nephrite artefact manufacture techniques by quartz burin from the result of use-wear observation (Kuo 2014b). Both adopted the Low Power magnification by optical microscope method for the use-wear observations on the stone tool surface. However, both agree that performing experimental archaeology is also necessary to verify the hypotheses arising from the use-wear analysis on the artefacts.

However, it is notable that the polishing and rounding traces on the surface may be the result of the process of manufacturing or of using, which is not easy to distinguish. The observations of the surface marks on the shoulder and the shouldered axe blade will therefore be verified by replication experiments, such as the method of production, hafting techniques and the function of use, especially as a hoe, although other potential applications will also be considered.

3.5 Experimental archaeology approach

Experimental replications can help to formulate, test and adjust a hypothesis. Preceding analysis of the surface marks on the blade edge of the shouldered implements from the Chanlungshan site led to the conclusions that the edge wear seems most likely to have resulted from the tool being applied to rather soft object(s) and from the tool being used as a hoe. Therefore, the experiments in this thesis will explore the following questions: 1. How are shouldered axes manufactured? 2. What method or method(s) can be used to haft shouldered axes? 3. What tasks can be undertaken with shouldered axes? 4. Do different hafting methods and/or different uses generate distinctive use-wear traces?

3.6 Phytolith analysis

Phytoliths are the micro-remains analysed in archaeological research into prehistoric plant resources and human consumption behaviour. The phytoliths distribution is usually regarded as being related to the livelihood of ancient people. There are plenty of cultivated crops among them which are associated with the development of human civilisation globally. Therefore, it is of great significance for archaeologists to study the plant resources of prehistoric times by employing phytolith analysis. Many cultivated crops can produce large amounts of phytoliths, for example, the rice, wheat, sugarcane, maize. However, the identification of phytoliths is not easy due to the rich diversity in the typological varieties. Phytoliths of rice plants are particularly of concern by the academics, which can the identification of the classification to family be achieved. In addition, a small amount of rice remains has been found in several Yuanshan Cultural Sites. (Huang 1999a, 1999b) It offers support to the suggestion of the shouldered axe as a farming tool. However, it is not accessible to those rice remains uncovered in the Yuanshan site. This study will, therefore, conduct the phytoliths experiment on the shouldered axes and soil sample collected from the Chihwuyuan Site as the replacement. The results of the plant citrate analysis have the potential to provide specific evidence for the use of the shouldered artefacts.

The ethnographic analogy also applied to explore the functional use of the shouldered axes. There are many accomplished archaeological examples of the advantages of using ethnographic records to reconstruct prehistoric human life patterns around the world, especially for enhancing the comprehension on the modes of production and usage of ancient objects. For example, Hayden (1987) studied the manufacture of Mesoamerican's quern stones, providing valuable insights into the manufacture of such artefacts in prehistoric times. Indigenous people in Taiwan have a long history of oral traditions and a wealth of material culture that together enhance knowledge of the object’s life history. This oral history and cultural traditions have preserved the aboriginal social culture and lifestyle since the 16th and 17th centuries through the records written by outsiders from across the world, for example, the manuscript of Governor of VOC, Spanish historical documents, travel notes of Chinese and British people (Chiang 2011, Borao Mateo 2001, 2002, Chou 2012). It enables current scholars to make good use of this literature to explore all aspects of aboriginal society.

This study will enhance understanding of the technological developments and agricultural activities of prehistoric humans in Northern Taiwan by comparing the ethnographic literature of indigenous people and the archaeological evidence. Thus, adopting the ethnographic information will be helpful in understanding the relationships between the archaeological material and indigenous activities, and potentially reveal the practical usage of the shouldered axes of the Yuanshan Culture.

Additionally, the field works in Taiwan were necessary in this thesis. This was undertaken for two purposes. The first was to examine the collections of shouldered axes in four museums and record the morphological measurements of the total sample of 325 shouldered artefacts. So that the results of the measurement data will apply the PCA and typological analysis to explore the form(s) that the preference of the shouldered axes may have and the production method(s) by the Yuanshan people. The second was to gather the raw materials of andesite from the Yangmingshan National Park for the pXRF analysis. The analytical results of the trace element analysis will be used to verify the location(s) of the quarry of andesite raw material, an issue that has long been speculated over by the Taiwanese academics, in particular the possibility that the andesite was obtained from the Tatun Volcano Group locally.

The final three chapters present results, discussions, conclusions and suggestions for studies in the future. A partially testified new explanation of the shouldered axes is offered in this dissertation, taking the analytical data presented into account.

Chapter 2-1_GEOGRAPHY AND PREHISTORY OF TAIWAN

Geographical overview of Taiwan

For the understanding of the acquisition and utilisation of materials for artefact production or the dietary content of ancient people, the palaeoenvironmental geography can provide crucial evidence for the interpretation of the issues under the temporal-spatial context of ancient human existence. Environmental and geographical conditions, including topography, geology, soil, climate, hydrology, flora and fauna, volcanic activity, sea surface changes, and underground resources, have all correlated with prehistoric human activities. These factors positively impact on ancient human behaviours, such as human migration, residential site selection, hunting and foraging choices, agricultural production, and cultural/economic activities. Therefore, the primary knowledge of the evolutionary processes of natural geography and environmental change will help archaeologists to present a more comprehensive and extensive interpretation of prehistoric human activities in individual regions. Among them, it is the Quaternary geological environment ecology about 2.6 million years ago that is the closest to the era of human emergence and the inseparable relationship with the evolution of human beings in all aspects (Lin 1966).

1. Outline of the natural environment in Taiwan

The shouldered axes that are the focus of this research are derived from Taiwan, which is located at the junction of the major, ever-shifting, tectonic plates of the Philippine Sea and Eurasia. It is an island state that is situated in the eastern part of Asia and the north-western side of the Pacific Ocean, lies between the islands of Ryukyu and Philippine, and is separated from China across the Taiwan Strait (MOI 2018[1], Fig. 2-1-1). In addition to the main island of Taiwan, it also comprises the Penghu Islands and several small islands around the main island, such as Kueishan Island, Green Island, Lanyu Island, and the farther Diaoyu (Senkaku) island. The main island of Taiwan covers an area of about 36,000 square kilometres, with a length of about 395 kilometres from north to south, a maximum width of about 144 kilometres from east to west, and a coastline that is 1,139 kilometres long.

Taiwan has five major terrains. Except for the high mountains formed by the compression of tectonic plates, others include hills, plains, terraces and basins (Chen 2008). Therefore, Taiwan is rich for the natural landscape. Taiwan locates on the coast of East Asia in a subtropical region, its climate is affected both by the continental and oceanic climate pattern (Central Weather Bureau[2]). Coupled with influence of the topography height of the Central Range, the climate of Taiwan is various regionally and seasonally. The climatic variability also acts on the distribution of vegetation and the habitat of organisms, so the ecological environment of Taiwan has become rich and diverse (Chiu *et al.* 2004). There are

[1] Ministry of Interior, 2018, Area and Length of Coast in Taiwan. Statistical Yearbook of Interior, Land Administration: 5-17, 5-18, 5-19. Available at **5 Land Adm.**

[2] Central Weather Bureau

129 rivers on the island. Since the Snow Mountain Range and the Central Range in the centre of the island as a watershed, the rivers are mostly flowing eastward to the Pacific Ocean or westward to the Taiwan Strait. The main characteristics of the rivers in Taiwan then, are the steep slope, high sand content, and turbulent currents (Hwang 1984). And, water resources rely on the groundwater or water reservoirs to be used as supplementary water for the sustainability during the dry season (Fig. 2-1-2). In short, Taiwan Island is a suitable environment for species habitat.

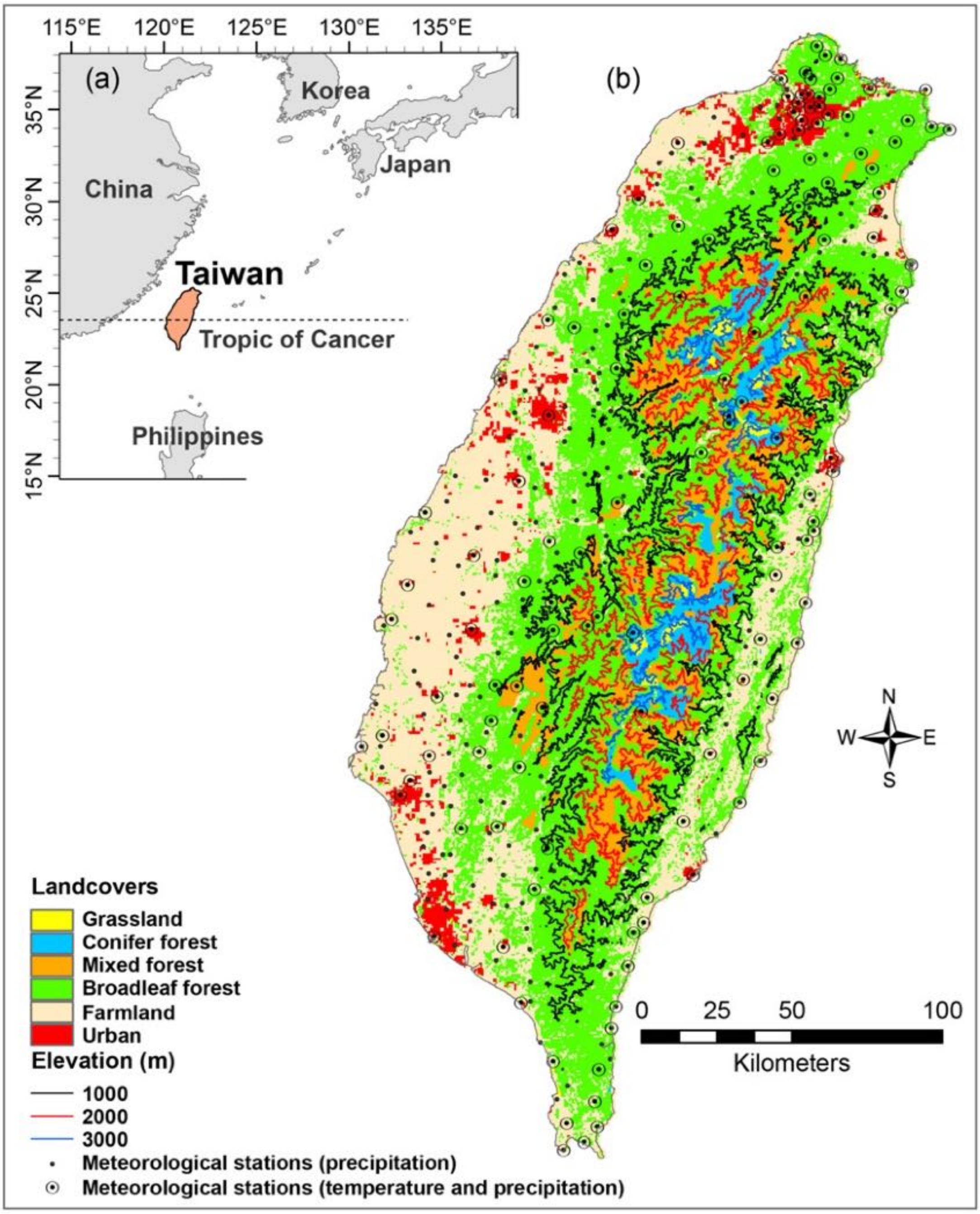
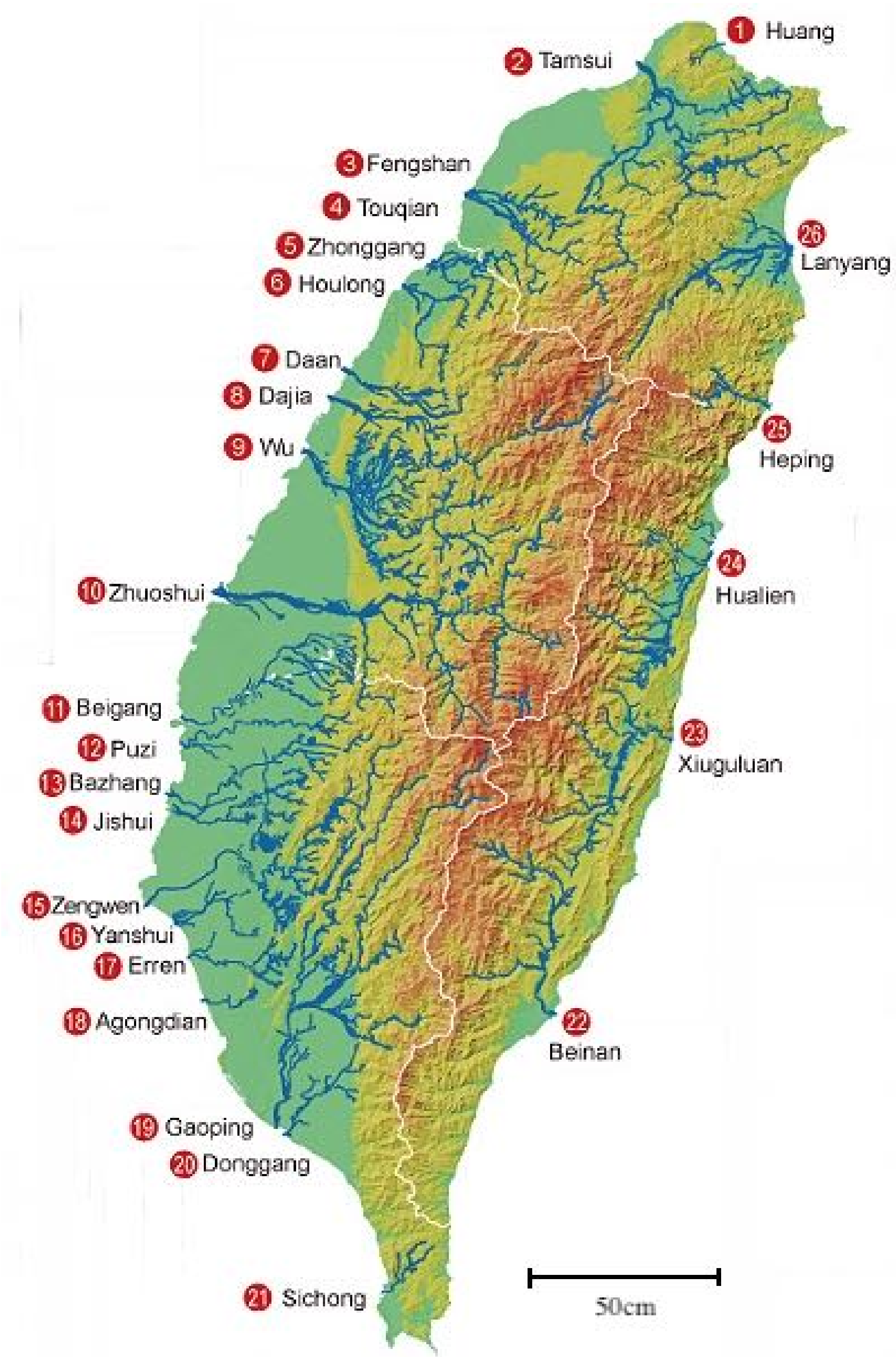


Fig. 2-1-1 Geography of Taiwan (Chang *et al.* 2013, Fig. 1).



[3]

Fig. 2-1-2 Major rivers in Taiwan (MOEA)

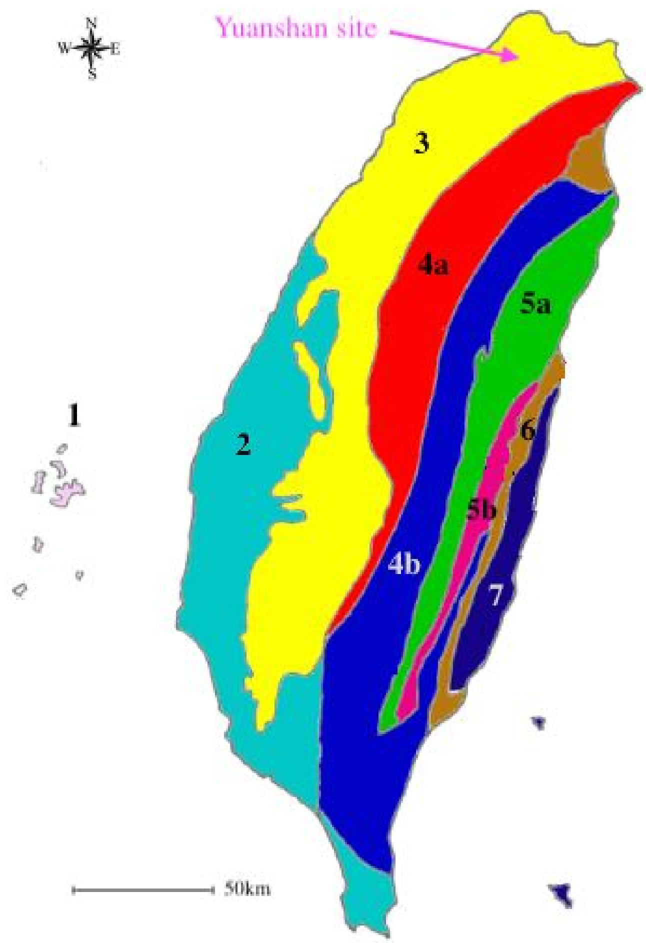
[3] Available at the Water Resource Ageny, MOEA.

1.1 Geological structure of Taiwan

Taiwan is a young island in the context of geological history globally. It was shaped to a similar size of today's terrain about six million years ago due to the influence of earth’s natural forces, principally the movements of the regional plates and orogenic processes, as well as climate change. Plate collision between the Luzon arc and the edge of the Chinese mainland caused the orogenic movements which dominated Taiwan's tectonic evolution throughout the Quaternary and resulted in the current terrain of Taiwan about two million years ago. In other words, the timing of the formation of the natural topography of Taiwan is covered in the Quaternary (Lin 1966, Chen 2008). To this day, Taiwan continues to be affected by various geological processes, resulting in the deformation of topography and landforms. The islands of Green and Lanyu for example, situated in the southeastern sea area, are still shifting towards to the main island of Taiwan (Deng 2007). Taiwan also has special volcanic landscapes because of lying within the volcanic belt of the Pacific Rim. From the perspective of geographical distribution and the geological structure of Taiwan, most of the outlying islands of Taiwan are formed by volcanoes. However, except for the Tatun volcano group and Kueishan Island in the north, there is no existing volcanic activity on the main island of Taiwan.

1.2 Topography and geology

The geological structure is an important factor in controlling the development of the terrain. Taiwan's main island is an area of young folded mountain. The stacked mountains show that they have been subjected to affects by the intense orogenic movements and river erosion. The arrangement of the geological tectonic belts in Taiwan shows changes in the east-west direction. The tectonic belts are parallel to the mountains and exhibit different characteristics topographically, stratigraphically and structurally. The geological structures of the main island from east to west are the Coastal Mountains, the East Rift Valley, the Central Range (the Ridge Mountains and Hsuehshan Range), the Western Foothills, the Plateaus, and the Coastal Plains (Chen 2008). In short, the topography of Taiwan can be divided into the alpine region, the hilly areas and the plains. The alpine region is situated in the centre of the island and is characterised by a north-south trend. The hilly areas are distributed in the periphery of the alpine area in the western region. The plains are located on both sides of the river and within the coastal area all around Taiwan. From the perspective of the orogen, the younger the rock formation exposed on the west side of the orogenic belt, the lower the mountain height and the degree of metamorphism, indicating that the time sequence of the orogenic belt uplift is from east to west (Chen 1997). Therefore, depending on the tectonic history and the differentiation of lithological characters, Taiwan is currently divided into seven major geological regions (Fig. 2-1-3). The Taipei Basin and its neighbouring areas studied in this thesis lie within the plains and the western foothills, as classified above.



1. Penghu Islands (Pleistocene basalt)
2. Western Coastal Plain (Quaternary Alluvium)
3. Western Foothills (New Tertiary clastic rock)
4. West Wing area of the Central Mountain Range (Tertiary metamorphic rock):
4a. Hsuehshan Range (hard shale or slate)
4b. Ridge mountain (slate or phyllite)
5. East Wing area of the Central Mountain Range (pre-Tertiary metamorphic complex):
5a. Taroko belt (schist, marble, granite)
5b. Yuli belt (schist, serpentine rock)
6. Eastern Rift Valley (plate suture zone)
7. Coastal Mountain Region (New Tertiary Volcanic Rock)

Fig. 2-1-3 Geological Formation of Taiwan.

The rocks exposed in Taiwan are very diverse, with metamorphic rocks, igneous rocks, and sedimentary rocks all visible across the islands. Following the geological tectonic division of the main island (see above), the exposed rocks of the Ridge Mountains have common metamorphic rocks such as gneiss, marble, schist, and slate; the Hsuehshan Range contains metamorphic rocks, principally sandstone, hard shale and slate. The rocks in the Western Foothills are mainly sedimentary rocks, principally conglomerate, sandstone, shale, and limestone. Igneous rocks like andesite are found in regions of the Tatun Volcano Group, Keelung, and the Coastal

Mountains, and basalts are found on the outlying islands of Penghu (Chen 1997, Chen 2008). The distribution of pre-Quaternary rocks in Taiwan is illustrated in Figure 2-1-4.

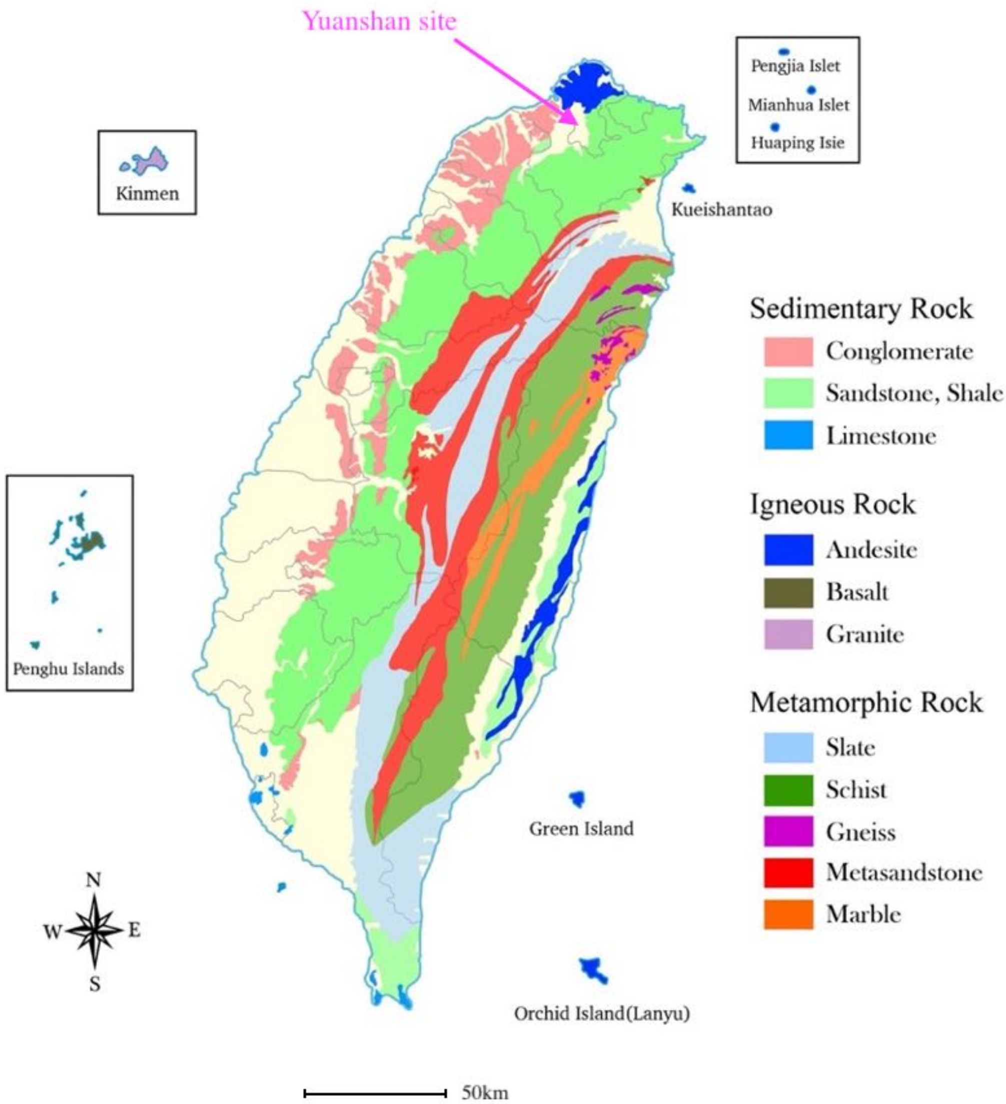


Fig. 2-1-4 Distribution of pre-Quaternary rock types in Taiwan.

The Quaternary strata in Taiwan are classified to the Toukoshan Formation geologically, and its development era consists of the Pleistocene and the Holocene, between *c*. 2.588 million and 10,000 years ago (Lin 1963). Most of the stratum are distributed in the outer margins of the western foothill belt, and towards the terraced ground, plains, and basins on its west side. The rock formations of the Toukoshan Formation are composed of sandstone, shale, and coral limestone, interspersed with a thin layer of conglomerate. The Toukoshan Formation is mainly divided into two facies, the Huoyenshan Facies (conglomerate) and the Hsiangshan Facies (sandstone and shale). The two represent different lithofacies in the same strata, and there is no relationship in terms of formation process between the upper and lower horizons, but the former usually overlies the latter. The main part of the Huoyenshan Facies consists of conglomerate layers interbedded with thin layers of sand and shale. The primary lithology of the Hsiangshan Facies is sandstone with inconspicuous stratification where the layer contains carbonised driftwood and the foraminifera fossils of the marine environment or the fragments of mammalian faunas. For instance, apart from the marine fossils such as malacofauna, foraminifera, solitary coral, Echinoidea, and polyzoa, there are some vertebrate animal fragments also found in the facies like stegodonts, elephants, rhinos, tapirs, bovids, cervids, felines, dolphins, whales, boars, horses, tigers, raccoon dogs, bears and hyaenas (Lin 1963, 1964, 1966, Lin 1992, Chen *et al.* 1992, Chen 2000a, b, Chen 2008).

The ages of geological deposits and the taxonomy of the species represented by mammalian fossils in Taiwan are the subject of ongoing research (Wei 2007). This research will clarify some of the problems associated with biogeographic and paleoenvironmental changes in East Asia, which include the utilisation of environmental resources by ancient humans and their possible paths of migration in the Asia-Pacific region. For example, Ho *et al.* employed the ancient fauna discovered in the Taiwan Landbridge and Taiwan to reconstruct the movement routes of prehistoric humans and their relationships to the animals during the Late Pleistocene and the Neolithic Age respectively (Ho and Yen 2008a, Ho and Qi 2008b, Ho 2010).

1.3 Climate and ecology of Taiwan

Taiwan is located in the zone of the East Asian monsoon and affected by the climatic types of the mainland and the ocean at the same time. In winter, there is a cold high-pressure zone from the Siberian continent, which is dominated by the northeast monsoon. In summer, there is a maritime high-pressure zone from the Pacific Ocean, dominated by the southwest monsoon. And the southwest monsoon dominates the summer when the marine high-pressure zone expands westward from the Pacific Ocean. The climatic types are divided into the subtropical monsoon in the north and tropical monsoon in the south. Coupled with the changes in the elevation of Taiwan's terrain, from sea level to nearly 4,000 meters, the climatic division also varies vertically, resulting in the many distinct types of climate seen in Taiwan, such as the climatic zones of tropical, subtropical, temperate, and cold.

Such a rich and multifarious climate pattern not only makes the landscapes of animals and plants vary vertically, but also provide the natural resources and the environments for the growth of plants and animals in a wide range of habitats. The complexity of the topography and climatic environments provides organisms with varied and abundant habitats, including marine, coastal wetlands, tropical rain forests, broad-leaved forests, coniferous forests, alpine tundra, rivers, and lakes. Such biodiversity and the natural environment of Taiwan therefore creates an affluent resource that has enabled a wide range of species to survive, including prehistoric humans (Chiu *et al.* 2004). The close interaction between humans and the natural environment constitutes a further ecosystem, with agriculture as the mainstay, in which the interaction differs from those of the natural systems. Forests in Taiwan account for about 60% of the total area, and arable land for only about 20%, and the latter is mainly located in plains and hills. These arable lands have been cultivated as rice fields, and as farms of tea and fruits. According to official statistics in 2017[4], the annual output value of Taiwan's agricultural products (referring to crops, forestry, fisheries and animal husbandry) is divided as follows: 51.16% (crops), 31.84% (livestock), 16.96% (fisheries), and 0.05% (forestry).

The ecological environment and natural resources of Taiwan would therefore have been sufficient for prehistoric humans living.

2、Natural environment in northern Taiwan

The Taipei Basin is a tectonic basin with low-lying flat land, and its altitude is 20 meters or less. The acreage of the basin bottom is about 150 square kilometers. The

[4] Official annual report of Taiwan’s agriculture, 2017. Available at the webpage of Council of Agriculture, Taiwan. https://eng.coa.gov.tw/ws.php?id=8842

hydrology in the basin is dominated by the Keelung River, Dahan Creek, and Xindian Creek. These three systems flow into the basin and converge in the Tamsui River in the Guandu area in the northwestern side of the Taipei Basin, and then flow out into the Taiwan Strait. The Taipei Basin is surrounded by hills, terraces, and mountains. There is the Tatun Volcano Group in the north, the Snowy Mountain Range in the south, the Sung San hilly terrain at the southeast and the Linkou Tableland in the west. Since the sources of the raw materials that the Yuanshan Culture's pottery and stone tools are produced from are closely related to the local geology, it is important to first understand the geological profile of the area.(Fig. 2-1-5)

Fig. 2-1-5 Landscape of Northern Taiwan.

Studies on the formation of the Taipei Basin have gradually reached a consensus owing to the increased gathering of research data in recent years, such as the well-examined pollen, or petrological or faulting studies (Fig. 2-1-6). As far as the geotectonic history of the formation of the Taipei Basin is concerned, about 400,000 years ago, the stratum subsidence of the Taipei Basin was caused by the eruption of the Tatun Volcano or the effect of regional faults (Su *et al.* 2015). At the beginning of the collapse of the Taipei Basin, a wide range of alluvial fan clusters developed on the surface of the depressed foothill area. The second occurred about 200,000 years ago, and the Taipei Basin sank into an inland lake. The third cave-in happened about tens of thousands of years ago, and not only initiated the invasion of seawater from Guandu, further to the southwest side of the basin, but also caused Dahan Creek to capture the old creek. Taipei basin, therefore, is a sea-connected and active inland collapse basin.

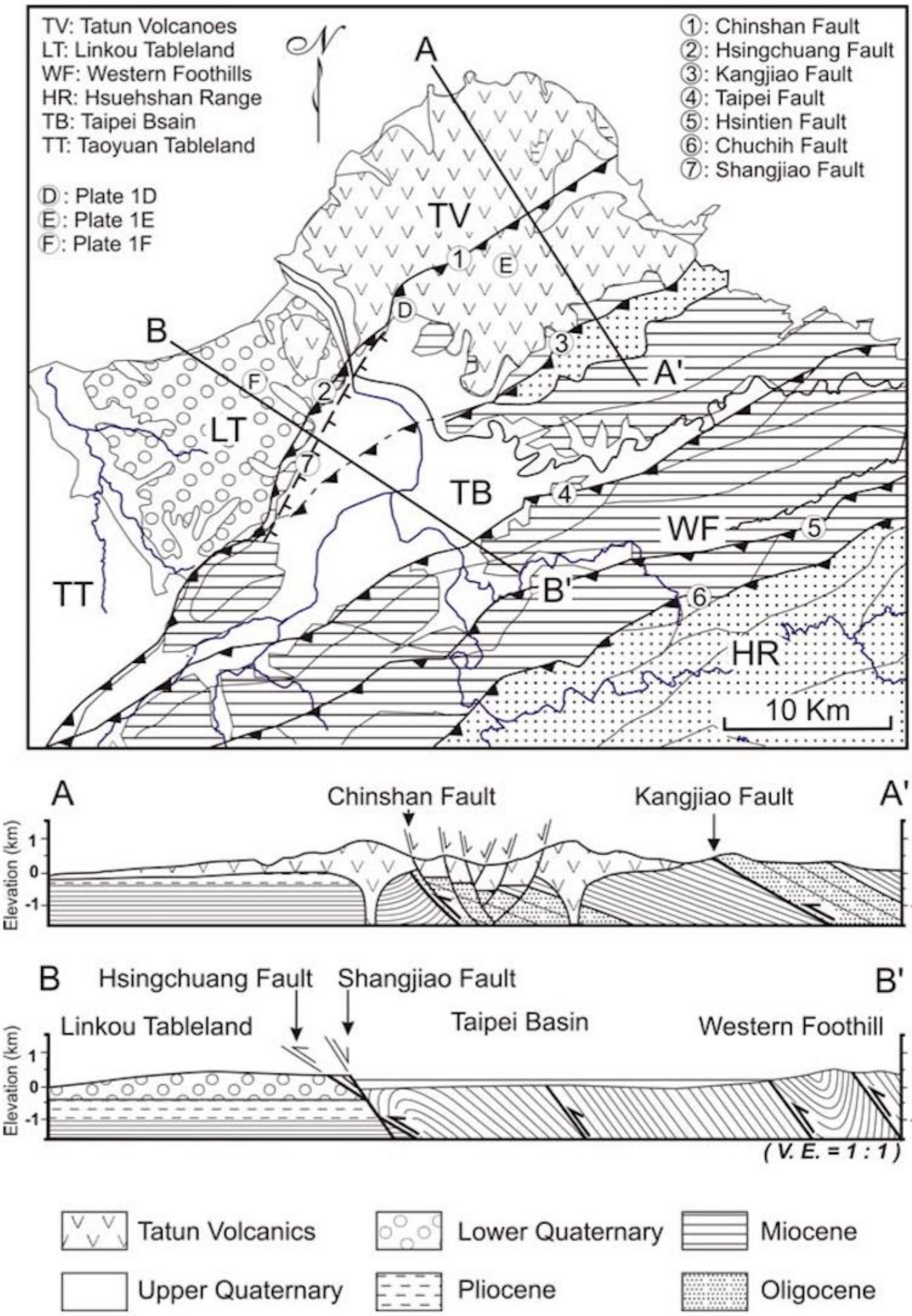


Fig. 2-1-6 Geological setting of the Taipei Basin (Teng *et al.* 2001, Fig.2).

In the early Holocene, about 10,000 years ago, global seawater rose as the glaciers melted. The Taipei Basin was flooded due to the rise in seawater, which the freshwater component of the lake was reduced to half. Seawater poured into the Taipei Basin area from Guandu (an estuary of the Tamsui River), forming into a lake called the Ancient Taipei Lake. Under the impact of alluvial and shallowing processes by three tributaries of the Tamsui River, the landform of Taipei Basin has shaped the landscape as today in the end. Sea-level rose and fell several times during the early and middle Holocene, causing the geo-environment of Taipei Basin to change between a lake, a swamp, and a wetland. This occurred until c. 6,000 years ago, after which the waters of the Ancient Taipei Lake reduced gradually and flowed into the sea from Guandu. Hence, the landscape of Taipei Basin has evolved from a lake to wetlands, and subsequently farmlands, up to the present day (Teng 1999a, Teng 2006, Hung *et al.* 2006, Tsai *et al.* 2014).

Judging from the distribution of the deposits of the Taipei Basin, the Quaternary strata are widely scattered in the plain area, where is dominated by the accumulation of river and lake deposits. There are four formations of Quaternary strata, divided from the bottom to the top: the Banchiao Formation, Wugu Formation, Jingmei Formation and Sungshan Formation (Fig. 2-1-7). The main rock layers are composed of thick layers of interbedded gravel, sand, mud, and sand. The Banchiao formation was formed 400,000 years ago and the main lithology is gravel . The lithology of the Wugu formation is composed of sand, gravel, mud and red gravels. The major lithology of the Jingmei formation is the layer of lateritic gravels that is an important index for the regional Quaternary stratigraphic system. The Sungshan formation is the uppermost stratum of the Taipei Basin and widely distributed in the region. The main lithology is composed of clay, silty clay and interbedded silty sand (Shaw *et al.* 1999, Teng *et al.* 1999b, Teng *et al.* 2001, Teng 2006). In addition to the Quaternary sedimentary rocks, igneous rocks from the Tatun Volcanic Group in the north of basin also appeared in this area and some of rocks exposed at the surface, mainly andesite. Figure 2-1-8 indicates the andesite vein where some of the outcrops are visible and accessible in the Yangmingshan National Park.

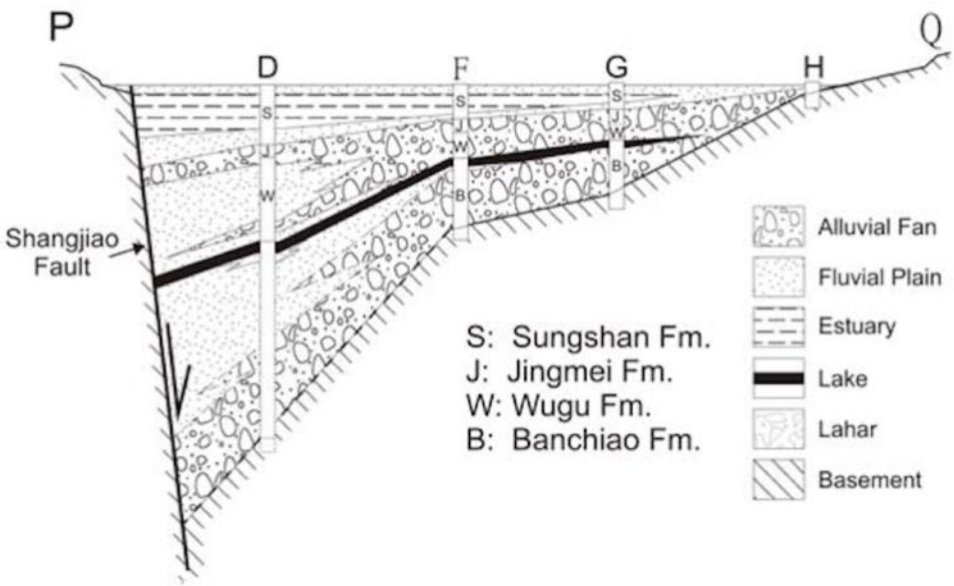


Fig. 2-1-7 Facies characteristics and basin configuration (Teng *et al.* 2001, Fig.4).

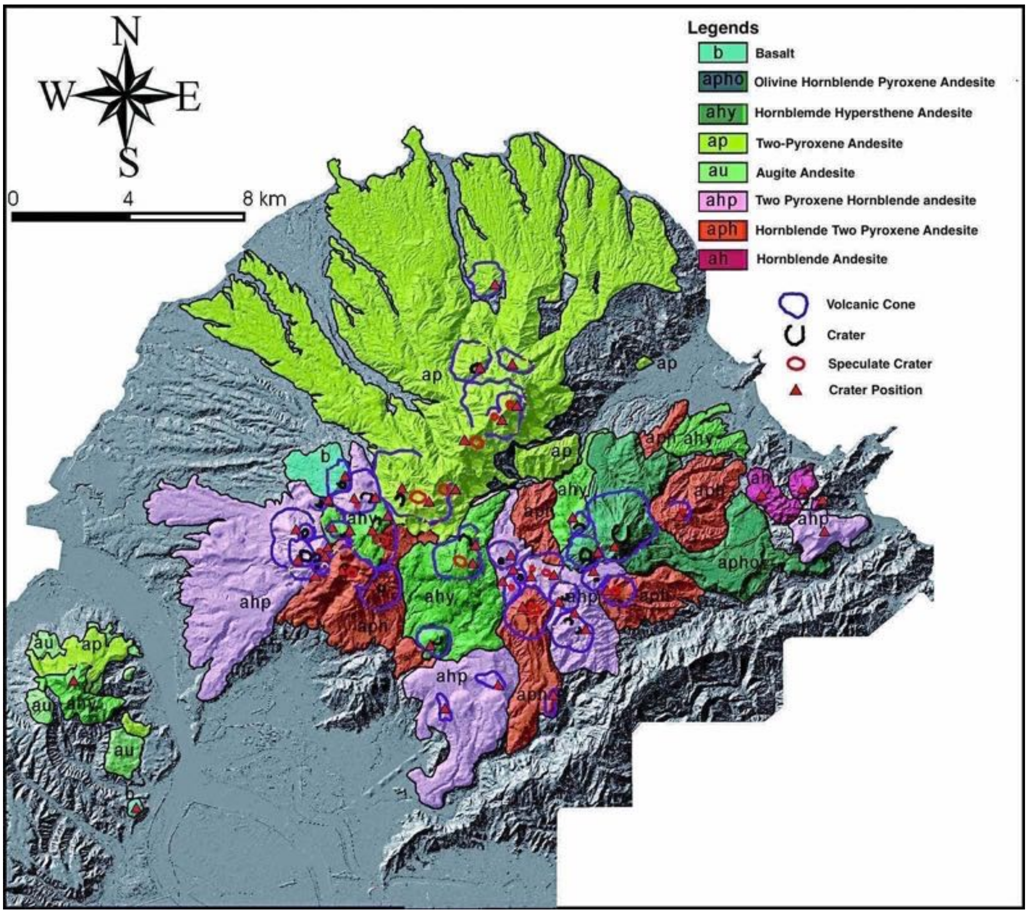


Fig. 2-1-8 Distribution of andesite in northern Taiwan (Translation based on Chen *et al.* 2007, Fig.1).

The weather is as diverse as the landscape in the Taipei Basin. The climate varies from subtropical in the lower areas to temperate or sub-temperate in the mountainous regions which surround the Taipei Basin. Different species can settle and breed in the rich and varied landscape environment of the Taipei Basin. For instance, the mangroves of the macrotherm plant grow in the coastal area of the Tamshi River, the *Bischofia javanica* is distributed widely in the hills or lower mountains around the Taipei Basin, and the *Chamaecyparis formosensis,* a subarctic zone plant, is found in the higher mountains of the upper Tamsui River (Li and Wang 2013, Shaw *et al.* 1999). The dense growth of plants from the bush to the arbor offers a suitable environment for terrestrial and aquatic animals, such as deer, pig, dog, and shellfish. Even rice can grow, and that provided stable food sources for the prehistoric peoples. In short, the Taipei Basin region is a suitable environment for human settlement.

As the largest urban conglomeration and basin plain in northern Taiwan, the Greater Taipei area has a flat terrain and abundant water resources, which is conducive to the development of agriculture. However, the agricultural activities before the 17th century lacked relevant records in the literature. It can only be learned from the literature after the middle and late 17th century that the route of the Han Chinese migration and reclamation to Taiwan was gradually from south to north. In the early 18th century, the Han people brought paddy rice cultivating techniques to the Taipei area, which progressively replaced the traditional shifting agricultural technique of slash and burn that was used by the aborigines and turned the dietary habits of indigenous people towards rice crops (Tu 1998, Tsai 2009, Chou 2012). According to Dr MacKay, whose served as the first Presbyterian missionary between 1871-1894 in Taiwan, the crops grown in northern Taiwan at the time were mainly rice, tea and sugar. (Fig. 2-1-9) The hilly region around the Taipei Basin grows tea because of its suitable conditions of climate and soil. The beginning of the development of Taiwan's tea industry relied on John Dodd, the British merchant, for his attempt at transplanting the Fujian tea varieties into northern Taiwan and establishing Taiwan as an important place of tea production (Yu-fu 2017). According to the published 2018 statistics report[5] of the Development of Economic Development of Taipei City Government, the arable land in the Taipei region is commonly distributed on the hilly slopes around the edge of the basin. The crop regime is dominated by vegetables, followed by rice and tea.

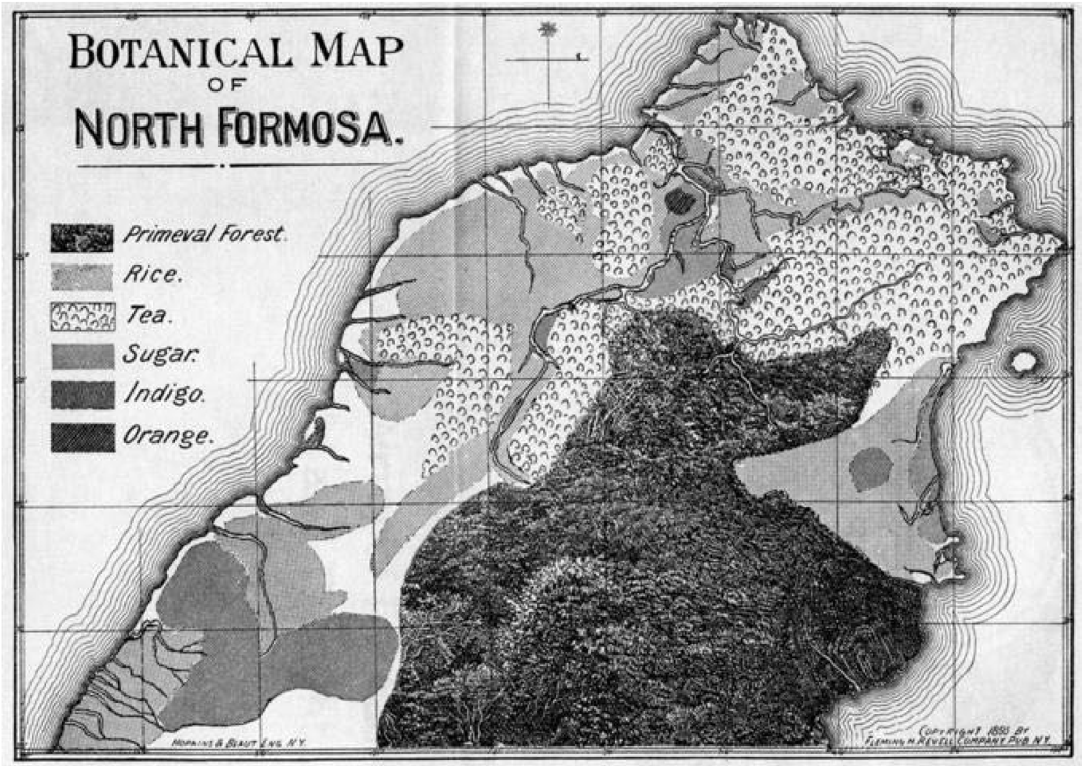


Fig. 2-1-9 Botanical map of North Formosa[6]. (Mackay and MacDonald 1896, [map faces p. 55])

3、The distribution and natural landscape of Yuanshan cultural Sites

The suitable ecological environment of the Taipei Basin encouraged prehistoric human occupations and the traces of prehistoric human activities are visible. In

[5] Department of Economic Development, Taipei City Government. Available at https://www.doed.gov.taipei/cp.aspx?n=5F00A87C0C77E23D

[6] Available at https://oregondigital.org/sets/easia/oregondigital:df72cv39k

order to understand the distance of each Yuanshan cultural site from the riverbank and the height from the sea level, the length of each site to the riverbank and the height from the water level was calculated from the Google map for these sites. Most Yuanshan cultural sites are located near the water source. Of the 71 Yuanshan cultural sites known, 69% of all sites lie in locations within 620 to 670 meters of a river bank. The altitudes of 87% of sites are situated between 49 to 70 meters (Fig. 2-1-10, 2-1-11). Geographic data indicates that the Yuanshan cultural people settled in environments near a water source and hilly region. Such a pattern seemingly reflects the habitat preferences of the Yuanshan people, as well as the visibility of the archaeology and/or the site taphonomy.

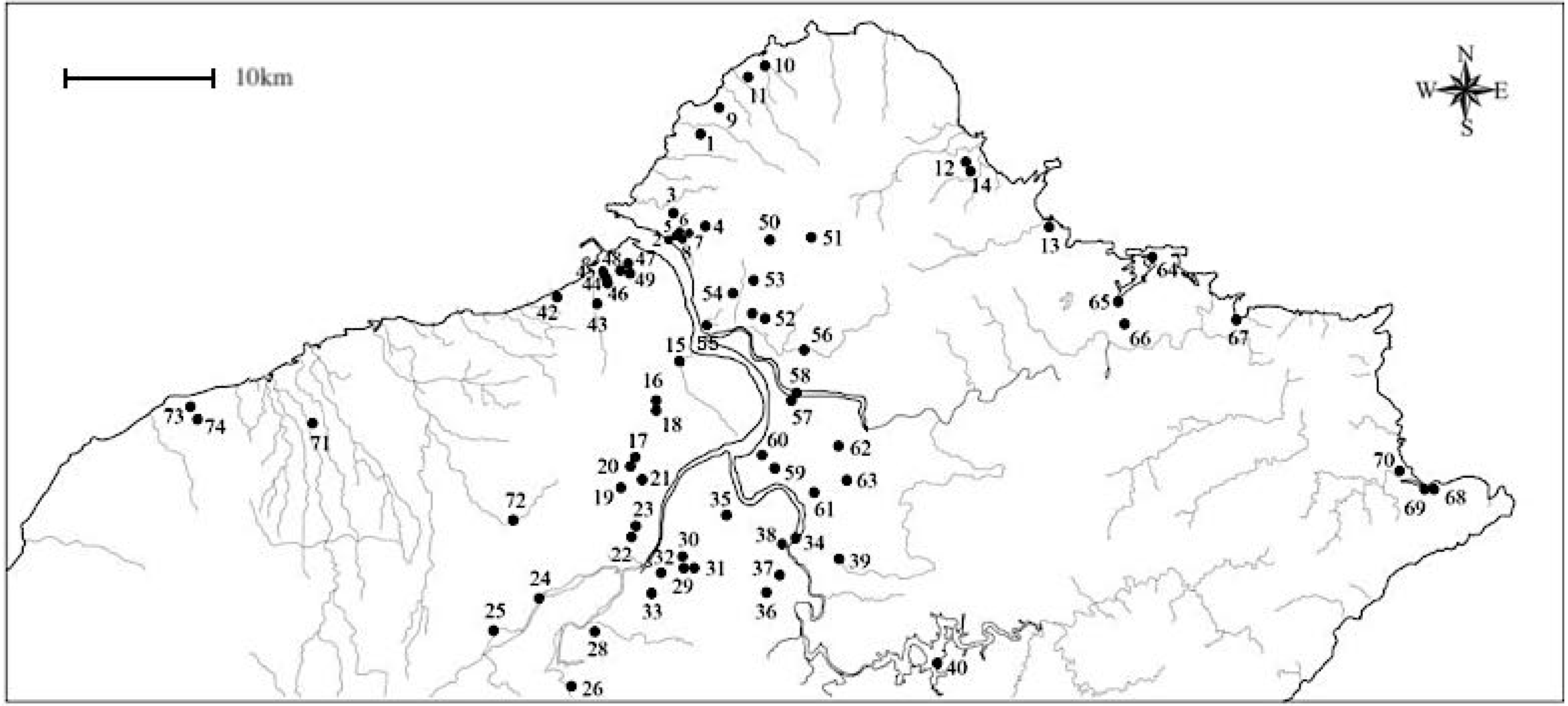


Fig. 2-1-10 Yuanshan Cultural Sites' Distribution in Northern Taiwan (Translation based on Kuo 2014a, Fig. 1)

1. Gonpuzi	2. Tamsui-Chinsuiyen	3. Yamuku I	4. Shanjiao-Litsuo	5. Yinzuanlu	6. Tatienliao	7. Guakepu	8. Tenkongguoxiao
9. Houtsuo II	10. Minzugonmiao I	11. Shanzi-Guzhuang	12. Gueizishan	13. Wanli-Shizitou	14. Wanli-jiatou	15. Siyunyen	16. Shitutikgon II
17. Gueizikong	18. Banzishan	19. Tingpishan	20.Shipafeng	21. Yinpankou	22. Chiuchashan	23. Tanti	24. Yingge
25. Chiaozitou	26. Wantan	27. Shantigonshan	28. Huweishan	29. Maoputou	30.Chanlungshan	31. Pingtingshan	32. Tutikongshan
33. Tuchen-huzishan	34. Jianshan	35. Yuanshanzhi	36. Chezilu	37. Zutushan	38. Waiwazishan	39. Baotoutsuo	40. Miaopu I
41. Daiyuku	42. Shiaguken	43.Chandaokenkou	44. TaipeiKang I	45. TaipeiKang II	46. Hsuntangpu	47. Gongtien	48. Shihsanhang
49. Tapenkeng	50. Mientienping	51. Zhuzihu	52. Chilian	53. Beitou	54. Kalaobei	55. Kuantu	56. Chihsanyen
57. Yuanshan	58. Chientang	59. Chihwuyuan	60. Wanhua	61. Futienting	62. Yenchijie	63. Liuchanli	64. Sheliaodao
65. Keelung station	66. Naronguoxiao	67. Shenou II	68. Fulonggouxiao	69. Gongliao-Huzishan	70. Tindian	71. Tayuanjianshan	72. Gueishan-guosi
73. Shulin-Haikou	74. Chaoluochingshan						

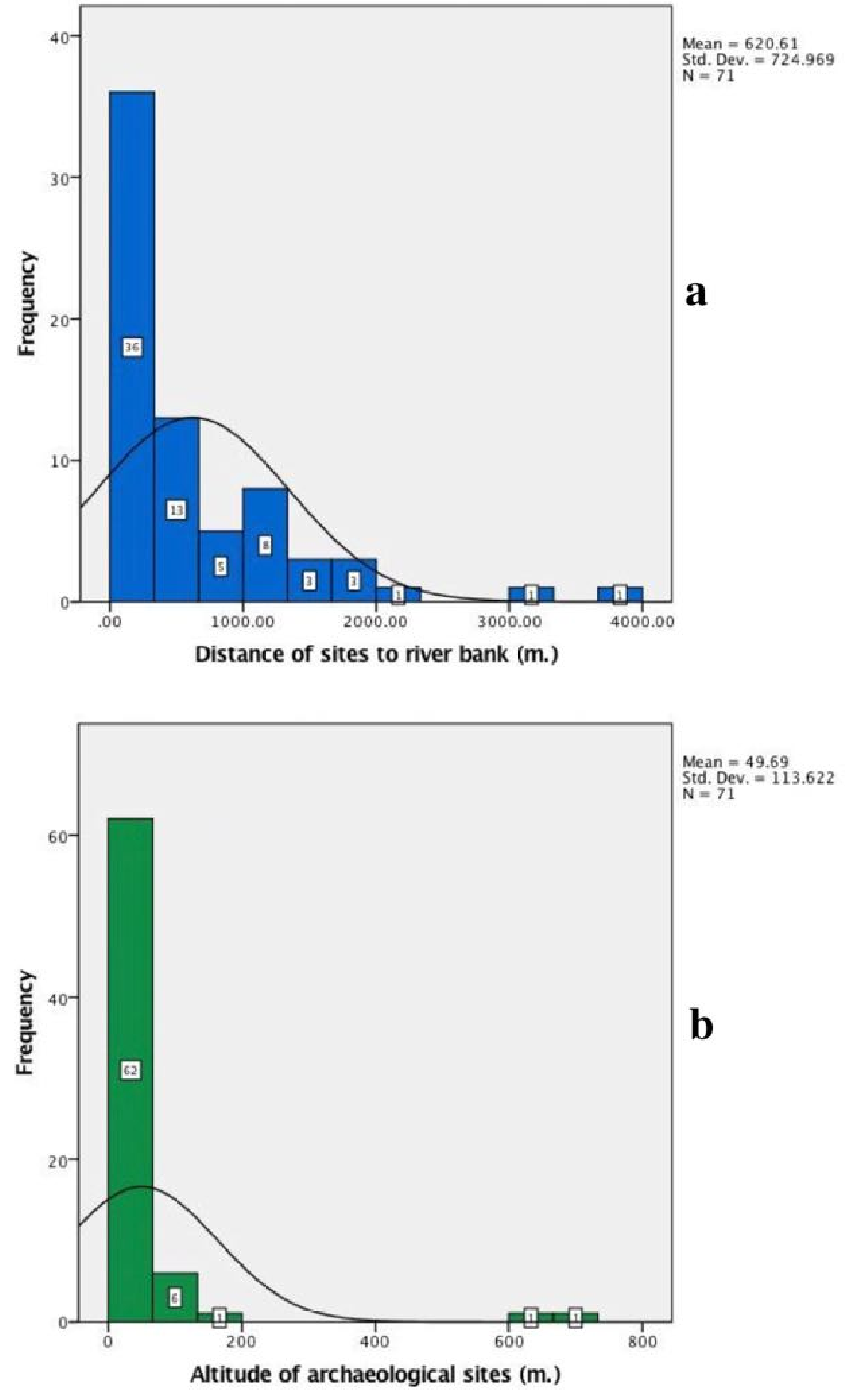


Fig. 2-1-11 Geographical environments of the Yuanshan cultural sites. (a: distance of sites to river bank; b: altitude of archaeological sites)

Judging from the artefact proportions within the Yuanshan Cultural assemblages, cross-referenced against the geographical environments of the archaeological sites, there is further evidence that human activity was linked to environmental factors. Shellfish and animal bones are unearthed in the Yuanshan site. They include *Corbicula maxima* Prime, *Viviparus* sp., *Melaoides* sp., *Ostrea* sp., *Trochus* sp., *Nassarius* sp., as well as the *Cervus nippon*, *Cervus univolor*, *Muniacus reevesi*, *Sus* sp. and *Canis* sp., etc. Result of stable isotope analysis shows that the *Corbicula maxima* Prime lived in a freshwater habitat, likely to be the wetland environment of the Ancient Taipei Lake. (Lee 2003) Tools made from animal bones have been discovered from the Yuanshan cultural sites, such as the bone adze, bone spear, antler harpoon, bone net sinker. Traces of use have been observed on the bones tools and are considered to be traces of actions such as cutting, scraping or sawing. In other words, the shellfish exploitation is reflected in a large number of unearthed tools of nets and harpoons. The discovery of bone tools and animal remains shows that small and medium-sized mammals, such as deer and pigs, were predominately the target for hunters. (Huang 1991, 1999a, 1999b)

It can be seen from the stone implements found on the Yuanshan cultural sites that the axe and hoe account for the majority, and these are probably related to agricultural activities. This is suggested by the remains of plant seeds discovered in the sites: *Melia* Azedarach L var. *subtripinnata* Miquel, *Mallotus* sp., *Broussonetia* sp., *Diospyros* sp., Melo L., and two burnt rice grains found in the archaeological contexts have been identified as the japonica varieties (Huang 1991, 1999a, 1999b).

These ecological remains and animal bones represent the environmental resources exploited in the Yuanshan diets, while the archaeological remains indicate the usage by prehistoric humans of implements such as the net sinker and axe for hunting, fishing and farming.

Taking these factors into consideration, it is natural to draw the following conclusions: The Yuanshan Culture people choose the hilly areas close to water sources as their main place of residence, and their food production model was mainly based on hunting or collecting marine or terrestrial animals and engaging in farming. Several questions are also derived from the above-mentioned conclusions: Is the settlement location preference of the Yuanshan Culture due to these people, regarded as foreign groups, being forced to adapt to the environment of the northern Taiwan region? Or is it due to their traditional habits of settlement choice in their original place of residence (possibly in the southeast coast of China)? Secondly, the rock materials used for stone tool-making by the Yuanshan people are mainly igneous andesites, rather the sandstones that were easily available around their occupation sites. Is it related to the preference of the rock's characteristics chosen for stone tool production?

These issues will be reviewed in the following chapter with the available and published literature on the geographical location of unearthed shouldered axes and their raw material of rocks procurement.

An Overview of Taiwan's Prehistoric Culture in the Neolithic Age

1. Prehistoric Cultures and Their Chronological Placement in Taiwan

The existing archaeological evidence shows that the Changbin culture found in southeastern Taiwan is considered as prehistoric culture developed between 50,000 and 40,000 years. It is the oldest and most widely distributed pre-pottery culture of the Paleolithic Age in Taiwan (Sung 1980). Based on the typology and production technique of flakes, Chang suggests it is the culture directly related to the flake tool cultures in South China and Southeast Asia (Chang 1970). Based on the chopper making method of Changbin Culture and a relative age determination, two[8] gravel choppers have been considered as a proof of human activities in the greater Taipei area from 10,000 to 6,000 BP.

A group of people from the southeastern coast of China may migrate and bring their culture to Taiwan, such as the coarse-corded pottery, ground stone tools and agriculture that probably grow a small number of rhizome crops, etc. (Fig. 2-1-15) Such culture is recognised as the Tapenkeng Culture and dated around six thousand years in the early and middle Neolithic age, which is widely distributed all over Taiwan, especially in the coastal region, and the outlying islands of Penghu (Tsang 1992, 2006b, 2012a, Liu 2002, Tsang and Li 2013).

[8] One was collected at Chihshanyen Site (Sung 1980:111), the other was unearthed at the Test-pitting in the south locality of Yuanshan Site (Huang 1992).

About 5,000 years ago, cereal and bean crops such as rice and millet began to appear in several archaeological sites and were considered to be affected by the continued immigration of outsiders (Chang 1969). In the middle of the Neolithic Age around 3,500 years ago, the prehistoric cultures in Taiwan showed the faces on their material cultures with complexity and diversity. The differentiation between cultures is manifested in their materiality, and the sources and developing directions of prehistoric cultures are not on the same track. For example, the decoration techniques of the pottery on the surface are more abundant than that of the archaeological culture earlier before. (Fig. 2-1-15 to 18 vs. 2-1-24 and 25) The number of sites has also increased rapidly, and the location of the sites in this period can be found from the seashore, plains, hills, and mountains. During this period, there are dwelling construction remains which indicate that the people gathered and lived in the settlement. There are groups developed into the tribal societies with the abilities of farming, animal husbandry. There are farming and animal husbandry. The technology for making stone tools is also more advanced than before. At the same time, there are also craft products with relatively fine and detailed technical requirements, such as pottery, textile, weaving, etc. For example, the ground stone tools were polished to reflect the gloss on the surface. (Fig. 2-1-19 and 20 vs. Fig. 2-1-26 and 27) This stage is usually regarded as the late Neolithic Age in Taiwan, the cultural development has gradually entered the stage of the Iron Age since then (Chang 1966, Liu 1996, Tsang 1999, Tsang 2012a, 2012b).

2. Prehistoric culture of the Neolithic Age

Apart from the Changbin culture of the Paleolithic Age, the study and important topics of prehistoric archaeology in Taiwan are laid on the prehistoric cultures in the Neolithic Age and after. The spatial-temporal framework of the prehistoric cultures in Taiwan was initially established under the context with a broad range of the cultural system which was studied and suggested by several scholars in the early 20th century, for instance, Kanaseki, Kokubu, and Kano. In the mid-20th century, archaeological scholars with profound experience in the excavation of the Anyang site in China like Li, Shi, and Kao, actively involved in the study. The archaeological research in Taiwan, as a result, has rapidly built the cultural sequence of Taiwan prehistory from the perspective of stratification and typology (Kano 2016, Sung 1956, Tsang 1999, Liu 1996, 2002d).

The characteristics of material culture in Neolithic Taiwan are the finds including the use and production of pottery, as well as the grindstone tools, and the behaviour of engaging in agricultural activities (Liu 1992). Yuanshan Culture is in this sequence of late Neolithic culture. The extraordinary of its content is that it existed only in northern Taiwan around 3500-2300 B.P., but also manufactured the artefacts by using the igneous rocks. The preference for the usage of the igneous rocks as such implies that the Yuanshan Culture followed on the production technology of the previous Hsuntangpu Culture for making stone tools or the temper(s) added to the clay for producing the pottery. And its apparent difference from the succeeded Chihwuyuan Culture between the material characteristics is that the Chihwuyuan cultural people apply the metamorphic rocks as the raw materials for artefact manufacturing. In the late Chihwuyuan Culture period, dated about 2000-1800 B.P., prehistoric cultures across Taiwan started the Iron Age at approximately the same time (Kuo 2002, 2014a, 2015). In other words, the feature of the massive application of the igneous rock on the production of the artefacts was rarely found in the later archaeological culture after the Yuanshan Culture in northern Taiwan.

Besides, the botanical garden culture that emerged in the later period of Yuanshan Culture has the style of the Huakangshan culture in eastern Taiwan in terms of pottery characteristics, which means that there is maybe an interaction or communication between the prehistoric people of northern and eastern Taiwan. Whether such communication is general in the archaeological cultures in the late Neolithic period is also crucial to the research of prehistoric culture in Taiwan. Perhaps we can find clues by comparing the properties and styles of archaeological objects in different prehistoric cultures in Taiwan during the mid-to-late Neolithic period around 4500-1800 B.P. The prehistoric cultures and their characteristics of the archaeological materials currently known in Taiwan are outlined below based on the chronological framework and the geographical distribution. (Fig. 2-1-12, 2-1-13, 2-1-14).

Fig. 2-1-12 Tapenkeng Culture in the Early Neolithic Age in Taiwan (After Liu 2002b).

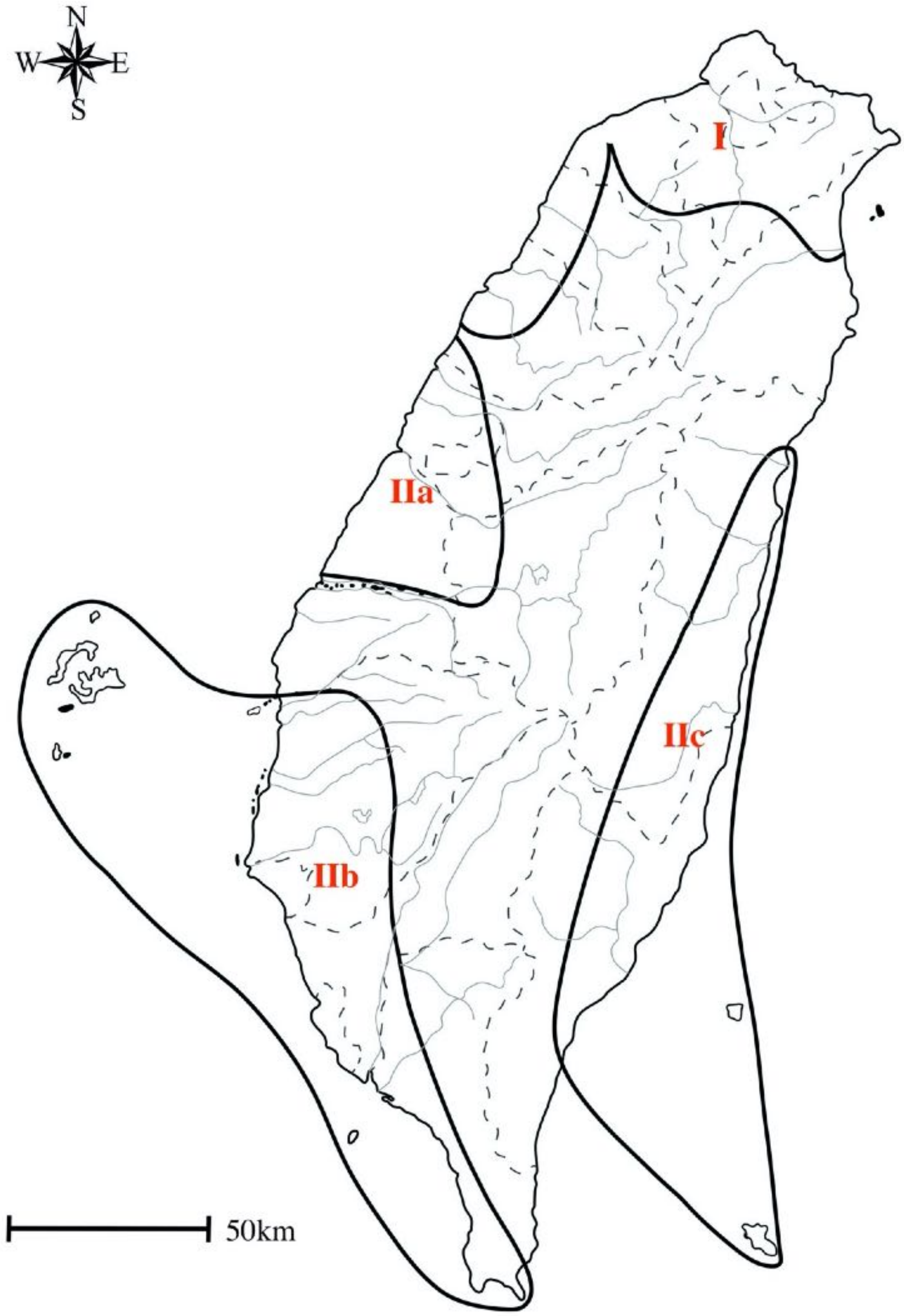


Fig. 2-1-13 The Scope of Each Archaeological Culture in the Middle Neolithic Age in Taiwan.

I: Hsuntangpu Culture. IIa: Niumatou Culture. IIb: Niuchozhi Culture. IIc: Eastern Coarse Corded Pottery Culture. (After Liu 2002b)

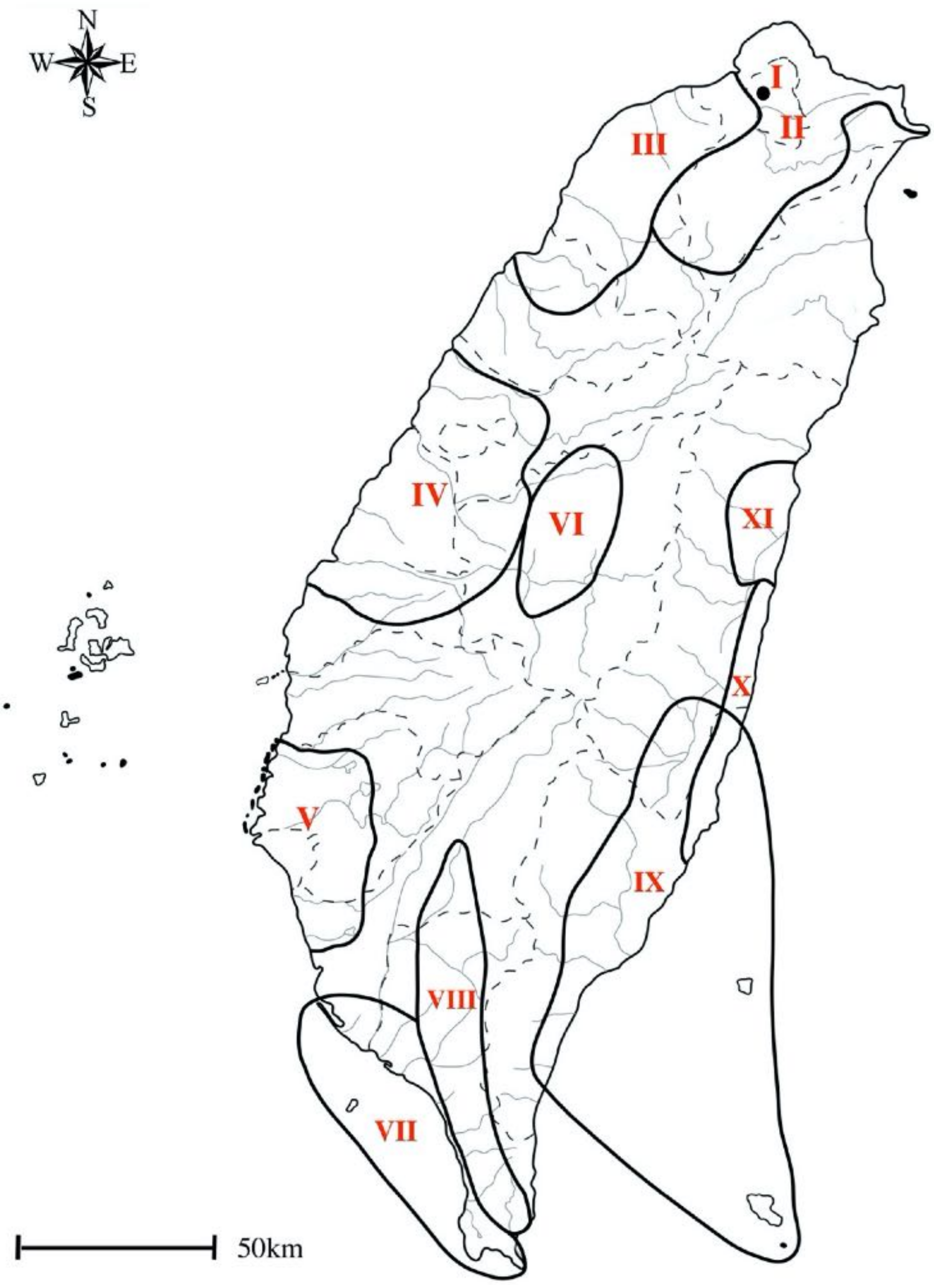


Fig. 2-1-14 The Scope of Each Archaeological Culture in the Late Neolithic Age in Taiwan.

I: Chihshanyen Culture. II: Yuanshan Culture. III: Chihwuyuan Culture. IV: Yinpu Culture. V: Tahu Culture. VI: Tamalin Culture. VII: Fengpitou Culture. VIII: Xianglin

Culture. IX: Peinan Culture. X: Chilin Culture. XI: Huakangshan Culture. (After Liu 2002b)

Tapenkeng Culture (Fig. 2-1-15)

The Tapenkeng Culture is the earliest Neolithic culture ever discovered in Taiwan. It is dated as earliest between 6,000 and 5,000 B.P. and also called the coarse-corded pottery culture (Tsang 1992). It is spread all over Taiwan and is the cultural subject of Taiwan prehistory in the early Neolithic age. The characteristics of this culture except for the coarse corded pottery, there are not many stone tools found in quantity and typology. Only the chipped and ground implements are discovered for fishing, hunting, and probably planting of root crops, such as axe, hoe, net sinker, and arrowhead. It is noted that a few basalts shouldered adzes appear in the late stage of the Tapenkeng Culture around 4800-4200 BP. It is speculated from the unearthed stone tools that the farming type was on the stage of the slash and burn mode, which the Tapenkeng people started to grow food as part of their subsistence. The time the Tapenkeng people started planting is unknow, but, according the archaeological evidence, the agricultural activates have already begun at least in the late stages around 4800-4200BP. Still, the main production activities of Tapenkeng people counted for hunting, fishing, and gathering. Most of the archaeological sites of the Tapenkeng Culture are located on the seashore, lakeside or estuary of rivers, which is considered to be a culture adapted to the environment of the ocean, rivers and wetlands and so on (Fig. 2-1-12). Many scholars agree on the hypothesis that the Tapenkeng Culture is a new culture in Taiwan migrated from the southeast coast of China and is one of the earliest ancestors of the Austronesian (Chang 1969, Tsang 2006b, 2012a, 2016).

Fig. 2-1-15 Pottery and stone tools of Tapenkeng Culture. (Huang and Liu 1980, plate 4.)

Fine corded mark pottery culture (Fig. 2-1-16, 2-1-17)

Between about 4,500 years ago and 3,500 B.P., Taiwan's prehistory gradually stepped into another stage of cultural development from the Tapenkeng Culture, and that stage of culture is generally called the Fine corded-mark pottery culture. This culture, like the previous culture, is widely spread across all coastal regions of Taiwan, and it was not until the late-stage around 3,800 to 3,500 B.P. that it moved along the river valley to the inland. The distinctive feature of this culture is the fine corded mark on the surface of the pottery. Its lifestyle is dominated by cereal agriculture but hunting and fishing still occupy an important position. On the base of the regional difference in the cultural essence from various areas, the fine corded-mark pottery culture therefore is subdivided into several sub-cultures, namely the Hsuntangpu Culture in the north, Niumatou culture in the central part, the Niuchozhi culture in the south, and the Eastern coarse corded red pottery culture in eastern Taiwan (Chang 1969, Li 1992, Liu 2001).

Fig. 2-1-16 Pottery Niumatou Culture. (Liu 2002b, plate 34.)

Fig. 2-1-17 Pottery of Niuchozhi Culture. (Liu 2002b, plate 10.)

Hsuntangpu Culture (Fig. 2-1-18, 2-1-19, 2-1-20)

Its age dates between 4,800 and 3,500 B.P. and is the latest identified regional culture in the middle of the Neolithic Age. It has the content of the fine corded-mark pottery to some extent, and gradually evolves during the late stage of the Tapenkeng Culture. Their site is large in scale and resides for a long time as a settlement and is a tribal society whose social class judgment comes from rare ornaments found in some sites (Liu 2001). Farming appliances account for a large proportion of all unearthed tools, and it is known that agriculture played an important role in various production activities of the society at that time. Remaining the typological similarity of pottery between the Hsuntangpu and Tapenkeng though, some have changed significantly in terms of the decorative design (Kuo 2015). The biggest discrepancy is the disappearance of the flared rim decorated with incised linear patterns. The stone tools appear in large-sized projectile points and stone knives, as well as the bark beaters which are believed to use as a tool for processing tree bark for clothing. On the distribution of settlements and the occurrence of stone knives indicate that the agricultural type of Hsuntangpu Culture may be capable of growing cereal crops, which is different from the slash-and-burn agriculture as the food supplements to the subsistence of the Tapenkeng Culture (Liu 2001, 2002b, Chu 2012, Kuo 2015).

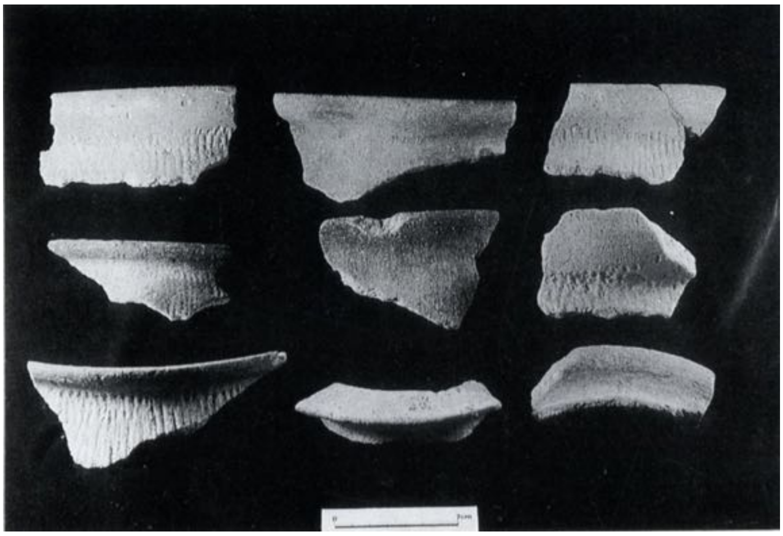


Fig. 2-1-18 Pottery of Hsuntangpu Culture. (Huang 1991, plate 27.)

Fig. 2-1-19 Stone tools of Hsuntangpu Culture from Talongtong Site. (Chu 2012, plate 189.)

Fig. 2-1-20 Stone tools of Hsuntangpu Culture from Talongtong Site. (Chu 2012, plate 193.)

Chihshanyen Culture (Fig. 2-1-21, 2-1-22, 2-1-23)

The culture currently only appears on the north side of the Taipei Basin, dates between 3,600 and 3,000 B.P. The surface of the pottery of this culture is mostly plain and polished, characterised by black or painted pottery. Innumerable remains of organic matter left over from the site, such as wooden utensils (digging sticks), ropes and plant seeds. A large amount of carbonised rice and agricultural appliances unearthed from the sites shows that the Chihsanyen people can farm the rice at that time. Lots of animal remains found at layers, for instance, pigs, fish remains, Formosan sika deer, and Formosan Reeve's muntjac, the hunting, and fishing still are one of the supplies activities for the food, apart from the rice cultivation (Huang 1984, Liu and Kuo 2000, Liu *et al.* 2004).

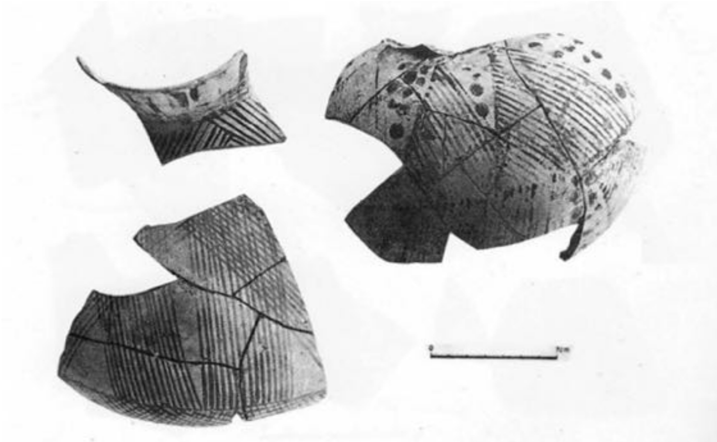


Fig. 2-1-21 Pottery of Chihshanyen Culture. (Huang 1984, plate 17.)

Fig. 2-1-22 Wooden drilling sticks of Chihshanyen Culture. (Huang 1984, plate 44.)

Fig. 2-1-23 Bone and stone tools of Chihshanyen Culture. (Huang 1984, plate 33.)

Yuanshan Culture (Fig. 2-1-24, 2-1-25, 2-1-26, 2-1-27)

The Yuanshan Culture is a prehistoric culture prevalent in the Taipei Basin dated around 3,500 to 2,300 B.P. in the late Neolithic period. It is also the civilisation that emerged from the north side of the Taipei Basin after the preceding cultures of Hsuntangpu and Chihsanyen. The existence of this culture lasted for about a thousand years, the change and divergence in the cultural essences of the previous and following period are presented on their materials (Kuo 2014a).

At that time of Yuanshan Culture retained, it is presumed that people lived on the upper part of the hill surrounding by the Taipei Basin and participated in the agricultural, hunting and fishing activities for the food. They probably had the knowledge to plant rice. The utensils of the Yuanshan Culture are featured by the shouldered axe, the stepped adze, a large-sized ground stone shovel and the double-mouthed with the ring-foot jar, etc. The large stone shovel is normally suitable for applying to the deeper-rooted agriculture or the wet clay soil where the Yuanshan site located. These traits are quite distinct from other cultures of a different period. It is generally believed that these are the characteristics of foreign immigrant culture, rather than evolved locally from succeeding the tradition of the Hsuntangpu Culture. The Yuanshan Culture has another subculture, called the type of Tutikungshan that the ages mostly are concentrated between 2800 and 2300BP, but maybe as late as 1700BP. (Fig. 2-1-28) This type is a new style of culture produced in the late Yuanshan Culture to adapt to the environment of the hilly area. At present, only a small amount of farming, fishing, and hunting tools are found (Sung 1980, Huang 1997, Liu and Kuo 2000, Liu *et al.* 2004, Kuo 2014a).

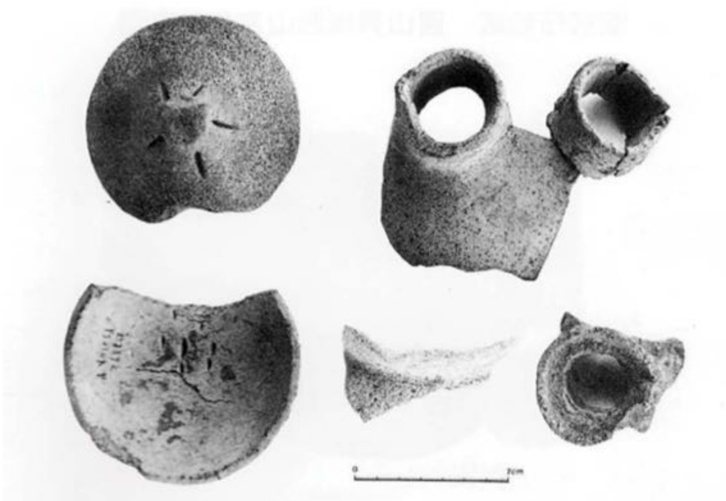


Fig. 2-1-24 Pottery of Yuanshan Culture. (Huang 1984, plate 51.)

Fig. 2-1-25 Pottery handles of Yuanshan Culture. (Huang 1984, plate 51.)

Fig. 2-1-26 Stone hoes of Yuanshan Culture. (Huang et al. 1999b, plate 52.)

Fig. 2-1-27 Stone knife and arrowheads of Yuanshan Culture. (Huang et al. 1999b, plate 54.)

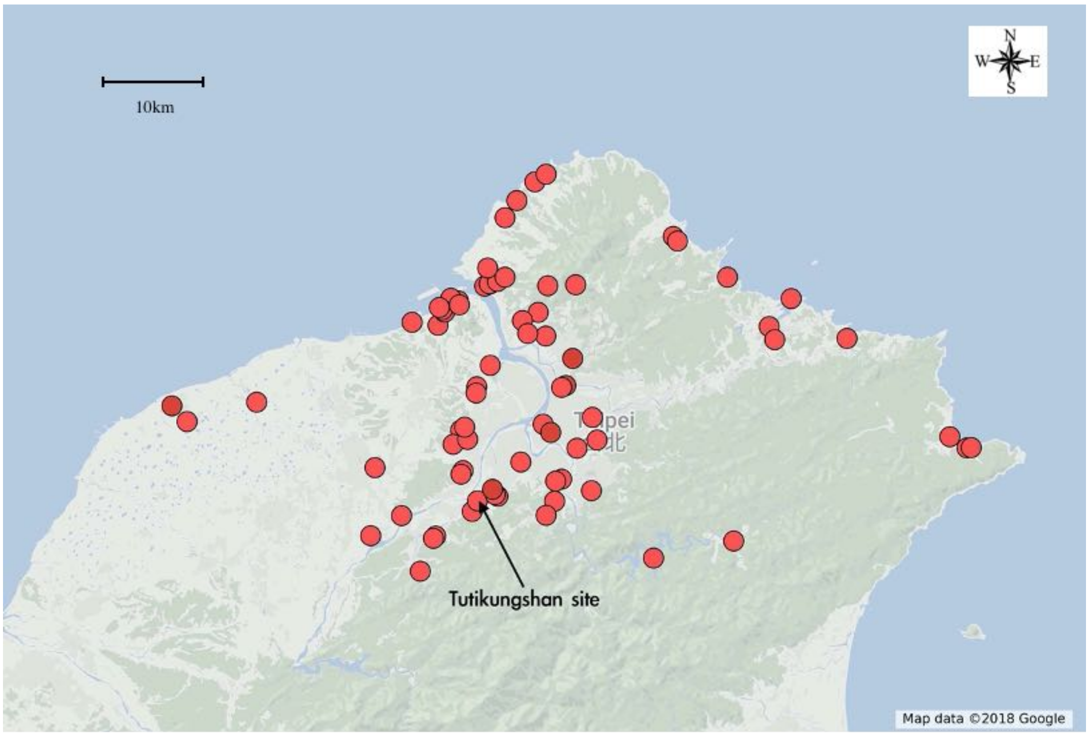


Fig. 2-1-28 Location of the Tutikungshan site in northern Taiwan.

Chihwuyuan Culture (Fig. 2-1-29)

It is the prehistoric culture that appeared in the Taipei Basin at the latest in the Neolithic Age, dating from about 2,500 to 1,800 B.P. The dispersion range of Chihwuyuan Culture is highly overlapping with that of Yuanshan Culture, mainly situated in the south of the Taipei Basin, on both sides of the Tahan Creek, and scattered in the terraces of the coastal areas along the North Coast of Taiwan during its late stage. This seems to imply that the site selection preference between two cultural people are similar, and also suggests the sequential relationship in time of two culture. However, the choice of raw materials, characteristics, and techniques of artefact production differ from the culture of Yuanshan (Liu and Kuo 2000, Chen 2001, Kuo 2002).

The pottery features are typically decorated with the stamped and plain on the surface, and normally shown the colours of brown or grayish-yellow, it is also called the impressed with lattice pattern pottery culture. The types of stone tools include the giant spoon-shaped hoe (also called the Patu[9]-shaped tool in Taiwan), the large-sized grinding axe, and the stepped adze, all are finely polished. Yet, there is no shouldered axe of the Yuanshan Culture discovered. Most of the raw material of stone is mainly shale and sandstone, and the use of andesite is rare. The unearthed stone tools are rich in the category and mostly the farming tools, and presumably, their sources of food rely more on agricultural production (Liu and Kuo 2000, Chen 2001, Kuo 2002, Liu 2002c, Chen and Kuo 2004, Liu *et al.* 2004, Chiu 2010, Chu 2012).

It coexisted with the Tutikungshan type which evolved from the late Yuanshan Culture for some time. Another study has a different view on the so-called coexistence of two cultures chronologically. This view holds that the Chihwuyuan

[9] Patu is a pounder used by the indigenous people of New Zealand.

Culture is a prehistoric culture that appeared in north Taiwan after the Yuanshan Culture. The relationship between the two should be regarded as successive rather than coexisting. This debate is currently continuing due to differences in the material culture of two (Liu and Kuo 2000, Kuo 2002, Liu *et al.* 2004).

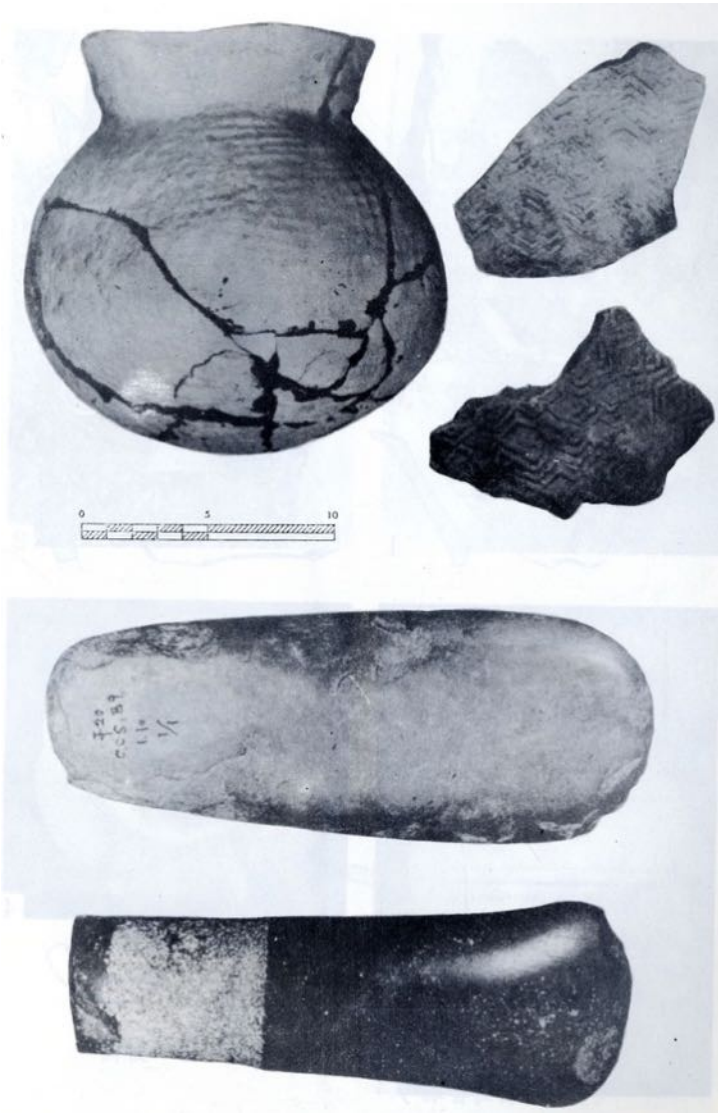


Fig. 2-1-29 Pottery and stone tools of Chihwuyuan Culture. (Liu 2002c, pp. 104)

Yingpu Culture (Fig. 2-1-30)

Yingpu Culture is a late Neolithic culture after the Niumatou Culture in central Taiwan. It dates about 3,500 to 2,000 B.P. It has a wide distribution range, including different terrains, such as coastal areas, plains, terraces near the riverside, showing greater flexibility of the adaptation to the natural resources. The Yingpu Culture is featured by the greyish-black pottery and the principal types are composed of earthen bowl and jar. The surface of the pottery is usually rich in decorative patterns. There are some patterns use as a base for further combinations to arrange and form different styles, such as a feather pattern, a concave pattern, a thorn pattern, and a circular pattern. There are rich in amounts and types of stone artefacts, consisting of the large-sized plough, axes, adzes, shovels, stone knives, net sinkers and a small number of jade products. Also, there are sherds with impressions of rice husks found. It can be inferred based on the impressions of rice husks, stone knives and plenty of agricultural appliances that the Yingpu Culture was quite dependent on rice farming for the dietary subsistence (Huang and Liu 1980, Liu 1999, Liu 2002b).

Fig. 2-1-30 Pottery and stone tools of Yingpu Culture. (Liu 2002b, plate 36.)

Tahu Culture (Fig. 2-1-31)

The Tahu culture is distributed from the Tahu Platform and the Tainan Terrace and existed between 3,500 to 2,000 B.P. Some scholars have subdivided the Tahu Culture into two types of Tahu and Wushantou according to the regional divergence on the pottery colours. The Tahu type has more red pottery and often has band-like wavy patterns around the rim and neck of the pottery, whilst the Wushantou type phase is dominated by greyish-black pottery with less decorative patterns on the surface (Chen 1980, Lee 1999, Liu 2002b).

Tahu cultural site appears usually in the form of a shell mound. Shell mounds and the extensive use of tools made of animal bones, antler and shells are the characteristics of the Tahu Culture. Fewer plant remains are found in this culture. The sites of the late Tahu Culture unearthed the ecological remains of rice and have learned to raise livestock like pigs. There are not many stone tools of Tahu Culture found. In the early stage, the stone tools are mostly made of a slate-like axe, hoe, knife, and arrowhead. In the later stage, the Patu-shaped tool made by sandstone and the basalt adze is seen frequently (Chen 1980, Tsang and Li 2013).

Fig. 2-1-31 Pottery and stone tools of Tahu Culture. (Liu 2002b, plate 15.)

Tamalin Culture (Fig. 2-1-32)

The Tamalin Culture developed in the inland areas of central Taiwan around the age between 3,600 to 1,000 B.P. Its main cultural features are the numerous unearthed stone and jade products and the burial tradition of stone slab coffin. The raw material of rocks to cut into the slab for burials are the slate that was procured from the quarry of the west side of the Central Mountain Range of Taiwan, and the jade material is dominantly by the nephrite collected from eastern Taiwan (Liu 2002b).

The cultural sites unearthed a large number of stone tools, including hoes, knives, sickles for farming, adzes, and chisels for woodworking, arrows and net sinkers for hunting and fishing, as well as hammerstones, saws, grindstones for making stools mentioned above (Liu 2002b). Jade articles are more common ornaments, such as ear pendants, bracelets, and tubular beads. Like the Peinan Culture, the Tamalin Culture is also familiar with making jade ornaments and using stone slab burials. The funeral objects of the slate slab burial are accustomed to jade products, or objects that conform to the identity of the dead. For example, the ceramic spindle whorl is normally buried with female aside. The production and use of a large number of stone artefacts show the prosperity of the stone manufacturing industry in Tamalin Culture. The characteristics of pottery are both presented in the fine corded-mark red pottery of the Niumatou Culture and the greyish-black pottery of the Yingpu Culture (Liu 2002b, Ho and Liu 2004, Liu 2006).

It can be learnt from the unearthed artefact assemblages that the Tamalin Culture presents a mode with emphasis on the activities of agriculture, fishing, and hunting for their subsistence. Besides, the cultural essence of Tamalin is complex and self-contained. There are four main sources of cultural composition in Tamalin culture: the Niumatou Culture and the Yingpu Culture in the central part of Taiwan, the Peinan Culture in the east, and the traditional culture of Tamalin. Such a rich cultural element may be caused by geographical proximity to the center of Taiwan and the influence of prehistoric cultures during different periods in the surrounding areas (Ho and Liu 2004, 2006).

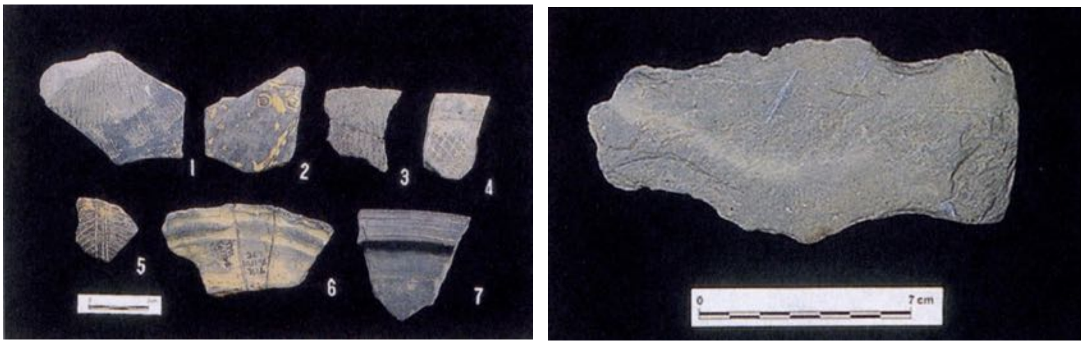


Fig. 2-1-32 Pottery and stone Ge (knife) of Tamalin Culture. (Liu 2002b, plate 37, 38.)

Fenpitou Culture (Fig. 2-1-33, 2-1-34)

Fenpitou Culture usually distributed on the coastal region of the southmost of the Hengchun Peninsula in south Taiwan, it dated to around 3,500 to 2,000 B.P. (Liu and Yang 1994) At the same time as the age of its existence with the Tahu Culture in central Taiwan, there seems to have an association between the two of some extent. Such as its type of pottery is similar to that of the Tahu Culture, but there are still distinct features that the Tahu Culture does not have (Liu 1991). There is an extensive proportion of the pottery which the surface is decoratived with patterns in the Fengpitou Culture (Yang 1997). The style of pottery in the early stage is similar to that of the Tahu Culture which was dominated by plain red pottery. Occasionally, there are several patterns on the pottery surface applied, such as a coarse corded pattern, an incised pattern, and a mat design. A small number of pieces are decorated with the geometric pattern on the surface of the painted pottery. In the middle of the Fenpitou Culture, the plain black pottery is often seen and occasionally applied with the incised pattern on the surface. Pottery of various shapes and colors can still be seen during this period. Pottery features of the late phase are mainly presented the polished greyish-black pottery with the stamped lattice pattern, as well as the patterns of shell impressed or incised lines. The classes of pottery are complex and diverse mainly with jars, pots, alms bowls, bottles, and basins (Yang, 1997, Liu and Chen 1997).

Some of the pottery fragments have also been found the traces of the rice husks impressions on the surface. Stone tools include stone axes, stone shovel, stone knives, stone mills, stone shovel, perforated stone knives, and other agricultural tools. Several stone appliances for daily work use of Fengpitou Culture were unearthed like axes, hoes, knives, grindstone, arrowheads, perforated knives. Inferring on the base of the rice husks impressions and the agricultural tools unearthed that the Fengpitou Culture somehow relied on rice farming for the dietary subsistence. In the late stage, the appearance of iron objects and glass beads suggests that human contact with outsiders may be quite frequent during this period (Chang 1969, Lee 1985, Liu and Yang 1994).

Fig. 2-1-33 Painted pottery of Fenpitou Culture. (Lee 1985, plate 18A.)

Fig. 2-1-34 Shoe-shape stone knife of Fenpitou Culture. (Lee 1985, plate 15B.)

Xianglin Culture (Fig. 2-1-35, 2-1-36)

Xianglin Culture is a prehistoric culture discovered in Kenting National Park of south Taiwan, dated at 2,700 B.P. The academic community currently has limited knowledge of this culture, only knowing that the culture is distributed in the river valley area along the Kangkou River in Pintung of south Taiwan. The pottery of this culture for most of part is composed of red plain pottery with the soft and friable texture. The traces of the slate slab burial also have been found in this culture. Additionally, the environmental adaptation of its cultural expression is different from the adaptation pattern of the prehistoric culture of the aforementioned coastal lowland type. For instance, the tools for fishing and hunting in the archaeological site such as the Yuanshan Culture, that commonly resided in the coastal regions, river banks or valleys are not found in the Xianling Culture (Kuo 2008).

Fig. 2-1-35 Pottery and stone tools of Xianglin Culture. (Academia Sinica[10])

Fig. 2-1-36 Sandstone slab coffin of Xianglin Culture. (Li 1999, pp. 36.)

Peinan Culture (Fig. 2-1-37, 2-1-38)

The sites of Peinan Culture are widely located across the regions from north to south in eastern Taiwan, especially in the South Section of Huadong Coast, East Rift Valley, and the Taitung Plain. It existed between 5,300 and 2,300 B.P. and coexisted

[10] The unearthed artefacts of the Xianglin Culture. Available at the webpage of the Prehistoric production activity, Academia Sinica, Taipei. http://proj1.sinica.edu.tw/~damta/kt05-4-1.html

with the Chilin culture for a long time. The peak period of Peinan Culture laid in around 3,500 to 2,000 B.P. The traits of Peinan Culture are well known for its jade craftsmanship, the slate slab burials customs and the large stone architectural remains (Sung and Lien 1987, 1988).

The sites of the Peinan Culture are all quite large. For example, the area of the Peinan site measures 800,000 square meters. Such a large dimension of the individual site indicates that the settlement of Peinan Culture is huge, the buildings are arranged rigorously in rows and imply an organised sociocultural structure already developed in society. In terms of the cultural content of Peinan, the subsistence of is mainly based on agriculture. Although there are not many axes and hoes unearthed in the sites, there are a large number of knives, sickles, and stone pestles for removing the rice husks. It is, therefore, speculated that the Peinan people are planting millet and land rice (Kang and Chen 2011, Kang 2013). Hunting tools like spears and arrowheads appear frequently and largely in the sites but lack the tools for collecting marine resources. But, fishing equipment, such as net settlers and pointers, unearthed from sites in coastal areas indicate a dependence on marine resources (Lee and Yeh 1995). The cause of such opposite behaviours on the application of marine resources may be a result in responding to differences in the location of settlements and their patterns of adaptation to the environmental resource (Sung and Lien 1987, 1988).

The pottery of the daily use utensils is mainly composed of coarse plain red pottery and orange plain pottery, and there is rarely decorative pattern on the surface of the pottery. The finished products of the jade are quite exquisite, and the jade funeral objects are commonly left aside with the dead in the slate slab coffin. The jade production technology at that time was quite good. A certain group or individuals likely specialise in the production of jade ornaments and trades the jade artefacts (Wang 1983, Lu and Xia 1997, Yang 1997).

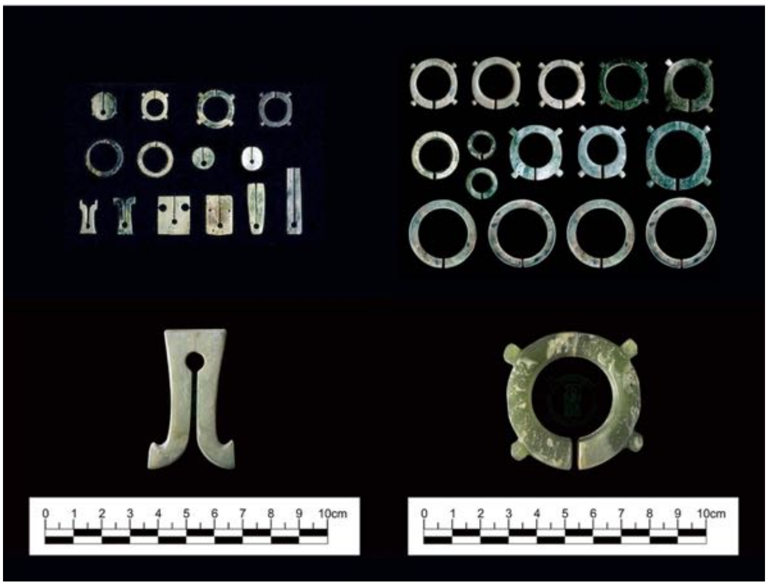


Fig. 2-1-37 Jade ornaments of Peinan Culture. (National Museum of Prehistory, Taitung[11].)

[11] The photo is posted on the Facebook of the National Musuem of Prehisotry, Taitung. https://www.facebook.com/NMPrehistory/photos/pcb.2299177006768146/2299175810101599/?type=3&theater

Fig. 2-1-38 Pottery of Peinan Culture. (Sung and Lien 1987, plate 24.)

Chilin Culture (Fig. 2-1-39)

The period of Chilin culture existence is similar to the peak of Peinan Culture around 3,000 B.P. Its sites are mainly distributed in the foothills of the middle part of the Coastal Ranges in eastern Taiwan. This culture also known as "the megalithic culture" in Taiwan, shows that the volume of its stone products is quite large, including stone wheels, stone statues, sarcophagi, monolith, and other types. The processed megaliths are considered to be associated with the ritual practices of Chilin culture. Like the Yuanshan Culture existed in north Taiwan, such megalithic features do not appear anywhere else in Taiwan (Liu 1993). Therefore, its origin is speculated to be related to the megalithic culture of the Southeast Asia Peninsula. The lifestyle of Chilin culture is probably centered on agriculture, and cereal crops are grown in the form of slash and burn. The pottery is dominated by the red plain pottery tempered with the andesite particles procured locally in the quarry of Coastal Ranges or the outlying islands of Green and Orchid (Liu 1993, Chao 2004).

Fig. 2-1-39 Pottery and stone tools of Chilin Culture. (Academia Sinica[12])

Huakangshan Culture (Fig. 2-1-40)

The Huakangshan Culture is scattered in the northern section of the east coast of Taiwan, dating from 3,000 to 1,500 B.P. (Chao *et al.* 2013) The characteristics of the pottery are decorative the surface of the abdomen with wavy or short-line impressed patterns, and the ornamental motifs on the pottery handle are typically decked with human, fish or beasts (Yeh 2001). There are also many potteries painted in red on the surface. The large-scale pottery urn burial is the key feature of the Huakangshan Culture that is different from other cultures in the East Coast region. Stone tools include as net sinkers, axes, knives, spears, arrowheads, adzes, chisels and so on (Chen 2017). A small number of tools made by animal bones, as well as ornaments of an earring, bracelet, jade pendants, and other decorations were unearthed. According to the volume on remains of the fishbone, small mammalian, and on the number of agricultural tools, it is presented the subsistence of Huakangsan Culture were dominated by both marine and terrestrial resources and

[12] Webpage of the Chilin Culture unearthed from the Chilin Site. Academia Sinica, Taipei. http://twstudy.iis.sinica.edu.tw/preHistory/img/p100-2.jpg

used agricultural production as a dietary supplement (Yeh 2001, Chao *et al.* 2013, Chen 2017).

Fig. 2-1-40 Pottery and stone tools of Huakangshan Culture (Chen 2017).

3. Neolithic prehistoric culture in northern Taiwan

Since 1896 Awano Dennojou discovered the Chihshanyen site in Taipei City (Liu and Kuo 2000), the study of prehistoric cultures and archaeological sites in Taiwan has been carried out by archaeologists more than a hundred years. Up until the official research plan of Survey of Archaeological Sites in the Taiwan Region for full-scale in 2004 (Liu 2004), there are 275 prehistoric sites have been discovered in Taipei Area namely three administrative divisions: New Taipei City, Taipei City and Keelung City (Tsang and Liu 2002，Liu and Kuo 2000). According to the research of artefacts assemblage and typology associated with the radiocarbon dating outcomes, five prehistoric cultures of Neolithic age in the great Taipei area have been identified and sequenced chronologically as Tapenkeng Culture, Hsuntangpu Culture, Chihshanyen Culture, Yuanshan Culture, and Chihwuyuan Culture.

Combined with the technological evolution of five prehistoric cultures in northern Taiwan, it is generally believed that the manufacturing methods of Yuanshan Culture pottery and stone tools may be influenced by outsiders, mainly from China (Chang 1954,1959, Sung 1954, 1964, 1980, Ferrell 1966, Huang 1985, Peng 1987, Wang 1988, Fu 1988, Liu 1988, Li and Fan 1995, Huang *et al.* 1999a, 1999b, Liu 2000, Kuo 2014a). And strengthened regional style after absorbing the content(s) from exterior factors, especially in the raw material procurement and production locally. The theme should be emphasized is that the selection of technology and raw materials is the key. With systematic research of shouldered axes technology enable us to clarify the development of Yuanshan Culture, that is, the urge for external stimulation and internal inheritance. The later cultures carry on such feature and continue its progress into a historical period in Northern Taiwan.

Chapter 2-2_BRIEF HISTORY OF THE YUANSHAN CULTURE RESEARCH

Literature review of the Yuanshan Culture

1. Introduction of the Yuanshan Site

Yuanshan is an independent small hill on the west side of the Taipei Basin. It is surrounded by flat land and is on the south bank of the Keelung River. It is about 36 meters high and was originally a Tertiary sandstone hillock. The site is located on a gentle slope on the west side of the Yuanshan. According to the archaeological evidence unearthed from abundance in succession, it is a site of multi-cultures. On the foundation of the chronological order, there are the pre-pottery culture, the Tapenkeng Culture (coarse corded pottery culture), the Hsuntangpu Culture (fine corded pottery culture), the Yuanshan Culture, the Chihwuyuan Culture, and the Shihsanhang Culture. The Yuanshan site covers almost every archaeological culture that occurs in the Taipei Basin and the surrounding area (Fig. 2-2-1 Map of Yuanshan site Area).

Since 1896, Awano Dennojou collected a stone axe at Chihsanyen and sent the message back to the Japanese academic community, drawing attention from people whose interest in the Taiwanese prehistory, including Ino Kanori. In 1897, Ino Kanori and Miyamura Eiichi went and investigated the area of Yuanshan near Chihsanyen for first test-pitting excavation which found prehistoric remains and named the shell mound as Yuanshan later. This discovery resolved the debate on the existence of prehistoric culture in Taiwan and attracted many scholars at that time to invest more in research. The most time devoted to research assuredly was the Yuanshan site, which became the beginning of Taiwan's prehistoric archaeological research. Afterward, RyuzoTorii, Ushinosuke Mori, and Tadao Kano published respectively reports of their surveys and discoveries in various regions and the mountainous areas where indigenous people inhabited all over Taiwan. These reports show that the Taiwanese archaeological working area in Taipei at that time, which has been centered on Yuanshan shell mound, is extended to the environment of the geographical conditions based on the river valley terraces, the hills and the mountains (Kanaseki and Kokubu 1990, Oda 2010).

During the time between the Japanese rule and the late 1960s, scholars of this stage intermittently conducted archaeological research on the plentiful material remains unearthed at the Yuanshan site (Ino1897, Torii 1897, 1911, Ishizaka 1923, Miyamoto 1939, Shih 1954a, 1954b, 1957, Sung 1954a, 1954b, 1955a, 1955b, Chang 1954, 1957, Liu 1963, Sung and Chang 1964, 1966, Kanaseki and Kobuku 1990). Until the late 1980s, after about 20 years of interruption, it again targeted the Yuanshan site and its surrounding areas for a series of intensive archaeological investigation and excavation work, in order to understand the content, origin and decline of the Yuanshan Culture to acquire the more reasonable existence era, and its relationship with the archaeological culture of the neighboring area (Lien 1988, Huang 1989, 1991, 1992, 1997, Chen 1994, Huang *et al.* 1999a, 1999b, Liu *et al.* 2008, Kuo *et al.* 2012, 2013). Simultaneously, under the principle of cultural assets protection, the coverage range of the Yuanshan site is demarcated about 2.7 hectares for maintenance and preservation (Huang 1999a). On May 1, 2006, it was announced as a national site by the Taiwan Executive Yuan[1]. At present, the Yuanshan site, like other national heritages, has been assigned an exclusive inspector(s) to track and report the current status of the site to the authority.

In recent years, scientific analysis has been applied to conduct topic-oriented research, such as the dietary of Yuanshan Culture people (Lee *et al.* 2016a、2016b). The aforementioned archaeological works, associated with surveying the archaeological sites in northern Taiwan and conducting excavations at some sites in the region, have obtained fruitful and intelligible archaeological materials. These shreds of pieces of evidence help to understand the different prehistoric cultural sequences, absolute ages, and the contents of various cultures in the site, which enable archaeologists to further explore the origin and significance of the Yuanshan Culture in the late Neolithic Age (Sheng 1962, Liu and Kuo 2000). The issues related to Taiwanese shouldered axes that this study attempts to solve are on the foundation of previous works and the application of scientific analysis approaches with emphasising the interpretations on both the quantitative data of artefacts and the old works of pictures and literature, regarding the study on the functional usage of the shouldered axe.

[1] Available at the National Cultural Heritage Database Management System https://nchdb.boch.gov.tw/assets/overview/archaeologicalSite/20060501000002

The Yuanshan site is the type site of the Yuanshan Culture. The cultural layers list chronologically in the Yuanshan site are the Tapenkeng Culture, the Hsuntangpu Culture, the Yuanshan Culture, the Chihwuyuan Culture, the Shihsanhang Culture and the Han Chinese culture of Qing Dynasty (Table 2-2-1).

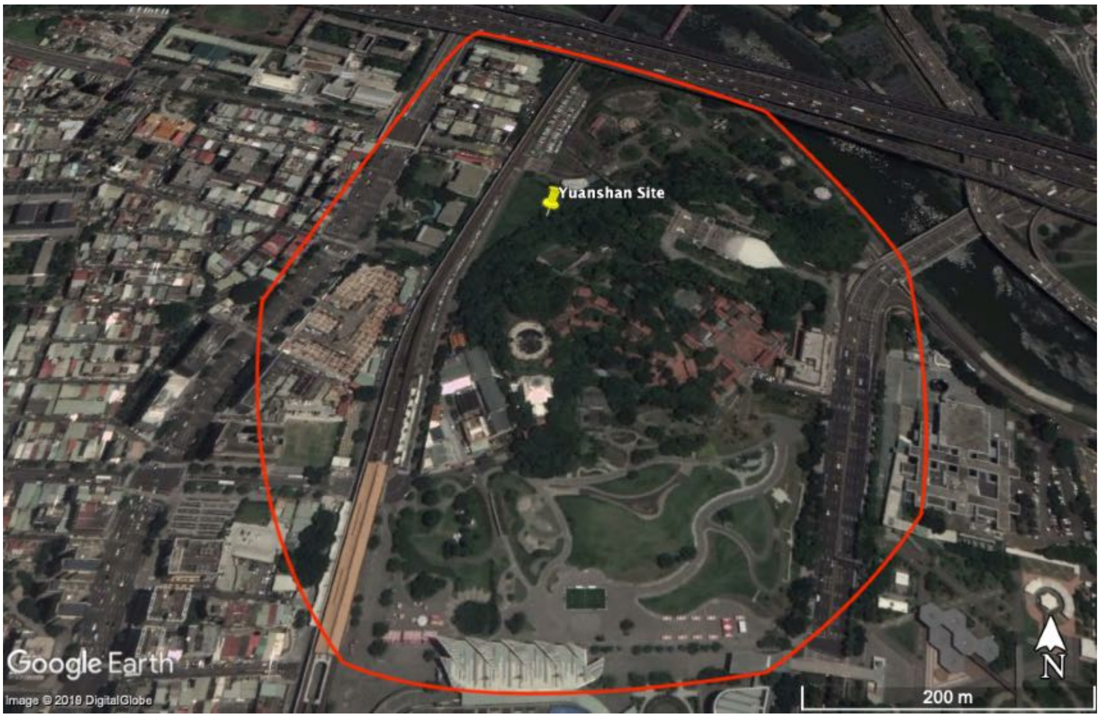


Fig. 2-2-1 Map of the Yuanshan Site Scope Area.

Layer	Archaeological culture	Age
7	Remains of the Han Chinese in the Qing Dynasty (1644 - 1912 A.D.)	Around 170 B.P.
6	Remains of the Shihsanhang Culture in the Iron Age	Around 1,000 - 160 B.P.
5	Remains of the Chihwuyuan Culture in the late Neolithic Age	Around 2,300 - 1,800 B.P.
4	Remains of the Yuanshan Culture in the late Neolithic Age	Around 3,300 - 2,300 B.P.

3	Remains of the Hsuntangpu Culture in the middle Neolithic Age	Around 4,500 - 3,500 B.P.
2	Remains of the Tapenkeng Culture in the early Neolithic Age	Around 6,000 - 4,500 B.P.
1	Remains of small flakes of the pre-pottery age unearthed on the bedrock of sandstone.	Age before 6,000 B.P.

Table. 2-2-1 Prehistoric cultures and each age covered by the Yuanshan site (after Kuo 2014a).

2. The distribution of the Yuanshan Cultural Site

Up till rescue excavation of Chanlungshan Site in 2013, there are 74 sites with Yuanshan Culture artefacts have been found in the area based on the archaeological evidence of material culture and the measured dating data that studied in Table 3-1-1 of Chapter 3-1. The distribution of archaeological sites the Yuanshan Culture is primarily within the drainage area of Tamsui River, Keelung River and Xindian Creek across the Taipei Basin, and the coastal region in Northern Taiwan, with the landscape of shell mound, the small hill and tableland. (Fig. 2-2-2)

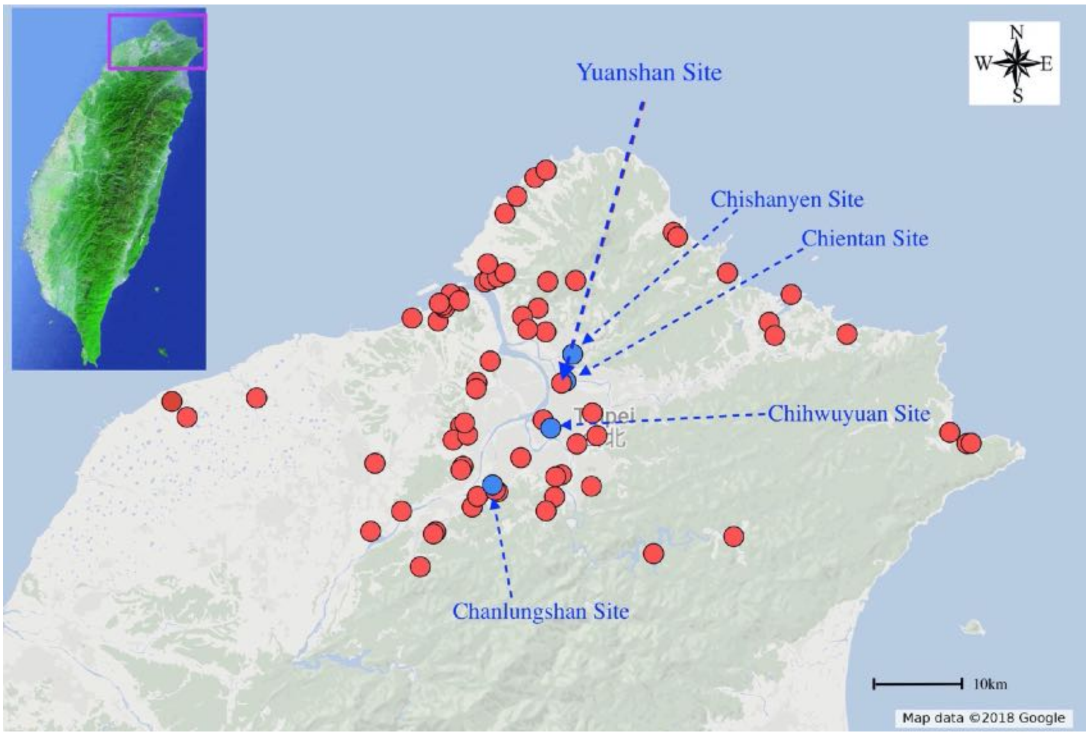


Fig. 2-2-2 Yuanshan Cultural Sites Distribution in Northern Taiwan. (Blue dots are the archaeological sites where the shouldered axes have been unearthed and examined scientifically in this dissertation.)

3. The age of Yuanshan Culture

Liu's (1963b) comparative study on the sources of a bronze arrowhead found in Taiwan opened up the discussion of the age of Yuanshan Culture. There is a bronze arrowhead found at the Yuanshan cultural layer of the Tapenkeng site in 1963, which Liu classified to the two-winged style arrowhead of Yinxu culture. The Yinxu culture is a Bronze age culture found in the Anyang site in north China in the 1930s. This type of small bronze arrowhead has been unearthed in Hong Kong, and the latest age of its incoming was presumed to be in the Western Han Dynasty by Father Finn, who's the discoverer (Finn 1958). Liu further surmised that the formation of the Yuanshan Culture would not exceed the first four or five centuries of the Western Zhou Dynasty based on the comparative study of the representative artefacts on stone tools and pottery between the Yuanshan Culture and that of the peninsula in Southeast Asia. The duration may be from the Warring States Period to the Han Dynasty, or it may extend a bit later to some times. However, the type of Yuanshan cultural bronze arrowhead from the Tapenkeng site was earlier than the one of the Warring States Period, which means the age of the Yuanshan Culture was earlier than the Warring States Period of China. Therefore, Liu believed that the age of the Yuanshan Culture may be laid between 1000 B.C. and 200 A.D. (Liu 1963b).

However, the problem occurred by Liu's comparative study was the misinterpretation of the Yuanshan cultural age. The cultural evolution and the technological development in Taiwanese prehistory differed from that of China. When the prehistoric culture entered the Bronze Age in ancient China (like the Erlitou culture dated to around 4000 B.P.), Taiwanese prehistoric culture just situated in the middle of the Neolithic Age (Liu 2017, Liu 2015). Therefore, Liu's research on the shape comparison of the bronze arrowhead between Yuanshan and Yinxu to discuss the age of Yuanshan Culture was not properly interpreted.

Lin (1963) applied the radiocarbon dating technique to determine the age of the Taipei peat layer, and the method of the chronological sequence inference of prehistoric cultures by the relative dating technique based on the analogy of artefact assemblages was replaced since then. This analytical method has greatly improved the accuracy and credibility on the discussion of archaeological culture chronology in Taiwan, including the age of Yuanshan Culture since then. (Lin 1963).

To obtain the absolute age of the Yuanshan Culture by applying the C^{14} technique, Sung and Chang again conducted small-scale excavation at the Yuanshan site in 1964, for collecting shell remains and charcoal specimens from the shell mound area. These samples, as well as the charcoal specimen obtained from the Yuanshan cultural layer of the Tapenkeng site, were together subjected to the radiocarbon dating examination. According to the dating results, Sung and Chang suggested that the age of Yuanshan Culture was about 4,500-2,000 B.P. and its existence continued for nearly 2,500 years (Sung and Chang 1964).

This is what currently admits being pioneering in chronological research to measure the age of a single culture and a site in Taiwan archaeology, marking a history to the Yuanshan Culture as the first prehistoric culture with absolute age, and has the significance of the academic achievement. However, because of the misinterpreting the age of long-term presence, and the Yuanshan cultural content showed no traces of transformation during the early and later stage, such as the characteristics of the pottery and stone tools, it caused serious obstacles for the research of Yuanshan Culture for decades. In short, the length of the Yuanshan Culture was over-estimated in this initial Radiocarbon dating measurement. At present, although there are more analytical data of radiocarbon dating and innumerable stratified evidence of archaeological sites, the age of Yuanshan Culture has not yet reached consensus in the academic circles. For example, some scholars consider that the age of Yuanshan Culture is possibly at its earliest around 3,500 B.P. (Huang 1997, Kuo 2016[2]), but another suggests that would not exceed to 3,300B.P. (Liu 2000).

This study will review the sixty-one dating data obtained from three material types, which are seven shell samples, one bulk of wood and fifty-three charcoal specimens collected from nine Yuanshan cultural sites. This study will review the ^{14}C dating results and adopt the relatively accurate analysis by the OxCal calibration modeling of all reference data for the sequence discussion into the archaeological assemblage (Bayliss 2015).

4、Definition of Yuanshan Culture

The definition of a single archaeological culture is based on its distinctive and recognisable cultural content presented in the material culture unearthed by excavations. The consistency or similarity of the material and cultural content of finds discovered at different sites are normally classified into the same category of archaeological cultures, such as the production techniques or decorative styles of artefacts, the resemblance model of subsistence (Childe 1929, Shennan 2003, Roberts and Vander Linden 2011). Most archaeological cultures are named after the type of sites or artefacts that define culture, and Taiwan is no exception. For example, culture may be named after a pottery type, such as the coarse corded pottery. Or, more commonly, sites that were first confirmed by an archaeological

[2] Exchange of opinions in private conversation.

culture which are not necessarily first discovered, such as the Clovis culture. Taiwan’s Yuanshan Culture is named after the latter.

The Yuanshan Culture is the earliest research object of Taiwan archaeology and has been the focus of scholars since the Japanese occupation (1895-1945). With the newly unearthed artefacts or the new ideas derived from the study of archaeological data accumulated in the past, each stage has a different understanding or a recognition of a certain topic of the Yuanshan Culture, and thus develop a broader and comprehensive knowledge system. The research and development history of Yuanshan Culture can be roughly divided into four stages and topics: the early days of the Japanese occupation (1897-1928), the late Japanese occupation (1929-1945), the post-war period (1946-1980), and the flourishing period (1981 to present day).

The first stage of the main work is the analysis and research of the discussion on archaeological artefacts typologically, technologically and chronologically. At this time, several important issues of the Yuanshan Culture have been raised, including its age and formation process, the study of the function of the shell mound, and who’s the owner or creator (Liu *et al.* 2006). In the second stage, the cultural significance, origin or change of the artefacts was studied due to the plenty of the small-scale archaeological excavation works in the north yielded and accumulated a large number of archaeological materials. During this period, the academic circles began to pay attention to the relationship of prehistoric cultures between Taiwan and the Asian continent. In the meantime, the initial framework of Taiwan's prehistoric culture was established accordingly.

The third stage of archaeological work is mainly to explore the study of humans and the environment relations by using up-to-date scientific-based methodology at the time, and to identify different cultural connotations and chronological sequences in northern Taiwan, the Yuanshan site included, such as the radiocarbon dating, the analytical techniques of palaeoenvironment, palaeobotany, and palaeozoology (Liu 1963a, 1963b, Sung and Chang 1964, 1966, Sung 1955a, 1955b, 1956, 1964, 1965, Chang 1959, 1966, 1969, Chang and Stuiver 1966). At this stage, the connection of the prehistoric cultures between Taiwan and the neighbouring areas of China and Southeast Asia has been unceasingly studied, and the research between the latest stage of prehistoric culture and contemporary aborigines has also been raised, which were argued basically on the newly finds from the archaeological sites located near or at the modern indigenous regions geographically. For example, the Kokubu directly compared the Ketagalan tribe to the archaeological remains excavated from two sites of Jinshan and Xiaojilong (Little Keelung) which linked the prehistoric culture to the aborigines (Kokubu 1981). The fourth stage of work so far, the re-recognition and more accurate interpretation of the content and stratigraphic sequence of prehistoric cultures in north Taiwan because of the fruitful archaeological finds and the analytical data of era, there is also a clearer discussion on the origin and evolution of individual culture (Chang 1981, 1987, 1898, Chang and Goodenough 1996, Huang 1985, 1990, 1997, Tsang 1992, 2006b, 2012a, 2016, Bellwood 2000, Bellwood and Dizon 2005, Bellwood *et al.* 2011). New ideas and issues have also been derived from this. For example, Liu's argument points that the Yuanshan Culture has long-term estrangement or hostility with other ethnic groups after entering the Taipei area, and the reasons for this estrangement need to be explored for further research. The basis of this argument is that there is no obvious change in the characteristics of pottery and stone tools being unearthed in the earliest and latest Yuanshan Culture layers of the archaeological sites of Yuanshan shell mound and Tapenkeng (Liu *et al.* 2006).

This research focuses on the content and origin of Yuanshan Culture by study its chronology, the manufacturing technology and usage of the shouldered axes. The obtained results may be illustrating the Yuanshan cultural contents if meet one of the theories as following: the external theory (multiregional origin) or a blend formation of the internal and external cultures (Chinese origin and local tradition).

4.1 Cultural identification of artefact characteristics

Since the identification of the Yuanshan site in 1897, the scholars' interpretation of the Yuanshan Culture mainly aimed at the basic understanding of the unearthed artefacts and summarising data: the classification of objects, the analysis of materials and features, and a small part is aimed at the interpretation of the meaning of the artefact culturally or socially. Such as the common typology of the utensils made of the raw material of rocks are the axes, hoes, chisels and the Patu-shaped tools. The temper added to clay in pottery making is mostly quartz or mica with a light brown or reddish colour (Tree Valley Foundation 2012, Kuo 2014a). The surface of the potsherds is commonly non-slipped plain and red-slipped, and a few are impressed the grid decorations. The jar is the mainstream of the pottery type, and the body often has a handle and a lid. Shells that are eaten mainly large clams that live in brackish water, using bone tools which are made of animal bones like fish bones or deer bones. Patu-shaped tool is a farm implement, as well as a symbol of religion or authority (Table. 2-2-2). Although the definition of content on these archaeological substances is not necessarily accurate or classified to the Yuanshan cultural artefacts, it is the cornerstone for the detailed study of the content of Yuanshan or other prehistoric cultures for future reference (Liu 2000, Liu and Kuo 2000, Kuo 2014a). Such as the Patu-shaped tool now identified as the object of the Chihwuyuan Culture that possibly is the farming tool.

Name of researcher	Characteristics of the collected artefacts form the Yuanshan site	Conjecture on cultural or socio-economic meaning
Denzo Sato	1.Plain potter 2.Mainly clams in eatable shells 3.Large chipped stone axe	Large chipped stone axe should be a farming tool.
Ryuzo Torii	1. No stone arrowhead 2. Featured in the stone chisel 3. Small iron chisel and Ming porcelain were unearthed in the upper shell mound 4. Bone spears with cutting marks	Small iron chisel of Yuanshan Culture implied to evolve from the stone age to the Iron Age.
Atsuhiro Miyahara	Featured in the pottery with a handle	
Takeo Itazawa	1. Stone types are: the chipped and ground stone axes, stone knives, net sinkers, spindle whorls 2. Animal bones are: deer and pigs	

Hotsuma Ozaki	Shell mound	Yuanshan shell mound was the factory of making shell coin, like the Seawan to the Native Americans.
Isao Hirayama	1. Patu-shaped stone tool 2. Large grindstone 3. Fish bones 4. Stone tools were made of marble rock	1. Patu-shaped tool used for farming and a symbolic utensil of religion or power. 2. Large grindstone indicates a class society developed of the Yuanshan Culture. 3. Fish bones and marble tools shows the navigating ability for sailing, and the subsistence of fish-hunting.
Nenozo Utsurikawa	Patu-shaped stone tool	Patu was evolved from the agricultural tool and a symbol of power.

Table. 2-2-2 The characteristics of Yuanshan Culture defined by researchers in the period of Japanese rule (Liu and Kuo 2000).

4.2 The external theory (single or multiregional origin)

In spite of the topics investigate in archaeology are wide diversity of range, such as the study on the domestication of cereal crops and human dietary, the settlement patterns and spatial analysis, the household survey and gender analysis, gathering archaeological materials, establishing chronology of prehistoric culture, and looking into the relationship between prehistoric cultures or the human-environment are the essential objectives of archaeological work. The archaeological issues of Taiwan in the early 19th century was almost revolved around the relation of prehistoric cultures across Asian regions to explore the exchange, spread or origin of artefacts, as well as the migration of people (Tsang 2006b). In contrast to building the initial understanding of the Yuanshan cultural assemblages in the first stage, researchers in this period started a series of conversation to explore the cultural affinity for the prehistoric cultures between Taiwan and surrounding areas. For example, the studies in the published literature of linking Taiwan's prehistoric culture with that of the surrounding areas, the starting point for scholars to explore is the source comparison of cultural and material approximation on the stone tools and/or pottery commonly found in prehistoric sites. This information allows a more detailed appreciation of the emergence of the Yuanshan Culture in Taiwan as related to other regions.

Scholars not only reflected on the connection between Taiwan, Southeast Asia, China, and the Pacific region by these constant discussions but also constructed the knowledge system of Taiwan archaeological research regarding the methods, validity, and scope. Since then, the research goal of Yuanshan Culture has not only been satisfied with the application of various scientific means to further understand its material remains for the significant meaning but also treats the content of the entire archaeological site with an attitude of the comprehension of the cultural system.

4.2.1 Multiregional origin theory

The earliest note and use of stone tools and pottery to infer the relationship between prehistoric culture in Taiwan and neighbouring areas is Ryuzo Torii. After his survey in the Yuanshan shell mound, Torii showed curiosity about the cultural sources of the Stone Age in Taiwan which could learn from several kinds of the literature of his investigating works (Kaneseki and Kokubu 1990). Torii believed that the types of stone tools in Taiwan may closely relate to the similar artefacts found in southern China, Vietnam, and the Philippines. This viewpoint of Torii has affected the development of the external source theory of the Taiwanese prehistoric culture to a considerable extent for nearly a century, including the Yuanshan Culture. In addition to the Torii, the other scholars also proposed the theories of the Yuanshan Culture origin by the comparative studies of similar artefacts between the Yuanshan Culture and that of the neighbouring regions. Because individual scholars have different sources of analogy for artifacts, resulting in the hypotheses of the Yuanshan Culture origin voice a great deal of variety as well (Table 2-2-4).

On the perspective of regional prehistoric archaeology and typology of stone artefacts which associates with the Yuanshan Culture research is mostly based on the pioneering study given by Heine-Geldern, the most influential and ground-breaking scholar for the classification of stone tools of the prehistoric culture in Southeast Asia. Heine-Geldern proposed the wave of culture theory in 1932 which was built after the Three Age system of Thomsen and influenced the study of Southeast Asian prehistory for decades (Kaneko 1970). Heine-Geldern considered the distribution of stone axe (adze[3]) which was often found in East and Southeast Asia geographically and chronologically and assumed that there were several migration waves had occurred in the Neolithic age. Therefore, Heine-Geldern suggested the three stages of prehistoric culture and migration in Southeast Asia during the Neolithic Age.

The typology of axe has been divided into three sub-types and explained their respective routes of travel by Heine-Geldern. The type of oval axe (Walzenbeil) represents the culture spread from North China, Japan, Taiwan, and the Philippines to the east part of Indonesia and Melanesia in the Pacific Ocean. The type of shouldered axe (Shouterbeil) indicates the Mon-Khmer culture of South Asian language in continental Southeast Asia which immigrates from northeastern India to Southeast Asia. The type of rectangular axe (Viekantbeil) has a wide distribution in East and Southeast Asia which marks the early Austronesians migration (Fig. 2-2-3, 2-2-4, 2-2-5). Heine-Geldern believes that this culture spread from North China to the Southeast Asia Peninsula and southern Malaya, then moved to Indonesia and branched out into two routes: one route went from southern Indonesia to New Guinea, another way started from Borneo to the Philippines, Taiwan, and finally arrived in Japan (Kaneko 1970, Tsang 2006b).

[3] Adze, the noun used in the academic circles has not yet been unified. Western scholars often refer to the "axe" to the "adze", the former the Chinese or Japanese scholars most called.

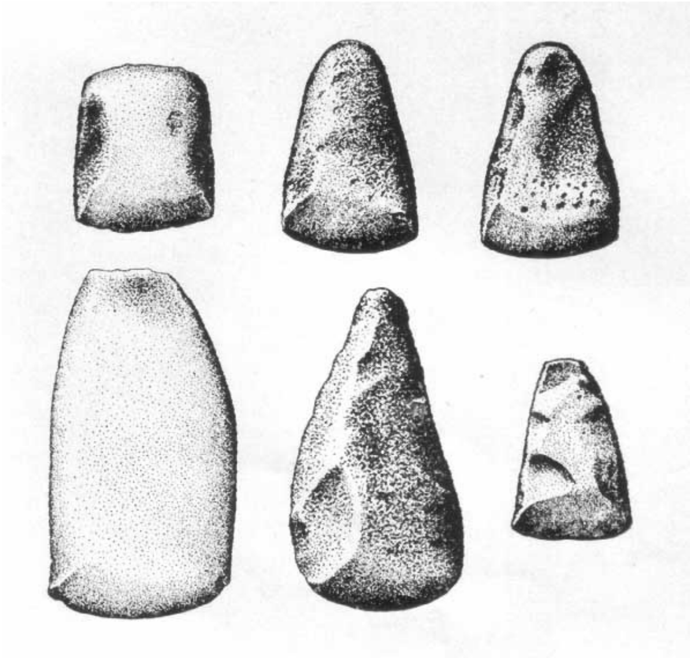


Fig. 2-2-3

Oval axe or Walzenbeil

(Tsang 2006b)

Fig. 2-2-4

Shouldered axe or

Shouterbeil (Tsang

2006b)

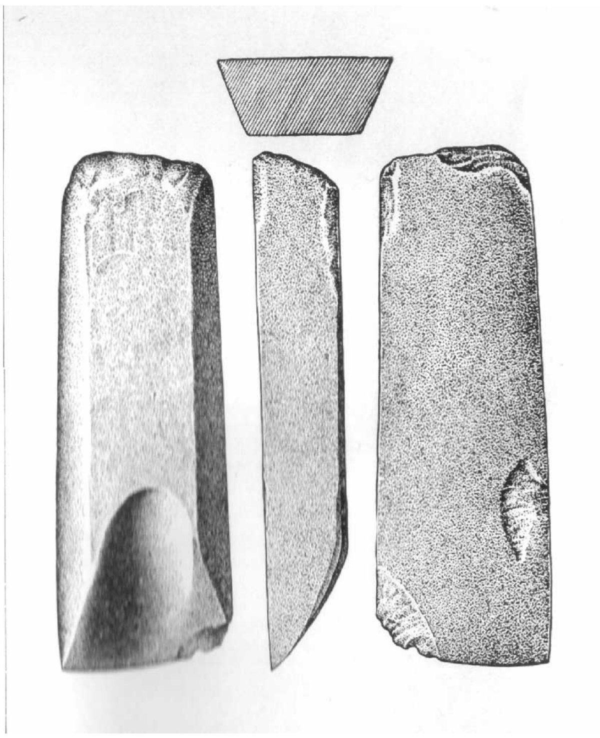


Fig. 2-2-5

Rectangular axe or

Viekantbeil (Tsang

2006b)

The stone tool typology and prehistoric culture circles built up by Heine-Geldern has served as one of a principle by Japanese scholars for exploring the relations of the prehistoric cultures among Taiwan, China, and Southeast Asia relations since the literature published, such as Nobuhiro Matsumoto and Masashi Nezu. The former is concerned with the extent of the distribution and chronology of the shouldered axe in Asian, whereas the later focuses on the significance of the shouldered axe to ancient East Asian crowds (Matsumoto1939, Nezu 1943).

In 1943, the excavation of the Jiangtou site (now named Kantu site) at two shell mounds of A and B which was conducted by Kanaseki and Kokubu have uncovered the archaeological remains of the Yuanshan Culture respectively. The shell layers of the midden A unearthed artefacts with the distinctive features of the Yuanshan Culture, including a number of the stone tools made of the andesite obtained from the Tatun Volcano area. And the types of these stone wares classified into the shouldered axes, stepped adze and, the shoe-shaped tools. The epipedon of the midden A was found the grid impressed potsherds, the pottery that was coated with the red-brown colour was unearthed from the shell layers as well. It can be confirmed that two layers of the different prehistoric cultures (Chihwuyuan Culture on the upper layer and Yuanshan Culture in the lower layer) overlapping in the midden A. The shell and epipedon layers of midden B both found the reddish-brown coarse potsherds coloured with a slight yellow on the surface with the characteristics of the Yuanshan Culture, as well as the thick coarse pots with grid impressed pattern (Kanaseki, Kokubu 1990). The grid impressed pottery of the Yuanshan Culture unearthed in this excavation has a similar decorative pattern and manufacturing technique with that of the prehistoric culture in the southeast coastal area of China, such as the Tanshishan culture in Fujian which dated 5,500 to 4,000 B.P. (Zhong 2005).

Kanaseki and Kokubu presented viewpoint separately on the issue of the Yuanshan Culture origin based on the archaeological materials accumulating from several works carried out by some scholars for years, including their co-operated excavations. Kanaseki (1943) inferred that the northern cultural elements contained in Taiwan's prehistoric culture with evidence of stone tools (stone knives, perforated stone arrowhead, and ground arrowhead with handle) and pottery (black pottery, painted pottery, and red pottery) may have introduced to Taiwan from North through the Southeast Coast of China. According to the shouldered axe, stepped adze and black pottery unearthed in Taiwan, Kokubu (1943) pointed out that these two kinds of stone implement found in northern Taiwan could consider the route traveling from the coastal area of China, across the Taiwan Strait and entered to the main island of Taiwan. Kokubu specifically indicated that Fujian is located in the middle, between north and south China, and its prehistoric culture may be yielded or presented as a result of overlapping or cross-influencing by two cultures. Therefore, the elements of northern China in Taiwan's prehistoric culture may be introduced from Fujian. As for the elements of South China or Southeast Asia (Nothern Vietnam) Peninsula contained in the Yuanshan Culture, Kokubu believed that it should be transferred from the southeast coast of the Asian continent to Taiwan and overlapped with the elements from the southern islands of Southeast Asia which then formed the prehistoric culture in Taiwan. Additionally, although the elements of the southern islands shifted with the Kuroshio into Taiwan, it could not be excluded the possibility of that being introduced via the southeast coast of China either (Kokubu 1981, Kanaseki and Kokubu 1990). In short, the theories given above illustrates that the Yuanshan Culture has northern and southern variants, influenced by external traditions originating in different regions.

A comprehensive expression of the external element theory of the Yuanshan Culture origin was given by Tadao Kano after looking into a broad and detailed study for years. Kano proposed the seven cultural layers hypothesis in 1946, which established the chronological sequence of Taiwan prehistory by the objective typology and the geographical distribution of the artefacts found in Taiwan, seven cultures include the Cord-marked Pottery Culture, Netted Pottery Culture, Black Pottery Culture, Stepped Axe Culture, Proto [4] Dongson Culture of Vietnam, Megalithic culture, and Iron Culture of Philippines.

Kano's hypothesis holds that the foundation of Taiwan's prehistoric culture is the culture that originated from China and presented distinguishable features at four cultures, which are characterised by the cord-marked pottery, the netted

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[4] The Dongson culture is a mixture of aboriginal culture and Han culture in northern Vietnam between 1,000 BC and 100 AD. The proto Dongson culture is purely the aboriginal culture before the influence of Han culture.

pottery, the black pottery, and the stepped axe. These four prehistoric cultures in the stage of Taiwan prehistory represent chronologically that the prehistoric development of Taiwan was affected by the cultural spreading from China for several times. The types of the stepped adze appear in Taiwan as examples, have both shapes with a flat and columnar which are the typical adze of the culture from Fujian, suggest the possibility that these tools were spread from the southeast coast of China to Taiwan. Later, Taiwan's prehistoric culture absorbs the mixture culture[5] which was constituted the artefacts made of stone and metal in the Southeast Asia peninsula, and both cultures of the proto Dongson and Megalithic appeared. The last wave of foreign culture that entered Taiwan is the iron culture introduced from the Philippines (Sung 1952, Liu 2002d).

Kano observes the geographical distribution of the Yuanshan Culture and accepts that such cultural layer occurs frequently in the sites of northern Taiwan yet is rather rare in the south during the late Neolithic Age. According to the shared qualities of the Yuanshan cultural materials to that of the Stepped axe culture, Kano arranges the Yuanshan Culture in the category of the Stepped Axe Culture. And Kano defines the characteristics and typology of archaeological materials of the Yuanshan cultural layer, such as the stone assemblages are the flat and columnar adze, the arrowhead, the shouldered axe, and the spoon-shaped axe. In the meantime, Kano suggests that the origin of the Yuanshan Culture may be in Fujian of China, and names the Yuanshan Culture because of the important feature of the shell mound

5 It is known as the chalcolithic age in Taiwan.

layers found in the Yuanshan site (Sung 1952). The first practical fieldwork in archaeology after the definition of Yuanshan Culture given by Kano is the survey of the sites located in the southern part of the Taipei Basin conducted by Kokubu and Sung *et al.* in 1948. The type of objects found in this survey is unique to the Lushan culture defined by Kano, such as the pottery lid, the pottery handle, the red-slipped pottery, and a large number of andesite stone tools (including shouldered axes). The site is thus identified as one of the Yuanshan cultural sites (Kaneseki and Kokubu 1990).

The topic of the Yuanshan Culture source remains its popularity in Taiwanese archaeology community and attracts scholars to invest in research constantly. As the archaeological evidence and research results are presented increasingly to the public, the theory of the Yuanshan Culture origin from China is placed in the top of all arguments.

4.2.2 Single origin (from the region of modern China)

After decades of argumentation, the preliminary definition of the Yuanshan cultural content and the existence of another earlier cord-marked pottery culture in northern Taiwan are of determination, and the relationship between these two cultures requires further clarification. The new challenge has also arisen on the topic of the origin of the Yuanshan Culture. That does not mean the completely negating the influence of Yuanshan Culture by the foreign culture or is itself a foreign culture in fact, but that more and more archaeological evidence uncovered cannot satisfy with the explanation on the Yuanshan Culture being formed simply by accepting the culture outside Taiwan. For example, the technique of chipping and rough grinding to make the andesite stone artefacts in the production process resembles that of the fine corded mark pottery culture (also known as the Hsuntangpu) in the earlier period (Kuo 2014a). As a result, while accepting a theory of the Yuanshan Culture as a foreign culture, a reflection on the possibility that the Yuanshan Culture is new emerged from the integrations of the local and foreign cultures has discussed in the academic circles. The so-called local culture refers to the prehistoric cultures that existed before the Yuanshan Culture in north Taiwan, such as the cord-marked pottery culture.

Lin (1955) enumerates the distinctive archaeological remains of the stepped adze, shouldered axe, impressed pottery, and painted potsherds based on the collections gathered during two surveys at the Yuanshan site in 1929 and 1935 and compares the prehistoric cultural traits between Taiwan and Fujian in detail. Lin considers that the material remains of Taiwan was originated in the southeastern part of China in the Neolithic age, and has a slightly features of Taiwanese technological tradition on the stone tool production. Besides, Lin suggests that the shouldered axe of the Yuanshan Culture must be a foreign product instead of the local one on the base of the typological comparison of the shouldered axes between Taiwan and Southeast China. The origin of the Yuanshan shouldered axe is likely from the region of the southeast coast of China and is circulated to Taiwan and/or

Southeast Asia. This region is also a place that should be the Ancient Yue[6] (Baiyue) people who reside in between 1,000 BC and 100 AD. Lin's suggestion indicates that the ancient Yue people held perhaps the shouldered axe production whether in technical or cultural. It implies that the shouldered axes production technology of Yuanshan Culture probably learns come from Baiyue.

In 1953 and 1954, Shi directed two excavations of the Yuanshan site and achieved the fruitful materials and five burials. Artefacts such as the shouldered axe and the pottery pot with two-ears ring-foot, Shi believed that the types of these objects were influenced dominantly by the culture from the Central Plains of China, and bluntly said that the ancestors of the Yuanshan Culture were on the mainland of China (Shih 1954a, 1954b).

These works of Shi also determined for the first time that the Yuanshan site has upper and lower two cultural layers (with or without shell layers), which are different regardless the properties and colours of soil, as well as the archaeological remains deposited in. Yet, the relationship between two layers could not be confirmed, that is, whether it is the evolution of a single culture or the temporal overlap of two cultures existence. This unsolved question lasted for decades and yields others, for instance, assuming that two cultures were different, on what extent the distribution and the existed time of this prehistoric culture had? who was the owner of this culture? Or contrariwise the same culture, what caused the

[6] It refers to the hundreds of indigenous groups living in the coastal area of China from the north of Shandong to the south of Fujian and Guangdong (Meacham 1996). Available at http://journals.lib.washington.edu/index.php/BIPPA/article/view/11537/10170

difference displayed on both material cultures? These issues were not answered until later successively.

Sung (1954a) further explained the content of Yuanshan Culture based on the archaeological excavations of Yuanshan Site by Shi. Shortly after, Chang (1956, 1969) defined the Yuanshan Culture based on his hypothesis[7] of seven cultures (Table. 2-2-3).

	Wen-hsun Sung	Kwang-chih Chang
Stone tools	1. The stepped adze 2. The shouldered axe 3. The spoon-shaped tool	1. The shouldered axe 2. The stepped adze 3. The tembeling knives 4. The Patu-shaped stone tool (also called the polished celts) 5. The triangular arrowhead 6. The chisel 7. The jade products
Pottery	1. The red plain potsherds (some of them were with the red coating on the surface) 2. The cord-marked potsherds	1. The tempers are coarse and comprised of the sandy particles. 2. The pottery is brown in the colour and often painted with red.

[7] Chang hypothesised the seven prehistoric cultures of Taiwan built upon the archaeological materials obtained from the fieldworks either of survey or excavation, which are the cord-marked pottery culture, the Yuanshan Culture, the brown grid impressed pottery, the grayish-black pottery, the red-slipped pottery, grayish-brown grid impressed pottery, and the red non-slipped pottery. These cultures are categorised by the pottery characteristics of each prehistoric culture (Chang 1956, Chang 1969).

		3. Some of the pottery covered with a lid on the top. 4. Motif decoration on the surface of pottery: the corded impressed or parallel dots patterns.
Fishing/hunting ability	1. The remains of the fishbones, animal bones, bone darts, net sinkers and arrowheads.	1. The bone tools
Agricultural activity	1. The stone farming tool: shouldered axe, large flat axe, curved flat axe, spoon-shaped axe, shoe-shaped tool, stone knife, and stone sickle. 2. Cooking or storing pottery: the pots with a round base, the large-size containers may be used to cook or store grains respectively.	
Economic Stage	Hunter-gather and agriculture	Hunter-gather, fishermen, horticultural cultivator and livestock breeder
Settlement	The groups of the pillar holes dug on the sandstone bedrock for building a house.	
Environment of the Yuanshan cultural sites	Situated in the flat and plain area of northern Taiwan	Located in the northern part of the west coast in Taiwan

Contact with the people in South China	Yes, based on the typological similarity of the stone tools and pottery.	Yes, based on the custom of tooth extraction.

Table 2-2-3 The definition of the Yuanshan cultural contents given by Sung (1954a) and Chang (1956, 1969).

The exposition of Sung and Chang on the cultural context of Yuanshan agree in the section of the stone objects; however, Sung regards the plain pottery and the cord-marked pottery as the Yuanshan cultural artefacts which differ from the viewpoint by Chang. Chang believes that two excavations carried out by Shi have unreserved proof that two cultural layers sediments existed in the Yuanshan site and divided respectively into the upper and lower: the upper layer is the deposit of the Yuanshan Culture dominated by plain pottery, and the lower layer is the culture of the cord-marked pottery. Chang simultaneously acknowledged that the cord-marked pottery culture in the lower layer is an existed culture locally in the region of Taiwan, the upper layer of the Yuanshan Culture, on the opposite, is a belated and strong culture like a conqueror (Chang 1957). Regarding the difference between the cultures of the Yuanshan Culture and the corded pottery in terms of the content, Kokubu already noticed from his works at the Yuanshsan site as early as in the 1940s which lacking sufficient evidence to form a suggestion (Kuo 2015). As far as the chronological-built prehistoric cultural sequence is concerned, Chang identified the cultural layers of the Yuanshan and corded pottery in the Yuanshan site that was consistent of the method on the pottery typological classification applying by Kano.

In short, there are two cultural layers of the Yuanshan site, that the characteristics and contents of each culture the opinions are controversial among scholars.

Chang further questions the idea of the "evolution of a single culture" which presented the contradiction both in contents and the stratigraphic in the cultural layers of the Yuanshan site. That the layers of the Yuanshan Culture and the cord-marked pottery culture were stacked on closely without interruption yet had totally different cultural contents. It is hard to explain the evolution of a single culture without any shifting process ever being observed. (Chang 1957) Chang, therefore, believes that the two cultures are not the internal evolution within a single culture eventually, but the sequential relationship of their individual developments. The corded pottery culture of local culture precedes the powerful culture of Yuanshan. In other words, Chang responded to the issue proposed by Shi about the relationship between the two cultures of the Yuanshan site. As for the source of the Yuanshan Culture, Chang (1959) considers the Lungshan horizon Culture of the Southeast Coast of China, which possessed the specific stone artefacts as its characteristics such as the shouldered axe and Patu-shaped stone tool. Shi (1962) attempts to explain the shouldered axe and the stepped adze found only in northern Taiwan from the perspective of sailing ability and the distance between two places, that Fuzhou of Fujian is away from Tamsui of Taipei about 237.5 kilo meter, and the two unique objects gradually spread and develop along the Tamsui River to the region in and around the Taipei Basin. In other words, Shi suggests that the shouldered axe and stepped adze probably originate from the area of Fujian, China. The prehistoric cultural people of this area crossed the Taiwan Strait and brought the stone tools into the northern coastal areas of Taiwan, entered the Taipei Basin along the Tamsui River and distributed throughout its surrounding hinterland.

Liu (1963b), the director of this excavation, considered that the type of this two-winged arrowhead was identified to the that of the Yinxu culture of China. Such type of bronze arrowhead once uncovered in the Lamma Island of Hongkong and South China (Finn 1958). Liu did not provide specific comments on the spread route of this artefact whether was directly introduced from the Central Plains or indirectly from South China (via Hong Kong?) but inferred that the type of this bronze arrowhead may come from China based on the traits of stone tools of the Yuanshan Culture. In addition, the stepped adze and the shouldered axe which mainly distributed in southern China and northern Vietnam and considered to be one of the typical stone tools of the local chalcolithic period appeared only in the Yuanshan cultural sites, no other prehistoric cultures of Taiwan. Therefore, the Yuanshan Culture may be the product of the combination of using both stone and metal materials, so the emergence of the bronze object of its archaeological assemblages is no exception (Liu 1963a, 1963b). Liu namely suggested that the appearance of the two-winged bronze arrowhead from the Yinxu culture of China in the Yuanshan cultural site was quite in line with the inference of the cultural traits and spread paths.

Sung additionally pointed out that the stone type of Yuanshan Culture was classified to the rectangular adze (axe), which was a local system of the stone typology widely distributed in the southeastern coast of China and Southeast Asia in the Neolithic Age. If it is not reversely passed down to the region of China from Taiwan, the source of the Yuanshan Culture should be the culture placed in the area between Haifeng and Guangzhou, China (Sung 1964, 1965). In the meantime, Sung revised the viewpoint on the cultural contents between the Yuanshan layer and the corded pottery layer in the Yuanshan site, that he accepted the pottery assemblages was divided into two categories: plain pottery and cord-marked pottery. There are many corded potteries without any decoration of the cord marks on the surface like plain pottery among the cord-marked pottery category. However, there has no cord-marked pottery ever appeared in the plain pottery category, nor the impressed dots pattern found on the surface of the corded pottery (Sung 1965). The so-called plain pottery and the corded pottery by Sung should be the stratigraphic concept of the plain pottery layer and the corded pottery layer. The meaning said in the above remarks by Sung is that many plain potteries were unearthed in the cord-marked pottery layer, but the corded pottery could not be found in the plain pottery layer. Yet Sung did not put forward ideas on the relationship between these two cultures.

Wang (1987) considered that the shape of Taiwanese shouldered axe is same as to that of the Lingnan area[8] when exploring the issues concerned to the

[8] It is the geographical region covering the lands of the modern southern provinces of China and North Vietnam.

distribution, origin, and usage of the Chinese shouldered axe. Peng (1987) looked at the source of the Yuanshan Culture from the aspect of the impressed pottery in southern China, indicating that the bronze arrowhead of the Yuanshan Culture could not be measured as a product of local casting, rather an outcome of frequent interaction with Chinese prehistoric culture. The stepped adze of the Yuanshan Culture is identical to those type of stone tools uncovered in the provinces of Fujian, Zhejiang, and Jiangxi; the form of the shouldered axe is the same as that unearthed in the area of the Pearl River Delta of Guangdong province. Therefore, the source of the Yuanshan Culture is undoubtedly from the coastal area of China. Peng also believed that the Yuanshan cultural people migrated from the southeast coast of China to Taiwan, and their culture later became the ancestral culture of Taiwan's indigenous people today. Fu (1988) held thought that the origin of the shouldered axe should mainly account the discovery region of the earliest in time and the largest in numbers of such tool, that mostly unearthed in the Pearl River Delta, China.

Li and Fan (1995) compared the shouldered tools of Fu'an in Fujian with those in the northern part of Taiwan enumerated in Chang’s book published in 1969 (Chang *et al.*, 1969 PL.90-B, G, PL.93-A, B, C, E). It seems that the shouldered axes of two places show a closer link between Taipei and Fu'an than with other regions. Liu (1988) views the contacts and interactions between the peoples of Taiwan and South China during this period from the perspective of the archaeological assemblages that the two places are closely related, such as some of the immigrants moved with their unique material culture into Taiwan. There are quite a lot of archaeological cultures in Taiwan during this period, that the material characteristics show the trend of an independent evolution regionally. Liu considers that there are plenty of the cultural traits of immigrants left within the Yuanshan Culture exampling via artefacts, that the traits possibly were inherited from and close to the archaeological culture centered on the region between Han River and Haifeng in Guangdong (Liu 1988).

Moreover, linguists apply the ethnographic and linguistic studies to compare them with archaeological data for exploring the relationship between the prehistoric cultures and Taiwan's existing indigenous cultures, as well as their sources.

In 1964, Ferrell branches off the Taiwanese aborigines into three main groups based on the ethnographic and linguistic materials of the Taiwanese aborigines he gathered, namely the Atayalic in the north, the Tsouic in the middle, and Paiwanic group in the south of Taiwan. Ferrell, then, has these three linguistic groups contrasted to three major archaeological cultures of Taiwan known at the time. Ferell concludes that the Atayal language group and the cord-marked pottery layer show clear ties with that of south and southwestern of China. The Tsou group and the Yuanshan Culture (the proto-Lungshanoid culture) in northern Taiwan have significant elements of north China, which may represent the Austronesian of Asian continent who lived in the coastal area of east China, or even further north to Japan and Korea in the early days. The Paiwanic group and the Lungshanoid Horizons in southern Taiwan (the geometric impressed pottery cultural layer), perhaps are from a certain place between the Atayal groups, that is the local native culture of southeast China before the Han Chinese culture invaded (Ferrell 1966).

Ferrell's research implies the cultural and ethnic correlations between three linguistic groups and three prehistoric cultures in Taiwan: the northern Atayal and the cord-marked pottery culture of the Yuanshan site, the central Tsou and the Yuanshan Culture, the southern Paiwan and the Lungshanoid Horizons. And most importantly, that the prehistoric cultures of Taiwan associated with these indigenous language groups are hypothesised that all the sources are in the region of modern China (Ferrell 1966). However, Ferrell links the Yuanshan Culture in north Taiwan with the Tsou group in the central mountainous area, which the theory does not fit in the archaeological evidence of the geographical distribution of the Yuanshan Culture.

In short, while accepting a theory of the Yuanshan Culture as a foreign culture, a discussion on the possibility that the Yuanshan Culture is new emerged from the integrations of the local and foreign cultures has had among the academic circles. And the so-called local culture refers to the prehistoric cultures that existed before the Yuanshan Culture in north Taiwan, such as the cord-marked pottery culture.

4.3 A blend formation of the local tradition and external culture (Chinese origin and local tradition)

Scholars in the 1950s did not think over the odds of the Yuanshan Culture evolving from one or more native prehistoric culture(s). Whether the Yuanshan Culture was constituted by the integration of foreign cultures with the local corded pottery culture, it was not until Chang made his observations on the archaeological materials and discussed this possibility. The first step above all, the newly discovered archaeological evidence once again has been examined the content of the Yuanshan Culture thoroughly.

Study by Chang and Stuvier (1966) reveals that the prehistoric cultures in the Far East area has no one that is completely consistent with the Yuanshan Culture, while the representative artifacts of the Yuanshan Culture are resembling the cultural elements of the Lungshan Horizon in the southeastern coastal region of China, such as the fundamental typology of the pottery and the stone adze. The shouldered axe, on the other hand, is more relevant to the archaeological culture of the Tonkin Gulf in modern north Vietnam. At this time, Chang and Stuvier have noticed the distinctness of the Yuanshan Culture appeared in the eastern region of Asia. After a detailed investigation of the archaeological cultures in the surrounding area that a culture the same to the Yuanshan Culture did not exist, Chang turned a thought on the possibility of the different origins of the representative artefacts of the Yuanshan Culture like the pottery, the stepped adze, and the shouldered axe. Simultaneously, Chang amends his view on the origin of Yuanshan Culture to propose that the Yuanshan Culture may be evolved from the native cord-marked pottery culture partially, and perhaps obtained elements from the prehistoric cultures of the coastal area in South China and the Tonkin Gulf of Vietnam, as well as the Lungshanoid Horizons (Chang *et al*., 1969:238, 239). This means that Chang began to think about the emergence of the Yuanshan Culture inherited the preceding culture of the cord-marked pottery, or absorbing elements partially from the cultures located in the coastal region of South China and North Vietnam, and accepting moderately the Lungshan Horizons culture.

Chang also speculates on the separation time of the language family between the northern Atayal and the southern Paiwan displayed by the linguistic data for comparing the relevance of the archaeological evidence between the Yuanshan Culture and the Lungshan Horizons culture. Based on the archaeological data of the Tapenkeng site in the north and the latest outcome from the excavations of the Fengpitou site in the south of 1965, Chang found that it is quite consistent with the date of separation for the ancient Taiwanese Austronesians tested by linguists.

Dyen's statistics of lexica presented that the two most important groups of the language family in Taiwan, the Atayal, and the Paiwan, had started the separation at the date about 2,500 B.C. (Dyen 1965). Archaeological evidence shows that there were two major and prevalent archaeological cultures at about 2,500 BC in Taiwan. The Yuanshan Culture was the one in the north, and another was the Lungshan Horizons culture that could be traced back to a certain cultural group in the southern part of China. According to the comparison in correlating the materials shown by the linguistic and archaeology, Chang theorised that the Paiwan language group is likely to be linked to the Lungshan Horizons culture, as revealed by the research of Ferrell previously. The similarity on the geographical distribution of the Atayal language group and the Yuanshan Culture, as well as the cultural traits of the Atayal and the Yuanshan Culture to that of the culture in the southwest part of China, therefore, it is likely that the two were closely related. Furthermore, Chang believes that the two prehistoric cultures of the Yuanshan and the Lungshan Horizons were of the great probability the backbone to the language family of the modern Taiwanese Austronesians (Ferrell 1966, Chang *et al*., 1969:240-242). This argument has enlightened the issue on the relationship between the separation of the Austronesian language group and the emergence of the distinctive prehistoric cultures regionally after 2,500 B.C. in Taiwan. The verification of the distribution range of each archaeological culture and the chronological sequence of cultural developments of all is the main concern to the archaeological study at the time, including the Yuanshan Culture of this study.

In 1979, Kanaseki and Kokubu hypothesised the scope of diffusion of the Yuanshan cultural site based on the materials being gathered then (Kanaseki and Kokubu 1990). Apart from the northern coastal region, Kanaseki and Kokubu determined that the Yuanshsan culture enters directly along the Tamsui River into the upper reaches of Dahan Creek and Xindian Creek, and the hinterland on both sides of the river are within its spread scope. That is, the remains of the Yuanshan Culture can be discovered in the region around the entire Taipei Basin. The shouldered axe and the stepped axe (adze) found in the Keelung area of the north may also be presumed that the Yuanshan Culture may arrive at the shore of the Keelung Port along the tributary of the Keelung River in the Yangming Mountain area of the northern Taipei Basin, and then leave their traces. (Fig. 2-2-2) It worth notice that all the sites studied in this dissertation are located very close to the river, which is consistent with the distribution range of Yuanshan Culture assumed by Kanaseki and Kokubu.

Kanaseki and Kokubu further revised the viewpoint of the origin of Yuanshan Culture, suggesting that the source of the artefacts should be discussed separately in accordance with their forms, such as a shouldered or stepped shape of stone tools. The reason is that stone assemblages of the Yuanshan Culture, mainly refers to the shouldered axe and stepped adze, are considered to be representative objects of the South in Asia (specifically in the southern China), leading to the arguments of past scholars about the origin of Taiwan's prehistoric culture are biased toward tracing the factors from southern Asia predominately. At present, the north line of the distribution of shouldered axe globally does not restrict at Taiwan. It can be found in the North, Central and Northeast of China, North Korea, as well as Ryukyu, Kyushu, Honshu, and Hokkaido of Japan, even extended to the northern part of Sakhalin, Russia (Groot 1972, Nordqvist and Häkälä 2014). Therefore, the judgment of the shouldered axe being directly introduced to Taiwan from the south of Asia is open to dispute. Kanaseki and Kokubu proposed the style of Taiwanese shouldered axe, at least some of which may be tracked to the prehistoric culture of the coastal areas in the north and central China, so did the stepped axe (adze) or the shoe-shaped stone tool (Kanaseki and Kokubu 1990). The viewpoint of Kanaseki and Kokubu suggests that the Yuanshan Culture may be a product by mixing multiple archaeological cultures of various regions (Kanaseki and Kokubu 1990). The following year, Sung once again mentioned that the stone tools of the Yuanshan Culture are similar to the archaeological culture located in the area between Hong Kong and Haifeng. Sung further addressed that the source of the Yuanshan Culture, or some of its elements, is originated from the prehistoric group resided in the coastal area of southeast China (Sung 1980).

In 1982, Huang carried out the rescue excavation of the Chihsanyen site and identified the existence of the Chihshanyen Culture that the layer lies below the layer of the Yuanshan Culture for the first time. Huang's work confirms that another prehistoric culture existed in the northern part of Taiwan apart from the recognised fine cord-marked (or corded red) pottery culture and Yuanshan Culture. Huang believes that this discovery means that immigrants were moving from their native land to Taiwan for a long time ago. Furthermore, the number of migrations is likely occurred several times, and the sources of immigration have more than a single place, and the location of immigration has scattered all over Taiwan. Huang further explains that the residents of the corded red pottery culture may have migrated from Fujian and Guangdong of China. Later cases such as Fenpitou and Chihsanyen, are the cultures believed to be brought by immigrants moved from the southeast coast of China. Another example of the immigrations may have occurred several times is that the theory proposed by Chang about the existed time of the grid impressed pottery culture (Huang 1984, 1985).

Huang views the phenomenon of Taiwan's prehistoric cultures presented by archaeological evidence and learns that the early cultures were widely distributed from south to north and even to the islands of Penghu, and showed a high rate extent of the consistency in culture, such as the Tapenkeng Culture and its following-up culture of the corded red pottery. The cultural disparity that followed has become more apparent in the later stage of Taiwan prehistory. There is hardly found that the cultural connection between the early stage and the late stage of a single culture. Or, it is difficult to observe that later stage of one culture was directly evolved from that of its early days (Huang 1984, 1985).

Besides, several prehistoric cultures coexisted in the same region is another phenomenon appeared in Taiwan. For example, the cultures of the Chihsanyen, Yuanshan, and Chihwuyuan appeared in the Taipei Basin were left by three distinct groups of people lived in the basin nearly the same time. Huang concludes that this phenomenon shows that more and more immigrants with various cultural background from different places move and settle in all parts of Taiwan for several times (Huang 1984, 1985). In short, according to the hypothesis of Huang, it has a possibility that the evolution of the Yuanshan Culture develops from integrating other archaeological culture with their cultural content.

Learning from the above passages, Huang did not state the relationships between the Yuanshan Culture and others in detail, only given his description on the phenomenon of the coexistence of the prehistoric culture in Taiwan. The correlation between the Yuanshan Culture and the fine corded mark pottery culture is impossible to find crucial evidence from the archaeological works carried out at the second location of the Yuanshan site in 1987 to prove that the Yuanshan Culture is indeed developed under the influence or inherited the content of the corded mark pottery culture. The excavation work of Huang at the Yuanshan site presents no difference from the results found in the previous works. Regardless of the shape, texture, and decorations, the potteries of two cultures are significantly different and no sign of the evolution of the Yuanshan Culture. Unlike Chang, Huang believes that there is no evidence of a notable connection between the Yuanshan Culture and the previous cord-marked pottery culture. Therefore, Huang believes that the Yuanshan Culture may not have evolved from the corded red pottery culture. On the other hand, Huang doubts and considers the need for furthering study on the theory of the later conquerors proposed by Chang (Huang 1989).

In addition to the topic of the origin, the Yuanshan Culture has also been brought into the discussion of the dispersal of the Austronesian language family. In the early 1980s, Chang and Bellwood have noticed that the typological similarity on several artefacts of the Tapenkeng Culture and the Yuanshan could link to that of the prehistoric culture in the Pacific Islands. Both believe that the dispersal of the Austronesian group may be related to the expansion of these cultures from Taiwan to the Pacific Islands (Bellwood 1985、Chang 1986). Bellwood argues that the culture of the Yuanshan has evolved from the culture of the Tapenkeng and spread to the Philippines. The archaeological evidence provided by Bellwood is the red-slipped pottery with a ring-foot and handle, the perforated slate arrowhead, and the adzes with the shouldered and stepped from the Sunget site (1700BC -500BC) in Bataan Island between Northern Luzon and Taiwan. These remains are very similar to the characteristics of the Yuanshan Culture (Bellwood 1985, 1997, 2000). The argument of Bellwood did not win any support by Taiwanese scholars, because of the radiocarbon dating evidence of the Yuanshan Culture. For decades, the age of the Yuanshan Culture was used to be considered starting at 4,500 years ago. The stratigraphic results and the age data obtained through archaeological excavations and the dating experiments show that the age of Yuanshan Culture starts about 3,500 years ago in recent years. The age of the Yuanshan Culture that Bellwood applied to hypothesis is the old measurement data of age, so the possibility of the Yuanshan Culture spread and its disseminated objects are needed to be re-evaluated (Chang 1969, Sung 1980, Liu 1996, 2000, Kuo 2014a).

4.4 Comprehension of Yuanshan Culture in Recent Years

Judging from the archaeological evidence and chronological sequence known at present, the emergence of the Yuanshan Culture was the period that the native culture in the southeast coast of China (Southern Fujian and Eastern Guangdong Province) under the influence by the cultures of the North and East (Jiangsu, Jiangxi and Zhejiang Province) China (Wu 1999). Wu believes that it is the cultural pressure that has caused some residents of the area to migrate overseas. In terms of time, the group of people at that time could indeed migrate to Taiwan. Besides, Liu observes the Yuanshan cultural content and is aware of its difference from the preceding culture of Hsuntangpu Culture and the Chishanyan culture based on the obvious disparity in the implements and the lifestyle. This sudden change in the material cultures shows that they are not a series of evolutions but causes by a group of invading immigrants. Liu believes that its source may be as revealed by Sung in 1965 in the coastal areas of the Guangdong Province and the Han River Basin (Sung 1980, Huang and Liu 1999a, 1999b, Liu 2000).

Kuo, on the other hand, considers that the Yuanshan Culture is a combination of foreign elements and local characteristics. For example, some types of the pottery and the stone tools, and the traditional production technique are related to the earlier local culture of the Hsuntangpu. The unique artefacts of the Yuanshan Culture, such as the decorations of the pottery with the handle or lid, the shouldered axe, the stepped adze, the bronze arrowhead, leave no traces for the clear development in north or other regions of Taiwan. However, these representative remains can find similarities in the archaeological culture of the same period in the southeastern coastal areas of China (Kuo 2014a). In other words, Kuo believes that the technique in the production process of the artefacts of the Yuanshan Culture was adopted both local tradition and foreign elements. As for the exact source of the external elements of the Yuanshan Culture, it only can put forward an acceptable theory under the larger spatiotemporal structure: it may come from the southeast coast of China.

Since the late 1980s, Huang, Liu, and others have invested efforts repeatedly and confirmed, at last, the connection between the corded mark pottery culture and the Yuanshan Culture after several excavations at the sites of Yuanshan and Chihishanyan. The layers of the cord-marked pottery and the plain pottery are stacked on in orders, showing the archaeological cultures that have developed successively, not the cultures that accompanied with each other at the same period. The results of the archaeological works during this period finally answered the question issued by Shi about the relationship between the two cultures in 1954. Huang separates the lower layer of the Hsuntangpu Culture from the upper layer of the Yuanshan Culture and renamed the corded mark pottery culture as the corded red pottery (that is the Hsuntangpu Culture) which normally shows the red colour on the surface as its characteristics (Huang *et al.* 1999a, 1999b).

Today, there is still a discrepancy between Taiwanese archaeologists on the age and origin of the Yuanshan Culture. However, there are several agreements on the characteristic of the Yuanshan Culture, including a foreign culture of some unknown extent, the plain pottery with the majority, and excluding the cord-marked pottery, typical stone tools are the shouldered axe and the stepped adze, etc.

Researcher	Year of the proposed theory	The definition of the artefacts and characteristics of Yuanshan Culture	Suggested cultural hearth
Ryuzo Torii	1930s (Kanaseki, Kokubu 1990)	Typology of stone artefacts	South China, Vietnam, Philippine
Naoichi Kokubu	1943 (Kokubu 1981)	Shouldered axe, stepped adze, black pottery	Islands of South (Southeast Asia), Southeast coast of China
Takeo Kanaseki and Naoichi Kokubu	1943 (Sung 1952)	Stone knife, polished drilled arrowhead, polished arrowhead with hilt, polished black pottery, red pottery and painted pottery	Northern China
	1979 (Kanaseki and Kokubu 1979)	Category of stone assemblages: shouldered axe, stepped axe or shoe-shaped stone tool	At least some of them may flow back to the Main island of Taiwan with the prehistoric cultures from north and central China coastal areas.
Tadao Kano	1946 (Sung 1952)	Coarse corded pottery, net impressed pottery, polished black pottery, stepped adze (flat and columnar)	Fujian, a province on the southeast coast of China
		combination of applying implements making of stone, bronze and iron	Southeast Asia Peninsula
		Iron implements	Philippines

Chang-ju Shih	1954 (Shih 1954)	Pottery pot with two-ears and ring-foot, shouldered axe	China（central region）
	1962 (Shih 1962)	Shouldered axe and stepped adze	Fuzhou, the capital city of Fujian province, China
Wen-hsun Sung	1954 (Sung 1954)	1. Shouldered axe, stepped axe, spoon-shaped axe, red-painted pottery, coarse corded pottery, etc. 2. Subsistence modes of hunting, gathering, and cultivation of crops 3. Formation of settlements	China (No "source" speculation is given, explained only a term "contact")
	1964 (Sung 1964)	Stone tool types of the Yuanshan Culture is under the category of rectangular axe	Southeast coast of China (a region between Haifeng and Guanzhou)
	1980 (Sung 1980)	Stone tool assemblages	Area in eastern Guangdong Province, Hongkong and Haifeng
Kwang-chih Chang	1959 (Chang 1959)	Coarse corded pottery	External (no specific place mentioned)
		Shouldered axe and Patu-shaped tool	Southeast coast region of China (typology of the Longshan Culture, China) (*c.* 4500-4000B.P.)
		Typology of pottery and stepped adze	Lungshan Horizons (*c.* 4500B.P.)
		Shouldered axe	Gulf of Tonkin (now named the Beibu Gulf), Vietnam
Huixiang Lin	1955 (Lin 1955)	Shouldered axe	Southeast China

Pin-Hsiung Liu	1963 (Liu 1963a, 1963b)	Bronze arrowhead	China (Central Plains or Hongkong of South China)
		Stepped and shouldered axe	South China, Southeast Asia Peninsula
Raleigh Ferrell	1964 (Ferrell 1966)	Atayal group equates to the coarse corded pottery cultural layers	South and southwest of China
		Tsou group equates to the Yuanshan cultural layers in northern Taiwan.	Lungshanoid Horizons (The elements of north China or the Austronesians who lived in the east coast at first or even the northern area of China)
		Paiwan group equates to the geometric impressed pottery cultural layers in southern Taiwan.	Lungshanoid Horizons (Somewhere in the south and southwestern China between the Atayal groups, or the south-eastern culture of China before the Han Chinese)
Kwang-chih Chang and Minze Stuvier	1966 (Chang and Stuvier 1966)	Typology of pottery and stepped adze	Lungshanoid Horizons (Southeast coast region of China)
		Shouldered axe and Patu-shaped tool	Gulf of Tonkin, Vietnam
Shih-chiang Huang	1985 (Huang 1985)	Tapenkeng Culture	Southeast coast region of China
		Coarse corded red pottery	Province of Fujian and Guangdong, southeast coast of China
		Archarological cultures of Fengpitou, Chihsanyen, Yingpu and Tahu, etc.	Southeast coast region of China

Shifan Peng	1987 (Peng 1987)	Bronze arrowhead	China
		Stepped adze	Provinces of Fujian, Zhejiang and Jiangxi, east and southeast coastal area of China
		Shouldered axe	The Pearl River Delta of Guangdong Province, China
Renxiang Wang	1987 (Wang 1987)	Shouldered axe	The Lingnan area, south China
Xianguo Fu	1988 (Fu 1988)	Shouldered axe	The Pearl River Delta of Guangdong Province, China
Jian-an Li and Zuo-qi Fan	1995 (Li and Fan 1995)	Shouldered axe	Fujian, a province on the southeast coast of China
Yi-chang Liu	1988 (Liu 1988, Huang *et al.* 1999a, 1999b, Liu 2000)	Yuanshan Culture	Regions between the coastal and Han River in Guangdong Province
Su-chiu Kuo	2014 (Kuo 2014a)	Small bronze artefacts (arrowhead, bracelet, axe, etc.)	Southeast coast region of China
		Stepped adze	
		1. External elements of Yuanshan Culture 2. Shouldered hoe (axe?), stepped adze	Province of Jiangxu, Zhejiang, Fujian and the Pearl River Delta of Guangdong Province, China

Table. 2-2-4 The Characteristics and Origins of the Yuanshan Culture defined by individual scholars after 1940.

The shouldered axes in Taiwan

1. An outline of the shouldered axes study

The shouldered artefacts are widely found in South China, the peninsula and the islands of Southeast Asia, and even farther to Thailand and India (Boer-Mah 2008, De Laet 1994[9]). As early as to the Peiligang culture in the early Neolithic period of the Central Plains in China around 8,000 B.P. has appeared such shape of tools and a certain number of the shouldered stone shovels been dug up (Cultural management committee of Kaifeng and Xinzheng 1978). A large number of specimens with shouldered appliances have been found diffusely in southern China and Southeast Asia in the 20th century. In view of the distribution of the shouldered axe in time and space, Komoto suggests that study of shouldered axe should consider the evolution of the cultural complex in regional prehistory and put into discussions, such as the correlation and the respective divergence of prehistoric cultures between South China and Vietnam during Late Neolithic Age (Komoto 2008). A relatively comprehensive understanding of the cultural origin or evolution based on the knowledge of a typological transformation of the shouldered axes can achieve in this way.

[9] The shouldered adzes found in the site of Garo Hills in northeast Indian has reported that is also made of igneous rock (dolerite or diabase).

Since the shoulder manufacture of Yuanshan Culture is most likely learnt overall from that of China as previous studies being proposed, why only three kinds of shoulder learn or choose by Yuanshan cultural people? What is the consideration for such learning, for instance, on the ground of the familiarity in the production techniques, the actual need for daily works in maintaining subsistence? or have other purposes?

The definition of shouldered is derived from the visual judgment of the appearance of stone objects. In general, the stone artefacts with shoulders, whether symmetrical or asymmetrical on shapes that show, on both sides of the object made on purpose by humans are regarded as shouldered objects. Such a definition is followed in this study. It is usually called a shouldered stone artefact in China and named the shouldered axe in Japan. Its name in Taiwan has inherited the academic tradition left over by the scholars under the Japanese rule, whilst the classification of stone assemblages is the same as to the Chinese principally.

The shouldered axes are characterized in that the whole shape is wide and flat, the upper part has a shoulder, the handle can be mounted, and the lower part is a blade. The shapes of the shouldered axe are relatively diverse presented in body and shoulder. The function and usage of the shouldered axe accordingly show differences as well, which can be theoretically arranged in the categories such as shovel, axe, and adze. For example, an adze is a single-sided ground blade, an axe is a double-sided ground blade. The volume of the shovel is large, and the axe and the adze are relatively small, that have been designed to withstand forces against the reaction forces of the materials like wood or soil. The shape classification of blade edge alone is different from that provided in the Japanese literature, which the definition of the shouldered axes has covered both blades of a single-sided and the double-sided (Wang 1987, Fu 1988). The shouldered axe of the Yuanshan Culture is recognised as an appliance with a double-sided blade edge and an axe-hoe in function.

Nezu (1943) assorts the shouldered axes into three categories according to the angle of the shoulder: right angle, acute angle and obtuse angle. Wang (1987) accounts that a thick and massive body is the key attribute of the shouldered axes, and a few of artefacts evidences with flat and thin, thereby, the thickness volume of the body is classified three types. Type A is large and thick of dimension and relatively rough in-process production. The manufacturing technique is usually chipping and rarely finer grinding. It's been spread mostly in northern China. This type is also visible in the south of the Yangtze River and delicately made with a polished surface. Type B presents a volume of thin and flat, the curvature of the blade edge is shallow, and the body of the shouldered axe has the perforation. Individual specimen among this type is made of jade, which appearance looks like the Type B in Wang’s study (Fig. 2-2-7). Type B is mainly popular in the middle reaches of the Yangtze River. The shape of type C is like a shuttle which the tip and blade are slightly reduced. It only appears in a few areas in northwestern China. Fu (1988) arranges the shouldered axe of the Pearl River basin in two major classes according to the appearance, rather than applying the possible function and usage as the standard of classification. The volume of type I is long without obvious shoulders. The manufacturing process and technique show roughly. There are flake scars commonly left on the shoulders and both sides of the body, and the trace marks on the surface of the blade edge are visible. The type II of noticeable shoulders is divided into right and obtuse angles by the shouldered angles. The production of type II is finer than type I and can be detailed with three sub-types. Fu also classifies the shouldered axes from the Southeast Asia peninsula into two type. Type A is found in Vietnam, has large and thick of dimension and fine-made in-process production, with the angle of right and acute. Type B of shouldered axes are commonly seen across the peninsula. Type C is rare form with two pair of shoulder. Regardless of type A and B, Fu considers that the shouldered axes found in the Southeast Asia peninsula are evolved from the types of that in the Pearl River Delta of China based on the chronological comparison between the sites in Vietnam and the South China and argued without providing dating data in the literature. The classification offered by Geng (1990) principally yields from integrating the shape, manufacturing technique and function and concludes the five categories. Simply put as: type 1 is the chipped stone shovel, type 2 is the polished rectangular axe, type 3 is the polished rectangular adze, type 4 is the polished narrow shoulder axe (unclear shoulder), and type 5 is the chipped axe with two pair shoulders. (Fig. 2-2-6, 2-2-7, 2-2-8, 2-2-9, 2-2-10).

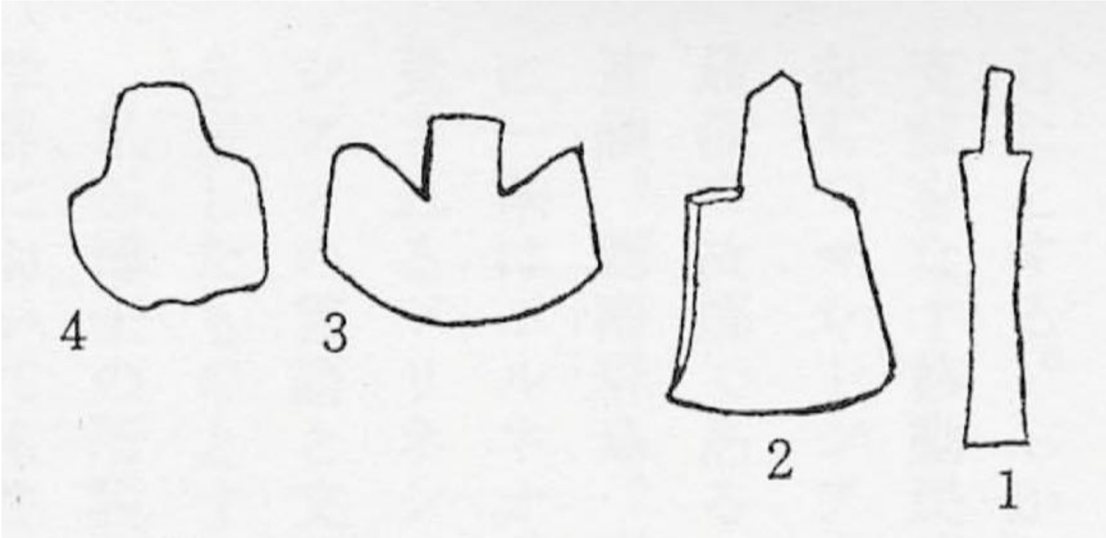

Fig. 2-2-6 Shouldered stone tools classification by Nezu. Right angle: 1 and 2. Obtuse angle: 3. Obtuse angle: 4. (Nezu 1943, plate 2.)

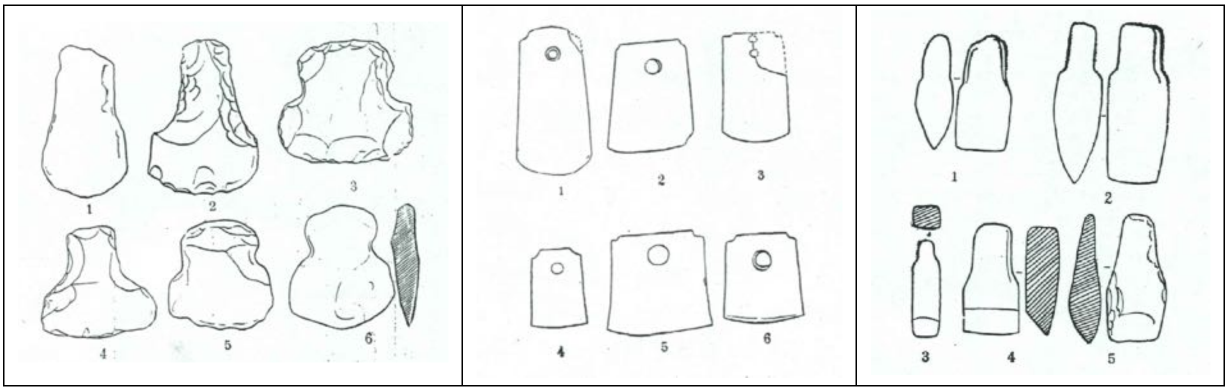

Fig. 2-2-7 Shouldered stone tools classification by Wang. From left to right: Type A, B, C (Wang 1987, plate 3 and 5: Type A and B, pp. 25, plate 5 and 4; Type C, pp. 23, plate3)

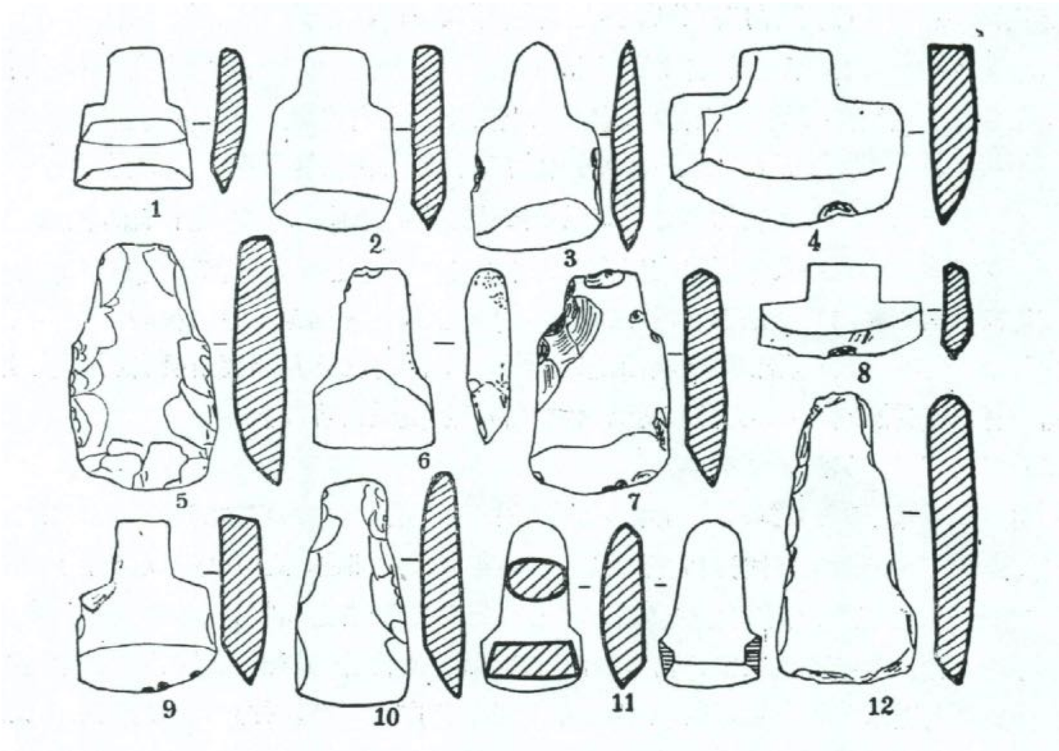

Fig. 2-2-8 Shouldered stone tools classification by Fu. Type I: 5, 10, 12. Type IIa: 4, 8. Type IIb: 6, 11. Type IIc: 1, 2, 3, 7, 9. (Fu 1988: pp. 15, plate 10)

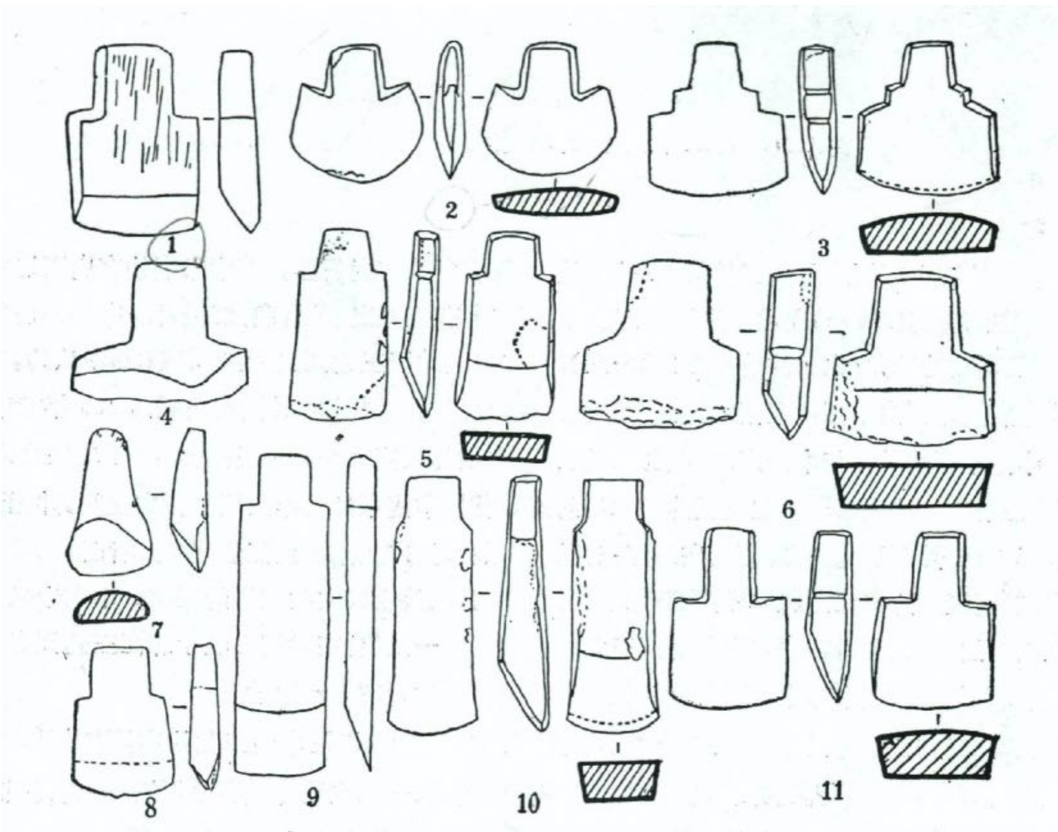

Fig. 2-2-9 Shouldered stone tools classification by Fu. Type A: 1, 2, 10.,11. Type B: 3-9. (Fu 1988: pp. 29, plate 16)

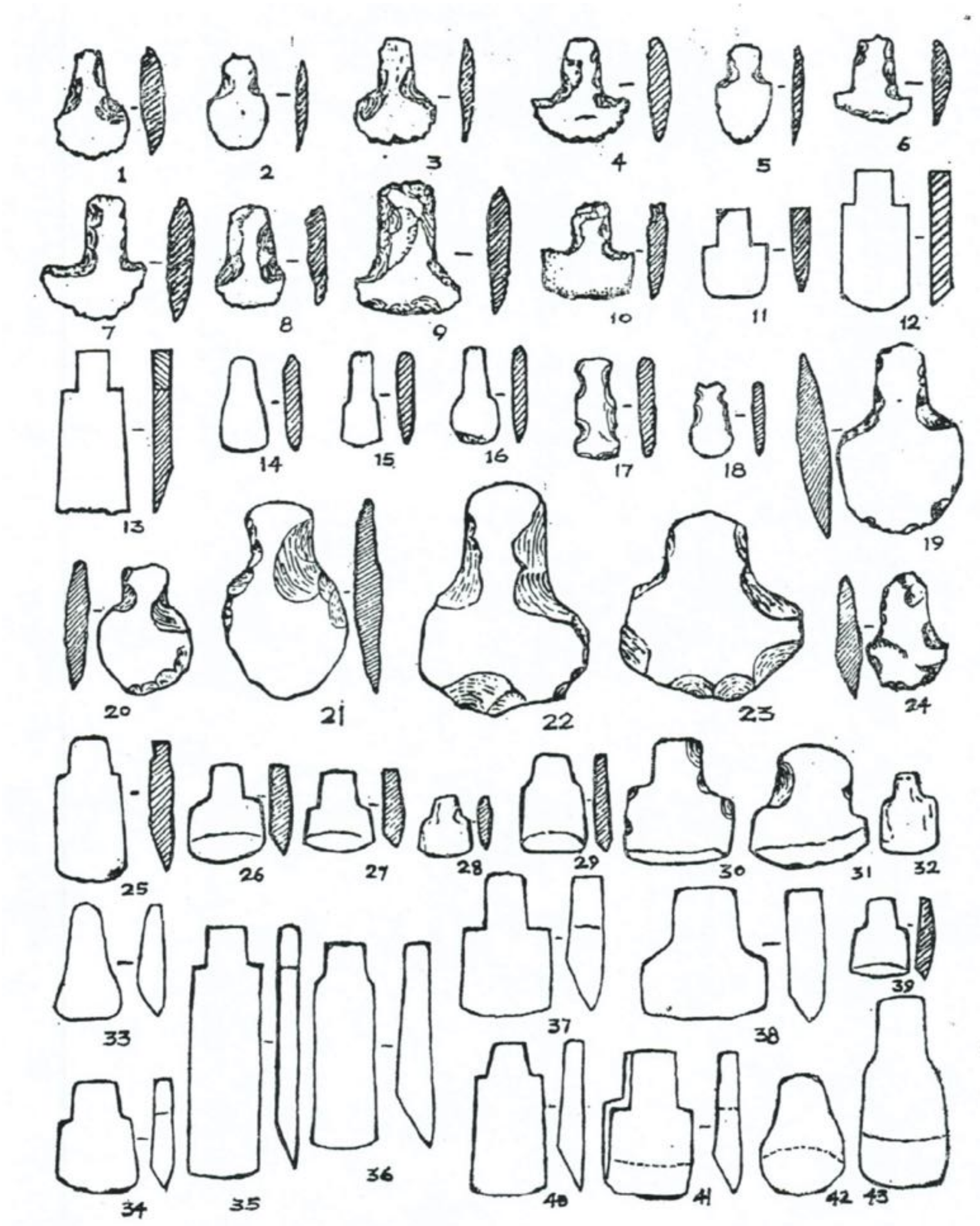

Fig. 2-2-10 Shouldered stone tools classification by Geng. Type 1: 1-10. Type 2: 11. Type 3: 12, 13. Type 4: 14, 33. Type 5: 17-18. (Geng 1990: cover page, plate 1).

Scholars in the above passages have proposed different classification on the requirement for the standardised study of the shouldered axe. Most of them judge from the appearance, function or production technique of the shouldered artefacts as a single or mixed principle to achieve a systematics knowledge morphologically and technologically. Starting with a single principle of classification which gradually establishing the typological transformation of the shouldered axe is an initial attempt by the scholars to standardise the artefacts research regionally in morphological, technological and functional. A comparative study of the shouldered axe in prehistoric cultures across regions would help to approach fully comprehension on the techno-typological evolution and the spreading routes of artefacts chronologically. The establishment of a cross-regional morphology database of the shouldered axes can be achieved based on such. This study will follow the positions of the Yuanshan Culture hypotheses since the post-late 1980s to classify typologically the Taiwanese shouldered axes as an attempt of cross-regional analogies on their types for learning the possible origins. (Table 2-2-4)

On building the cross-regional database for the typological and chronological research of the shouldered axes is not easy at present. Several causes have resulted in this. First of all, the archaeological materials unearthed in the early days are mostly the surface collections during a survey or gathered unintentionally by chance from personal traveling around, lacking completely the stratigraphic and archaeological contexts related the sites. For example, Type A in the Wang's classification has several similar shouldered axes in Taiwan, but most of the specimens are the surface collection from fieldworks or the collections of transfers or resale the museum by the amateur cultural workers picked up. Therefore, the insufficient information of chronology and stratigraphy of this type of shouldered axes limits the study that only the morphology and raw material of rocks could be reached. Secondly, the incomplete information of the unearthed materials published in various regions or the inaccessibility of the original materials, make the research relatively difficult. The general cases are that the published archaeological literature only provide partial or individual materials of some important specimens for specific archaeological work(s). Third, the determination or identification of the actual function or usage on some stone implements needs great efforts which often leads to the difficulty in defining the name of each artefact. A damaged stone tool as an example may be retouched, yet, the partial marks on the surface left by the previous manufacturing or user may also remain visible. If the orders of production or usage are recognisable from the surface traces, it is easy to clear a name and a definition of the object. However, confusion arises when the difference cannot be read. Finally, the production technology and style are exchanged between the known artefacts, resulting in a different shape from the past understanding of a certain standard form, which is not conducive to classification. For example, the shouldered axe and the stepped adze become shouldered adze and stepped axe, or the shouldered and stepped have been appeared on the same piece of a tool at the same time (Kuo 2014a).

Regardless of the divergence in style, merely focus on the forms and production technology of the shouldered axes, some of the Yuanshan artefacts are resembled highly to the proposed classification to those shown in the figures indeed, such as type A of Wang and type I of Fu. The explanation of the cases of the foregoing two types with the common striking scars which were left on the surface also corresponds to that of some stone objects of the Yuanshan Culture.

Morphological comparative study of the artefacts is an ordinary mean applied in the archaeological research for surmising on the evolution in forms of particular objects or on the relations between the prehistoric cultures which those objects are classified too. For example, the study of the lingling-o (Fig. 2-1-36), a double-headed pendant which normally was made of jade and with various types is regarded as a distinct object of the Austronesians during late Neolithic Age. Although the raw material of lingling-o is the Taiwanese jade, its shape and manufacturing technology are varied from place to place in the Southeast Asia (Bellwood *et al.* 2011, Hung and Iizuka 2017). Such particularity on its shape and production helps archaeologist to classify chronologically and regionally.

The typological comparison of the shouldered axes of the Yuanshan Culture, identically, is one of the methods to explore the affinity or source of the Yuanshan Culture with the prehistoric cultures in the neighbouring areas. The standardisation attempts of the aforementioned scholars have their reference value for the present.

The shoulder is the most basic and important feature of the shouldered artefacts for its identification. Nezu uses the shoulder angle as a key feature of the typological classification. Approaching on the ground of the identification of the shoulder angle and furthering the research of distinguishing the production technology and the functional usage, are relatively effective to build the morphological categories of the Taiwanese shouldered axes. The typological categories of the shouldered axe of the Yuanshan Culture in this study adopt the shoulder angle as a standard for the classification so that further the usage and the applied objects of the shouldered axe could be answered. The cross-regional typology database of the shouldered axes is an individual expectation and a goal that could be achieved in the future if this study fruits.

2. Types of stone assemblages in Yuanshan Culture

The typology of stone tool collected from Yuanshan cultural sites can be classified into several categories because of the ecological lifestyle. Herein the base of the quantity and variation in types, the axe accounts for the largest number of all stone tools, and then is followed by chisels, arrows, knives, and net sinkers (Fig. 2-2-4, 2-2-5).

The ratio of the stone implement types is rather variable from each site (Fig. 2-2-11). Axe-hoe[10] type in the total amount of stone tools in each site accounts for at least 40%, Chanlungshan Site attains to 66.9%, Kuantu site even reaches up to 88%. The-second largest number of stone types is adze-chisel[11] among Yuanshan cultural sites with a proportional change of each, such 47% in Yuanshan Site, while only 10%

[10] A category habit in Taiwanese archaeological literature, referring to the incomplete object which possibly uses as an axe or hoe.
[11] A category habit in Taiwanese archaeological literature, referring to the incomplete object which possibly uses as an adze or chisel.

in Kuantu Site and Tutikongshan Site. The proportion of variation in stone objects in each site is also evidently observed, the arrowhead with 26% in Tapenkeng Site and 2% in Kuantu Site. Knife found sporadically, only a few in Tutikongshan Site. The same situation occurs in the sinker, a certain amount unearthed in Tutikongshan Site and Huweishan Site of Dahan Creek drainage area, while only a little found in Yuanshan Site and Guandu Site. On the whole, the use (consumption) of the axe-hoe and adze-chisel by the Yuanshan people is relatively high, which may imply that the daily activities of the Yuanshan people are probably focused on the agricultural and forestry environmental.

Judging from the proportion of variation in stone utilities associated with the landscape of sites, it seems that the environmental factors determine the human choice of using certain tools in order to adapt the landscape. However, it must be pointed out that the interpretations corresponding to the actions taken by humans to adapt the environment based on the typological studies of archaeological artefacts may oversimplify and obscure the characteristics between different cultures for the cross-regional research.

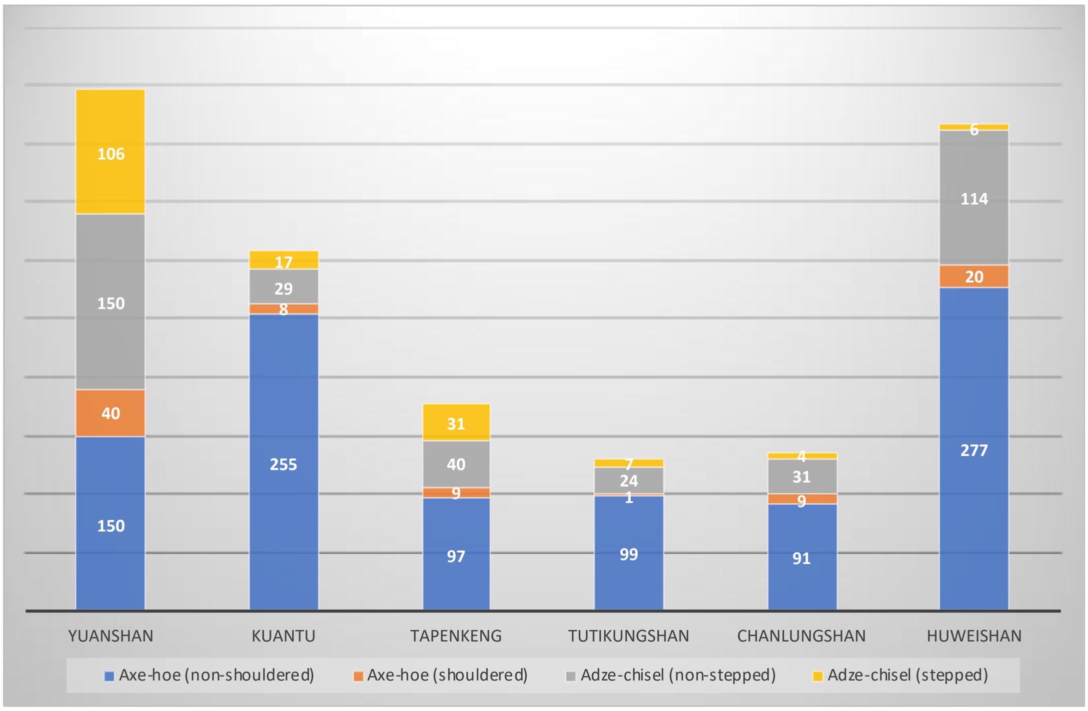

Fig. 2-2-11 Statistical data of the composition of Yuanshan cultural stone assemblages. (Sources: 1. Yuanshan site by Sung 1954b, 1955a,b. 2. Kuantu site by Sheng 1962. 3. Tapenkeng stie by Chang *et al.* 1969. 4. Tutikungshan site by Liu *et al.* 1961. 5. Sites of Chanlungshan and Huweishan by Kuo *et al.* 2012)

3. Evolution and Origin of shouldered technology in Northern Taiwan

The progress of shouldered development did not gradually evolve along with the prehistoric cultural sequence of Northern Taiwan. Comparing the production technique on the stone objects between the Yuanshan Culture and the others, the shouldered technology demand seems to be a selective requirement. In contrast to the given stone assemblage information from the earlier and the later archaeological cultural sites around Taiwan, the quantity and typology of Yuanshan Cultural shouldered tools emerged in a large number at a certain of time about 3200 to 1800 BP, then disappeared all of a sudden. (Liu *et al.* 2004) Without any historical trajectory of the shouldered technology which appeared and disappeared in

Northern Taiwan. It is easy to assume that the shouldered technology is introduced by the people of other cultural groups which are possessing the technical knowledge and passing it to the Yuanshan cultural people.

Regarding the external factors embedded in the Yuanshan cultural content has been the most recognised theory in the academic community, especially for the distinctive stone implements, such as the shouldered axes and the stepped adzes. There are four regions of these typological origins have been mentioned in the literature which lies in the adjacent areas of Taiwan: Central Plain region in China, Southeast coast China, Pearl River region of Guangdong Province in South China, Red River region in Northern Vietnam. (Shih 1950, Wang 1987, Fu 1988, Tsang 2012, Kuo 2014a) The morphology and the development of shouldered technology appeared separately and locally from region to region. For instance, another trait of Yuanshan Culture is the co-existing of shouldered axe-hoe and stepped adze-chisel which the techniques apply to the certain object only and develop simultaneously. Contrast to that, the development of shouldered and stepped tools separately and the processing pattern applies to the objects mutually in China and Southeast Asia. (Fu 1988, Tsang 2012, Kuo 2014)

The comparative study of processing technique on shouldered stone tools in China by the literature review, the mainstream of manufacturing method is the polished products. In Southwest China and Southeast Asia, the form of the shouldered axe and the time of occurrence in the Late Neolithic Age are similar.

While the emergence of the shouldered axe in Southeast China is earlier than the 2 areas mentioned above during the Middle Neolithic Age. Chen's research suggests that the origin of polished shouldered tools is more likely from Southeast Coast China, namely Pearl River Delta region, yet the chipped shouldered objects develop individually by the regions. (Chen 2006) This study provides a view of thinking that the concept or the technique of the roughly polished on the shouldered tool manufacture by the Yuanshan cultural people may learn from the people in Southeast China.

However, the stone artefact production of the Yuanshan Culture technically is not completely transplanted from its mother culture (Kuo 2014a). Observing the majority of the Yuanshan cultural stone tools are not entirely the new technology learning from the foreigner as previous studies assumed, it's products of following the Hsuntangpu Culture manufacturing tradition and developing gradually. For instance, the chipped and polished non-shouldered tools made from andesite has been discovered in Hsuntangpu Culture. Such production methods and raw material selections already found on the stone assemblages of Tapenkeng Culture went down to the Hsuntangpu Culture and succeeded by the Yuanshan Culture. On this basis, the stone implement manufacturing with a further trend of object shape – the shouldered/stepped stone tools appeared largely and obviously in Yuanshan Cultural sites during the Late Neolithic Northern Taiwan. In other words, the shoulder-making technique of Yuanshan Culture may be a new product that integrates the local tradition of making stone objects with the external elements in terms of the shoulder style.

Besides, comparing the production technique on the stone objects between the Yuanshan Culture and the others, the shouldered technology demand seems to be a selective requirement. Because of the unshouldered axes of the Yuanshan Culture were also uncovered in sites (Kuo 2014a). It is a typical and common seen axe in other archaeological cultures in Taiwan. The volume of the unshouldered axe is thicker than the shouldered one. And the shapes formed, as well as the raw material of rocks used on these axes, vary in time and space. Sometimes even in the same site, an unshouldered axe made of different rocks can be found in stratigraphic layers of single or multiple cultures, such as the Yuanshan site. Due to the difference in the unearthed condition and the functional definition of the same type of utensils, the axe and the hoe are generally placed in the same category of stone assemblages and classified into an exact type after being examined carefully for its distinguishable function. Normally the functional usage of the unshouldered axe is considered a tool for farming or woodworking. As a result, the function of the shouldered axe is believed as equal to the unshouldered one.

It is considered that the agricultural activity had increased a substantial proportion in the society through time, and gradually moves into the Yuanshan Culture period. Chang (1981) conjectures that the stone hoes and axes found at the earliest site located at the mouth of the Tamsui River are per the people having a primitive agricultural activity based on the ethnographic parallels. For instance, people use the stone hoes or axes for planting root crops by slash-and-burn technique and know the methods for producing the farming tool of aids. The later archaeological sites in the region have been unearthed the extensively cultivated rice remains, and the farming equipment which is at large amount in all tools. It is supposed, therefore, that the uncovered stone hoes and axes are presumably employed as an agricultural tool as the tradition in Northern Taiwan. In this thesis, consequently, there are 309 pieces of shouldered axes of the museum’s collection and sixteen shouldered axes will be studied on the manufacture methods, the usage of the farming activities and the emergence of the shouldered artefacts from four Yuanshan Cultural sites: the Chanlungshan, the Chihwuyuan, Chientang, and the Chihshanyen Site. (Blue dot in Fig. 2-2-2) Simultaneously, the technological choices will be employed to the study on the shouldered technology development in Northern Taiwan during the Neolithic Age. (Sillar and Tite 2000)

4. The processing technique of the shouldered axe production

About 80% of the shouldered artefacts found so far were made of andesite, followed by sandstone or other stones. The raw material of andesite examination followed the original records from the museums and reviewed by me in this study. While the shouldered axe collection of the National Museum of Prehistory (NMP) were examined by Dr Hsiao-chin Yang, the geologist of NMP. The difference in the cleavage mode between andesite and sandstone require distinct cracking methods to meet the position when making stoneware. Primary modification of andesite with taking a shape of a core by cleavage cracking, while metasandstone by percussion flaking. Axe-hoe, whether shouldered or not, usually strike laterally into the crude embryo, then chipping, pecking and retouching into a finished object.

Although the use of raw materials in axe-hoe producing is significantly different, a high percentage of chipped and roughly polished for manufacturing andesite and sandstone axe-hoe shared the technique. In other words, except either simply chipped or polished methods, combine with the chipped and roughly polished technique apply to Yuanshan cultural stone axe-hoe manufacturing is one of the unique features in Northern Taiwan. In China, the mainstream among shouldered stone tools is a polished product during the Neolithic Age (Appendix 1). Comparing the forms of shouldered axe between Southwest China and Southeast Asia are similar and emerge from the Late Neolithic Age to Bronze Age. While shouldered axe appeared in Southeast Coast China is around Middle Neolithic Age. It is suggested that the origin of polished shouldered tools is more like from Southeast Coast China, namely Pearl River Delta region, yet the chipped shouldered objects develop locally from region to region (Chen 2006).

Shouldered axe-hoe and stepped adze-chisel reflects the Yuanshan cultural trait of lithic technology (Sung 1980, Huang 1985). It is worth mentioning that, not alike the tools found in South China and Southeast Asia, a stone object with both shouldered and stepped has not been found in Yuanshan cultural sites by far. Neither discovered a swap of shouldered or stepped technology apply to the object of Yuanshan Culture, for example, shouldered adze-chisel or stepped axe-hoe which has been commonly seen in the sites of South China and Southeast Asia. Shouldered or stepped in profile and chipping or polishing in the process has a set of shouldered/stepped production in South China and Southeast Asia, which means an object could have both shouldered/stepped outward, and chipping or polishing in the application. Yet there is likely a reverse processing mode of production for Yuanshan cultural people, an object has either a shouldered or stepped profile to chip and polish roughly. If the concept of shouldered/stepped introduced from the outsider, what causes such a change? Since the chipping and roughly polishing is so distinctive to the Yuanshan cultural stone assemblage, could the polishing be the important concept/knowledge of making tools to Yuanshan cultural people? So important to polish object roughly in order not to confuse the original concept/knowledge of shouldered/stepped technology? In order to understand these issues, this study will focus on the typological analysis of shouldered axes in Taiwan and try to assess the reasons for the change in production technology from the shapes of the stone tools. In other words, the production technology and style of shouldered axes is the focus of this research.

5. Style in Shoulder

The current definition for a shouldered tool of Yuanshan Culture remains unclear. It is mainly applied the technique by chipping and roughly polishing in the production process, but the shoulder has been a visible divergence in appearances (Mastumoto 1939, Huang 1989, 1992, 1997, Huang *et al.* 1999a, 1999b). Shapes and angles of the shouldered tool in the Yuanshan Culture are commonly seen with plain shouldered (a, b), droop shouldered (c), and shrug shouldered (d) (Fig. 2-2-12).

Three shoulder style is relatively simple in contrast to those shouldered artefacts from China. The style in the shoulder from shouldered tools in China is rich and diverse in the shapes of the shoulder and the body on the shouldered tools from various regions (Fu 1988). As learnt from the above passage, the style/design of the Yuanshan cultural shouldered axe is rather concerned with the shoulders then body.

Fig. 2-2-12 Shoulder types of the Yuanshan Cultural shouldered tools. (a: Chanlungshan Site, b: National Taiwan University, c: National Museum of Prehistory, d: Institute of Ethnology in Academia Sinica) (Photographed by Li-Chi Chiang)

The Yuanshan cultural people inherit the production technique tradition of the stone tools from the earlier archaeological culture, such as the volcanic rocks use and the production method of the chipping and roughly polishing. Kuo suggests that the stone artefact of the Yuanshan Culture in the production process was inherited technically from the local tradition of Hsuntangpu Culture (Kuo 2014a). As far as known the earliest shouldered axe is unearthed at the Nankuanli East Site in Tainan Science Park in southern Taiwan and dated around 4,800 to 4,200 B.P. in the Tapenkeng Culture period. The was unearthed. The raw material of rock for this shouldered axe was made of the olivine basalt and procured from the quarry in Penghu, the outlying islands situated in the Taiwan Strait, west of the main island of Taiwan (Tsang *et al.* 2006). The appearance of this olivine basalt shouldered object is similar to the shape of the shouldered one that is common in the Yuanshan Culture (Fig. 2-2-13). To be emphasized that there is no necessary to link the Tapenkeng Culture and Yuanshan Culture in terms of the direct production technology heritage.

Fig. 2-2-13 Typological comparison of shouldered tools. Left: axe-Chanlungshan, Right: adze-Nankuanli East. (Photographed by Li-Chi Chiang)

However, the higher the familiarity of traditional production techniques and knowledge is, it is doubtless easier to control the quality in the production process of stone artefacts, such as the choice of the rocks by properties or of the technical production by flaking and grinding. The fact that the appearance of the artefacts is fewer (or even no) changes seemly indicates that the Yuanshan Culture chooses to continue the tradition rather than adopting a large variety of exotic design styles, which may be owing to the familiarity with local production technology.

On the issue of whether the shoulders are practical or not, the opinions of scholars are different. Shih considers that the shoulder is a practical use as a farming tool, the shoulder can be tied with wooden handle by cordage, which is convenient for the operation of the shouldered axe. This is the theory that most agreed on among the Taiwanese archaeologists. Kuo, on the other hand, points out that the shoulder is rather a fashion style popular regionally at the time, and less in the functional usage (Shih 1950, Kuo 2014a).

As stated above, in terms of practicality and familiarity of artefact production, if the three shoulder styles can meet the needs of the daily works of the Yuanshan Culture people (for farming or woodworking), it is unnecessary to spend time learning or considering other forms to make different shoulder on the shouldered axe. On the contrary, if the shoulder is not practical enough in use, such as easily break whilst user's employing, it is simple as to throw making shoulder away directly without considering learning more forms of shoulder production. Secondly, if concerning the viewpoint of popular fashion trends across the regions, three forms of shoulder do not be many in numbers seemly to choose for artefact decoration. Perhaps it can be said that these styles are the mainstream for the shoulder design of the shouldered axe in the Asian continent and Southeast Asian.

The concept of fashion design is not easy to be detected physically on the appearance of the shouldered axe. However, the traces left on the surface of the shoulder and the blade edge are visible by examining the typology and the surface marks of the shoulder and the shouldered axe from the practical usage. It means that the shoulder most likely has a functional requirement for easy use and effort saving. From this point of view, the production method and the use of the shoulder is the key theme in this project for answering the questions mentioned above.

The typological analysis in this thesis will classify and record several attributes of shouldered artefacts, such as shape, raw material of rock, dimension (shoulder and blade edge), etc. Then, compare the types of shouldered tools by the similarity across regions. At the same time, the function of the shouldered stone tools is going to test by applying the method of use-wear analysis and replica experiments.

6. Raw material Procurement and networking

Selection of raw material for producing tools as an agricultural, woodworking or daily use instrument of Yuanshan cultural people reflects the probable networking among Yuanshan cultural sites and the geological zone of rocks in Northern Taiwan.

It seems that the use of rocks is slightly different between the sites in the north and south of Taipei Basin since the distance from the quarry is varied. Such as the Yuanshan Site and the Chihsanyen Site are located near the Tatun Volcano Group in the north of Taipei Basin, the andesite is widely used for stone tool manufacture, and combined with the use of other rocks of shale, sandstone, and basalt. Yet, the sites in the south of Taipei Basin, for example, the Chanlungshan Site, the finds of stone implements are partly made from metasandstone, quartz sandstone, and shale which are procured from the local quarry. There are also a few stone tools made from tuff and basalt which are found in the other Yuanshan cultural sites (Huang 1984, Kuo 2014a, 2015).

The typology and/or production techniques of cultural materials resemble across regions, which may not assess as an archaeological evidence in term of the spread of technological concepts between region. Yet, Taiwanese archaeologists believe that the lithic technology of Yuanshan Culture is progress, the stone tools made locally, and the raw material of rocks procured from the neighbouring area in Northern Taiwan. The local tradition production content is inside of the Yuanshan Cultural assemblages. For instance, many igneous rocks are being used as a raw material to produce pottery and stone tools. Apart from the local rocks of andesite, sandstone, metasandstone[12], and shale are using as the raw material of manufacture,

[12] It is the lightly metamorphic sandstone and almost every particle is hard quartz.

there are also a small number of rocks from other regions. Such as the nephrite tools which are collected from Fongtien where is known for the nephrite quarry in Eastern Taiwan are discovered at the Chanlungshan Site. Most studies notice that the shouldered tools in North Taiwan for example, are mostly produced by the andesite that could be derived from the outcrops of the Tatun Volcano Group in the surrounding of Taipei basin. Yet, those studies do not provide any geochemical or petrological analysis results on the shouldered artefacts research as a shred of crucial evidence to verify the theory that the use of andesite by the Yuanshan people are indeed collected from the Tatun Volcano Group. (Huang 1997, Kuo 2014a) The andesite quarry will be tested by the pXRF analysis in this study.

Regarding the durability of rocks, the metasandstone or the quartz sandstone is a better choice for making tools than a soft rock of andesite or basalt. Nevertheless, igneous rock as a raw material for making a shouldered tool by Yuanshan cultural people seems intentional, especially the use of andesite. Once the andesite is difficult to acquire from a distance or other reasons, the adoption of the local igneous rock seems most likely an important choice as the raw material of shouldered tool production, such as basalt. (Chen and Kuo, 2001) The reason for the igneous rocks adoption to produce the shouldered tool presumably is accepting the manufacture tradition of the andesite from the earlier culture in Northern Taiwan.

Furthermore, judging the consistency of stone assemblage types and raw materials from each Yuanshan cultural site, it appears that there is possibly one or

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http://www.nadmgl.tw/nadm/cht/fossil_detail.php?serial=520#

several stone manufacture centres existing in Northern Taiwan, like workshops of andesite which some are in the north and others in the south. Thereupon, the Yuanshan cultural people probably obtain the supply of daily use tools by a certain or some kinds of networking like an agency. There are two andesite shouldered tools from the site which is in the south of the Taipei Basin has the resemblances of raw material, production technique, and forms to those from the sites in the central and the north of Taipei Basin. These two objects with fine polishing surface indicate that they are the finished goods and brought into the site, instead of acquiring the raw material of andesite from the quarry and producing locally. It is worthy of discussion the operation of the networking and the exchange system on the base of the raw material of rocks selection regionally, regarding the sites of the Yuanshan Culture concentrated in Northern Taiwan. Therefore, comparing the raw material source data with the locations of the Yuanshan cultural sites will be assessed in this study by pXRF analysis.

7. Usage and function of the shouldered axes

There is a long belief in the agricultural usage of a shouldered axe which is widespread in the East and Southeast Asia (Mizuno 1933, Mastumoto 1939, Shih 1950, Obayashi 1982). There is a long belief in the agricultural usage of a shouldered axe which is widespread in the East and Southeast Asia (Mizuno 1933, Mastumoto 1939, Shih 1950, Obayashi 1982). The length of stone tools implied by the prevalence of farming and demonstrated the concept of deep ploughing ability. Such as, there are stone tools with greater than or equal to 20-30 centimetre in length were found in the Yuanshan Culture, which may use for deep ploughing. Shouldered tools, on the contrary, is smaller in the size dimension than the large ones. Moreover, the stone tools of axe and hoe usually have been recorded as a tool for the multi-functional stoneware, especially the incomplete axe or hoe artefact which is uncovered from the archaeological sites in Taiwan. It is necessary to clarify the usage type of farming.

The content of Taiwanese ethnography may provide relevant information as a reference potentially, although the risks of ethnographic parallels should be considered. Miyamoto (1939) mentioned in the description of the manufacturing method of the stone shovel of the Yami people in the Island of Lanyu, that its usage is consistent with the shovel of the Bunun group which is used for farming (Fig. 2-2-14, 2-2-15). Kokubu (1981) observes the composite tools used by the Bunun in central Taiwan, both stone shovel and the aforementioned shoe-shaped stone tools appear in the type of daily use at the same time (Fig. 2-2-16, 2-2-17, 2-2-18). The former tool is a typical utensil for slash-and-burn shifting agriculture used by the Bunun people for farming, and the latter is also an agricultural tool for weeding the cultivated field. There is no detail description of the type of the former stone shovel in the ethnographic literature, but the shoe-shaped tool is classified to the asymmetric shoulder type which is one of the shouldered axes on the whole. Therefore, the shouldered appliance is also possible to use as a tool for removing weeds in farmland before farming or during the period of crops growing.

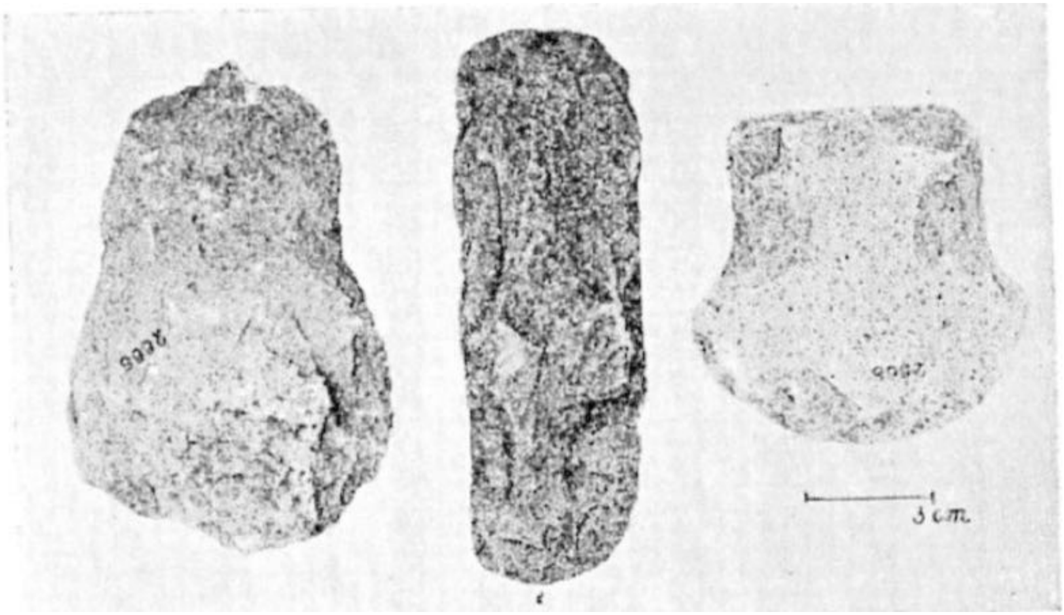

Fig. 2-2-14 Chipped stone shovel from Orchid Island. (Miyamoto 1939: plate 5.)

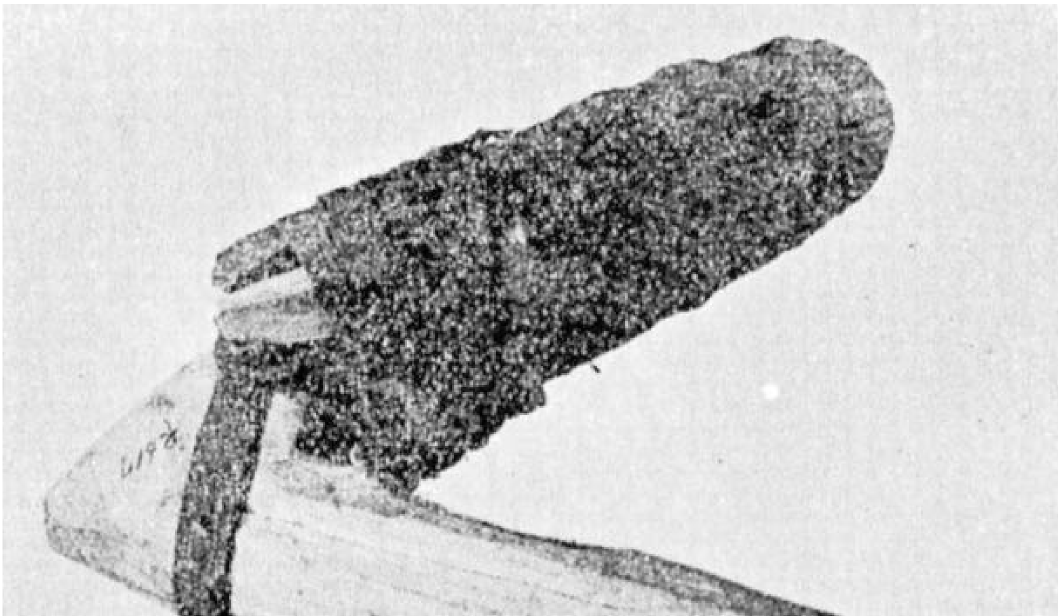

Fig. 2-2-15 The Bunun's chipped stone shovel binding with rattan on wooden handle. (Miyamoto 1939: plate 6.)

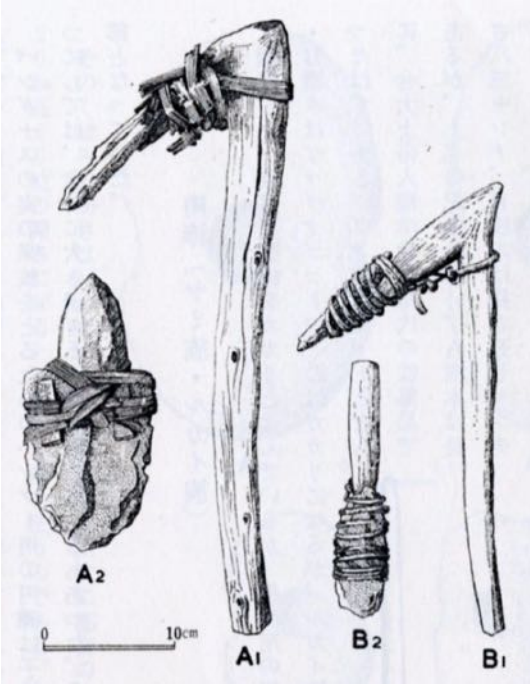

Fig. 2-2-16 The Bunun's chipped stone shovel fixing with rattan on wooden handle. (Kokubu 1981, pp. 428.)

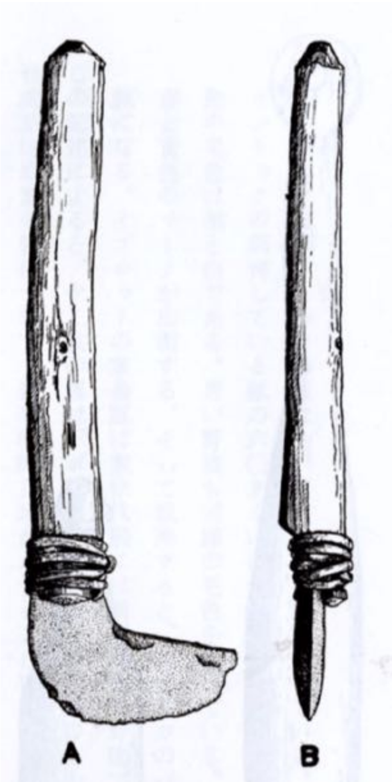

Fig. 2-2-17 Shoe-shape tools of Bunun. (Kokubu 1981, pp. 431.)

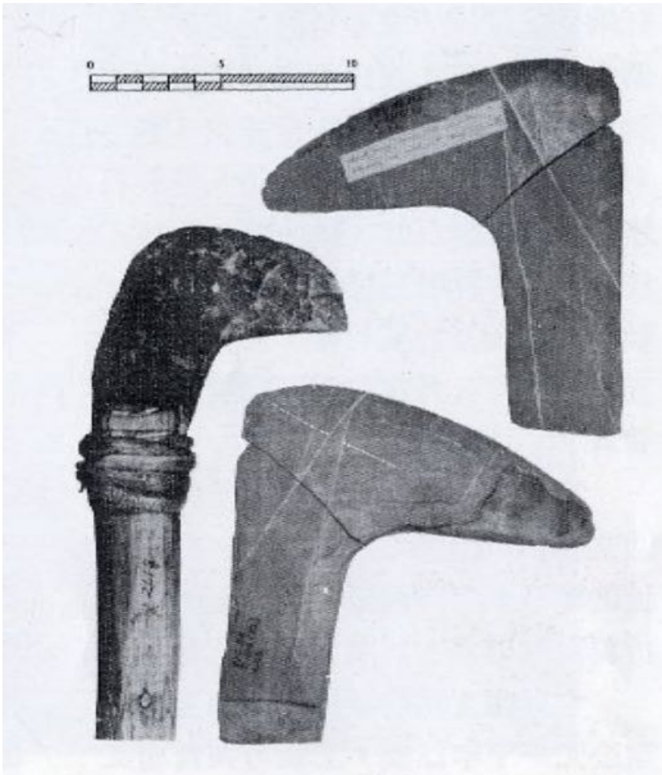

Fig. 2-2-18 Shoe-shape stone tools from Eluanbi 2nd Site. (Huang 1986, pp. 14. The photo is from the report written by Kuang-Chou Li, 1985)

Yet, some shouldered objects of Yuanshan Culture even have been theorised as a shovel and hoe. (Liu and Kuo 2000, Kuo 2014a) In the study of the shouldered tools, the usage and the function of axe, hoe, and shovel should be defined clearly. Thus, it will be reasonable for selecting the most likely function of the shouldered tools for conducting the experimental archaeology. Three appliances are defined as follow: hoe is used mainly for weeding and breaking the soil; axe is used for chopping wood typically; shovel is larger in the size than previous two and used for digging, removing loose matter on or beneath the ground.

Observing the use-wear on the shouldered tools of Chanlungshan Site, some surface marks do not look like employed to the hard substance. Shih suggests that the shoulder is to tie the wooden handle for weeding, ploughing or woodworking possibly. (Shih 1950) Roy (1981) defines the shouldered adze unearthed in Garo Hills in northeastern India as a hoe for shifting agriculture. Boer-Mah's research supports the idea of the shouldered technology development may be associated with woodworking or economic control of raw materials by effectively applying the morphological analysis of shouldered adze from Thailand. (Boer-Mah 2008) Considering the hypothesis from Shih as well as the microwear observation result, the function and the usage of the shouldered tool is likely as a hoe. Taiwan's ethnographic context has words in describing the aboriginal people tied the stone hoe on the wooden handle by cordage for farming as well (Miyamoto 1939).

Hafting techniques of the shouldered axes, on the other hand, there are two modes to attach the handle onto the tools. One is the wooden handle that provides a space for the head of a tool to fit in, another is using string to tie the tool directly on the wooden handle. Hung gives further five hafting methods on her study of the adzes in Taiwan, South China, and Southeast Asia. (Fig. 2-2-19, 2-2-20, Hung 2000, Chen 2006) The information of hafting from Chen and Hung can be referenced as the hafting experimental archaeology of shouldered axes.

Therefore, in this research, the replica experimental works on the production method and usage/function of the shouldered axes could be answered.

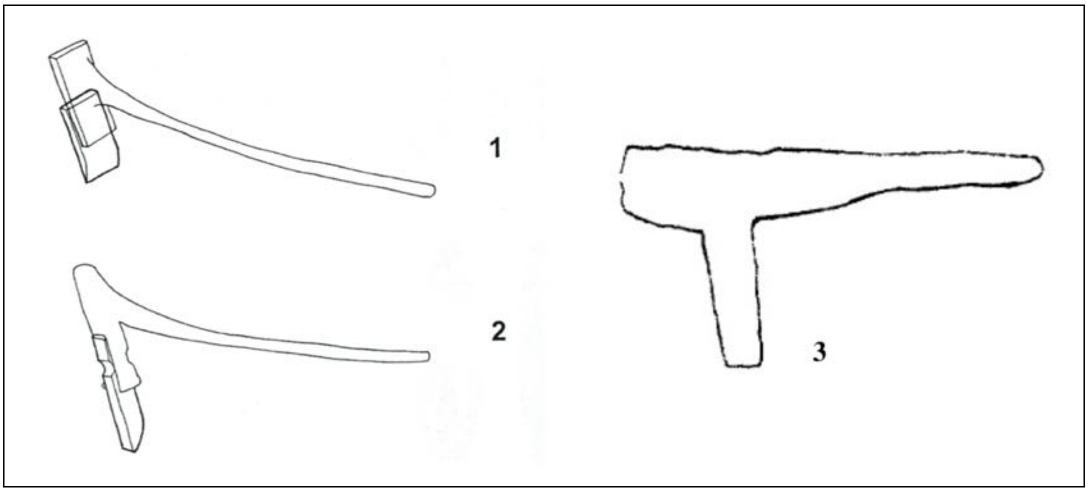

Fig. 2-2-19 Hafting mode 1(Hung 2000, p.118; Chen 2006, p.30)

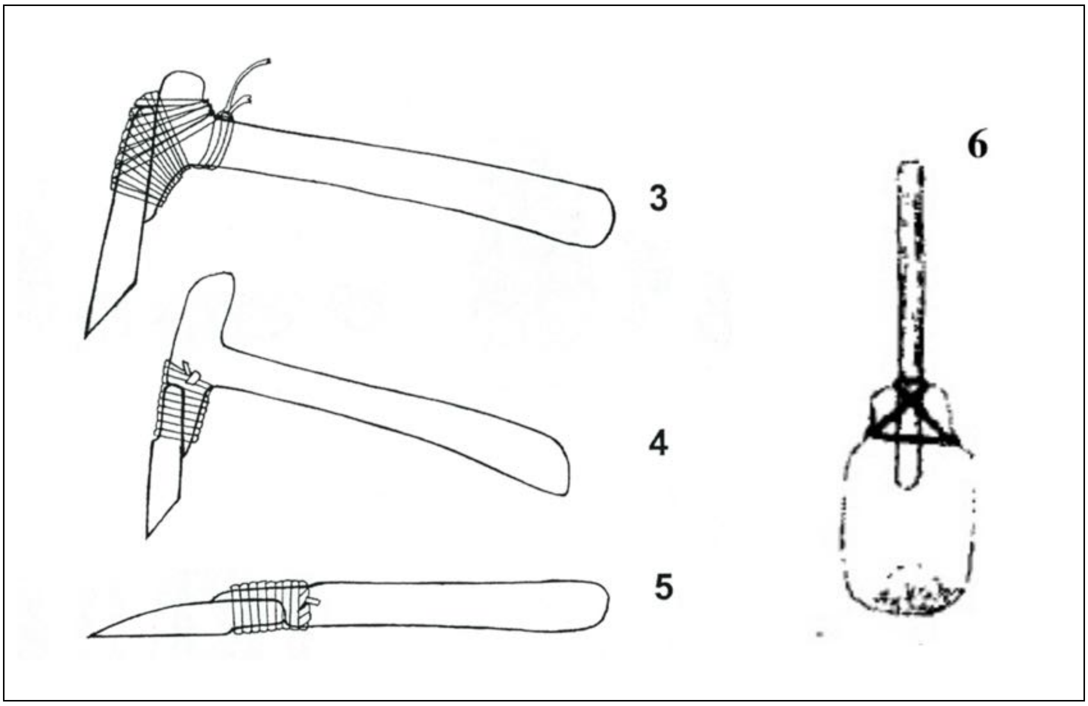

Fig. 2-2-20 Hafting mode 2 (Hung 2000, p.118; Chen 2006, p.34)

8. The relation between shouldered tools and the bronze artefact production

There have been unearthed a few small bronze objects from the Yuanshan Cultural sites in Northern Taiwan, including bronze arrowhead, bronze bracelet, and bronze flake. There is one bronze axe of Tutikungshan site discovered with part of a recognizable edge, yet it is not in a good condition. The outcome of residue analysis suggests that the bronze axe was equipped with a wooden handle in which the edge contained with decaying wood. (Chen 1994) These bronze objects scatter over the region and have different types. Kuo considers that the bronze objects should be brought into the Yuanshan cultural sites from multiple ways in a different period, which is referred to the contact with people from the Southeast coast of China for several times. (Kuo 2014a)

Yet, the evidence to support the relationship of material culture between the development of Chinese bronzes and the shouldered axes of the Yuanshan Culture remains obscure currently. If place the archaeological assemblages of Yuanshan Culture into the spatial context of Taiwan, South China, and Southeast Asia, the manufacturing techniques on stone style presumably are sharing the similar properties within the archaeological sites in the regions during the same period.

In the early 20th century, the connection between a shouldered axe and bronze yue (axe) has been discussed as progress on the use of money, a pattern like shouldered axe-metal shovel-bronze yue. (Matsumoto 1939) Another research puts forward the direct link between the shouldered axe and the bronze yue, which are seemly co-existing and self-developing regionally in Southwest China. (Chen 2006) This offers a viewpoint of the development of the shouldered tools and the bronze tools in the whole area. The value of Yuanshan cultural shouldered tools and the evolution of shouldered technology may be well understood chronologically and locally in Taiwan, South China, and Southeast Asia.

To sum up, the origin of the Yuanshan Culture, and the production technology and usage/function of the shoulder axes which is one of the key parts of its culture, are the main issues of this research. The methods of typological analysis and scientific experiments, for example, analyses of pXRF, use-wear and typology, and the experimental archaeology will be used to try to solve these issues.

Chapter 2-3_INTRODUCTION OF THE RICE CULTIVATION ENVIRONMENT AND ACTIVITY IN TAIWAN

Environment of rice cultivation in Taiwan

Knowledge of the agricultural environment in Taiwan, during either the ancient or modern age, is essential to verify the hypothesis on usage of the shouldered axe relating to rice cultivation (Shih 1950, Huang 1997, Kuo 2014). The rice remains unearthed from several archaeological sites also show that the residents at the time before the Han Chinese moved to Taiwan in the 17th century are likely to have had the ability to plant rice (Huang 1984, 1999a, 1999b, Tree Valley Foundation 2012). Since the Han people introduced the wet rice varieties and farming techniques for rice cultivation into Taiwan, the indigenous people from the 17th century onwards not only had an abundant food supply to support a large population, but also sufficient labour force to invest in the rice farming business (Huang 1975). As a consequence, the transitions in the social structure and ecological environment has enabled aborigines to shift to a stable agricultural society, from the prior mode of fishing and hunting. Therefore, the development of rice agriculture has had a profound impact on the historical evolution of Taiwan (Huang 1975, Tsai 2009).

The climatic conditions required for the growth of rice in Taiwan need high temperature and rainy areas. For example, the suitable temperature for rice cultivation depends on the growing phases of rice, the annual rainfall is more than 1,000 millimetres, or the sufficient irrigated water as the supplemented water. The soil conditions required for paddy fields are slightly acidic soil with the pH5.5-pH7.0, such as loam, humus loam or clay loam (Wu 1998, Chang 1999).

1. Characteristics of rice

Rice is one of the oldest grains in the world, with high yield and high nutritional value, and together with wheat and corn are called the three major food crops of humankind globally (Katz and Weaver 2003). According to the biological taxonomy, rice is a member of the *Poaceae* or *Gramineae* family which is classified to the genus *Oryza*. The rice planted today is known as *Oryza sativ*a, and its ancestral species is *Oryza rufipogon*. There are more than 20 varieties of wild rice in the world, most of which are distributed in Asia, Africa, Latin America, and Australia. Wild rice is rich in genetic diversity and is an important treasury for cultivated rice breeding. It is also an indispensable material for studying the origin, evolution, and differentiation of rice varieties (Wu 2007).

About 10,000 years ago, the last ice age ended, and the world entered the warmer interglacial period of the Holocene. Although there is some debate about the relationships between agriculture and civilisations, the ecosystems of different geographical regions around the world domesticated various animals and plants and laid the foundations for the development of human agricultural civilizations. Cultivated rice has also evolved gradually from wild rice over the course of the Holocene, spanning about 9000 years (Huang 2006, Allaby 2013, Larson *et al.* 201, Zeder 20154). There are two presently known cultivated rice species of the *Oryza* family, the Asian rice cultivars (Asian cultigen, *Oryza sativa L.*) and the African rice cultivars (African cultigen, *Oryza glaberrima Steudel*). The generally cultivated rice is the Asian species, and the planting of African rice is limited to the western part of Africa. Observing the amount and distribution of the two cultivated rice species in the present, the following scholars agree on the theory that cultivated rice originated from the Asian region, but the specific location has not yet been conclusively identified. The study by Londo *et al.* suggests that Asian cultivated rice originates from India or the Indo-China peninsula, Fuller considers dual origins from both China and India, Huang *et al.* explores the possibility of the central part of the Pearl River in southern China as the origin, van Driem identified the eastern Himalayas, and Choi et al. recommend a multi-origin model (Londo *et al.* 2006, Fuller 2011, Huang *et al.* 2012, van Driem 2017, Choi *et al.* 2017). There are currently three subspecies of Asian rice, which can be categorised into japonica, indica, and javanica. The types of japonica and indica are the major varieties of cultivation in the Asian rice family, and the most extensively planted (Huang 2006). The japonica varieties are farmed in the dry land of the temperate zone, such as East Asia, and in areas of high elevations in Southeast and South Asia. The indica type, however, is normally grown in the lowlands in the tropical and subtropical zone throughout Asia. In Taiwan, which is situated on the boundary of the Asian continent and the Kuroshio Path, both the japonica and indica varieties may have been imported, accompanying the migration of human beings at various times.

2. Natural conditions of rice growth in Taiwan

The growth of rice is closely related to the regional climatic and geographical conditions, such as the characteristics and fertility of the soil, temperature, and the intensity and duration of rainfall and sunshine. Rice is a widely cultivated grain universally, where it ranges between 53°N and 40°S (Sweeney and Mccouch 2007). Rice is a semi-aquatic plant, with about 90% of its origin in Asia, and is concentrated in the environment of the hot and rainy East Asian monsoon zone. Taiwan is located in the position of this monsoon zone and is consequently a key area of rice production.

2.1 Soil of Taiwan

According to the soil taxonomy of United States Department of Agriculture (USDA), the main agricultural soils in Taiwan are alfisols, inceptisols, and entisols. The alfisols are distributed in the arable lands of the main alluvial plains in western Taiwan, the inceptisols are scattered in the hilly areas and some of the alluvial plains in the west. The entisols are mostly located in the mountains, the estuaries of the river delta and the alluvial plains. The inceptisols account for about half of the agricultural land in Taiwan, followed by alfisols, and these two types of soil represent 73% in total of the agricultural land in Taiwan (Chen and Hseu 2002). The distribution of the three types of agricultural soils shows that the alluvial plains, basins and some hilly areas below 100 meters in elevation have suitable soil for rice cultivation in Taiwan.

2.2 Terrain of Taiwan

The terrain in Taiwan can be roughly categorised into three, namely flatlands, hilly regions, and high mountainous areas. Flatland refers to plains, basins, alluvial fans, rift valleys, and terraces that include low altitudes. The hilly region is mainly the land with an altitude of more than 100 metres above sea level, or an elevation of fewer than 100 metres combined with an average slope of more than 5%. The high mountain areas are defined as lying more than 500 metres above sea level. The areas of the rice production operations are predominantly in the flatlands and some hilly regions. The arable areas of flat land accounts for 31% of the total land area in Taiwan, generally scattered in the western coastal plain. Due to the Tilting land of the hilly area, it is necessary to make cuts into the slopes along the contour lines to create a space for rice cultivation. As a result, the rice planting area of the hilly areas is limited. Mountain rice planting, at an elevation of more than 1,000 metres, accounts for about 32% of the total area of rice cultivation (Chen 1993).

2.3 Hydrology of Taiwan

Water is one of the most important environmental resources that determines the development of agriculture. Taiwan's agricultural irrigation water is mainly derived from rainwater, surface water, and groundwater. Surface water includes the water of rivers, glaciers, lakes, and swamps that are stored on land or exposed to the atmosphere. Rivers are the main source of agricultural water in Taiwan. Because of the large differential in water volumes between the dry and wet seasons and the unstable supply of water in the rivers, Taiwan consequently depends on the construction of water conservancy facilities to effectively utilise its river resources. Unlike the surface water, groundwater is a subsurface water resource stored underground and is a significant supplementary water source for the agricultural operations (Chen 1993).

2.4 Rain volume and rainy season of Taiwan

Rice is a half-aquatic plant that requires sufficient water for growth. The farm field needs to retain a water depth of 3-5 centimetres and relative humidity between 50% -90% during the growing season of rice. It needs an adequate rainwater supply for the area where there are insufficient irrigation water resources. Even if there are well-developed water conservancy facilities, it is still necessary to rely on rainwater to maintain abundant water resources in rivers, lakes and even underground water sources. Therefore, the key to the growing of rice is adequate water resources. As mentioned above, rainwater is an important source of water for paddy fields. The annual rainfall required for rice cultivation is at least 1,000 millimetres (Yoshida 1994). Taiwan is located in the monsoon climate zone. The northeast wind in winter and the southwest wind in summer carries water vapor from the sea, so rainfall is quite plentiful throughout the year in Taiwan. (Fig. 2-3-1)

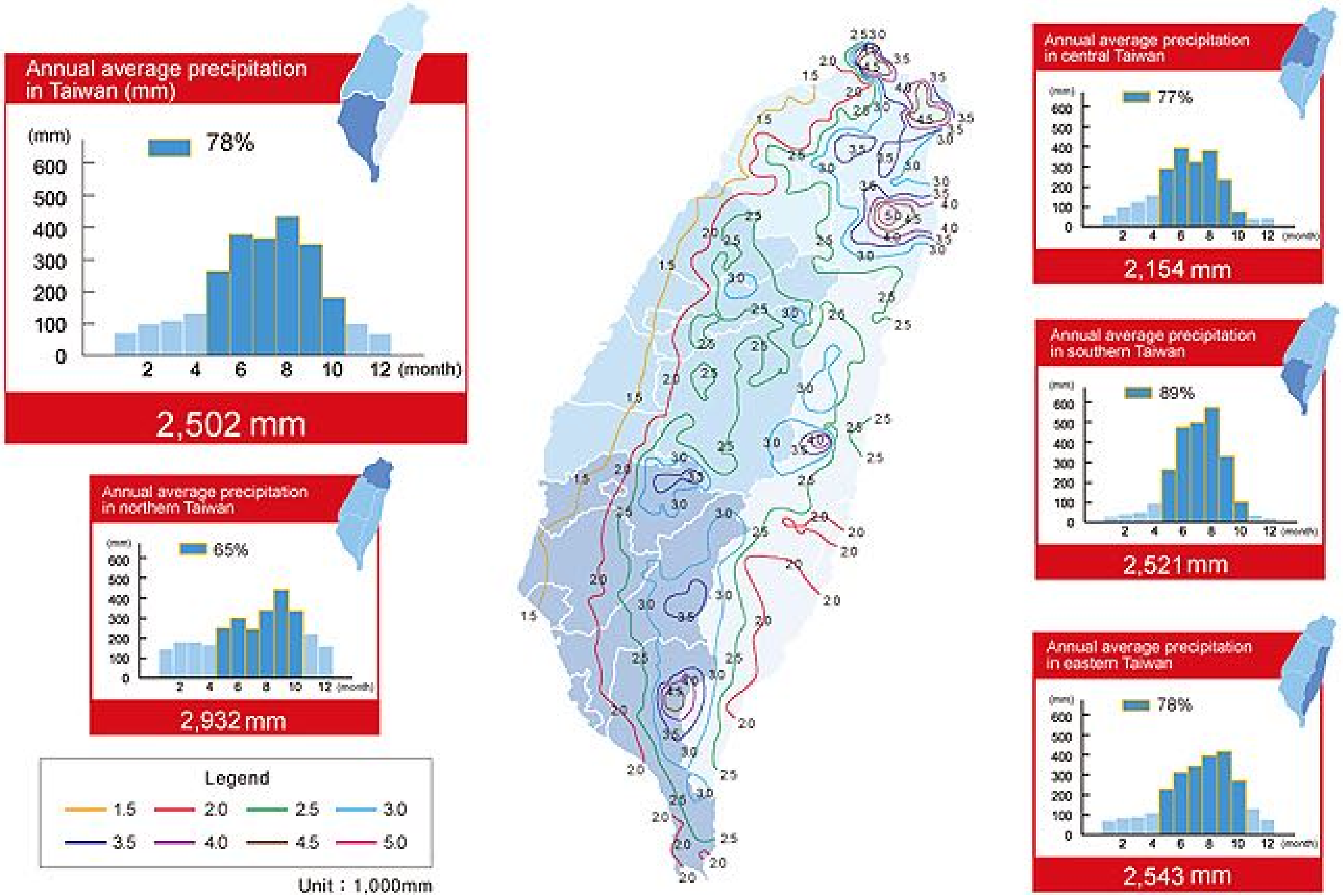

Fig. 2-3-1 Map[1] of Distribution of Average Annual Precipitation in Taiwan between 1949 to 2009.

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[1] Water Resources Agency, MOEA, Taiwan. Available at https://eng.wra.gov.tw/7618/7664/7718/7719/7720/12622/

Yet, the direction of the monsoon blows perpendicular to that of mountains in Taiwan, resulting in rainfall that is quite uneven in its spatial and temporal distribution, which is unfavourable for rice cultivation operations. As a result, the rice farming operations across Taiwan vary both in locations and degree of success depending on the natural conditions of the farmlands in which they are situated, such as geographical location, topography, and rainfall. For example, the annual rainfall in Taipei is more than 2,000 mm which are beneficial to rice cropping. Whilst in the northeastern part of Taiwan, the annual rainfall is over 3,000 mm, and the winter rainfall is stronger than in the summer, and insufficient sunshine which is not conducive to rice cultivation (Tsai 2009).

2.5 Temperature of Taiwan

The temperature required for rice growth depends on the growing phases, normally the range lies between 20 and 30°C (Wu 1998). Taiwan lies across the tropical and subtropical zones, ensuring sufficient sunshine and low latitudes, between 21.35°N and 25.18°N . The coastal currents on the west side of Taiwan have a Kuroshio Current flow throughout the year. In the summer, the south-western monsoon drifts through the South China Sea, making the average annual temperature in the plains of Taiwan all above 21°C. Therefore, in terms of temperature conditions, the flat lands in Taiwan are suitable for the operation of rice agriculture.

2.6 Duration of sunshine in Taiwan

A well-lit environment provides the solar energy source needed for important photosynthesis in crop growth. The distribution of the duration of sunshine in Taiwan is closely related to topography and precipitation. For example, the duration of sunshine in the high mountainous area is less than that in the flat area, and sunshine duration on the east coast is less than on the west. Because of the different stages of rice growth, the duration of sunshine required for rice varies between those stages. Rice heading is highly correlated with sunshine hours. When the sunshine is short-lived, the rice plant is short and the seed setting rate is high; otherwise, the rice plant is long with a low seed setting rate. From heading to maturity, an increase in the sunshine is beneficial to rice yield. If there is insufficient sunshine before and after the earing, the spike of rice will be delayed, and the grain will not be full. It can be seen that the availability of sunshine also affects the size of the harvest (Tsai 2009).

In short, Taiwan has excellent natural conditions for the development of rice farming, such as fertile soil, arable land, suitable temperature and an appropriate amount of sunshine for rice growth. The water resources are, on the whole, adequate, yet they are also unevenly distributed. The investment in, and construction of, water conservancy facilities can achieve stable provision of the required water volumes and humidity, which is favourable for rice operations.

3. Archaeological evidence

The arguments used to support a hypothesis on the agricultural activities existence in a prehistoric culture had by archaeologists mainly rely on the artefact function and the ecological remains. The artefacts that archaeologists can associate with the prehistoric agriculture, in general, are the farming tools like stone knife, axe or hoe, the pottery containers for storing plant seeds, the plant remains and the ruins of the storage place for food. The Comparative study on the functional use of tools between the prehistoric material and the indigenous one also adopts the ethnographic survey reports to trace the possibility. On the basis of the comparison of forms between archaeological examples and the ethnographic literature, the usage of the stone knife is suspected to be similar to the aboriginal iron knife used for the crops harvest, and the stone sickle is like the iron sickle for gathering millet. The prehistoric stone knives of both Hsuntangpu and Yuanshan Culture are generally recognised as a tool for gleaning cereal crops (Huang 1996, Fig. 2-3-2; Chu 2012, Fig. 2-3-3). Presumably speaking, the unearthed stone knife probably used as a harvesting tool and implied that the prehistoric people has a farming ability to grow crops, not to mention the ecological remains and the hoes or/and axes uncovered simultaneously in the same site maybe as an evidence to support the argument (Ma *et al.* 2012, Li *et al.* 2013, Yang *et al.* 2014).

Fig. 2-3-2 Stone knife from Yuanshan Site and the illustration of its usage on harvesting the rice. (Huang 1996, pp.28.)

Fig. 2-3-3 Different forms of stone knife from the Hsuntangpu Culture of Talungtong Site and the illustration of its usage on harvesting the rice. (Chu 2012, plate 201.)

Most of the sites found the rice remains in Taiwan are also uncovered stone knives, which the pieces of evidences are presented in Taiwanese archaeological data in Table 2-3-1. These stone knives usually have a thin flaky shape and a small size with visible at least one perforation on it. Huang suggests that the perforations are used to tie the cordage and then slightly fix it on to the user's wrist so that its motion will not move beyond the range of motion of the wrist can be. This method should be designed to prevent the stone knife from falling off the hand and being damaged whilst at work (Huang 1996). The inference for the usage of stone knives with ropes offers the basis for reviewing the technical capabilities of the shouldered axe hafted with a handle.

Archaeological Site	14^C Date (B.P.)	Archaeological material	Rice Type	Knife found
Chishanyen, Taipei	3,500-3,000	carbonised rice seed remains	Japonica	*
Yuanshan, Taipei	3,500-2,300	One rice seed remain	Japonica	*
Talungtong, Taipei	4,500-3,800	Rice seed remains		*
Shihsanhang, Taipei	1,800-500	Rice seed remains		
Yingpu, Taichung	3,500-1,500	rice husk impression on two pottery fragments	Japonica	*
Huelai, Taichung	2,000-400	carbonised rice seed remains	Indica	*
Nanshikeng, Taichung	1,000-400	Phytolith of plant remains	Japonica	
Nankuanli East, Tainan Science Park	5,000-4200	carbonised rice seed remains	Japonica 98%, Indica 2%	*
Nankuanli, Tainan Science Park	5,000-4,200	carbonised rice seed remains		*
Youxianfang, Tainan Science Park	3,800-3,300	carbonised rice seed remains	Japonica 83%, Indica 17%	*
Youxianfang South 2, Tainan Science Park	3,300-2,800	carbonised rice seed remains		*
Niuniaogang, Tainan Science Park	2,800-2,000	carbonised rice seed remains		*
Wangang, Tainan	2,800-2,000	carbonised rice seed		*

Science Park		remains		
Daoye, Tainan Science Park	1,800-1,400	carbonised rice seed remains		＊
Wujiancuo, Tainan Science Park	1,400-1,000	carbonised rice seed remains	Javanica	＊
Shenei, Tainan Science Park	500-400	carbonised rice seed remains		
Dadaogong, Tainan Science Park	500-300	carbonised rice seed remains		
Shiqiao, Tainan	1,800-1,300	carbonised rice seed remains	Japonica	＊
Kenting, Pingtung	4,130-3,840	rice husk impression on the pottery fragment	Indica	＊
Peinan, Taitung	5,200-2,300	Phytolith and rice husk impression on the pottery fragment	Indica	＊
Chaolaiqiao, Taitung	4,250-3,680	Phytolith of plant remains	Indica	＊
Fushan, Taitung	4,000-3,500	Phytolith of plant remains	Indica	＊
Chikang B, Penghu	4,200-4,000	rice husk impression on the pottery fragment	Indica	
Suokang, Penghu	4,200-3,800	rice husk impression on the pottery fragment	Indica	

Table. 2-3-1 Archaeological site, rice type and knife of ancient rice unearthed in Taiwan.

Although Chang proposed the growing plants are probably the root crops in the Tapenkeng Culture, however, there is not any plant remains ever found in the Tapenkeng cultural sites. The reasons are that the preservation environment in Taiwan is quite unfavorable for organic matter, and the area of archaeological excavations in early years is small in general or only survey ever conducts, so it is difficult to find the organic remains in a site. Still, it can infer agricultural activities in prehistoric cultures by the excavated materials based on the forms of the plant left, even without any plant remains being found. Taking archaeological materials of carbonised rice, rice imprints or phytoliths as examples, it is believed that the rice cultivation activities have prevailed at least in 4,800 B.P., and widely prospered in prehistoric cultures across Taiwan in the Iron Age (Tsang and Li 2013).

Many hoes, axes, knives, as well as remains of plant and their seeds like rice and millet, have been unearthed in prehistoric cultural sites around Taiwan after the end of the Tapenkeng Culture. These ecological remains are also found in several archaeological sites in northern Taiwan. A few amounts of rice remain were unearthed in the Hsuntangpu cultural layer at the Talungtong Site (Tree Valley Foundation 2012, Fig. 2-3-12). The Chihshanyen cultural layer at the Chihshanyen site has uncovered a large scale of carbonised rice, and the proportion of agricultural tools in the tools is quite large (Huang 1984, Fig. 2-3-4). It can be supposed that agriculture has occupied a considerable scale in the society at the time between 3,600 and 3,000 B.P., according to the materials given by previous excavation reports (Huang 1984, 1999a, 1999b, Tree Valley Foundation 2012). The Yuanshan Culture, which the chronology is quite similar to the Chihshanyen Culture (possibly slightly later), was also unearthed four carbonised rice seeds (Huang 1999a, b, Fig. 2-3-5). Among the unearthed assemblages of the above three sites, stone knives are also found. And the hoes and axes account for the highest proportion of all stone tools as observed in the stone proportions described above. Therefore, the Taiwanese archaeologists generally believe that all three archaeological cultures have had agricultural activities, especially those related to the rice cultivation. The actual usage of the stone knife and the corresponding plant types of cultivated crops are still to be further studied, particularly on rice harvest. Yet, functional usage as a piece of harvesting equipment has been proved by the relevant experimental evidence in several published literature (Kang 2013, Yang *et al.* 2014).

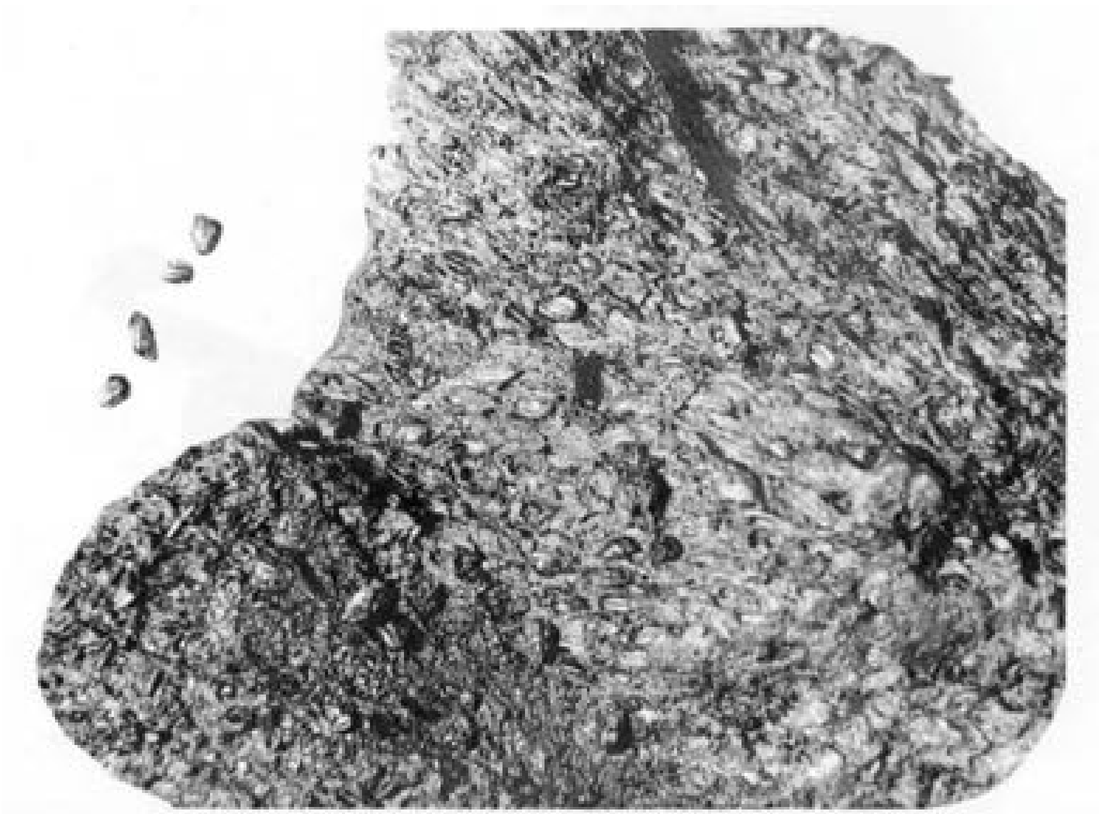


Fig. 2-3-4 Unearthed carbonised rice. (Top: Tree Valley Foundation 2012[2], plate 46.

Bottom: Huang 1984, plate 46-2.)

[2] The rice types are visibly different in their shapes: type in the left side is narrow and long, type in right is wide and flat. Both remains are unearthed from the Hsuntangpu cultural layer in the Talungtong Site.

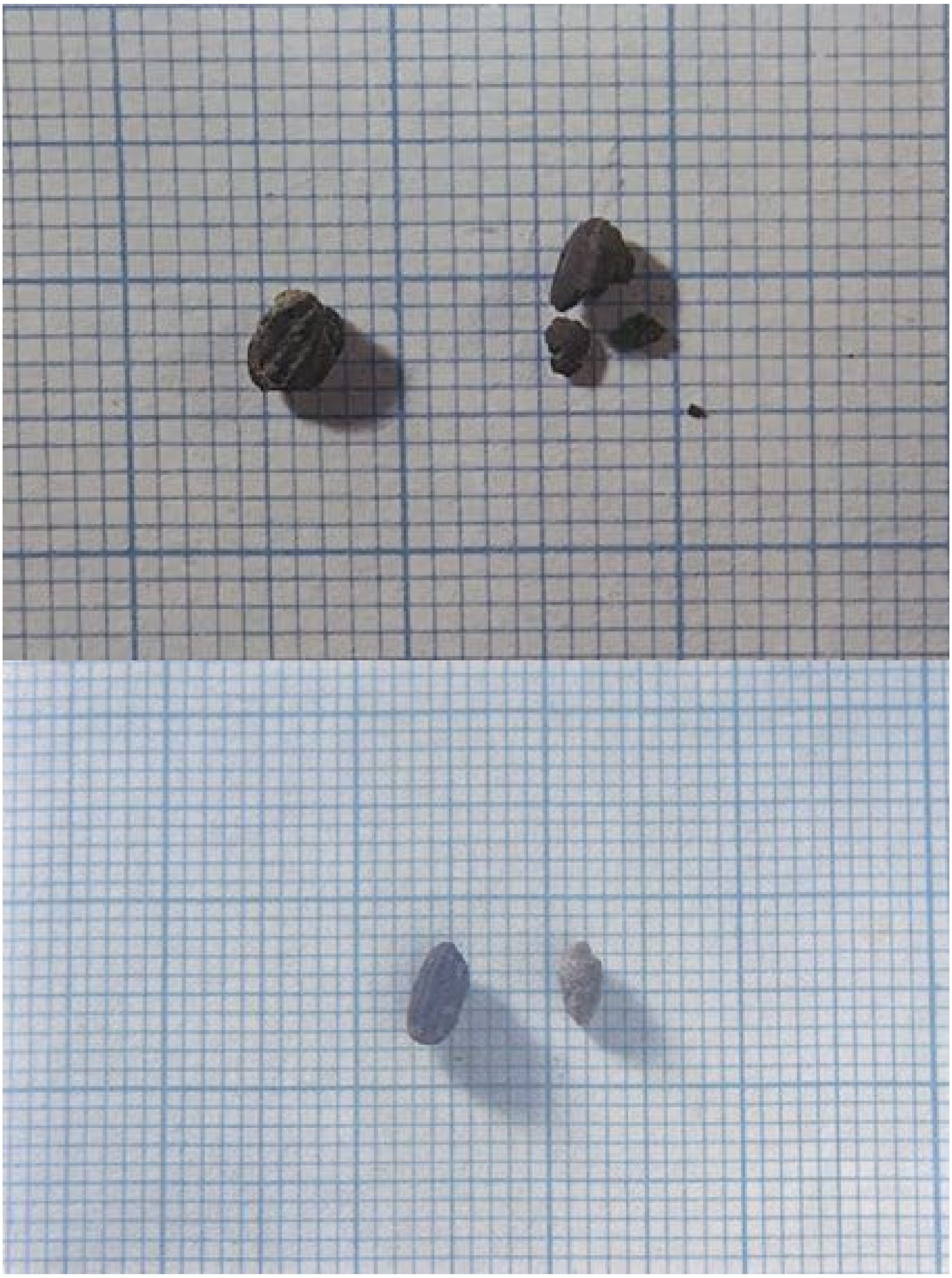


Fig. 2-3-5 Unearthed carbonised rice seeds from Yuanshan Site by Huang. (Top: 1999a, plate 68. Bottom: 1999b, plate 62.)

There are also bone tools excavated from the Chihshanyen Site, some of these tools the functional definition as a hoe given by Huang (1984, 1986). The appearance of such a tool is completely different from the common typology of stone hoe in Taiwan, and its usage may not be in the same way as a hoe either (Fig. 2-3-6). However, it seems to be close to the digging stick in the archaeological objects judging from the used ends of bone tool. Such utensil is also similar to the tool used by the indigenous people to dig the root crops on the ethnographic description (Wang 2001). It is a bit difficult to judge the function of these bone tools like a hoe for the cultivation of crops for the time being and is required further verification on this topic. It is a widely accepted hypothesis in China that the function of Si made of buffalo scapula is used as a hoe for rice cultivation, also faces a challenge (Fig. 2-3-7). The experimental results of Xie *et al.* indicate that the Si should not be labelled as a farming implement. Because it has a low rate of occurrence frequency in the archaeological site, and only under the specific soil condition that the buffalo scapula implement could effectively function (Xie *et al.* 2017). Additionally, Additionally, there is a problem of classify different -looking artefacts into the same general category. The definition of Si offered by Huang is obviously different in the morphology and function from those of Xie *et al.* Huang named some of the stone fragments unearthed from the Yuanshan Site as Si, and considered that the function of such stone Si is an agricultural implement hafted with a wooden handle and used as a shovel (Huang 1996, Fig. 2-3-8). These two types of artefact are all defined as Si which is different in the morphology and function as well. The assumptions of the method they are used are consistent with a hoe: upturning the soil or removing the weeds. Both require for further verification based on the archaeological materials and the replicating experiments to solve this issue.

Fig. 2-3-6 Bone Hoe from Chihshanyen Site. (Huang 1984, plate 39)

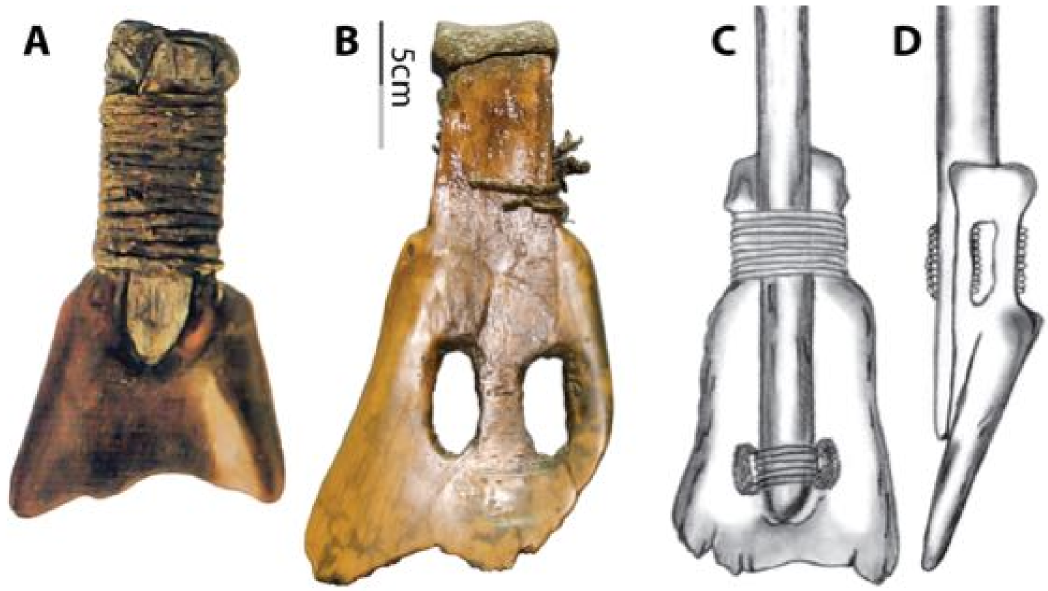


Fig. 2-3-7 Hafting style for scapular earth-working implements. (Xie at al. 2017, Fig. 4)

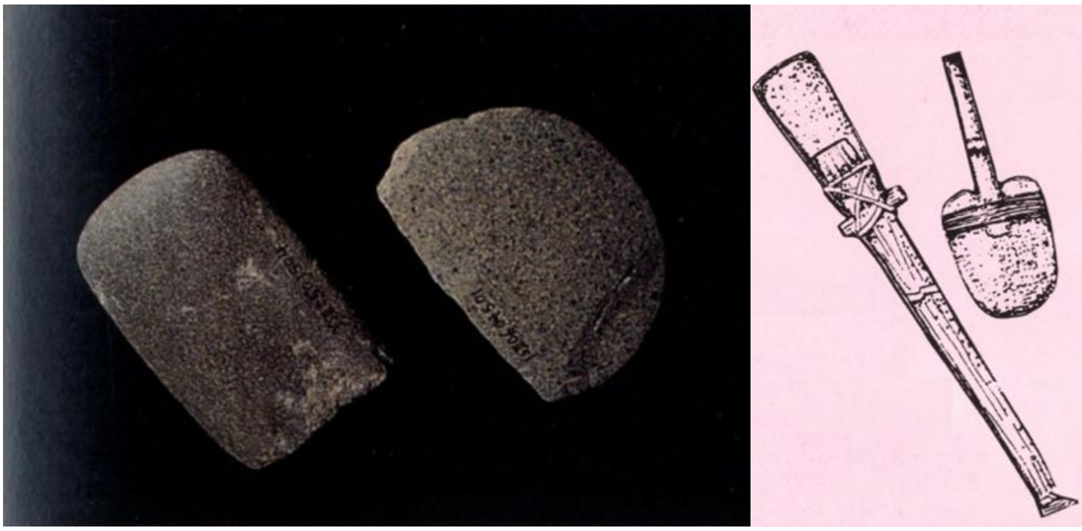


Fig. 2-3-8 Stone shovel from Yuanshan Site and the illustration of its usage and fixing into the wooden handle with strings. (Huang 1984, pp. 30, 31.)

The shouldered axe of the Yuanshan Culture is thought to be a composite agricultural implement which is tied the wooden handle with its shoulders by the cordage then practise it. However, this speculation may not be supported by the archaeological evidence just like the most of the arguments on the topic of the function or usage, such as the discovery of stone tools together with the remains of rice or other crops, or the phytoliths or residues left on the stone tools, which probably used as another tool than the hypothesis (Kang 2013). The difference in the function and usage of the agricultural implements, the variations of the implement typology also have corresponded with it. Besides, the rice remains were uncovered from the Chihwuyuan site in 2018, which is the archaeological site the shouldered axes examined in this study. From the given materials of morphology and the ecological remains of Chihwuyuan site, it can be inferred that the specific function of the shouldered axe should be related to the agronomic activities.

According to the outward appearance of the shouldered axe, it can basically be centred on the shoulders and divided into upper and lower parts. The shouldered axe with a shorter upper part and longer lower part, the shape of the lower part is normally rectangular with a thick blade edge. If the upper and lower part similar in length of a shouldered axe, the form of the lower part is a sector with a thin edge of the blade. The overall volume of a shouldered axe is relatively small and thin compared to other non-shouldered stone tools. In terms of the proportion of the object, the longer lower half can penetrate deep into the soil, which can reasonably be considered as a hoe used by human beings for crops cultivation. The planting depth of farmland for the cultivation of the crops by using hoe with manpower invested into is deeper than that of ploughing, especially to the rice. This was one of the challenges in the promotion of ploughing technique to plant rice by Japanese in the late 19th century because the peasants who used traditional manpower farming did not adapt to the way of ploughing practise (Iinuma and Horino 1976).

Secondly, judging from the natural environment, it is also reasonable to adopt a shouldered as a hoe under the farming condition required. Compared with hoeing by manpower, the ploughing technique, in general, needs a flat terrain to conduct the cultivating process, which the slope farming practise is unfavourable of such kind. The archaeological site of Yuanshan, Tapenkeng, and Chihshanyan are all in the location on the slopes of the small hill near the riverbank, similar to the living environment of the aborigines using the hoes noted in the ethnography.

The last, Miyamoto (1939) once described a weeding tool used by the Bunun for the slash and burn farming, which is known as a shoe-shaped stone implement in Taiwan. Huang (1986) names it the shoe-shape stone axe which has a pair of asymmetric shoulders and a sector blade edge of the lower part. The characteristic of a sector blade is similar to one of the morphological classifications of the shouldered axe. Therefore, the function of the shouldered axe which has a sector blade edge is speculated probably used as a weeding tool. Consequently, the shouldered axe of the Yuanshan Culture has hypothesised two functions on the foundation of the morphological divergence between the lower parts. One has a rectangular lower part that is used as a hoe, and the other is a weeding tool which has a sector blade edge. Both hoe and weeding tool is the essential farming tools for indigenous people for practising the slash and burn agriculture according to the ethnographic reports.

As stated by the previous passage, the comparative studies of the archaeological finds, ethnography and historical literature following the traditional shifting agricultural lifestyle of the Taiwanese aborigines, that can be the materials for the inferring the two functions of the shouldered axe based on the typological variations of the lower part designed. The function of the shouldered axe, therefore, can be considered of two kinds respectively: as a hoe and weeding tool. In the meantime, the shouldered axe also is viewed as a composite tool which can be tied with a wooden stick. The design of the shoulders should be functioned on the purpose of fixing the axe onto the handle and binding with the ropes. These hypotheses are going to verify through the replicating experiment in this research.

Chapter 2-4_ETHNOGRAPHIC RESEARCH OF TAIWANESE ABORIGINES

1. Study of Archaeology and Indigenous Peoples in Taiwan

The indigenous peoples of Taiwan have been considered by most linguists as the region that currently holds the oldest Austronesian languages because of the study of its language family. Therefore, Taiwan is assumed to be the hometown to the Austronesian speaking peoples across the region from East African, Southeast Asia to Oceania. On the hypothesis of the Austronesian dispersal and its origin ('Out of Taiwan' theory), there are plenty of opinions exchanged and debated from archaeological, linguistic or genetic research perspectives over decades. The 'Out of Taiwan' advocates such as Cox, Bellwood, and Spriggs, and opponents include Solheim and Richards (Cox 2005, Bellwood and Dizon 2005, Bellwood 1988, 2008, Bellwood et al. 2011, Spriggs 2007, Solheim 1988, 1996, Richards et al. 1998). A long-standing viewpoint has been acknowledged consistently by the Taiwanese archaeologists that the prehistoric human beings in Taiwan are the foreign migrants recognised later as the Austronesian, from the area in the southeast coastal region of the Asian continent possibly. Whether the prehistoric movement of the Austronesian family or other groups in this area, see Taiwan as their ultimate destination or relay station. The wealth of remains left by these ancestors does provide lots of materials for contemporary studies to trace the connection between the prehistoric peoples and modern Taiwanese aborigines.

Taiwan's aborigines did not develop a writing system to record and keep their history. Even the people in neighbouring regions with long-term writing ability, such as Han Chinese, there are few descriptions of Taiwanese aborigines ever before the 17th century, and the knowledge about their origins is also limited. As a result, archaeologists assume usually that Taiwan's prehistoric archaeological culture is closely related to the ancestors (Austronesian language family) of modern aborigines based on the archaeological, linguistic, material cultural comparison and genetic studies for decades. The method of verifying this assumption is to find out the connection between the two by accumulating the archaeological remains of underground excavation and the textual materials as the basis of the research (Liu 2002a, 2002b, Tsang 2016, Chen 2016). Consultation of the oral traditions and material culture of the modern aborigines also makes one of the means of corroboration by applying the anthropological and ethnographic research methods for getting the information through the interviewing and observing the living pattern of the indigenous people in their tribes.

Since the 17th century, the information of Taiwanese aborigines has left a wealth of documentary records and ethnographic materials from travellers, officials or missionaries from China, Japan and the European countries, enables today's scholars to look into the lifestyles of aborigines at the time they wrote, such as the manuscript of Governor of VOC, Spanish historical documents, travel notes of Chinese and British people (Chiang 2011, Borao Mateo 2001, 2002, Chou 2012). Among them, the descriptions of the material culture and life of the aborigines in the ethnographic writings of Japanese in 19th and 20th century are the most widely used by Taiwan archaeologists as a reference for straightening out the tasks linked to prehistoric materials, for instance, the production technology, functions and objects of use, etc. Several cases of well-integrated ethnographic archives and archaeological finds are illustrated below. Combining the ethnography archives and the archaeological artefacts link the usage of the stone adze to the construction of boat/canoe or the house of pole fence type by reviewing the literature of Taiwan indigenous people (Hung 2000). Lin examines the pieces of the literature mentioned the procuring activities of the coal mines, sand gold and sulfur mines by the Ketagalan in northern Taiwan and compares to the archaeological remains found in nine sites, and draws the conclusion that these sites left behind by the ancestors of the Ketagalan (Lin 1965).

In other words, archaeologists may directly carry out all or in part of analogy based on the similarity between aboriginal and prehistoric artefacts, as well as the overlap of ethnic distribution areas and the proximity of existing time. And presume that a certain prehistoric culture owner may be the ancestors of a particular ethnic group in Taiwan today. Several examples are explained below. Tsang judges that the Shihsanhang culture of the Iron Age was related to the Ketagalan. The materials for judgment are based on the conditions like the similar years of existence, the use of square-stamped pottery, and the range of the human activities in the northern coast (Tsang 2012a). Or the relationship between the Chiuhsianlan site and the Paiwan tribe in the eastern part of Taiwan from about 1,400-1,200 B.P. is bond by the Deinagkistrodon acutus ornament on pottery and stoneware (Lee 2006). The connection between archaeological culture and the aborigines will also be enhanced by the proximity of the age and the evidence with the signification. The Badsikan cultural site about 800 years ago in the Yunlin area of central Taiwan has almost been confirmed as a site left by the ancestors of local aborigines (Liu 2011). However, one must notice that most of the archaeological works lack of the explanation on the issues of human behaviour through materials, such as how/why the archaeological remains are varied with differences or how the society organised.

The ethnographic record also offers information on the type of settlement and living environment as a reference for archaeologists to study prehistoric ecological environment or prehistoric human dietary resources in the region. Chen (1852) wrote down that the Kavalan people in the northeastern part of Taiwan are engaged in the livelihood of fishing, hunting (mainly the Formosan sika deer) and cultivation of root crops. Plant seeds remain, including rice, the wooden and iron shovels which are unearthed from the Kivulan site about 1500-600 years ago, can prove that the Kavalans at that time were capable to cultivate plants; the large quantities of the edible marine shellfish found offers evidence to theories that the site was relatively close to the coast in northeastern Taiwan (Chen 2012). On the contrary, the geographical changes of prehistoric settlements from the archaeological materials evidence the indigenous tribe distribution in the area on linking to the ethnographic archives through times, and the knowledge of the aboriginal culture development is acquired thereupon. Such as the inhabitants were taken root generally in the hill region of northern Taiwan in the early phase of the Neolithic Age, settled down in the plains of the western area in the middle phase, then scattered over the lowlands of the eastern and western coastal area during the late phase. The residents of the Iron Age began to migrate to the mountains. (Cai 2015). Not only the location of the indigenous group, but the cross-matching method of the two materials are also applicable to the exploration of ancient cities or ancient buildings as following example presented. The joint project[1]of the Heping Island archaeological excavation at Keelung between Taiwan and Spain since 2011, applies the written files of ethnography, old maps and manuscripts to locate a city/fort named San Salvador which was constructed in northern Taiwan under the Spanish brief occupation in the early half of the 17th century from 1626 to 1642. In the first season of the project, the bone remains of three adults are unearthed and confirmed their identity to be the European missionaries by the burial means, and the place they buried recognised as the monastery (Cruz Berrocal *et al.* 2014).

In recent years, Taiwanese archaeologists have sought to cooperate with indigenous people resided in the traditional territories in research work in response to political or social requirements on the topics of the aborigines. Since Taiwan's social movements of the aboriginal recertification and ethnic identification awareness increased in 1990, archaeologists have repeatedly invited local aboriginal people to participate in the fieldworks which is going to conducted in indigenous traditional territories, whilst listening to their oral history and the used substances

[1] Archaeological Team led by Professor Tsang Cheng-hwa of Academica Sinica/National Tsing-Hua University and Dr María Cruz Berrocal of Consejo Superior de Investigaciones Científicas/Universidad de Cantabria. The second season of the project has started in May 2019.

in tradition which the coming archaeological excavations can benefit from such materials probably. This practice not only serves the archaeologists to grasp and comprehend the contents of the archaeological materials found from the indigenous realm but also has the potential to untie the relationship between the prehistoric culture and modern aboriginal peoples for a better interpretation. Local aborigines receive primary professional training of archaeology by participating in excavation opportunities in order to know the specific knowldedge of archaeological work and the means of cultural relics conservation and restoration available in archaeology.

Taking the personal experience as an example, I worked with Dr Kuo of Institute of History and Philology for research excavated at the Paiwan traditional territory in Pingtung of south Taiwan, a slate rectangular stoneware about 8 centimetres in length, 3 centimetres in width and 0.3-centimetre thickness was found during the digging. There are visible traces of the breakage at one end of the object, one of the aboriginal colleagues immediately recognised and told us that it was their ritual supplies without answering any instructions by use whilst we asked. In addition, we also assist in repairing large-scale pottery pot based on the knowledge of reviewing relevant archaeological evidence and returning to the indigenous community immediately after the restoration completion. Archaeologists and indigenous peoples can share their knowledge and research results on professional and traditional with each other through such cooperation.

Borrowing plenty of excellent ethnographic works as a valuable reference to study the archaeological materials are introduced constantly to the historical archaeology study in Taiwan. This study will learn the technological development and agricultural activity of prehistoric human in Northern Taiwan by comparing the ethnography literature of indigenous people and the archaeological evidence. Thus, adopting the ethnography information will be helpful to well understand the relation between the archaeological material and indigenous activities to reveal the practical usage of shouldered stone tools of Yuanshan Culture. The explanation on the topic of the morphology and function of the Bunun's farming equipment in Taiwan in the previous section is an example.

There have the resources to the historical documents and ethnographic materials selected in this section are the records of the earliest subsistence mode of Taiwan's aborigines and the reference materials most cited by the Taiwanese academic community. These archives include the Don Fan Ji written by Chen in the 17th century, the Tai Hai Shih Cha Lu by Huang and the Aborigine Tribal Panorama Prints by Liu-Shi-Qi appeared firstly in the 18th Century, as well as the investigation reports noted for all kinds of aspects consciously by the Japanese between the late 19th and the first half of the 20th century. It is expected to find the tradition and evolution associated with the usage of utensils (farm tools) from the daily life patterns in the aborigines recorded in different periods, that could provide a foundation for testifying the given hypothesis of the function of the shouldered axe in this study.

However, it must be remembered that there are no written records of the Taiwanese aborigine before the 17th century to provide direct connection between them with earlier prehistoric humans evidently. All ethnographic materials must be cross-referenced when used in order to get closer to the archaeological materials. In this way, archaeologists can detail toward the usage or production of the stone tools or the living context of prehistoric humans.

2. Introduction of indigenous peoples in Taiwan

The current knowledge of Taiwan's aborigines is basically from the literature documented by the foreign regimes like Spain, Netherlands, Ming and Qing Empire of ancient China and Japan that have changed over time since the 17^{th} century, including the names, titles, and cultural ecology of the ethnic groups. These changes are of great significance to the modern Taiwanese Aborigines in tracing history and identity of ethnic groups through times.

First is that the identity of the indigenous peoples is divided into the plain and the mountain aborigines which have been differentiated on the basis of the extents of the capability on paying the taxes and being educated under the Qing rule period since the 17^{th} century. Plain aborigines refer to the people who accept the requirement of the tax payment and Han Chinese education by the Qing authorities, mountains are the opposite. Two calls have been changed into the Pingpu Zu (Plain) and Gaoshan Zu (Mountain) ethnic groups until the Japanese occupational period in the late 19^{th} century (Chan 1996). Zu (族), a proper noun refers to an ethnic group or indigenous/cultural community. However, Fan(番, group) and She (社, community) are more recognisable nouns from ethnography archives in Taiwan. The settlements and lifestyles of the Pingpu peoples are close to and similar with the Han Chinese, and they are widely distributed in the plain areas, including northern and the western plains of Taiwan (Fig. 2-4-1). The Gaoshan people move further to the hilly areas away from Han and keep mostly of their traditional lifestyles for some time until the current government taking the authorities from the Japanese. Among the sixteen indigenous peoples currently recognised officially by Taiwan government[2], several indigenous groups that had been assigned to the Pingpu Zu for centuries which have been respectively certified and restored to their original identification, the Saisiyat and the Thao for example (Fig. 2-4-2).

Regardless of the Pingpu (the Plain) or the Gaoshan (the Mountain), in terms of ethnic identity, are the collective name of multiple ethnic groups, and purely the easy name to the foreign political power for managing the aborigines at convenience. Therefore, the archaeological studies which propose the fieldworks related to the indigenous peoples in Taiwan, carry out on the premise of respecting the traditions to all tribes. In general, the traditional rituals are performed by the elder and priest of the indigenous tribe before the archaeological excavation, usually the pigs, betel nuts and cigarettes are dedicated to the spirits of tribal ancestors to pray for the work to be achieved smoothly (Tan 2007). Such a ritual performance was held by

[2] Available at webpage of the Council of Indigenous Peoples https://www.apc.gov.tw/portal/cateInfo.html?CID=5DD9C4959C302B9FD0636733C6861689

the elderly and priest of the local tribe before Dr Su-chiu Kuo's archaeological team that I participated in excavated at the Pucunug site in Pingtung in 2014.

Before a large number of Han Chinese immigrants came to Taiwan in the Ming and Qing Dynasties, the aborigines were the main body of Taiwanese history, and this subjectivity even had a great possibility extended to the prehistoric time. Since then, the Han people have used the cultural and economic advantages to invade the living space of the aborigines and make tremendous changes in their original way of life. The transformation, that is, the indigenous people learned the paddy farming techniques from the Han people, including farming tools, water conservancy, and irrigation facilities and the various species for cultivation. Thus, their life patterns have gradually become Sinicisation. The change of the aborigines living in areas suitable for rice cultivation is most obvious, the Pinpu and Sasiyat are two examples among them (Miyamoto 1992). This means that the change in the lifestyle of the indigenous peoples is due to the learning of new agricultural production techniques, which makes their lives stable and changes at all levels. Some of the indigenous groups are integrated into the Han people and gradually lose their language and culture, and only nouns of these people exist ever in the historical records.

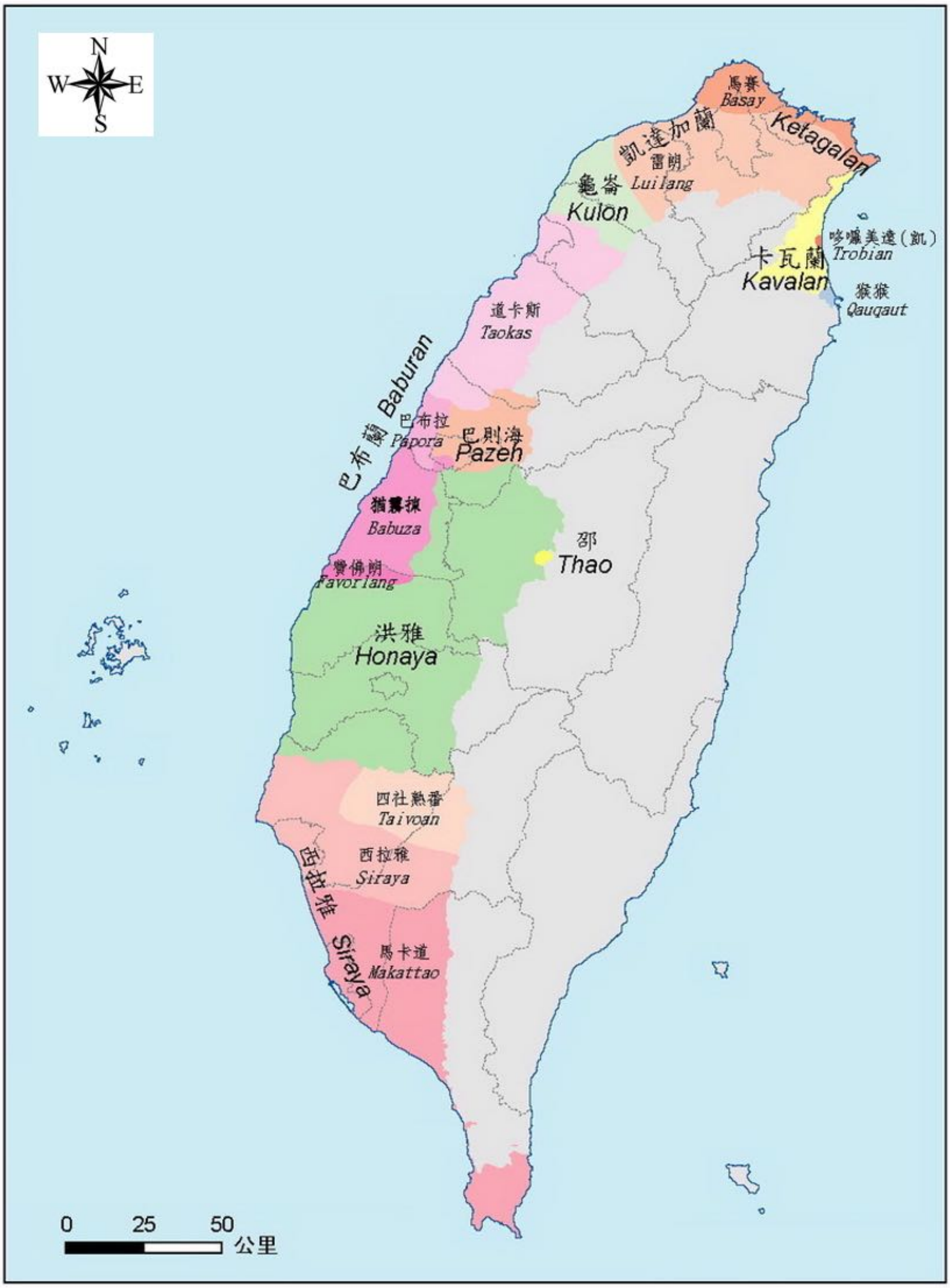


Fig. 2-4-1 Classification and Distribution of subgroups of Pinpu Zu. (Li 2004)

Fig. 2-4-2 Distribution of sixteen indigenous peoples in Taiwan (Taiwan Indigenous People's Knowledge Economic Development Association[3]).

3. The subsistence of Taiwan's indigenous peoples

According to the records of the 18th century Huang and the 19th-century Ino's survey, the aborigines widely dispersed in the northern part of Taiwan are the Pingpu with a total of 19 communities (Huang 1996, Ino 2011). Li (2004) believes

[3] Available at the webpage of Taiwan Indigenous People's Knowledge Economic Development Association http://www.twedance.org/aboriginal00.aspx

that the Pingpu people in this area can be subdivided into three sub-groups: Ketagalan is located in the northern part of the Taipei Basin, Luilang (Ruiron) settles in the southern part of the basin, and the Atayal people distribute to the outer rim of the basin and the hilly area of the south. The Atayal is the only group among the northern Pingpu recorded by Ino which still exists in their traditional area currently, and the other two may have been integrated into the Han Chinese community and disappeared (Fig. 2-4-3). These Pingpu settlements were located on the bank of the river and slightly inland compared to the Yuanshan cultural sites (Fig. 2–4-3).

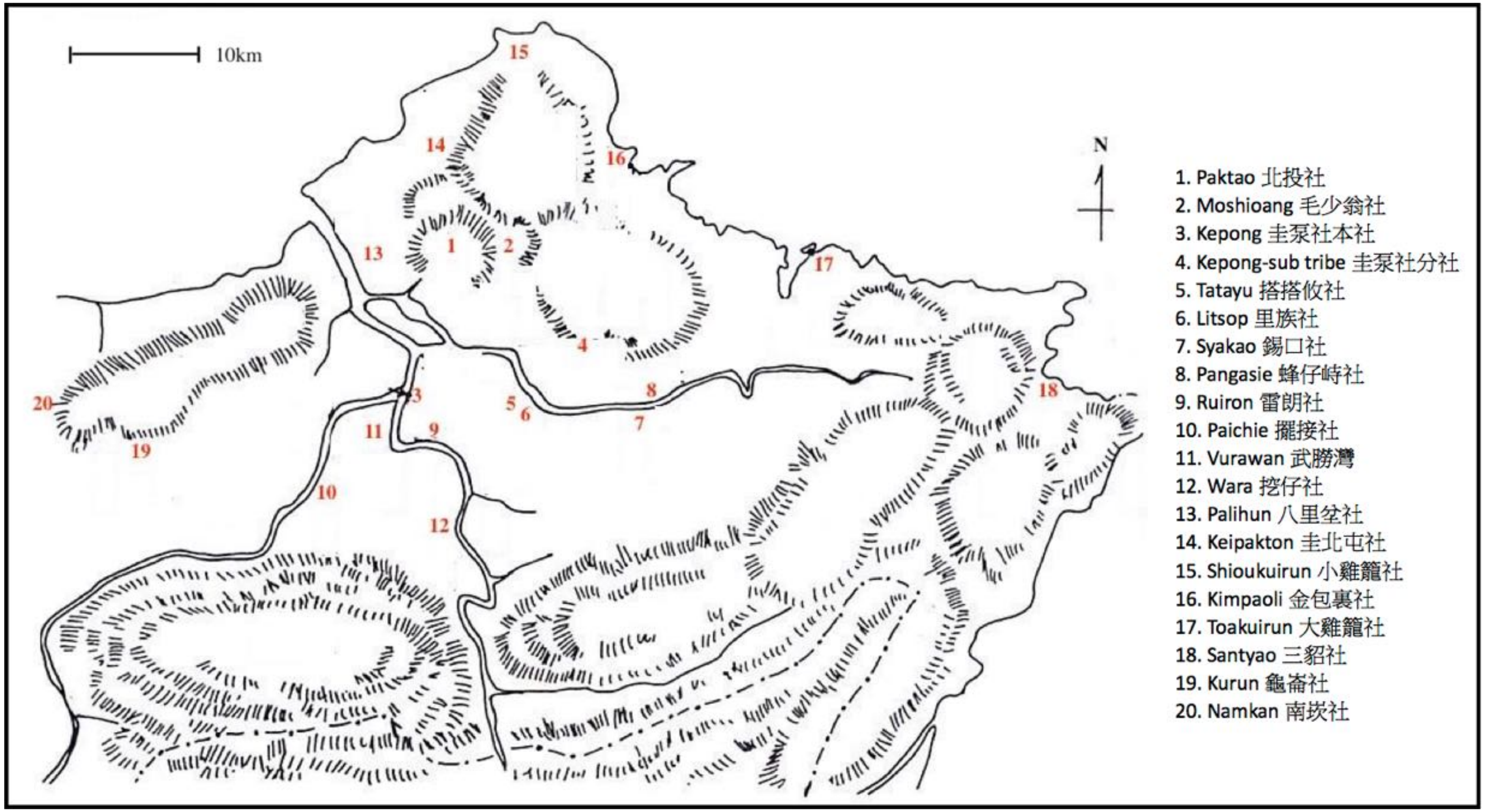


Fig. 2-4-3 Distribution of Pinpu Zu nineteen tribes in Old Tamsui County. (Translate and label after the manuscript of Kanori INO, mapping by the Journal of the Anthropological Society of Tokyo.)

According to the records of Dong Fan Ji by Chen[4] in 1603, the lifestyle of the Pingpu people in the southwestern plains of Taiwan shows that in the early 17th century they engage in the cultivation of the upland rice, land hunting, fishing in the river or at sea, and living in the stilt style houses. They do not wear clothes during the summertime and put on loose garments like the animal skin cloaks for keeping out the cold in winter. It is the society of gender division for labour – male hunt animals and female farm crops (Chou 2012). The above passage states that the importance of aboriginal farming at that time accounted for a certain portion in daily life, but no water irrigation measures have been developed. That demonstrates no paddy field for farming, the main technique applied for the agricultural mode should be the traditional method of the slash and burn which females were responsible for that works (Fig. 2-4-4, 2-4-5). The species of rice they eat are different from the Han people have. It is speculated that agriculture may have a low rate of self- sufficient and is in the auxiliary position of aboriginal life, the hunter-gathering is in the dominant place for live earning. Compared with the agricultural production technology of the Han people in the 17th century, the aborigines seem to be quite primitive, but in the case of sparse population, it is the best survival mode of the aborigines (Tsai 2009). In addition, their relationship with foreigners is based on the exchange of goods for need, such as trading the venison, deerskin or antlers of Formosan sika deer for the glass beads, porcelain, salt, copper, guns, gunpowder, and other items (Chou 2012). They mainly exchange deerskin and forestry with the

[4] This archive is the earliest known work of the Han people to depict the life of the Pingpu people, and the literature on the customs and geography of the aborigines on the western coast of Taiwan.

Han Chinese, and cloth and iron tools with the Japanese. The deer products were exchanged for their required items, and it was obvious that the number of sika deer in Taiwan at that time was huge and inexhaustible effectively given the size of the aboriginal populations. The Pingpu group living in northern Taiwan should be sharing the same way of life with those residing in the southwestern plain described by Chen at that time.

Fig. 2-4-4 Bunun's Clothing. (Photographed by Ushinosuke Mori in October 1904. Yang, 2012, pp. 153.)

Fig. 2-4-5 Tsou women collecting sweet potatoes after farming in the field.

(Photographed by Ushinosuke Mori in December 1914. Yang, 2012, pp. 165.)

The primitive lifestyle of the Pingpu people lasted for a long time until the 17th century, when the southern part of Taiwan was invaded by the Dutch in 1624 and the northern part by the Spanish in 1626, and the Han people extensively reclaimed and colonised in various districts. Since then, the traditional living habits of the Pingpu people has undergone a major transformation (Chiu 2012). Taiwan at this stage is also a crucial period that Taiwanese aboriginals have stepped into modern times as the assumption Ferrell proposed (Ferrell 1969).

The slash and burn mode are a form of the shifting agriculture which the plants cutting and burning is involved to open up a land for crops cultivation after burning happened. Such agricultural pattern is commonly applied by the Taiwanese indigenous people for creating a cultivating field (Fig. 2-4-6). Miyamoto (1992) wrote in the form of memoirs of his Taiwanese aboriginal survey results mentioned that the Atayal and Bunun people set fire to burn the vegetation and clear farmland for planting crops like hill rice, taros, and millets. This farming culture has lasted for a very long time in different parts of the world and is considered to be the mode of production of primitive agriculture (Spencer 1966). The slash and burn, or known as the swidden farming or shifting cultivation, is a traditional crop cultivation method used by farmers living in the Southeast Asia or the tropical climate regions where most of the root crops or upland rice are domesticated. It is the process of cutting and burning the trees and vegetation in the forest for releasing nutrient stored in those plants and the ashes provided to the soil so that the farmers can utilise the nutrient to plant their crops in the newly-cleared land which has been fertilised (Kleinman *et al.* 1995). A few years later, when the soil of farmland is depleted of nutrients and no longer been used, the farmers must move and find other fields for crops cultivation.

Fig. 2-4-6 Swidden farming field of Atayal. (Photographed and collected by Hideo Suzuki between 1915 to 1935. Huang 2016)

The crops can only be replanted after the soil of field has been replenished with sufficient nutrients for at least 10-15 years (Dietrich Schmidt-Vogt 1995). This mode of production is a self-sufficiency model developed by people who simply adapt and utilize the natural environment.

The knowledge transfer of such farming can be consulted to infer the agricultural activities of early Indigenous Peoples before the impact of Han people bringing the food production techniques in, including the types of crops, and methods of use of agricultural tools, by observing the actual operation of modern Taiwanese aborigines (Wang and Tien 2009). For example, the determination of the fallow period of the cultivated land or the crops suitable for planting in a certain area, etc., these are the accumulated experience or the knowledge that needs to be transferred. According to research given by Wang *et al.*, the cultivation of the slash and burn mode of the planting and the fallow period of modern indigenous people are carried out on the basis of the rules of thumb. The way in which each indigenous tribe is implemented differs depending on the natural environment and the crops they planted. For example, the Rukai people think that the nutrients required for taro growing must be sufficient, cultivated land, therefore, has to be a long-term fallow land with trees of the forest. Whilst the millet only needs a bush fallow land covered with shrubs for planting. The southern Paiwan people consider that upland rice has a higher demand for nutrients of land soil, so the farmland where rice is planted required a longer fallow period to recover, yet the millet and sweet potato need the less fertile soil land than rice (Wang and Tien 2009). Not all indigenous groups in Taiwan today use traditional slash-and-burn methods to grow crops, except for a few tribes that maintain such farming methods, such as the Yami in Taitung or Paiwan in Pingtung.

When the Han Chinese moved to Taiwan and brought the agricultural pattern of paddy farming and the use of the plow, it was different from the customary way of the aborigines. The plow is capable for the multiple jobs in the cultivating process like earthing up, building rice field ridges or ploughing and weeding. Also, it can operate with animals such as cattle and/or horse as animal-drawn implements, so that the efficiency of the agricultural job is greatly improved (Curwen 1953). Therefore, paddy farming is the production value of the Han Chinese to impart relevant knowledge to the indigenous people to help them improve their sustainability of the agricultural fields, such as the experience of the relevant agricultural tools, water conservancy facilities and plant species suitable for cultivating. Aboriginal people can thus get rid of the unstable life of the food self-sufficiency rate from traditional farming, hunting, and gathering, which is the foundation for the establishment of sustainable development in general civilization (Grolier Incorporated 2000). In the 19th century, a German, Joest recorded that the Pingpu people in the Taipei area had learned to use rice irrigation techniques to grow rice (Yao 2018). The technology and strength of the paddy farming model often exceed what the locals can provide, and indirectly creates a complex external network. This changes the original self-sufficient cultural and social system of the aboriginal society and the interaction with the natural environment (Huang 1975).

4. Documentary records on agricultural activities

The farming techniques brought by the Han Chinese immigrants to the Taiwanese indigenous have seen changes in the technological aspects in the agricultural activities of the aborigines in the 17th and the 18th centuries. The living habits of some of the aboriginal groups described by Huang in 1772 can provide this information (Huang 1996). From the merging information given by Huang in Table 2-4-1, it can be seen that the indigenous tools used for keeping the tradition of the slash and burn agriculture are mostly hoes or knives, and a small number of axes, the main species of plants cultivated is taro. The transformation of farming methods is more common in the use of Han Chinese ploughing techniques, and probably be used as the rice cultivation for farming the paddy rice brought from Han people. In addition to the aforementioned ordinary crop plants that the indigenous people cultivating like the millet, upland rice and taro of cereals as examples, there are also other items planted like the beans, flax, pearl barley, vegetables with spring onion and ginger and fruits with coconut, sugar cane, bergamot and Taiwan Persimmon (Chou 2012). Non-Taiwan native plant species such as peas, sugar cane was introduced by the Dutch in the 17th century apart from the wet paddy rice and sweet potato brought by the Han Chinese. It is clear that although there are many types of crops that can be grown by the aborigines, in terms of the traditional farming pattern at that time, the yield showed a small amount of planting yet. It is noticed from the table 2-4-1 that some of the aboriginal groups began to alter the method in farming the wet rice and consume the japonica rice which shows that the indigenous people had changed the type of rice to the rice cultivation introduced by the Han people.

Indigenous group	Lifestyle of agricultural activity	Change in farming technique
Siraya (in the coastal area)	Using ox cart and plough for rice cultivation	○
Siraya (in the inland area)	Cutting tree's root by knife or axe and planting taros. Building rice field ridges and planting the paddy rice.	○ (partially change)
Taokas	Using plough for rice cultivation like Han people do.	○

Indigenous group	Lifestyle of agricultural activity	Change in farming technique
Tsou	Using small hoe and short knife for cultivating.	×
Ketagalan, Kavalan, Amis	Using hoe and no implements for the farm field arrangement.	×
Rukai, Paiwan (northern)	Using plough without animal power support. Cultivating plants by iron made tools like hoe, awl and chisel.	×
Paiwan (southern)	Cutting trees and digging roots for planting taros.	×
Honaya	Consuming two types of rice: upland rice and paddy rice.	○ (alter in the type of plants cultivated)

Table. 2-4-1 Changes in the lifestyle and techniques on the basis of the agricultural activities among the Taiwanese indigenous groups in the 17th century. (Huang 1996)

It is the history of changing aboriginal agricultural practices must be understand in order to justify the use of ethnographic examples. To sum up, although the agricultural behavior of indigenous people in the 17th century still adopts the slash and burn method as one of the sources of food crops, it is gradually changed after contact with the people from outside of Taiwan and acquiring techniques to improve their crop production since then.

A similar scene description appeared in the painting pieces of the custom catalogue of indigenous tribes depicted by Liu-Shi-Qi, an official of the Qing Dynasty in the 18th century (Tu 1998). This catalogue is a collection of aboriginal custom pictures drawn by the painters between the year 1744 and 1747, who followed the order from Liu-Shi-Qi who was on the inspection of Taiwan during that time. There are inscriptions on each picture to illustrate the content so that the readers can learn the meaning of the painting work.

The Geng Zhong (rice cultivation) portrays the scene of the Pingpu people who are deeply Sinicised in their daily life and rooted in rice cultivation, the farming mode indicates that both hoe and plough are used. The rice varieties in the picture are believed to be the indica rice of which the seeds and cultivating techniques were introduced by the Han Chinese at the time they moved into Taiwan (Fig. 2-4-7, Tu 1998). According to the 17th century archives of the De Dagregisters van het Kasteel Zeelandia 1629-1662, it points that the farm tools such as hoes and plowshares were almost imported from China - the hometown of the Han Chinese immigrants - after 1645 (Chiang 2011). The single import volume of tools for agricultural works was large which indicates that there were surely a certain number of farmers on demand for the farming tools at that time. Besides, the existence of aboriginal women is presented in the painting, which is consistent with the documented aboriginal women participating in farming and even the main source of labour for agricultural production. Therefore, it is speculated that the Han Chinese ploughing techniques were learned first by indigenous females and then passed the knowledge to other aboriginal males. The task of a male was generally to deliver meals to the female working in the field. By the mid-eighteenth century, male labour had also invested in farming, such as the opening of the drainage ditches.

The Yi He (rice harvest) described the Pingpu people harvesting rice by their hands without using the small sickle for cutting rice stalk and collecting rice spikes because of the property of the rice type planted was long and soft in the 18th century (Fig. 2-4-8, Tu 1998). In the early nineteenth, sharpen sickles were used in some place for the rice harvest. The rice farming system of the indigenous people is one-year cultivating then one-year fallow to wait for the land gained the nutrients and recovered. At the time of the harvest season, the entire community has worked together to collect rice and set the order of harvesting activities. Worshiping gods by offering the livestock and liquor before harvesting, the whole community enjoy the feasting, drinking, dancing, and singing after harvest. Additionally, the garments in the painting can also distinguish the short of style between the Pingpu Zu (Plain) and Gaoshan Zu (Mountain) groups. Gaoshan groups wear the animal skin cloaks like they were used to, yet the clothes of Pingpu resemble the Han Chinese, only with a slight difference. For example, compared with the ploughing Han people in Figure 2-4-7, the hat of the Han people is not like that of the Pingpu's cloth head kerchief.

The Zhong Yu illustrates that the dress style of the aborigines like that should be the Gaoshan people who live in the mountainous area (Fig. 2-4-9, Tu 1998). They hold the tools of hoe and axe to plant taros at the farmland in the hillside of mountain. What needs to be pointed out is that only the use of axe and hoe has been mentioned for the taro planting in the archives, not any further information of the shouldered axe ever described. The cultivated crops of Taiwan's indigenous people are like Southeast Asia, are dominated by *Colocasia esculenta*, which is different from the rice in the Yangtze River basin in China, the millet in the Yellow River Basin, or the wheat in West Asia. The tradition of planting taros is still visible today in some aboriginal tribes, such as the Yami (Tao) who reside in the outlying island named Orchid Island. According to the inscriptions on Figure 2-4-9 and other documents, the taros were buried and burnt with soil for feeding everyone around. This is a very primitive way of cooking, the people of the same society share food and eat together, quite a wind of primitive communism.

The painting collection of Liu-Shi-Qi reflects not only the degree of sinicisation of the Pingpu people in the 18th century, but also the significant divergence in the lifestyles of the Gaoshan groups on clothing and agricultural activities from those of the Pingpu.

The records of ethnography in the late 19th and early 20th century is greatly based on the lives of Gaoshan tribes. At that time, the aborigines described by scholars mostly maintained the traditional lifestyle as the hunter-gathering and sifting agriculture society, which such descriptions could be partly influenced by the political or social agendas at the time the record written, and potentially be bias. The agricultural tools for growing and harvesting the crops like taro or millet that the indigenous people had were the old-fashioned ones such as a hoe, shovel, and spade. These implements are usually compound tools, which are tied to the wooden handle with ropes and are suitable for manpower farming on drylands or mountainous slopes, just like the form of the objects drawn by Miyamoto or the Kokubu in their notes (Miyamoto 1939、Kokubu 1981). It can tell from the above passage that the aborigines who maintain the method of agricultural production traditionally mostly lived in the hilly areas since the 17th century, and the farming tools for crops cultivation they used had never changed significantly either. Only the raw material produced the cultivating utensils has been changed from the stone rocks to the iron.

Probably on the basis of a belief in maintaining cultural traditions, some of aboriginal people keep the traditional habits of artefacts unchanged. For example, one of the Paiwan legend being told that the ceramic pot is the sacred good given from their god(s), which is the identity of the social status, only the mamazangilan (Aboriginal leader of tribe) owns it. Once the daughter of mamazangilan is going to marry, the mamazangilan will pinch off a piece of the pot and give the rest to the bride as a gift showing her status. If the groom is not aristocracy, his social status will be enhanced by the Paiwan pot. The symbolic significance and social function of the Paiwan ceramic pots is still maintained among the modern Paiwan societies. Above case shows that an archaeologist who studies a specific artefact in the discussion of the functions and manufacturing techniques of prehistoric implements can benefit from having a good reference value by the ethnographic archives.

Again, the ethnographic archives provide the information of the indigenous people using axe and hoe tools to grow taro or learn the techniques of rice farming from the Han people. However, whether this can indicate that prehistoric humans used shouldered axe to grow crops remains to be verified. This is also the part of this research that will be carried out in Chapter 4.

Fig. 2-4-7 Geng Zhong (Rice cultivation). (Tu 1998)

Fig. 2-4-8 Yi He (Rice harvest). (Tu 1998)

Fig. 2-4-9 Zhong Yu (Taros planting). (Tu 1998)

Chapter 3_A BRIEF INTRODUCION OF THE METHODOLOGY

This article attempts to answer three topics including the age of Yuanshan culture, the provenance of the raw rocks of the shouldered axes, as well as the production technology and usage/functions of the shouldered axe through the following methods: Bayesian radiocarbon modelling, pXRF analysis, use-wear analysis, PCA and typological analysis, phytoliths analysis and experimental archaeology (Fig. 3-1).

The chronology of Yuanshan Culture will be reviewed and modelled chronologically by the Bayesian radiocarbon modelling method to obtain the range of the Yuanshan Culture age.

The raw material sourcing of the shouldered axes applies pXRF analysis technology and the results yielded may offer proof that the andesite rocks made of the shouldered axes indeed procured from the local quarry of the Tatun Volcano Group.

The approaches on the production technology and the function of the shouldered axes study have two steps. First, the applications of principal component analysis (PCA) and typological analysis, use-wear analysis and phytoliths analysis will make use of obtaining as much the information of the shouldered axes for proposing a hypothesis. The second step then is to verify the hypothesis of the first step by means of replica experiments.

The last, the above analytical results will summarise and discuss in Chapter 5 to make a reasonable explanation or answer the questions that the goals set for in this dissertation: the production technology and usage/function of the shouldered axes, the raw material provenance of the shouldered axe and the possible origin of the Yuanshan culture.

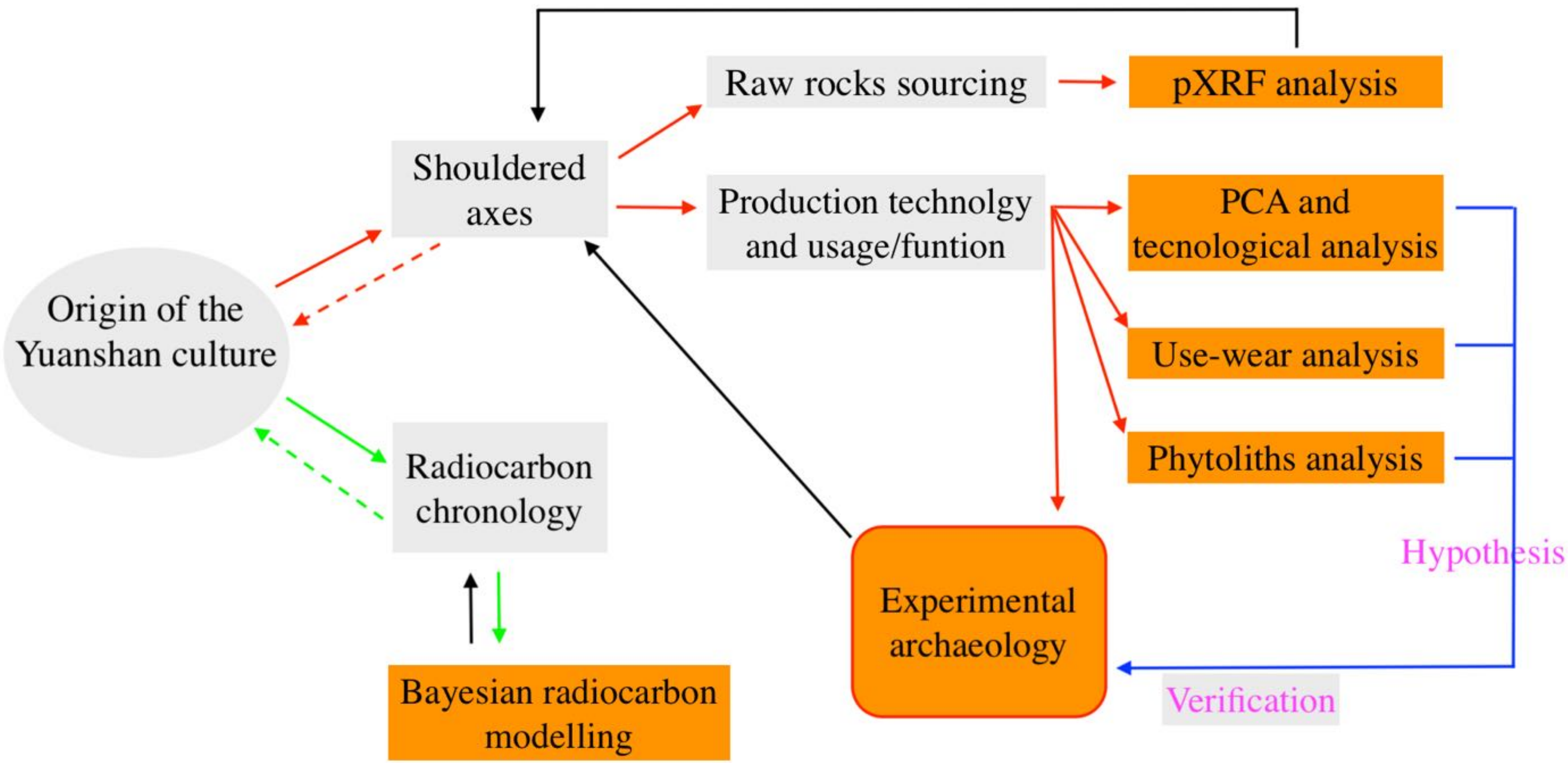


Fig. 3-1 Flow chart of the research methodology.

Chapter 3-1_METHODOLOGY OF RADIOCARBON CHRONOLOGY

Archaeology is a science based on analysing the material remains and environmental data of the prehistoric humans. When sorting the materials and studying the issues, judging the dates of archaeological objects is the essential foundation in all. Archaeological chronology is the determination of archaeological materials sequence by relative or absolute chronology. Relative chronology is that two or more changes or events can be ordered sequence relative to one another. For example, archaeologists judge the relative chronology of archaeological assemblages, sites, or cultures based on the sequence of the stratigraphic relationship in the field or the seriation technique of the objects but cannot determine their absolute chronology. In contrast, absolute chronology takes a year or years as a unit of measurement through various scientific dating methods so that a specific occurrence can be assigned a proper date. Such as, the age of the Yuanshan site is marked as 3280±80 BP. Relative chronology and absolute chronology differ from each other with regard to the concepts of time and the methods of determination process (Walker 2005).

Relative chronology

Archaeological study on the stratigraphic relation in a single site or between sites shared the same culture, as well as the seriation technique of materials are usually formed the root for the judgment of relative chronology. Archaeological stratigraphy is a subject derived from the geological study of strata which allows archaeologist to learn formation of layers with accumulated deposits and their sequence in the archaeological site. The concept of stratigraphy is to firstly confirm the order of each cultural layer and then determine their position on the time scale. It is impossible for the artefacts identified as later stages to appear in the early layers when using stratification to judge chronologically. Such as, the Iron Age glass beads in Taiwan do not appear in the early/middle Neolithic or Palaeolithic strata at sites (Wang *et al.* 2014, Chao 2015). Typology in archaeological material study is to classify types of objects into different groups systematically and associated with chronology. According to the order of continuity variability in the pattern of the same artefact type, the sequence relationship of different patterns in the same type of archaeological objects and the evolution process of the type in time are recognisable. Such applications are most common in the classification of pottery, such as Lapita pottery, is one of the representative objects for studying the migration of people across the Pacific region (Chiu 2012, Sand *et al*. 2013).

Absolute chronology

The application of determining the absolute chronology in archaeology can be roughly divided into two fields. In the historical archaeology with written words, the literature records, archives and calendar dates can be used as a tool for judging specific age of particular event. However, it is necessary to assess carefully and repeatedly on documentary records and calendar ages to determine the dates of various archaeological materials for the absolute chronology study. For instance, academics across disciplines collaborate on the study of investigating the Fort

Zeelandia built by the Dutch between 1624 and 1634 in southern Taiwan, identify the location and the approximate extent of the Fort Zeelandia in Anping District, Tainan, after the assessment and comparison of the archaeological artefacts, historical archives and antique maps (Fu *et al.* 2003). Another example is the use of records correlating the Maya calendar and the radiocarbon dates so that two data can be compared and studied on the specific events or issues related to each other in terms of time in the Mayan civilisation (Kennett *et al.* 2013, Aldana 2016). Or the applications of ^{14}C dating and Bayesian statistics analyse and review the topic of the industrial-scale metal production at KEN around 10th to 9th c. BCE in ancient Edom mentioned in the historical text (Levy *et al.* 2008).

Application of scientific dating methods

In the field of prehistoric archaeology lacking written records, the determination of absolute dates must rely on various research techniques and analytical methods developed in natural science. Techniques and methods are commonly applied include ^{14}C dating, Tree-ring dating (dendrochronology), Thermoluminescence dating (TL), Obsidian hydration layer dating and Potassium-argon dating (K-Ar), etc (Aitken, 1999, Walker 2005, Shackley 2015). Each of these dating methods has its own applicable material. ^{14}C dating is a method applied to the carbon-contained organic materials, such as a bulk of charcoal or wooden artefacts, by following the principle of decay and half-life of carbon isotopes. So that the age of the studied objects can be measured and now widely used in the various chronological establishment of archaeological research globally, especially for the prehistoric culture and the early phase in the historical era. Tree-ring dating is commonly being used as an attempt to extend as the calibration of the ^{14}C dating. In the meantime, the method also can estimate the time from the annual rings of living trees which allows to establish the exact dating of trees. Thermoluminescence dating is applied mostly to ceramic materials and can be used to determine the time the potteries have been discarded or buried under ground in the site (Li 1999). Potassium argon dating can estimate the existing time of ancient artefacts deposited in the volcanic rock formations (Walter 1997). The application of these natural science techniques and methods offers the chronological basis for the archaeological study on the time-scale.

Each method on the determination of time in archaeology, however, also has its own drawbacks. For example, the most frequently employed ^{14}C dating requires not only calibration in analysis, but the age of its sample targets sometimes does not match the age of the archaeological events. In addition, the age it can measure is limited to tens of thousands of years, the samples with older ages must estimate by the other dating techniques then. Dating methods of obsidian hydration layers and potassium argon among adopted several applications above-mentioned in calculating the archaeological ages cannot be practised to the dates determination of most prehistoric cultures in Taiwan. The reasons are as follows: 1). There is no obsidian in the rock formations in the volcanic areas across Taiwan, certainly no stone tools found in the prehistoric sites are made from the obsidian used as the raw material of rocks. The obsidian hydration dating, therefore, is not fit to be used in Taiwan; 2). The earliest known archaeological site in Taiwan, Baxiandong, dates between 25,000 and 30,000 years BP (Tsang 2013). For the potassium argon dating that cannot accurately measure the age less than 100,000 years, it is not suitable for use in the relatively young archaeological cultures in prehistoric Taiwan. It can be seen that no matter what kind of dating method is applied, the following practices can improve and help to obtain the more precise data from absolute ages of dating methods: 1). Control the sampling process to avoid the contamination of samples for dating; 2). Employ a suitable dating method for research the objects; 3). Compare the available dating results for cross references.

It is known that the dating error of marine shell can be higher than that of charcoal due to the marine reservoir effect (Ascough *et al.* 2007, Yoneda *et al.* 2002, 2007, 2017, Alves *et al.* 2018). In the north Taiwan region, it is responsible for returning dates on marine shell dating up to 6,310±40 years. Using the C14 dating results of the P5 pit charcoal and shell samples from the 1998 Yuanshan site excavation as an example of the severity of the marine reservoir effect in this region, there is a gap of 700-800 years between the two layers. A shell sample from the layer L2d has been dated to 3,760 ± 40BP, whilst the age dates to 2,930 ± 70 BP from charcoal taken from layer L3b (Table 4-1-1, Lab No. NTU-2864 and NTU-2543 respectively). In this example, either a post-depositional inversion of dating material has occurred and/or a marine reservoir effect has resulted in a disparity in dating evidence. The marine reservoir affects the radiocarbon dating results because the carbon consumed by the oceanic organisms is older than that by land. The marine reservoir affects the radiocarbon dating results because the carbon consumed by the oceanic organisms is older than that by land. Therefore, the correction of the marine reservoir effect is necessary for taking account of the changes in the oceans.

Bayesian chronological model

Bayesian statistical method is used for updating the probability of a hypothesis when more evidence is available, and so that a natural framework is offered for the combination of various sources of evidence (Buck *et al.* 1996, Bayliss 2015). Such technique offers a potential solution to the imprecise chronology in archaeological contexts. Bayesian statistical modelling approach is rapidly becoming a dominant exemplification of choice of building the chronological framework in archaeology because of the tailor-made online software for free. Take the OxCal analytical software (https://c14.arch.ox.ac.uk/oxcal/OxCal.html) widely used by archaeologists at present as an example, it is hosted by the the Oxford Radiocarbon Accelerator Unit at Oxford University and provides powerful means for chronological model construction for users who may be unfamiliar or lacking the background knowledge of statistical analysis or computer programming (Bronk Ramsey 2009). Another online free software performing the similar computing functions of Bayesian ^{14}C calibration tool is BCal (https://bcal.shef.ac.uk) hosted by the School of Mathematics and Statistics at the University of Sheffield (Buck *et al.* 1999). Bayesian chronological models were developed more than twenty years specifically for the interpretation of radiocarbon dates in archaeological and palaeoenviromental research communities by statisticians and software developers (Buck *et al.* 1996, Buck 2015, Bayliss 2015).

Bayesian chronological modelling utilises prior archaeological information to simulate the probability distribution of unknown parameters, then produces a modelled posterior probability distribution which is a more accurate estimate of archaeological phenomena (Bronk Ramsey 2009; Bronk Ramsey and Lee 2013). As the resulting distribution of chronology reflects both data and prior assumptions, an inappropriate prior information can greatly influence the accuracy of the data, users must be bear in mind that the translation of the archaeological knowledge into statistical inputs should be careful (Buck *et al*. 1996:26). A simple application of the Bayesian method is the calibration of the ^{14}C measurement data using statistical methods (Bayliss *et al.* 2004). Different calibration curves and a series of algorithmic functions, therefore, are built into the software in response to different materials of ^{14}C measurements. For instance, there is a set of algorithmic functions built into the OxCal analytical software to exploit tree-ring calibration curve, because of the important usage of tree-ring data to the overall calibration of radiocarbon data and in the archaeological contexts. Generally, there are greater numbers of ^{14}C measurements in most dating applications, and it is an expectation to relate those to events in the past. Such analysis can be carried out as a coherent framework by using Bayesian radiocarbon modelling and is become a core component in plenty of ^{14}C dating projects (Overholtzer 2014). This method provides a better reliable way to interpret the total radiocarbon dates if performed correctly (Bronk Ramsey 1998).

The combination of archaeological knowledge and probabilistic models can better estimate dates and meticulous chronologies, sometimes even on the scale of a single event, such as the date of the Santorini eruption (Friedrich *et al*. 2006).

Among Taiwanese archaeology community currently, there is only one formal published doctoral thesis using online software of OxCal to interpret the time range of a specific archaeological culture based on the modeled chronology by applying the Bayesian radiocarbon modelling in one of a chapter (Lu 2017). Though the presenters never give detailed illustration of modelled chronology, the trend of the archaeological chronology interpretation using the Bayesian statistical technique with OxCal analytical software can be seen in various archaeological seminars and conference for past three to five years in Taiwan. It can be expected that the application of Bayesian chronological modelling method on the construction of archaeological chronology in the study of Taiwanese prehistoric culture will appear in the published literature in the coming years. This thesis is going to collect the published ^{14}C measurement data of the Yuanshan Culture on the literature and estimate the time-span range of the Yuanshan Culture by utilising the online free analytical software OxCal.

Material and method for the Yuanshan Culture chronology study

Radiocarbon dating is the primary method for building Yuanshan cultural chronology in Northern Taiwan. Sixty-one samples of three material types were collected from nine Yuanshan sites: Table 3-1-1 - cross-reference seven on shell (clam), one on wood and 53 bulk charcoal samples were used to establish a chronology for Yuanshan Culture for ^{14}C dating. Radiocarbon dates were calibrated using OxCal ^{14}C plotting software (Bronk Ramsey 2009) and the IntCal13 atmospheric calibration curve (Reimer *et al.* 2013). Dates on marine-based organic material were calibrated using the IntCal13 atmospheric and Marine13 calibration curves (Reimer *et al.* 2013), using a ΔR regional offset from the CHRONO Marine Reservoir Database of 71±35 years (Yoneda *et al.* 2007).

Bayesian models of cultural phases were generated in OxCal to provide lower and upper chronological boundaries used to interpret the material culture (Bronk Ramsey 2009). Summed Calibration Probability Density (SCPD) estimates were extracted from these models to provide an impression of intensity of cultural activity in time. These are used with caution to augment the Bayesian models (Williams 2012; Michczyński and Michczyńska, 2006). In addition, a further ^{14}C date (Beta-480358) was obtained as part of this PhD thesis via a successful application to a School of Archaeology, Geography & Environmental Sciences (SAGES) research division budget (Objects, Material and People; Table 4-4-1). This date was obtained on bulk charcoal sample associated with the Hsuntangpu Culture that conventionally dates to 3,420±40 cal. BP.

Chapter 3-2_METHODOLOGY OF pXRF ANALYSIS

Introduction

Elemental analysis method is the base to determine the source of geological components or to address overall composition on the study of the archaeological materials. However, the instruments used in this analytical method are typically destructive in nature and the cost (time and money) consumed by the experimental process, such as INAA (Instrumental Neutron Activation Analysis), AAS (Atomic Absorption Spectroscopy), ICP-MS (Inductively Coupled Plasma-Mass Spectrometry), EPMA (Electron Probe Microanalysis), which limits the number and/or size of archaeological objects tested (Liritzis and Zacharias 2011, Frahm *et al.* 2013, Tykot 2017). Since the portable X-ray fluorescence (pXRF) analysers being developed and improved their performance over a decade, they allow to generate multi-element analytical data reaching up for hundreds of samples per day and to provide the cost-effective and non-destructive techniques on any size artefacts and materials in the fields and museums all over the world. Therefore, the pXRF instruments have drawn considerable attention within the archaeological community and been involved in the archaeological applications on the compositional analysis of various objects increasingly, for example, ceramics (Forster *et al.* 2011, Frahm 2018), glasses (Burley and Simonin 2011, Jia *et al.* 2010, Liu *et al.* 2012), bricks (Bonizzoni *et al.* 2013) and metals (Charalambous *et al.* 2014, Dussubieux *et al.* 2015). The most fruitful achievement of using pXRF instrument in the archaeological applications is to discriminate the sources of obsidian raw materials systematically, which has been demonstrated the compositional data obtained and accumulated a certain amount outcome as the references regarding the elemental analysis of rocks and the instrumental technique to the academic circles (Craig *et al.* 2007, Forster *et al.* 2012, Frahm *et al.* 2013, 2014a, 2014b, Frahm 2016, Millhauser *et al.* 2011, Moholy-Nagy *et al.* 2013, Phillips *et al.* 2009, Sheppard *et al.* 2010, 2011, Tykot 2017).

pXRF instrumentation and analytical principle

pXRF analysers have been labelled and described a wide variety of instruments because of the size of instrument and the performance characteristics based on the designed system with the radioactive isotopes or miniaturised X-ray tubes. For example, the types of pXRF devices defined by Frahm *et al.* (2013) are as follow: museum-type pXRF (a commercial deconstructed benchtop system with capability to identify materials of museum collections for conservation or authentication), components-type pXRF (the set-ups of XRF components being transported and reassembled in a workplace), field-portable XRF/handheld pXRF (the handheld instruments which are actually field portable devices to archaeologists of interest). The typical application range of pXRF devices include, the monitoring spatial distribution of elements on the contaminated land, geochemical prospecting for locating deposits of economic ore, monitoring hazard in air or working places for generating the health and safety information, detecting the forgeries or evaluating restoration techniques to the artworks or the cultural heritage, and chemical sourcing of artefacts in archaeological investigations. The instrument of pXRF that archaeologists concern and use most is the device truly portable equipped with the miniaturised X-ray tube which allows measuring precisely and accurately and leaves the artefact intact, so that either practising the non-destructive analysis at the museums, excavations or geological resources (Environmental Protection Agency 2007, Wu *et al.* 2012, Tykot 2016, 2017).

pXRF analysers have benefited lately from the developments in the miniaturisation of components to make them compact, light weight, hand held devices. The system design of pXRF analyser is similar to general laboratory-based X-ray instruments with an X-ray tube which works on wavelength dispersive spectroscopic principles, identifies the chemical elements more easily than the lab-based XRF and provides the ability to calculate element concentrations in parts per million (ppm) in a shorter time. The typical analytical range for a portable XRF instrument is magnesium (Mg) through uranium (U). F For those requirements of detecting the heavy elements such as barium (Ba), barium (Sb), lead (Pb) or xenon (Sr), the pXRF technology with unique analytical performance enable to support. Although the critical penetration depth of the fluorescence X-ray of use are slightly different by various types of pXRF instruments, the analytical measurements are derived from surface layers roughly about 1 mm in depth. In addition, pXRF analyser has the capability of the technique to undertake in situ analytical measurements of archeological artefacts, the analyser is taken to the item to be analysed, placed in contact with the it and initiated the analysis sequence. An analytical measurement is undertaken, and the result is immediately available to the operator. This operation mode cannot effectively be made by other techniques. Unlike conventional laboratory methods, pXRF analysers do not involve the sample preparation, the sample selection is available to analysts for the flexibility of need (Liritzis and Zacharias 2011, Goodale *et al.* 2012, Frahm *et al.* 2013, Shackley 2012, Tykot 2017, Williams-Thorpe 2008). An elemental analysis method of pXRF device, thus, shows promise for the acquisition of the source attributions in terms of the broad archaeological applications.

Briefly, the pXRF technology can be applied wherever rapid, no-destructive and in situ analysis of chemical elements is needed to construct the past cultural contexts of raw material procurement and use.

Limitations and solutions of pXRF applications

The instrumental developments of pXRF have raised the debate in recent years, dominated by scepticism over their analytical performance because of the downsized components of device which probably lead to account of rather less accuracy on analysing data than the laboratory benchtop ones. The discussed issues mainly, as a result, are over the generated compositional data using pXRF analyser on its reliability, accuracy, precision, sensitivity, and performance limitation. At the same time, suggestions for the methodological and practical applications of pXRF are also proposed for these concerns as aforesaid. Combined with the pragmatic approach to the elemental analysis measurements yielded by the pXRF device, the analytical data generated gives significant information for reducing the doubts of instrumental performance to the archaeological circles of concerns (Frahm *et al.* 2013, Frahm and Doonan 2014a, Goodale *et al.* 2012, Grave *et al.* 2012, Liritzis and Zacharias 2011, Newlander *et al.* 2015, Tykot 2016,2017).

Lithic resources identification is the centre of these studies. Provenance analysis among the broad available technologies and methods for studying stone tools and their by-products of production, has been proved especially effective for explaining strategies on the raw rocks' procurement by ancient people. Source analysis depends on precise elemental composition estimation to differentiate among geological origins of raw material and for attribution of artefacts to those sources. A range of techniques can be applied to this task on using pXRF instruments to analyse the elemental compositions of stone artefacts, which are abundant in almost every archaeological site and invariably the best preserved of any other remains. Most analytical provenance techniques remained the prerequisite of destructive sampling to the archaeological artefacts is a major restriction, however, pXRF method represents a rapid and non-destructive alternative in favour of archaeologists' need (Forster *et al.* 2011; Lundblad *et al.* 2007).

Craig *et al.* (2007) examined sixty-eight obsidian artefacts from the Jiskairumoko site in southern Peru´ by pXRF and XRF, and compared the analytical data obtained from both analysers. Results yielded from two analysers show the consistency of individual element concentrations and source determination. Although individual element comparisons of studied item show the differences, these can be resolved by a well cross calibrated pXRF analyser. Such instrument generates the compositional data comparable to the data obtained using other analytical techniques that differences between elements. Frahm *et al.* (2014a) performed two correction schemes (soils and mining) with two calibrations (factory-set and linear regression) for two pXRF (new and old) using four published obsidian analytical data of elements and compared the accuracy of analytical performance. The outcomes of new device present the consistency of the accuracy on instrumental performance by testing with two correction schemes, which means the application of non-destructive pXRF analyser for obsidian sourcing may be successful. The given study of volcanic ground-edged hatchets in the southern Australia by Grave *et al.* (2012) has demonstrated that applying pXRF to detect both the volcanic rock samples and the archaeological artefacts (basalt) and compare their elemental measurements, which can achieve the high-resolution discrimination of the possible geological resources of samples with appropriate abundances of elements. Another work on sourcing Armenia obsidian of Frahm (2014) emphasised the advantage of pXRF application, including the analysing ability of large numbers of specimens, variability recognition, etc.

In contrast to the positive and productive studies aforementioned, the following examples are relatively optimistic caution about the application of pXRF instruments on compositional analysis or geological identification. Newlander *et al.* (2015) stated that the compositional data of obsidian generated by pXRF is favourably compared to data obtained using other analytical techniques. Elemental composition data of other rocks obtained using pXRF, such as Jakes Wash andesite, several analytes (e.g. Fe, Rb) need to be well-calibrated additionally for comparison with the analytical data generated by laboratory XRF. Goodale *et al.* (2012) utilise two pXRF analysers to detect the trace elements of five fine-grained volcanic sources and four obsidian sources in the Great Basin and compare the wavelength-dispersive with calibrated geological standards of two pXRF to the conventional benchtop. Despite the precise outcomes yielded by pXRF instruments for most elements, some elements mischaracterise concentrations.

Future of pXRF applications in archaeology

Most of archaeologist devoting to the improvement of pXRF techniques and devices sees a promise for productive use of pXRF instruments in archaeological studies. It is not a lab-based analysers replacement but a potential technology to be employed in novel ways. The contexts of innovation and adoption are the crucial issues as any other successful technological development in human history. The use of pXRF is considerably depending on method that the technical capability to analyse archaeological materials effectively using portable instruments may exist and allow to expand the archaeological study in new methodological and theoretical frameworks. In the meantime, the same strict protocols applied in laboratory-based XRF analyses, involving instrument calibration, evaluation of inter-instrument performance, and comparison to accepted geological standards, need to be applied in pXRF analysis. (Frahm *et al.* 2013, 2014a, Goodale *et al.* 2012, Grave *et al.* 2012, Shackley 2010) Working with manufacturers to develop robust calibrations of geological materials is rather an approach toward the accuracy of analytical data generated by pXRF. Whether it is a cautious or optimistic view of pXRF application, for obtaining the precision and accuracy of analytical data generated by pXRF, archaeologists need to take times on establishing a rigorous and consistent analytical protocol through systematic experimentation and evaluation.

Purpose of pXRF application to the Taiwanese andesite shouldered axes

The research applications of pXRF analytical method in Taiwan are mostly lying in the disciplines that need to be tracked or tested at different time scales, such as earth science, environmental science and public health, etc. (Environmental Protection Agency 2007, Wu *et al.* 2012). The chemical composition analysis of the Shihsanhang cultural artefacts using pXRF analyser on the metal objects research being performed by Dr Chen (Chen *et al.* 2010) is the first of pXRF application in the Taiwanese archaeologist's community. I participated in Chen's research, however, I did not have a chance to use the pXRF device. Because I did not qualify for the operation of radiation instrument at that time before my training completion. The acquisition of the involvement on this research are that I learn the experience and basic knowledge of using the pXRF analyser and recognise the convenience and advantage on the application of pXRF technology on the elemental analysis of chemical compositions in stone material research for sourcing.

Secondly, most of Yuanshan andesite shouldered axes have never been examined by the geochemical methods to confirm the source of andesite, nor the shouldered tools of this study are not available for the destructive tests. Nevertheless, this can be solved by non-destructive experiment by conducting the pXRF method. Additionally, given the favourable outcomes achieved with the works using pXRF analyser on the obsidian above-mentioned and the fine-grained volcanic artefacts (Goodale *et al.*, 2012; Grave *et al.*, 2012), therefore, this study will apply the pXRF method to analyse the major and trace elements in compositional analysis for 16 shouldered stone axes and eight raw material of andesite collected from Yangmingshan National Park. The data generated by PXRF will be compared to the published literature results generated by other laboratory instruments, such as XRF (X-ray fluorescence), EDX-XRF (Energy Dispersive X-ray Spectroscopy X-ray fluorescence), XRD, ICP-AES (Inductively Coupled Plasma – Atomic Emission Spectrometry), SEM-EDS (Scanning electron microscopy-energy dispersive X-ray spectrometry), EMPA (Electron Microprobe Analysis), CL (Cathodoluminescence).

Chapter 3-3_ METHODOLOGY OF PCA AND TYPOLOGICAL ANALYSIS

The statistical method of Principal Component Analysis (PCA) was invented by British mathematician Car Pearson one hundred years ago. It is a method of linear dimensionality reduction still widely and effectively apply in the field of statistics to analyse data, reduce and disassociate data dimensions. It is a linear transformation. This transformation transforms the data into a new coordinate system so that the first large variance of any data projection is on the first coordinate (called the first principal component), and the second-largest variance is on the second coordinate (the second principal component). Ingredients), and so on. The principal component analysis often uses to reduce the dimensionality of the data set while maintaining the feature that contributes the most to the variance of the data set. This is done by keeping low-order principal components and ignoring high-order principal components. Such low-level components can often retain the most important aspects of the data. Then, PCA extracts the crucial information from the data and comprehensively judge and classify the variables. Therefore, it is employed as a tool in exploratory data analysis and for making predictive models. (Field 2013)

The PCA analysis is going to perform on the measured values of the attributes of the artefact type, especially the angle of the shoulder and the blade edge on the stone tool in this study. Hence, with the new variables extracted and sorted out by the data, the angle of the shouldered tools can be used to classify the typological group of objects statistically. The consistent production behaviour and concept of the shouldered type would be explained potentially by applying the PCA analysis, as well as help to verify the direction of the subsequent replica experiments. For example, the number of angles between the shoulder and the axis can be classified as 60°, 90°, or 120°. These three-angle groups can provide a discussion on whether the angling group has a positive correlation to the hafting method of the shouldered axes.

The purpose of grouping is to understand whether or not: a). the Yuanshan Cultural people has a specific angle preference on the production of the shouldered axe, and b). the shoulder is functional, such as for hafting. If there is, a special group of dimensions or variables can not only be applied as one of a bases for the identification of shouldered axe (except for the morphology of the shouldered tool itself and the use of andesite), but also for the shoulder practicality to further discussion. If there is no, the variability of the shoulder manufacturing technology opens a broader research toward its' reason. One of the reasons is to discuss the possibility of shape simulating or learning from other archaeological culture in terms of the stone tool manufacture.

Despite the application of advanced technologies such as a radiocarbon dating, the study of the shapes and forms of artefacts and the cultural patterns that divide them into specific periods in archaeology, typological analysis is still a crucial mean and the most fundamental unit of archaeological analysis.

Typology in archaeology is a methodology that summarizes, classifies, and compares the collected archaeological objects on their physical characteristics scientifically and systematically. The research method is to, firstly, observe the research object thoroughly and record in detail its attributes as many as possible, such as the form, surface decoration, manufacturing technique, section, raw material, weight, colour, production traces, etc. Second, establish a set of classification standard like the shape, colour, function, technique, decorative pattern, raw material and so on, after degerming the classification purpose. Then, sort these data into types, classes or groups based on the similarity between the objects. The last, verify all the outcomes of classification through the stratigraphic data, documentation, and historical research. Such research method of typological analysis by comparing the forms of archaeological artefacts in order to explore the regularity of its changes, the sequence of logical development and the interrelationship among them, can be applied to the archaeological objects that have a particular shape and last for a certain period of time. Therefore, typological analysis is widely used to study archaeological tools with relatively short life cycles and obvious appearance changes, such as pottery, porcelain, or stone tools. (Renfrew and Bahn 2012)

When scientific absolute dating techniques cannot be adopted - especially if only stone tools, pottery, metal artefacts or eco-remains are available (as is often the case) - the relative dating based on the forms or the patterns of objects collected from a site is achievable. A common example is the typological analysis of pottery.

Prehistoric pottery is usually presented as fragments in the stratum when they were found. The intact pottery is quite rarely seen during the excavation in Taiwan. As a consequence, an accurate classification system is needed for the study of pottery to gradually establish single pottery style on its evolution process and law, which is used as a criterion for identifying specific archaeological cultures. Taking the Yuanshan cultural pottery as an example, its unique features different from other pottery of archaeological cultures are shown in the form of its mouth and rim. If fragments with the aforementioned characteristics appear in the pottery cluster dug up from a site, archaeologists can recognise that the archaeological culture of the stratum has pertained to the Yuanshan culture. In other words, as long as a genuine and well-defined classification system with an operational consistency can be maintained, the classification criteria adopted in a single study are the best. Further, in theory, one of the goals of a systematic or analytical classification system is to reduce the ambiguity of category, because not all definable objects are valid archaeological types. (Huang 1997, Whittaker *et al.* 1998, Read 2007)

The same method applies to the classification of stone types. Although the appearance of utensils is the most common standard of classification, other attributes of a stone object are equally important. Odell (2004) employed four attributes as the classification criteria for stone tools: shape, technique, use-wears, and the type and position of refitting. In practice, researchers of stone tools usually follow the aforementioned criteria to arrange the classes of stone tools, and rarely focusing on one aspect and ignoring others. Although the shouldered axes in Taiwan are identified to be a unique and only exist in the Yuanshan cultural sites, most of the specimen is collected from the surface around/near the sites decades ago, the appearances and styles of them show slightly difference, and they have never been systematically examined and studied. Based on these reasons, this study will carry out a typological analysis of shouldered stone tools for sorting the basic form(s) of one or several shouldered artefacts of Yuanshan culture, and comparing their morphological diversity, and then speculate the production technique, evolution process and its probable origin.

Various scientific analysis methods have more or fewer limitations in practical use, and typological analysis is no exception. For example, it can only determine the logical sequence of the time that the artefacts appear in order. However, it is impossible to determine the specific age for the existence of a single type of archaeological objects. Secondly, it can only determine the relative time of the existence of the artefacts, not the length of the interval between each form of an object. Third, the variant forms and shapes of archaeological objects cannot apply the typological analysis method for the study. The last, typological analysis is an imperfect induction, the arranged sequences and the summarised discipline have certain assumptions. With the accumulation of new data gradually, the original classification criteria need to be supplemented or modified. In the case of insufficient data, it may not even reflect the actual situation on the typological classification at all, and it is necessary to re-queue the types after the data is added. (Chang 1999) In this paper, apart from the application of the typological analysis and the PCA analysis, both use-wear analysis of the stone tools and the experimental archaeology will be conducted at the same time to verify the production method and usage/function of the Taiwanese shouldered axes. Therefore, the experiments in this study are focused on the following questions:

- How are shouldered axes manufactured?
- What method or method(s) can be used to haft shouldered axes?
- What tasks can be undertaken with shouldered axes?
- Do different hafting methods and/or different uses generate distinctive use wear traces?

It is hoped that the production techniques and the usage of the shouldered axes could be learn through these methods in this study.

Chapter 3-4_METHODOLOGY OF USE-WEAR ANALYSIS

The understanding of the surface marks on stone tools is the most important foundation to quest the usage and function. Use-wear analysis is a powerful medium to study the cultural biography of stone tools for understanding lithic assemblages and human behaviour in ancient societies, which could promote the comprehension on the functional studies of archaeological tools (Akoshima and Kanomata 2015). Therefore, this study will employ the use-wear analysis to shouldered axes and focus on the wears of shoulder and the blade edge on the shouldered artefacts found in the Neolithic Taiwan. By applying the use-wear analysis to follow the production methods, and to explore the use and function of the shoulder and the shouldered tools.

Brief history of microwear analysis

Microwear analysis, in broad idea, is the microscopic examination of wears and scars occur on surface of artefacts which are difficult to observe or distinguish with the naked eyes. It provides information of the microscopic wear and fracture scar characteristics resulting from the usage of tool so that archaeologists could categorise systematically the worked material (e.g. hide, wood, meat, bone) and the application of force and motion (e.g. hafting, cutting, scraping). As early as in the 19th century, it was proposed to speculate the function of the stone by examining the surface traces of the stone tools. The was based on the observation of the shape/morphology of the stone appearance (Greenwell 1865, Evans 1872, Barnes 1932). In the early 20th century, Curwen employed the microscopic technique to observe the wears of stone artefacts for functional study (1930, 1935). Curwen used a normal magnifier to examine the surface wears of flint sickle, which the polishes of the usage trace were seen obviously. However, this method could not observe more finer traces, it was a non-mainstream research method at that time. It was not until the pioneering work of Semenov (1964) published groundbreakingly research results attracted the community attention, the method of microwear analysis was gradually accepted and applied by archaeologists on the functional study of artefacts (Olausson 1980, Evans 2014). Semenov recognised and documented the polish, striations, edge rounding and scarring on the surface of Palaeolithic stone tools, also the first person had systematically used microscopes to study these phenomena. Semenov stressed additionally the importance of experimentation for providing a reference collection with which to compare wear traces visible on archaeological objects. After that, the characteristics of the wear marks generated by worked materials are summarized to infer the use and function of the stone products.

After prospective work of Semenov, the differences in the application of microscopic techniques and the arguments caused by them marks another stage of the microwear analysis method expansion. The application of the microscopic technique refers to the magnification of low-power (optical microscopes) and high-power (metallographic microscopes) methods of using a single microscope device to observe the trace marks on the surface of an archaeological object. Examples of microwears analysis are studied in low or high magnification, the former has such as Curwen (1930, 1935), Semenov (1957), Odell (1975, 1980), Odell and Odel-Vereecken (1980), Shen and Chen (2001), the latter has Keeley (1974, 1980), Vaughan (1985), Wang (2005), Van Gijn and Lammers-Keijsers (2010), etc. The arguments between two technical applications are upheld by Odell and Keeley respectively, and each stand has proposed the traces of wear on the object that has been successfully identified. Odell recognised the characteristics of flake scars by using the low magnification. Whilst Keeley used the high-power method to examine the micro-marks of the flint tool and noticed the use-wear polish with identifiable characteristic features resulting from the different worked materials.

The debate of application between low and high-power magnification has been settled for years. It is considered that the choice of microscope magnification is based on favouring the purpose of microwear research, and now both channels considered as the complementary skills and the best practise working together (Olausson 1990, Hou 1992, Akoshima 2000, 2010, Midoshima 2005, Van Gijn and Little 2016, Wu 2017).

Experiment of microwear analysis

The most specific effective way to identify the trace marks typology and testing the hypothesised function by the microscopic observation technique on the tool surface is to carry out the experimental archaeological work (Renfrew and Bahn 2012). The purpose of the early microwear experiment was to identify the characteristic features of the trace, like the cause of polish (Suprrell 1892, Semonov 1964). However, the complexity and diversity of the microwear appearances on their holistic development are far beyond the current knowledge, for instance raw material of tool, processing types, worked materials, and motion patterns, all of which have a large impact on the formation of the traces and the function of the artefacts (Hurcombe 1988, Odell 2004, Wu 2017). Designing and conducting a series of well-defined microwear experiments to look carefully at the periodic changes in the trace marks, therefore, helps analysers grasp the microwears formation of integrated progress and the relations between them. Functional study of tool, the ultimate goal of microwear experiment, can be achieved by this, just like the work of Semenov.

The microwear experiment must be controllable. The experimental purpose, working materials, steps and results need detailed records and narratives so that the experimental process can be repeatable, and results can be compared and tested. The experimental results can be compared and tested. The experimental techniques employed will be selected based on the experimental objective.

Keeley and Odell all agree on that there is a possibility to achieve the research on the use-wear analysis of archaeological objects through controlled experimental methods (Keeley 1974, 1980, Odell 1975, 1980). Though they not only have different observation means at magnification selection, but also at the viewpoint of experimental purpose. Such as, Keeley believes that the purpose of trace experiment should sought to restore prehistoric working condition, including outdoor works, practising with ancient human behaviour (sheep-shearing), non-single action of tool (cutting or drilling), recording the effective completed work, etc. For the purpose of this experiment, the use-wear on the stone tool surface produced by different working behaviours will compare to the analytical results yielded from the other scientific methods, like principal component analysis and the typological analysis. The disadvantage is that the scarring on the edge of tool cannot be accurately verified. Odell accounts that, on the contrary, the experiments must be performed scientifically and repeatably, practising both at indoors or outdoors, demonstrating the tool actions and processed objects, using tools in the same way among the same experiment, documenting the state of movements (frequency or times) in detail, for example. Experiments of Odell clearly shows the whole process of use-wears development (e.g. scarring). The significance of the these microwear experiment is that, regardless of the success or failure, after an experiment is completed, it can be objectively stated, and the complete experimental process can be presented to other experimenters.

Whilst the microwear analysis method has raised controversy and reflective narratives, more and more scholars have participated in the field, which has led to a large number of experiments and tests. Series of experiments ever conducted by several colleagues display that both experimental techniques applied to the microwear study are important and complementary (Shea 1985, Levi-Sara 1986, 1996). For example, the experiments by Shea *et al.* (1993) discern the difference between the trampling marks of humans or animals and the characteristics of used scarring. These two types of experiments have had a tremendous influence today still.

Applications of microwear analysis

Most of the published literature on the use-wear research of the stone tools so far is mainly made of chert, studies on artefacts made of other rocks or from different raw materials (organic or inorganic objects) have being started around the 1990s, for instance, animal bones (LeMoine 1994, Christidou 2008, Li and Shen 2010, Wu *et al.* 2008, Shi and Wu 2011), shell or coral (Kelly and Van Gijn 2008, Tumung *et al.* 2015, Cuenca-Solana *et al.* 2017), pottery (Julien Vieugué 2014, Forte *et al.* 2018), metal wares (Andrea Dolfini 2011, Sáez and Lerma 2015, Dolfini and Crellin 2016), etc. Also, there are methods and insights of several established disciplines or field of study has been practised together with microwear analysis for seeking the functional research of the tool. Examples of applying residue and phytolith analysis means allow archaeologists to extend ability on the functional and paleoenvironmental study of tools apart from microwear method, because the extracted residue or phytolith of objects is capable to offer the knowledge of contact materials of tool and/or ancient environment where the object was buried at the time (Fullagar and Matheson 2004, Marreiros *et al.* 2014, Liu *et al.* 2017).

The identification of the micro-mark features has made more finer in observation means with the application of advanced developing microscope equipment to makes the acquisition of information on the tools with no need for casting or sample preparation, such as applying the laser scanning microscopy technique to document the 2D or 3D images of marks pattern or formation process on the examined object type (Macdonald and Evans 2014, Ollé and Vergès 2014, Little *et al.* 2016). Or using dental impression method to obtain the microwears from the edge of stone artefact and read the traces directly under microscopes (Liu *et al.* 2017). There are also colleagues employ digital microscopy with depth of field function which could measure and capture the image of the surface marks on the examined tool in order to getting the 3D data for establishing a digital model to analyse surface traces on animal bones or stone tools (Yang *et al.* 2008, Wu *et al.* 2008, Wu *et al.* 2009). The system functions of digital microscopy constantly being modified and developed, enable archaeologists to extend the ability on the microwear analysis of archaeological study. Using digital microscopes for archaeological objects research among Taiwanese community has also begun in recent years. The study of observation on the pottery making traces employed the digital microscope by Wu (2017), a researcher at the National Prehistoric Museum in Taitung, is the first published literature of its use.

The field of microwear analysis has been unceasingly progressed and matured in methodology and technology and has become an indispensable part of archaeological research and a widely employed means of functional research of tools.

Problems and solutions of microwear analysis

Microwear analysis research enables archaeologists directly imitating ancient activities with a considerable potential to reconstruct past human behaviour. Lacking widely accepted methodological standardization framework and effective interpretation are the key problems restricting capability of microwear analysis, which need to be overcome by analysts to facilitate the methodological framework construction and explanation of human behaviour through microwear analysis. Microwear analysis method is on constant learning curve. Manifold perspectives or approaches on methodological refinement and raising reliability of outcomes can be achieved by the efforts from members in academic community.

First, increase the overall understanding of the developmental process or formation of wears and the identification criteria for individual traces, such as whether the post-depositional wears are acceptable for microwear analysis, and what the identifiable criteria are if accepted then. Work of Donahue and Evans (2012) provides some methods for clarification and develop protocols to improve the standardization of practise for laboratory jobs. Ollé and Vergès (2014) advocate the accumulation of experimental designs, using repeatedly the same set of experimental tools over a set period of time, analyzing same set of experimental tool assemblage, enabling performers directly observe the development of wears on the same instrument at long-term use. The second is to make a good use of new technologies and techniques to elaborate acceptable standards for the analytical approach of quantitative based or visual evidence. For example, the use of high-end equipment, such as laser profilometry or laser scanning confocal microscopy, to supplement the existing analytical techniques, to increase the accuracy and precision of microwear data as a benchmark for quantitative assessment (Evans and Donahue 2008, Evans et al. 2013, Stemp 2014).

The last, the consistent and effective standards for support the reliability of microwear analysis study are serious in need of being developed, including well-defined terminology, quantitative analytical method, and recognised practise protocols, etc. Evans (2014) proposes an agreement to develop reliable calibration standards and analytical frameworks to improve methodological accuracy of consequents and to help researchers interpret effectively of results. For example, the blind test data is used as a basis for quantitative analysis to evaluate and compare the meaning of taxonomy and interpretation of various traces. Or overt each step and result of microwear experiments and offer definition of terms used and micro-images taken, so that allows readers to get a clear picture of various trace patterns and the experimental progress as a ground for follow-up study on the functional study of tools or human behaviour mode (Adams 2014, Van Gijn 2014, Evans 2014, Evans *et al.* 2014, Rots 2010, 2015a,b, Coppe and Rots 2017).

In addition, the resource sharing, experience dialoguing or reflection on the status quo of the research among analysers is also beneficial to promote the advance maturity and development of the microwear analysis on methodology and discipline. Van Gijn (2014), for instance, emphasizes the importance of quantitative analysis method and ethnographic data to microwear study. The establishment of Association of Archaeological Wear and Residue Analysis (AWRANA http://awrana.com/) and several seminars held offers a good place to share opinions among analysts or colleagues as well.

In short, the developmental process of microwear analysis method on functional study of tools has been questioned and controversial by sceptics incessantly. Researchers respond those doubts by making efforts continuously on a series of strictly controlled experiments and blind tests for refining the accuracy and validity results and formulating the methodological standardisation, making it the mainstream technique for the tool usage research in one of archaeological methods.

Status of microwear research in Taiwan

Currently, the study of surface wears on Taiwanese stone objects depends on the visual observation either by microscopic examination. Hung (2000) has observed the use wear on the edge of stone adze by conducting the optical microscope and SEM-EDX analysis and found the linear marks on the backside of adze. Accordingly, Hung surmising the most probable use for adze is as a woodworking tool or, a planer tool for processing the animal skin to produce the leather. Kuo has observed the striation of the annular notch on the quartz sandstone by the optical microscope. Kuo (2014b), then, proposes a theory on the rotating cutting technology and rotating machinery movement for the nephrite artefact manufacture techniques from the result of use wear observation. Both adopt the Low power magnification by the optical microscope for the use wear observation on the stone tool surface. Ke (2016) uses the microwear analysis means to explore the function and usage of the stone knife of Tahu culture in the late Neolithic age. All agree that performing the experimental archaeology is necessary to verify the hypothesis of the use wear analysis on the artefact usage.

In this study, the surface traces of the examined samples were observed with a digital microscope at a magnification between 10X and 200X for systematic recording, quantitative assessments, and discussed correlation between the typology and usage of shoulders, and then inferred the functional use and production method of shoulders and shouldered axes. Again, the following questions need to be answered in this study: How are shouldered axe made? Is the shouldered axe hafted with the handle for use? Do different binding methods produce different traces on the shouldered axe? What is the function of the shouldered axe?

The focus is centred on the morphology of surface traces left on shouldered axes, such as edge damages, striations and rounding polish. Because the majority of shouldered axes are made of andesites which are easily weathered and left small amount of traces on stone surface. It must be noted that the shouldered artefacts are slightly polished stone tools. The polishing and rounding surface may be the traces of the process on manufacturing or using, which is not easy to distinguish. Per the surface condition of 16 shouldered tools and the research experience on the rotating cutting technology working, the low magnification technique on the use wear inspection and the experimental archaeology will be applied in this project for exploring the manufacturing techniques and usage of shoulder, the function of the shouldered artefacts.

The equipment used in this study is UPMOST UPG650 USB digital microscope, the standard magnification is at 10-200 X working with the image sensing component of 1/4" Colour CMOS. The digital microscope is directly connected to the computer via USB and operated for microwear observation or images taking. Digital microscopes have many advantages that are beyond the optical microscopes used in the laboratory, easy to carry, low-cost, built-in photo and/or video function, and can be directly operated on a computer (PC or Mac operating platform) or tablet, mobile phone (iOS or Android), no need to prepare a camera or charging device, etc. It is ideal for researchers who need to move around in fields or museums to collect the data from artefacts for further detail analysis.

Chapter 3-5_METHODOLOGY OF EXPERIMENTAL ARCHAEOLOGY

Nature of experimental archaeology

Experimental archaeology, as the name suggests, is the application of modern experimental analytical methods to explore archaeological processes and questions. Mathieu (2002, pp.1) defines experimental archaeology as a 'controllable imitative experiment to replicate past phenomena…in order to generate and test hypotheses to provide or enhance analogies for archaeological interpretation'. The research content of experimental archaeology includes not only physical characteristics of materials, but also issues such as human behaviour, beliefs and values, and/or the wider socio-political context (e.g. institutions and systems).

In the late 19th and the early 20th century, with the general archaeological focus on the identification and classification of the properties of artefacts and on the chronological sequences of archaeological cultures, it is the curiosity of human nature on the production and usage of archaeological objects with the imagination and conjecture. This curiosity drives humans to pursue the understanding of the process and methods of making tools, for example, the Aurignacian blade has been studies by Martin (1906). Experiments exploring artefact production and use were common during this period. The research purpose and the method used in such type of experiment was mainly based on the desire of understanding and sequencing the manufacture and function of artefacts. With the improved development of archaeological techniques, analytical methods and research theories, experimental archaeology has gradually become a more valued component of the discipline, and more standardised in its approaches. Such as the experimental result provided by Shea and Klenck (1993) is meaningful to understand the trampling traces caused between the human and animals which the appearance of stone tool will be changed.

In the broadest sense, the term experimental archaeology encompasses all experiments that address archaeological matters (Coles 1979). According to Coles, experimental archaeology generally focuses on (1) understanding the techniques and functions of artefact production, (2) restoring structures based on above surface or underground archaeological features, (3) studying the destruction of buildings and the decay of goods, and (4) understanding agricultural activities and resource management. To be more precise, experimental archaeology is a systematic methodology designed to test, evaluate, and interpret the methods, techniques, presuppositions, assumptions, and theories applied at any level of archaeological research. It is a viable discipline that can generate a better understanding of what happened in the past.

Design of experimental archaeology

A good experiment depends on the researcher’s mastery of the technique(s) and a feasible experimental design. Experimental design refers to the designed task that aims to describe and/or explain the variation in some or all of the experimental materials, under conditions that are hypothesized to reflect the archaeological past, in whole or in part. It is generally correlated the experiments with the assumed conditions that directly affect or influence the variation are selected for observation. The factors or variables affecting the experiment must be carefully deliberated, and the observed changes and measurements should be recorded in detail, for example, the practicing time and the change of form of the applied object. Repeating the experiments to test whether or not the initial experimental results are replicable, and representative is an important aspect. Quantitative datasets generated from repeated experiments are critical for statistically robust analyses. Consequently, the time spent on the experimental planning stage is often longer than the experimental operation phase(s).

When and what needs to be recorded is an integral part of the experimental design. All these issues are defined by the overarching archaeological questions and are influenced by the experimental conditions. Through archeological issues and corresponding restrictive experimental conditions, the tasks of archaeology that can be answered by experimental archaeology are relatively unitary, but it is the answers to the topics with the possibility by confirming or excluding. For example, the manufacturing method of the shoulder on the shouldered axe is whether grinding the raw rock on a large grindstone or using another tool to grind it, in particular the hand-held grindstone. The manufacturing method of the stone axe can be excluded or decided via experiments. If the experimental archaeological work can be carried out continuously and systematically and accumulate a variety of possible outputs, it can provide extensive insights into an individual object’s life history. For example, experimental archaeology aids interpretation of archaeological materials, such as the use-wear research on the surface of stone tools and pottery, or provide quantified data, such as the weight of meat and other products that can be acquired from different animals. The experimental results given by shea and Klenck (1993) aforementioned provide the significant explanation on the effect of trampling on the transformation of the traces on the stone tool. Experimental archaeology can also show how natural processes influence the formation of archaeological sites. Banerjea *et al.* (2015) study activity residues and sediments in the experimental buildings at Buster Ancient Farm, St. Fagans and Lejre to understand the formation process of archaeological sites, and the influence of the post-depositional alteration occurred in the buildings.

Concisely, archaeological experiments are underpinned by hypothesis testing, related to an outstanding question from the archaeological record. Experiments can accurately reflect the environmental conditions of past scenarios, by using practical methods and materials that were available during the archaeological period under investigation. All materials and methods in the experiments must therefore relate to both the hypothesis and to the archaeological period. All materials and methods in the experiments must therefore relate to both the hypothesis and to the archaeological period. The resulting experimental interpretations arising the experiments can be applied to archaeological explanations.

Examples of experimental archaeology in global and Taiwan

There are many different topics/issues for different stone tool experiments which are seeking the probable explanations, such as the impact of trample on the post-depositional movement of artefacts in the archaeological site, the relationship between the choice of raw material and the ease of production, or the characteristics of the hafting traces from the usage of stone tools. The following are case studies of the experimental archaeology work on stone tools in the world. Ben Marwick (2017) trampled experimentally produced flaked stone artefacts into sediments excavated from Malakunanja II to show that it was unlikely that they had moved extensively through the deposit during the Pleistocene. Killian Driscoll (2011, 2016) undertook an experiment to examine the ease of identification of quartz stone tools; and compared this experimental result to the trampling effects on flint tools. Veerle Rots (2001, 2010, 2014) conducted aa series of hafting experiments to generate traces of hafting practices: this database of experimental marks enabled archaeologists to identify or characterize the use-wear produced from the usage of archaeological stone tools.

In Taiwan, experimental archaeology has developed slowly since 1990. In the study of stone tools, the first Taiwanese research applying experimental archaeology is Liu's master dissertation in 1990. Liu focus’ was on the manufacturing methods of Peinan Culture arrow and spear heads. The experiment itself is very successful in completion of process although the length of the experimental description in the dissertation is limited. Another master’s dissertation, written by Lin (1996), is the first research literature based on the experimental archaeology method. Lin mainly engaged in percussion experiments on various pitted peddle stone items of the

Shihsanhang Culture and inferred the possible usage of the pitted peddle stone tools by comparing the traces of the wears found on the surface of the archaeological artefacts with the results of the experiments. Yin (2008) employed an experimental archaeology methodology on a master's dissertation study of rotating cutting technology of nephrite artefacts, using the objects unearthed at the Pinglin site as control samples.

In addition to experimental archaeological results in the form of written dissertations, Tsung *et al*. (2017) presents a preliminary study on the production and utilisation of stone flake tools at the 2016 Taiwan Archaeological Annual Meeting in a poster and video format. The latter presented the process of experimental archaeology in the form of visualisation, which can reinforce and complement the texts which can fail to describe one-by-one performances and actions during the experimental process. It is worth mentioning that outside of the archaeological community in Taiwan, scholars from other disciplines regularly conduct similar archaeological experiments. Professor Hsien-Ho Tsien (2003) of Department of Geosciences, National Taiwan University, performed experiments on prehistoric nephrite artefacts and published the results of research, for example, the production tools to make the jade artefacts, manufacturing process and the production techniques. Archaeologists benefit from the various perspectives and fields of jade study across the inter-disciplines, including the outcomes yielded from the geosciences study like Tsien.

The increasing experimental archaeological literature is encouraging further engagement of researchers with experimental approaches. A critical need in experiment archaeology is for full publication of experimental methodologies and results, so that it is available to the academic community for reference and/or so that other researchers can attempt to replicate experiments. Open-access experimental data is a key aspect of this process. (Bell 2009)

Tasks of experimental archaeology in this study

Outram (2008) summarises briefly the five major backbone of experimental archaeology, based on Reynolds' key definition in 1999. The experimental goal of this study is the second of the aforementioned five classes of archaeological experiments: processes and functional experiments.

As noted above experimental replications of manufacturing and function can support the testing of specific hypotheses. Preceding discussions of the surface marks on the blade edge of the shouldered implements from Chanlungshan site suggested that the edge wear seems most likely to be derived from the application of the edge to soft object(s) and being used as a hoe. Besides, the hypothesis of the prevalent fashion on shoulder design from Kuo is a new perspective on the shouldered tool research. (Kuo 2014a) Kuo’s hypothesis can be tested through experiments to see if the production technology of the shouldered axe can reflect the popular style at that time. The procedures to perform experimental archaeology are as follows:

- A selection of raw material of andesite and sandstone from Taiwan.
- Making 2 replicas of shouldered axes with different shoulder types.
- Haft the experimental axes (two shoulder types) using two different techniques. (Fig.3-5-1, 3-5-2)
- Undertake use experiments with the shouldered axes, working different materials (e.g. plants and soils) and using different motions (e.g. hoeing, chopping and root cutting).
- Recording the experimental data: all the experimental activities (replication and use) will be recorded by digital video (including timings data and participants' commentaries). Wears on the shoulder (arc-shaped) and the blade edge will be recorded and analysed microscopically.

The design of the experimental content is divided into two parts. The first part is the replication of experimental objects, including shouldered axes, cordage and wooden handles. The second part is the actual operation exercise of experimental replicas. For the selection of materials for the experimental tools production, wooden handles and nettles are collected locally at or in the vicinity of the University of Reading. The choice of stone raw materials is based on the rocks commonly used to make the shouldered axes in Northern Taiwan, which are the andesite, sandstone and shale. Andesites are collected from the Yangmingshan National Park where is situated the geological area of Tatun Volcano Group, one sandstone is picked in the adjoin area on the outcrop of sandstone bedrock where the Yuanshan Site now situates on it. Shales and another sandstone used as ground stone come from the Geology Collection of University of Reading.

The second stage of the practising experiment is expected to receive the practical experience on the use of materials and motions of shouldered axe. Works in the field subject to the time factor, the usage experiment of shouldered axe will be undertaken on the material of soil as well as the using motion of hoeing. All the activities data will be recorded by photos and compared the traces on the shouldered axe yielded from hoeing activity to those data I collect, to see if the use-wear matched.

Fig. 3-5-1 Hafting Mode 1

(Drawing by Li-Chi Chiang)

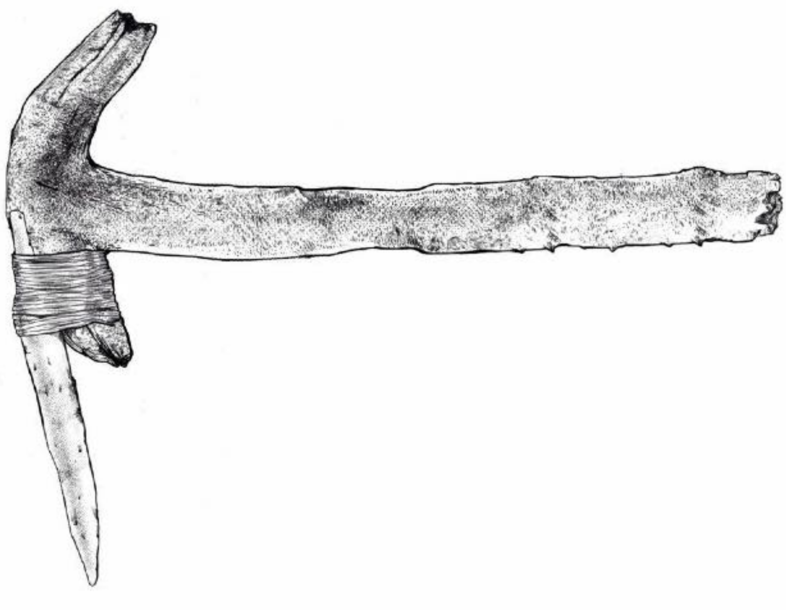


Fig. 3-5-2 Hafting Mode 2 (Drawing by Li-Chi Chiang)

Chapter 3-6_METHODOLOGY OF PHYTOLITH ANALYSIS

Introduction

Phytolith commonly refers to siliceous botanic remains, which are made of silica and found in plant tissues which remains in the soil after the organic matter decomposition. Phytolith analysis is a study of silica particles developed in higher plant cells. The size and shape of phytoliths are related to certain plant species and parts, and their morphology has the significance of identification, especially Poaceae plants (grass family. It is a discipline of palaeobotany and an integral part of archaeobotany and environmental archaeology as well. Study of phytolith has been more than 180 years of history, this long course of research has briefly summarised into stages by Piperno (2006) and Hart (2016) according to the expansion and growth of knowledge with disciplines. And it is valued and applied by the archaeologists for over 50 years. This is common in most disciplines in recent years, due to the development of hardware and software technologies and the development of phytolith systematics and taxonomic paradigms is a challenge for the discipline. However, research contents of archaeological materials have gradually become mature and several databases of phytoliths taxonomy have been established. Meanwhile, research topics and directions have also been expanded into other field, for example, forensic botany. The research of phytoliths analysis employed to archaeological study, therefore, has progressed and increased substantially in quantity and quality. (Hart 2016, Zurro *et al*. 2016)

Principle

Plant phytoliths formation is based on the principle that certain plants absorb soluble silicon dioxide (SiO_2) from the groundwater in the soil through the root system and are transported via vascular bundles and appear as silicon dioxide at the intracellular or extracellular structure of plants. After the plant cell decayed, the insoluble silica which known as phytolith, thus replaced the original form of the plant structure (Piperno 2006). Such the formation of insoluble silica accounted for more than 90% of the total silica of plant. The morphology of the insoluble silica is shaped as to the original plant cell and the interspace between the cells as the form they were. Different plants or different parts of the same plant, the forms and characteristics of phytolith are distinctive. Phytolith analysis, thereupon, is taking advantages of the characteristics of phytolith with high residuals and the type of specificity, to infer the family and genus of plant, sometimes even trace down to the species level through morphometric analyses. (Ball *et al.* 2016) It can be said that the morphology of phytolith may contain plant taxonomic significance, although the taxonomic classification is often difficult.

Characteristics of phytolith analysis and application in archaeology

From the perspective of chemical physical point of view, phytoliths are small in size (range between 2-2000 μm, normally between 20-200 μm), high in yield (about 200,000 phytoliths in 1 gram of rice leaves), resistant to burnt (melting point at 950°C), weathered-resistance, acid and alkali-resistance (PH value at or below 9, silicate solubility free from affected), refractive index ranging from 1.41 to 1.47, higher in the specific gravity (1.5-2.3), etc. (Piperno 2006) In addition, phytolith can also be used for C14 dating or detection of environmental chemistry elements. However, it must be aware of the form of phytoliths will change after being burnt. In short, phytoliths are widely found in monocotyledonous and dicotyledonous plants and are not subject to the bacterial decomposition. And it is easy to be preserved in kinds of environmental condition, even presence after burnt (Hsu *et al*. 2006, Tang 2004, Piperno 2006).

Similar to other microfossil analysis such as the pollen analysis for studying paleoenvironment and ancient plants, the application of phytoliths analysis can complement and supplement other sources of palaeobotanical dat. First of all, most of the phytolith are deposited in the soil sediments. It can easily access and collect the soil samples from the sediment layers in the site. Unlike the lightweight pollen which is suitable for a wide-ranging palaeoenvironment research and easily carried with the wind for miles, phytoliths are sampled from the site where they buried and contributed to the study of specific or smaller ancient environment. Secondly, the pollen morphology of some species of plant is difficult to recognise due to the similarity of their forms, for example, the grasses that have a high correlation with human activities. However, the phytolith analysis identify mainly grasses and it is a considerable method that can complement the shortcomings of pollen analysis in plant identification. In general, the results on the identification of phytolith in Gramineae plants is higher and much successful than woody plants. Among the cultivated plants, Gramineae, Compositae, Sangke, Pepper, Urtica and Plants of the Rosaceae can produce abundant and significant classifications of phytolith (Kondo and Sase 1986, Chen 2006, Kang 2013, Lee 2014).

Last, the nature of phytolith is resistant to most depositional and post-depositional processes and can be found in stable and resistant to weathering and decomposing with no difficulty, so that can be found in soil, pottery, stoneware, ash pits, fire ponds, human or animal teeth and faeces in the archaeological sites. Resistance to high temperature of phytolith also can be applied to the study of plant remains from the site located in the volcanic area, or to the clay sample taken from the pottery for learning phytolith analysis. (Osterrieth *et al.* 2009) As a result, method for learning phytolith analysis is diffusely employed by archaeologists with the research topics related to, such as the nature and transformation of paleoenvironment of site, origin and dispersal of the domesticated crops, development of agricultural cultivation, the availability of wild plants and the economic strategy, and further to the relations among the technical and social organisations, etc. Apart from archaeology, the method of phytolith analysis is well accepted and applied mainly in the disciplines of botany, soil science, geology and agriculture.

Limitations and challenges

Current knowledge of all kinds of plant phytolith is still insufficient comprehensive, the phytolith systematics or taxonomy is still one of the bid challenges facing the discipline. For instance, the recognition on the type of phytolith in woody plants is less ideal than Gramineae plants. Sometimes the similarity of phytolith morphology between plants with only subtle distinction, it makes the work of plant type identification hard. Among the disadvantages, Over-representation of grass relative amounts due to differential phytolith production, grasses and monocots in general produce large quantities (Tsartsidou *et al.* 2007). Moreover, existing research procedure of phytolith are vary (including on-site soil sampling, application of equipment techniques, data presentation and illustration, etc.), and the interpretations of the research outcomes naturally shows a discrepancy. So that the academics recommend, that establishing a set of feasible standardised agreement or protocol of phytolith study and, sharing research findings publicly and accepting checking from other experts, is imperative (Zurro *et al*. 2016). There are currently some active databases of phytoliths online for share, reference and discussion by scholars in the world, which offers a critical achievement in phytolith research of archaeological and comparative studies, such as the Plaeoethnobotany Laboratory from University of Missouri (http://phytolith.missouri.edu), the PhytCore DB (Albert *et al.* 2016) (http://www.phytcore.org/) and the Old World Reference Phytoliths from the University College London (http://www.homepages.ucl.ac.uk/%7Etcrndfu/phytoliths.html), etc. (Hart 2016, Lee 2014). Works of ethnoarchaeology and experimental archaeology, as well as the identification results of phytolith analysis, can also exploit as a comparative study to understand the relationship or interaction between human activities and the ecological environment. (Lu 2016, Friesem 2016) It is obviously that the quality and quantity of phytoliths research is promising in a potential growth of regular, rich and mature through the online database expansion of phytoliths contents and data sharing, as well as the comparative study across interdisciplinary.

Phytolith study of Asian rice and the application in Taiwan archaeology

Although phytolith study of plants needs to further its efforts continuously in plant morphological identification and classification in general, the morphology of phytoliths in the Asian rice has significant features, and a set of identification criteria has been evolved. Research of phytolith analysis is widely applied by scholars in judgement Asian rice species.

Ball *et al.* (2016: 39-40) review the phytolith research of Asian rice plants for past two decades and summarise the results from those studies. Three morphotypes of phytolith are recognised in different location of rice cells, which are the double-peaked glume from the husk, bulliform (fan-shaped or cuneiform) from leaves, and articulated bilobate from stems and leaves. Double-peaked glume phytoliths in particular, is a distinctive morphology of the genus Oryza which is capable differentiate domesticated rice from the nine wild rice species of South and Southeast Asia.

Since year 2000, Taiwanese archaeologists start to apply the phytolith analysis in the unearthed plant remains from archaeological sites except for the method of pollen analysis, and gradually disclose the outcome of the phytolith analysis study.

Research is targeting mainly to rice and farming tools which are closely related to agricultural activities of human beings, such as stone knifes. Scholars use phytoliths extracted from the soil or pottery to verify the presence of rice remains in the archaeological site, and so that to identify the rice species by the phytolith morphology. Phytoliths analysis research offers a new path related to the study of farming in ancient Taiwan. Xu *et al.* (2006) conduct phytolith analysis which the phytoliths of plant were extracted from the soil samples collected from the Huilai Site in Taichung City, found and recognised that many bulliform phytoliths were derived from the plant of rice. This research result, then, is presented to the Annual Conference of Taiwan Archaeologists in 2006, and a pioneer study of phytolith analysis application in Taiwan archaeology. Chen (2006, 2009), Lee (2010) and Kang (2013) extracted phytoliths from fragments of pottery, and also identified the fan-shaped phytoliths of rice presence. Chen even starts a database for collecting various fan-shaped phytoliths of plants which are related to the study of archaeobotany and palaeoenvironment in Taiwan since then. Lee *et al.* (2015) compare the fan-shaped phytoliths of rice from the archaeological sites in both east and west of Taiwan, shows that the species of rice on the east and the west of Taiwan dating back 4,000 BP. are different. Phytolith morphology of rice from eastern Taiwan is partial towards the Oryza sativa subsp. Indica, whilst the western rice is more like the Oryza sativa subsp. Japonica. The result provides an idea of the divergent origins of species of Oryza sativa in Taiwan in 4,000 BP. Liao (2016) finds a small amount of Miscanthus phytoliths extracted from the sediment samples and stone knifes by employing the starch grain analysis on his research of examining the function of stone knife as a farming tool for rice harvesting instead. Deng *et al.* (2017) found evidence of rice domestication in eastern Taiwan as early as to 4200 B.P.

It is undoubtedly that the ancient rice issue is one of the important topics in Taiwan archaeological study by applying the phytolith analysis, which given the outcome shown on the studies above. It is not only a research for learning the rice family of domesticated and wild itself, but also the answer to questions related to the origins, migration and dispersal of cultivated rice in Taiwan. Therefore, the use of phytoliths analysis method in Taiwan archaeology is a potential favourably means to link the plant remains discovered in archaeological sites with relationships between the prehistoric plant remains and human activities. The archaeological research object in this dissertation is the shouldered axe of the Yuanshan Culture, which has long been considered to be related to the agricultural rice cultivation. Lee *et al.* (2016) presents their findings of C3 plants which are contributed substantially to the dietary of Yuanshan people. Interestingly, their work may be related to this study. The method of phytolith analysis will be used to reply the supposition of whether shouldered axes has the agronomic function as past researches proposed. However, considering only two samples of the shouldered axe and one sediment sample can be examined for the phytolith analysis in this study, it will focus on the potential contribution to delineating tool use, including in agronomic function.

In order to attain the results of the aforesaid objectives, this experiment adapts the method of rapid phytolith extraction for analysis of phytolith concentrations and assemblages, which enables to determine the phytolith concentrations and morphotypes within hours (Katz *et al.*, 2010). This experiment is going to collect sediment samples from shouldered axes and the sites unearthed the stone tools for comparative research of microplant remnants. Phytoliths analysis can be applied to deduce the environment and plant species at the time of the site's occupation. In addition, the comparative analysis of phytoliths morphotypes in both the experimental group (shouldered axes) and the control group (site sediment) can provide the expected information for the different environments of stone artefacts and their buried area. The latter, therefore, can be used as a principle for discriminating whether stone tools worked in respective environmental conditions, such as farming land.

Chapter 4-1_RESULTS OF RADIOCARBON CHRONOLOGY

The first radiocarbon dates for Yuanshan Culture were obtained over 40 years ago by testing marine shell and bulk charcoal samples discovered at the Yuanshan Shell Mound and the Yuanshan Cultural layer of the Tapenkeng Site (Sung and Chang 1964, 1966; Table 4-1-1, Lab No. Y-1498, Y-1551, Y-1547 to Y-1549). The results showed a difference between the start of the Yuanshan Culture at these two sites of ~1300 years, with dating evidence suggesting that the shell mound represented the earliest phase of Yuanshan Culture at Tapenkeng.

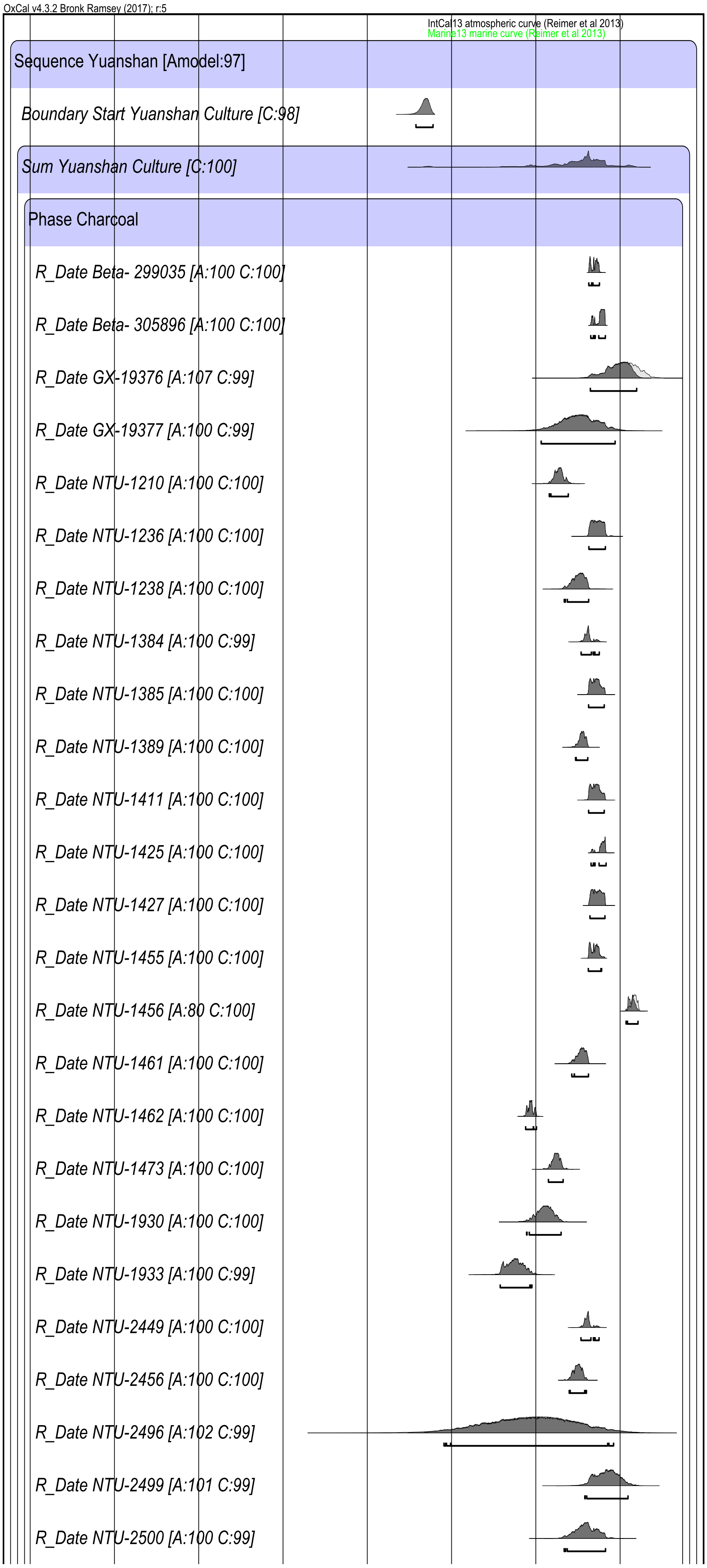
This study has re-calibrated the existing radiocarbon dating data from Yuanshan Culture sites consisting of eight marine shells, 53 bulk charcoal samples and one sample of unburnt wood (NTU-3205, Table 4-1-1), to establish a revised chronology of the Yuanshan Culture using the Bayesian modelling method (Bronk Ramsey 2009). In addition, a new AMS ^{14}C date (Beta-480358) obtained from charcoal from the preceding archaeological culture (Hsuntangpu Culture) collected at the Chihwuyuan site excavation in 2015, provides a comparator to establish the timing for the start of the Yuanshan Culture (Table 4-1-1).

Lab. No.	Site	Layer or Depth(cm)	Material	^{14}C (BP)	Cal BP (95.4%)	δ ^{13}C (‰)	Reference (s)
NTU-2863	Yuanshan		Shell	6310±40	*6710-6420*	-	Huang *et al.* 1999a
NTU-2864	Yuanshan	P5 L2d, 46-56cm	Shell	3760±40	*3670-3380*	-	Huang *et al.* 1999a
NTU-xx1	Yuanshan, Locality2		Shell	4220±60	*4350-3920*	-	Huang 1989
NTU-xx2	Yuanshan		Shell	3830±50	*3800-3440*	-	Huang 1989
NTU-xx3	Yuanshan	62cm	Shell	3510±50	*3390-3050*	-	Huang 1989
Y-1547	Yuanshan		Shell	3860±80	*3880-3430*	-	Sung and Chang 1966
Y-1548	Yuanshan		Shell	3540±80	*3490-3020*	-	Sung and Chang 1966
Y-1549	Yuanshan		Shell	3190±80	*3080-2660*	-	Sung and Chang 1966
Beta- 299035	Tayuanchienshan	B-T1P6 L23c	Charcoal	2520±30	*2750-2490*	-	Kuo 2014
Beta- 305896	Tayuanchienshan	C-T2P8 L6a	Charcoal	2420±30	*2700-2350*	-	Kuo 2014
GX-19376	Tutikungshan		Charcoal	1945±300	*2710-1600*	-	Chen 1994
GX-19377	Tutikungshan		Charcoal	2815±355	*3880-2110*	-	Chen 1994
NTU-1210	Tandi		Charcoal	3220±90	*3690-3220*	-	Chu 1990, Liu *et al.* 2004
NTU-1236	Tandi	0.2-0.8cm	Charcoal	2460±90	*2750-2350*	-	Chu 1990, Liu *et al.* 2004
NTU-1238	Tandi		Charcoal	2830±120	*3330-2740*	-	Chu 1990, Liu *et al.* 2004
NTU-1384	Tutikungshan	P1 L5-L6	Charcoal	2640±70	*2930-2490*	-	Liu 1992
NTU-1385	Tutikungshan	P7cex L6	Charcoal	2510±70	*2750-2370*	-	Liu 1992
NTU-1389	Tutikungshan	P7ex L11	Charcoal	2790±60	*3060-2760*	-	Liu 1992
NTU-1411	Tutikungshan	P7cex L8	Charcoal	2510±70	*2750-2370*	-	Liu 1992
NTU-1425	Tutikungshan	P7d L14	Charcoal	2380±40	*2690-2330*	-	Liu 1992
NTU-1427	Tutikungshan	P11b L9	Charcoal	2460±60	*2720-2360*	-	Liu 1992
NTU-1455	Tutikungshan	P7cex L10	Charcoal	2530±50	*2760-2430*	-	Liu 1992
NTU-1456	Tutikungshan		Charcoal	1750±50	*1860-1570*	-	Liu 1992
NTU-1461	Chanlungshan	P11 L2-L4	Charcoal	2790±90	*3150-2750*	-	Liu 1992
NTU-1462	Yuanshan		Charcoal	3760±40	*4250-3980*	-	Huang 1992, Kuo 2014
NTU-1473	Yuanshan		Charcoal	3280±80	*3710-3350*	-	Huang 1992, Liu *et al.* 2004
NTU-1930	Tutikungshan		Charcoal	3490±150	*4220-3390*	-	Chen 1994
NTU-1933	Tutikungshan		Charcoal	4010±140	*4850-4090*	-	Chen 1994
NTU-2449	Wanlichiatou	TP1L 6, 70cm	Charcoal	2650±70	*2930-2490*	-	Liu 1997a
NTU-2456	Chihshanyen	F08.B.S. ext. L6 210~220cm	Charcoal	2870±70	*3210-2790*	-	Liu 1997b, Kuo 2014
NTU-2496	Chihshanyen	TP3 L7	Charcoal	3610±860	*6180-2150*	-	Kuo 2014
NTU-2499	Chihshanyen	P6 L2a	Charcoal	2270±220	*2840-1810*	-	Liu *et al*. 2004
NTU-2500	Chihshanyen	P6 L2b	Charcoal	2690±190	*3330-2340*	-	Liu 2000, Liu *et al.* 2004
NTU-2505	Chihshanyen	F06.D. L2, 155cm	Charcoal	2970±40	*3320-2990*	-	Liu 1997, Liu *et al.* 2004
NTU-2539	Yuanshan	P8 L5d, 217-229cm	Charcoal	2600±40	*2790-2500*	-	Huang *et al.* 1999a, Chiu *et al.* 2010
NTU-2541	Chihshanyen	F08.B.S. ext.	Charcoal	2970±100	*3380-2870*	-	Liu 1997

		L8, 230cm					
NTU-2543	Yuanshan	P5 L3b, 60-70cm	Charcoal	2930±70	*3330-2870*	-	Huang *et al.* 1999a, Chiu *et al.* 2010
NTU-2544	Yuanshan	P6 L5b, 125-135cm	Charcoal	2330±60	*2700-2150*	-	Huang *et al.* 1999a, Chiu *et al.* 2010
NTU-2545	Yuanshan	P8 L7b, 269-274cm	Charcoal	2640±50	*2870-2540*	-	Huang *et al.* 1999a, Chiu *et al.* 2010
NTU-2546	Yuanshan	P8 L4d, 178-188cm	Charcoal	2590±110	*2920-2350*	-	Huang *et al.* 1999a, Chiu *et al.* 2010
NTU-2857	Chihshanyen	TP3 L3	Charcoal	2790±110	*3220-2730*	-	Liu and Kuo 2000
NTU-2861	Chihshanyen	TP3 L3	Charcoal	2950±70	*3340-2890*	-	Liu and Kuo 2000
NTU-2870	Yuanshan	P8 L6b, 240-250cm	Charcoal	2700±40	*2870-2740*	-	Huang *et al.* 1999a, Chiu *et al.* 2010
NTU-2871	Yuanshan		Charcoal	4130±150	*5210-4160*	-	Huang *et al.* 1999a
NTU-2933	Yuanshan		Charcoal	3650±100	*4290-3690*	-	Huang *et al.* 1999b
NTU-2993	Chihshanyen	TP3 B-d L3e-F2, 91cm	Charcoal	2620±140	*3060-2350*	-	Liu 2000, Liu and Kuo 2000
NTU-3205	Yuanshan	P8 L8b, 285-298cm	Wood	2650±40	*2850-2730*	-	Huang *et al.* 1999a, Chiu *et al.* 2010
NTU-3207	Yuanshan	T10L6, 90cm	Charcoal	2810±70	*3140-2760*	-	Huang *et al.* 1999a, Chiu *et al.* 2010
NTU-3211	Chihshanyen	TP3 B-d L3e, 91cm	Charcoal	2390±130	*2760-2140*	-	Liu and Kuo 2000
NTU-3224	Yuanshan	P6 III D L4b, 208-218cm	Charcoal	2950±110	*3390-2840*	-	Huang *et al.* 1999b
NTU-3889	Tayuanchienshan	TYCS-P1	Charcoal	2750±30	*2930-2770*	-	Kuo 2014
NTU-4789	Tayuanchienshan	TP1 L3a F1-L2 1.09-1.17cm	Charcoal	2180±60	*2340-2000*	-	Liu *et al.* 2008
NTU-4790	Tayuanchienshan	TP1 L3a F1-L3 1.17-1.22cm	Charcoal	1860±50	*1930-1690*	-	Liu *et al.* 2008
NTU-4798	Tayuanchienshan	TP1 L5b F4-L1 1.36-1.45cm	Charcoal	2810±60	*3080-2770*	-	Liu *et al.* 2008
NTU-4799	Tayuanchienshan	TP1 L5b F4-L4 1.66-1.75cm	Charcoal	2490±60	*2740-2370*	-	Liu *et al.* 2008
NTU-5810	Chanlungshan		Charcoal	3000±50	*3350-3000*	-	Kuo *et al.* 2013
NTU-5815	Chanlungshan		Charcoal	2390±70	*2720-2320*	-	Kuo *et al.* 2013
NTU-5827	Chanlungshan		Charcoal	2540±80	*2770-2360*	-	Kuo *et al.* 2013
NTU-5828	Chanlungshan		Charcoal	2420±70	*2720-2340*	-	Kuo *et al.* 2013 (ZLS-006)
NTU-5835	Chanlungshan		Charcoal	2510±80	*2750-2360*	-	Kuo *et al.* 2013
Y-1498	Tapenkeng		Charcoal	2030±80	*2300-1810*	-	Sung and Chang 1964
Y-1551	Tapenkeng		Charcoal	2850±200	*3480-2480*	-	Sung and Chang 1964
Beta-480358	Chihwuyuan		Charcoal	3420±40	*3830-3570*	-	This study (Chiang 2020)

Table 4-1-1. Posterior density estimates for Yuanshan Cultural Sites in northern Taiwan.

The output of Bayesian modelling of radiocarbon dates are posterior density estimates – calibrated radiocarbon dates constrained by stratigraphic interpretation (Table 4-1-1). The lower and upper boundary estimates shown in Figure 4-1-1 suggest that the beginning of the Yuanshan Culture falls at *6850-6430 cal BP* and disappears from the radiocarbon-dated record at *1820-1430 cal BP* (Fig. 4-1-1). There is a discontinuity in radiocarbon-dated evidence between c. *6400-* and *4800* cal BP. The summed calibrated probability distribution (SCPD) of all radiocarbon dates from the region shown in Figure 4-1-2 suggests that Yuanshan Culture emerged again, initially gradually, after c. *4800* cal BP becoming widespread by c. *3600* cal BP and continuing for a further *3200* years. Its' demise was abrupt after c. *2300* cal BP, disappearing from the radiocarbon-dated record by c. *1600* cal BP. The sum shows that Yuanshan Culture reached its zenith between c. *3600-2400* BP.


OxCal v4.3.2 Bronk Ramsey (2017); r:5
IntCal13 atmospheric curve (Reimer et al 2013)
Marine13 marine curve (Reimer et al 2013)
Sequence Yuanshan [Amodel:97]
Boundary Start Yuanshan Culture [C:98]
Sum Yuanshan Culture [C:100]
Phase Charcoal
R_Date Beta- 299035 [A:100 C:100]
R_Date Beta- 305896 [A:100 C:100]
R_Date GX-19376 [A:107 C:99]
R_Date GX-19377 [A:100 C:99]
R_Date NTU-1210 [A:100 C:100]
R_Date NTU-1236 [A:100 C:100]
R_Date NTU-1238 [A:100 C:100]
R_Date NTU-1384 [A:100 C:99]
R_Date NTU-1385 [A:100 C:100]
R_Date NTU-1389 [A:100 C:100]
R_Date NTU-1411 [A:100 C:100]
R_Date NTU-1425 [A:100 C:100]
R_Date NTU-1427 [A:100 C:100]
R_Date NTU-1455 [A:100 C:100]
R_Date NTU-1456 [A:80 C:100]
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R_Date NTU-2456 [A:100 C:100]
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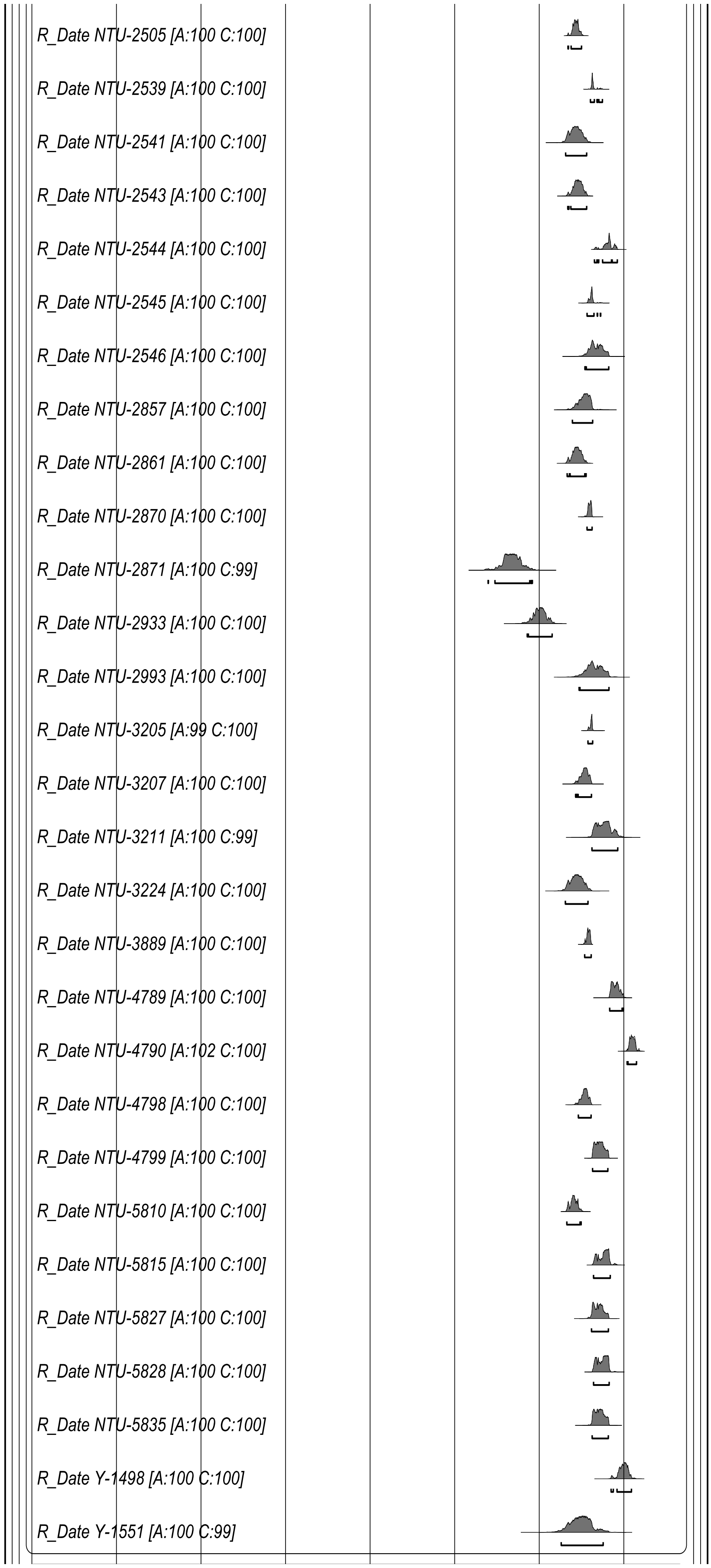
R_Date NTU-2500 [A:100 C:99]


R_Date NTU-2505 [A:100 C:100]
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R_Date NTU-3205 [A:99 C:100]
R_Date NTU-3207 [A:100 C:100]
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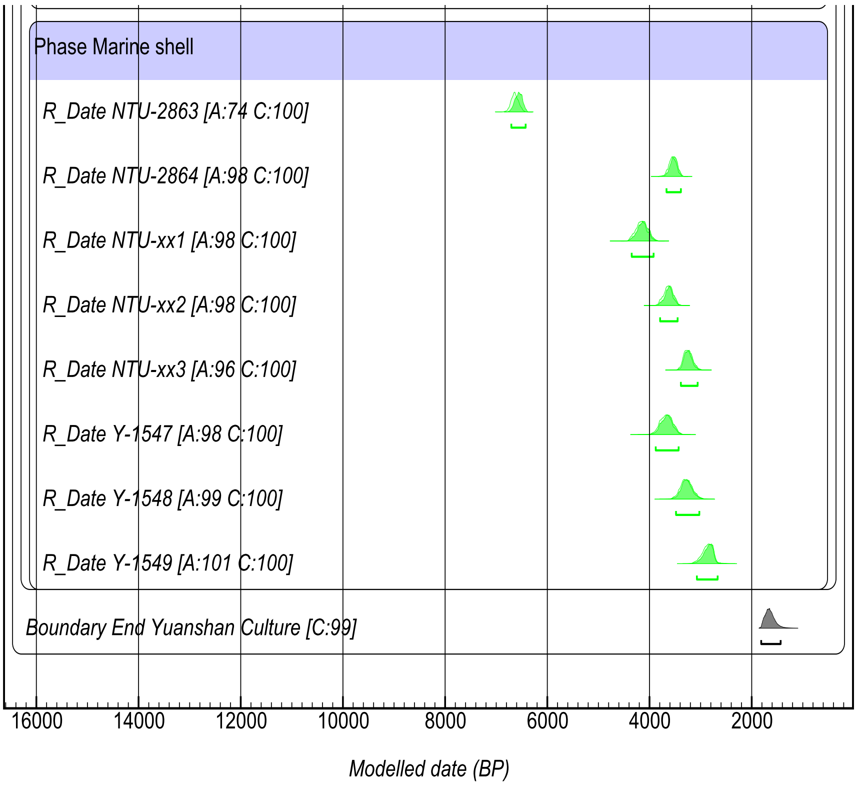

Fig. 4-1-1 OxCal plot showing the chronology of Yuanshan Culture obtained from charcoal and marine shell corrected for a marine reservoir effect.

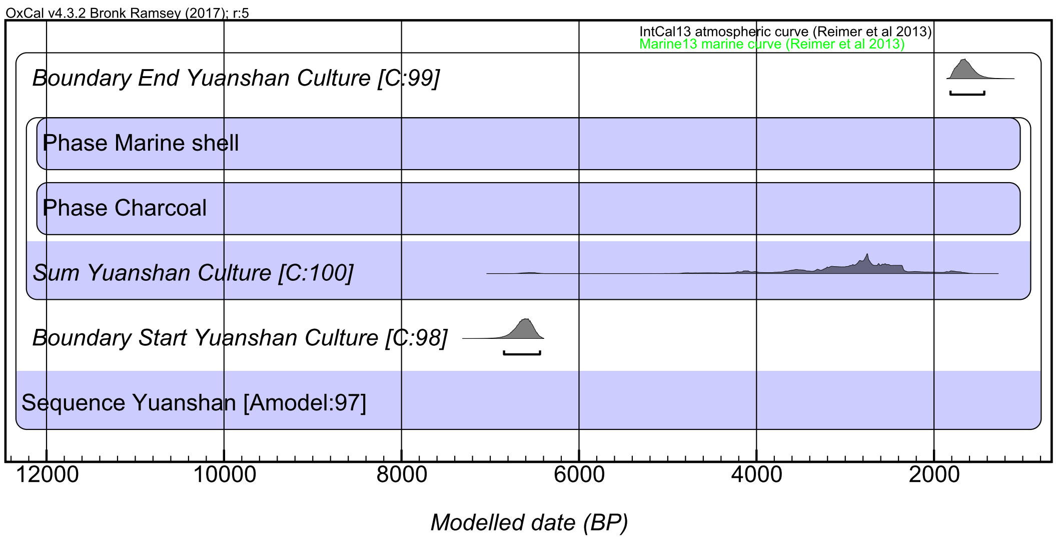

Fig. 4-1-2 OxCal plot showing the lower and upper boundary estimates marking the start and end of the Yuanshan Culture in northern Taiwan.

Discussion

As the majority of dates used in this study were obtained prior to the advent of AMS dating techniques, it has not been possible to correct for the degree of fractionation of the delta ^{12}C and ^{13}C isotopes to determine the accuracy of the measured radiocarbon age. Furthermore, the carbon content of Beta-480358 derived from charcoal is too low to perform the standard practise of obtaining deviations of ^{13}C to ^{12}C isotope data (Table 4-1-1). Therefore, this study will discuss the estimated age of Yuanshan Culture with respect to the modeled chronological values, acknowledging that chronological interpretations may be revised if new radiocarbon date data becomes available for analysis.

In this batch of data, the shell sample of NTU-2863 (Table 4-1-1) from the Yuanshan site is dated at *6710-6420* cal BP, which is the earliest date for the Yuanshan cultural site. NTU-2871 (Table 4-1-1), a bulk charcoal sample collected by the same excavation project, is also detected earlier at *5210-4160* cal BP. Dates from these two samples appear older than others, perhaps because of the out-dated bulk radiometric method by which they were measured, or probably due to the influence of the marine carbon reservoir and the old wood effector respectively. For example, Sung and Chang (1964, 1966) achieved apparently early dating ages derived from marine shell samples from the Tapenkeng site, and later revised these dates using a marine reservoir offset by 4500 years. In addition, there is a significant discontinuity between the earliest date falling at c. *6720* cal BP and the re-emergence of widespread radiocarbon-dated evidence for Yuanshan Culture after c. *4800* cal BP. Hence, the modelled starting date range of *6870-6440 cal BP* will be disregarded from the discussion as a likely contaminant caused by differential fractionation known to occur across marine shell surface and interior layers used for dating, e.g. Wicks and Mithen (2014, Appendix1 pp. 259). Interpretation of chronological results must also assume the majority of dates were obtained on bulk samples of unidentified wood charcoal potentially consisting of hard wood and large branches from long lived woodland species. It is beyond the scope for this study to determine the chronology of the Yuanshan Culture.

Before the mid-1990s, archaeologists thought that the chronological range of the Yuanshan Culture was at about 4500-2000 BP. (Lin 1963, Sung and Chang 1964, 1966, Huang 1989, Chu 1990, Liu 1992, Chen 1994). This age of Yuanshan Culture mainly follows the research of five ^{14}C dating results from Sung and Chang (1964, 1966). Chronological inference of Yuanshan Culture by Song and Chang was based on the stratigraphic relationships between the Yuanshan and Tapenkeng Cultures in both Yuanshan and Tapenkeng site, using a date on the peat layer of the Taipei Basin at 4880±300 BP (Lab. WR-1016, Lin 1966, pp. 23) proposed by Lin as a basal point / *terminus post quem* for the stratigraphic succession (Fig. 4-1-3).

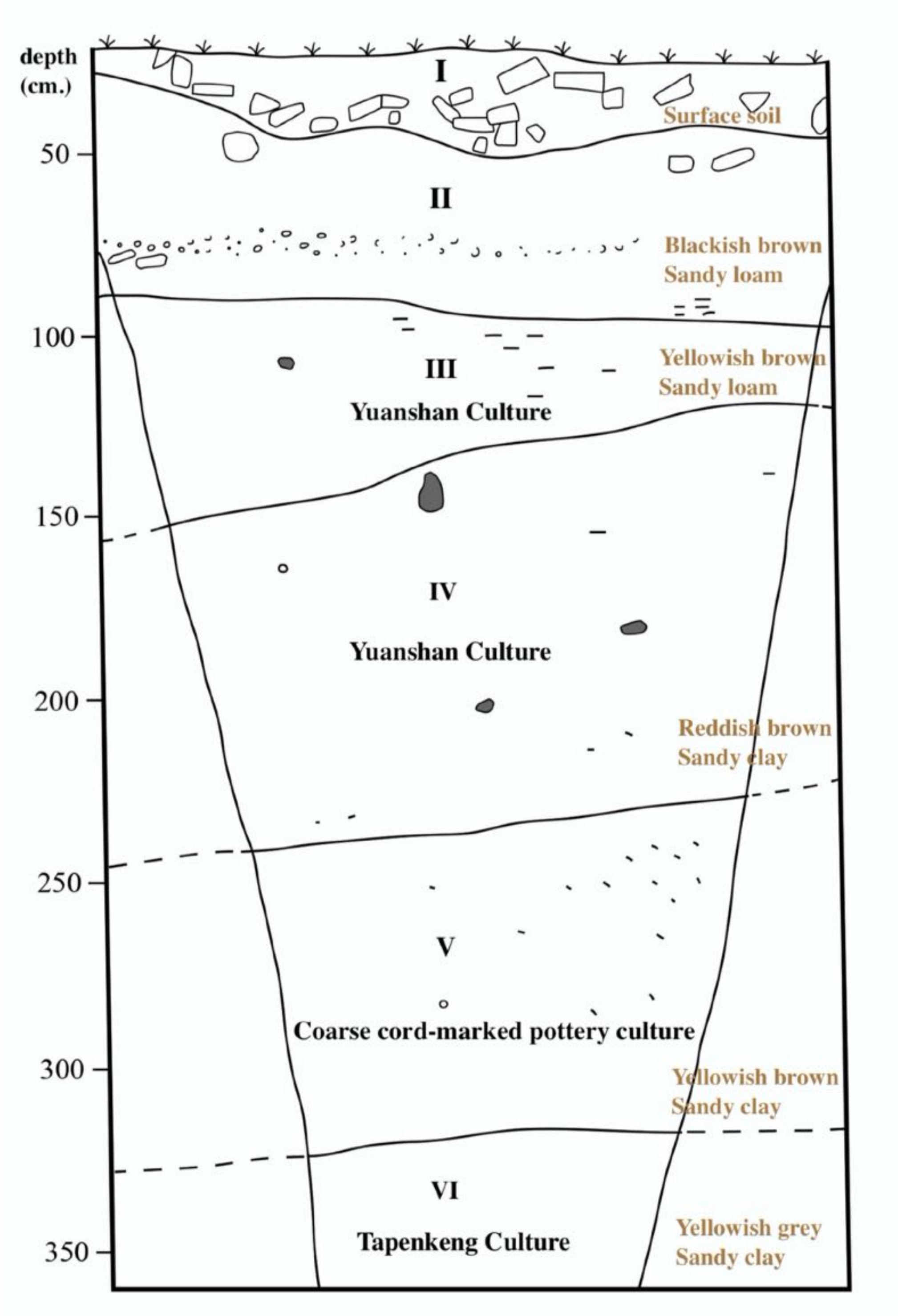

Fig. 4-1-3 Stratigraphic section of the Yuanshan site excavation in 1999. (Translation based on Huang *et al.*, 1999a, Fig.7)

After several archaeological excavations of Yuanshan site in the later 1990s, archaeologists gained a better understanding of the archaeological cultures and chronological sequences within the site by accumulating archaeological information and ^{14}C data, and by comparing archaeological finds with other sites in northern Taiwan. The maximum dating range accepted by most scholars currently is at about 3500-2300 cal BP (Huang 1984, Liu 1997a, b, Huang *et al.* 1999a, b, Liu and Kuo 2000, Chiu 2010). This presently recognised interval of Yuanshan Culture is quite close to the re-modelled age of *3600-2300 cal* BP modelled by this study, however, with slightly differences. The lower limit at 3500 BP is a hundred years younger than that of the modelled estimate. The modelled upper limit of *2300 cal* BP is similar to that of the Tutikungshan type period in the late phase of Yuanshan Culture. Furthermore, the SCPD shows a sharply decreasing curve between *c. 2400-2300 cal* BP for the first time (Fig. 4-1-2). In response to these divergences, chronological insights are suggested for the preceding and succeeding archaeological cultures of Yuanshan Culture, i.e. Hsuntangpu, Chihshanyen and Chihwuyuan Cultures.

The reason Taiwanese scholars generally accept that the beginning of Yuanshan Culture at 3500 BP lies in the continuity of stratigraphic relationships between Yuanshan Culture and other archaeological cultures within sites chronologically. The following will describe the sequence of stratigraphy and timeline of Yuanshan Culture and other archaeological cultures in the sites of Chihshanyen, Yuanshan and Tapenkeng.

In terms of the vertical and continuous cultural layers discovered in the

Chihshanyen site, the order from the top to the bottom are: Yuanshan Culture, Chihshanyen Culture and Hsuntangpu Culture (see Chapter 2-2, Table 2-2-1). The ^{14}C dating result for Chihshanyen Culture at Chihshanyen falls between 3470-3390 BP (Huang 1984). This date is the key to archaeologists' speculations concerning the timing for the appearance of Yuanshan Culture at about 3500 BP. However, Chihshanyen Culture only appears in the Chihshanyen site and is not found in other archaeological sites throughout the rest of Taiwan. This date needs to be used with caution if it is to be used as the lower limit for the start of Yuanshan Culture (even if correct and reliably associated), as the relationship between Chihshanyen Culture and other prehistoric cultures in northern Taiwan remains unclear currently. As such, this relationship remains unresolved within broader discussions concerned with the archaeological cultural structure of prehistoric Northern Taiwan.

Currently, there is general agreement that the chronology of Hsuntangpu Culture is mainly concentrated between 4800-4000 BP and continues until around 3500 BP (Huang *et al*. 1999a, b, Chen and Kuo 2004, Chu 2012, Kuo 2015). In other words, the timing of the Hsuntangpu Culture existence occurs at about 4800-3500 BP. Recent research combines the evolution of pottery making techniques and the re-modelled ^{14}C dates using the Oxcal programme to obtain the latest chronological range of the Hsuntangpu culture (Lu 2017). Lu suggests that the end of Hsuntangpu culture should be pushed back from 3500 BP to 3600 cal BP, which supports a ^{14}C dating result of this study and Liu's point of view given earlier (Liu 2008; Table 1; Lab. No. Beta-480358).

Liu and Lu's recommendation for the range of the Hsuntangpu Culture chronology is in line with the 4800-3600 BP of the modelling age, which presents a less and continuous material culture in the modelling date. Material culture dating to this period is classified to the Hsuntangpu Culture rather than the Yuanshan Culture. From the perspective of stratigraphy, the Yuanshan cultural layer is also directly overlaid on the layer of the Hsuntangpu Culture unearthed in the sites of Yuanshan and Tapenkeng. Both archaeological cultures occupied these two sties successively. The estimation of the time of the Yuanshan Culture emergence, consequently, should be referenced the Hsuntangpu Culture ending time at c. 3600 BP are shown in Fig. 4-1-2.

The Chihwuyuan Culture is developed later than Yuanshan Culture in Northern Taiwan. It is generally believed that the Chihwuyuan Culture arrives on a large scale from about 2500 to 1800 BP. Some sites may even continue as late as to 1500 BP (Huang *et al*. 1999b, Liu 2000, Liu and Kuo 2000, Kuo 2002, Liu 2011). That is to say, the existence period of the Chihwuyuan Culture is approximately between 2500 and 1500 BP. Judging from the gradual decline and disappearance of Yuanshan Culture at c. 2300-1800 BP, this should be overlapped with the stage of the Chihwuyuan Culture period. The upper limit of the Chihwuyuan Culture age and the lower limit of the Yuanshan Culture Modelling date show a difference of two hundred years at 2500 BP and 2300 cal BP.

Of significance is the discovery of a small amount of Chihwuyuan cultural artefacts, such as pottery fragments, in the layer of late Yuanshan Culture at some archaeological sites (Huang *et al*. 1999b). In accordance with such phenomenon, most archaeologists conclude that the Yuanshan Culture and Chihwuyuan Culture coexisted for some time during the latter stages of Yuanshan Culture (Huang and Liu 1980, Liu 1982, Huang *et al*. 1999b, Liu 2000, Liu and Kuo 2002). The time for the coexistence of Yuanshan Culture and Chihwuyuan Culture should be the aforementioned at 2500-2300 BP 200-year gap discussed above.

It is worth noting that the SDCP sudden drop sharply in the calibration curve during the modelling period at 2400-2300 cal BP indicates that the Yuanshan Culture has experienced a large-scale recession during this time. This is consistent with Kuo's proposed the centralised stage of the Yuanshan Culture at about 3300-2400 BP by the observation of its cultural artefacts appeared widely (Kuo 2014a). The fall of Yuanshan Culture is probably substituted by the rising prominence of Chihwuyuan Culture, which becomes gradually a dominant culture sometime after 2400 BP. In addition, the geographical distribution of the Yuanshan cultural sites based on the chronological data is spreading toward south and west from the Yuanshan site centred in the northern of the Taipei Basin (Table 4-1-1).

Conclusion

Some researchers still question the chronology of Yuanshan Culture as indicated by dates obtained from marine shell, due to the influence of the marine reservoir effect, arguing that Yuanshan Culture should not exceed 3200 cal BP. However, it is quite reasonable and credible to obtain c. 3,600-2,300 BP by applying current AMS dating techniques, internationally accepted calibration curves (IntCal 13 and Marine 13) and Bayesian statistical modelling methods (OxCal v. 4.2 ^{14}C plot) to test the chronological data of all Yuanshan Culture.

Chapter 4-2_RESULTS OF pXRF ANALYSIS

1. Observation of the 325 shouldered axes

There are 325 shouldered artefacts from four museums were examined and recorded. Except for the sixteen specimens from the sites of Chanlungshan, Chihwuyuan, Chientang and Chihshanyen borrowed from Dr Su-chiu Kuo of the Institute of History and Philology (IHP) at Academia Sinica in Taipei the rest were from museums in Taiwan. Four museums visited are as following: (Fig. 4-2-1)

- the Southern Taiwan Science-based Park Branch Museum of the National Museum of Prehistory, Tainan. (STSP of NMP)
- the National Museum of Prehistory, Taitung. (NMP)
- the Museum of Institute of Ethnology, Academia Sinica, Taipei. (IOE)
- the Museum of Anthropology of the National Taiwan University, Taipei. (MANTU)
- the Yangmingshan National Park (Tatun Volcano Group, Taipei)

Fig. 4-2-1 Locations of the fieldwork.

Concerning the standardised measurement of all samples, different tools were used during the fieldwork: a micro-digital Scales, an L-shaped photo scale, a credit card photography scale and a 150-millimetre digital LCD calliper. For observing the trace on the sample surface, an USB Digital Microviewer (digital zoom up to 200x) with a mini flashlight has been applied for the first time in this study. Normal photography of 325 shouldered tools were taken by a Canon digital camera. (Fig. 4-

2-2)

Fig. 4-2-2 Tools of the sample recording and photo taking.

2. Raw material of the andesite sampling in the Yangmingshan National Park

The Tatun Volcano Group, situated in the Yangmingshan National Park of Northern Taiwan, is a favoured and not hard to get andesite quarry for the building material by local resident. Because of the schedule constraints and the difficulty of knocking down the andesite sample from the large rock by mini mattock, sampling location selection therefore started with finding a small broken andesite sample on the modern roadside where the traffic is convenient, and the rock formation is vaguely visible. Four location has been visited, and eight raw material of andesite collected from three location in the Yangmingshan National Park. (Fig. 4-2-3)

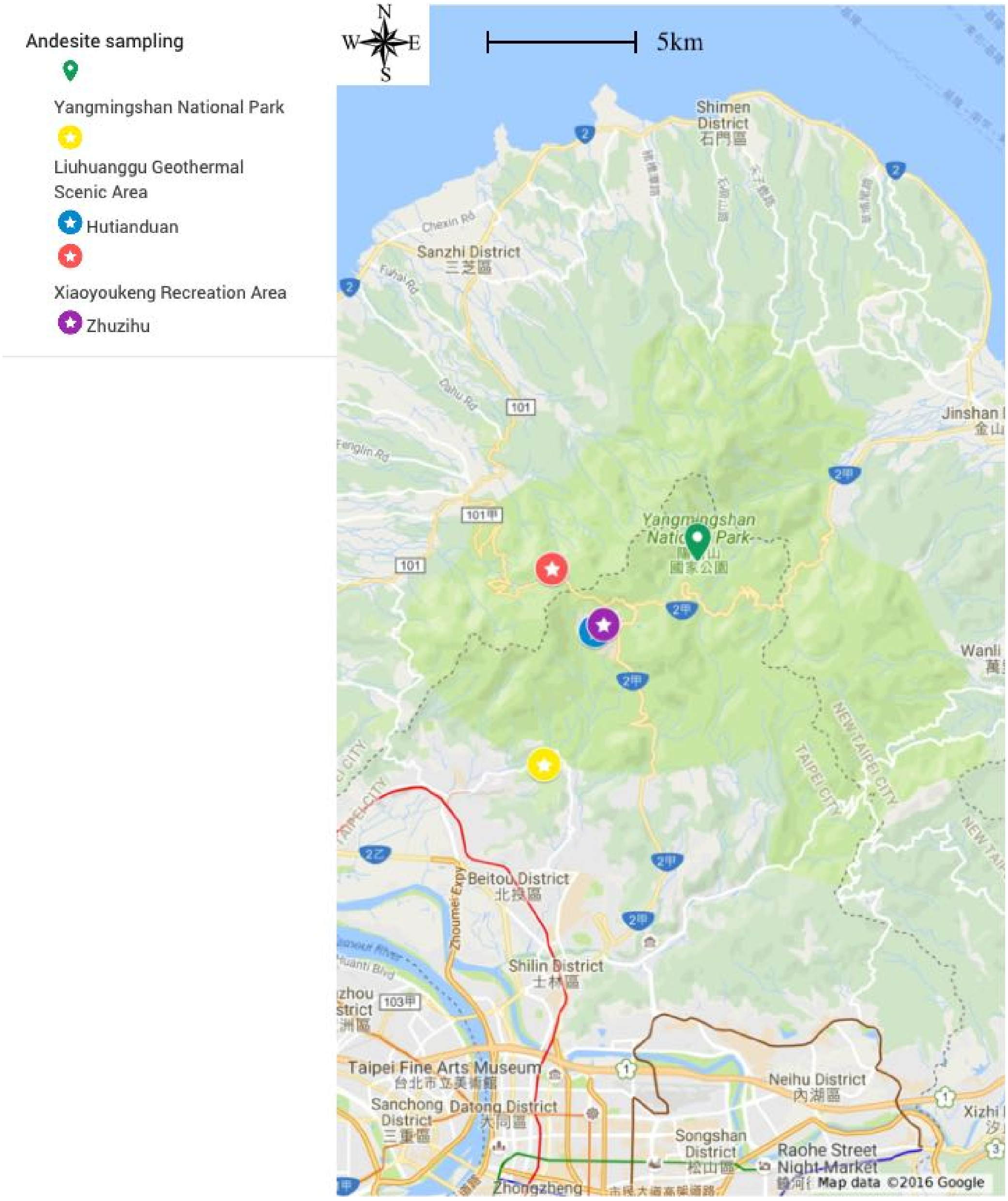

Fig. 4-2-3 Visiting location of andesite sampling.

There are visible outcrops of andesite in the location 1, the Liuhuanggu Geothermal Scenic Area. (Fig. 4-2-4) The rock of andesite in the location 1 is not suitable for the experiment by the pXRF and the SEM-EDX, since the outcrops are unlikely to be reached. In addition, the high temperature and strong acid sulfur gas from the nearby geothermal pool has made the raw material of andesite susceptible to crumble into small rocks or even powdery particles by judging from the black surface of outcrops and the corrosion of the small fragments on the ground.

Fig. 4-2-4 Location 1: Liuhuanggu Geothermal Scenic Area.

Location 2, the Hutianduan, is located at the highly historical value area of the Ciao Mountain Water Supply System. Alongside the path are the modern houses, several large rocks lie on the ground in an open space where an orchard just nearby. Two small pieces of rock are discovered on the ground and been collected from this location. (Fig. 4-2-5, 4-2-6)

Fig. 4-2-5 Location 2: Hutianduan.

Fig. 4-2-6 Raw material of rocks from the Location 2.

Xiaoyoukeng Recreation Area is the third location having been visited in the Yangmingshan National Park. The landscape of the road around this area is a slope on the one side, and a rock formation covered with trees and grass on the other. It is a good location for collecting rocks and four samples having been taken. (Fig. 4-2-7, 4-2-8)

Fig. 4-2-7 Location 3. Xiaoyoukeng Recreation Area

Fig. 4-2-8 Raw material of rocks from the Location 3.

The final location is in the Zhuzihu area, surrounded by the trees on both sides of the path. The rocks on the ground is smaller than that found at Location 2 and 3. Two samples has been picked for the pXRF and SEM-EDX experiment. (Fig. 4-2-9, 4-2-10)

Fig. 4-2-9 Location 4: Zhuzihu.

Fig. 4-2-10 Raw material of rocks from the Location 4.

The Portable XRF (pXRF) experiments were applied to examine the andesite and sandstone samples from the archaeological sites of Chanlugnshan, Chihshanyen, Chientang and Chihwuyuan, as well as the raw material of andesite collected from the Yangmingshan National Park in the geological district of the Tatun Volcano Group, where is long believed to be the andesite quarry of the shouldered axes of the Yuanshan Culture by the Taiwanese archaeologists. Due to the time limits for working hours in the field, the number of the andesite samples taken for the provenance in this study is only eight.

The Tatun Volcano Group consists of mainly andesite which has complex chemical composition including heavy metals. This project is going to conduct the pXRF experiment on 16 Yuanshan Cultural shouldered tools and 8 raw material of andesite for sourcing by detecting the variation of the elements and chemical composition.

Andesite is one of the Igneous rocks. Chemical compositions of the Igneous rocks are classified by their relative alkali (Na_2O + K_2O) and silica (SiO_2) weight contents. (Le Bas *et al*. 1986, Le Maitre 2002) The content of SiO_2 in the andesite varies from 52% to 63%. The ratio of (K_2O + Na_2O) / (SiO_2) of andesite is generally less than 3.3. Hence, content of SiO_2 is low whilst CaO is high, and Na_2O is greater to K_2O.

Based on the studies of the Tatun andesite, the content of SiO_2 varies from 57% to 63%. The major elements of K_2O-SiO_2 plot shows that the Tatun andesites resemble the calc-alkaline series. Consequently, the major elements of Tatun andesite can be clearly distinguished from higher K and Ca, lower Ti and Na, and similar Si, Fe, Al and Mg from the average content of the andesite. The variations of SiO_2 content in Tatun andesite are analysed, SiO_2 increase with the K_2O and Na_2O increasing, whilst content Cao and FeO decrease with the increasing of SiO_2. (Chen and Lin 1982, Lo 1982) It is namely that the variations of the major and trace elements in the andesite should be examined, such as Ca, Fe, Si, K, Mg, Na Ti, Ba, Sr, Rb, Zr.

pXRF experiment information:

pXRF series model: Thermo Nitro^{TM} XL3t Analyzer

Reading type: mining

Reading unit: ppm

Detecting elements: major and trace

Reading duration: the shouldered axes - 150s/each reading;

the raw material of andesite - 120s/each reading

The pXRF analysis shows that the variation diagrams of element contents in the raw material of andesite reflect the slightly difference to those of shouldered samples, which is probably caused by the weathering. (Tsai *et al*. 2008). The content of Na_2O is not detected, SiO_2 and CaO content is lower than the data given on the literature. Whilst the contents of Al_2O_3, K_2O, FeO, Ti_2O are increasing. The opposite outcome is possibly derived from the andesite sampling method, which is collecting directly on the ground off the modern road instead of knocking the fresh samples down from the rock. Nevertheless, the experimental data still has value as a reference to the knowledge of Tatun andesite. The diagrams of SiO_2 variation for CaO, K_2O and FeO, as well as the plots of the major and trace elements for Sr, Ba, Rb and Zr, demonstrate that 12 artefacts indeed were made from andesite. They are possibly obtained from the Tatun Volcano group. (Fig. 4-2-11,4-2-12, 4-2-13, 4-2-14, 4-2-15, 4-2-16, 4-2-17)

Comparing the analytical data of Tatun andesite generated by the pXRF experiment with that of the literature, the variation diagrams of the element contents show that ratios of 3 artefacts are seemly grouping and some spacing away from other specimens. (Fig. 4-2-15, 4-2-16) The result of the pXRF analysis reveals two types of rock which are used as raw materials in 16 shouldered tools. (Fig. 4-2-17) One is in one of the largest numbers of andesite, the other is the sandstone which represents in three samples. These two rocks have been used as raw materials for making stone implement by the people in the Chanlungshan site during the late Neolithic Age. It is fully in line with fieldwork consequence of the mainly use of raw materials by the Yuanshan cultural people. In this study, the andesite rock materials collected on the roadside are not obtained from the quarry of the Tatun Volcano

Group, and it is impossible to determine its origin. In the future, the method of thin section analysis will apply for sourcing of the raw rocks in further study.

(ppm) Element compostion of Tatun andesite (wt%)

	Shouldered artefacts																Raw material of andesite							
Sample	zls-001	zls-002	zls-003	zls-004	zls-005	zls-006	zls-007	zls-008	zls-009	zls-010	zls-011	zls-012	csy-001	ct-001	s-135-00001	s-156-00001	yms-htd-01	yms-htd-02	yms-zzh-01	yms-zzh-02	yms-xyk-01	yms-xyk-02	yms-xyk-03	yms-xyk-04
P2O5	0.22	0.83	1.04	0.75	0.66	0.77	0.89	1.09	1.59	1.01	0.75	2.24	0.56	1.29	0.46	0	0.33	1.37	0	0.53	0.71	0.86	0	0.38
FeO	0.92	9.52	14.63	8.01	10	9.48	8.95	10.35	2.04	10.44	0.74	11.17	7.31	1.08	7.84	3.94	5.04	3.62	2.57	5.35	5.44	7.12	4.45	4.99
Fe2O3	1.02	10.57	16.26	8.9	11.11	10.54	9.94	11.51	2.26	11.6	0.82	12.41	8.12	1.2	8.71	4.38	5.61	4.02	2.86	5.95	6.04	7.92	4.94	5.55
ZnO	0	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0	0.01
PbO	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0	0	0.01	0.02	0	0	0	0	0	0	0.04	0
CuO	0	0.01	0.02	0.01	0	0.01	0	0.01	0.14	0.01	0	0	0	0	0	0	0	0.01	0	0.01	0	0.01	0.01	0.01
Rb2O	0	0.01	0	0.01	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0	0.01	0.01	0	0	0.01	0	0.01	0.01	0.01
BaO	0.02	0.08	0.05	0.08	0.07	0.07	0.07	0.08	0.03	0.08	0.02	0.06	0.06	0.05	0.08	0.07	0.06	0.06	0.05	0.07	0.06	0.08	0.04	0.09
ZrO2	0.06	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.07	0.01	0.04	0.02	0.01	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SrO	0	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0	0.02	0	0.02	0.03	0	0.03	0.02	0.05	0.03	0.02	0.04	0.03	0.02	0.04	0.06
MnO	n.d.	0.18	0.29	0.12	0.16	0.2	0.14	0.15	0.11	0.22	n.d.	0.24	0.15	n.d.	0.12	0.06	0.09	0.06	0.05	0.1	0.13	0.11	0.06	0.08
Cr2O3	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01
V2O5	0.01	0.08	0.11	0.08	0.1	0.07	0.08	0.1	0.01	0.08	0.02	0.09	0.07	0.02	0.09	0.05	0.02	0.05	0.03	0.07	0.05	0.07	0.05	0.03
TiO2	0.22	0.68	0.91	0.72	0.82	0.66	0.64	0.91	0.23	0.66	0.23	0.74	0.78	0.41	0.73	1.07	0.33	0.34	0.22	0.44	0.38	0.57	0.36	0.43
CaO	0.06	0.85	2.06	1.84	2.04	1.04	1.15	1.92	0.05	1.18	0.05	1.6	1.4	0.95	1.16	1.48	3.84	4.54	2.26	5.63	6.34	0.95	4.38	4.81
K2O	1.1	2.69	1.84	2.13	2.38	2.6	2.32	2.32	1.01	2.59	1.23	2.96	2.13	1.8	2.85	2.18	1.57	1.4	1.16	2.04	1.22	2.54	1.77	1.95
Al2O3	3.14	6.45	6.36	10.4	9.44	7.13	9.07	8.78	3.04	5.7	5.17	7.19	9.55	4.4	6.97	3.6	4.86	10.33	8.59	11.58	14.45	11.7	7.45	4.23
SiO2	64.76	57.39	56.11	62.08	53.56	60.4	53.48	47.96	54.58	52.86	75.88	58.77	49.72	52.2	54.94	29.6	32.32	43.21	25.61	52.09	61.81	39.39	39.35	29.14
SO3	0	0	0	0	0	0	0	0.25	0.1	0	0	0	0.09	0	0.24	0	0.04	0.67	1.21	0.14	0.42	0.2	0	0.54
P	962.38	3634.88	4542.62	3282.44	2894.33	3338.97	3879.23	4757.02	6943.74	4415.96	3273.49	9757.93	2454.47	5639.71	2018.43	0.00	1456.57	5991.70	0.00	2331.75	3104.62	3756.17	0.00	1663.05
Fe	7159.80	73960.86	113719.52	62280.69	77719.55	73690.76	69542.52	80477.65	15834.18	81145.35	5729.91	86819.65	56804.15	8383.28	60920.96	30606.78	39205.36	28130.39	19987.14	41601.67	42263.35	55367.29	34564.23	38821.88
Zn	10.69	104.19	129.95	85.59	87.88	110.49	88.61	70.88	42.53	117.46	9.15	108.48	84.76	52.32	75.97	109.16	53.56	62.83	14.18	60.56	70.75	72.65	24.05	50.79
Pb	11.79	28.22	16.68	29.66	22.28	20.55	32.20	84.88	61.17	22.31	18.77	28.40	21.02	10.69	83.78	143.43	0.00	12.87	0.00	9.56	7.48	13.12	328.54	0.00
Cu	0.00	47.07	149.79	42.55	24.68	50.58	35.00	54.12	1082.45	76.03	0.00	39.32	38.00	0.00	31.10	0.00	26.35	56.34	0.00	47.39	27.74	91.20	78.77	58.36
Rb	28.95	50.52	38.49	50.57	53.24	69.22	51.87	69.82	32.07	70.55	35.36	78.16	70.61	49.66	45.66	59.08	65.53	34.04	32.06	56.83	41.92	94.88	69.46	131.13
Mo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.20	0.00	0.00	0.00	0.00	0.00	0.00	4.31
Nb	9.10	9.24	6.64	7.91	7.01	7.45	7.24	10.44	13.51	7.50	7.33	9.39	10.48	11.68	7.92	6.66	0.00	4.21	3.68	5.80	4.64	7.29	4.89	6.00
Ba	216.77	708.47	445.06	709.49	592.69	597.41	634.93	739.96	273.78	682.34	215.67	576.60	545.68	433.20	721.17	615.19	571.54	500.28	490.82	596.32	557.81	674.37	362.98	766.64
Zr	414.18	120.36	89.80	106.84	95.58	109.48	99.65	99.06	505.38	105.29	261.95	116.01	108.29	456.42	104.99	79.50	61.17	56.63	49.46	59.33	46.96	100.88	66.96	78.29
Sr	13.71	187.65	76.88	131.40	128.68	133.57	173.54	187.33	15.46	149.58	28.56	148.19	217.32	32.96	287.16	162.09	389.54	288.21	196.59	367.24	291.47	178.54	314.31	508.85
Bi	12.36	17.28	8.60	13.32	11.05	13.34	13.55	18.04	24.69	15.11	11.58	13.47	13.98	11.74	14.71	8.90	0.00	4.95	6.56	13.68	4.33	16.50	8.41	0.00
As	5.54	9.89	10.40	9.37	12.29	8.11	13.56	24.61	4.22	8.95	0.00	8.11	6.76	4.74	15.52	22.05	0.00	11.71	6.76	5.15	0.00	7.27	0.00	0.00
Mn	0.00	1386.52	2275.29	898.60	1240.45	1527.97	1116.17	1188.36	848.12	1728.81	0.00	1844.50	1179.20	0.00	924.13	493.97	705.43	464.28	357.44	791.39	993.27	875.82	429.33	641.02
Cr	62.83	90.79	138.07	85.95	103.63	67.44	85.30	104.05	65.21	78.57	30.98	81.54	94.68	102.06	107.78	100.28	49.80	64.37	26.68	97.27	38.51	80.75	37.37	33.22
V	72.61	461.27	631.16	455.76	554.51	416.99	454.28	558.84	72.13	450.22	86.54	477.97	402.14	134.62	520.12	252.89	124.79	262.40	178.17	377.25	279.13	403.26	307.85	144.51
Ti	1338.22	4089.38	5425.58	4341.41	4894.77	3928.32	3821.74	5455.57	1381.21	3973.40	1372.91	4411.35	4666.00	2438.13	4348.50	6396.57	1947.79	2020.14	1344.71	2652.48	2297.25	3387.68	2155.59	2564.62
Ca	417.03	6044.00	14757.21	13115.36	14562.42	7412.98	8222.28	13754.46	346.72	8444.12	364.36	11406.12	9994.55	6798.05	8283.67	10580.93	27422.98	32467.75	16178.70	40202.29	45306.39	6781.32	31300.07	34364.81
K	9151.99	22344.83	15299.13	17652.59	19763.02	21566.53	18983.89	19284.94	8380.21	21513.06	10200.32	24584.10	17665.81	14978.14	23630.95	18135.41	13065.10	11583.17	9609.11	16925.30	10104.76	21052.86	14658.19	16208.49
Al	16601.69	34134.31	33673.59	55056.26	49945.04	37742.91	47990.82	46474.07	16112.42	30186.02	27345.42	38066.99	50564.47	23309.93	36875.63	19047.51	25740.86	54670.63	45466.00	61259.61	76465.88	61901.64	39404.20	22398.65
Si	302738.00	268267.48	262309.92	290221.23	250360.17	282347.31	249990.59	224207.39	255129.56	247088.31	354734.45	274715.31	232433.80	244028.05	256821.45	138361.72	151069.41	201974.83	119722.24	243487.56	288918.38	184140.78	183925.02	136238.75
Cl	0.00	193.84	229.24	119.95	159.98	222.45	0.00	0.00	6.85	0.00	0.00	152.93	0.00	29.42	0.00	0.00	414.91	372.62	0.00	0.00	0.00	0.00	0.00	72.38
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1020.05	385.49	0.00	0.00	0.00	372.00	8908.78	977.47	0.00	149.03	2680.54	4856.19	566.27	1682.11	793.29	0.00	219.69

Fig. 4-2-11 Major and trace element composition data of the shouldered artefacts and the Tatun andesite generated by the pXRF. (elements in ppm; oxides in wt.%)

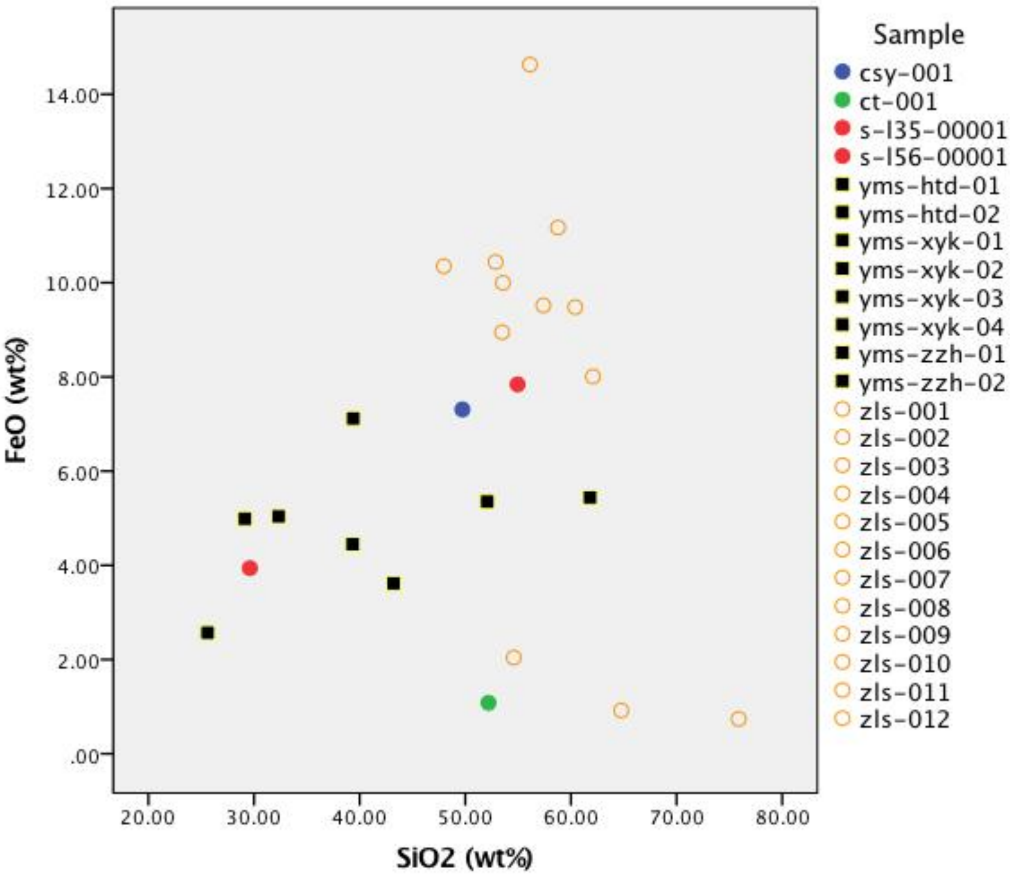

Fig. 4-2-12 Variation diagrams of SiO2 versus FeO (Initials: csy=Chihshanyen Site; ct=Chientan Site; s-135/156=Chihwuyuan Site; zls=Chanlungshan Site. Symbol: ■=raw material of andesite).

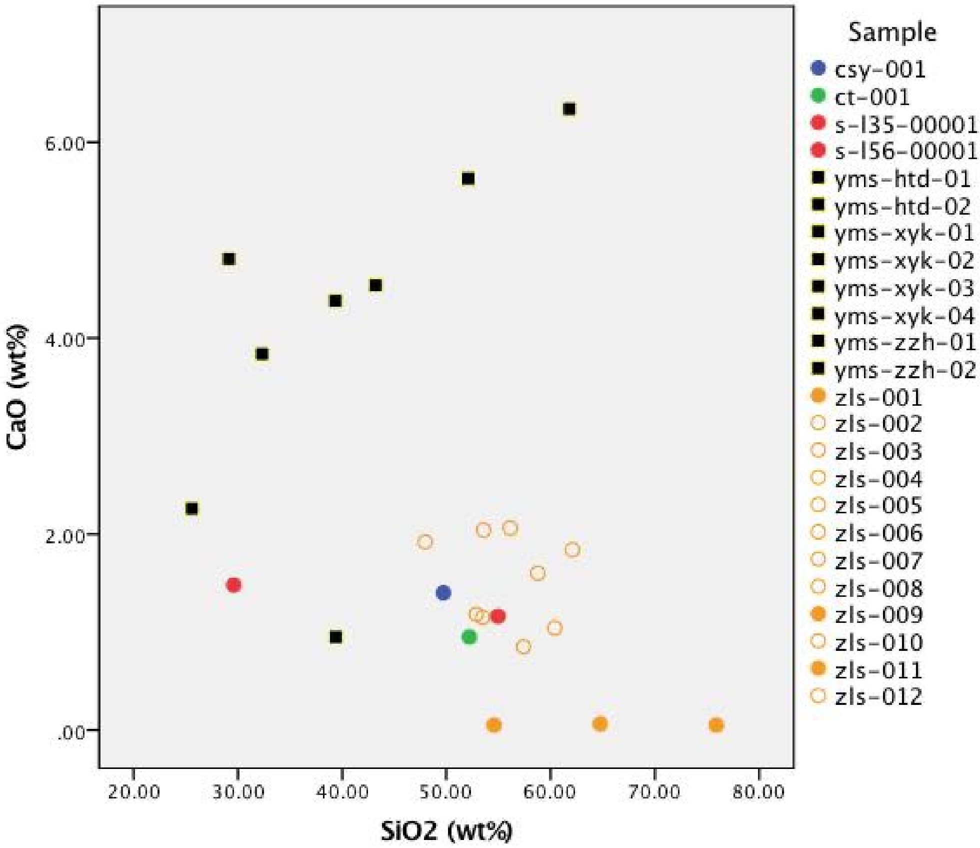

Fig. 4-2-13 Variation diagrams of SiO2 versus CaO (Initials: csy=Chihshanyen Site; ct=Chientan Site; s-135/156=Chihwuyuan Site; zls=Chanlungshan Site. Symbol: ■=raw material of andesite).

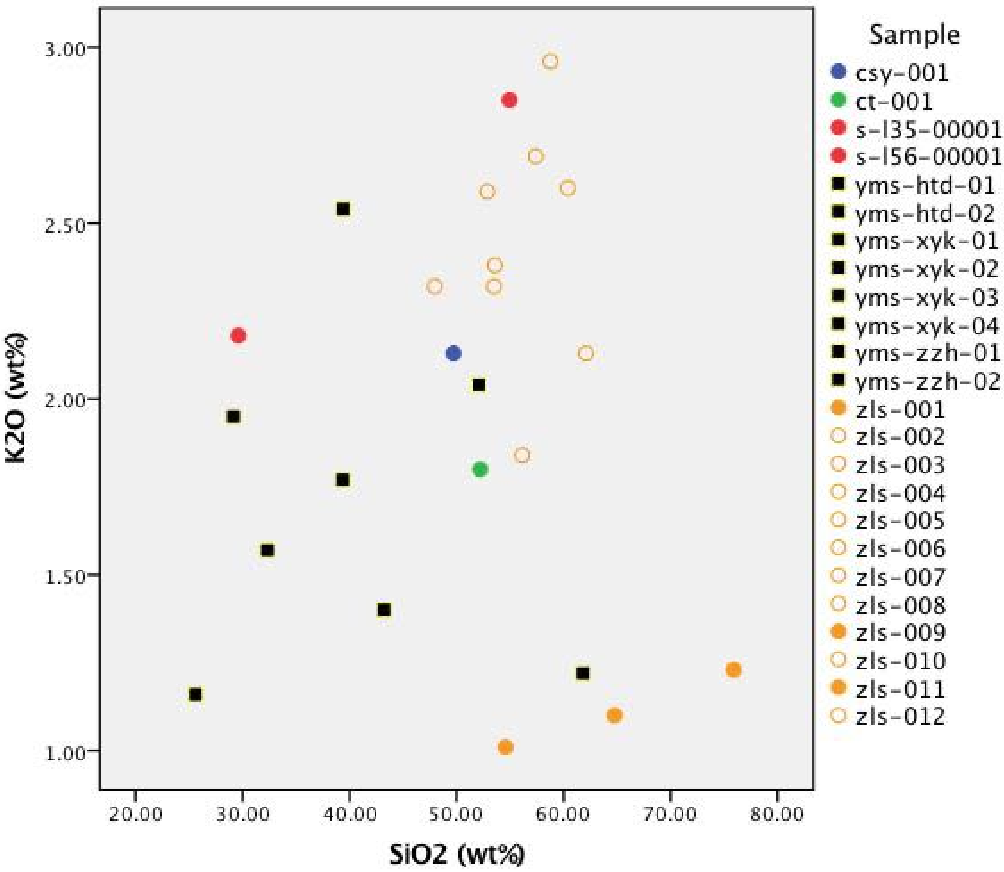

Fig. 4-2-14 Variation diagrams of SiO2 versus K2O (Initials: csy=Chihshanyen Site; ct=Chientan Site; s-135/156=Chihwuyuan Site; zls=Chanlungshan Site. Symbol: ■=raw material of andesite).

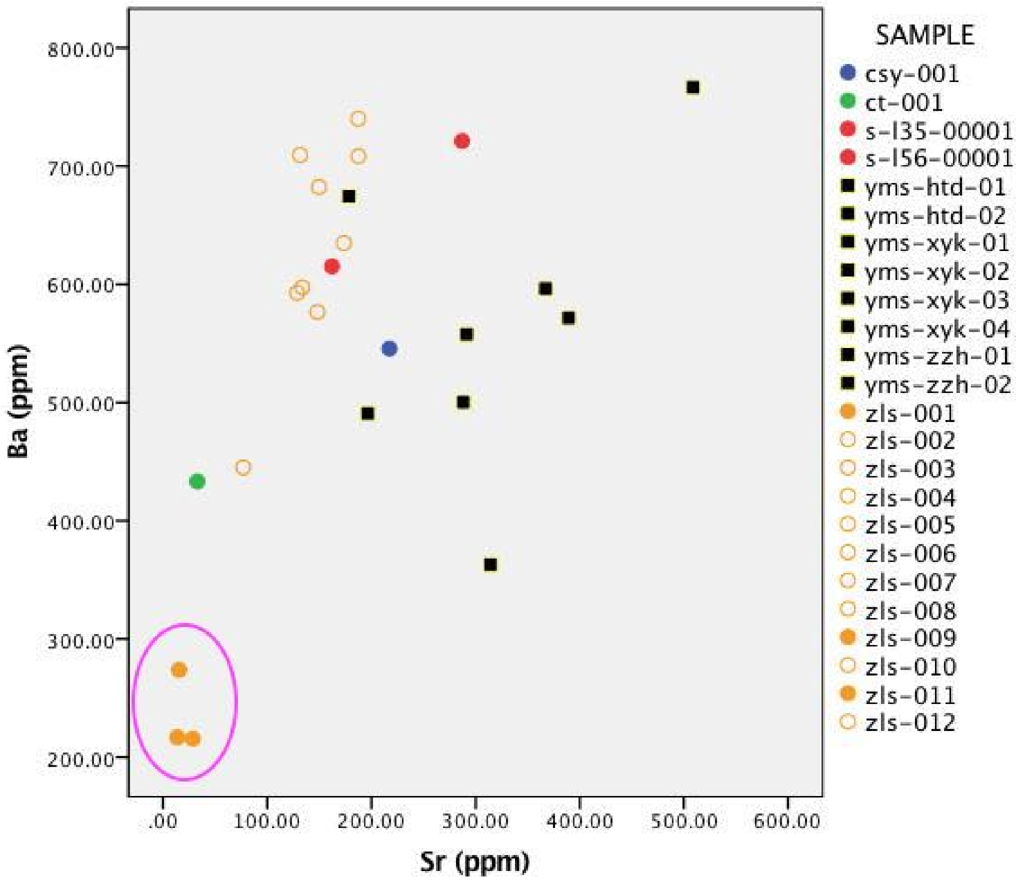

Fig. 4-2-15 Variation diagrams of Ba versus Sr (Initials: csy=Chihshanyen Site; ct=Chientan Site; s-135/156=Chihwuyuan Site; zls=Chanlungshan Site. Symbol: ■=raw material of andesite).

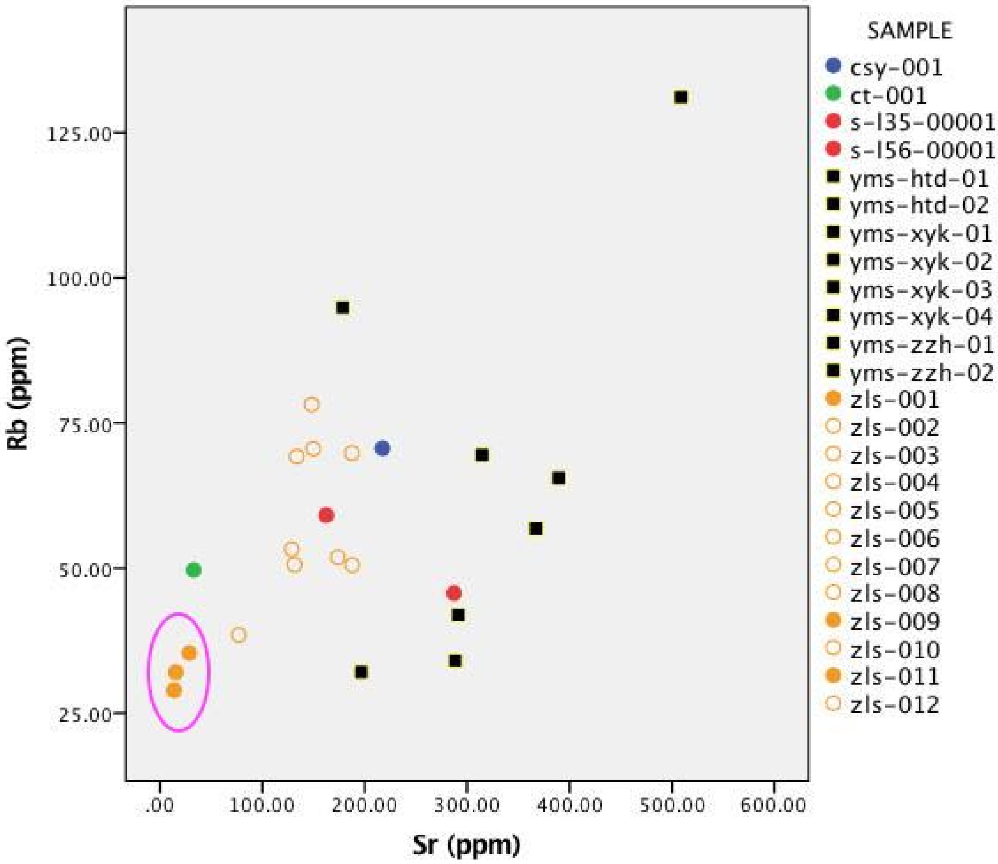

Fig. 4-2-16 Variation diagrams of Rb versus Sr (Initials: csy=Chihshanyen Site; ct=Chientan Site; s-135/156=Chihwuyuan Site; zls=Chanlungshan Site. Symbol: ■=raw material of andesite).

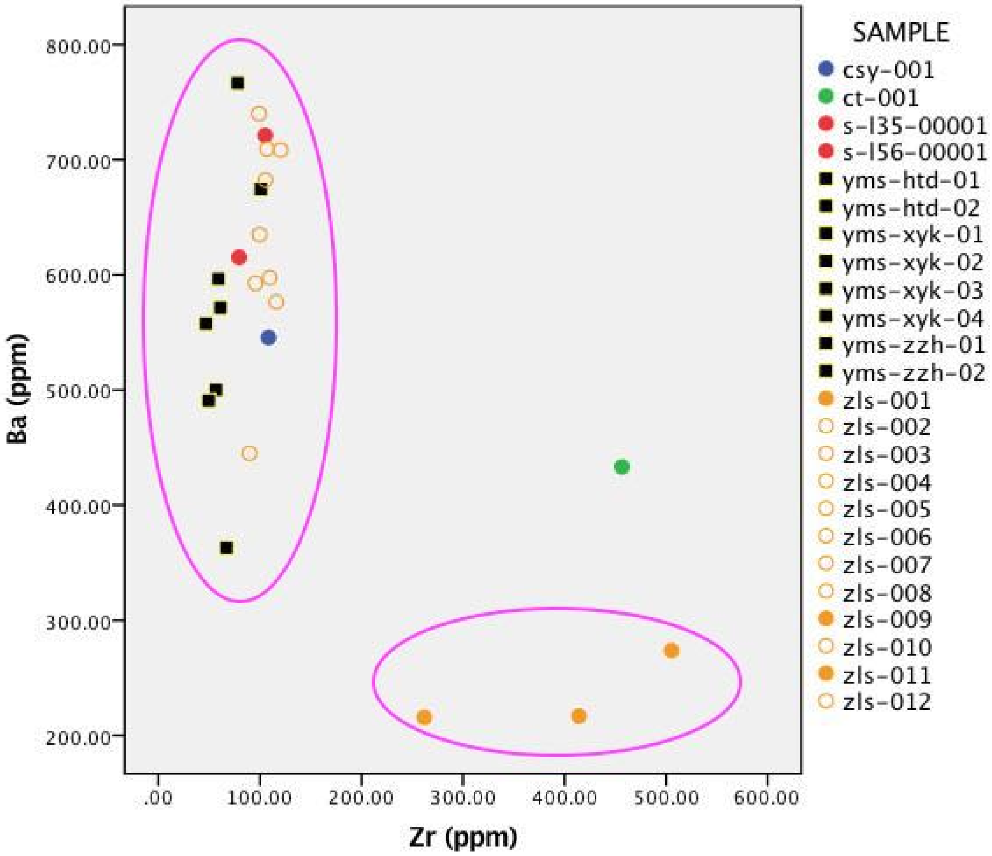

Fig. 4-2-17 Variation diagrams of Ba versus Zr (Initials: csy=Chihshanyen Site; ct=Chientan Site; s-135/156=Chihwuyuan Site; zls=Chanlungshan Site. Symbol: ■=raw material of andesite).

Chapter 4-3_ RESULTS OF PCA and TYPOLOGIAL ANALYSIS

Results: PCA analysis

There are a total of 325 measurement data of shouldered axe samples which have recorded in this study. (Table 4-3-1) These samples are finds of the on-going archaeological project and the museum collections from an archaeologist and four museums in Taiwan. Out of the 325 shouldered specimens observed in this research, a total of 257 samples are surface collections that lack archaeological contexts.

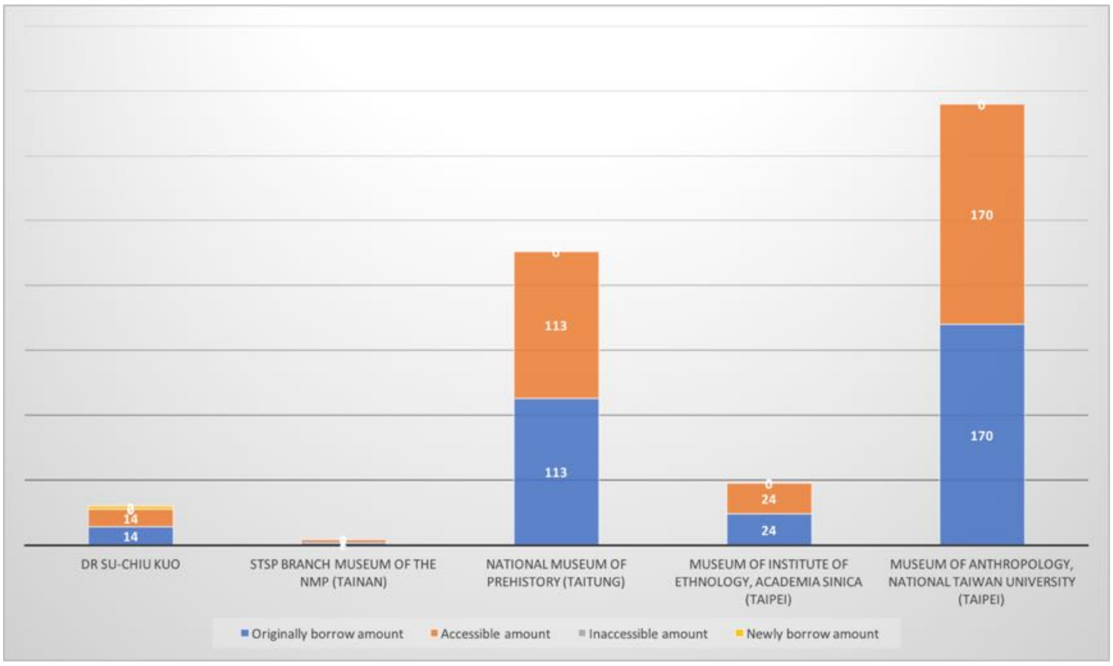

Fig. 4-3-1 Sources of the shouldered axes for this study.

Initial quantitative analysis of data

- 94.8% of the shouldered axes are collected from the sites in or around the Taipei Basin, where are located near the Tatun Volcano Group and easily obtained the raw material of the andesite to make the shouldered tools (Fig. 4-3-2 and 4-3-3).
- There are 86.5% shouldered axes from the museum collections are made of the andesite. Meta sandstone is in the second place with total 3.4% (Fig.4-3-4).
- Judging each shouldered axe from the appearance condition, majority of the shouldered tools are having two (a pair) shoulders, and the sample with only one shoulder is accounting for 12.6%. Interestingly, four shoulders (two pairs) on one shouldered axe has been found in three samples from two different sites in the Taipei Basin (1 x Chanlungshan and 2 x Yuanshan). Three samples are made of andesite. Yet, there are 31 specimens record zero due to the lost or serious damage of their shoulders (Fig. 4-3-5, 4-3-6). The state of the shoulders and blades, and the number of shoulders of the shouldered axes are shown in Figures 4-3-7 and 4-3-8.
- 90.5% of the shouldered axes are confirmed to be shouldered tools. There are 9.5% of the stone tools could not be determined whether the specimen is shouldered or not, because of the heavily damage on the surface or with a shape of the difficulty to identify (“0” shoulder in the Fig. 4-3-9).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Chanlungshan[a]	12	3.7	3.7	3.7
	Chientan[a]	1	.3	.3	4.0
	Chihshanyen[a]	46	14.2	14.2	18.2
	Chihwuyuan[a]	2	.6	.6	18.8
	Chinshui[b]	1	.3	.3	19.1
	Chiuchashan[a]	1	.3	.3	19.4
	Chungho Chienshan[a]	1	.3	.3	19.7
	Chushan[b]	1	.3	.3	20.0
	Dazhi Taipei[a]	1	.3	.3	20.3
	Fengpitou[b]	2	.6	.6	20.9
	Huweishan[a]	3	.9	.9	21.8
	Kuantu[a]	18	5.5	5.5	27.4
	Nankuanli[b]	2	.6	.6	28.0
	Shaunlungshe[b]	1	.3	.3	28.3
	Shihpafen[a]	3	.9	.9	29.2
	Tantou[b]	1	.3	.3	29.5
	Tapenkeng[a]	13	4.0	4.0	33.5
	Tapu[b]	1	.3	.3	33.8
	Unknow Site[c]	8	2.5	2.5	36.3
	Yuanshan[a]	202	62.2	62.2	98.5
	Yuanshan or Chientan[a]	1	.3	.3	98.8
	Yuanshantzu[a]	2	.6	.6	99.4
	Zhongyishan[a]	2	.6	.6	100.0
	Total	325	100.0	100.0	

Fig. 4-3-2 Archaeological sites of 325 shouldered axes have been observed.

(a: sites locate in or around the Taipei Basin. b: sites in other area of Taiwan. c: Unknown sites)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	In or around Taipei basin	308	94.8	94.8	94.8
	In other area of Taiwan	9	2.8	2.8	97.6
	Unknown collecting area	8	2.5	2.5	100.0
	Total	325	100.0	100.0	

Fig. 4-3-3 Collecting area of shouldered axes.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Andesite	281	86.5	86.5	86.5
	Argillite	2	.6	.6	87.1
	Basalt	1	.3	.3	87.4
	Hard Shale	1	.3	.3	88.0
	Meta-Sandstone	7	2.2	2.2	90.2
	Olivine Basalt	3	.9	.9	91.1
	Possible Andesite	6	1.8	1.8	92.9
	Possible Basalt	1	.3	.3	87.7
	Quartz-Sandstone	1	.3	.3	93.2
	Sandstone	11	3.4	3.4	96.6
	Schist	2	.6	.6	97.2
	Serpentine	1	.3	.3	97.5
	Slate	6	1.8	1.8	99.4
	Tuff Sandstone	2	.6	.6	100.0
	Total	325	100.0	100.0	

Fig. 4-3-4 Raw material of rocks of 325 shouldered axes have been observed. (Except for the shouldered axes from the National Museum of Prehistory which were identified by Dr Hsiao-Chin Yang, the others are categorised based on personal knowledge of stones.)

		Frequency		Percent		Valid Percent		Cumulative Percent	
		Shoulder	Blade edge	Shoulder	Blade edge	Shoulder	Blade edge	Shoulder	Blade edge
Valid	Fair	89	41	27.4	12.6	27.4	12.6	27.4	12.6
	Good	158	123	48.6	37.8	48.6	37.8	76.0	50.5
	Poor	78	161	24.0	49.5	24.0	49.5	100.0	100.0
	Total	325	325	100.0	100.0	100.0	100.0		

Fig. 4-3-5 Condition of the shoulder and blade edge.

(Good: Object shape and surface detail still visible; no/little surface damage. Fair: Object shape and surface detail still visible; surface damage. Poor: Object cracked.)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	31	9.5	9.5	9.5
	1	41	12.6	12.6	22.2
	2	249	76.6	76.6	98.8
	3	1	.3	.3	99.1
	4	3	.9	.9	100.0
	Total	325	100.0	100.0	

Fig. 4-3-6 Visible amount of shoulder.

(0: the shoulder is damaged or lost which is unable to count. 1: the damage shoulder which cannot be confirmed as one of the pair of shoulder. 4: a single sample has two pairs of shoulders.)

Fair **Good** **Poor**

Fig. 4-3-7 Examples of the shoulder condition of the shouldered axe (Photographed by Li-Chi Chiang).

Fair **Good** **Poor**

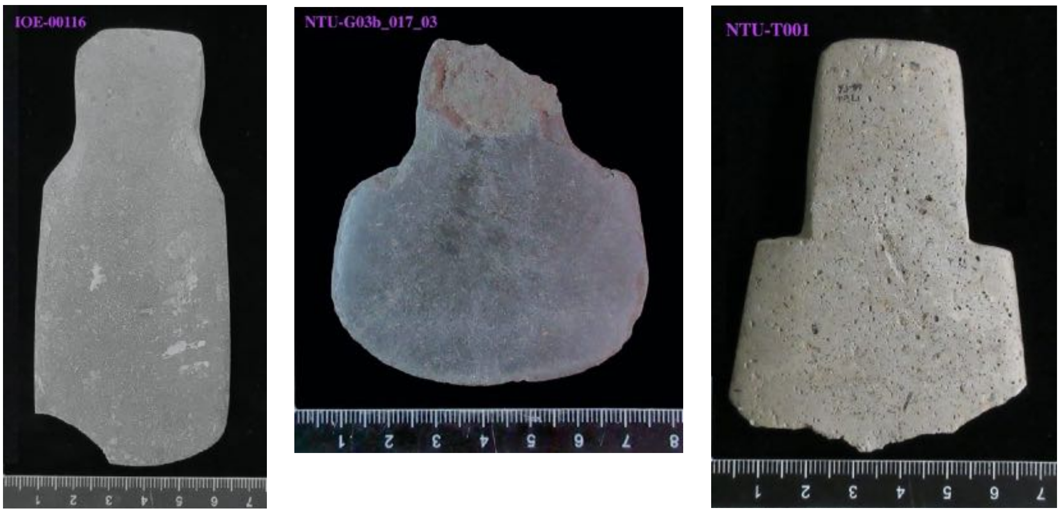

Fig. 4-3-8 Examples of the blade condition of the shouldered axe (Photographed by Li-Chi Chiang).

0	1	2
		

3	4
	

Fig. 4-3-9 Examples of the shoulder amount of the shouldered axe (Photographed by Li-Chi Chiang).

Angle grouping of the shoulder and the blade edge

All the three-dimensional outline of the shouldered axes has been analysed statistically by the SPSS. The frequency of the descriptive statistics is employed to demonstrate the initial quantitative analysis of variables in the data set and to group the shoulder angle. The principal component analysis applies to display the relevance in the dimensional measurement and/or the relationship between other variables of the shouldered axes. Results show that the shoulders seem to have several angle groups with numbers of samples, but it does not present a particular preference for the design of the shoulder angle. Same result presents in the angle group analysis of the blade edge.

The most common shoulder angle as presented in the histogram groups into four: 45-50˚, 55-60˚, 60-65˚and 25-30˚. (Fig. 4-3-10) 45-50˚appears to be the leading group of the shoulder angle. Groups of angles 55-60˚, 60-65˚and 25-30˚arrange in the following position in the order of the frequency. From the angle classification of shoulder by the frequency analysis, the angle between 45-50˚is most likely the shouldered axes were made with the specific angles of the Yuanshan cultural people. It is also given the shoulder angle between 44-48˚by the grouping result of the frequency analysis from the shouldered axes data of the Yuanshan site only (Fig.4-3-11).

Even so, groups with angles of larger or smaller than 45-50˚are all having considerable frequency which cannot rule out from the perspective of the shoulder production diversification discussion. The angle of the blade edge is shown to fall between 20°to 32°with three groups included. (Fig. 4-3-12) The reason of the less frequency of the blade edge angle occurrence lies in the missing or severely damage of the blade, and the data are recorded zero. Consequently, group with angle 0-4° need to be excluded in the functional and morphological discussion. The same situation applies to the group of shoulder angle 0-5°.

Whether or not a dominant angle group is sufficient as a resistance in hafting, to tie the shouldered axe easily and to prevent the axe slipping out of the handle whilst being used, the functionality of shoulder is clearly necessary to be verified by the experimental archaeology.

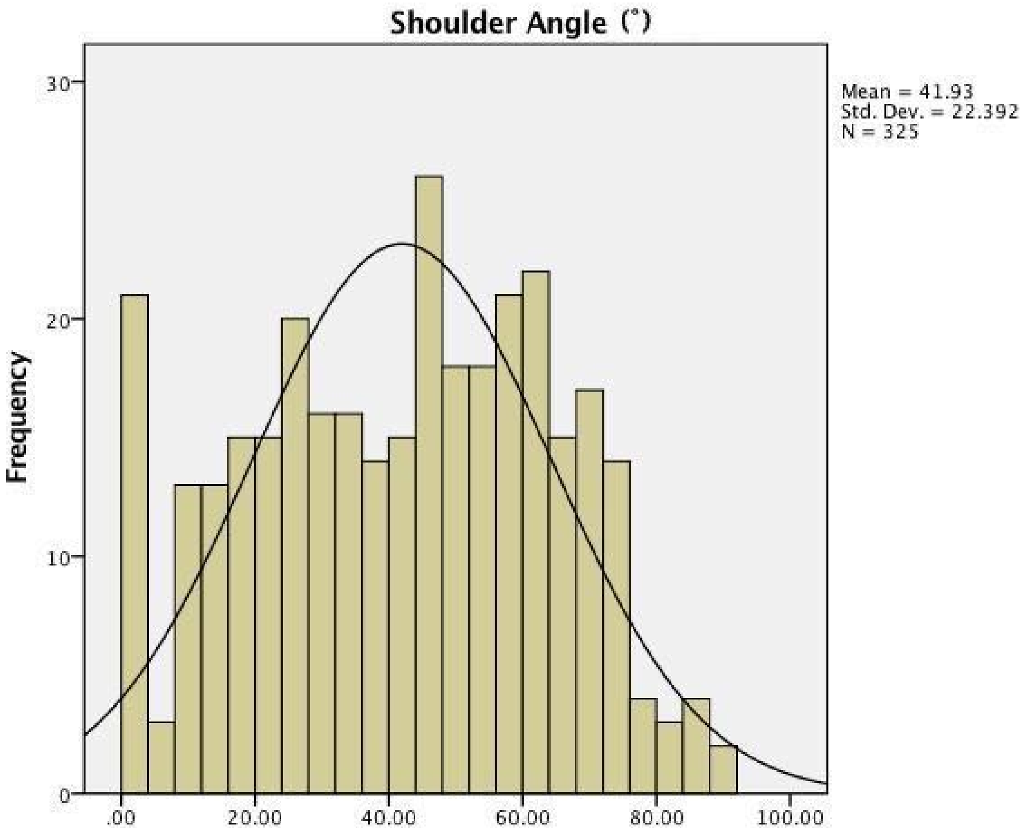

Fig. 4-3-10 Frequency of the shoulder angle on the shouldered axes.

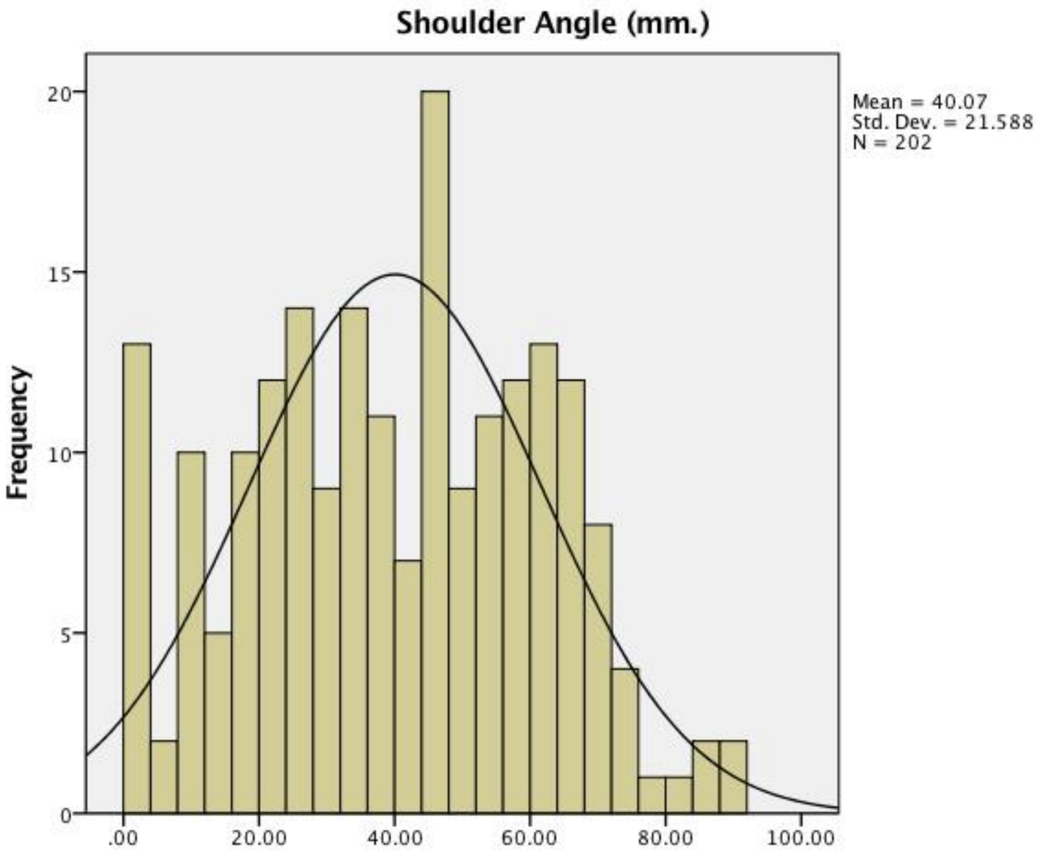

Fig. 4-3-11 Frequency of the shoulder angle on the shouldered axes from Yuanshan site.

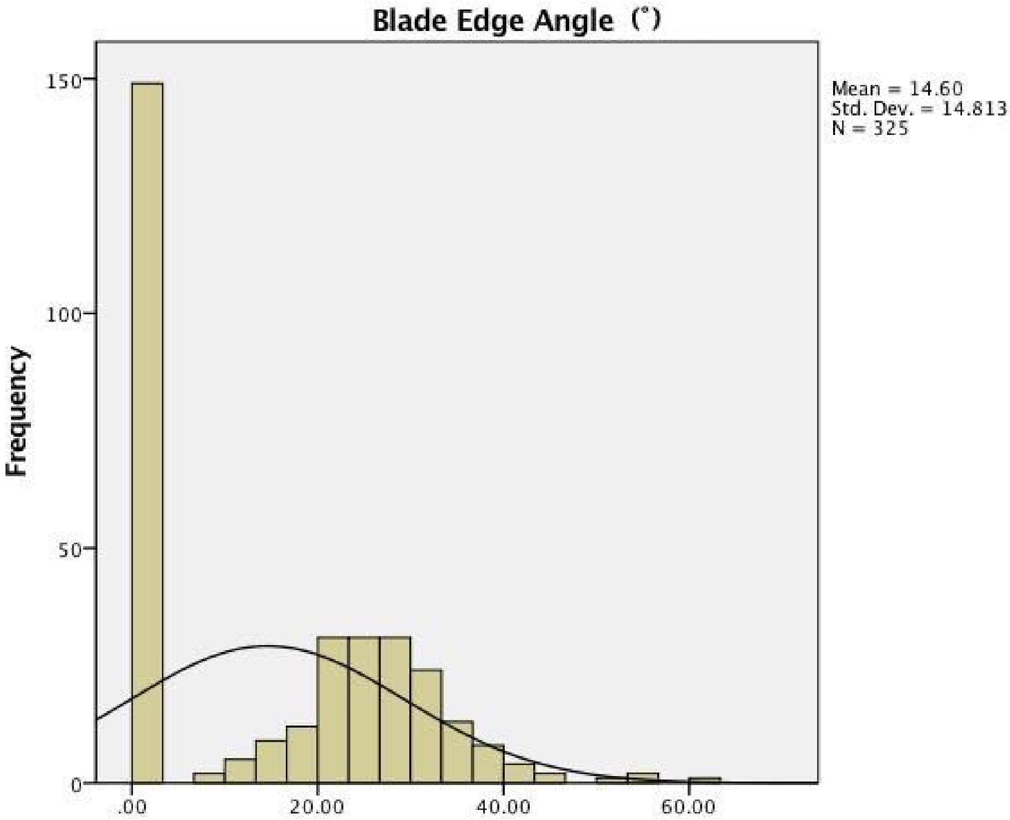

Fig. 4-3-12 Frequency of the blade edge angle on the shouldered axes.

Principle Component Analysis

The analytical results suggest that the angle between a shoulder, a blade edge and the dimension of a shouldered axe has a low correlation. The Bartlett spherical test results suggest that the variables are not irrelevant to each other (X^2 = 5551.419, df = 66, p <.001), while KMO is .600, showing that this data is mediocre for Factor Analysis. (Fig. 4-3-13) According to the eigenvalue of more than one principle (Field 2009), should take four components. (Fig. 4-3-14) The scree plot also shows that the four components should be taken. The four components are extracted by the principal component analysis (PCA) to perform the Promax rotation. The results are shown in Figure 4-3-15.

The first component contains all variables, it displays that the variables of the dimensional measurement of individual shouldered axe are all related to each other. Eight variables are included in the second component showing that the measurement of the shoulder is associated with that of each shouldered axe. The third component contains seven variables indicating the measurement of the shoulder and the blade edge are associated (except for the shoulder length). The fourth component has seven variables representing the width of shouldered axe are linked to the length and width of shoulder, as well as the all measurement of the blade edge.

These four components can explain 83.688% of the variance. The correlation between the four factors is shown in the Component Correlation Matrix. In other words, the correlation between angle and stone tool design is very low. (Fig. 4-3-16)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.600
Bartlett's Test of Sphericity	Approx. Chi-Square	5551.419
	df	66
	Sig.	.000

Fig. 4-3-13 KMO and Bartlett's Test.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.567	38.055	38.055	4.567	38.055	38.055	4.099
2	2.547	21.223	59.279	2.547	21.223	59.279	3.199
3	1.650	13.750	73.029	1.650	13.750	73.029	2.469
4	1.279	10.659	83.688	1.279	10.659	83.688	1.700
5	.812	6.770	90.458				
6	.398	3.318	93.775				
7	.362	3.016	96.791				
8	.206	1.719	98.510				
9	.119	.993	99.503				
10	.053	.439	99.942				
11	.006	.047	99.989				
12	.001	.011	100.000				

Fig. 4-3-14 Total Variance Explained.

Extraction Method: Principal Component Analysis[a].

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

	Component			
	1	2	3	4
Length	.728	.229	-.409	-.096
Width	.334	.283	-.221	.254
Thickness or Height	.502	.411	-.554	-.273
Weight	.671	.361	-.554	-.140
Shoulder Length	.335	.786	.434	.220
Shoulder Width	.085	.491	-.008	.775
Shoulder Height	.379	.692	.543	-.120
Shoulder Angle	.269	.327	.461	-.645
Blade Edge Length	.894	-.374	.141	.077
Blade Edge Width	.868	-.359	.152	.074
Blade Edge Height	.879	-.391	.101	.088
Blade Edge Angle	.751	-.499	.267	.115

Fig. 4-3-15 Component Matrix[a].

Extraction Method: Principal Component Analysis[a].

a. 4 components extracted.

Component	1	2	3	4
1	1.000	.350	.116	-.007
2	.350	1.000	.247	.148
3	.116	.247	1.000	.203
4	-.007	.148	.203	1.000

Fig. 4-3-16 Component Correlation Matrix.

Extraction Method: Principal Component Analysis.

Rotation Method: Promax with Kaiser Normalization.

Discussion

The shoulder angle has a group that appears more frequently than the other groups, the other angle groups also appear more or less. This represents that the distribution of the angle values is extensive, and the shoulder of the shouldered axes may not have a specific favour of angle requirement. In other words, the angle of shoulder probably is not the centre of the consideration in the shouldered axe production. Therefore, shoulder of shouldered axe is unnecessary functional in terms of manufacturing request, even if the shoulder itself may be practical in use, for example, easy for hafting or save effort.

Although there are three groups of blade edge angle show the same frequency, the angle of blade edge is shallow in overall. The shallow angle presented by the blade edge may be increasing the contact surface between the shouldered axe and the object during use. So that the object could be easily upturned, removed or cut off by the shouldered axe. Observing the damaged state of the specimens in Figures 4-3-7, 4-3- 8 and 4-3-9, it seems that there is a set of usage patterns that cause such a feature. It probably is used with a handle hafted, therefore, it will be verified by the replica experiment.

The outcomes of the angle analysis on the shoulder and the blade present diversely, which means that the Yuanshan cultural people do not have a set of standard procedures for making (designing) the shoulder or the shouldered axe.

Results: typological analysis

A. Types of shoulder

After observing the shoulders of the shouldered axes, there are six types can be categorised. The shape and size of the shoulder on the shouldered axes in Taiwan are relatively balanced and symmetrical and are traditionally divided into three categories. Type 1 is the shape of the plain shoulder, Type 2 of a droop shape shoulder and a shrugged shoulder on Type 3 shouldered axe. (Fig. 4-3-17) In addition to Type 7 which was the inability to judge the shape of the excessive damage shoulder, this study noticed that the shape of the shoulder on the shouldered tools was mixed with two of the aforementioned three types at the same time. Three categories are classified as Type 4 (Type 1 with 2), Type 5 (Type 2 with 3) and Type6 (Type 1 with 3) after observing the forms of the shoulder on the tools, because such mixed type of shoulder appearance may be related to the method of making the shoulder. (Fig. 4-3-18)

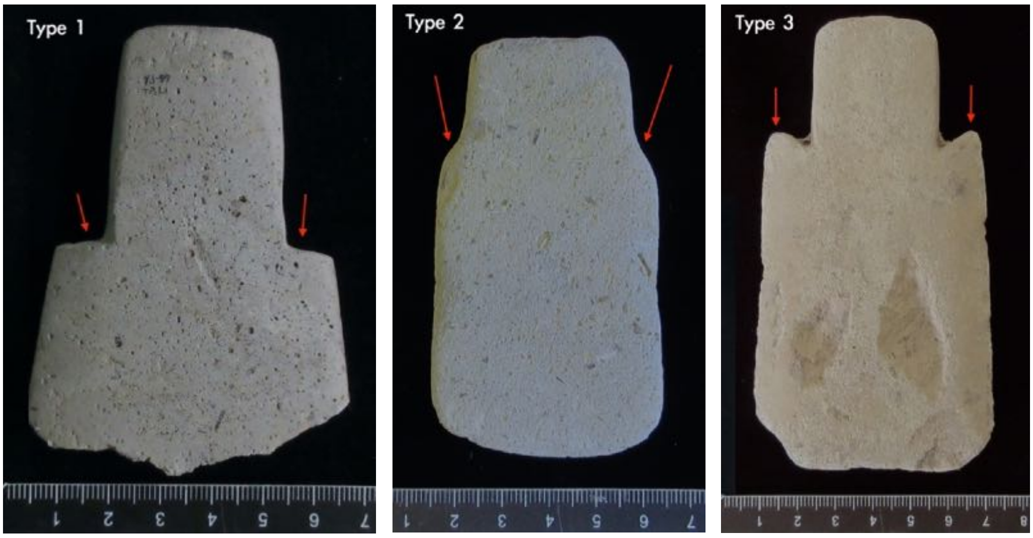

Fig. 4-3-17 Shoulder types. Type 1: Yuanshan site (MANTU). Type 2: Chanlungshan site (Kuo, IHP). Type 3: Yuanshan site (IOE). (Photographed by Li-Chi Chiang).

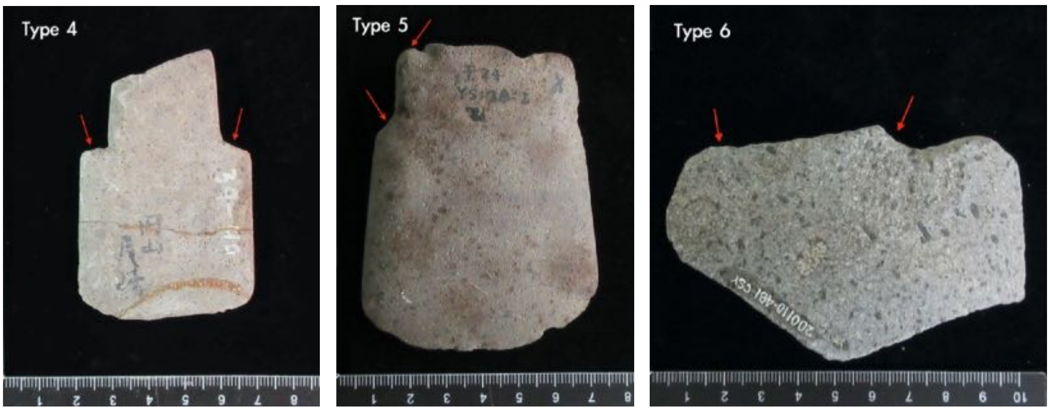

Fig. 4-3-18 Shoulder types Type 4: Yuanshan site (MANTU). Type5: Yuanshan site (MANTU). Type 6: Chihshanyen site (NMP). (Photographed by Li-Chi Chiang).

Figure 4-3-19 demonstrates the number of shoulder shapes of the shouldered tools collected from each site. Type 2 accounted for 57.54% of the total number, followed by 23.38% of Type 1. These two types account for 80% of the majority. Of all the shouldered axes examined, one was found in each of Type 5 and Type 6. The former may be caused by the processing or refitting of the shouldered specimen. The cause of Type 6 is unclear and may be the consequence of the severe damage by original use or stratigraphic environment. This data presents that Type 2 is the main form of the shoulder.

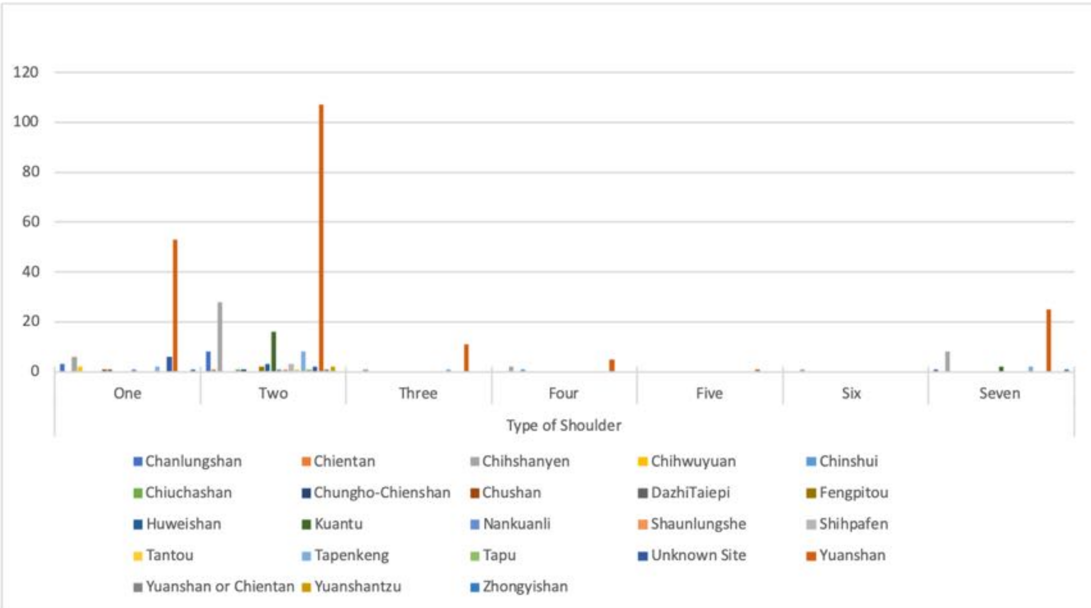

Fig. 4-3-19 Type of shoulder of a shouldered axe in each archaeological site.

The preliminary statistics of Figure 4-3-20 show that among the shouldered tools unearthed at each site, the number of symmetrical form accounts for about 62.77%, the number of asymmetric shoulders is about 12.31%. And the number of shouldered tools which were unable to confirm whether the shoulder was symmetrical or asymmetrical is 24.92%. The reason for the failure of the morphology identification of the shoulder is related to the damage of the stone tools. For example, only a shoulder of the whole tool can be identified as a shouldered artefact without having a recognisable form or symmetry of its shoulder, and the rest are missing. If the unidentifiable data is excluded, and only the number of shoulder shape can be recognised, the symmetrical form of Taiwan's shouldered stone artefacts is still the majority. Therefore, it can be seen that the symmetrical shape of shoulders on the shouldered axes in Taiwan still accounts for the mainstream of the production.

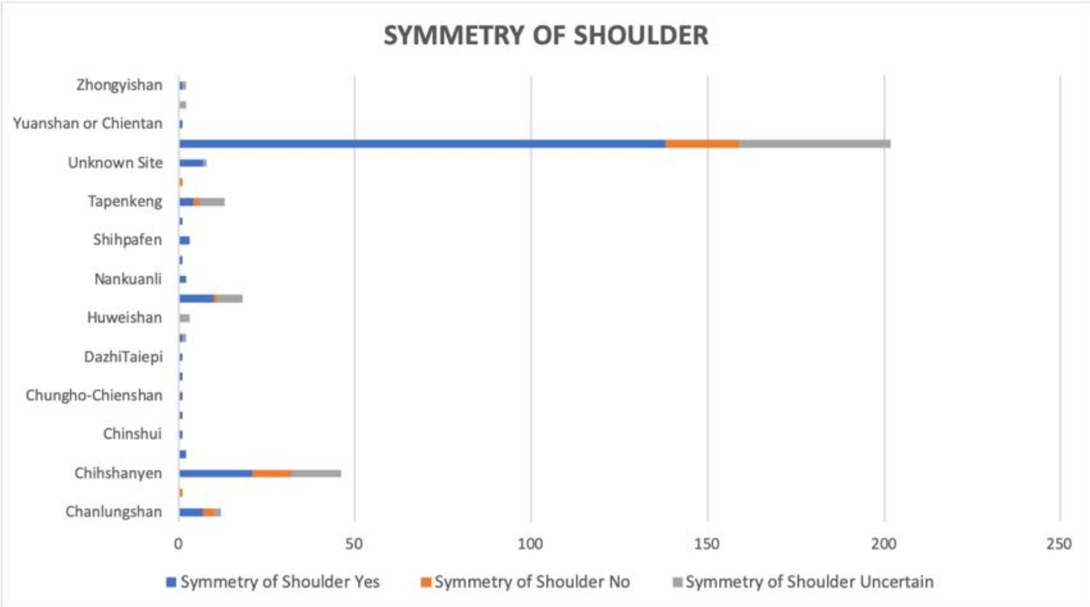

Fig. 4-3-20 Symmetry of the shoulder (s) of a shouldered axe in each archaeological site.

The relationship between the number of shoulders and the raw material of rocks of the shouldered axes is given in Figure 4-3-21. The number of shoulders on the andesite shouldered tools is largely pointed at the category of two, followed by one. The sandstone material with the second largest number of shouldered stone tools also shows that it is mainly with two shoulders. It must be noted that the reason for one shoulder being recorded in this study is mostly linked to the damage of the shouldered specimen with only one shoulder observed.

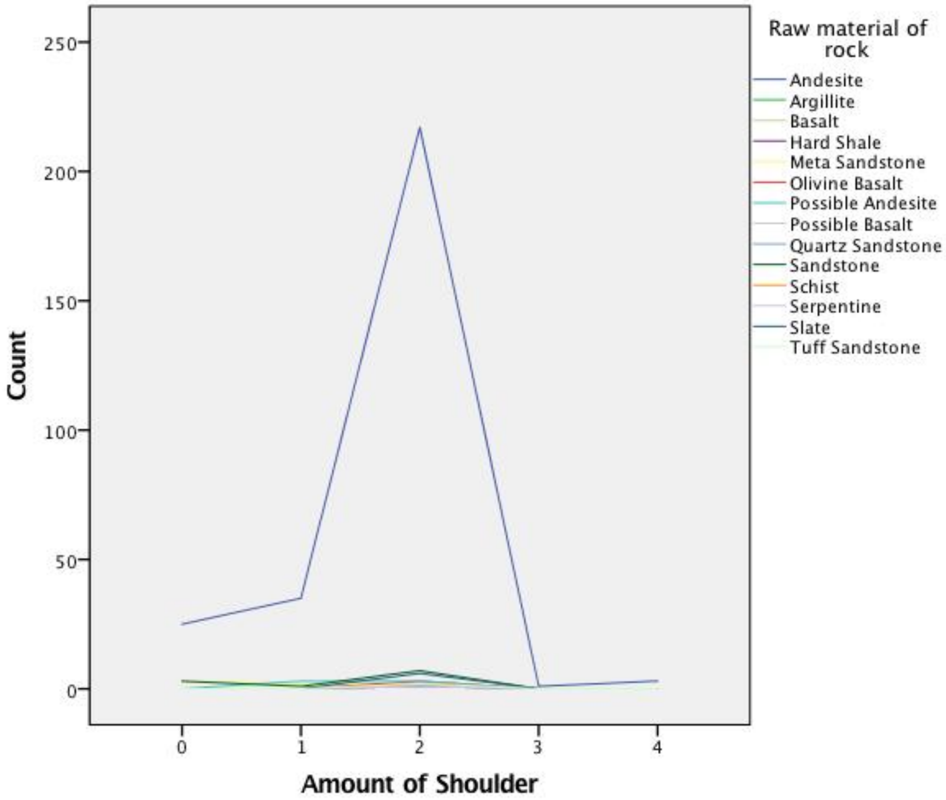

Fig. 4-3-21 Number of the Raw material of rock vs. amount of shoulder.

B. Typological groups of shouldered axes

Compared to the simple classification of shoulder forms, the classification of the Taiwanese shouldered axe itself seems more complicated than its shoulder type. The reason for the relatively complicated classification is not only that the shape of the shoulders is different, but also the obvious overall appearance variation of the shouldered axe, so that the inference of the usage/function or the production technology of the Taiwanese shouldered stone tools is varied. Therefore, the typological classification in this section refers to both the overall appearance of the shouldered axe and the shoulder type as a criterion for a broader classification of groups. (Fig. 4-3-24) In other words, there are the types of Taiwanese shouldered axes defined in this study. Besides, since there are not sufficient intact shouldered objects, reference to incomplete specimens can also be identified and satisfying as many classification conditions as possible for grouping. It is hoped that a wide range of typological observations and information for sourcing the Taiwanese shouldered tools can be obtained through the broader group classification. The classification principles of each group are explained sequentially below.

- Group 1 is classified by the shoulder type with the flat characteristic.
- Group 2 is grouping by the shoulder type with a shrug feature and the size of the head and body, and it can be divided into three sub-groups based on the difference between the shoulder and the body. 2a is the shrug feature with a bit sharp tip on both the outer side of the shoulder. While 2b is with a bit round tip. 2c is the shrug feature with a small top of the head and a large body.
- Group 3 is mainly classified by the shoulder type, form, and size of the body, the arc-shaped mark on the shoulder neck, as well as the rounded edge. 3a is a short and flat/droop features of the shoulder with a square body and a shallow rounded edge. The categorising conditions of 3b are added arc-shaped mark than 3a. 3c adds a condition of the extended body of the shouldered axe except those classifying conditions fulfilled in the 3a and 3b.

- Group 4 has features of a drooping shoulder and a rounded edge. The difference between 4a and 4b is the length of their square body: 4a is shorter against the 4b.
- Group 5 is grouping by the conditions of the features with a steep down shoulder, an extended both sides of the body toward the edge, and a rounded edge.
- Group 6 is a sample featured with a drooping shoulder, an oval shape of the body, and a rounded edge.
- Group 7 has conditions of the drooping shoulder and a round edge, and a body with slightly narrowing down from both sides toward the edge.
- Group 8 has no clear line between shoulder and body, the shape of the drooping shoulder on one side, extended both sides of the body toward the edge, and a rounded edge.
- Group 9 is classified by the conditions of its steeping down shoulder, an extended body from both sides toward the edge and a rounded edge, which 9b is the model. 9a adds a condition of the double shoulders. 9c is similar to 9b in morphology, except its longer length of the body.
- Group 10 has features with a long head, a drooping shoulder on one side and a parallel edge against the axis.
- Group 11 has a form that resembles Group 8, except its clear drooping shoulder on both sides.
- Group 12 is grouping by the asymmetrical shoulders, a small head on the top, the sharpening and grinding side edge of the body.

The typology of the shouldered axes in Taiwan falls mostly into these 12 groups. The subtle differences in the forms of utensils can be distinguished into various groups of examined artefacts. Among them, the 9th and 10th types are relatively rare in Taiwan. The rest of the Yuanshan cultural shouldered tools have seen in a higher probability. Apart from the concept of shoulders on the stone object, it seems that the shouldered axes of theYuanshan Culture cannot be attributed to specific typological preferences.

As to the evolution of the shouldered axe types, although this study grouped the types of the shouldered axes, not all specimens have their archaeological context. Therefore, in the discussion of typological evolution will only sort and surmise the andesite shouldered axes from the sites of Chanlungshan and Chihwuyuan both known accurate age.

Group 2 has the earliest currently know form among these groups because of the No.7 in Fig. 4-3-24 is found at the Hsuntangpu cultural layer of the Chihwuyuan site, dated to c. *3830-3570 cal.* BP. The Yuanshan cultural shouldered axe Specimen No. 10 in the same group which collected from the Tapenkeng site, has similar forms of No.7.

Groups of 3-6, 8, 9,10, 11 have the shouldered axes of Chanlungshan site examined in this dissertation, which dated to *c. 3350-2350 cal* BP. It is the time that the Yuanshan Culture are recognised as the' booming' period in Taiwanese archaeologists. (Liu *et al.* 2004) If the types of shouldered axes of Chanlugnshan site sorted by the cultural layers in the stratum, the order of the types evolved would be: the specimen from the layer 4 have No.25 of Group 4b /No.40 of Group8/No.44 of Group 9, the specimen from layer 1 has No.30 of Group 5. Interestingly, the unearthed layers of the two Chanlugnshan samples in group 3a are different: No.12 of layer 4 and No.14 of layer 1.

The shape and dimension of shouldered axes from layer 4 are varied. Even the shouldered axes unearthed in the same layer still have significant differences in their types. The two specimens of layer 1 classified in the same group in this study, the age of No. 12 should be earlier than that of No. 14. And the dimension of No. 12 (L: W: H = 89.05 x 8.25 x12.21mm.) is larger than No. 14 (L: W: H = 79.82 x 50.9 x 9.88mm.). The size of No. 14 is similar to that of No. 30 in Table 4-3-25 (L: W: H = 79.65 x 61.57 x 12.93mm.) of Group 5 discovered in the same layer.

If considering the size of the shouldered tools from the earliest Chihwuyuan specimen of the Hsuntangpu Culture of the Chihwuyuan site to that of the Chanlungshan, the dimensions of the shouldered axes are gradually reduced. One of the reasons for the reduction in the size of the shouldered axes may be that the Chanlungshan site was located in the south of the Taipei Basin and far from the andesite quarry of the Tatun Volcano Group in the north. It is difficult to obtain the raw material of andesite to produce shouldered tools. Consequently, andesite is so precious to make into small tools only. However, in view of the discovery of

Taiwanese jade found at the prehistoric sites in the Philippines or Vietnam, the distance of the quarry form single site does not the only answer to the size reduction of a stone tool. (Liu 2019) Or just re-shape the original larger andesite tool for use. In terms of the usage approach, Liu's category of stone tools from the Chiuchashan site presents in Figure 4-3-22 that Group 4 should be classified as a necked stone hoe. (Liu 1982) A neck or shoulder on the stone tool is descriptively difference of shape only that the neck extends longitudinally, and the shoulder extends laterally. Therefore, from the typological aspect, the function of the shouldered axe can be used as a hoe. However, further verification with replicate experiments is still required.

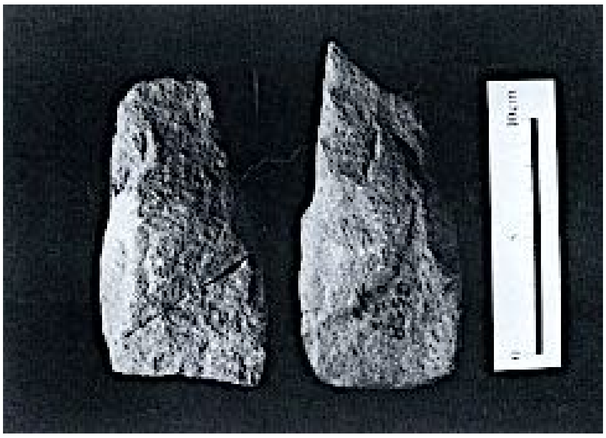

Fig. 4-3-22 Necked stone hoe. (Liu 1982, plate 20 and 22)

Considering the typological comparison of the shouldered axes between Taiwan and that of the southeast coast of China and the Southeast Asia Peninsula (Fig. 4-3-23), in the types of Group 3 and 4 are respectively similar to type IIc and type I of the Pearl River Delta types of Fu’s classification. (Fu 1988, Fig. 2-2-8) The form of Group 6 is alike to that of the Nujiang River type in southwest China classified by Geng (Geng 1990, Fig. 2-2-10). Group 9 is close to Type C and Group 2 resembles Type A of aina Peninsula which are categorised by Fu (Fu 1988, Fig. 2-2-9). Group 8 and 11 are similar to Type A of Wang's category (Wang 1987, Fig. 2-2-7). Three scholars provide only the dating data of a single site in a large scale of area (watersheds in south China) as a relative time explanation for typological comparison, therefore, it is difficult to judge the development order of forms of the shouldered axes in terms of time. However, the typological classifications across regions show that some of the shapes of the Taiwanese shouldered axes resemble those types from the Pearl River Delta, Nujiang River and Southeast Asia Peninsula. It must be mentioned that the similarity in forms cannot explain the origin of Taiwanese shouldered axes, because the chronological evidence is not supported. For example, sites with shouldered tools unearthed in Vietnam are generally no earlier than 3000-2800 BP, whilst the date of the No.44 of Group 9a from the Yuanshan cultural layer in the Chanlungshan site *c.* 3300 - 2700 BP.

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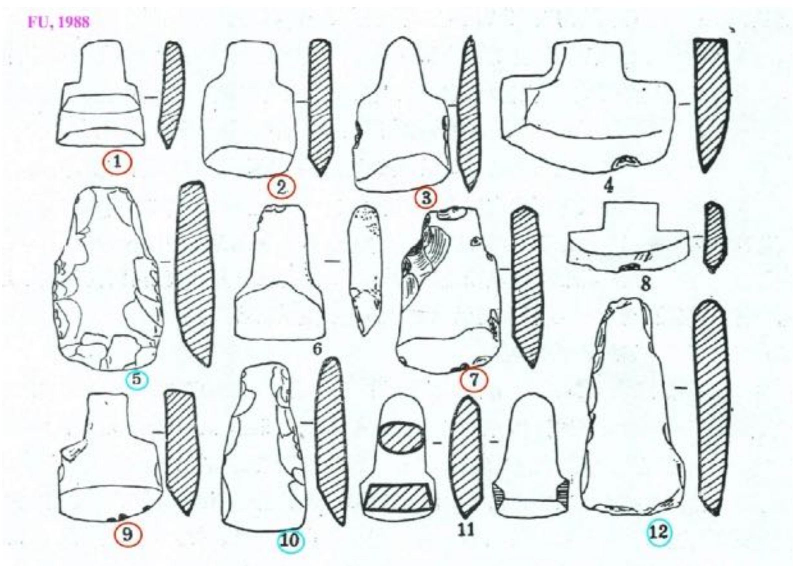
<td rowspan="2">
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<td>
Group 4 (blue circle)</td>
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<td>
Group 3 (red circle)</td>
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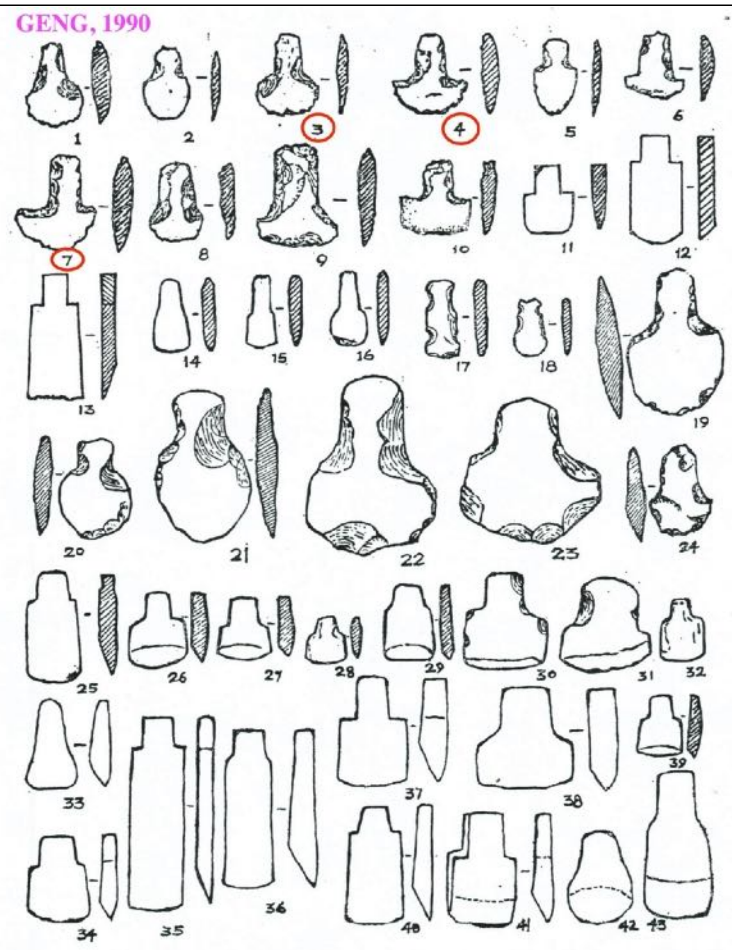
<td>
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Group 6 (red circle)</td>
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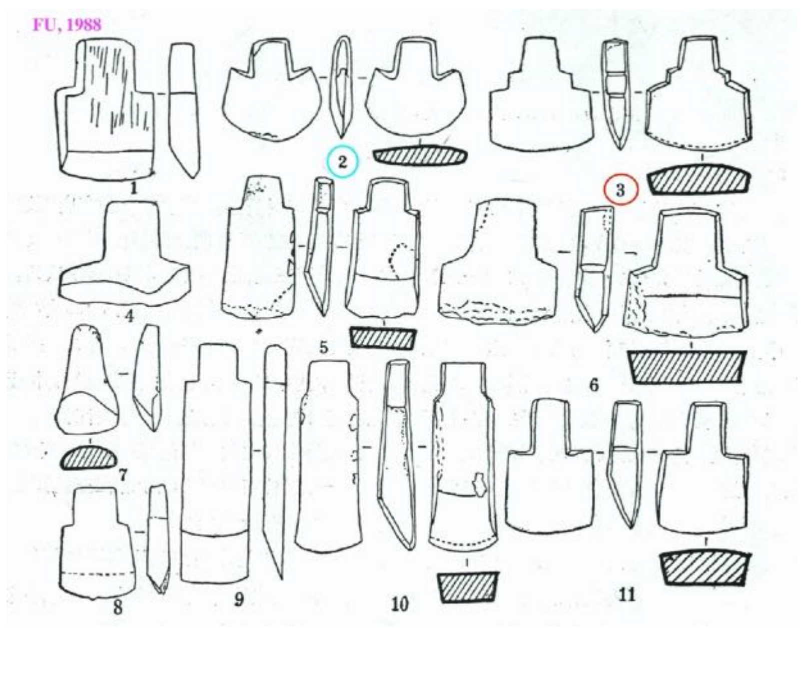


Group 9 (red circle)

Group 2 (blue circle)

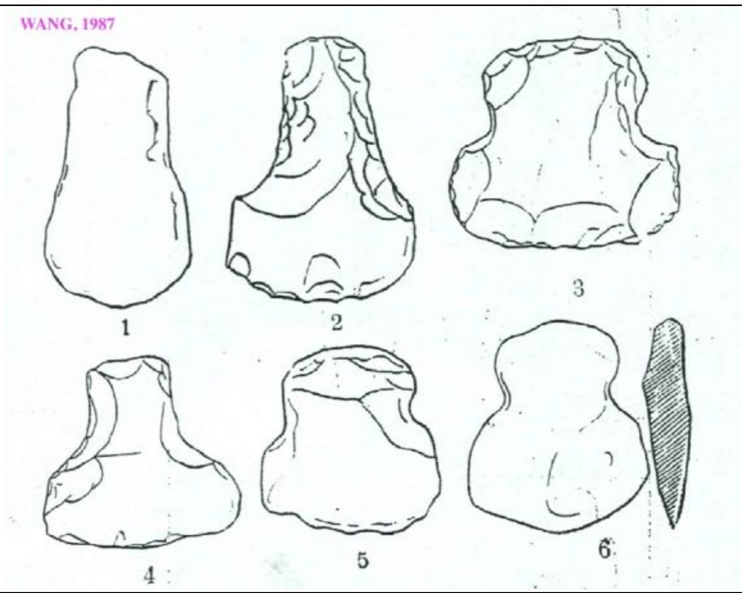


Fig. 4-3-23 The comparison of the shouldered axes between Taiwan and that of the southeast coast of China and the Southeast Asia Peninsula.

Discussion

The typological classification given in this study presents that the forms of the Taiwanese shouldered axes have a variety of styles, including the dimensions of the tools. One thing shared is forming the shoulder on a tool. In other words, neither the size nor the body of the shouldered axes requires a standard shape for manufacturing, but the shoulders must be on it. Even if there are shoulders on the shouldered axes, the appearance of the shoulders of each stone tool is slightly different too. Also, the form of the shoulder with the symmetrical and a pair of the shoulder is the mainstream of the production style. The former accounts for about 62.77% of the total number, while the latter is 76.31%. A small number of mixed types of shoulders (Type 3-6) accounted for about 7.08% of the total specimens. The modification method of the shouldered axes with grinding and fine grinding is 93.23% of the total observed samples, and the pecking only accounts for 1.84%, both processing with the modification of grinding and pecking found on the specimen is about 4.31% of the total. (Fig. 4-3-25 a, b) Different statistical data may also be a result related to production technology. The reason for the difference from the statistics is presumed to be the making techniques of the shouldered tools as well. The production method of shouldered axes will be tested by replica experiments. Besides, despite the information collected at this stage is not enough to explore specifically the origin of Taiwanese shouldered axes. It is achieved in this study that some of the types of the Taiwanese shouldered axes are close to that appeared in south China and the Peninsula of Southeast Asia.

Archaeological site	Prehistoric culture	Date (B.P.)
Chanlungshan site	Chihwuyuan culture	2,800-1,800
	Yuanshan culture	3,200-1,800
Chientang site	Shisanghang culture	1,800-400
	Chihwuyuan culture	2,800-1,800
	Yuanshan culture	3,200-1,800
	Hsuntangpu culture	4,500-3,500
Chihshanyen site	Chihwuyuan culture	2,800-1,800
	Yuanshan culture	3,200-1,800
	Chihshanyen culture	3,800-3,200
	Hsuntangpu culture	4,500-3,500
	Tapenkeng culture	6,300-4,500
	Palaeolithic culture (the late stage)	6,000 >
Chihwuyuan site	Shisanghang culture	1,800-400
	Chihwuyuan culture	2,800-1,800
	Yuanshan culture	3,200-1,800
	Hsuntangpu culture	4,500-3,500
Chiuchashan	Chihwuyuan culture	2,800-1,800
	Yuanshan culture	3,200-1,800
Chungho Chienshan	Chihwuyuan culture	2,800-1,800
	Yuanshan culture	3,200-1,800
Huweishan site	Chihwuyuan culture	2,800-1,800
	Yuanshan culture (the late stage)	2,500-1,800
	Hsuntangpu culture	4,500-3,500
Kuantu site	Shisanghang culture (the late stage)	1,800-350
	Chihwuyuan culture	2,800-1,800
	Yuanshan culture	3,200-2,800
	Chihshanyen culture	3,800-3,200
	Tapenkeng culture (the late stage)	5,000-4,500
Shihpafen site	Chihwuyuan culture	2,800-1,800

	Yuanshan culture	3,200-1,800
Tapenkeng site	Shisanghang culture	1,800-400
	Chihwuyuan culture	2,800-1,800
	Yuanshan culture	3,200-2,800
	Hsuntangpu culture	4,500-3,500
	Tapenkeng culture	5,000-4,500
Yuanshan site	Shisanghang culture (the late stage)	1,800-400
	Chihwuyuan culture	2,800-1,800
	Yuanshan culture	3,200-1,800
	Chihshanyen culture	3,800-3,200
	Hsuntangpu culture	4,500-3,300
	Tapenkeng culture	6,300-4,500
	Pre-pottery culture	> 6,500
Yuanshantzu site	Yuanshan culture	3,200-1,800
	Hsuntangpu culture	4,500-3,500
Zhongyishan site	Yuanshan culture	3,200-1,800

Table. 4-3-1 Archaeological sites and their dates which unearthed the Yuanshan cultural layer with the shouldered axes in Northern Taiwan. (Liu *et al.* 2004)

Group	Sub-group	Images
1		   1 2 3
2	2a	    4 5 6 7
	2b	 8

	2c	  	9 10 11
3	3a	  	12 13 14
	3b	  	15 16 17

	3c	 18 19 20 21 22
4	4a	 23 24
	4b	 25 26 27 28 29

5		 	30 31
6		   	32 33 34 35
7		   	36 37 38 39
8		   	40 41 42 43

9	9a	  44 45
	9b	 46
	9c	  47 48

10		 49
11		    50 51 52 53
12		  54 55

Fig. 4-3-24 Classification of Shouldered Axes Typology (Photograph by Li-Chi Chiang).

Chanlungshan site: 12, 14, 18, 25, 30, 32, 40, 44 of IHP (Kuo). Chientang site: 50 of IHP (Kuo). Chihshanyen site: 48 and 55 of NMP; 49 of IHP (Kuo). Chihwuyuan site: 7 and 20 of IHP. Huweishan site: 24, 26, 43 (Chen); 28, 36, 51 of IHP (Kuo 2012). Chiuchashan site: 39 of NMP. Chungho-

Chienshan site: 34 of MANTU. Kuantu site: 17, 29, 41, 42 of NMP. Shihpafen site: 33 of NMP. Tapenkeng site: 10 and 52 of NMP. Tutigonshan site: 23 of CAD (NTCG). Unknown site(s): 19 of NTM. Yuanshan site: 1, 2, 3, 5, 22, 35, 37 of IOE; 4, 6, 8, 9, 11, 15, 21, 27, 31, 46, 47, 53 of MANTU; 13, 16, 19, 38 of NTM; 45 and 54 of NMP. (IHP=Institute of History and Philology, Academia Sinica. NMP=National Museum of Prehistory. MANTU=Museum of Anthropology, National Taiwan University. CAD, NTCG= Cultural Affairs Department, New Taipei City Government. NTM=National Taiwan Museum.)

Archaeological Site	Amount of specimen	Condition of Shoulder			Symmetry of Shoulder			Type of Shoulder							Shouldered			Amount of shoulder				
		Good	Fair	Poor	Yes	No	Uncertain	One	Two	Three	Four	Five	Sixe	Seven	Yes	No	Uncertain	Non	One	Two	Three	Four
Chanlungshan	12	5	3	4	7	3	2	3	8	0	0	0	0	1	8	1	3	4	1	6	0	1
Chientan	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0
Chihshanyen	46	10	15	21	21	11	14	6	28	1	2	0	1	8	38	2	6	7	7	32	0	0
Chihwuyuan	2	2	0	0	2	0	0	2	0	0	0	0	0	0	2	0	0	0	0	2	0	0
Chinshui	1	0	1	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0
Chiuchashan	1	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0
Chungho-Chienshan	1	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0
Chushan	1	1	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0
DazhiTaiepi	1	1	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0
Fengpitou	2	1	1	0	1	0	1	0	2	0	0	0	0	0	2	0	0	0	0	2	0	0
Huweishan	3	0	1	2	0	0	3	0	3	0	0	0	0	0	1	0	2	1	2	0	0	0
Kuantu	18	7	8	3	10	1	7	0	16	0	0	0	0	2	10	1	7	8	0	10	0	0
Nankuanli	2	0	2	0	2	0	0	1	1	0	0	0	0	0	2	0	0	0	0	2	0	0
Shaunlungshe	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0
Shihpafen	3	1	1	1	3	0	0	0	3	0	0	0	0	0	3	0	0	0	0	3	0	0
Tantou	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0
Tapenkeng	13	6	3	4	4	2	7	2	8	1	0	0	0	2	10	0	3	0	2	10	0	1
Tapu	1	0	0	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0
Unknown Site	8	7	1	0	7	0	1	6	2	0	0	0	0	0	7	0	1	0	0	8	0	0
Yuanshan	202	114	48	40	138	21	43	53	107	11	5	1	0	25	181	5	16	10	27	162	1	2
Yuanshan or Chientan	1	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0
Yuanshantzu	2	0	1	1	0	0	2	0	2	0	0	0	0	0	1	0	1	1	1	0	0	0
Zhongyishan	2	0	1	1	1	0	1	1	0	0	0	0	0	1	2	0	0	0	1	1	0	0
Total amount of specimen	325	158	89	78	204	40	81	76	187	13	8	1	1	39	276	9	40	31	41	248	1	4

Fig. 4-3-25a Preliminary statistics of the typological attributes of Taiwanese shouldered axes in each archaeological site. (Detailed records of the attributes and measurements of 325 shouldered axes are available in Appendix 2-1 and 2-2.)

Archaeological Site	Amount of specimen	Raw mateiral				Modification Method						Possible Function					Condition of Edge		
		Andesite	Sandstone	Basalt	Others	Grind	Grind with fine polished	Peck	Peck and Grind	Peck and grind with fine polished	raw rock	Adze	Axe-Hoe	Knife	Suspected Axe-Hoe	Uncertain	Good	Fair	Poor
Chanlungshan	12	9	3	0	0	9	1	0	1	1	0	0	9	0	3	0	7	2	3
Chientan	1	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0
Chihshanyen	46	40	6	0	0	3	38	2	2	0	1	0	23	0	23	0	13	6	27
Chihwuyuan	2	2	0	0	0	2	0	0	0	0	0	0	1	0	1	0	1	0	1
Chinshui	1	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0
Chiuchashan	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0
Chungho-Chienshan	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0
Chushan	1	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0
DazhiTaiepi	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0
Fengpitou	2	0	1	1	0	0	1	0	1	0	0	0	1	0	1	0	0	0	2
Huweishan	3	0	3	0	0	0	0	3	0	0	0	0	0	0	3	0	0	0	3
Kuantu	18	18	0	0	0	18	0	0	0	0	0	0	10	0	8	0	4	3	11
Nankuanli	2	0	0	2	0	2	0	0	0	0	0	0	2	0	0	0	1	1	0
Shaunlungshe	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	0
Shihpafen	3	3	0	0	0	3	0	0	0	0	0	0	2	0	1	0	1	1	1
Tantou	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0
Tapenkeng	13	11	1	0	1	12	0	0	1	0	0	0	7	0	6	0	5	1	7
Tapu	1	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1
Unknown Site	8	8	0	0	0	8	0	0	0	0	0	0	3	0	5	0	2	1	5
Yuanshan	202	188	3	1	10	180	15	0	7	0	0	1	107	1	89	4	81	23	98
Yuanshan or Chientan	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0
Yuanshantzu	2	1	1	0	0	1	0	1	0	0	0	0	0	0	2	0	1	0	1
Zhongyishan	2	2	0	0	0	2	0	0	0	0	0	0	0	0	2	0	1	0	1
Total amount of specimen	325	287	21	5	12	248	55	6	14	1	1	1	174	1	145	4	123	41	161

Fig. 4-3-25b Preliminary statistics of the typological attributes of Taiwanese shouldered axes in each archaeological site. (Detailed records of the attributes and measurements of 325 shouldered axes are available in Appendix 2-1 and 2-2.)

Chapter 4-4_RESULTS OF USE-WEAR ANALYSIS

A total of 325 shouldered stone tools were observed for the microwear on the surface by a digital microscope. About 86.5% of all specimens observed were made of andesite. (Appendix 2) Most of the marks on the surface of the andesite shouldered tools are difficult to observe due to the disappearance of the original wears by weathering or severe damage. An only a small number of the shouldered axes can be noticed the use-wears on their surface. The sandstone shouldered tools include in observables. The sandstone is in the second large raw material of rock that the shouldered axes made of, which accounts for about 12.6% of the total. To understand the manufacturing technology and the usage of the shouldered axes, the focus of the inspection is on the shoulder and the blade edge of the stone tools. The trace patterns that can be observed are explained below.

Observing the surface on the shoulder of these tools, the identification principle of the use-wear analysis applying to the working surface of the stone artefacts, are all appeared in observables of shouldered axes, such as the striations, edge rounding, gloss and polishing. (Fig. 4-4-1, 4-4-2, 4-4-3) Among these use-wears, the most recognisable marks are the arc-shaped with the short striations, sometimes has two or more arc-shaped on one shoulder. (Fig. 4-4-4, 4-4-5, 4-4-6, 4-4-7, 4-4-8) There are also some midlines occurred between the arc-shaped marks, especially on the shoulder with more than two arc-shaped. The features of arc-shaped and midline left on the shoulder are probably the production traces. And, the positions of the arc-shaped trace on the shoulder are varied, which implies that there is no standard procedure for making. All the striations on one shoulder are parallel to each other. The reason such a plurality of striations is formed in parallel is presumed to be the direction of grinding during production, and possibly the worker grips the rock and grinds directly on the ground stone. Also, the section of the broken edge on the object has some rounding traces and gloss, which might be caused by the use. However, it must note that the grinding and polishing activity will leave the gloss on the surface of stone tools too. Therefore, except for rounded edges that may be the use-wears, the cause of gloss is currently unknown.

A great majority of the blade on the shouldered artefacts are missing, a few tools containing the blade can be observed accounts for about 37.85% in the total. The vertical striations paralleled to the axis of the shouldered axes are found on the surface of both sides of the edge. (Fig. 4-4-9, 4-4-10, 4-4-11, 4-4-12, 4-4-13, 4-4-14, 4-4-15) Such a pattern can be understood as the result of generating the traces by engaging the interaction force on both sides of the surface whilst the shouldered tool is in use. The presentation of the traces differs from that occurred on the surface of the stone adze, which the vertical striations appeared on the backside mostly. This may indicate that the shouldered axe is used differently from the stone adze of which most probably applying for the woodworking, the process of treating skins and hides of animals for procuring their leathers. (Hung 2000) The striations on the blade edge provide the evidence on the usage/function of the shouldered axe that excludes the aforementioned use of adze, rather refers to the agronomic activity potentially.

There are 55 specimens documented in the original excavation records as the shouldered axes, which are the fragments of the shouldered axe having left the head or the shoulder with body only. A total of 33 head samples reviewed that were further dividing into three sub-types. Type A has a no shoulder left on it, Type B has a single shoulder, and Type C has visible a pair of shoulders. There are 22 pieces of the shoulder with body fragments, which can also categorise into three sub-types. Type I has shoulders and a partial head that can easily identify with, Type II is an also recognisable type which part of the shoulder(s) and/or the head is missing, and Type III has a broken head diagonally toward the opposite side of a shoulder. Except for the Type A without a shoulder to determine whether it is a shouldered tool, the fracture appearance of other specimens seems to reflect a set of patterns for the breakage. Therefore, such a breakage feature is suspected caused by the usage of the shouldered axe hafting with a handle (Fig. 4-4-16, 4-4-17, 4-4-18, 4-4-19).

Results of the use-wear analysis in this study offer the basis for the hypotheses on the production techniques and the usage/function of the shouldered axes all these need to perform the experimental archaeology for further verification.

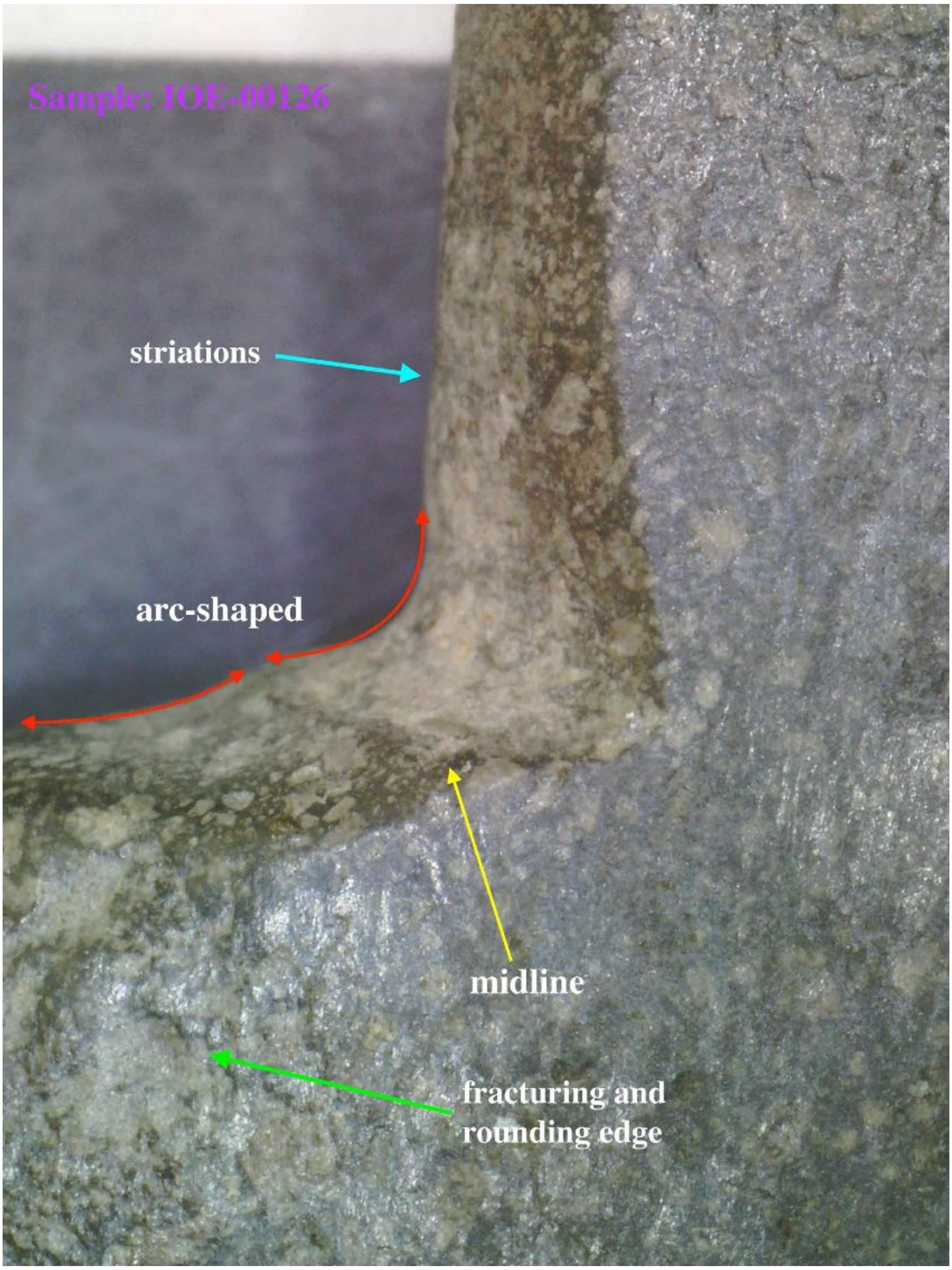


Fig. 4-4-1 Use-wear on the shoulder (Photographed by Li-Chi Chiang).

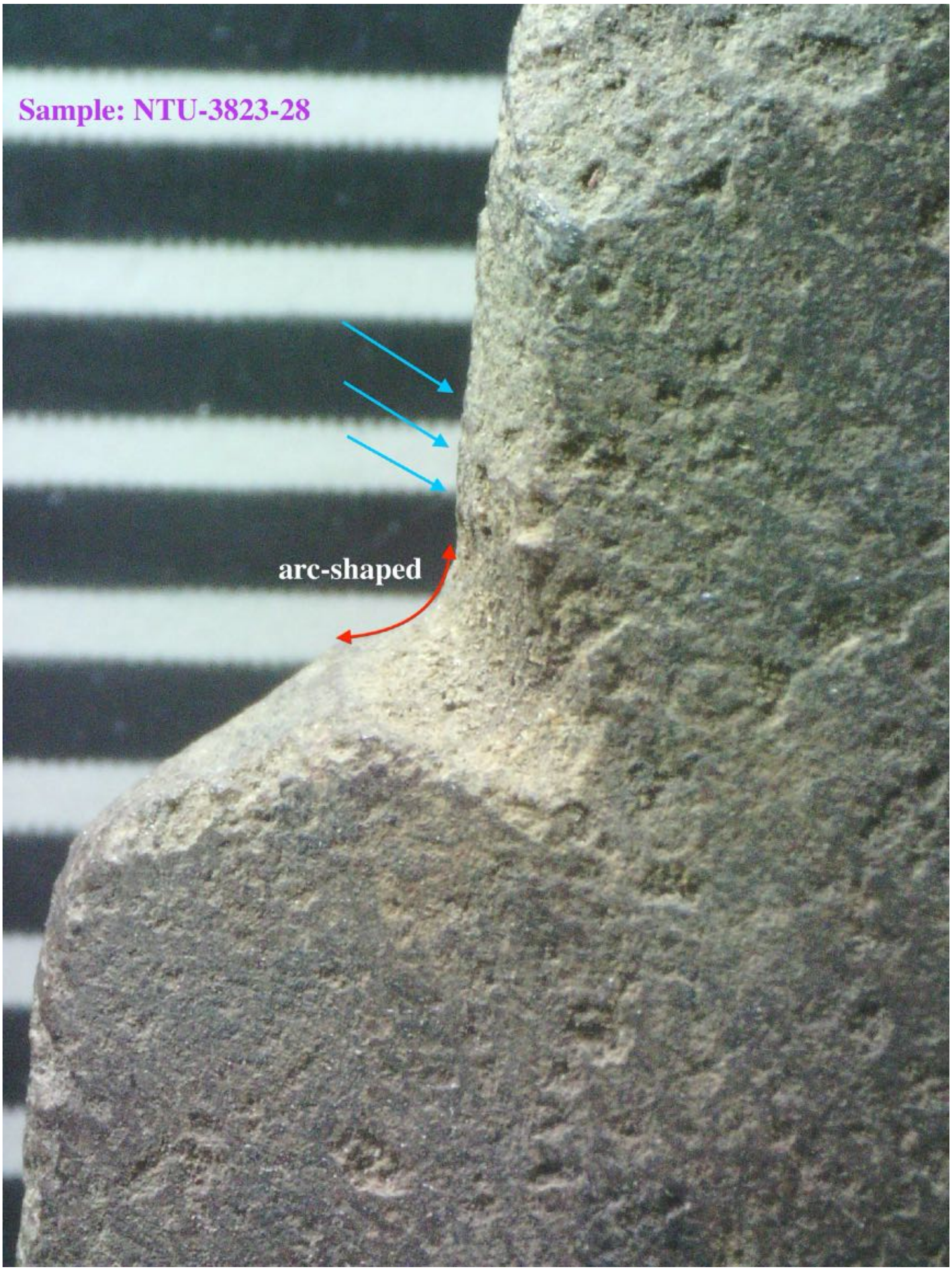


Fig. 4-4-2 Use-wear on the shoulder (Photographed by Li-Chi Chiang).

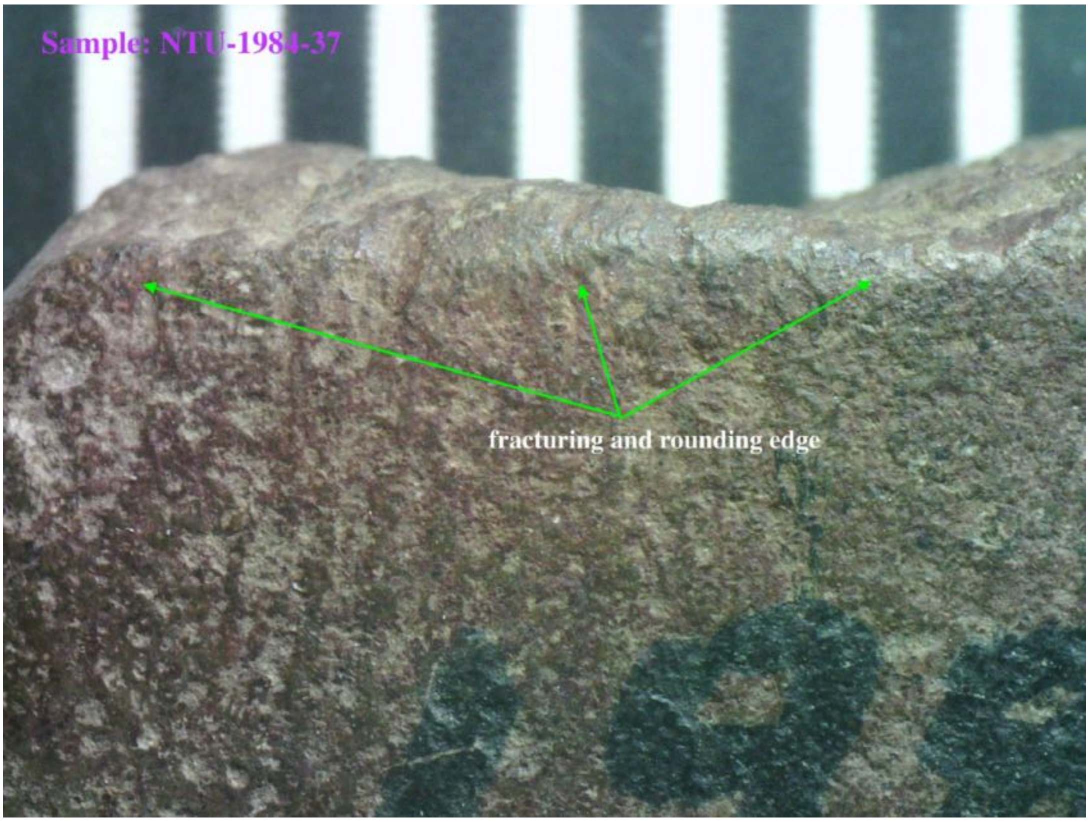


Fig. 4-4-3 Use-wear on the shoulder (Photographed by Li-Chi Chiang).

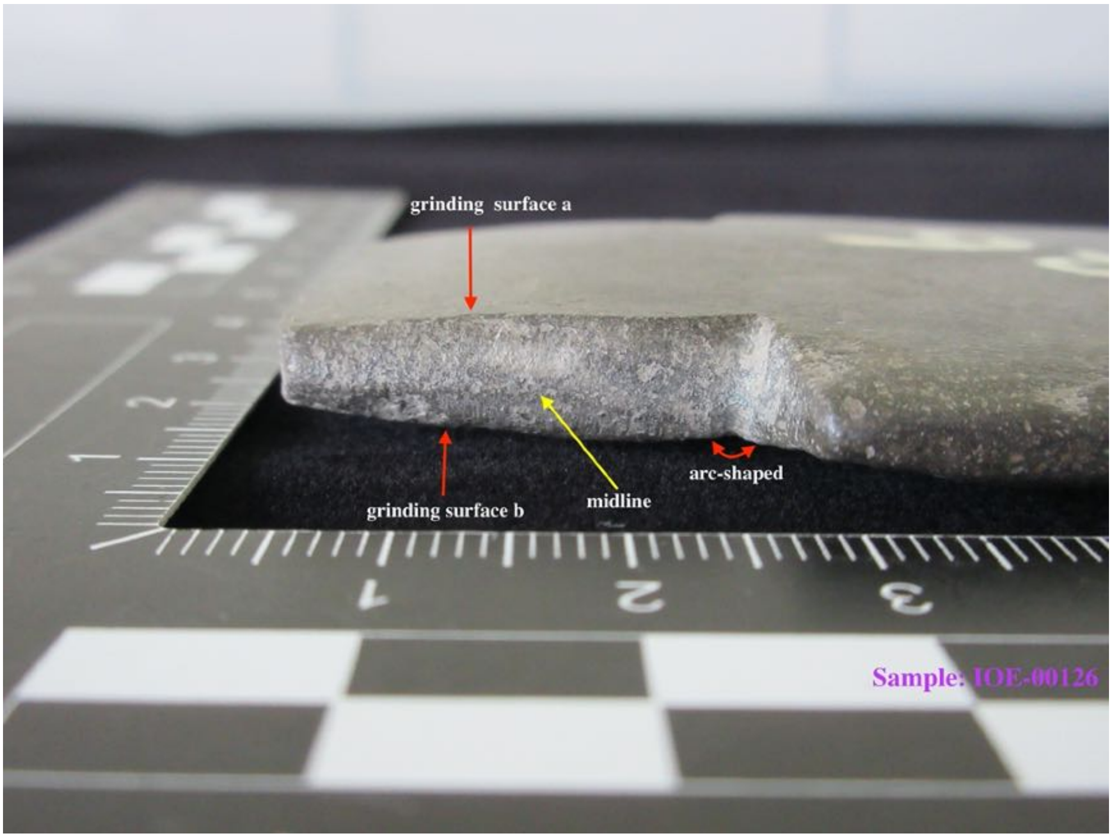


Fig. 4-4-4 Use-wear on the head and shoulder (Photographed by Li-Chi Chiang).

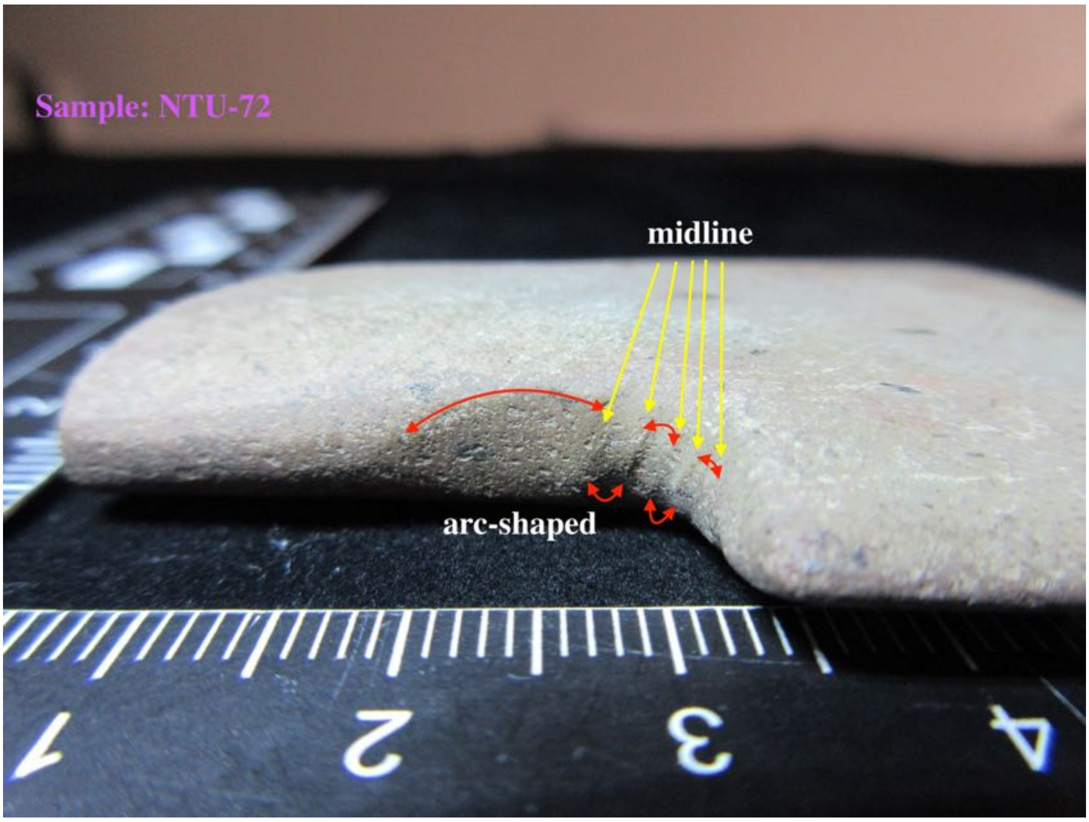


Fig. 4-4-5 Use-wear on the head and shoulder (Photographed by Li-Chi Chiang).

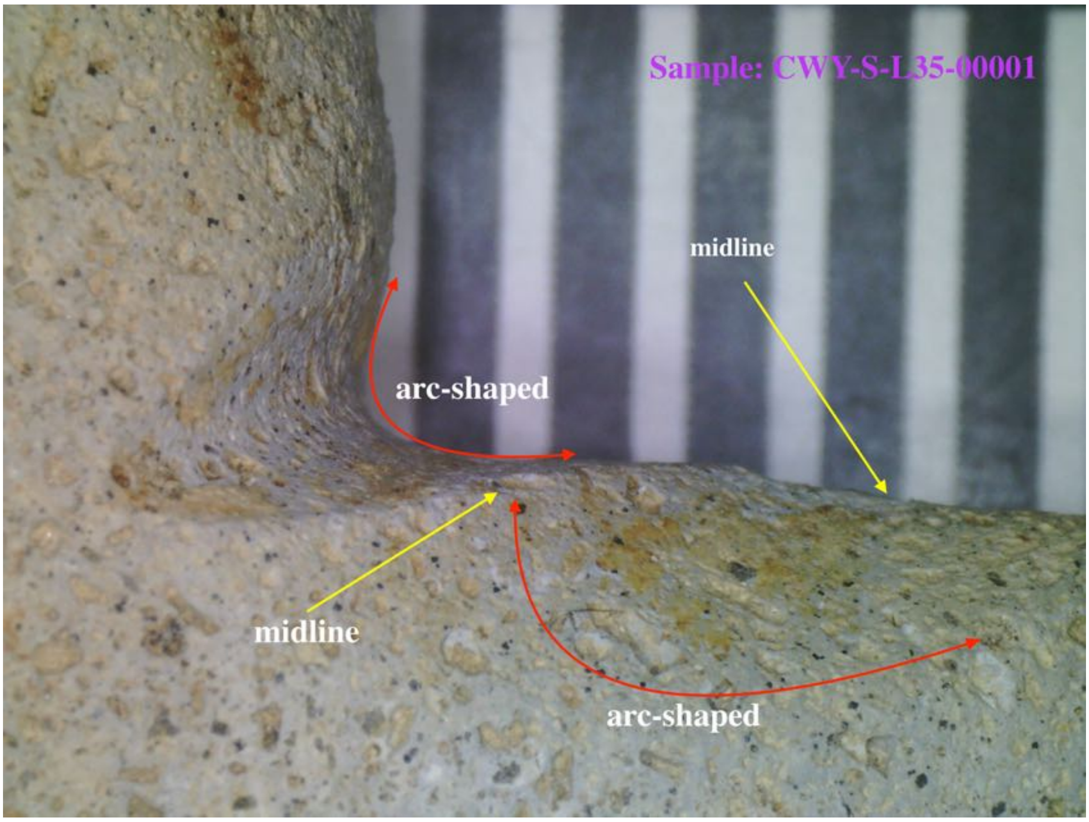


Fig. 4-4-6 Use-wear on the shoulder (Photographed by Li-Chi Chiang).

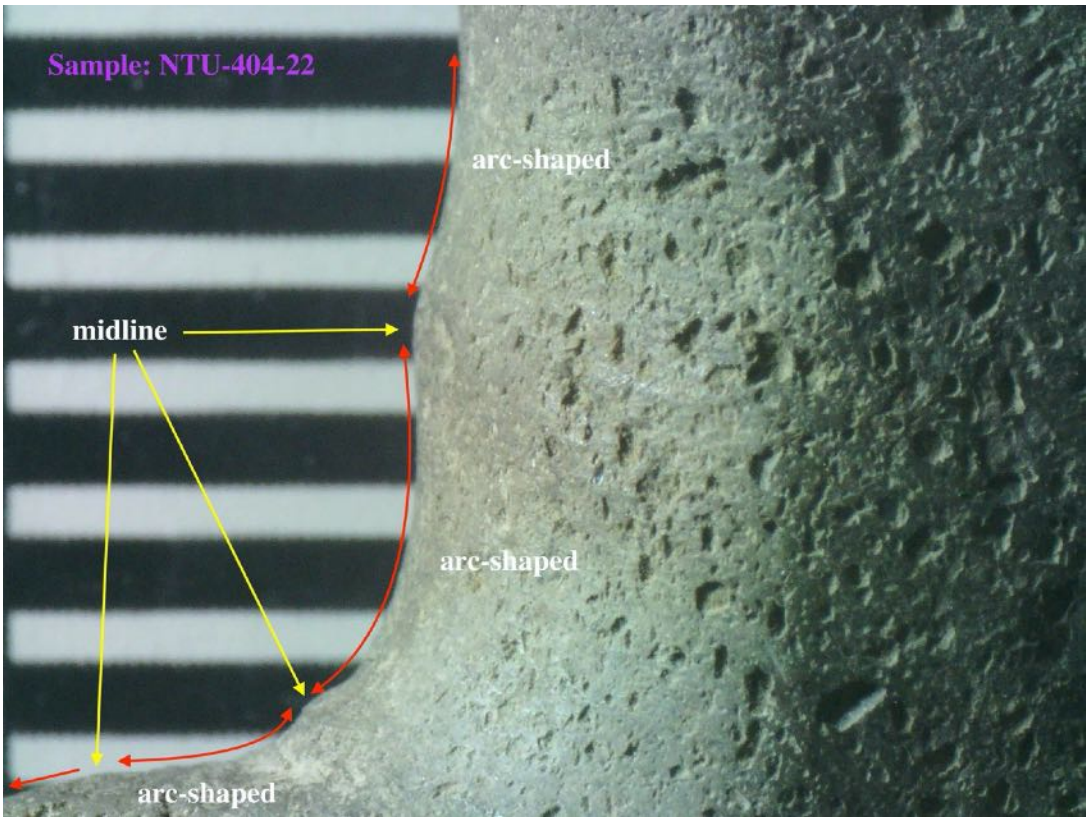


Fig. 4-4-7 Use-wear on the shoulder (Photographed by Li-Chi Chiang).

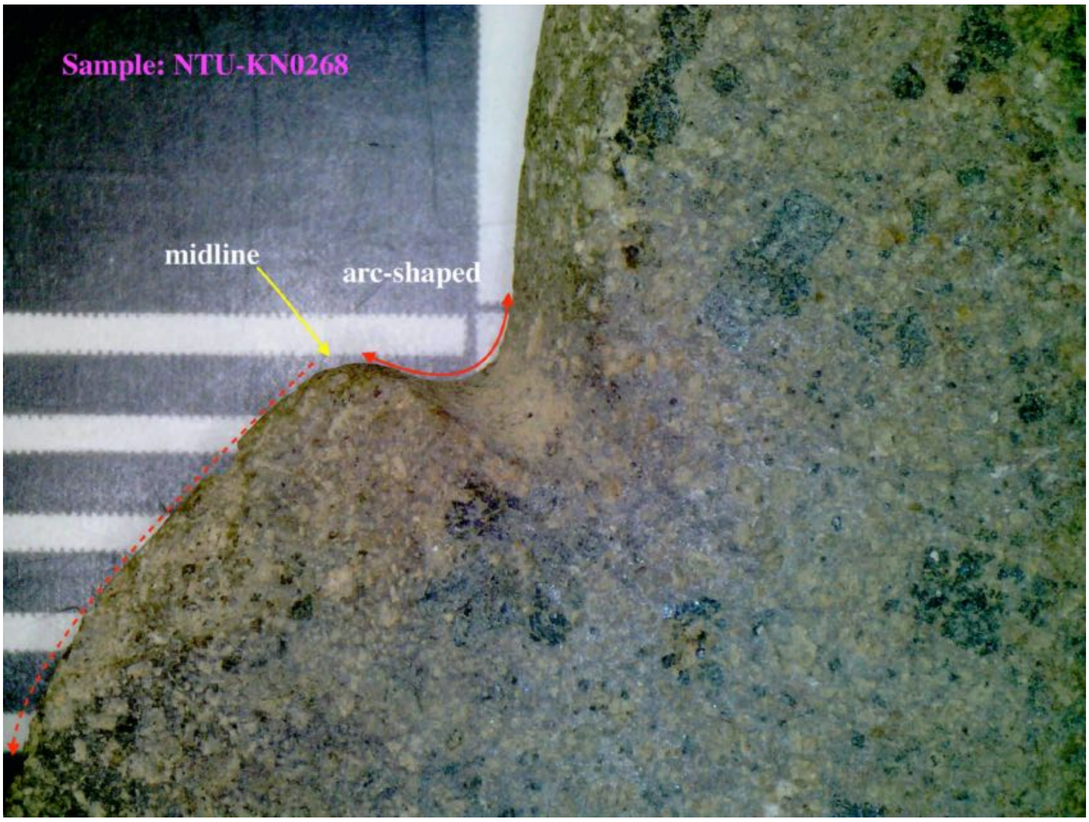


Fig. 4-4-8 Use-wear on the shoulder (Photographed by Li-Chi Chiang).

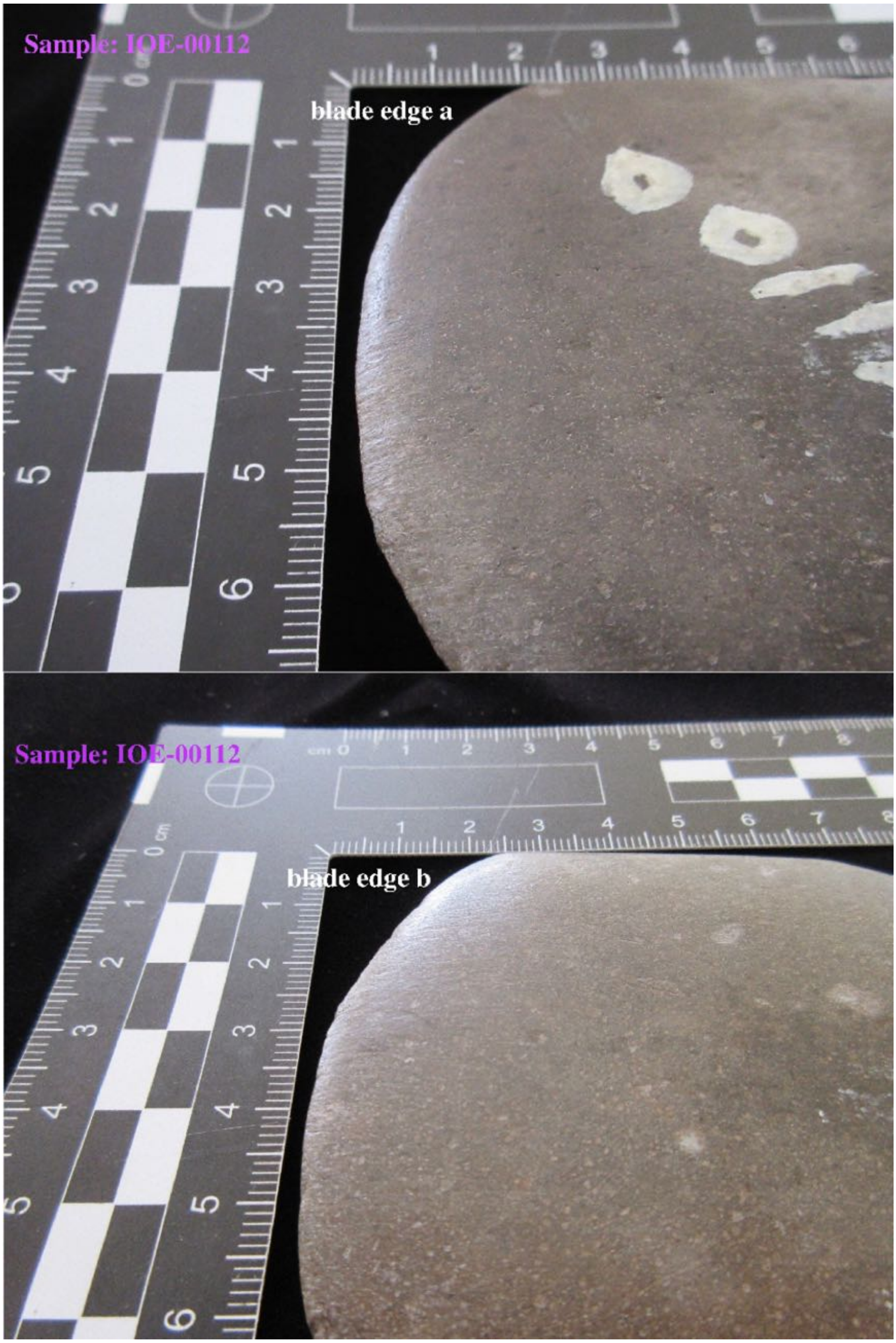


Fig. 4-4-9 Use-wear on the blade edge (Photographed by Li-Chi Chiang).

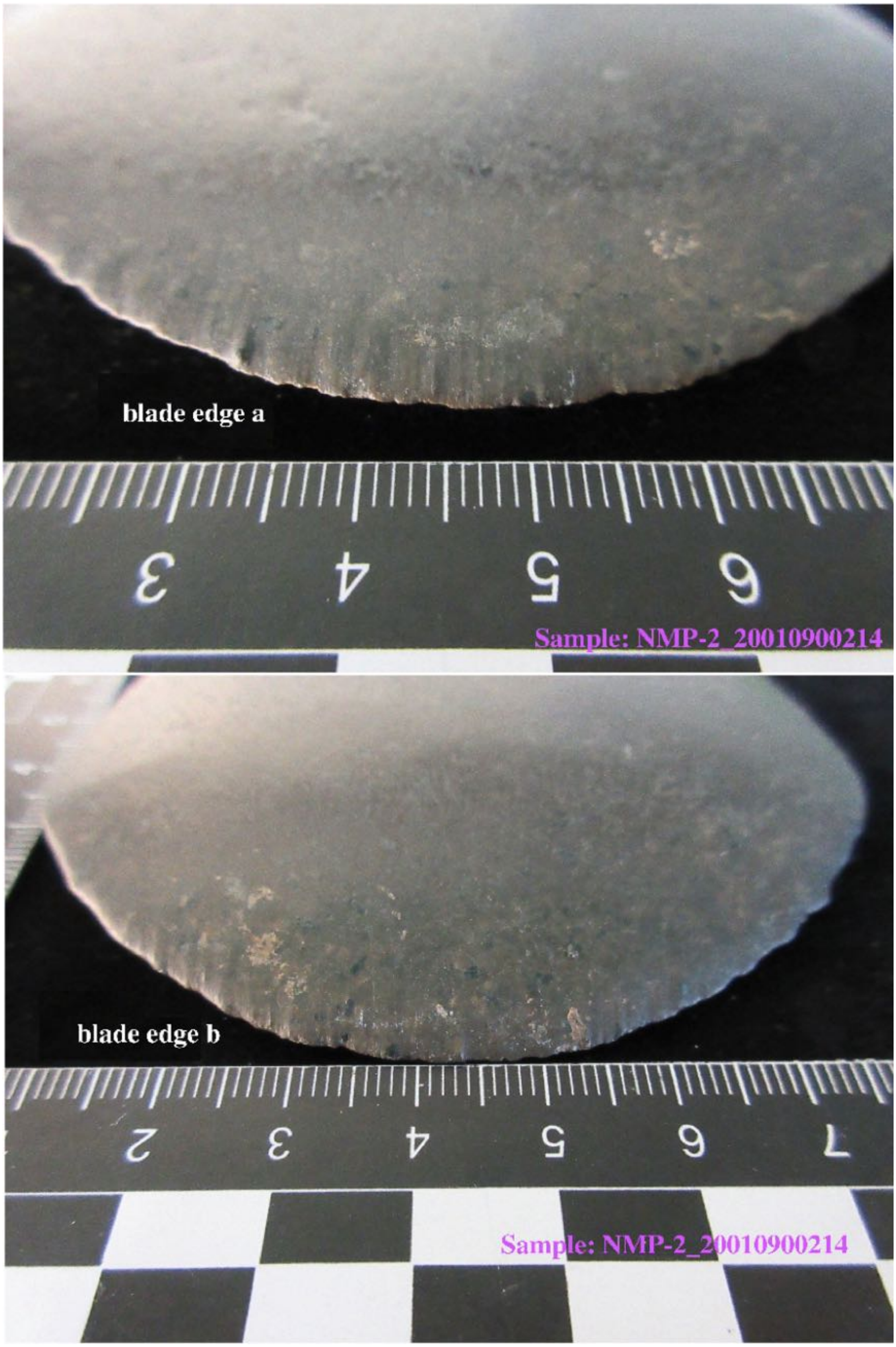


Fig. 4-4-10 Use-wear on the blade edge (Photographed by Li-Chi Chiang).

Fig. 4-4-11 Use-wear on the blade edge (Photographed by Li-Chi Chiang).

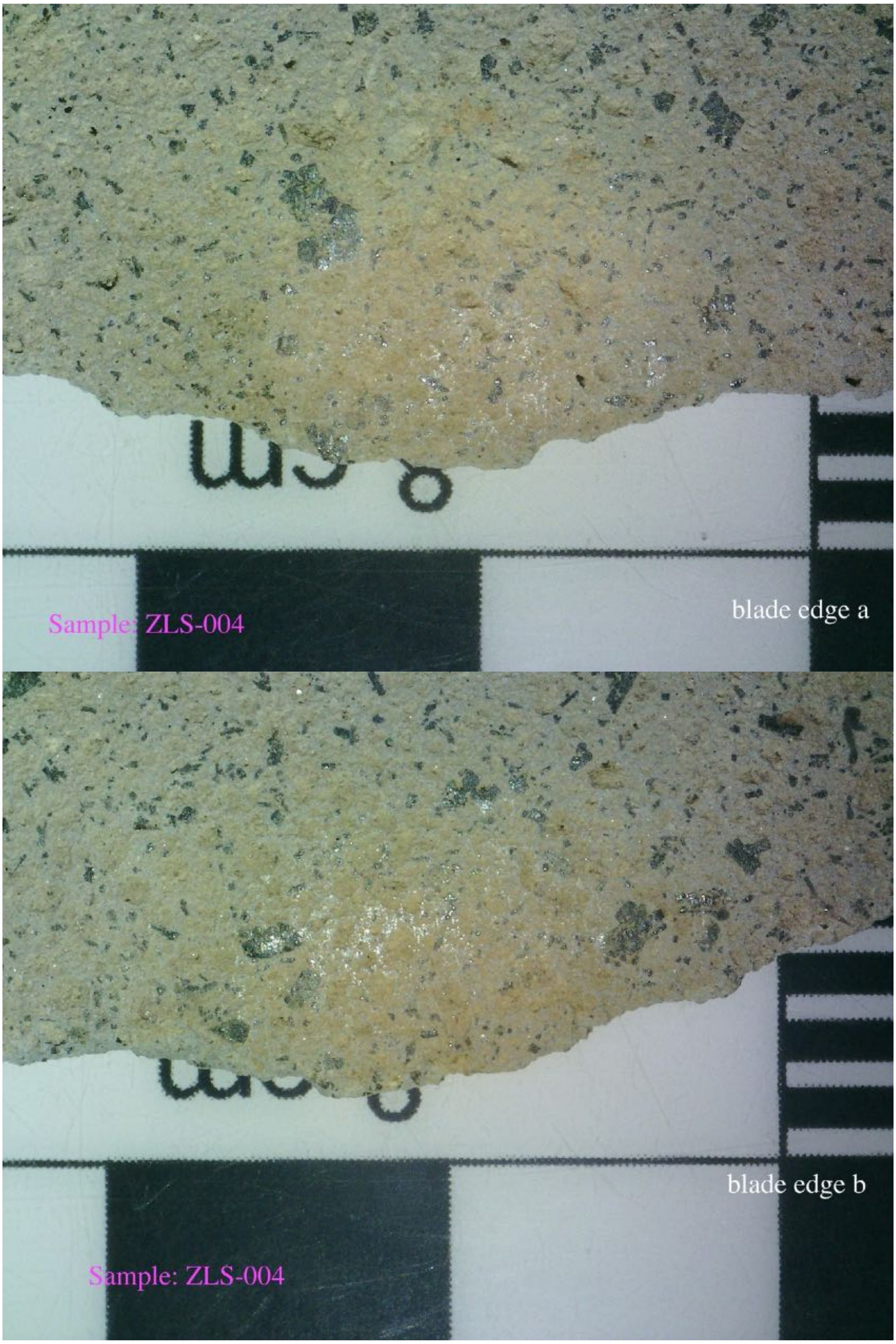


Fig. 4-4-12 Use-wear on the blade edge (Photographed by Li-Chi Chiang).

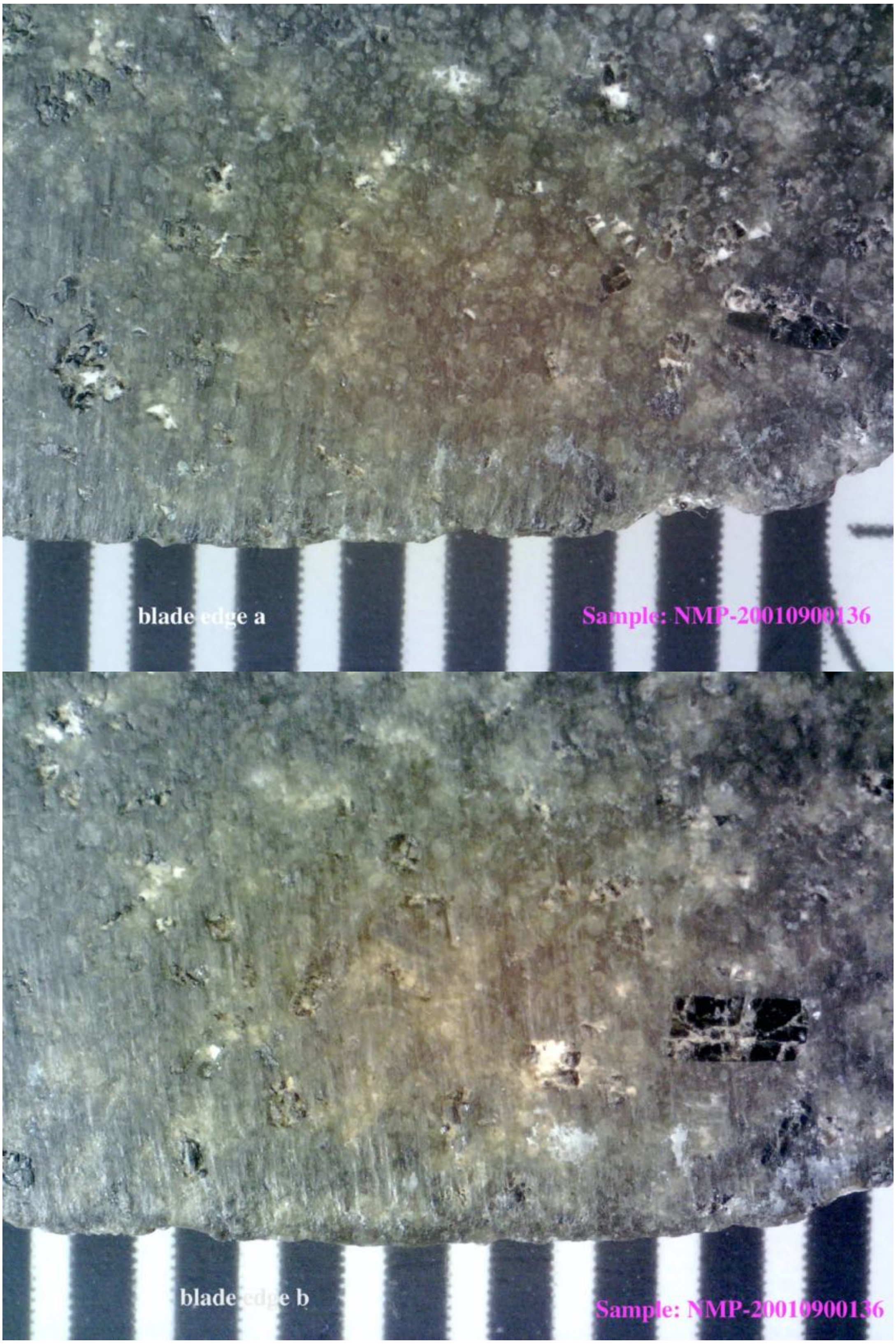


Fig. 4-4-13 Use-wear on the blade edge (Photographed by Li-Chi Chiang).

Fig. 4-4-14 Use-wear on the blade edge (Photographed by Li-Chi Chiang).

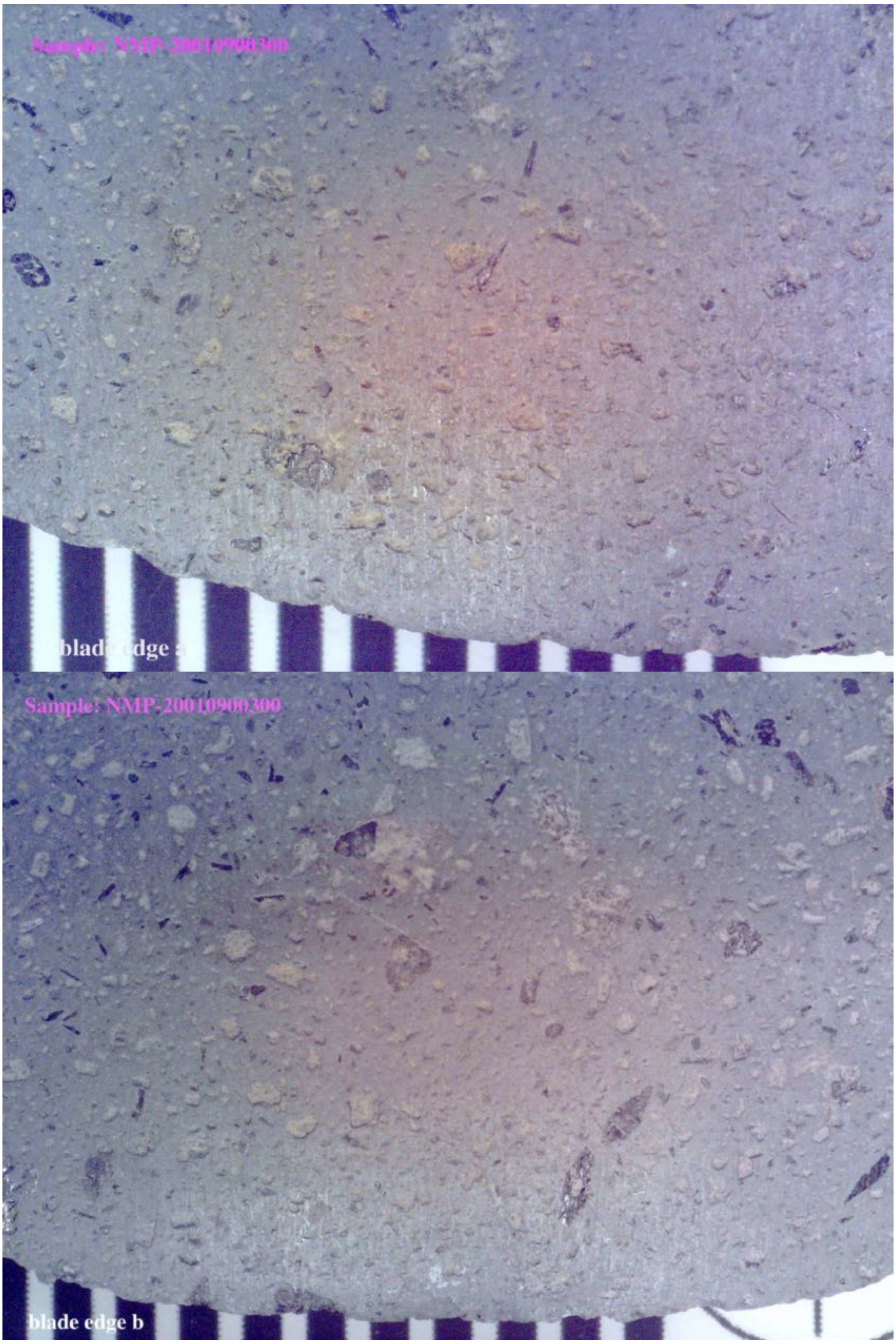


Fig. 4-4-15 Use-wear on the blade edge (Photographed by Li-Chi Chiang).

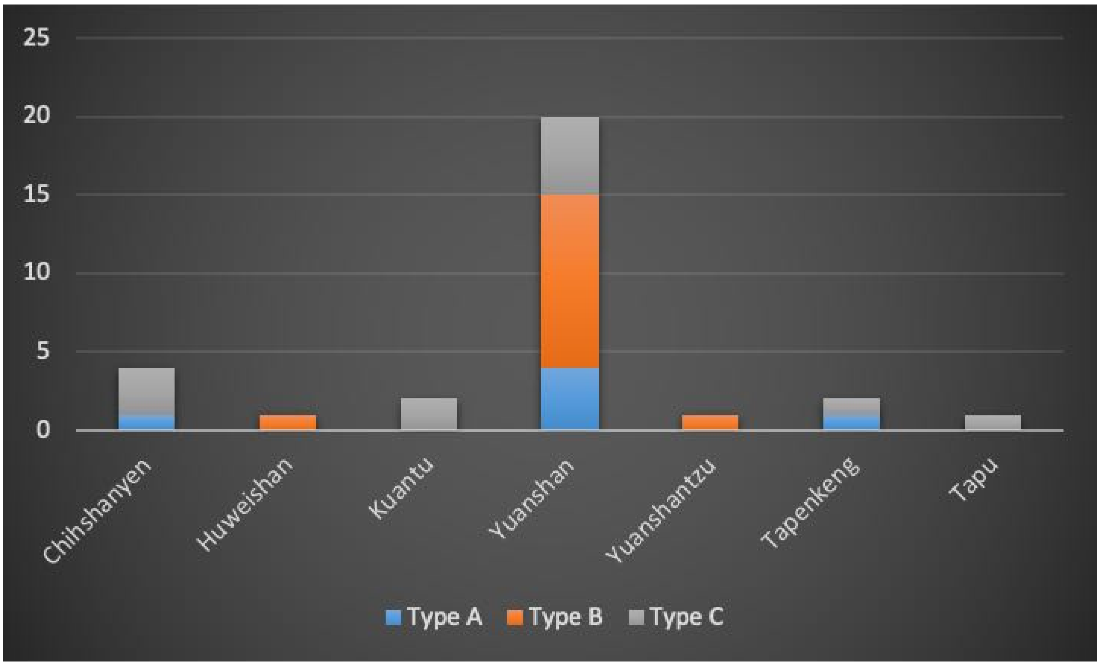


Fig. 4-4-16 Types of the head fragments and the finding amounts of each Yuanshan cultural site.

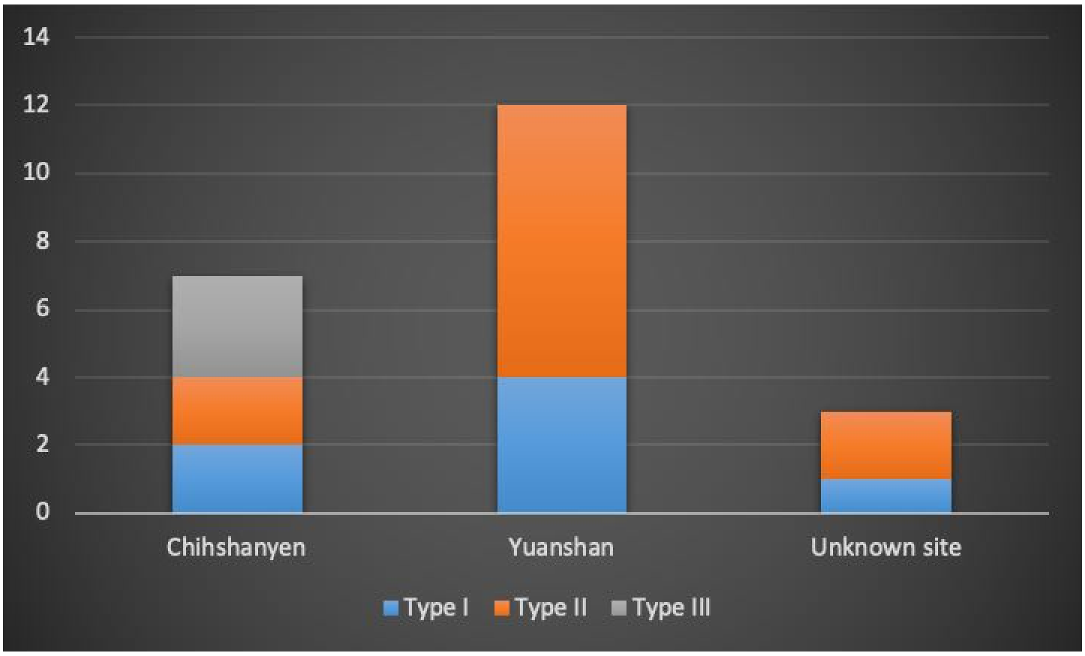


Fig. 4-4-17 Types of the shoulder with the body fragments and the finding amounts of each Yuanshan cultural site.

Type A	Type B	Type C
		

Fig. 4-4-18 The appearance of the head fragment. (Type A: from Yuanshan site, MANTU. Type B: from Yuanshan site, NMP. Type C: from Chanlungshan site, IHP) (Photographed by Li-Chi Chiang)

Type I	Type II	Type III
		

Fig. 4-4-19 The appearance of the shoulder(s) with the body fragment. (Type I: from Yuanshan site, MANTU. Type II: from Yuanshan site, MANTU. Type III: from Chihshanyen site, NMP) (Photographed by Li-Chi Chiang)

Chapter 4-5_RESULTS OF EXPERIMENTAL ARCHAEOLOGY

A total of six experimental object preparations are shown in Table 4-5-1. The two pieces of shale were trial items, the sandstone and two pieces of andesite were replicas made for the purpose of the hoeing experiments. One of the andesite replicas (YMS-HTD-02) is similar in both dimensions and morphology to the archaeological shouldered axe in the left at Fig. 4-5-1. Three nettle cordages were made separately and provided to use at the same time. Two wooden handles were created, with two different types of slot for hafting the axes. The grindstone required for the production of the shouldered replica is a raw material of sandstone collected in the School of Archaeology, Geography and Environmental Sciences, University of Reading.

Replica No.	Material	Production Time (mins.)	Work(s)
Replica 1	Shale (UK)	15	Shaping one side of shale as a handheld stone tool for grinding shoulders
Replica 2	Shale (UK)	20	Shaping one side of shale to create a Type 1 shoulder
Replica 3	Sandstone (TW)	180	Grinding two sides of sandstone sample
YMS-XYK-04	Andesite (TW)	60	Grinding two sides of andesite sample to create a Type 2 shoulder
YMS-HTD-02	Andesite (TW)	30	Grinding whole andesite sample to create a Type 4 shoulder (Fig. 1)
Cordage	Nettle (UK)	120	Collecting nettle, stripping stings and leaves, crushing stem, barking and splitting strands, twisting the nettle fibre and making the cordage

Table. 4-5-1 Production of replicas.

Fig. 4-5-1 Dimensional and morphological comparison between YMS-HTD-02 (left) and archaeological shouldered axe (right). (Photographed by Li-Chi Chiang).

1. Replication Experiments

1.1 Replica 1 and 2 (Fig. 4-5-2)

Material: Shales

Time: Fifteen and twenty minutes

Work: The original appliance setting is to shape an edge appear arc-shaped and use as a handheld cylindrical tool for grinding the shoulders on shouldered axes. This idea of setting comes from the arc-shaped observed on the shoulder of the shouldered axe. Because the shape and size of these traces are similar to those unidentifiable cylindrical stone implements (owned by amateur collectors, no drawings can be referenced), which are made of hard shale or sandstone, and average of the length is about 5 cm. with less than 0.5 cm. in diameter. Such type of tools slightly differs from each other in the size and appearance, that is alike the non-uniform of the arc-shaped. Tiny circular marks on the surface tools surrounding the entire columnar body appear parallel to each other and show no overlap traces or lapping caused by back and forth grinding during production. Therefore, the original setting of the shoulder production method is to use another small cylindrical-like grinding stone as a production tool instead of shaping by large one.

It is not difficult to aware of feedback from the grinding action on a shale blank during the actual production process. The second shale raw material (Replica 2) directly challenges the shaping of the shoulders by forming the shoulder easily after failing work on one side of the arc-shaped edge of the first shale (Replica 1). Replica 2 only takes five minutes more than the Replica 1, that is, 20 minutes to accomplish the grinding on one face of shale, a shoulder included.

Fig. 4-5-2 Top: Replica 1, Bottom: Replica 2, shales (UK). (Photographed by Li-Chi Chiang)

1.2 Replica 3 (Fig. 4-5-3)

Material: Sandstone (Taiwan)

Time: Three hours

Work: On both lateral edges of the sandstone blank an attempt was made to create shoulders by grinding with sandstone grindstone, that the raw material of grindstone commonly uses the sandstone to make of in the prehistory of Taiwan. In replica experiments, the same or as similar requirements as the original material used is also one of the conditions that determine the success of the experiment.

After a three-hour grinding process, there were only shallow notches on both lateral edges.

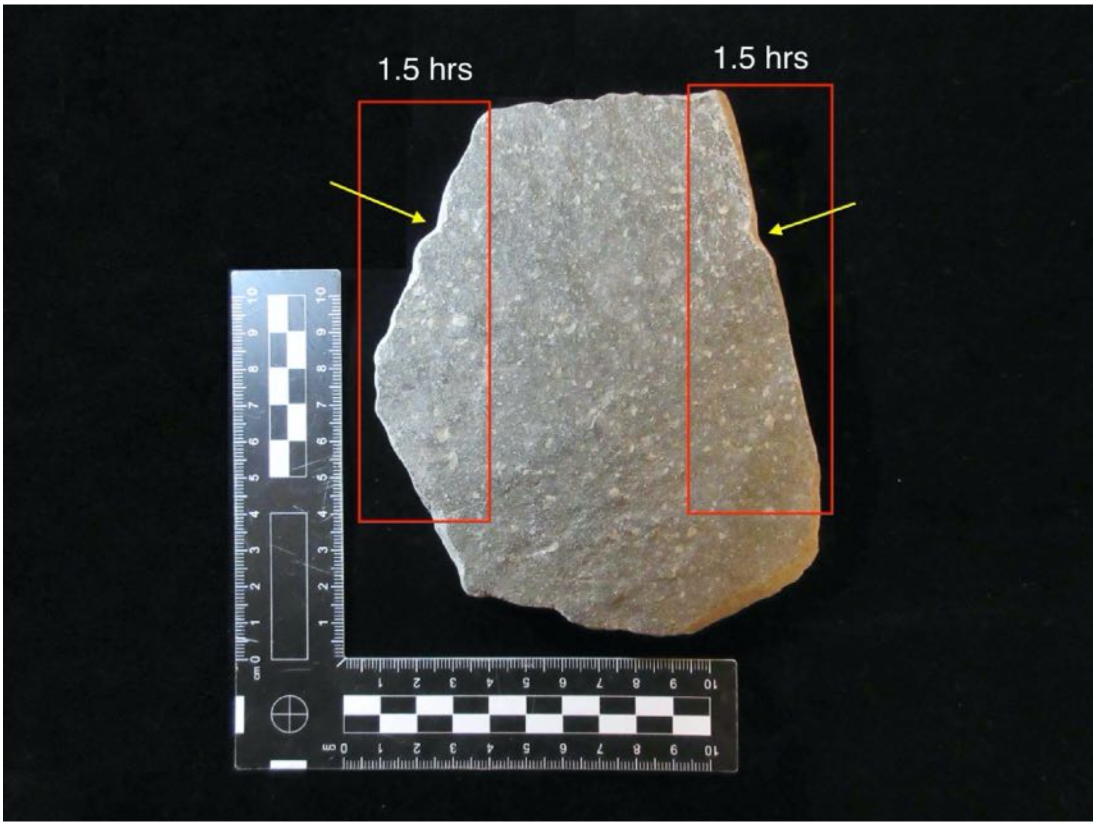


Fig. 4-5-3 Replica 3, Sandstone (Taiwan). (Photographed by Li-Chi Chiang)

1.3 YMS - XYK -04 (Fig. 4-5-4, 4-5-5)

Material: Andesite

Time: One hour

Work: There are two arcs visible on one of the lateral shoulders. These were visible from front, side and rear viewpoints. They were apparently caused by the sliding of the specimen during the grinding process against the grindstone. Specimen sliding causes may be: 1. the manufacturer's hand fatigue, as a result of which the specimen could not be gripped and slipped off the grindstone during grinding; and/or 2. The grinding surface of the grindstone is not uniform, and so the axe was sometimes deflected from the main grinding axis.

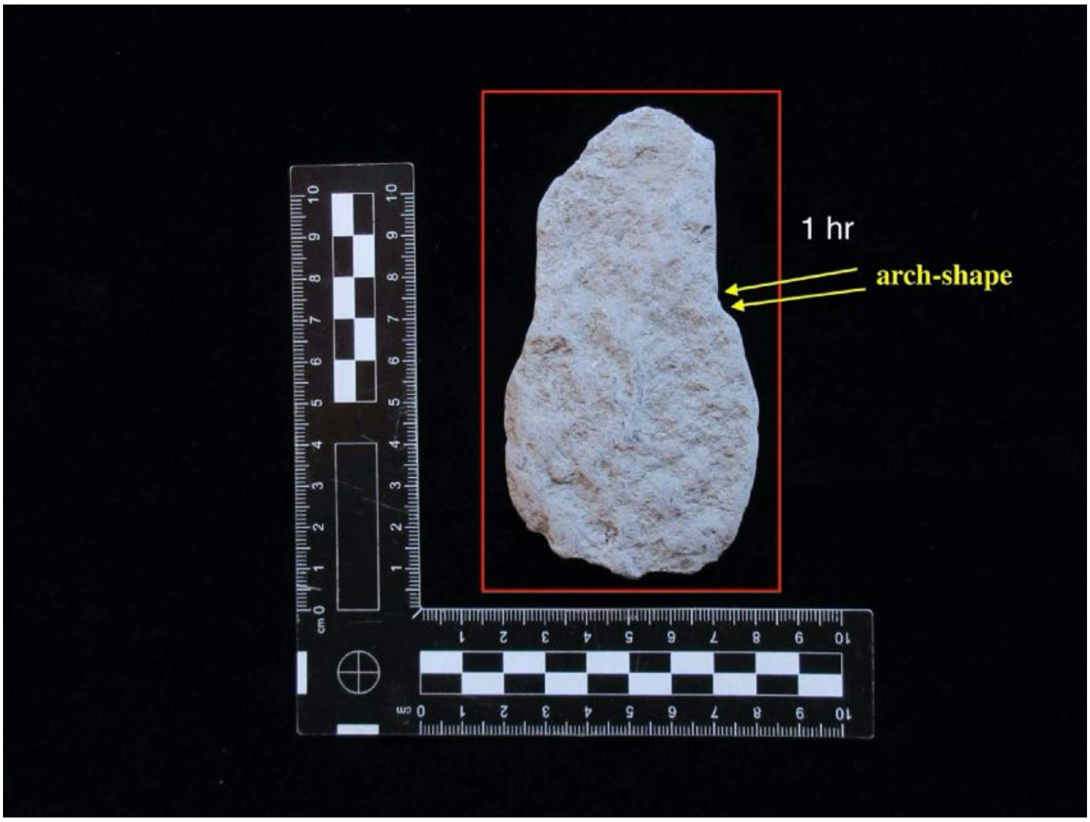


Fig. 4-5-4 Replica YMS-XYK-04, andesite (Taiwan) shouldered axe with type 2 shoulder. (Photographed by Li-Chi Chiang)

Fig. 4-5-5 Close-up of the shoulder section on the Replica YMS-XYK-04, andesite (Taiwan) shouldered axe with type 2 shoulder. (Photographed by Li-Chi Chiang)

1.4 YMS - HTD -02 (Fig. 4-5-6, 4-5-7)

Material: Andesite

Time：Thirty minutes

Work: Because of the weathered nature of the sampled andesite (YMS - HTD -02), it can be crushed easily and therefore ground easily (*c*. 30 minutes) into a replica shouldered axe, including surface polishing. The new experimental replications indicated that the most effective (= faster and reduced energy required) method was to (1) grasp the raw material by the lateral margins; (2) orientate the sample so that the intended neck was closest to the grindstone, and the blade edge was opposed to the grindstone; and (3) grind the shoulders with a linear motion, transversely oriented to the edge of the grindstone (Fig. 4-5-8). If the blank is orientated in the opposite direction (i.e. with the intended blade edge closest to the grindstone) then the process is much more difficult.

Fig. 4-5-6 Replica YMS-HTD-02, andesite (Taiwan) shouldered axe with type 4 shoulder. (Photographed by Li-Chi Chiang)

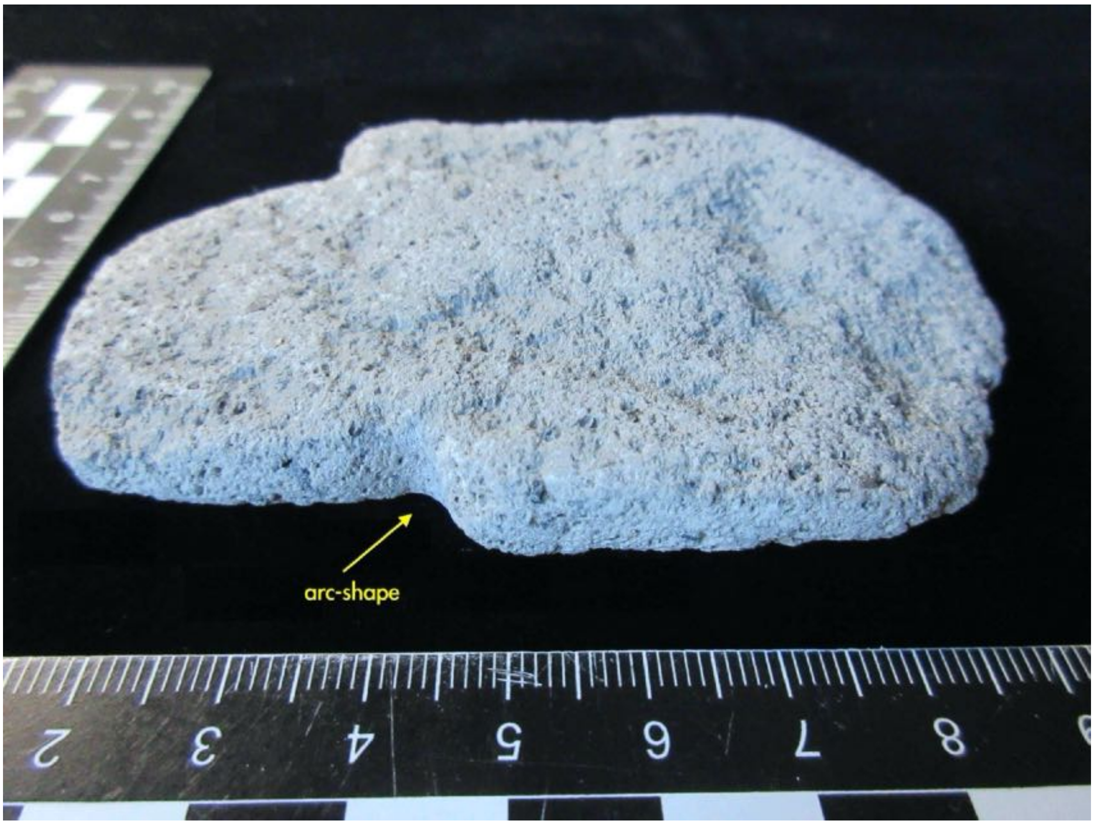


Fig. 4-5-7 Close-up of the shoulder section of the Replica YMS-HTD-02, andesite (Taiwan) shouldered axe with type 4 shoulder. (Photographed by Li-Chi Chiang)

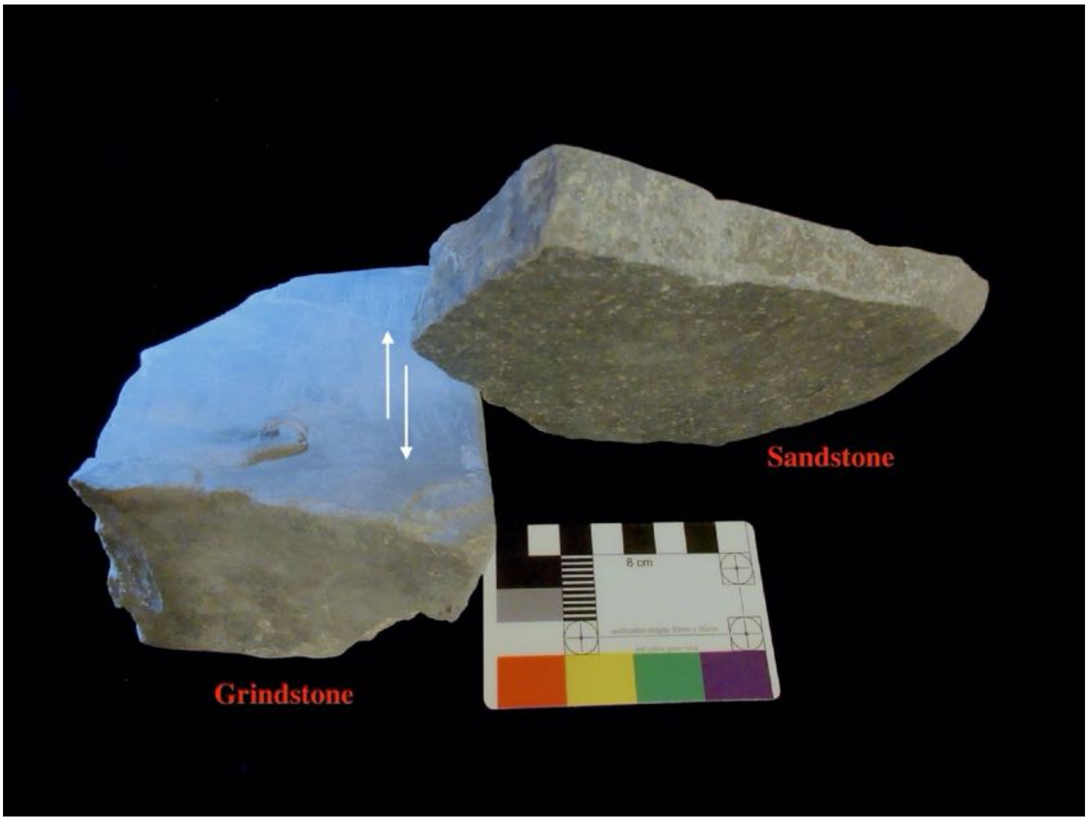


Fig. 4-5-8 Linear motion of grinding, showing the direction by white arrows.

(Photographed by Li-Chi Chiang)

1.5 Cordage (Fig. 4-5-9, 4-5-10)

Material: Nettles

Time: Five hours for three lengths of cordage

Work: Collecting nettles found on the roadside around the London Road Campus of University of Reading. Stripping stings and leaves, crushing stem, barking and splitting strands, twisting the nettle fibre and then completion of the cordage making.

Fig. 4-5-9 Nettles on the roadside around the London Road Campus, University of Reading (Photographed by Li-Chi Chiang).

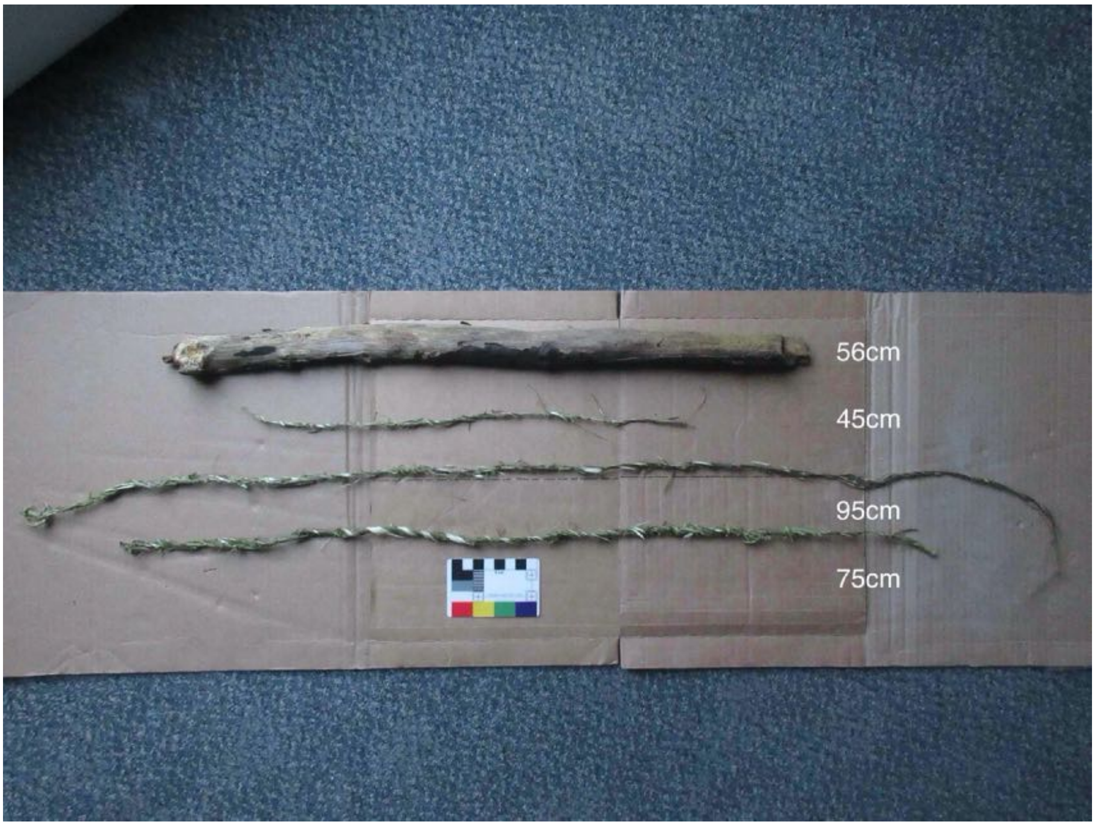


Fig. 4-5-10 Length of the nettle cordages and the first wooden handle

(Photographed by Li-Chi Chiang)

1.6 Binding practise (Fig. 4-5-11)

Material: Replicas of shouldered axe (one shale, two andesite, one sandstone), wooden handle and nettle cordage

Work: Three pieces of small shouldered axe replica can be tied onto a trimmed flat surface on one face of a wooden handle. However, the durability of the ropes is not tested due the time limit.

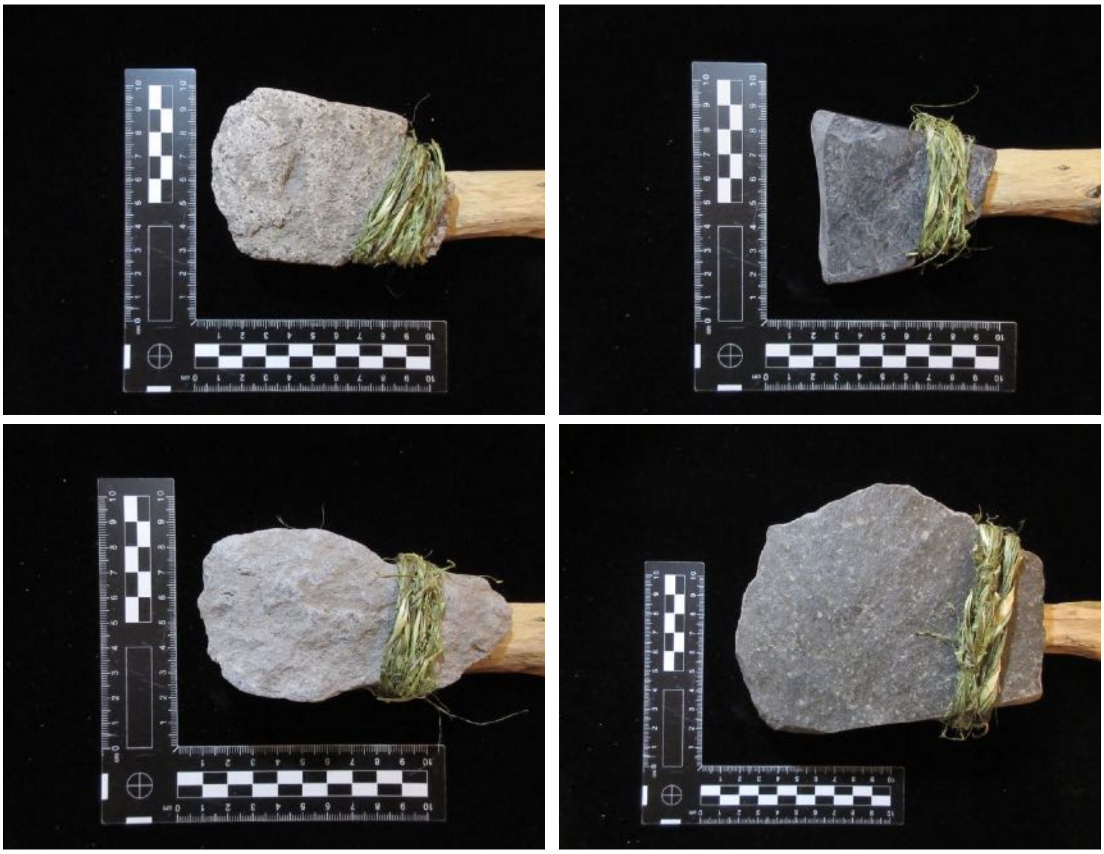


Fig. 4-5-11 Nettle cord bound around the joint of the haft and the shoulder

(Photographed by Li-Chi Chiang)

1.7 Wooden handles (Fig. 4-5-12)

Two wooden handles were made with two types of slot. (Fig. 4-5-10)This enabled both types of hafting technique to be tested, including their functionality during the hoeing experiment.

Handle 1 had a notch with a flattened surface, cut parallel to the long axis of the handle. Handle 2 had a groove cut int the handle, into which the upper part of shouldered axe can be inserted. Morphometric data of slots and handles are given in Table4-5-2.

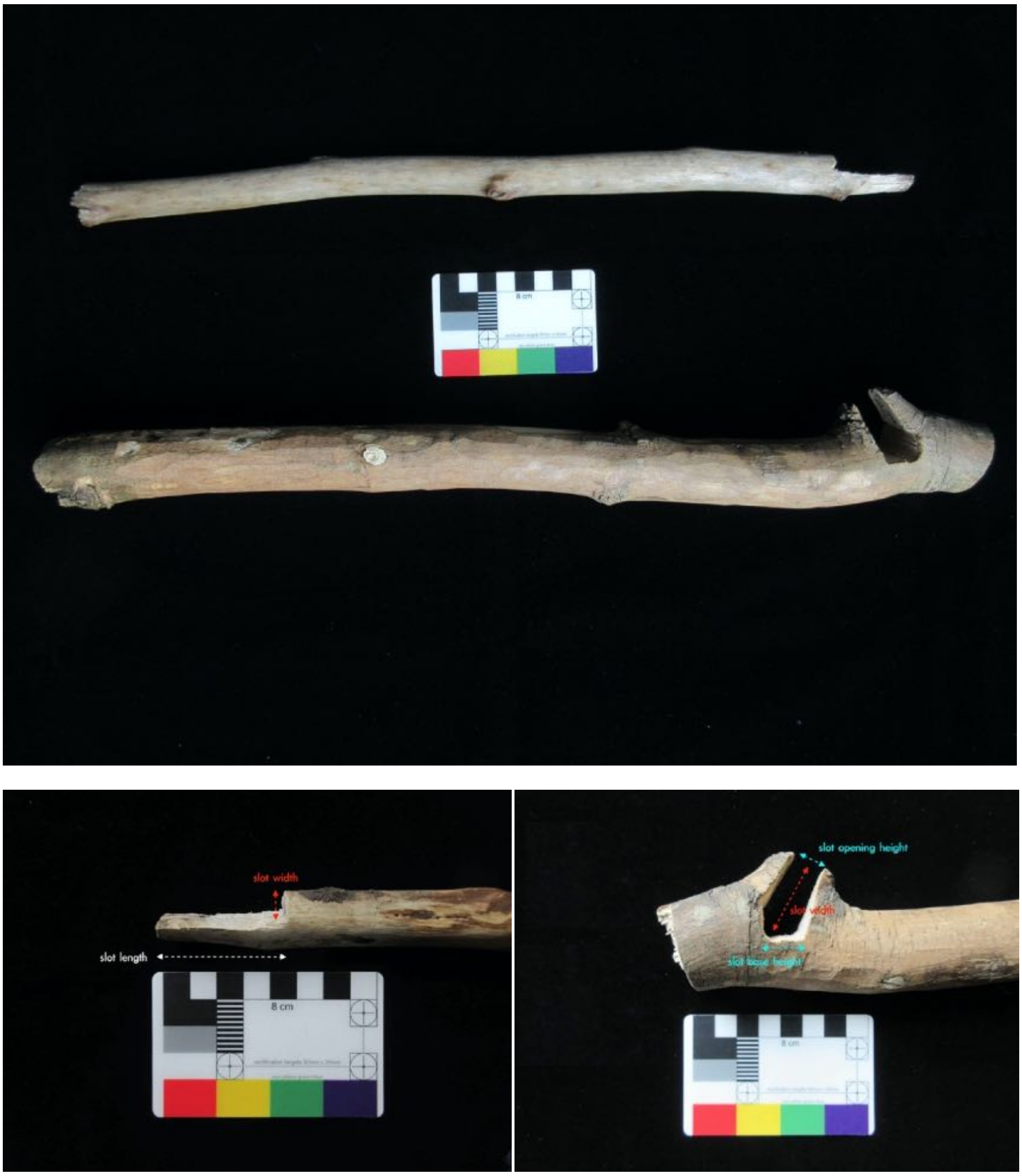


Fig. 4-5-12 Wooden Handles with two types of slot. Bottom left: handle 1 with a flattened surface. Bottom right: handle 2 with a slot (Photographed by Li-Chi Chiang)

Handle No.	Handle Length (cm.)	Slot length (mm.)	Slot Opening Width (mm.)	Slot Base Width (mm.)	Slot Opening Height (mm.)	Slot Base Height (mm.)
1	45	24	20	38	1	---
2	45	37	17	38	13	19

Table. 4-5-2 Dimensions of slot of wooden handle.

2. Hoeing practise experiments

Two andesite replicas of shouldered axes with distinct types of shoulder and comparable in size to the archaeological tools, were selected for the hoeing activity (Fig. 4-5-4, 4-5-6 and Table 4-5-3). The previously made cordages were loose by the time of the experiments and could no longer be used. Due to time limitations it was not possible to produce further cordage. Modern cotton string, therefore, was adopted for binding in this phase of the experiment, which this use of a standard binding controlled for one of the variables within the experiment. The venue for the experiment was the Harris Gardens, University of Reading. According to a survey map on the website of Cranfield Soil and Agrifodd Institute[1], the soil texture of the Reading area is loamy soil. The wet and viscous soil texture in the area is similar to the soil in the Taipei Basin, and was suitable as a working type of soil for the hoeing test.

[1] See the Webpage

The time of hoeing activity was set to 60 minutes per operation, and the surface condition of each replica was noted after each period of practise stopped. The number of times the cotton binding need to be re-tightened was also recorded. At the completion of each experiment, record the total number of bindings used in each exercise to understand that the number of times the utensils fall off from handle is related to the method of cordage binding.

Replica No.				Shoulder			Edge		
	Length (mm.)	Width (mm.)	Thickness (mm.)	Thickness (mm.)	Width (mm.)	Length (mm.)	Thickness (mm.)	Width (mm.)	Length (mm.)
YMS-HTD-02	90	64	18	17	12/9	4	4	61/37	11
YMS-XYK-04	106	60	19	19	7	6	3	45/28	8

Table. 4-5-3 Dimensions of two experimental shouldered axe replicas.

2.1 Functional Experiments: the first time

The head of axe replica YMS-HTD-02 was hafted onto wooden handle 1 and bound with cotton string. The hafted axe was then used to perform a soil hoeing task (Fig. 4-5-13). The replica YMS-HTD-02 was broke into two pieces at the neck and the experiment was ended after 15 minutes (Fig. 4-5-14). There were three episodes of re-tightening the binding during this operation, and the actual consumption/use time of the replica YMS-HTD-02 is eight minutes in total.

The head of replica axe YMS-XYK-04 was hafted onto wooden handle 1 and bound with cotton string (Fig. 4-5-15). During the functional experiment the replica axe YMS-XYK-04 did not de-haft , and performed effectively for 36 minutes in total (Fig. 4-5-16).

The dimensions of the furrow in the first experiment was about 30 cm in length and six - eight cm in depth. The hoeing trench was 87.9 cm. long and six - eight cm deep in the second experiment. The total length of furrow hoeing on the first time of experiment was 117.9 cm. (Fig. 4-5-17).

Fig. 4-5-13 First hoeing practise with Replica YMS-HTD-02 in the first time of experiment (Photographed by Hsin Hsieh)

Fig. 4-5-14 Breaking of Replica YMS-HTD-02 after first hoeing practise in the first time of experiment (Photographed by Li-Chi Chiang).

Fig. 4-5-15 First hoeing practise with replica YMS-XYK-04 (Photographed by Hsin

Hsieh).

Fig. 4-5-16 Comparison of shouldered axe replicas after first hoeing practise (Photographed by Li-Chi Chiang).

Fig. 4-5-17 Experimental furrow of hoeing practise in the first time of experiment (Photographed by Li-Chi Chiang).

2.2 Functional Experiments: the second time

The head of replica axe YMS-XYK-04 was hafted onto wooden handle 2 and bound with cotton string. The axe was used to perform soil hoeing tasks (Fig. 4-5-18). The replica axe YMS-XYK-04 broke into two pieces at the neck and the experiment was finished after 37 minutes (Fig. 4-5-19, 4-5-20). There were five episodes of re-tightening of the binding during this experiment, and the actual use time of the replica axe YMS-XYK-04 was six minutes in total. The dimensions of the furrow hoeing was about 95.5 cm in length and four cm in depth (Fig. 4-5-20). The data from the two times of hoeing experiments is presented in Table 4-5-4.

Fig. 4-5-18 Slotted hafting technique of replica YMS-XYK-04 in the hoeing practise of the second experiment (Photographed by Li-Chi Chiang).

Fig. 4-5-19 Breaking of Replica YMS-XYK-04 after first hoeing practise in the second experiment (Photographed by Li-Chi Chiang).

Fig. 4-5-20 Experimental furrow of hoeing practise in the second experiment (Photographed by Li-Chi Chiang).

Practise Day	Practise No.	Replica No.	Hafting Technique	Frequency of re-binding	Practise Time (mins.)	Furrow Length (cm.)	Furrow Width (cm.)	Furrow Depth (cm.)
1	1	YMS-HTD-02	Flattened	3	8	30	9-13	6-8
1	2	YMS-XYK-04	Flattened	0	36	87.9	9-13	6-8
2	3	YMS-XYK-04	Slotted	5	6	95.5	10	4

Table. 4-5-4 Records data of hoeing practising activities.

Discussion

Considering the outcomes presented by the experimental replication data, workability of the three rock types of raw material is different when being ground using a sandstone grindstone. Taiwanese sandstone takes the longest time to grind, and the stone surface undergoes the least modification. Shales from Britain and the andesites of Taiwan are relatively easy to grind, and shoulders can be created on the stone blanks.

The favoured grinding process results in distinctive shoulder asymmetry and produces arc-shape traces during grinding, that are reminiscent of the examples in the archaeological record. These experiments suggest that directly grinding the raw material on a grindstone is an effective way of producing shouldered axe forms, when using workable materials such as andesite. Moreover, this procedure creates axe morphologies, both the shoulders and the overall shape, which are reminiscent of the archaeological evidence in their variability and asymmetry. The experiments indicate that the favoured grinding process (detailed above) was unstandardised. This insight, combined with the similarities between the archaeological and experimental artefacts, suggests that the Neolithic production of shouldered axes may have been a casual and variable process, resulting in arbitrary variations in the shouldered axes' overall forms and in the morphology of their shoulders. Such manufacturing variations in shouldered axes may have depended on the craftsman's individual techniques, e.g. in terms of methods for gripping the blank or selecting a grinding position on the grindstone.

Although the duration of the hoeing experiments were limited due to the breakage of the two andesite replicas, the results from the two-day experiments provide the basis for a preliminary discussion on the usage and/or function of the shouldered axes. From the ratio of use time to the dimensions of the furrows, the efficiency of the shouldered axe/Handle 1 combination is less than the shouldered axe/Handle 2 combination.

Some probable reasons for these differences can be suggested. In the first place, the content of soil between the two furrows showed small variations, , although the hoeing experiments were conducted at the same venue and in soils of a comparable texture. On the first day of the experiments, there were many plant roots and small stones in the soil of the furrow. This was unlike the relatively clean soil of the furrow on the second day (Fig. 4-5-21). It took some time to remove the small piece of flints and cut the roots of plants during the hoeing experiments on the first day, whereas on the second day no such time-consuming actions were needed.

The second point is the difference between the direction and movement of the tools, when using two wooden handles with two different hafting styles. There are multiple choices of holding methods and use motions/directions for Handle 1, and it is easier to control the angle of the hoeing motion, as well as to remove other substances in the soil (Fig. 4-5-22). The disadvantages are that the hands of operator are prone to fatigue, and the technique requires great physical energy consumption. The Handle 2 arrangement grip easily and permits control over the direction of the hoeing operation and is comparatively less energy-demanding. The shortcoming of the Handle 2 arrangement is that the angle of the haft to the handle axis is low (or shallow), thus naturally the angle of the replica hafted axe relative to the handle axe is also rather small (Fig. 4-5-23). This leads to insufficient depth of penetration of the replica axe into the soil, thus the overall depth of excavation is shallower than on the first experiment. In addition, if there is any impurity in the soil, the axe can easily get stuck during operation. Or because of the insufficient hoeing depth in soil, it is directly swept over (skim over/off) from the surface without removing any grass or impurities in the ground.

The last observation is that, whether using an axe in the Handle 1 or 2 arrangement for hoeing, the similarity of axe breakage between two andesite replicas is clear: fracture in a transverse direction across the neck of the axe (Fig. 4-5-24). This type of breakage of shouldered stone artefacts can also be seen in considerable number of the archaeological shouldered objects in the museum collections in Taiwan: twenty-two specimen with missing head and thirty -three of specimen with missing body. The results from this small experimental study can therefore be applied as a tool for interpreting the presence/absence of shouldered axe fragments and the usage and/or function of shouldered axes.

Fig. 4-5-21 Comparison of the furrow range of two hoeing practice (Top: the first experiment, bottom: the second experiment) (Photographed by Li-Chi Chiang).

Fig. 4-5-22 Samples of the root-cutting in the first day practise (Photographed by Li-Chi Chiang).

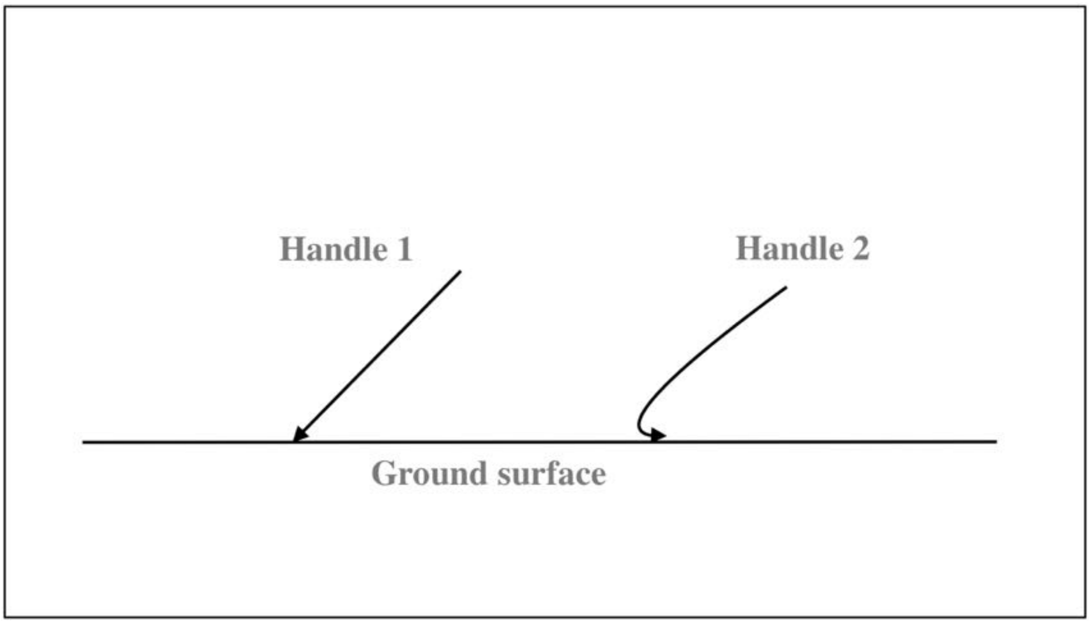


Fig. 4-5-23 Illustration of contact angle between replica hafted and ground surface (Drawing by Li-Chi Chiang).

Fig. 4-5-24 Breakage of shouldered axe replicas after hoeing practise in two times of experiments (Photographed by Li-Chi Chiang).

Chapter 4-6_RESULTS OF PHYTOLITHS ANALYSIS

A total of three samples for conducting the phytoliths analysis at this experiment are selected from the Chihwuyuan Site, and the basic unearthed description are shown in Table 4-6-1. The analytical results show that 80% of the phytoliths are gramineous, and it is unable to confirm that the usage of the shouldered axe as agricultural tools, especially for the rice cultivation. The reason for choice three samples is that the those meet the initial experimental design, only the ones dug up from the layers of the test pit in the Chihwuyuan Site during the first-year excavation carried out by Dr Su-chiu Kuo in 2015, where a shouldered axe (CWY-1) and a soil sediment (CWY-C) sample are uncovered. So that is capable to perform the phytoliths analysis experiment with two samples as the comparative substances. In view of the insufficient number of samples will affect the reliability of the interpretation of the experimental results, another piece of shouldered axe (CWY-2) excavated at the same site is also subjected to exercise the phytoliths analysis simultaneously. For the three samples of this phytolith analysis experiment, two shouldered axes are designated as the experimental group and the site sediment as the control group. Through the comparative study of the experimental results of two groups, the usage environment of the shouldered axes will be revealed whether it is not the same as the depositional environment of the soil sample. If the results are different, it implies that the shouldered axes maybe used in another environments. The terms used and morphological identification in this study follows the International Code for Phytolith Nomenclature and standard literature (Madella *et al.*, 2005, Portillo *et al.*, 2014).

No. Sample	No. Artefact	Layer	Square	^{14}C years BP	material
CWY-1	S-L56-00001	56	T59P4	3,830-3,570	Andesite shouldered axe
CWY-2	S-L35-00001	35	T55P4	≦3,000	Andesite shouldered axe
CWY-C	T59P4-E001	56	T59P4	3,830-3,570	Site sediment

Table 4-6-1. Field, Radiocarbon dates and material descriptions of samples.

Procedure

1. Preparation of the experimental specimen

1.1 Two shouldered axes of the Chihwuyuan Site were scrubbed the deposits on the surface of the artefacts into two different beakers with distilled water.

1.2 Two beakers containing sediment mixed with pure water were placed in an oven at the temperature of 60°C until the moisture in both beakers completely evaporated and the dried deposits remained (Fig. 4-6-1).

1.3 The dried, powdered deposits in the two beakers are separately wrapped in two pieces of aluminium foil, then placed in a specimen bag and labelled as CWY-1 and CWY-2.

1.4 The dry site sediment is ground into powder in the mortar, then placed in a specimen bag and labelled as CWY-C.

2. Phytoliths extraction from specimen

2.1 Equipment required

- Disposable microcentrifuge tubes: 0.5 & 1.5 (size)
- Nozzles for pipettes
- SPT (Sodium polytungstate)
- 6N HCl
- Precision scales
- Automatic pipettes
- Sonicator (Fig. 4-6-2)
- Thermo Micro centrifuge (Fig. 4-6-3)
- Slides
- Entellan resin

2.2. Phytoliths extraction and slides mounting

- Weigh three samples into tube using spatula separately: c. 40-50mg. (CWY-1: 45mg, CWY-2: 45.2mg, CWY-3: 45.8mg)
- Add 50 μl 6N HCI into three tubes using pipette to dissolve the carbonates in the sediments.
- Shake the tubes manually and wait for the reaction to end.

- Add 50 µl SPT into three tubes using pipette and shake the tubes manually.
- Shake the tubes intensively to disperse minerals using sonicator for five minutes.
- Shake the tubes to separate the phytoliths from the sediments using micro centrifuge for five minutes with speed five.
- Remove all the liquid as much as possible in each one of the tubes (Fig. 4-6-4) and place the liquid in new labelled tube.
- Take 50 µl liquid from each tube and drop in centre of slide, place cover slip.

2.3. Phytoliths preservation (Get rid of acid and SPT)

- Fill the tubes with deionised water and shake using micro centrifuge for five minutes with speed five.
- Take out and remove excess liquid to a jar for SPT recycling.
- (Repeat this process until the liquid is clear, only processed sediment sample leave in the bottom of the tube.)
- Take the tube with sediment sample out on heat to dry overnight.
- Remove the sediment sample from the tube and place in centre of slide, mix with Entellan resin for mounting the permanent slides to preserve the phytoliths (Fig. 4-6-5).

Results

Place the microscopic slides of three samples and observe the extracted phytoliths at 200x and 400x magnification using Leica DM EP optical microscope (Fig. 4-6-6). The accounted data of microscopic examination provide information regarding the extent of amounts and morphotypes of phytoliths in the samples on fields of each slide at 400x magnification. Quantifying results of phytoliths in concentrations and morphological profiles are present in Table 4-6-2. Unidentifiable phytoliths which are caused by the dissolution are listed as the weathered morphotypes in the data sheet. It is difficult to identify the plant type of phytoliths with unclear features due to the phytoliths in three samples in general, are all in a small number and the poor preservation condition, even the suspected rice phytoliths are found on experimental samples. Although it is not easy to identify the plant species, count the phytolith assemblages in the samples about 80% of all morphological types are dominated by grasses (Fig. 4-6-10). Anatomical structure of the grass phytoliths are morphologically divided into the different parts of plant in inflorescence and leaves/stems, and the proportions of the phytolith assemblages' structure in the samples are shown in the Figure 4-6-11.

No. Sample	IW	Phytoliths	Fields	Factor	Phytoliths slide	Phytoliths 1g. sediment
CWY-1	40.02	97	23	654	2758.173913	689,199
CWY-2	40	71	25	654	1857.36	464,340
CWY-C	40.39	114	32	654	2329.875	576,845

Table 4-6-2. Counting phytoliths on slides of three sample.

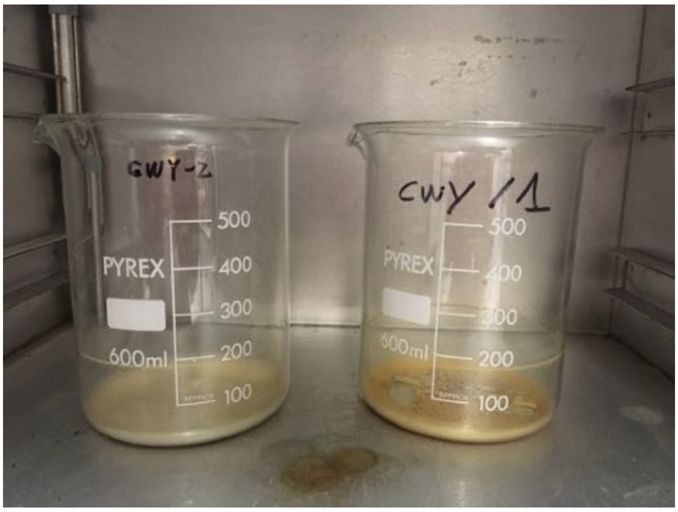


Fig. 4-6-1 Beakers with dried sediments of CWY-1 and CWY-2 in the oven.

Fig. 4-6-2 Sonicator for shaking to disperse minerals.

Fig. 4-6-3 Micro centrifuge for shaking to separate the pytholiths from the sediment.

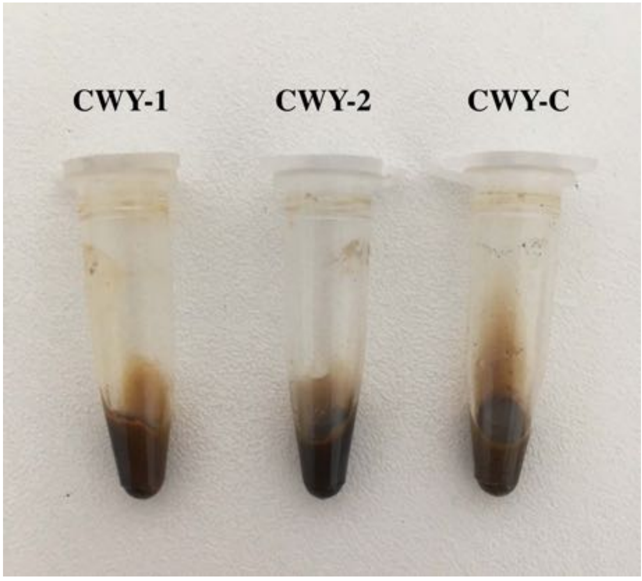


Fig. 4-6-4 All liquid removed, and the sediments left in the bottom of the tube.

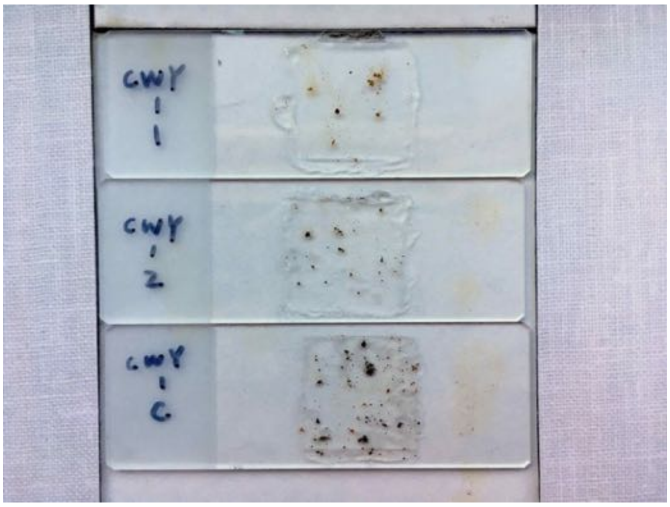


Fig. 4-6-5 Permanent slides for morphological observation and preservation of phytoliths.

Fig. 4-6-6 Leica DM Polarizing Microscope.

Discussion

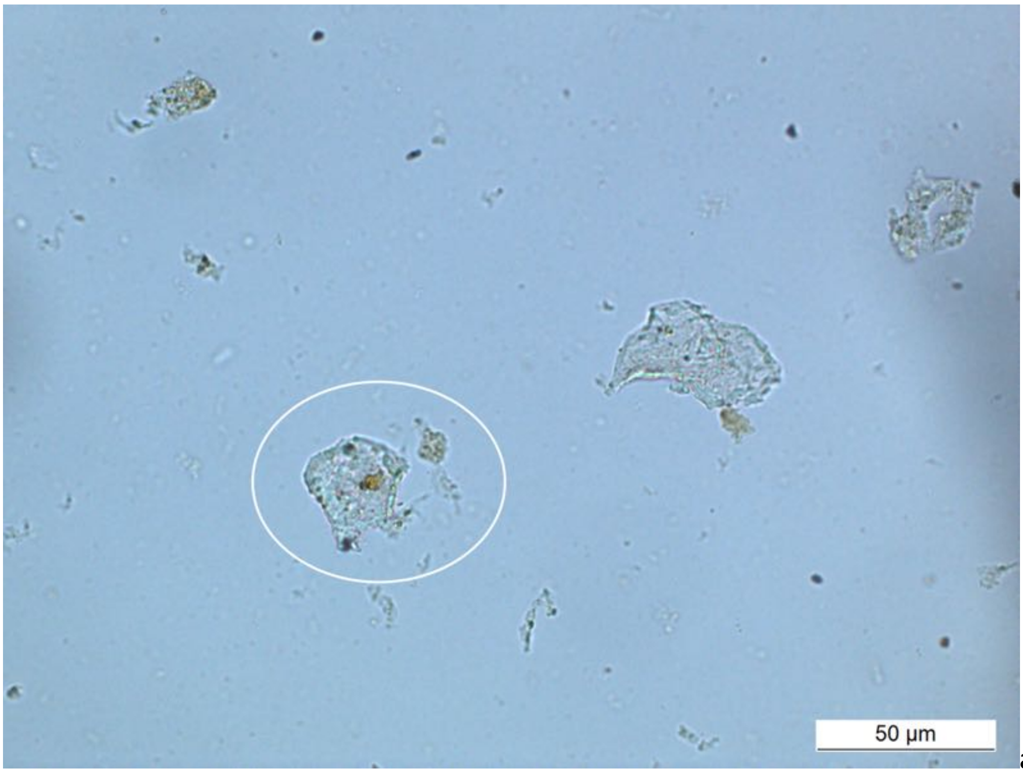
Examining the morphological types of phytoliths in the sample individually, the morphotypes of plant phytoliths from the control sample are varied and different from that on experimental samples (Fig. 4-6-7, 8, 9). Such a difference is also shown in the plant anatomical structure statistics of phytoliths (Fig. 4-6-11).

The discrimination of phytolith assemblages between control and experimental samples indicates that the experimental samples are used in certain environmental settings. Grasses are classified to the *Pooideae* subfamily common in well-watered lands. Two sponge spicules of diagnostic phytolith from experimental samples are recorded and considered as a typical grass common in a wet environment. The deposits of the sedimentary stratigraphy in the Chihwuyuan Site shows the site is formed mainly of river sediments of alluvial plains and reveals its wet palaeoenvironmental condition according to the geological prospecting study (Lin and Kuo 2017). Findings of sponge spicules phytoliths on the experimental samples acknowledging that the object they are applied to involves in the plant species grown in the moist ancient circumstance.

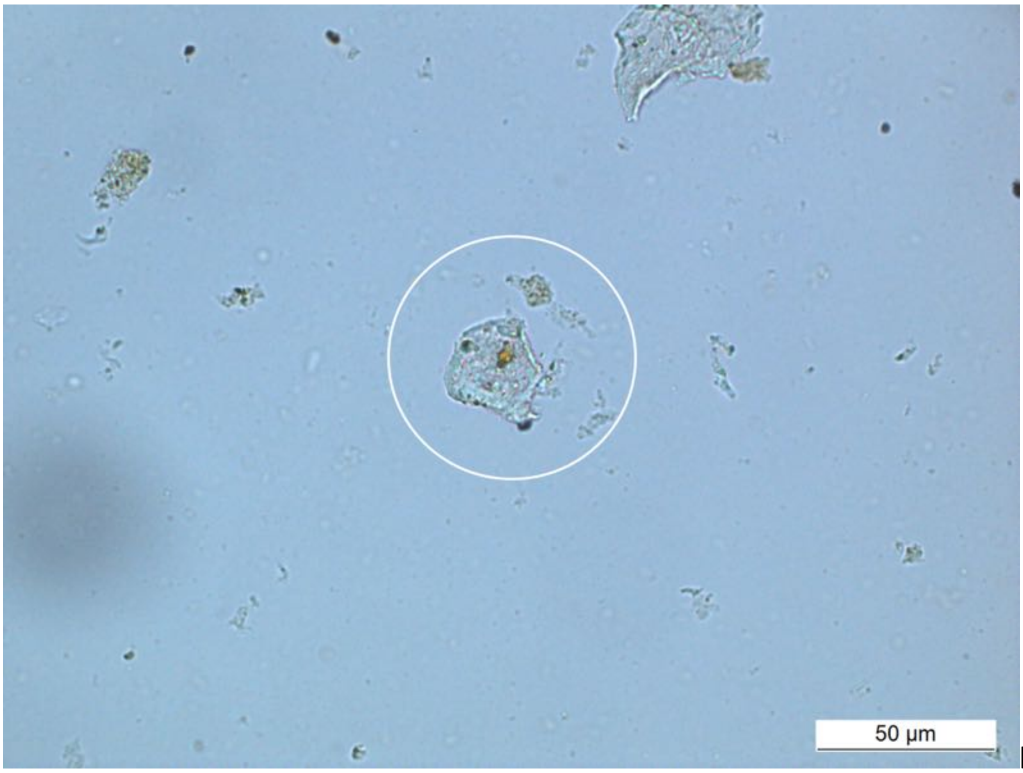
Moreover, there is a weed phytolith unable to determine the specific plant discovered from experimental sample (Fig. 4-6-8: f). Weeds are commonly considered as an unwanted plant in a particular environment situation, and normally removed from the agricultural land. There are a small amount of carbonised plant remains excavated at the Yuanshan cultural Sites, the carbonised rice contained (Huang *et al.* 1999a, b). The result of bone collagen study by applying the carbon and nitrogen isotope analyses demonstrates that the Yuanshan people has a dietary habit of consuming C3-based foods as the main source of nutrients, for instance rice, millet and other C3 plants (Lee *et al*. 2016a, b).

The latest and yet unpublished phytoliths analysis research of the Chihwuyuan site by Dr Zhenhua Deng and Dr Hsiao-chun Hung reveals the evidence of rice and millet appeared in the site (private communication with Dr Su-chiu Kuo in February 2018). Comprehensive evidence from the above-mentioned phytoliths analysis and other archaeological studies shows that shouldered axes as an experimental group may indeed be utilised in the agricultural-related working environments, such as rice and millet of the C3 plants cultivated in the wetland condition.

The results of the phytolith analysis present that the phytoliths extracted from three samples have 80% of gramineous plants. And the phytoliths extracted from two shouldered axes still cannot provide a crucial explanation on their usage/function evidently, in particular use as farming tools for rice cultivation. In addition, the phytoliths found from sediment sample are different from that of two shouldered axes. It suggests that the shouldered axes were used in an environment(s) different from where the sediment sample at.



a



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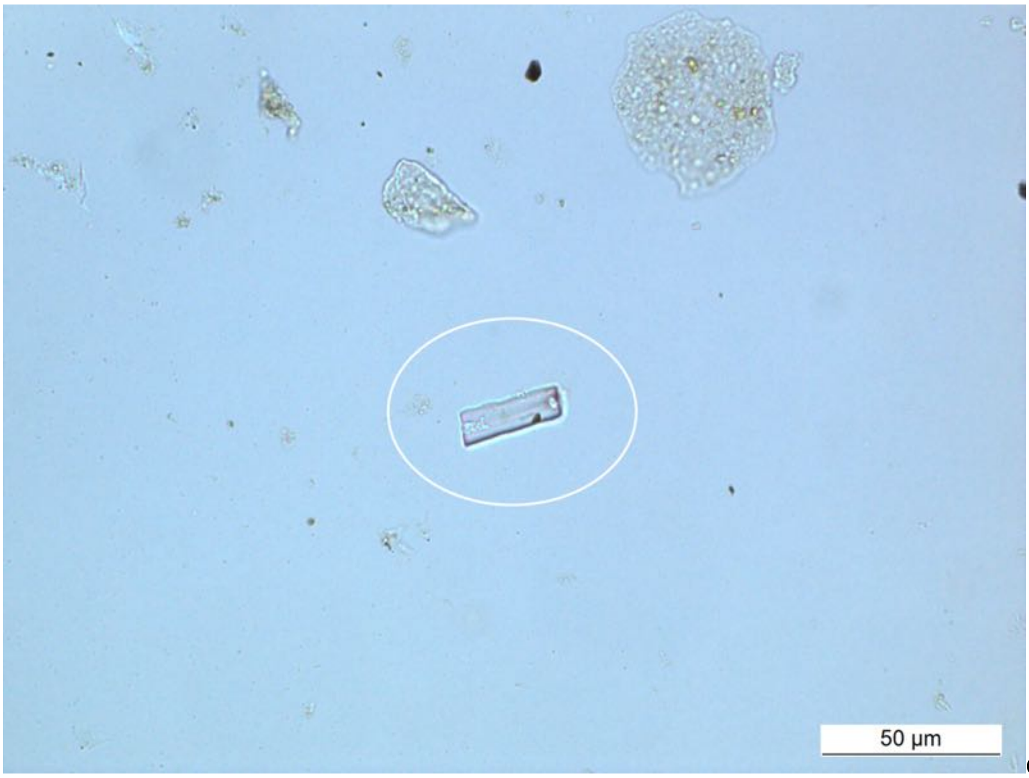

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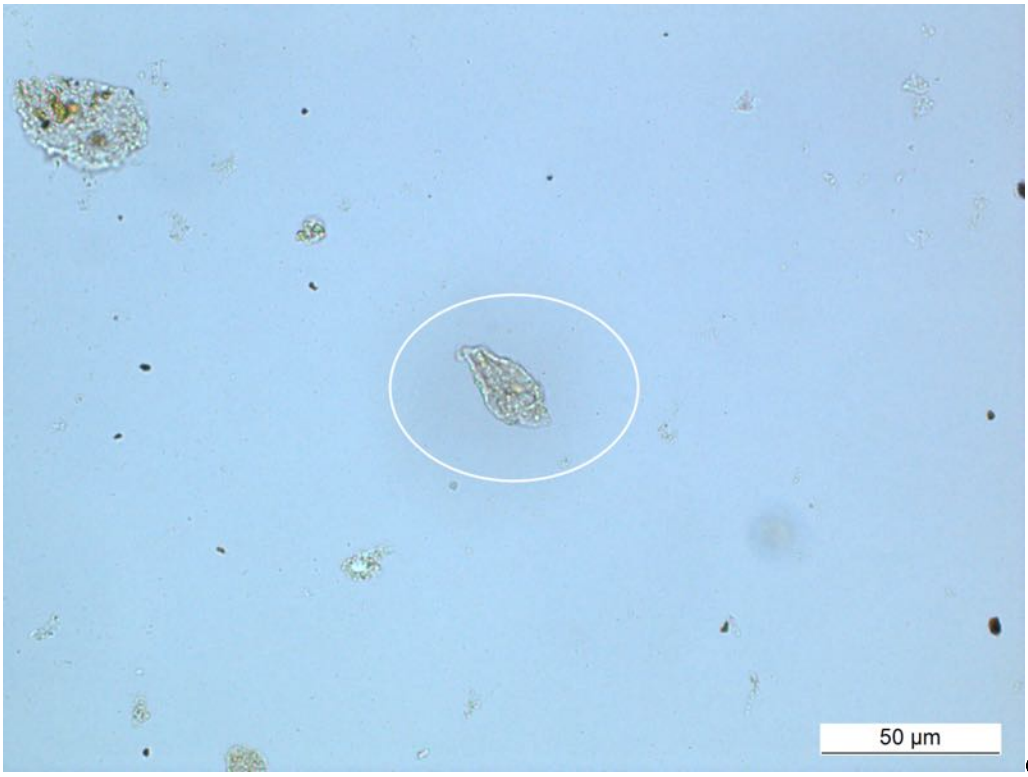

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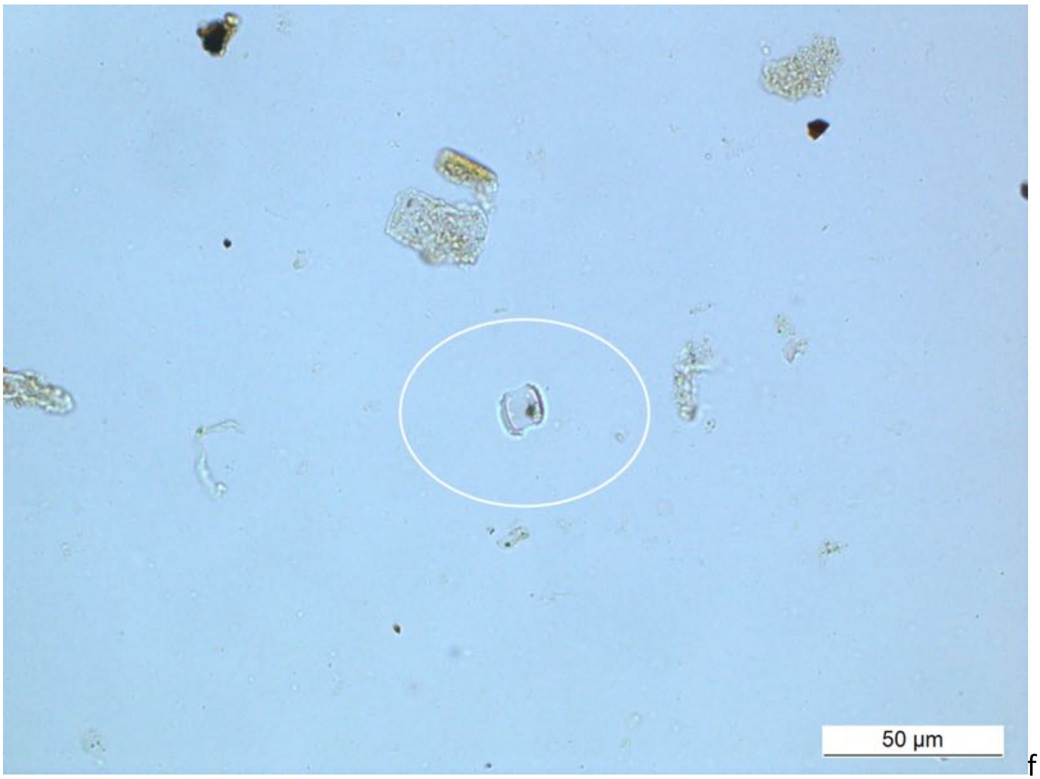
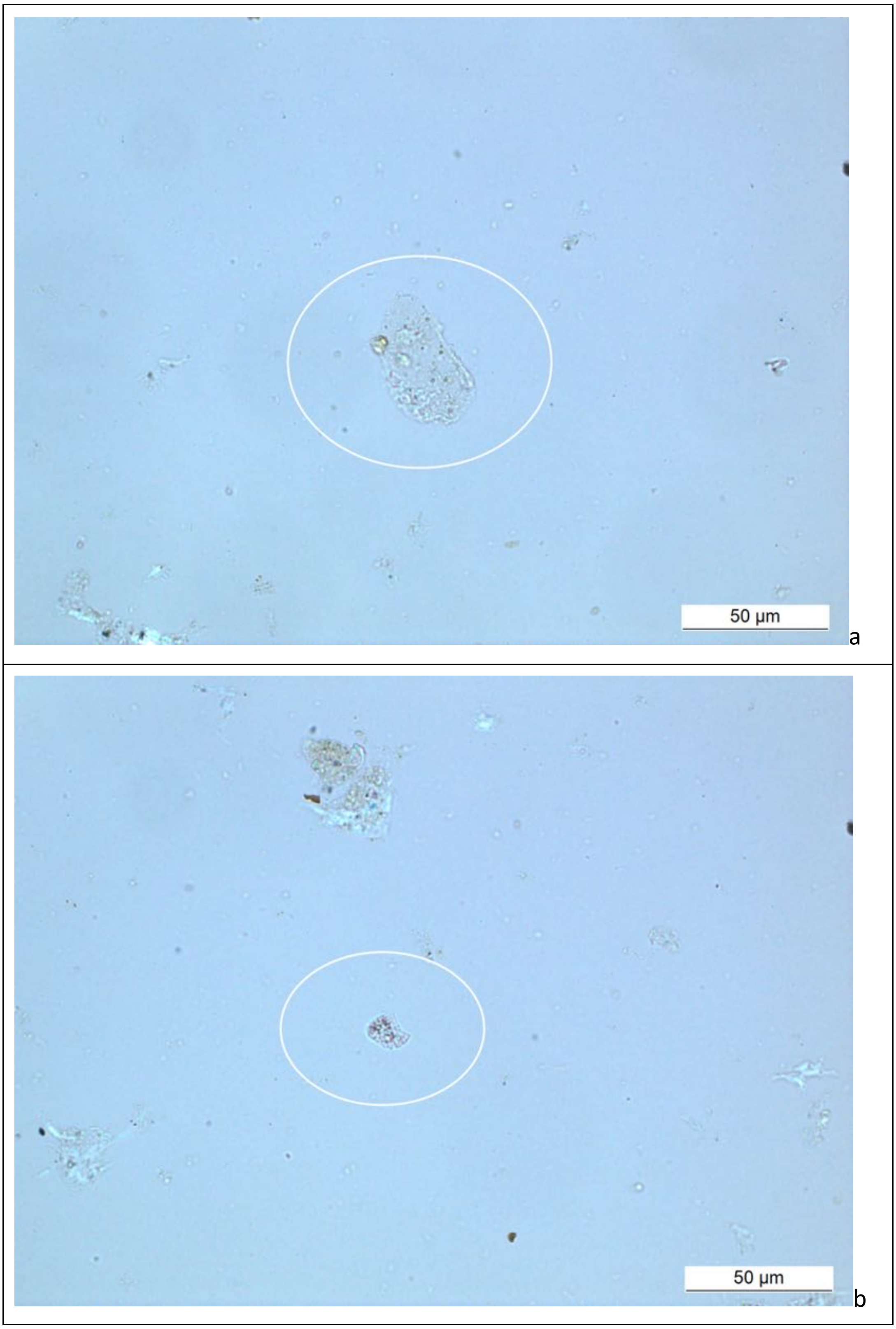


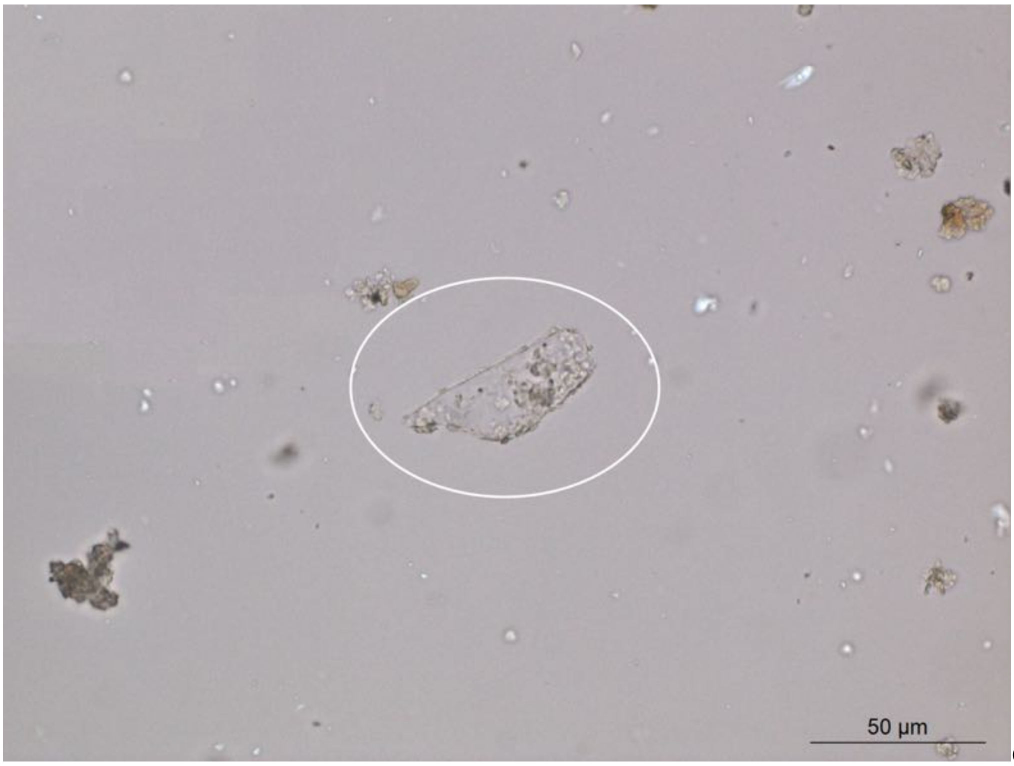
f

Fig. 4-6-7 Phytoliths morphotypes found in the CWY-1 (a and b=bulliform, c=elongate, d and e=acute bulbosus, f=saddle).


50 μm
a
50 μm
b

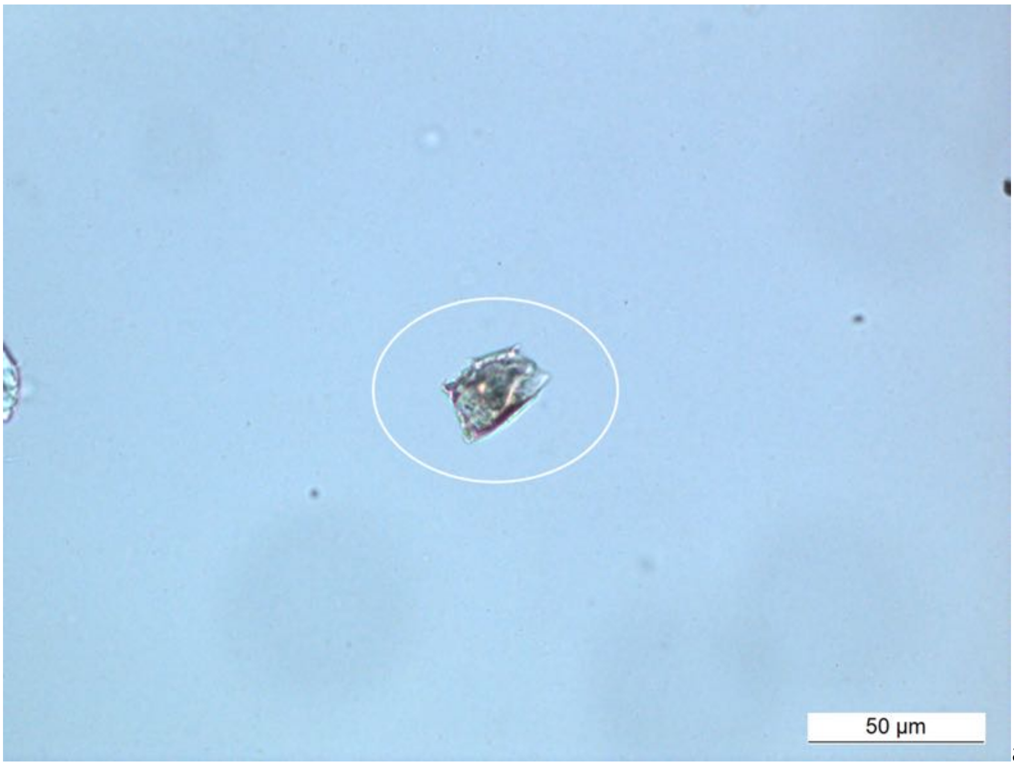
c

d

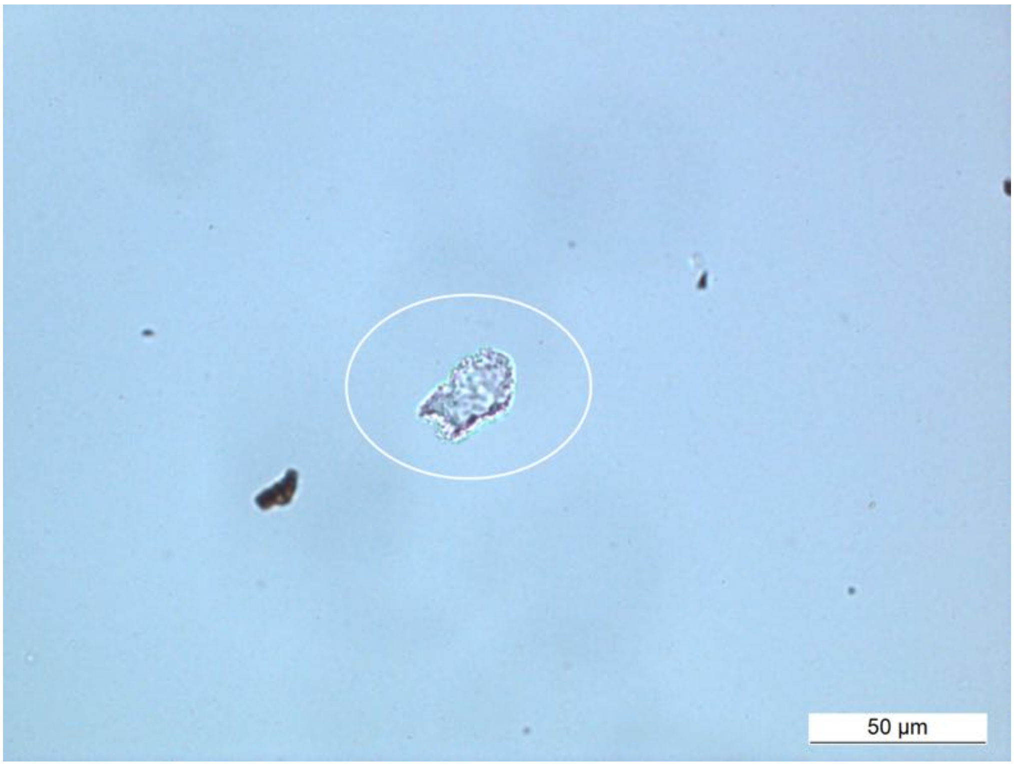


e

Fig. 4-6-8 Phytoliths morphotypes found in the CWY-2 (a=bulliform, b and c=weathered morphotype, d=elongate, e=prickle).



a



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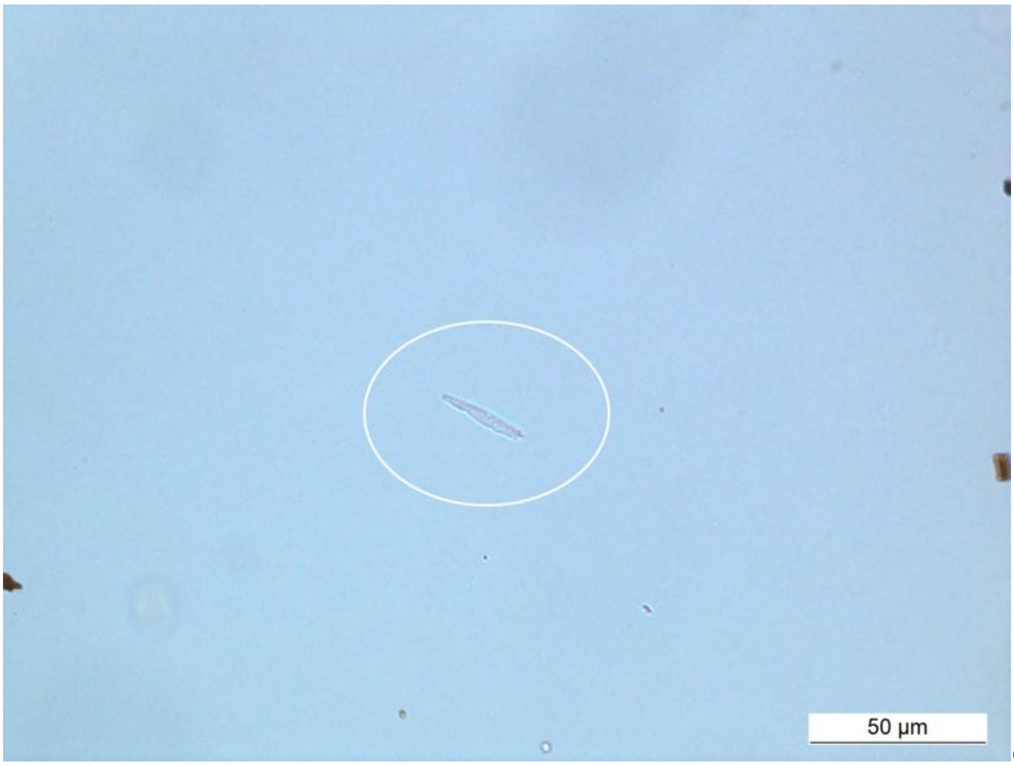

c

d

e

Fig. 4-6-9 Phytoliths morphotypes found in the CWY-C (a and b=bulliform, c=hair, d=long cell, e=rondel, f=bulliform pillow).

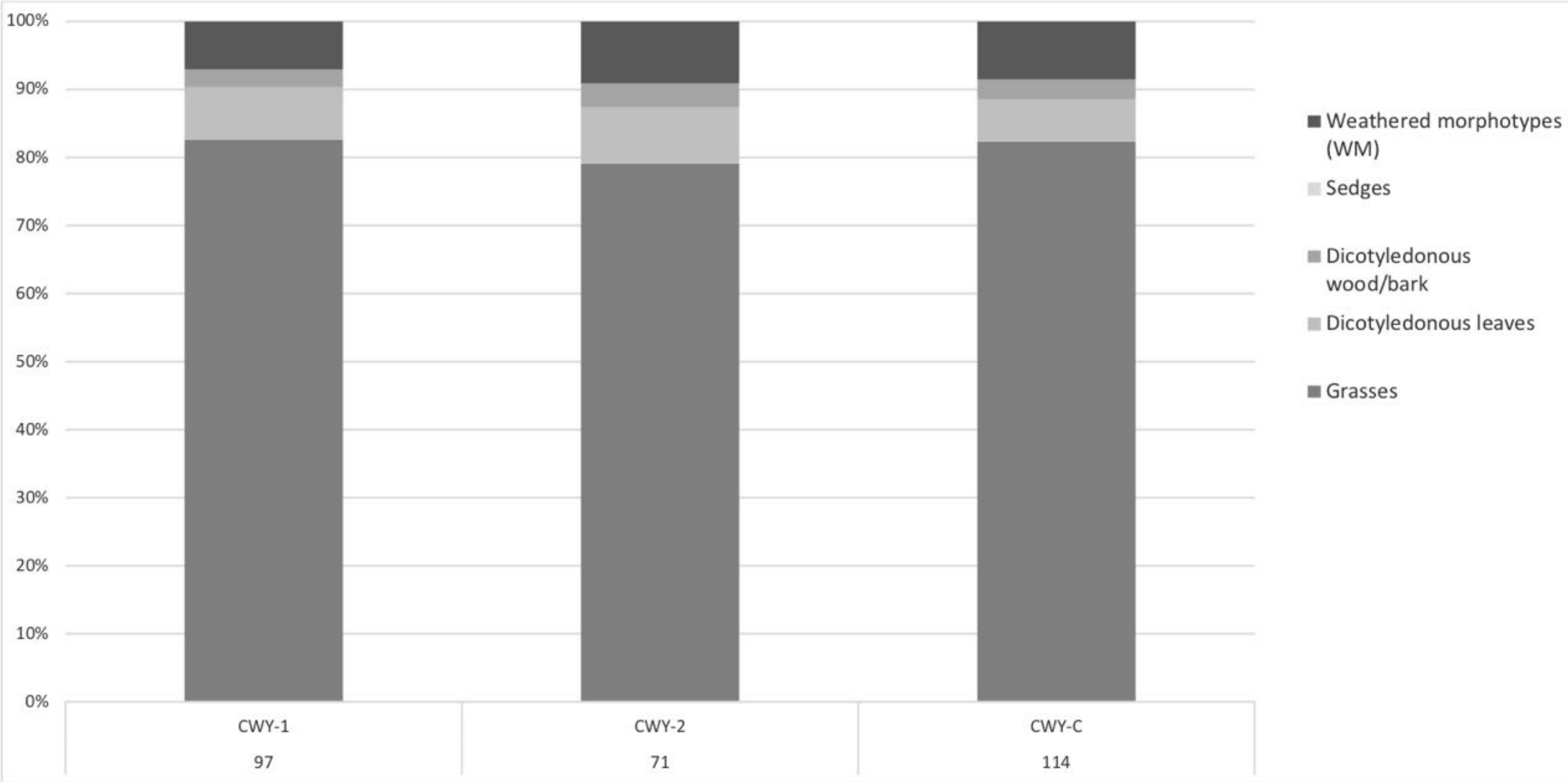

Fig. 4-6-10 Relative abundances of phytoliths from grasses, dicotyledonous leaves, dicotyledonous wood/bark and weathered morphotypes.

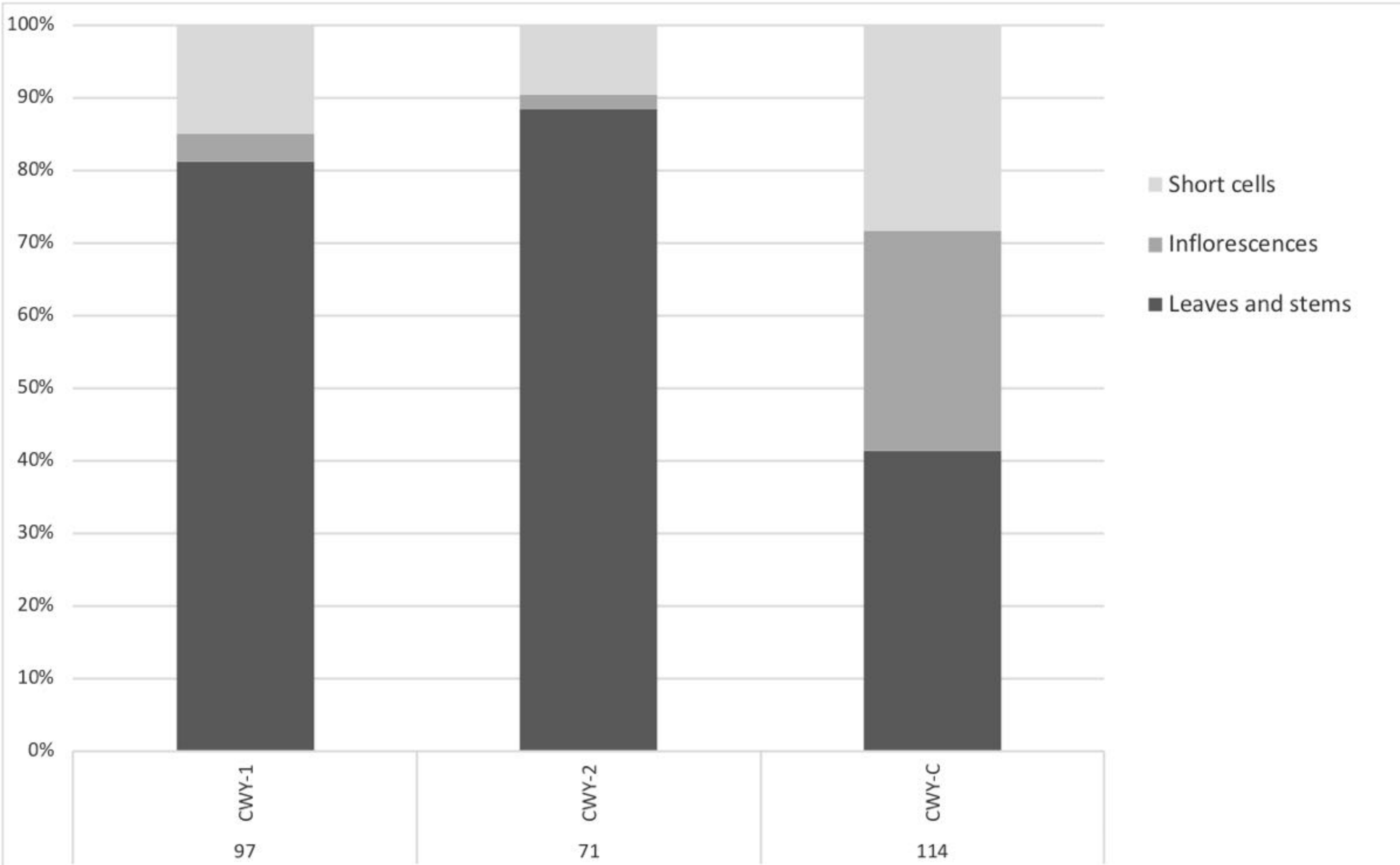

Fig. 4-6-11. Anatomical structure of the grass phytoliths identified in the samples.

Chapter 5_DISCUSSIONS

When discussion coming to the relevance between material culture and social culture, it is the technology the root for distinguishing culture in the archaeological study, and the conversation of artefacts will eventually be put back into the cultural context (Chen 1996). In other words, the artefact production technology is one of the cornerstones for discussing/distinguishing prehistoric archaeological culture. Ancient human beings most likely also used an array of organic materials, stones are usually the only artefacts preserved in the record and, therefore, are key to trace the emergence of technology in human evolution. To resolve the means of the production and function of the shouldered axe, many of the research methods adopted in this dissertation which are consisting of the Bayesian chronological modelling, pXRF analysis, use-wear analysis, PCA analysis, phytoliths analysis and experimental archaeology. In the meantime, with regard to the idea of the shouldered axe pattern may or may not exist in the Yuanshan Culture furthers the discussion in-depth, including whether there is any special intention in the production, any spatial or chronological patterning in the shouldered axes, or any distinctive methods and applying objects in performance. And towards the ultimate goal of answering the source of Yuanshan Culture in the end.

1. Preliminary results

This study focuses on the approachable 325 Taiwanese shouldered axes in total, including 309 collections from four museums and sixteen unearthed archaeological finds, by comparing and analysing of morphological classification. Based on this, the aspects of the manufacturing technology, the function/usage and the concept of the shouldered axe are argued thoroughly. New findings and opinions on the topics are presented as well and verified by using scientific means. Moreover, by referring to the relevant information from the neighbouring region to illustrate the rationality of point of view, then try to offer an idea of the possible sources of Yuanshan Culture in the end. In spite of that, this paper has some shortcomings in the richness and accessibility of the content due to some irresistible factors in the research process. The preliminary results of this study are summarised in the following conclusions:

1.1 Rethinking the Yuanshan Culture Chronology

The Chronology of Yuanshan Culture is earliest up to *3,600* B.P. and lasts to the age between *2,400* and *2,300* B.P., a few sites even delay to *2,000 - 1,800* B.P. and disappear.

1.2 Sourcing the raw material of shouldered axe

The analytical results of sixteen shouldered axes by using pXRF show that thirteen shouldered axes were made of andesite and the other three were made of sandstone. The trace element values of the sixteen artefacts, then, are compared with the experimental data of nine published literature and eight andesite raw materials collected from the Tatun Volcano Group area. The diagrams of SiO_2

variation for CaO, K_2O and FeO, as well as the plots of the major and trace elements for Sr, Ba, Rb and Zr, demonstrate that the element values examined of andesite shouldered axe ZLS-003 from Chanlungshan Site is similar to the known andesite values collected from the Tatun Volcano Group in two published literature, whilst the andesite shouldered axe S-135 from Chihwuyuan Site is close to the raw material XYK-01 picked up by the 2016 fieldwork in this study. Therefore, it is highly likely that the shouldered axe ZLS-003 and S-135 are obtained from the local quarry: the Tatun Volcano Group. The other eleven shouldered axes are temporarily unable to trace the procurement, only the raw material of andesite is confirmed.

1.3 Production technology of the shouldered axe and shoulder

All of the andesite shouldered axes are grinding tools, other marks like chipping or flaking on the surface can be seen clearly on some axes as well, which presumably they are initially flaked and then ground into their final form. The traces of the sandstone shouldered axes are basically visible the process of flaking and grinding, normally the traces are flaking first, then cover by the grinding. That is, strictly speaking, the traces of flaking are removed by grinding. Replica experiments have shown that the shoulder with a shoulder axe can be ground directly on the grindstone without the need of additional tools for processing into the form.

1.4 Morphological classification of the shouldered axe and shoulder

The analytical results of the measurement dataset with the typology of the shouldered axe show that there is no high-density concentration of one or several specific angle groups and is continuous variability. The typology of the shouldered axe is changeable and does not present a consistent concept of design requirement as the morphological analysis demonstrated. Inferencing from the perspective of production technology, it maybe causes by the uncertainty of the grinding course of objects, such as the different angle in grinding between the rock material and grindstone, the length of grinding time, the characteristics of stone, or the lassitude of the craftsman.

1.5 Usage/Function of the shouldered axe and its shoulder

The original records of 325 artefacts (if any) offered by the archaeological project director or the administrative officers in the museums suggest that the function of Taiwanese shouldered stone axe can be recognised to use as an axe, hoe and shovel (Shih 1950, Liu and Kuo 2000, Kuo 2014a). The replicating experiments of the shouldered axe carry out with the function of a hoe in this study. The shouldered axe used as a hoe for farmland preparation in crops cultivation is quite possible as the experimental results demonstrated. Two slot types of wooden handle are produced for the hafting technique of the shouldered axe experiments. The durability of the adze used wooden handle is higher than the one with a groove. The breakage pattern between the upper and lower part of two shouldered axe replicas are the same, the shoulder is broken parallel to the axis. The fracture type produced by two hafting techniques of the shouldered axe exercised is consistent with the appearance of the damaged artefacts among the observed 325 specimens.

The outcomes of the use-wear observation demonstrate that the blade edge of the shouldered axe has short striations against to the axis. It should be created rather by the soft-consumption behaviour like digging or weeding, instead of the state of heavy strength toward the objects as cutting or smashing. There are arc-shaped traces can be seen on the intact shoulders of the shouldered axes, which are the manufacturing wears revealed in this study for the first time. The trace marks of round polishes or striations on the incomplete shoulders are the most observed on the surface of the artefacts if they are not weathered. The use-wear analysis in this study recommends that the shoulder with the shouldered axe is indeed a practical function in use, such as the experimental results yielded of the hafting aspect in chapter 4-5.

1.6 Sources of the shouldered axe and the Yuanshan Culture

Comparing the typology of the shouldered axes unearthed from the sties in Taiwan, South China, and Indochina Peninsula, it is presumed that some of the shouldered artefact types of the Yuanshan Culture are similar to that of the prehistoric cultures that the area extends from the southeast coast of China to the Indochina Peninsula. The conclusion reaches on the basis of these, such concepts in the Yuanshan Culture may share with the prehistoric culture (s) across this region.

2. Discussion

This study simultaneous applications of several scientific techniques like analyses of use-wear, phytoliths, pXRF and the replica experiments, the outcomes yielded by those methods have studied in companying with referencing the ethnographic documents to explore the production technology and function/usage of the shouldered axe. This is just the beginning. There are still many issues in this study that can be extended and discussed, also the methodological limitations take place during the research process. The following discussion will present some suggestions and directions for further research in the future.

2.1 Limitations, revisions, and extensions on applying the scientific methods

The quarry of andesite raw material of the Yuanshan Culture does not answer as expected which the aim is to confirm that the andesite is indeed procured from the Tatun Volcano Group on the basis of the pXRF experiments. The reason for the inability to identify the quarry is presumed to be associated with the easily weathered characteristics of andesite. Such weathering property of andesite presents the analytical deviations of detected trace elements by pXRF equipment between the unearthed shouldered axes and fresh andesite materials in the literature. (Asio and Chen 1998, Tsai *et al.* 2008) Nevertheless, the experimental data of this study still has value as a reference for understanding the composition analysis of the andesite from Tatun Volcano Group. The thirteen shouldered axes are examined by pXRF and confirmed to be made of andesite, so it is feasible to test the igneous rocks with non-destructive instruments.

It seems that the easy-to-weathered andesite causes most of the trace marks on the surface of shouldered axe disappeared or hardly observe, only the remnants of the fracture sections are available for speculation of the function/usage. On the contrary, the traces on the sandstone shouldered axes are much clear and identifiable. Through the use-wear observations on the shouldered axe by the low-power microscope, identify the short striations on both sides of the blade edge, as well as the arc-shaped of the shoulder as grinding marks in the production process for the first time in this research. The use-wear pattern of the blade edge is different from that of Hung's observation on the adzes of the Yuanshan which the striation traces of shouldered axes left on both side of the bade edge surface. The different wear patterns between the shouldered axe and adze suggest that the function of the shouldered axe is distinct from the adze in evidence (Hung 1999a). In other words, the use of a shouldered axe can preclude the typical function of adze recognised as woodworking tools. The arc-shaped of shoulder manufacturing marks is successfully offered an idea for the replicating experiment practise. The breakage pattern of the binding shouldered axe after use provides the fundamental materials for identifying the fragments of the shouldered axe (the upper or lower part) (Fig. 5-1). In addition, the causes of the damage marks on the upper part of a shouldered axe cannot be judged presently, whether it is produced by the use with hafting handle or other factors like the post-depositional alterations.

Fig. 5-1 Fragmented pieces of the shouldered axes. Left: a piece of head with the shoulders visible (IHP). Right: a piece of a body (MANTU). (Photographed by Li-Chi Chiang)

The application of the use-wear analysis for questing the issues on the making and using of the shouldered axe as an attempt in this dissertation for the first time in Taiwanese archaeology. It is offered from the considerably specific investigation results that the manufacturing traces and use wears on the shouldered objects by the low-power magnification microscope is rather practical as expected. The condition and distribution presented from various usage marks can be inferred from some fixed patterns and the utilisation of the trace states for different forms, can also be learned in order to grasping the modes the operation of the shouldered axe by the human beings probably.

There are certain limitations of the application of the use-wear analysis in the evaluation of the stone tools because of the various factors, such as the post-depositional alterations of the stone, the property of raw material or rocks or the unclear extent of the use rates (Midoshima 2005). The main observational difficulty encountered in this study is that the surface of the andesite shouldered axe is severely weathered, leads to the use-wears blurred or disappeared and fails to identify. The 325 shouldered axes of Yuanshan Culture examined are fragments in a majority of total. The speculation on the performing motion directions of certain types by the distribution of the use-wears on a few intact shouldered axes and the rest fragments in a large amount. At the same time, the surface of shouldered axe is ground entirely, many traces caused during the making progress disappear after the succeeding grinding. Only the damaged parts of shouldered axe left some marks can be inspected. For example, a specimen (No. IOE-00124) borrowed from the Institute of Ethnology, Academia Sinica in this study reveals such marks. (Fig. 5-2) The shoulders on both sides of this sample are slightly damaged, and the lower edge of the abrasion surface on one shoulder has ground, the original damaged traces have covered by the succeeding grinding. At that time, there was no digital microscope on hand to take those marks, only records the observed condition of a sample. In addition, there are incomplete archaeological records of the shouldered axes in their unearthed information over half of the artefacts investigated, which leads to the evaluation of the use-wear analysis are lost effectiveness to link to the entire prehistoric community of the Yuanshan Culture. It is thus a challenge to delve into the exploration of the shouldered axe from the perspective of social and cultural significance.

Fig. 5-2 A sample has the marks of the succeeding grinding traces covered on the previous damaged surface (IOE, Academia Sinica). (Photographed by Li-Chi Chiang)

The above restriction encountered during the research process is not unbreakable, just as the application of the experimental archaeology does have its necessity in verifying the hypothesis offered by the analytical outcomes of use-wear observation. In the case studies of use-wear analysis listed in the Methodology chapter, many of the important discussions are based on the comparison database obtained from experimental archaeological results, then confirm the credibility of the database by blind testing. As such, the observations have an explanatory effective. There is presently no relevant use-wear experimental database of stone artefact available in Taiwan for comparison. At this stage of the study, there is no sufficient time for thorough and comprehensive experiments to test only the traces that could be successfully identified. Another example is the raw material selection of the rocks: why the Yuanshan Culture uses the andesite. The production technique of the shoulder on the shouldered axe can also be seen through the low-power optical microscope, which may answer the question of stone choices. The experimental results of this study show that sandstone is time-consuming and labour-intensive compared to that of andesite, which is compatible with the conclusions suggested by Zhai (2015) for the replica grinding experiments on the material of sandstone. The degree of difficulty and the length of time on the making process of shouldered axe may be two of the reasons, not exclusively, the Yuanshan Culture people chose igneous rock as raw material for the stone objects production. Intentionally, the method of applying use-wear analysis together with experimental archaeology is feasible, and the unfinished work in this study is left to be continued as the next stage in the future.

The conceptual issue of the archaeological materials is relatively difficult to test by scientific methods. It is only able to apply the quantitative data analysis of artefact typology to search out and explain the possible motivation of human behaviour. For example, whether the shouldered axe (shoulder) has a non-practical meaning other than practicabilities like a prestige good or ritual stuff, if the view from the perspectives of culture, society, and symbolism.

The data set of 325 shouldered axe assemblage shows that the angle and shape of the shoulder and blade on each object are varied and not assigned to one or several certain angle group either. Experiments with replicas have shown that the morphological asymmetry of the shouldered axe does not seemly affect the actual use, same as to the well-performed of the shoulder and blade. There is an abundance of the conversations about the correlation between the typological symmetry of the prehistoric stone artefacts and the human behaviour, which may be echoed the meaning of the used and/or made marks left on the stone tools, such as production preferences or practical considerations (Machin *et al*. 2007, Cole 2015).

The variations of the typological asymmetry and the degree of angle displayed in the experimental performance suggest that the production of the shouldered axe does not have a specific design of its appearance. The production of the shouldered axe does not have a particular design preference which implies likely no explicit manufacturing process. It highlights that, on the contrary, the Yuanshan Culture people may have the concept of designing a "shoulder" onto the stone artefact. In other words, there is an intention to produce a generic shoulder on the shouldered axe for hafting. It is worth mentioning that, not alike the unearthed tools which were produced under a series of the manufacturing process in South China and Southeast Asia, a stone object with both shouldered and stepped has not been found in Yuanshan cultural sites by far. Neither discovered a swap of shouldered or stepped technology apply to the object of Yuanshan Culture, for example, shouldered adze-chisel or stepped axe-hoe which has been commonly seen in the sites of South China and Southeast Asia. Shouldered or stepped in profile and chipping or polishing in the process apparently has a set of shouldered/stepped production in South China and Southeast Asia, which means an object could have both shouldered/stepped outward, and chipping or polishing in the application.

In the meantime, the exact idea of a shoulder angle with the extent of the preference in the shouldered axe production is unknown and hard to evaluate. Kuo (2014a) comments on the shoulder design of stone tool from the perspective of popular culture at that time, which may explain why the Yuanshan Culture people are obsessed with manufacturing a shoulder on the shouldered axe. However, the results obtained from the use-wear analysis that the shouldered axe is used, together with the low durability of the shouldered object presented in the experiment, indirectly implies that the market acceptance of such stone tools is low. In the prehistory of Taiwan, only the Yuanshan Culture has such the special artefact in view of the stone axe morphology in general and is not seen in others, it is probably one of the reasons that the shouldered axe is no longer used because of its vulnerable property.

The traces patterns as seen on the shouldered axe under the optical microscope are used to infer the way of the shouldered axe usage, and thus the modes of operation in correlating with the hafting techniques for practising the experiment are established. The replicas of the shouldered axe are subjected to the experiment of hoeing and created two types of the slot on wooden handles for testing the hafting methods, and then performed until the object fractured into the piece. This experiment shows that the shouldered axe hafted with a handle to operates quite smoothly as a hoe for upturning the soil in the ground. Meanwhile, the breakage pattern of the shouldered replicas presented after the operations has resembled some of the fragments in the museum collections of shouldered axes. The pattern of the breakage means that the shoulder is broken off from the lower part of the shouldered axe. This result unexpectedly provides a chance for reviewing the relationship between the fracture pattern of the shouldered axe and the user action by human beings. In other words, it can be judged from the break marks that a certain piece of fragments may have been used as a hoe tied with a wooden stick. It must be noted that there are many reasons for the breakage of prehistoric stone tools. This judgment is limited to the shouldered axe which broke after used with binding a handle in combination.

An exception of hafting the shoulder is occurred at the close inspection by applying use-wear analysis in this study. The Yuanshan Cultural shouldered axe of the National Museum of Prehistory, code number NMP-20010900215, has an intact pair of shoulders, however, the surface marks appear on both sides of the lower part below the shoulders (Fig. 5-3). If this shouldered axe has been bound with a handle and used as a hoe, the two-sided traces below the shoulder indicates that the cordage is not tied to the shoulder as assumed in this experiment, but on the bilateral of the lower part of the shouldered axe. It is reasoned that the hafting position on the shouldered axe is moved down below the shoulder, may be related to excessive force took and easy breakage, when it used in combination with the handle. The shoulders may also be re-grinded after being damaged, and it is not necessarily the reason for the place of the cordage being lowered if it is not used on purpose. The judgement of the lower part of being used instead of shoulders on the artefact is that the surface of it shows no signs of the damage being re-grinded and covered by that polished traces. Besides, cross-regional comparison of the typological analysis of the shouldered axes shows that this is a rare type of the Indochina Peninsula. Rare seeing artefacts may have social or symbolic meanings, such as prestige goods for the promotion of one's social status, or an item for practising ritual ceremony. However, it is not excluded that they are so vulnerable to breakage to use rarely. In sum, the theory presented in this study that the shouldered axes as a unique artefact of the Yuanshan Culture, are not practical enough to be used any more is more rational.

Fig. 5-3 Shouldered axe of the Yuanshan site (NMP). (Photographed by Li-Chi Chiang)

This study suggests that the shouldered axe may be gradually eliminated by the Yuanshan cultural people due to lack of practicality, but there are also non-practical ideas for production purposes, such as currency imagery or ritual artefacts. There is a bronze axe of Yuanshan Culture discovered and resembled the bronze Yue which is the symbol of currency during the Warring States period of ancient China, dated to 500 -221 B.C. Matusmoto (1939) therefore speculates from the appearance similarity that there probably has a process of evolution of bronze Yue used as currency, which is developed from the shouldered axe to a metal shovel and later to a bronze Yue. The shouldered axe of Yuanshan Culture may be the prototype of the Chinese bronze currency during its evolution. Although the hypothesis of Matsumoto lacks the support of more evidence, it brings out the issue placed on the development of shouldered axe and bronze artefacts across the area from South China to the Southeast Asia peninsula. The amount of unearthed bronze materials from Taiwan during this period is insufficient and failed to provide further explanation on this issue because there is no any prehistoric culture characterised by the use of bronze in Taiwanese prehistory. If there are any bronze objects are ever excavated from the archaeological sites, it has to be something bringing by someone from outside of Taiwan. As a result, the origin of the bronze artefacts found in the Yuanshan Culture is a significant question that can be concerned and explored across regions. The currency idea given above is a theory used to illustrate the conceptual meaning of the shouldered tools may have. This study still focuses on the usage/function of the shouldered axes as an agricultural implement fundamentally.

During the rescue excavation project of the Pukou Site in central Taiwan in 2018, there are unearthed a shouldered axe along with a stone knife and a clay pot in the same layer for the first time (Fig. 5-4). The archaeological site is contained two prehistoric cultures, the lower layer is the Niumatou Culture traced to 4,500 B.P.-3,500 B.P., the upper layer is the Yingpu Culture dated between 3,500 B.P. and 2,000 B.P. The shouldered axe is found in the layer of the Niumatou Culture. The radiocarbon dating of all samples has not been fully completed and the analytical results of the data have not been interpreted thoroughly. Only one data of the completed experiment is shown the date is between 4,000 B.P. and 3,800 B.P. This data is the sample collected from the Niumatou Culture layer, according to the conversation with Dr Yen, the director of the Pukou Site excavation. In the light of the messages passing by Dr Yen, the raw material of this shouldered axe is andesite and the use wears on its exterior is visible evidently. On the basis of the unearthed assemblage of the artefacts and the traces of use, Dr Yen is convinced by the symbolic meanings of the shouldered axe as ritual goods for the agricultural activities possibly. Mainly because of the stone knife and pottery pot for the judgment of agricultural activities are found together with the shouldered axe in the same deposit layer. Such a small pot is commonly used as a container for storing the crop seeds, and the stone knife is associated with the rice harvesting works in traditional farming courses stated in the previous chapter. However, concerning the scientific analyses of all the archaeological materials discovered at the site has not been completed, as examples like the statistical analysis of artefacts classification, the examinations of the soil or on the stone knife and shouldered axe by applying the residue, use-wear and phytoliths analyses, etc. It is far from being the reliable evidence given to ascertain whether the contents and soil samples inside the pot well present the agricultural behaviour that may be produced at that time, nor even reflects suitably the practical function of the shouldered axe during its operation out of the question. The one and only material of found shouldered axe at the Pukou Site at present needs more archaeological evidence to support the interpretation of its symbolic concepts such as codes, rules, or beliefs. It is, therefore, holding a reservation on this symbolic explanation of the shouldered axe in this dissertation.

Fig.5-4 Ceramic Pot, Stone Knife and Andesite Shouldered Axe. (Photo offered by the Ancient Culture Ltd.)

Another find of olivine basalt shouldered axe unearthed from the Pukou Site can be extensively studied broadly in the temporal and spatial background (Fig. 5-5, left). This shouldered axe is similar in the typology to the one excavated from the Nangkuagli Site, code number NMP-STSP-SA-0044, which is kept in the branch of the National Museum of Prehistory in Tainan (Fig. 5-5, right). The specimen discovered at the Nankanli site is dated between 4,800 B.P. and 4,100B.P., existed in the late period of the Tapenkeng Culture. It is widely accepted by the Taiwanese archaeologists that the essence of the Niumatou cultural materials is evolved and transformed from the Tapenkeng culture (Kuo 2015, Lu 2017). Same as to the other two prehistoric cultures, they have inherited the material essence of the Tapenkeng Culture then developed separately in a different area. One is the Hsuntangpu culture in the north and another is Niuchozhi culture in the south. Sorting the cultural chronology of the Taiwanese prehistory, the Niumatou culture of the Pukou site in central Taiwan is later than the Tapenkeng culture of the Nankuanli site in southern Taiwan. Therefore, it can be assumed reasonably that the earliest time for the shouldered axe entry into Taiwan is about 4,800 B.P., the appearance of shouldered axe in prehistoric cultures can be seen in southern and central Taiwan at least around 4,000 B.P. Yet, it currently lacks of sufficient evidence that the Yuanshan Culture is evolved from the preceding cultures.

Additionally, the andesite shouldered axe borrowed from Dr Kuo, code number S-L56-00001, is uncovered from the Hsuntangpu Cultural layer of the Chihwuyuan Site and dated to 3,800-3,500B.P. in this study. The Yuanshan Culture with the largest number of the unearthed shouldered axe is later in the age of its existence and the sites are scattered in the north part of Taiwan. Judging from the chronological sequence and the distribution of sites of the shouldered axes found in the mentioned prehistoric cultures above regionally, the use/dispersal of the shouldered axe is progressively developing/moving from the south to the north in Taiwan. Another interesting phenomenon is that the shouldered axes of these prehistoric cultures are all made of igneous rocks. The choice of raw materials is expressly diverse regionally. The olivine basalt is used in the south, the andesite applied in the north instead. The reasons for this difference need to be continuously explored, such as the distance between the settlement and the quarries to procure, or the network of the rock supply to function regionally. This variability may suggest that the idea of the artefact moves either through or with the people that made them, rather than the artefacts themselves.

Observing two unearthed olivine basalt shouldered axes, the two prehistoric cultures of Tapenkeng and Niuchozhi use rocks procured from the Penghu Islands to make shouldered artefacts. The visible traces of mark on the objects are demonstrating a tendency of the practical usage toward a specific type of human behaviour. The wears above the shoulder are produced maybe by hafting with handle, the faint striations on both sides of the blade edge are probably caused by the soft-consuming motion. These two igneous shouldered objects are highly likely used as a hoe, just like the function of the andesite artefacts do display in this dissertation. Paradoxically enough, during the period of 4,800-3,800 B.P., the non-shouldered tools at various archaeological sites are unearthed more than shouldered ones, typical stone tools like axe or hoe. If the shouldered axe is used as a hoe, the unearthed number of objects is obviously insufficient to support a large amount of crop remains left in the site implied that the great dozens of the tools are required for agricultural activities, such as the Nankuanli Site. And the non-shouldered stone tools may reflect a different pattern of hafting practices.

The consequence of the foregoing discussions is consistent with the two inferences of this study: one is that the shoulders are not practical enough to last long whilst using, and the other is that the shoulder design is a cultural concept among the people who possessed and spread. This may imply that the non-practical significance of shouldered stone tools cannot be ruled out, just like Dr Yen theorised the function of the shouldered axe found in the Pukou site (Fig. 5-4). For that reason, it is necessary to conduct the same replicating experiment on the non-shouldered axe with the handle bound for hoeing, and the results will be compared with the outcomes of the shouldered ones. It is hoped to strengthen the hypothesis of the shouldered axe as a popular style of cultural concept in stone artefact production in the area, which is possibly prevalent in the time between 8,000BP and 2,000 BP.

Fig. 5-5 Olivine basalt shouldered axes. Left: Pukou Site (Photo offered by the Ancient Culture Ltd.). Right: Nakuangli Site. (Photographed by Li-Chi Chiang)

The last, the cleansing technique of the archaeological finds in the early days spoil the scientific methods which are required detection or extraction of the fine particles inside the artefacts or other organic samples. It is of course that the progress of the scientific methods will advance persistently, the obstacle of cleansing the artefacts overly in particular to the experiments based on the specimens contained the residue or the phytoliths in unknown extent, still has a chance led to the experimental analysis failed. It is also the case happened to apply the phytoliths analysis on two shouldered axes for speculating the objective condition when they were used, such as the environment or the object. The preliminary results of the phytoliths show that the two shouldered axes indeed have designated to specific use in a certain natural setting. Yet, it is failed to obtain the object predicted by the experimental goal: the phytoliths of rice.

There is a phytolith of weeds washed from the shouldered axe discovered instead. Weeds are generally considered to be the invasive plant in the farming systems by their proliferation and spread during the growth of crops and must be removed. According to the farming model of the slash-and-burn tradition of the Taiwanese aborigines recorded in the ethnography, which is a method applied by cutting down and burning the natural vegetation for releasing the nutrients to the agricultural land to plant the crops. After the harvesting completion of the crops, the second burning of the farmland is applied, and the weeds grow rapidly during this period. It is thereupon that the measure to protect agricultural production is to perform repeatedly weeding practices during crop growth. This study found a phytolith of weeds on the shouldered axe demonstrates that the usage of such implement as a hoe has another evidence: a weeding tool. This is also the record revealed in the ethnographic documents (Miyamoto 1939). Another supporting material of the shouldered axe as a weeding tool is provided by the pollen research of the paleoenvironment in the Taipei Basin. The given information by Tseng *et al.* (1999) shows that there are two short-term events of the Chenopodiaceae high concentration at 3,800 B.P. and 3,500 B.P. respectively. Tseng recommends that these events are most likely caused by the vegetation change of land because of the human reclamation to the cultivated fields. It is the traditional slash and burns farming systems that are capable of giving rise to a large-scale change of the vegetation of the farmland. These two time periods coincided with the age of the existence of two prehistoric cultures in the Taipei Basin: the Chihshanyen Culture with a discovery of a large amount of the rice remains, and the freshly germinated Yuanshan Culture.

Apart from the preserving condition factors that result in the rare plant remains left of the Yuanshan Culture, large-scale removal of surface weed vegetation and the environmental change of the land may also be a cause of the inability to cultivate the cereal crops, such as the slash and burn behaviour documented in the ethnographic archives. If so, compared to other prehistoric cultures, the shouldered axe emerges in this culture in large numbers perhaps because it is a tool for weeding. Whether it is for breaking up the soil or weeding, the chance of the usage of shouldered axe designed for a hoe is quite high. It is also worth noting that the ethnographic record only refers to the function of weeding without mentioning another typical application of the hoe for upturning or breaking the soil. Whether a shouldered axe is likely to be a single-purpose agronomic tool needs further clarification. It is thus, the verification of the shouldered axe as a weeding implement will also be the experimental archaeological work for the next stage.

Regarding the risk of the ethnographic parallels to the archaeological evidence on the aspect of the explanation requires the cross-referencing assessments. Ethnographic as a reference is sometimes the obstacle of research, for example, the contradiction occurred between different the records. The function of the stone knives for harvesting the rice crop has been discussed and verified by quite an amount of the studies in experimental archaeology (Ma *et al.* 2012, Li *et al.* 2013, Yang *et al.* 2014). The 17th century written Spanish document shows that the aborigines of southwestern Taiwan harvested rice with a knife-like tool during the Dutch period between 1624 and 1662. (Leonard Blussé 2010: 64). However, another portrays with the images and descriptions of the aborigine's livelihood demonstrates that they grasp and twist off the rice stalk by hands directly without any assistance of implements, which is clearly contradictory to the aforementioned literature (Liu-Shi-Qi 1998). The contradiction maybe causes by the discrepancy in the temporal and spatial, as in the background of author's or the ways in language use, even the change of the agricultural forms of the aborigines, etc. This study enriches the knowledge of the production and function on the traditional artefacts used by the Taiwanese aborigines through referencing the ethnographic archives as the ground on the discussion. It is required, consequently, to cross-check against the ethnographic documents over and over in order to be as close as to the real situation of a targeting tool, which the information gathered and judged possibly affected by the unknown extent of factors mentioned above.

The combination of ethnography and archaeological data can extend research topics like the reasons for the formation of the millet culture in the Taiwanese aborigine's society instead of the rice. Millet plays a predominant role in the traditional lives among all the groups of Taiwanese aborigines, which covers the dietary of food, social life, legendary taboo and ceremonial rites as examples. It can be said that the lives of aborigines surround the millet to performed, rice is almost ignored or not seen in the daily life of the aboriginal culture. The number of the plant remains unearthed in the archaeological sites increased after 1992 because of applying the flotation technique which the finer seeds can be screened more than ever. It is believed that the capacity of ancient people of the cultivation of the crops has commenced as early as the age around 5,000 B.P. in Taiwan (Tsang 2012). Among the remains of cereal crops, rice, millets and beans are the most commonly seen in the sites, which illustrates that these three plants are the dominated crops for planting in the prehistoric cultures in Taiwan. Rice cultivation given by the archaeological materials shows that it has been lasting for a long time since 5,000 B. P. and never been interrupted by any factors of changes. Millets, on the contrary, has experienced several reductions of production or disappeared totally. The number of millets found in the archaeological sites of the Southern Taiwan Science Park decreased evidently at the age about 3,300 B.P., for example, and completely die out and replaced by the rice after 1,400 B.P. (Tsang 2012, Tsang and Li 2013). The cause for the disappearance of the millets after the 1,400 B.P. and unseen in the archaeological sites is not clear presently. It may be that the millets have been spoiled in the unfavourable preserved soil environment in Taiwan, or that the archaeological excavation carries out in a small portion of a site, or that the fieldwork only aims to conduct the surface survey, all these results in the difficulty for finding the remains of millet. This phenomenon continued into the 17th century. The literature Dong Fan Ji also described that the Taiwanese aborigines had rice (upland rice) in their food, but no millets seen at all (Chou 2012). There is insufficient evidence to explore the relationship between millet and the shouldered axes, however, it is informative to study usage of the shouldered axe with the millet cultivation according to the research given above. So that this will the issue for studying the shouldered axes usage next stage.

Regarding the above discussion, it is clear that the millet cultivation has listed along with the rice for a long time in ancient Taiwan. But in the subsequent development, there have been cases of disappearance or interruption on planting. The view of the modern aboriginal millet culture tracing back to the source of 5,000 years ago needs further clarification. Nevertheless, rice cultivation has always existed in the prehistoric cultures of Taiwan without any disconnection. The tradition of modern aborigines resists rice into their lives may be the taboos related. For example, the Paiwans regard rice as an ominous thing for not being cultivated in their traditional land. Therefore, it is the grain crops like rice, corn and rhizome taro are planted mainly (Kuo 2003). Although this study has not effectively verified the direct connection between the shouldered axe and rice farming, it can extend the issue to the study of the rice varieties, cultivation techniques and crop sources or routes of dispersal. This is also the direction of development that will continue in the future.

2.2 Sources of the Yuanshan Culture

The discussion of the relationship between prehistoric humans and the environment, from the early environmental determinism, sociocultural determinism to the integration of two extreme theories and the emergence of new research orientations, the environment and human beings are intricately interrelated (Kalhofer 1996). Any change in one party will cause the other to make the corresponding change, and the two can be said to be co-evolution, the shifting agriculture model of Taiwanese aborigines as an example. It is not recommended that adaptive changes in patterns of causality in the linear or balanced model between prehistoric humans and the environment. On the contrary, environmental information can provide archaeologists to identify different strategies and value systems created in different local or regional ecosystems from different prehistoric cultural groups.

The landscape types of 26 locations obtained from 36 specimens with shoulder stones from 26 Chinese literature (Appendix 1) were found to be similar to the landscape of the Yuanshan cultural sites in northern Taiwan. The published literature shows that the use of these tools as the shouldered axe is in the half of total and found in the southern provinces of China. Eighteen shouldered axes are discovered at the shell mounds in particular in Guangdong Province where is considered to be one of the origins of shouldered technology. The Yuanshan Site is the shell mound in the landscape. Archaeological sites have found similarities in the living environment of shouldered artefacts, and it is a hypothesis to test that users who apply or develop these shouldered tools choose to settle down at a suitable location resemble their place of origin. The raw material of rocks selection is also common in igneous rocks and a small part of sedimentary rocks (such as sandstone), which is consistent with the ratio between the sandstone and the andesite selected by the Yuanshan cultural people.

A comparison of cultural sources on shouldered axe of the Yuanshan Culture and found in the other regions and periods within Taiwan, may provide the external factors to the discussion as references. Such as one shouldered axe of the northern Hsuntangpu Culture discovered at Chihwuyuan Site in this study and the other two unearthed in the Pukou Site of Niumatou Culture. Both cultures originated from the Tapenkeng Culture of being recognised as foreign culture outside of Taiwan and developed respectively and independently into distinctive systems of material and culture around the year between 4,500B.P. and 3,500 B.P. The essence in materials of the Yuanshan Culture is characterised by the production technology of Hsuntangpu Culture and the use of igneous rocks (Kuo 2014a). In other words, apart from its own characteristics as known, Yuanshan Culture develops continuously on the basis of the inheritance of Hsuntangpu Culture followed its foreign trace of the Tapenkeng Culture.

The shouldered axe is rather an accidental product of Yuanshan Culture than a unique artefact that brought by the external culture from other regions on the ground of the discussion mentioned above, which has a low extent of the durability, a small number in the total of lithic assemblages, only seen in the Yuanshan Culture, and resembled the Hsuntangpu Culture with the raw material of rock selection and its production technology, etc. On this account, it is required to review the proposed external culture argument of the Yuanshan Culture by the essence of its material culture. It is supposed that there was a large-scale migration of particular group population and brings their culture to north Taiwan and completely replaced the local ones during the time of the late Hsuntangpu Culture around *3,600 - 3,500*B.P. It is demonstrated by the study of the shouldered axe that the stone tools presented with shouldered or stepped as examples, is more appropriately consider that the distinctive styles on the artefacts of the Yuanshan Culture reflected as the external links or factors with culture from other regions. Rather is not the complete transplantation of the external culture into northern Taiwan. In view of this, it is the artefacts appeared the characteristics of foreign culture, instead of the concept that the Yuanshan Culture as a whole is an external culture. Which not the source of the Yuanshan Culture, in fact, should be traced, rather, the origin of the external features displayed on the artefacts of the Yuanshan Culture requires to be explored. Taking the specimen form of Group 9a in this study at Chapter 4-3 as example, the number of such type of shouldered axe is quite small about 1.23% of the total examined samples. Because of the particularity of this style, the factors that highlight the external connection are presented in the production style of the shoulder stone.

3. Recommendations for future

Due to time constraints, some of the recommendations that are not completed in this study may continue in the future for in-depth related issues.

3.1 Functional orientation experiment of the shoulder

The stone axe-hoes of the Yuanshan Culture are uncovered simultaneously with types of shouldered and non-shouldered, and the latter being more in the quantity. The presence of shouldered or non-shouldered, the convenience of using the handle, and the use efficiency of the utensils, are all subject to be measured the similarity or dissimilarity between two types. It is only the experiments on the usage of the shouldered axes bound with handles as a hoe, no non-shouldered one's performance tested. Therefore, the two types of comparative studies are necessary for intensive discussion to explore the presence or absence of shoulder function.

3.2 Research on the andesite quarry in Taiwan

Only sixteen out of 325 shouldered artefacts observed in this study were subjected to non-destructive trace elements examination by pXRF, and two of the results were highly correlated to the quarry of the Tatun Volcano Group. It is expected that the rest of the 309 specimens can be analyzed by applying pXRF for trace elements and comparing the analytical data with the given data from published literature in order to establish a data set of prehistoric andesite. At the same time, cross-validation with the andesite rock materials collected from the Tatun Volcano Group area and the east coast of Taiwan to verify and strengthen the inference of the andesite quarry of the Yuanshan Culture in this study. It is hoped that is the basis for the study on the raw material of andesite artefacts in prehistoric Taiwan.

3.3 Sharing research data

There are collections of excavation or surface collection of the shouldered axes kept currently in four museums for decades. The archaeological context of the related materials is not either accessible or verified easily, and it is far-fetched to gather more information on the clarification of the life history on an individual shouldered axe. Moreover, the archaeological excavation data is too dispersion, and there is no platform for integrating all resources, which are disadvantageous for interrelated study. On that account, all the materials of this study, including the analytical results of data, and the pictures and text descriptions of the shouldered axes, will be fed to these museums which loaned and helped to the shouldered axes for this research. All will be disclosured to the public, and it is hoped that researchers can reference these details for advanced study of the shouldered axe or other stone tools in the future.

3.4 The establishment, accumulation and sharing of database

3.4.1 Shouldered axe

Concentrate and synthesise on the topic of the shouldered axe research that is scattered across the units and set up a dedicated platform through the digitisation process to preserve the information at large. So that the relevant data can be effectively used to facilitate the delicate study step wisely. Secondly, it would promote the professionalism of regional research on the shouldered axe and open up an entry point for exploring and understanding the prehistoric culture and the stoneware's research in Taiwan.

3.4.2 Traces of usage on the shouldered axe

The functional analysis of stone tools study, the classification of uses is an essential basis, and different classification criteria can explain different aspects of the usage of stone objects. In this study, take the advantage of the use-wear analysis outcomes of the shouldered axe as the basis for classifying the "production technique" and the "use motion", which are contained the practising modes like the producing traces or using marks, digging or cutting. Through the surface marks observation, it can be inferred how the shoulder is made and the probable performance of the shouldered axe. Accordingly, the analysis results describe not only the actions and objects corresponding to the stone tools, but also determine the human behaviour displayed by the meaning of the classification through the observation results of use-wear. The traces of use-wear on stoneware traditionally refers to the appearance of several identifiable features of the archaeological artefacts after employing, such as the edge rounding, polishing or various types of striations. The shoulder-making traces of this study obviously appear in the grinding or breaking of specific parts on the shouldered object only. The database, thereupon, is built for the special traces of the specific artefacts like a shouldered axe, and the results of the experimental archaeological works are combined in order to effectively assist the researcher in discriminating the meaning of human behaviour demonstrated by the surface traces on the object.

3.4.3. Collecting the ancient rice materials of China and Southeast Asia

Accumulate and collect information on prehistoric rice unearthed from sites in Taiwan, China and Southeast Asia. In this study, only the open-access or associated information of ancient rice in Taiwan are sorted out briefly, and the archaeological context of ancient rice is unable to proceed due to the limitation on the time and the inaccessibility of those archaeological data. Therefore, new archaeological materials will continue to be concerned. Focusing on and collecting new archaeological materials of uncovered rice will be an ongoing task. During the research, it is also noted that the plant remains data in the eastern part of Taiwan is relatively insufficient. Except for the rice remains excavated from the archaeological sites which are undisclosed or small in the number left over for conducting the phytoliths analysis inspection as one of the reasons, another is that not many researchers are involved with such topic either. At present, only those who have resources can be expected to disclose the ancient rice materials and look forward to more researchers investing in such work in the eastern region of Taiwan.

In the early days, prehistoric agriculture research in Taiwan constantly focused on the origin and spread of cultivated rice and/or millets, mainly on the prehistoric trade and exchange, population mobility and culture diffusion between Taiwan and China. It is worth noting that, during sorting out these excavated rice materials, the rice varieties are different in various parts of Taiwan. The Indica rice is concentrated in the southeast and south, and the japonica rice is dominant in the central and north. The distribution of ancient rice species in Taiwan may represent different sources of prehistoric human interaction between the regions of north and south. For example, the prehistoric culture of northern Taiwan has more connections with China, and the south instead is closer to that of Southeast Asia. It is ration that the geographical proximity offers ties on the rice trade and exchange in a different area in prehistory respectively, the central and north of Taiwan links to China, south part of Taiwan relates to Southeast Asia. Consequently, there is necessary to gather as much information as possible on the topic of the prehistoric rice from China and Southeast Asia in the future to be further confirmed and clarified the factors that may cause the distribution phenomenon as the archaeological evidence presented.

3.4.4. Collecting and comparing existing plants to archaeological plant remains in Taiwan

The basis of phytoliths analysis is the comparison and identification of prehistoric plant remains to the current existing plants, which the sound base database will increase the speed of analysis and the effectiveness of results. There are many published pieces of literature and databases of the existing plants in Taiwan and the rest of the world that can be utilised conveniently for comparison and reference if needed. The plant remains unconverted in the archaeological sites yet to be established in Taiwan. At present, the data of the phytoliths citrate is only collected progressively by individual colleagues for their own research or teaching purpose, and there is no real shared database for others to use openly. Therefore, concentrate and merge the phytoliths data collected by Taiwanese archaeologists, and expand the types of the gramineous plant citrate will be the first task to be dealt with in the future. The study of phytoliths in rice (both ancient and modern) is more than that of millets. In addition to rice, the development of phytoliths examination in ancient millet is also important for the study of prehistoric cultivated crops in Taiwan. It is a pity that the phytoliths in unearthed have not been able to effectively find a recognisable shape for breakthrough progress so far. This should be an aspect which needs more efforts and devoted in the future. Adjustment of the experimental steps or upgrade of the scientific technique applied to the phytoliths analysis may be effective in improving and moving forward to the research of phytoliths in millets in the future.

3.5 Cross-regional comprehensive research

The shouldered axes can be seen diffusely from the Asian continent to Southeast Asia, yet it is far beyond the capability to access and inspect all of the shouldered unearthed in various places can be direct. In order to observe the exterior marks and the morphological pattern of the shouldered axe by employing the low power magnification of the digital microscope, there are exclusively the Taiwanese shouldered axes selected for this study. The shouldered axes of other places in the region can only try to collect as much information as possible from published literature for not being able to examine the trace marks or measure for functional and morphological analysis of artefacts in direct. The cross-regional research on the similarities and divergence of the shouldered axe yet to be resolved, such as the characteristics presented respectively in each individual prehistoric culture on the typological and technological method on the shouldered axe production, or the consistency or differentiation of the features manifested on the function/usage of the shouldered axe. The study can combine with other subsistence instruments for understanding the role of the shouldered axe played in the whole assemblages of the stone materials, stone adze as an example, which are generally accompanied and unearthed in the cultural layer with the shouldered axe. It would be helped to seek the real usage of the shouldered axe by excluding the function of an individual utensil which is reviewed and recognised.

Province	Site	Raw Materials	Processing Methods	Landscape	Length (cm)	Usage	Reference
Heilongjiang	Yinggeling（鶯歌嶺）		chipped	Small hill	14.5	Hoe	Provincial Team of Cultural Relics and Archaeology. *Archaeology*, Vol.6 (1980):481-491.
					18	Hoe	
Shandong	Longmenkou（龍門口）		polished		19.4	Axe	TaiAn shi Bowuguan. *Cultural Relics*, Vol.12 (2004):4-12.
Shanxi	Dongxiafeng（東下馮）		chipped	tableland	17.8	Shovel	Xu *et al. Archaeology*, Vol.2 (1980): 97-107.
Shanxi	Taosi（陶寺）		polished	Small hill		Shovel	Gao and Zhang. *Archaeology*, Vol.1 (1980):18-31.
			polished		4.2	Shovel	
			polished		12.4	Shovel	
Shaanxi	Zhangjiaba（張家垻）	Gravel	chipped and polished	Small hill		hoe	Li. *Archaeology*, Vol.6 (1983):484-488, 495.
Henan	Gushuihe（谷水河）			tableland		Shovel	Lou Yang Archaeological Team of IA, CASS.
				tableland		Shovel	

							Archaeology, Vol.1 (1978):23-34, 80-81.
Henan	Gushuihe （谷水河）		polished	tableland	14	Shovel	The Henan Provincial Museum. Archaeology, Vol.4 (1979):300-307.
Henan	Peiligang （裴李崗）		chipped	Small hill	15.3	Shovel	Wen guan hui of Kaifeng and Xin zheng. *Archaeology*, Vol.2 (1978):73-79, 145-146.
Inner Mongolia	Baiyinchanghan （白音長汗）		polished		18.6	Another kind of shovel(耜)	Neimenggu wenwu kaogu yanjiusuo and Jilin University. *Cultural Relics*, Vol.1 (2002):4-26.
Inner Mongolia	Dongshanzui （東山咀）	Sandstone/Basalt/Diorite		Small hill	10	Shovel	Li et al. *Archaeology*, Vol.5 (1983):420-429, 484.
		Sandstone/Basalt/Diorite		Small hill	14.5	Hoe	
		Sandstone/Basalt/Diorite	polished	Small hill	14.2	hoe	
Hubei	Caojialou	Gravel	polished	tableland	12.6	Axe	Archaeological Section,

	（曹嘉樓）						Department of History, Wuhan University, and Xiangfan Municipal Museum and Yicheng County Museum, Hubei Province. *Acta Archaeological Sinica*, Vol.1 (1988):51-73.
Hunan	Zhengxikou（征溪口）	Metasandstone	chipped and polished	Shell mound	7.5	Adze	Institute of archaeology of Hunan province. *Cultural Relics*, Vol.6 (2001):17-27.
Jiangsu	Sanxingcun（三星村）	Pebble grain/Gravel	polished		8.8	Axe	Joint archaeological team at Sanxingcun. *Cultural Relics*, Vol.2 (2004):4-26.
Jiangsu	Guangfucun（廣福村）		polished	Small hill	10.8	Axe	Suzhou Bowuguan, WU Jiangshi wenwu chenlieshi. *Cultural Relics*, Vol.3 (2001):41-51.
Jiangsu	Yuecheng（越城）	Gray Shale	chipped	Small hill	14.4	Axe	Wang and Li. *Archaeology*, Vol.5 (1982):463-473, 561-
		Gabbro	chipped		17.8	Axe	

							564.
Zhejiang	Sunjiashan （孫家山）	Shale/Breccia/ Gravel	chipped?			Axe	Wang and Chen. *Archaeology,* Vol.1 (1983):4-9.
Zhejiang	Tangjiadun （唐家墩）	Metamorphic/ Igneous Rock	polished		20.7	Axe	Wang. *SU Zhoubowuguan, WU Jiangshiwenwuchenlieshi* Vol.1(1984):86-87.
		Metamorphic/ Igneous Rock	polished		16	Axe	
Jiangxi	Wucheng （吳城）		fine polished	Small hill	5.6	Shovel	Jiangxi wenwu kaogu yanjiusuo and Zhangshu Museum. *Reports of the archaeological excavation in Wucheng*. 2005, pp.124-125.
Guangdong	Xiqiaoshan （西樵山）	Felsitic/Flint/C hert	polished	Small hill		Axe	Huang *et al., Archaeology*, Vol.4 (1979):289-299.
Guangdong	Jinyen （錦岩）	Felsitic/Flint/C hert	chipped	Small hill		Shouldered Axe	He. *Archaeology,* Vol.12 (1983):1085-1091.
Guangdong	Zhentou （鎮頭）	Felsitic/Flint/C hert	chipped	Shell mound		Shouldered Axe	

Guangdong	Zaogang（灶崗）	Felsitic	polished	Shell mound	8.6	Shouldered Axe	Chen and He. *Archaeology*, Vol.3 (1984):203-212.
Guangxi	Xiangshui（響水）	Sandstone/Silicolites/Flint/Chert	polished	tableland	6.6	Axe	Huang and Chen. *Arhcaeology*, Vol.7 (1983):577-583.
Guangxi	Duliao（獨料）	Limestone	chipped	Small hill	9.2	Axe	Yu and Fang. *Archaeology*, Vol.1 (1982):1-8.
Guangxi	Dalongtan（大龍潭）	Slate/Shale/Sandstone/Argillite	polished	Small hill	15.5	Shovel	Chen *et al.*, *Archaeology*, Vol.1 (1982):9-17, 113-115.
Yunan	Tuguoshan（土鍋山）	Gravel	chipped	tableland	13.1	Axe	Geng. *Southeast Culture*, Vol.1 (1991):191-199.
Yunan	Xiaohedong（小河洞）	Dark Green Basalt	polished	cave	5	Axe	Zhang and Qiu. *Archaeology*, Vol.12 (1983):1108-1111.
		Gray Siliceous Metamorphic	polished		4.8	Axe	

Table 5-1. Database of Chinese Shouldered Stone Tools.

36 shouldered stone samples of 26 sites from 26 Chinese Literatures.

- Raw material: unknown (14), identified (9), general information (12)

  (It seems like the raw materials of shouldered stone samples obtained locally)

- Processing methods: unknown (4), polished (19), chipped (10 samples, 1 sample with highly suspicious), chipped and polished (2)
- Landscape of sites: unknown (6), shell mound (3), cave (2), small hill (18) or tableland (7) with rivers around (25 in sum)
- Given length from 28 samples: between 4.2cm to 20.7cm
- Blade section: edge unknown (23), sided edged (2), biface (11)
- Usage: hoe (5), axe (15), shouldered axe (3), shovel (12), adze (1)

Chapter 6_QUESTIONS

Firstly, the chronological data yielded from the C^{14} examinations of the Yuanshan Culture in north Taiwan is collated and modelled in order to discuss the regional development process of Yuanshan Culture. This chronological modelling can be used to clarify whether the Yuanshan Culture has been widely distributed in the Taipei Basin from the beginning or expanded slowly from the coastal area to the inland region. If the former, it reflects that the development of the Yuanshan Culture is presumably influenced by a foreign culture, or indeed a foreign culture which is possibly originated from the South or Southeast Coastal area of China. Additionally, with the help from the geographical analysis of the archaeological sites where unearthed the shouldered axe, including the sites in Taiwan and China, this may expand the comprehension of the characteristics of the location chosen by the people who utilised the shouldered axe.. Also, it achieves the speculation on the use environment of the shouldered tools, even the preference on the raw material of rock selection. It will offer relatively in-depth information about the prehistoric human activities within the region.

The people of the Yuanshan Culture appear at the inland of the Taipei Basin from the beginning and spread rapidly across northern Taiwan. The settlement location is chosen mainly at or near both side of river banks and the area along with the coastlines in north Taiwan. The ecological environment of these sites is liveable and sufficient with resources like water and food, which is a suitable place for hunting and gathering, even the crops cultivation. The rock formations in northern Taiwan are rich in igneous and sedimentary rocks, which are associated with the properties of the stoneware materials selected by the people of the Yuanshan Culture. The maturity in term of the material production technology of the Yuanshan Culture and no similarity prehistoric culture in the neighbouring area demonstrate that the Yuanshan Culture has evolved by succeeding the local tradition and emerging out of it under the affection of the foreign factors. It is suggested that the external factors of the Yuanshan Culture may link to the prehistoric culture that existed in the coastal area of South China around the same time by comparing the pieces of literature mentioned previously in the study that can be accessed.

Secondly, the results of this study had further the regional study of the shouldered tools and agriculture development to a new perspective. Most studies on the function and usage of the shouldered axe, which are widely discovered in numbers in the agricultural areas of Taiwan, South China and Southeast Asia during the Neolithic age, are mainly floored on the morphological classification. It is recommended that the usage of the shouldered implements is associated with the agricultural or wood-working activities, e.g. hoeing, chopping or cutting. This project demonstrates the probability of the shouldered axe as a farming implement for the function of a hoe or weeding tool and the environment of crops cultivation in the region by the application of the experimental archaeology and the phytoliths analysis.

The replicating experimental results answer the method of producing the shouldered axe and its shoulders and reveal the practicality and functional deficiency of the shoulders on practising as a hoe by hafting with wooden handle in two modes. Such deficiency in function and practice implies that the shouldered axe may not be entirely use as a farming tool. It is reasonable to utilise the shouldered axe as a farming tool for agricultural activities. The gramineous plants are the primary objects the shouldered axe performed to. The usage in particular maybe is both of a hoe, or the weeding tool referencing from the ethnographic archives.

Thirdly, the shoulder production technique on the shouldered axes has not been systematically studied yet. In this research, the application of the microwear observation is made a point on the arc-shaped mark as a manufacturing method on several Taiwanese shouldered artefacts for the first time. Such traces appear in certain quantities of shouldered axes; it can provide a new discussion for the production technique and the usage on the shoulder. Simultaneously, the regional study of shouldered artefacts in Taiwan, South China and Southeast Asia will benefit from this study on the shouldered technology as a reference for the shouldered axe research on both typology and production technology locally. The diversity in the morphological classification of the shouldered axe may be correlated to the variability of the shoulder forms, rather than the function of use. The number of shouldered axes unearthed from Taiwan's prehistoric sites is relatively small compared to other stone implements, and it is classified into axes, hoes and shovel in form and application as before. Because the usage/function of the shouldered axes may a multiple used, rather as a farming tool for the crops cultivation only. Making use of the morphological features of the shoulder as the classification foundation which can be employed systematically, would be served to gradually integrate each piece of the research material about the shouldered axe into a knowledge system of the shouldered artefacts regionally. Such a knowledge system can provide an opportunity to exchange ideas on various topics such as the evolution of the production process of the shouldered axe, the identification of the usage or function, and the divergence in the prehistoric material culture between regions.

Alternatively, the application of the use-wear analysis to observe the surface of the igneous rock that is easily weathered has an obvious difficulty currently. It is thus that the lithic study on the topics of the usage ground on the micro-traces needs to be combined with other scientific analytical techniques and experimental archaeological works in order to achieve the functional interpretation more accurately. Such as applying the Polyvinyl siloxane (PVS) impressions to record the surface details of the shouldered axe at high resolution of optical microscope.

At last, the experimental archaeology and the phytoliths analysis are used on the Taiwanese shouldered axes accordance with the ethnographic archives about the agricultural tools for daily use by the aborigines for the first time, to assess the argument of the shouldered object as a hoe for a farming activity in the late Neolithic Age. This will establish a new and feasible research method for the lithic study in Taiwan. The request of ethnographic material also needs to be cross-matching and consider the possible limitations in order to obtain the accurate or relatively precise description and drawing at the functional use of the artefact. So as to avoid inadvertently falling into speculative errors on the explanation of the usage or function of a certain tool.

BIBLIOGRAPHY

Adams, Jenny L.

2013 Ground stone analysis: a technological approach. Salt Lake City UT: University of Utah Press.

2014 Ground stone use-wear analysis: a review of terminology and experimental archaeology. Journal of Archaeological Science 48:129-138.

Aitken, M. J.

1999 Archaeological dating using physical phenomena. Reports on Progress in Physics 62(9):1333-1376.

Akoshima, Kaoru

2000 Use wear of stone tools]. Tokyo, Japan: New Science Co., Ltd.

2010 Lithic use-wear analysis: Method and theory now and then. In The 15th International Symposium: Suyanggae and Her Neighbours. Pp. 56-62. Danyang Country Office, Korea: Institute of Korean Prehistory.

Akoshima, Kaoru and Yoshitaka Kanomata

2015 Technological organization and lithic microwear analysis: An alternative methodology. Journal of Anthropological Archaeology 38:17-24.

Aldana Y. V.; Gerardo

2016 ^{14}C and Maya Long Count dates: using Bayesian modeling to develop robust site chronologies. Archaeometry 58(5): 863-880.

Albert, Rosa M.; Jose A. Ruíz and Andreu Sans

2016 ^{14}C PhytCore ODB: A new tool to improve efficiency in the management and exchange of information on phytoliths. Journal of Archaeological Science 68(5): 98-105.

Allaby, Michael

2013 A Dictionary of Geology and Earth Sciences (Fourth ed.). Oxford University Press.

Alves, E.Q.; Kita Macario; Philippa Ascough and C. Bronk Ramsey

2018 The Worldwide Marine Radiocarbon Reservoir Effect: Definitions, Mechanisms, and Prospects. Reviews of Geophysics 56(1): 279-305.

Andrefsky, William Jr.

2005 Lithics: Macroscopic Approaches to Analysis. Cambridge University Press.

2012 Lithic Technology Measures of Production, Use and Curation. Cambridge University Press.

Aoyagi, Yoji; Melchor L. Aguilera, Jr.; Hidefumi Ogawa; Kazuhiko Tanaka

1993 Excavation of Hill Top Site, Magapit Shell Midden in Lal-lo Shell Middens, Northern Luzon, Philippines. Man and Culture in Oceania 9:127-155.

Asio, Victor B. and Zueng-Sang Chen

1998 Study of Andesite Weathering in Northern Taiwan Using Micromophological Approaches. Taiwan Journal of Forest Science 13(4):259-269.

Ascough, P. L.; G.T. Cook; A.J. Dugmore; E.M. Scott

2007 The North Atlantic marine reservoir effect in the Early Holocene: implications for defining and understanding MRE values. Nuclear Instruments and Methods in Physics Research B 259: 438-447.

Ball, T.B.; AnnaLisa Davis' Rand R. Evett; Jammi L. Ladwig; Monica Tromp; Welmoed A. Out and Marta Portillo

2016 Morphometric analysis of phytoliths: recommendations towards standardization from the International Committee for Phytolith Morphometrics. Journal of Archaeological Science 68: 106-111.

Barnes, Alfred S.

1932 Modes of prehension of some forms of Upper Paleolithic implements. Proceedings of the Prehistoric Society of East Anglia 7(1):43-56.

Bayliss, Alex

2015 Quality in Bayesian chronological models in archaeology. World Archaeology 47(4):677-700.

Bayliss, Alex; Gerry McCormac and Hans van der Plicht

2004 An illustrated guide to measuring radiocarbon from archaeological samples. Physics Education 39(2):1-8.

Bell, M.

2009 Experimental archaeology: changing science agendas and perceptual perspectives. In Land and People: Papers in Memory of John G. Evans. M.J. Allen; N. Sharples and T. O'Connor (eds.). Pp. 31-45. Oxbow, Oxford.

Bellwood, Peter

1985 Prehistory of the Indo-Malaysian Archipelago First Edition Sydney: Academic Press.

1988 A hypothesis for Austronesian origins. Asian Perspectives 26(1):107-117.

1997 Prehistory of the Indo-Malaysian Archipelago Revised Edition Honolulu: University of Hawai'i Press.

2000 Formosan prehistory and Austronesian dispersal. Austronesian Taiwan, David Blundell (ed.), pp.337-365. Berkeley CA: Phoebe A. Hearst Museum of Anthropology.

2008 Archaeology and the origins of language families. In Handbook of Archaeological Theories, R. A. Bentley, H. D. G. Maschner and C. Chippindale (eds.). Pp. 225-244. Lanham: Altamira Press.

Bellwood, Peter and E. Dizon

2005 The Batanes archaeological project and the 'Out of Taiwan' hypothesis for Austronesian dispersal. Journal of Austronesian Studies 1(1): 1-33.

Bellwood, Peter; G. Chambers, M. Ross and H. C. Hung

2011 Are 'cultures' inherited? Multidisciplinary perspectives on the origins and migrations of Austronesian-speaking peoples prior to 1000 BC. In Investigating Archaeological Cultures: Material Culture, Variability and Transmission, B. Roberts and M. Linden (eds.). Pp. 321-354. Dordrecht: Springer.

Bellwood, Peter, Hsiao-Chun, Hung, Yoshiyuki Iizuka

2011 Taiwan Jade in the Philippines: 3,000 Years of Trade and Long-distance Interaction. In Benitez-Johannof, Purissima ed. *Paths of Origins: The Austronesian Heritage*. ArtpostAsia Pte Ltd. Pp. 30–41.

Banerjia, Rowena Y.; Martin Bell; Wendy Matthews and Alex Brown

2015 Applications of micromorphology to understanding activity areas and site formation processes in experimental hut floors. Archaeological and Anthropological Sciences, Vol.7(1): 89-112.

Boer-Mah, Tessa

2008 Reduction and Adze Form: ground stone adzes from Ban Non Wat, Northeast Thailand. Journal of Indo-Pacific Archaeology 28 (Proceedings of the 18th Congress of the Indo-Pacific Prehistory Association, Manila, Philippines, 20 to 26 March 2006):44-51.

Bonizzoni, Letizia; Anna Galli; Marco Gondola and Marco Martini

2013 Comparison between XRF, TXRF, and PXRF analyses for provenance classification of archaeological bricks. X-Ray Spectrometry 42:262-267.

Borao Mateo, José Eugenio

2001 *Spaniards in Taiwan*, Vol. I (1582-1641). Taipei, Taiwan: SMC Publishing Ltd.

2002 *Spaniards in Taiwan*, Vol II (1642-1682). Taipei, Taiwan: SMC Publishing Ltd.

Bronk Ramsey, Christopher

1998 Probability and dating. Radiocarbon 40(1):461-474.

2009 Bayesian analysis of radiocarbon dates. Radiocarbon 5(1):337-360.

Bronk Ramsey, Christopher and Sharen Lee

2013 Recent and Planned Developments of the Program OxCal. Radiocarbon 55(2-3):720-730.

Buck, Caitlin E.

2015 On being a good Bayesian. World Archaeology 47(4):567-584.

Buck, Caitlin E.; W.G. Cavanaugh and C.D. Litton

1996 Bayesian approach to interpreting archaeological data. Chichester: Wiley.

Buck, Caitlin E.; J. Andrés Christen and Gary N. James

1999 BCal: an on-line Bayesian radiocarbon calibration tool. Internet Archaeology 7. Available at https://doi.org/10.11141/ia.7.1

Bureau of Cultural Heritage, Ministry of Culture

2006 Official Document of Bureau of Cultural Heritage No. 09500017951. Available at https://nchdb.boch.gov.tw/assets/overview/archaeologicalSite/20060501000002

Burley, David V.; Peter J. Sheppard and Maia Simonin

2011 Tongan and Samoan volcanic glass: pXRF analysis and implications for constructs of ancestral Polynesian society. Journal of Archaeological Science 38 (10):2625-2632.

Cai, Yen

2015 On the Development of the Taiwan Aboriginal Culture in the Light of the Geographical Changes of the Prehistoric Settlements Discovered There. Huaxia Archaeology, No.2: 68-78.

Central Weather Bureau, Taiwan

2016 GPS satellite geodetic survey. Available at https://www.cwb.gov.tw/V8/E/W/OBS_Sat.html

Chan, Su-Chuan

1995 The Being and Becoming of Ethnic Group History Studies: The Case of P'ingpu Studies. New History 6(4):127-163.

Chang, Chai-chuan (ed.)

1999 The history of Taiwan's rice farming. Council of Agriculture, Executive Yuan. Taipei, Taiwan.

Chang, Chung-Te, Hsueh-Ching Wang and Cho-ying Huang

2013 Impacts of vegetation onset time on the net primary productivity in a mountainous island in Pacific Asia. Environmental Research Letters, 8 (2013) 045030 (11pp). IOP Publishing.

Chang, Kwang-chih

1954 Contribution of the Yuanshan Site excavation to the prehisotric study in Taiwan. The Continent Magazine, Vol.9, No. 2, pp. 4-9.

1956 A brief Survey of the Archaeology of Formosa. Southwestern Journal of Anthropology 12: 371-386.

1957 A human tooth unearthed from the Yuanshan Site. Journal of Archaeology and Anthropology [Bulletin of the Department of Anthropology], No. 9/10:146-148.

1959 A working hypothesis of the early cultural history of South China. Bulletin of the Institute of Ethnology No.7: 43-104. Taipei: Institute of Ethnology, Academia Sinica.

1969 Fengpitou, Tapenkeng and the Prehistory of Taiwan. 73 vols. Volume Yale University Publications in Anthropology. New Haven: Yale University Press.

1970 Prehistoric culture of south China. Bulletin of the Institute of History and Philology Academia Sinica, vol.42, part1, pp. 143-178. Taipei, Taiwan: Academia Sinica.

1981 The affluent foragers in the coastal areas of China: Extrapolation from evidence on the transition to agriculture. Senri Ethnolonical Studies 9 (Affluent Foragers: Pacific Coasts East and West):177-186.

1986 The Archaeology of Ancient China (4th edition) New Haven, Yale University Press.

1987 Archaeology on the Southeast Coast of China and the Issues of the Austronesian Origin. Southern Ethnology and Archaeology 1:1-14.

1988 Classification in Archaeology. Six Seminars in Archeaology. Pp. 63-74. Taipei: Dawshiang Publishign Co. Ltd.

1989 Taiwan Strait in the Neolithic Age. Archaeology 6:541-550,569.

Chang, Kwang-chih; Ward H. Goodenough

1996 Archaeology of southeastern China and its bearing on the Austronesian homeland. In Prehistoric Settlement of the Pacific. W.H. Goodenough, ed. Pp. 36-56. Transactions of the American Philosophical Society. Philadelphia: Ameican Philosophical Society.

Chang, Kwang-chih; Minze Stuiver

1966 Recent Advances in the Prehistoric Archaeology of Formosa. Proceedings of the National Academy of Sciences, Vol.4, No.3, pp. 539-543.

Chang, Kwang-chih; Wen-hsun Sung

1966 Errata in the “Chronology of the Yuan-Shan Culture”. Journal of Archaeology and Anthropology [Bulletin of the Department of Anthropology] 27:36.

Chang, Mao-Don; Ju-Chin Chen

1979 Geochemistry of Andesites from Kueishantao. Acta Oceanographica Taiwanica - Science Reports of the National Taiwan University 9:39-49.

Chao, Chin-yung

2004 Preliminary Report of Shia-tien-tzu Site and Its Significance to the Study of Chilin Phase in the Eastern Coast of Taiwan. Field Archaeology of Taiwan, 8(1/2):45-93.

2015 Early glass beads in prehistoric Taiwan and their significance in the Southeast Asia. Paper presented at the conference ‘Taiwan Maritime Landscapes from Neolithic to Early Modern Times: Cross-Regional Perspectives’, 18 November 2015, Paris.

Chao, Chin-yung; Yi-chang Liu and Kuo-feng Chung

2013 On "Upper Huakangshan Culture": A Proposal. Field Archaeology of

Taiwan, 16(2):53-79.

Charalambous, Andreas; Vasiliki Kassianidou and George Papasavvas

2014 A compositional study of Cypriot bronzes dating to the Early Iron Age using portable X-ray fluorescence spectrometry (pXRF). Journal of Archaeological Science 46:205-216.

Chen, Cheng-Siang

1993 A Geography of Taiwan. Taipei: SMC Publishing Inc.

Chen, Chung-yu

1994 Preliminary Report of the 3rd Excavation in the Tutikungshan Site – MRT Tucheng Line. Institute of History and Philology, Academia Sinica.

Chen, Ju-Chin and Fei-Jan Lin

1982 Chemical Characteristics of Andesites from Taiwan. Acta Geologica Taiwanica - Science Reports of the National Taiwan University 13:1-11.

Chen, Kwang-tzuu

2000a On Taiwan Mammalian Faunas in Different Periods of Time and Related Problems: The Background Materials for Taiwan Zooarchaeological Studies: I. Bulletin of the Institute of History and Philology Academia Sinica, vol.71, part1, pp. 129-198. Taipei, Taiwan: Academia Sinica.

2000b On Taiwan Mammalian Faunas in Different Periods of Time and Related Problems: The Background Materials for Taiwan Zooarchaeological Studies: II. Bulletin of the Institute of History and Philology Academia Sinica, vol.71, part2, pp. 367-457. Taipei, Taiwan: Academia Sinica.

Chen, Kwang-tzuu; Li-Chi Chiang and Shin-mei Lin

2010 The Follow-up Study of Shihsanhang Site: bronze technology. New Taipei City, Taiwan: Shihsanhang Museum of Archaeology.

Chen, Na

2006 The Analysis on the Double-shoulder Stoneware in Southwest China, School of History and Culture(Tourism), Sichuan University.

Chen, Pei-Yuan

2008 Geology of Taiwan. Taipei, Taiwan: Professional Association of Applied Geologist.

Chen, Shu-jun

1852 Kavalan Ting Zhi (History of Kavalan Perfecture). Nantou: Taiwan Historica.

Chen, Teh-jen

2001 PreliminaryInvestigation Report of the Huweishan Prehistoric Site in Sanxia. New Taipei City: Sansia Junior High School.

Chen, Teh-jen; Su-chiu Kuo

2004 Report of the Archaeological Material Collection and Research Plan for the Chihwuyuan Site, Taipei. New Taipei City: Sansia Junior High School.

Chen, Wen-Shan

1997 Rocks for Beginners. Taipei: Yuan-Liou Publishing Co. Ltd.

Chen, Wen-Shan, Chih-Cheng Yang, Hsiao-Chin Yang, Jin-King Liu, Yu-Chang Chan, Kae-Shyuan Shieh, Yu-Chung Hsieh

2007 Scenning Laser Mapping (2M×2M DTM) Of The Pleistocene Tatun Volcanic Landform. Special Publication of the Central Geological Survey, No.20, pp. 101-128. Taipei: Central Geological Survey, MOEA.

Chen, Yu-mei

1980 Dahu prehistoric relic of Kaohsiung County (Unpublished). Department of Anthropology, National Taiwan University.

1996 Cultural Contact and Material Culture Change: An Ethnoarchaeological Example from the Yami, Orchid Island, Taiwan. Bulletin of IHP Vol.67, Part 2., pp.415-444. Taipei, Taiwan: Institute of History and Philology, Academia Sinica.

Chen, Yu-Pei

2016 Examining the Significance of the Foreign Artefacts Excavated at Kiwulan. Archaeology, History and Indigenous Peoples New Perspectives on the Ethnic Relations of Taiwan, Li-wan Hung (ed.), pp. 165-194. Taipei: Shung Ye Museum of Formosan Aborigines.

Chen, Yu-Pei

2017 Report of the rescue excavation for the construction of Huakangshan Elderly Hall. Taipei, Taiwan: Department of Anthropology, National Taiwan University.

Chen, Zen-Hwa, Wen-Shan Chen, Yuan Wang and Mien-Ming Chen

1992 Petrographical Study of Foreland Sandstones and Its Relation to Unroofing History of the Fold-Thrust Belt in Central Taiwan. Ti-Chih, Vol. 12, No.2, pp. 147-165.

Chen, Zueng-Sang and Zeng-Yei Hseu

2002 Taiwan's Soil. Taipei: Walkers Culture Publisher.

Chiang, Shu-Sheng

2011 De Dagregisters van het Kasteel Zeelandia 1629-1662, VOC. Tainan, Taiwan: Cultural Affairs Bureau, Tainan City Government.

Childe, V. Gordon

1929 The Danube in Prehistory. Pp. 5-6. Oxford: Oxford University Press.

Chiu, Chyi-Rong, Yu-Chi Liang, Yen-Jen Lai and Ming-Yuan Huang

2004 A Study of Delineation and Application of the Climatic Zones in Taiwan. Journal of Taiwan Geographic Information Science (1): 41-62.

Chiu, Scarlett

2012 The way of doing things: what Lapita pottery can tell us about the stories of Austronesian expansion. The Journal of Austronesian Studies 3(1): 1-25.

Chiu, Shui-jin

2010 Report of Archaeological Test-pitting of the MRT LG02 Station-Chihwuyuan Site (Unpublished). Tainan, Taiwan: Tree Valley Foundation.

Choi, Jae Young; Adrian E. Platts, Dorian Q. Fuller, Yue-Ie Hsing, Rod A. Wing and Michael D. Purugganan

2017 The Rice Paradox: Multiple Origins but Single Domestication in Asian Rice. Mol Biol Evol. 2017 Apr 1, 34(4):969-979.

Chou, Wan-yao

2012 Dong Fan Ji: Fieldwork Report of the Southwestern Plain in Taiwan during the early 17th Century. Study on the Ocean and Colonial Taiwan. Pp. 107-150. Taipei: Linking Publishing.

Christidou, Rozalia

2008 An application of micro-wear analysis to bone experimentally worked using bronze tools. Journal of Archaeological Science 35(3):733-751.

Chu, Cheng-yi

1990 Collection of Radiocarbon Dates of Taiwan. Field Archaeology of Taiwan 1(1):95-122.

2012 Report of Talungtung Tainan Resue Excavation and Construction Monitoring Project (Unpublished). Tainan, Taiwan: Tree Valley Foundation.

Coles, James

2015 Handaxe symmetry in the Lower and Middle Palaeolithic:

implications for the Acheulean gaze. Settlement, Society and Cognition in Human Evolution: Landscapes in Mind, F. Coward, R. Hosfield, M. Pope and F.F. Wenban-Smith (eds.). Pp.234-257. Cambridge University Press, Cambridge.

Coles, John

1979 Experimental Archaeology. London: Academic Press.

Collingwood, Cuthbert

1867 A boat journey across the northern end of Formosa, from Tam-suy, on the west, to Kee-lung, on the east; with notices of Hoo-wei, Mangka, and Kelung. Proceedings of the Royal Geographical Society 11: 167-173.

Coppe, Justin and Veerle Rots

2017 Focus on the target. The importance of a transparent fracture terminology for understanding projectile points and projecting modes. Journal of Archaeological Science: Reports 12:109–123.

Cox, M. P.

2005 Indonesian mitochondrial DNA and its opposition to a Pleistocene Era origin of Proto-Polynesian in Island Southeast Asia.” Human Biology 77(2): 179-188.

Craig, Robert J. Speakman; Rachel S. Popelka-Filcoff; Michael D. Glascock; J. David Robertson; M. Steven Shackley and Mark S. Aldenderfer

2007 Comparison of XRF and PXRF for analysis of archaeological obsidian from southern Peru. Journal of Archaeological Science 34 (12):2012-2024.

Cruz Berrocal, María; Elena Serrano Herrero; Susana Consuegra Rodríguez; Mar Torra; Marc Gener and Cheng-hwa Tsang

2014 Excavations in Hoping Dao, Keelung, Report of activities, 2011-2013.

Cuenca-Solana, David; Igor Gutiérrez-Zugasti and Manuel R. González-Morales

2017 Use-wear analysis: An optimal methodology for the study of shell tools. Quaternary International 427(A):192-200.

Cultural management committee of Kaifeng and Xinzheng

1978 Neolithic Site of Peiligang in Xinzheng, Henan. Archaeology, No.2: 73-79, 145-146.

Curwen, E. Cecil

1930 Prehistoric flint sickles. Antiquity 4: 179-186.

1935 Agriculture and the Flint sickle in Palestine. Antiquity 9: 62-66.

1953 Plough and pasture: the early history of farming. New York: Henry Schuman.

De Laet, Sigfried J.

1994 History of Humanity: Volume I: Prehistory and the Beginnings of Civilization. Chapter 43: Southern Asia: The Neolithic Pattern of North-Eastern India. Pp. 1059-1082.UNESCO. Available at https://unesdoc.unesco.org/ark:/48223/pf0000119149

Deng, Zhenhua; Hsiao-chun Hung; Mike T. Carson; Peter Bellwood; Shu-ling Yang and Houyuan Lu

2017 The First Discovery of Neolithic Rice Remains in Eastern Taiwan: Phytolith Evidence from the Chaolaiqiao Site. Archaeological and Anthropological Sciences, pp.1-8. doi:10.1007/s12520-017-0471-z

Dolfini, Andrea

2011 The function of Chalcolithic metalwork in Italy: an assessment based on use-wear analysis. Journal of Archaeological Science 38(5):1037-1049.

Dolfini, Andrea and Rachel J. Crellin

2016 Metalwork wear analysis: The loss of innocence. Journal of Archaeological Science 66:78-87.

Donahue, Randolph E. and Adrian A. Evans

2012 Lithic microwear analysis. In Neanderthals amongst Mammoths: Excavations at Lynford Quarry, Norfolk. W. Boismeier and C. Gamble (eds). Pp. 261-274. London: English Heritage.

Driscoll, Killian

2011 Identifying and classifying vein quartz artefacts: an experiment conducted at the World Archaeological Congress, 2008. Archaeometry, 53 (6): 1280-1296.

Driscoll, Killian; Jonas Alcaina; Natâlia Égüez; Xavier Mangado; Josep-Maria Fulloa and José-Miguel Tejero

2016 Trampled under foot: A quartz and chert human trampling experiment at the Cova del Parco rock shelter, Spain. Quaternary International, 424 (7): 130-142.

Dussubieux, Laure and Heather Walder

2015 Identifying American native and European smelted coppers with pXRF: a case study of artifacts from the Upper Great Lakes region. Journal of

Archaeological Science 59:169-178.

Dyen, Isidore

1965 A Lexicostatistical Classification of the Austronesian Languages. International Journal of American Linguistics, memoir 19. Baltimore.

Environmental Protection Agency

2007 EPA Method 6200: Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment. Taipei, Taiwan: Environmental Protection Agency of Taiwan, pp.1–32. Available at: http://www.epa.gov/ SW–846/pdfs/6200.pdf

Evans, Adrian A.

2014 On the importance of blind testing in archaeological science: the example from lithic functional studies. Journal of Archaeological Science 48:5-14.

Evans, Adrian A. and Randolph E. Donahue

2008 Laser scanning confocal microscopy: a potential technique for the study of lithic microwear. Journal of Archaeological Science 35(8):2223-2230.

Evans, Adrian A., M. Maxwell and G. Cruickshanks

2013 From lidar to LSCM: micro-topographies of archaeological finds. Interpreting Archaeological Topography: 3D Data, Visualisation and Observation. Pp. 123-135. Oxbow Books.

Evans, Adrian A., H. Lerner, D.A. Macdonald, W.J. Stemp and P.C. Anderson

2014 Standardization, calibration and innovation: a special issue on lithic microwear method. Journal of Archaeological Science 48:1-4.

Evans, John

1872 The Ancient Stone Implements. Weapons and Ornaments of Great Britain. London: Longmans, Green, Reader, and Dyer.

Ferrell, Raleigh

1966 The Formosan Tribes: A Preliminary Linguistic, Archaeological and Cultural Synthesis. Bulletin of the Institute of Ethnology No.21: 97-130. Taipei: Institute of Ethnology, Academia Sinica.

1969 Taiwan Aboriginal Groups: Problems in Cultural and Linguistic Classification. Taipei: Institute of Ethnology, Academia Sinica, 1969.

Field, Andy

2013 Discovering Statistics Using IBM SPSS Statistics (4th Edition). London: SAGE Publications Ltd.

Finn, Daneil J.

1958 Archaeological finds on Lamma Island near Hong Kong, (Ricci publications). Ricci Hall, University of Hong Kong.

Forster, Nicola; Peter Grave; Nancy Vickery and Lisa Kealhofer

2011 Non-destructive analysis using PXRF: methodology and application to archaeological ceramics. X-Ray Spectrometry 40(5):389-398.

Forster, Nicola and Peter Grave

2012 Non-destructive PXRF analysis of museum-curated obsidian from the Near East. Journal of Archaeological Science 39 (3):728-736.

Forte, Vanessa; Stella Nunziante Cesaro and Laura Medeghini

2018 Cooking traces on Copper Age pottery from central Italy: An integrated approach comprising use wear analysis, spectroscopic analysis and experimental archaeology. Journal of Archaeological Science: Reports 18:121-138.

Frahm, Ellery

2014 Characterizing obsidian sources with portable XRF: accuracy, reproducibility, and field relationships in a case study from Armenia. Journal of Archaeological Science 49:105-125.

2016 Can I get chips with that? Sourcing small obsidian artifacts down to microdebitage scales with portable XRF. Journal of Archaeological Science: Reports 9:448-467.

2018 Ceramic studies using portable XRF: From experimental tempered ceramics to imports and imitations at Tell Mozan, Syria. Journal of Archaeological Science 90:12-38.

Frahm, Ellery; R. Doonan and V. Kilikoglou

2013 The technological versus methodological revolution of portable XRF in archaeology, Journal of Archaeological Science 40 (2):1425-1434.

2014a Handheld portable X-ray fluorescence of Aegean obsidians. Archaeometry 56:228-260.

Frahm, Ellery; Beverly A. Schmidt; Boris Gasparyan; Benik Yeritsyan; Sergei Karapetian; Khachatur Meliksetian and Daniel S. Adler

2014b Ten seconds in the field: rapid Armenian obsidian sourcing with portable XRF to inform excavations and surveys, Journal of Archaeological Science 41:333-348.

Freeman, J. D.

1955 Iban Agriculture: A Report on the Shifting Cultivation of Hill Rice by the Iban of Sarawak. (Colonial Office. Colonial Research Studies, No. 18.) London, Her Majesty's Printing Office.

Friedman, I.; F. W. Trembour and R.E. Hughes

1997 Obsidian Hydration Dating. In Chronometric Dating in Archaeology. Advances in Archaeological and Museum Science, vol 2. R.E. Taylor and M.J. Aitken (eds). Springer, Boston, MA.

Friesem, David E.

2016 Geo-ethnoarchaeology in action. Journal of Archaeological Science 70:145-157.

Friedrich, Walter L.; Bernard Kromer; Michael Friedrich; Jan Heinemeier; Tom Pfeiffer and Sahra Talamo

2006 Santorini eruption radiocarbon dated to 1627–1600 B.C. Science 312(5773):548.

Fu, Chao-Ching; Yi-chang Liu and Der-Her Lee

2003 Preliminary research project of the Fort Zeelandia. Tainan City Government, Taiwan.

Fu, Xianguo

1988 On the Stepped Adze and Shouldered Stone Tools. Acta Archaeologica Sinica (1):1-37.

Fullagar, Richard and Carney Matheson

2004 Stone Tool Use-wear and Residue Analysis. In Encyclopedia of Global Archaeology, Clair Smith, ed. New York: Springer.

Fuller, Q. Dorian

2011 Pathways to Asian Civilizations: Tracing the Origins and Spread of Rice and Rice Cultures. Rice 4(3/4):78-92.

Geng, Deming

1990 The Two-Shouldered Stone Implements of the Neolithic Age in the Middle Reaches of the Nujiang River. Journal of Yunnan Nationalities Institute, No.1, pp. 64-72.

Goodale, Nathan; David G. Bailey; George T. Jones; Catherine Prescott; Elizabeth

Scholz; Nick Stagliano and Chelsea Lewis

2012 pXRF: a study of inter-instrument performance. Journal of Archaeological Science 39 (4):875-883.

Goodale, Nathan; David G. Bailey; George T. Jones; Catherine Prescott; Elizabeth Scholz; Nick Stagliano and Chelsea Lewis

2012 pXRF: a study of inter-instrument performance. Journal of Archaeological Science 39 (4):875-883.

Grace, Roger

1990 The limitations and pplications of use wear analysis. In: The interpretative possibilities of microwear studies: Proceedings of the international conference on lithic use-wear analysis, 15th-17th February 1989 in Uppsala, Sweden. Bo Gräslund; H. Knutsson; K. Knutsson and J. Taffinder (eds.). Uppsala: Societas Archaeologica Upsaliensis. Pp. 9-14.

Grave, Peter; Val Attenbrow; Lin Sutherland; Ross Pogson and Nicola Forster,

2012 Non-destructive pXRF of mafic stone tools. Journal of Archaeological Science 39(6):1674-1686.

Greenwell, The Rev. William

1865 Notices of the examination of ancient grave-hills in the North Riding of Yorkshire. The Archaeological Journal 22(1): 97-117.

Grolier Incorporated

2000 The encyclopedia Americana, Vol.1, pp.353. Danbury, Conn.: Grolier Incorporated.

Groot Gerald J.

2013 The Prehistory of Japan. Bertram S. Kraus (ed.). Literary Licensing, LLC.

Guo, Zhengfu; Tianlong Jiao; Barry V. Rolett and Jiaqi Liu

2005 Tracking Neolithic Interactions in Southeast China: evidence from stone adze geochemistry. Geoarchaeology 20(8):765-776.

Harding, P.

2015 Working with flint tools: personal experience making a Neolithic axe haft. Lithics: the Journal of the Lithic Studies Society 35:40-53.

Hayden, Brian

1987 Lithic Studies Among the Contemporary Highland Maya. University of Arizona Press.

Heine-Geldern, Robert

1932 Urheimat und Früheste Wanderungen dez Austronesier. *Anthropos* 27 (3/4): 543-619.

Heng, Sophady

2007 A Study of Polished Stone Tools from Samrong Sen, Cambodia: The French Museum Collections. Master's thesis, Department of Prehistory, Museum National d'Histoire Naturelle, Paris.

Ho, Chuan-Kun

2010 Underwater archaeology and the Taiwan Landbridge Fauna. Newsletter of National Museum of Natural Science, Vol. 266. Available at http://web2.nmns.edu.tw/PubLib/NewsLetter/99/266/a-1.pdf

Ho, Chuan-Kun and Whei-lee Chu

2007 Rescue excavation of Huei-Lai Site in Taichung. Newsletter of National Museum of Natural Science, Vol. 240. Available at http://web2.nmns.edu.tw/PubLib/NewsLetter/96/240/3.pdf

Ho, Chuan-Kun and Ke-hong Liu

2004 Archaeological excavation report of Tamalin site. Taichung: National Museum of Natural Science.

2006 New views on the Tamalin culture. Newsletter of National Museum of Natural Science, Vol. 227. Availabe at http://web2.nmns.edu.tw/PubLib/NewsLetter/95/227/3.pdf

Ho, Chuan-Kun and Ling-Da Yen

2008a Study on mtDNA and genetic relationship between Taiwan and East Asian sika deer. Newsletter of National Museum of Natural Science, Vol. 245. Available at http://web2.nmns.edu.tw/PubLib/NewsLetter/97/245/2.pdf

Ho, Chuan-Kun and Guo-qin Qi

2008b Palaeoecological environment and fauna restoration of the Landbridge in the Late Pleistocene of China. Newsletter of National Museum of Natural Science, Vol. 248. Available at http://web2.nmns.edu.tw/PubLib/NewsLetter/97/248/2.pdf

Hou, Yamei

1992 Experimental, Studies of microwear analysis on stone artifacts. Acta Anthropologica Sinica 11(3):202-215, Fig. I-III.

Hsieh, Jaw-shu; Yue-ie Caroline Hsing; Tze-fu Hsu; Paul Jen-kuei Li; Kuang-ti Li and Cheng-hwa Tsang

2011 Studies on Ancient Rice—Where Botanists, Agronomists, Archeologists, Linguists, and Ethnologists Meet. Rice 4:178-183.

Hsu, L.C.

1963 Petrology of The Pleistocene Andesite From Kueishantao, Northern Taiwan. Acta Geologica Taiwanica - Science Reports of the National Taiwan University 10:29-40.

Huang, Jun-Lin

2006 Domestication of Rice, Newsletter of National Museum of Natural Science, Vol.227.

Huang, Shih-chiang

1984 Reprot of ChihShanYen Excavation. Taipei, Taiwan: Taipei City Archives.

1985 A Study on the Relationship of Prehistoric Culture between Southeastern China and Taiwan in the Neolithic Age. Humanitas Taiwanica 34:194-214. Taipei: College of Liberal Arts, National Taiwan University.

1986 Introduction of Taiwan Prehistory. Taipei, Taiwan: National Taiwan Museum.

1989 Excavation at locality 2 of Yuan-Shan shell-mound. Journal of Archaeology and Anthropology [Bulletin of the Department of Anthropology] 45:20-65.

1991 The Excavation and Assessment Report for the locality of Chung-shan 33rd Road, Yuan-Shan Site (Unpublished). Department of Anthropology, National Taiwan University.

1992 The Excavation and Assessment Report for the Extent of the First-class Historical Monument, Yuan-Shan Site (Unpublished). Department of Anthropology, National Taiwan University.

1997 Yuanshan Site – Grade One Historic Site. Taipei: Taipei: Taipei Children's Recreation Center.

Huang, Shih-chiang; Yi-chang Liu

1980 Survey and Maintenance Proposal for Important Historical Sites in Taiwan (Unpublished). Department of Anthropology, National Taiwan University.

Huang, Shih-chiang; Yi-chang Liu; Feng-ping Yang

1999a Archaeological survey report of the Yuanshan site in the Taipei Children's Recreation Centre (Unpublished). Department of Anthropology, National Taiwan University, T.T.C.s.R. Center.

1999b Archaeological Excavation Project for the Extent of Historic Monument Park of Yuan-Shan Site (Unpublished). Department of Anthropology, National Taiwan University, T.T.C.s.R. Center.

Huang, Shu-jiang

1996 Tai Hai Shih Cha Lu [臺海使槎錄 1772]. Nantou: Taiwan Historica.

Huang, Xuehui, Nori Kurata, Xinghua Wei, Zi-Xuan Wang, Ahong Wang, Qiang Zhao, Yan Zhao, Kunyan Liu, Hengyun Lu, Wenjun Li, Yunli Guo, Yiqi Lu, Congcong Zhou , Danlin Fan, Qijun Weng, Chuanrang Zhu, Tao Huang, Lei Zhang, Yongchun Wang, Lei Feng, Hiroyasu Furuumi, Takahiko Kubo, Toshie Miyabayashi, Xiaoping Yuan, Qun Xu, Guojun Dong, Qilin Zhan, Canyang Li, Asao Fujiyama, Atsushi Toyoda, Tingting Lu, Qi Feng, Qian Qian, Jiayang Li and Bin Han

2012 A map of rice genome variation reveals the origin of cultivated rice. Nature, Vol.490, pp.497-501.

Huang, Ying-Kuei

1975 Swidden agriculture and paddy cultivation. Man and Culture 6:37-42.

Huang, Yu-zhi

2016 Outlook of Taiwan aborigines. Taiwan: Nanganshan Culture Office.

Hung, Eason, Hwei-Lan Poan, Huan-Chi Liu, Tzu-Hua Lai, Chih-Chao Huang and Li-Yuan Fei

2006 The Sedimentary Facies and Paleo-enviroment Analysis of the Taipei Basin. Western Pacific Earth Sciences, Vol. 6, pp. 59-86.

Hung, Hsiao-chun

2000 Comparative Studies of Stone Adzes in Taiwan, South China and the Philippines (Unpublished). Department of Anthropology, National Taiwan University.

Hung, Hsiao-chun and Yoshiyuki Iizuka

2017 Nephrite and mica industries: a link towards the Austronesian world, in B. Bellina (ed.) Khao Sam Kaeo: a late prehistoric early port-city between the Indian Ocean and the South China Sea. Paris: École française d'Extrême-

Orient.

Hurcombe, Linda

1988 Some criticisms and suggestions in response to Newcomer *et al.* (1986). Journal of Archaeological Science 15(1):1-10.

Hwang, Chao-En

1984 Topographical Research on Taiwan Watershed Characteristics and Their Correlation. Reports of Geographical Studies, Issue 4, pp.3. Taipei, Taiwan: Department of Geography Chinese Culture University.

Ino, Kanori

1897 Taiwan Communication, No.16. The Journal of the Anthropological Society of Tokyo, Vol. 12-134, pp299-310.

2011 Research trips among the Plains Aborigines: Selections from Ino Kanori's Taiwan diaries=PING PU ZU DIAO CHA LV XING – YI NENG JIA JU (TAI WAN TONG XIN) XUAN JI. N. Yang, transl. Taipei, Taiwan: Yuan-Liou Publishing Company.

Iinuma, Jiro and Takashi Horino

1976 Farming Tools. Hosei University Press. Pp. 162-164.

Ishizaka, Shōsaku

1923 Large whestone of Yuanshan. Ancient inscriptions of North Taiwan, pp. 82. Japan.

Jia, Peter Weiming; Trudy Doelman, Chuanjia Chen, Hailong Zhao, Sam Lin, Robin Torrence and Michael D. Glascock

2010 Moving sources: A preliminary study of volcanic glass artifact distributions in northeast China using pXRF. Journal of Archaeological Science 37 (7):1670-1677.

Jien, Shi-lang and Su-chiu Kuo

2013 A prelimimary report of the Rescuing Excavation of the Chanlungshan Site. New Taipei City: Cultural Affairs Department..

Kanaseki, Takeo

1943 Influence of Northern Culture in Taiwan Prehistory. Taiwanese Culture, Vol.1, pp.1-16。Taipei: Chingshui Bookstore.

Kanaseki, Takeo and Naoichi Kokubu

1990 Taiwan Archaeology. Taipei: Woolin Publishing Ltd.

Kaneko, Erika

1970 Robert von Heine-Geldern: 1885-1968. Asian Perspectives 13: 1-10.

Kang, Yun-Ning and Yu-Pei Chen

2011 Preliminary report on the fan-shaped phytoliths analysis of plant remains from the Peinan Site. A paper presented to the Annual Conference of Taiwan Archaeologists, 2010. Taitung, Taiwan: National Museum of Prehistory.

Kang, Yun-Nin

2013 Discussion of Plant Remains in the Peinan Site Based on Phytolith Analysis and Plant Impression Replica Method on Pottery (Unpublished). Department of Anthropology, National Taiwan University.

Kano, Tadao (translated by Sung Wen-hsun)

1955 An overview of Taiwanese archaeology and ethnology. Nantou, Taiwan: Taiwan Historica, Academia Historica.

2016 Prehistoric Studies on the Southeast Asian Ethnology. Taipei: Council of Indigenous Peoples.

Katz, Ofir; Dan Cabanes; Stephen Weiner; Aren M. Maeir; Elisabetta Boaretto and Ruth Shahack-Gross

2010 Rapid phytolith extraction for analysis of phytolith concentrations and assemblages during an excavation: an application at Tell es-Safi/Gath, Israel. Journal of Archaeological Science, 37:1557–1563.

Katz, Solomon H. and William Woys Weaver

2003 Encyclopaedia of Food and Culture. New York: Scribner.

Ke, Jing-Wen

2016 A Study of Stone Knife Typology and Use-wear Pattern of Dahu Culture in Southwestern Taiwan (Unpublished). Institute of Anthropology, National Tsing Hua University.

Kealhofer, Lisa

1996 Human-Environmental Relationships in Prehistory: An Introduction to Current Research in South and Southeast Asia. Asian Perspectives, Vol.35, No.2, pp.111-117.

Keeley, Lawrence H.

1974 Technique and methodology in microwear studies: a critical review. World Archaeology 5:323-336.

1980 Experimental Determination of Stone Tool Uses: A Microwear

Analysis. University of Chicago Press, Chicago.

Kelley, Harold J. and Annelou L. Van Gijn

2008 Understanding the function of coral tools from Anse a la Gourde: an experimental approach. In Crossing Disciplinary Boundaries and National Borders. New Methods and Techniques in the Study of Archaeological Materials from the Caribbean. C.L. Hofman; M. Hoogland and A.L. Van Gijn, eds., pp.115-124. Tuscaloosa AL: Alabama University Press.

Kemps, D.R.C.

1983 Raw Materials and Miscellaneous Uses of Stones. In The Petorlogy of Archaeological Artefacts. D.R.C.K.a.A.P. Harvey, ed. Pp. 53-79. Oxford, UK: Oxford University Press.

Kennett, Douglas J.; Irka Hajadas; Brendon J. Culleton; Soumaya Belmecheri; Simon Martin; Hector Neff; Jaime Awe; Heather V. Graham; Katherine H. Freeman; Lee Newsom; David L. Lentz; Flavio S. Anselmetti; Mark Robinson; Norbert Marwan; John Southon; David A. Hodell and Gerald H. Haug

2013 Correlating the Ancient Maya and Modern European Calendars with High-Precision AMS ^{14}C Dating. doi: 10.1038/srep01597

Kleinman,R.J.A., D. Pimentel, R.B.Bryant

1995 The ecological sustainability of slash-and-burn agriculture. Agriculture, Ecosystem & Environment 52(2-3): 235-249.

Kokubu, Naoichi

1981 Taiwan archaeological ethnography. Tokyo: Keiyusha Publishing.

Kuo, Su-chiu

2002 The “Botanical Garden Culture” in the Northern Taiwan. Literature and Philosogy 1:273-332. Kaohsiung, Taiwan: Department of Chinese Literature, National Sun Yat-sen University.

2008 Viewing the Origin of the Paiwan Group from the Archaeological materials of the late Prehistoric Era in Southern Taiwan. Annual conference of the Taiwan Society for Anthropology and Ethnology: Anthropological challenges and overcoming. Taipei, Taiwan: Institute of Ethnology, Academia Sinica.

2010 Report of water collecting well at the Yuanshan Site, Taipei. Taipei, Taiwan: Department of Cultural Affairs, Taipei City.

2014a A Discussion on the Essence of the Yuanshan Culture in Northern

Taiwan. The Journal of Austronesian Studies 5(2):69-152.

2014b Preliminary Investigation of the Neolithic Rotating Cutting Technology and its Rotating Machinery in Taiwan. The International Conference on Prehistoric Rotary Technology and Related Issues at Hac Sa, Macao, Macao, 2014, pp. 268-299. Department of Cultural Activites and Recreation, Macao.

2015 Analysis of the Xuntangpu (Hsuntangpu) Culture in Northern Taiwan. In Prehistory of Taiwan, Special Volume for Institute of History and Linguistic, Academic Sinica. Y.-C Liu, eds. Pp. 185-246. Taipei, Taiwan: Academia Sinica, Linking Publishing.

Kuo, Su-chiu; Teh-jen Chen

2012 Research report of the Huweishan site in Sanxia District, New Taipei City. Institute of History and Philology, Academia Sinica, N.T.C.G. Cultural Affairs Department.

Kuo, Tung-Shoung

2003 Taro in Tsuvetsekadan. Aboriginal Education Quaterly, Vol.30, pp.91-116.

Larson,Greger, Dolores R. Piperno, Robin G. Allaby, Michael D. Purugganan , Leif Andersson, Manuel Arroyo-Kalin, Loukas Barton, Cynthia Climer Vigueira, Tim Denham, Keith Dobney, Andrew N. Doust, Paul Gepts, M. Thomas P. Gilbert, Kristen J. Gremillion, Leilani Lucas, Lewis Lukens, Fiona B. Marshall, Kenneth M. Olsen, J. Chris Pires, Peter J. Richerson, Rafael Rubio de Casas, Oris I. Sanjur, Mark G. Thomas, and Dorian Q. Fuller

2014 Current perspectives and the future of domestication studies. Proceedings of the National Academy of Sciences of the United States of America, 112 (11):6139-6146.

Le Bas, M. J. ; R. W. Le Maitre; A. Streckeisen; B. Zanettin

1986 A Chemical Classification of Volcanic Rocks Based on the Total Alkali-Silica Diagram. Journal of Petrology 27(3):745-750.

Le Maitre, R.W.

2002 Igneous rocks : a classification and glossary of terms : recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks. New York: Cambridge University Press.

Leonard Blussé, Natalic Everts and Evelien Frech

2010 The Formosan Encounter Notes on Formosa's Aboriginal Society: A Selection of Documents from Dutch Archival Sources Vol. I, 1623-1635. Taipei, Taiwan: Shung Ye Museum of Formosan Aborigines.

Lee, Cheng-Yi; Maa-Ling Chen; Li-Hung Lin; Peter Ditchfield; Pei-Ling Wang; Hsiu-Man-Lin; A. Mark Pollard; Ching-Hua Lo and Hsi-Kuei Tsai

2016a Diet and subsistence mode of Neolithic Yuan-Shan people in Taiwan: Perspective from carbon and nitrogen isotope analyses of bone collagen. Archaeology Research in Asia 7:18-27.

Lee, Cheng-Yi; Maa-Ling Chen; Peter Ditchfield; Li-Hung Lin; Pei-Ling Wang; A. Mark Pollard; Hsiu-Man-Lin; Ching-Hua Lo; Hsi-Kuei Tsai

2016b Paleodietary pattern of the Yuan-Shan Neolithic people in Taiwan: Evidence from carbon and nitrogen stable isotopic analyses of human skeletons and faunal remains. Journal of Archaeology and Anthropology [Bulletin of the Department of Anthropology] 85:109-138. Department of Anthropology, National Taiwan University.

Lee, Na-li

2003 Study on the subsistence pattern and economic strategy of Yuanshan Culture - taking the animal remains of the Yuanshan site as an example (Unpublished). Department of Anthropology, National Taiwan University.

Lee, Kuang-chou

1985 Archaeological investigation report of the Kenting National Park. Taipei: Construction and Planning Agency, Ministry of the Interior.

Lee, Kun-hsiu

1999 Preliminary report of the rescue excavation of Wushantou Site. Taitung: the National Museum of Prehistory.

2006 Rescue excavation of Old Xianglan Site and its important findings in Taitung. Taitung Historical Journal 12:17-47.

Lee, Kun-hsiu and Mei-chen Yeh

1995 Excavations at Fushan site of Eastern Taiwan in 1994. Newsletter of the National Museum of Prehistory 5(5):33–49.

Lee, Tsuoting; I-ling Wu; Kuangti Li; Kun-hsiu Lee

2010 Research on development of rice farming in prehistoric society in

Taiwan-Focusing on plant opal analysis and stone harvesting equipment (Unpublished). PhD dissertation, Faculty of Social and Cultural Studies, Kyushu University.

2012 Using Replica-SEM Method for Analysis of Oryza Husk Impressions on a Ceramic Sample Collected from Siagukeng Site, Field Archaeology of Taiwan, Vol. 15(2): 91-104.

2014 Phytolith and the recovery of prehisotric plant resources and environment for human beings. Newsletter of the National Museum of Natural Science 318:4.

Lee, Tsuoting; I-ling Wu; Kuangti Li; Kun-hsiu Lee

2015 The Origin of Rice Cultivation at 4,000 Years Ago on the East Coast of Taiwan: Preliminary Results of Phytolith Analysis. The Journal of Austronesian Studies 6(1):25-50.

LeMoine, Genevieve M.

1994 Use Wear on Bone and Antler Tools from the Mackenzie Delta, Northwest Territories. American Antiquity 59(2):316-334.

Levi-Sala, Irene

1986 Use wear and post-depositional surface modification: A word of caution. Journal of Archaeological Science 13(3):229-244.

1996 A study of microscopic polish on flint implements. BAR International Series Vol. 629. Oxford: Tempus Reparatum.

Levy, Tsuoting; Tomas E., Thomas Higham; Christopher Bronk Bronk Ramsey; Neil G. Smith; Erez Ben-Yosef; Mark Robinson; Stefan Mu¨nger; Kyle Knabb; Ju¨rgen P. Schulze; Mohammad Najjar and Lisa Tauxe

2008 High-precision radiocarbon dating and historical biblical archaeology in southern Jordan. Proceedings of the National Academy of Sciences of the United States of America 105(43):16460-16465.

Li, Ching-yao; Chiu-mei Wang

2013 Two Woods from Sungshan Formation, Taipei Basin. ournal of the National Taiwan Museum 66(4):1-8.

Li, Jian-an and Zuo-qi Fan

1995 Shouldered axes in Fu-an area, Fujian. Archaeology Vol.10:895-901.

Li, Kuang-Chou

1985 Archaeological study report of the Kenting National Park. Pingtung, Taiwan: Kenting National Park Headquarters.

1999 Prehistoric Cultures of the Kenting National Park. Taipei: Artist Publishing.

Li, Kuang-ti

1999 Supplementary investigation report on the excavation of cultural site along the river in the north of Tamshui River. Ministry of Transportation and Communications, Taiwan.

Li, Mingqi; Xiaoyan Yang, Quansheng Ge, Xiaoyan Ren and Zhiwei Wan

2013 Starch grains analysis of stone knives from Changning site, Qinghai Province, Northwest China. Journal of Archaeological Science 40(4):1667-1672.

Li, Paul Jen-Kuei

2004 Classification of Taiwanese Pinpuzu and their relationship. Ethnic and Linguistic of Austronesian in Yilang. Yilang, Taiwan: Yilan County Cultural Centre.

Li, Te-jen

1992 A test-pitting report of Niuchozhi site in Rende District, Tainan City, Taiwan (Unpublished). Department of Anthropology, National Taiwan University.

Li, Zhanyang and Chen Shen

2010 A Preliminary confirmation of microwear observation on Palaeolithic bone tools at the Lingjing site in Xuchang. Chinese Science Bulletin 55(10): 895-903.

Liao, Po-An

2016 A Study of Plant-use Strategy in the Dahu Culture Wushantou Phase Based on Starch grains extracted from Stone-knifes and Soils (Unpublished). Institute of Anthropology, National
Tsing Hua University.

Lien, Chao-mei

1988 Report on the research status of the Yuanshan Site, Taipei. Taipei City Archives: No.83:1-48.

Lin, Chao-Chi

1957 Topography. History of Land. Geography, Vol. I. Taiwansheng Tongzhigao [The Chronicle of Taiwan]. Nantou, Taiwan: The Taiwan

Historica.

1963 Quaternary of Taiwan. Taiwan Historica. Vol.15, No.1/2, pp.1-91.

1964 Geology and Ecology of Taiwan Prehistory. Asian Perspective VII (1-2): 203-213.

1965 Mining Industries of The Ketagalan Tribe in Taiwan. The Taiwan Mining Industry 17(2/3):37-57.

1966 An Outline of Taiwan's Quaternary Geohistory with a Special Discussion of the Relation between Natural History and Cultural History in Taiwan. Bulletin of the Department of Anthropology [Journal of Archaeology and Anthropology] 28:7-44.

Lin, Huixiang

1955 Research on the Stone Age Relics in Taiwan. Journal of Xiamen University (Arts & Social Sciences) 4:135-155.

Lin, Jia-wei

1996 Research into concave stone unearthed at the Shihsanhang relic (Unpublished). Department of Anthropology, National Taiwan University.

Lin, Jiun-Chuan

1992 Slope Erosion of the Hoyenshan Area of Miaoli, Taiwan. Department of Geography, National Taiwan University, Journal of Geographical Science 15:63-79.

Lin, Shu-fen and Su-chiu Kuo

2017 Paleoenvironmental reconstruction of Chihwuyuan Site, Taipei. A paper presented to Annual Conference of Taiwan Archaeologists, 2016. Pp. 48-56. Taichung, Taiwan: National Museum of Natural Science.

Liritzis, Ioannis and Nikolaos Zacharias

2011 Portable XRF of Archaeological Artefacts: Current Research, Potentials and Limitations. In Portable XRF of Archaeological Artefacts: Current Research, Potentials and Limitations. M. S. Shackley (ed.). Pp.109-142.

Little, A., B. Elliott, C. Conneller, D. Pomstra, A.A. Evans, L.C. Fitton, A. Holland, R. Davis, R. Kershaw, S. O'Connor, T. O'Connor, T. Sparrow, A.S. Wilson, P. Jordan, M.J. Collins, A.C. Colonese, O.E. Craig, R. Knight, A.J.A. Lucquin, B. Taylor and N. Milner

2016 Technological Analysis of the World's Earliest Shamanic Costume: A Multi-Scalar, Experimental Study of a Red Deer Headdress from the Early

Holocene Site of Star Carr, North Yorkshire, UK. Plos One 11 (4).

Liu, Ke-hong

1990 Research into arrow and spear head shaped objects of Beinan culture (Unpublished). Department of Anthropology, National Taiwan University.

2011 Preliminary report of the Nanshikeng Site excavation in 2011. Newsletter of National Museum of Natural Science, Vol. 287. Available at http://web2.nmns.edu.tw/PubLib/NewsLetter/100/287/a-4.pdf

2014 Stone knife. Newsletter of National Museum of Natural Science, Vol. 320. Available at http://web2.nmns.edu.tw/PubLib/NewsLetter/103/320/a1.pdf

Liu, Li and Xingcan Chen

2017 The Archaeology of China: From the Late Palaeolithic to the Early Bronze Age. SDX Joint Publishing Company.

Liu, Li; Jiajing Wang and Maureece J. Levin

2017 Use-wear and residue analyses of experimental harvesting stone tools for archaeological research. Journal of Archaeological Science: Reports 14: 439-453.

Liu, Pin-Hsiung

1963a Excavations and Discoveries at Tap'enk'eng (Tapenkeng) and Other Prehistoric Sites of Pali District. Asian Perspectives 7(1/2): 214-223. University Press of Hawaii.

1963b Excavations of at the prehistoric site in Palipen. Taipei Historical Documents Quarterly, No.3: 52-64. Taipei: Taipei City Archives.

Liu, S.; Q. H. Li; F. X. Gan; P. Zhang and James W. Lankton

2012 Silk Road glass in Xinjiang, China: chemical compositional analysis and interpretation using a high-resolution portable XRF spectrometer. Journal of Archaeological Science 39(7): 2128-2142.

Liu, Yi-chang

1982 Gouti mountain relic, Shulin twonship, Taipei County (Unpublished). Department of Anthropology, National Taiwan University.

1988 Preliminary study on the Relationship between Taiwan and South China in Prehistoric Times. Essays in Chinese maritime history, No.3:1-27. Taipei: Research Center for Humanities and Social Science, Academia Sinica.

1991 An essay on the Nature of Fengbitou Culture and the Age of Peinan Culture. In: Archaeology, History and Culture: collected papers celebrating the 80th birthday of Mr Chu-Hsiun Kao, Vol.1. Wen-hsun Sung ed. Pp.321-327. Taipei, Taiwan: Cheng Chung Bookstore.

1992 Report of the Excavation of Tutikungshan site and Chanlungshan Site, Tucheng District, New Taipei City. Field Archaeology of Taiwan 3(1):21-57.

1993 Prehistoric culture in the eastern Taiwan. Taitung: East Coast National Scenic Area.

1996 Prehistoric Cultures and Archaeological Sites of Taiwan. Nantou: Taiwan Historica.

1997a Report of the archaeological sites investigation of the northern coastal area in the Niew Taipei City. New Taipei City: New Taipei City Art Center.

1997b Investigation report of the Chihshanyen sites under the influcence of the secondary pipework in the Taipei City. Taipei, Taiwan: Department of Civil Affairs, Taipei City Government.

1999 Archaeological sites and prehistoric culture in Taichung. Taichung, Taiwan: Taichung City Government.

2000 Review of the Yuanshan Culture Chronology and the cultural change in the prehistory of Taipei Basin. In Proceedings of the symposium of the native culture research in Northern Taiwan. W.-M. Chou, eds. Pp. 71-112. Taipei, Taiwan: Department of History, National Chengchi University.

2001 Newly identified Hsuntangpu Culture in Northern Taiwan. Paper presented to the Forum of Archaeology in the Pearl River Delta and Taiwan Region: New Discoveries and Assessments in Recent Years. Sponsored by Taiwan and Southeas Asia Archaeological Research Offie, Institute of History and Philology, Academia Sinica.

2002a Archaeology and the Pinpu Zu study. In Symposium on the Pinpu aborigines and Taiwan history. Shu-chuan Chan and Ying-hai Pang (eds.). Pp. 185-203. Taipei, Taiwan: Institute of Taiwan History, Academia Sinica.

2002b The History of Formosan Aborigines: Prehistory. Nantou: Taiwan Historica.

2002c Prehistory and People in the estuary of Tamsui River. New Taipei

City: The Shihsanhang Museum of Archaeology.

2002d Reflections on the Study of the Prehistoric Cultural Sequences in Taiwan. In Proceedings of Academician Chang-ju Shih's 100th Birthday, Sung *et al.* (eds.), pp. 349-362. Taipei: SMC Publishing Inc.

The Shihsanhang Museum of Archaeology.

2005 Speculation of Human Mobility between Taiwan and the Philippines in the Early Time--The Excavation of the Xuntangpu (Hsuntangpu) Site and Its Significance. Academia Sinica Weekly, No. 1048. Taipei, Taiwan: Academia Sinica.

2006 The Discipline of Taiwanese Archaeology and Studies of Indigenous People Groups. Journal of Archaeology and Anthropology 66:70-93.

2015 Introduction: Recent breakthroughs in Taiwanese Archaeology. In Prehistory of Taiwan, Special Volume for Institute of History and Linguistic, Academic Sinica. Y.-C Liu, eds. Pp. 1-58. Taipei, Taiwan: Academia Sinica, Linking Publishing.

Liu, Yi-chang; Su-chiu Kuo

2000 Report of the archaeological sites investigation and research in the Taipei City. Taipei, Taiwan: Department of Civil Affairs, Taipei City Government. (Unpublished)

Liu, Yi-chang; Yu-mei Chen

1997 Prehistory and archaeological sites of Kaohsiung. Series of the Kaohsiung Histography Archives, No. 3. Kaohsiung, Taiwan.

Liu, Yi-chang; Chung-yu Chen; Kwang-tzuu Chen

2004 Survey of Archeological Sites in the Taiwan Region – The Seventh Research Plan: New Taipei City, Taipei City and Keelung City. Institute of History and Philology, Academia Sinica.

Liu, Yi-chang; Shu-jin Wang; Mei-chi Lin

2006 Retrospect and prospect of archaeological study in the Yangmingshan and the neighbouring area. Taipei, Taiwan: National Park Association in Taiwan.

Liu, Yi-chang; Kuo-feng Chung; Mei-chi Lin

2008 Report of test-pitting evaluation project of the Tayuanshienshan Site: Dayuan District, Taoyuan City. Dayuan District, Taoyuan City: Dayuan Primary School.

Liu, Yi-chang; Mei-chi Lin

2011 Assessment report on the essence and range of Chiuchashan Site in Shulin District, New Taipei City (Unpublished). Cultural Affair Department, New Taipei City, Taiwan.

Liu, Yi-chang; Shih-lang Jian

2011 Brief Report of the Study Results on the essence and scope of the Badsikan Cultural Sites. Literature on Yun-lin 53:143.150. Feng-ping Yang

Liu, Yi-chang; Feng-ping Yang

1994 The scope and culture of the Fengbitou site. Kaohsiung: Kaohsiung City Government.

Lu, Li-Cheng; Li-Fang Xia

1997 Peinan Site and Peinan Culture. Taitung: National Museum of Prehistory.

Lo, Howard H.

1982 Compositions of Tatun Andesites, Northern Taiwan. Journal of Volcanology and Geothermal Research 13(1-2):173-187.

Lo, Huann-Jih; Sheng-Rong Song

2000 Factors Controlling the Distribution of Zeolites in the Andesitic Rocks of the Central Coastal Range of Eastern Taiwan. Terrestrial, Atmospheric and Oceanic Sciences (TAO) 11(2):501-514.

Londo, Jason P.; Yu-Chung Chiang, Kuo-Hsiang Hung, Tzen-Yuh Chiang and Barbara A. Schaal

2006 Phylogeography of Asian wild rice, Oryza rufipogon, reveals multiple independent domestications of cultivated rice, Oryza sativa. Proc Natl Acad Sci U S A. June 20, 2006 103(25):9578-9583. doi.org/10.1073/pnas.0603152103

Lu, Tai-Lung

2017 A Study on the Prehistoric Culture In the North of Taiwan From 5000 to 4000 Years. Department of Anthropology, National Taiwan University.

Lu, Tracy L.-D.

2017 Integrating Experimental Archaeology, Phytolith Analysis and. Ethnographic Fieldwork to Study the Origin of Farming in China. New Perspectives in Southeast Asian and Pacific Prehistory, Philip J. Piper *et al.* (eds.) vol. 45, ANU Press, Acton ACT, Australia, 2017, pp. 243–250.

Lundblad, Steve; Peter R. Mills and Ken Hon

2007 Analysing archaeological basalt using non-destructive energy-dispersive X-ray Fluorescence (EDXRF): effects of postdepositional chemical weathering and sample size on analytical precision. Archaeometry 50:1-11.

Macdonald, A.J., R.T. Hosfield and S.J. Mithen

2007 Why are some handaxes symmetrical? Testing the influence of handaxe morphology on butchery effectiveness. Journal of Archaeological Science 34(6):883-893.

Machin, D.A. and Adrian A. Evans

2014 Evaluating Surface Cleaning Techniques of Stone Tools Using Laser Scanning Confocal Microscopy. Microscopy Today 22(3):22-26.

Madella, M.; A. Alexandre; T. BALL and ICPN WORKING GROUP

2005 International Code for Phytolith Nomenclature 1.0. Annals of Botany, 96(2):253–260.

Manning, Katie; Adrian Timpson, Sue Colledge, Enrico Crema, Kevan Edinborough, Tim Kerig and Stephen Shennan

2015 The chronology of culture: a comparative assessment of European Neolithic dating approaches. Antiquity 88(342):1065-1080.

Ma, Zhikun; Xaioyan Yang, Quan Li, Zhiwei Wan, Mingqi Li and Quansheng Ge

2012 Stone Knife's Function: Simulation Experiment via Starch Grain Analysis. Quaternary Sciences, Vol.32, No.2, pp.247-255.

Marreiros, João Manuel; Juan F. Gibaja Bao and Nuno Ferreira Bicho (eds.)

2014 Use-Wear and Residue Analysis in Archaeology. New York: Springer.

Martin, H.

1906 Industrie Moustérienne perfectionnée. Station de La Quina (Charente)". Bulletin de la Société Préhistorique de France. 3 (6): 233–239. (in French)

Marwick, Ben; Elspeth Hayes; Chris Clarkson and Richard Fullagar

2017 Movement of lithics by trampling: An experiment in the Madjedbebe sediments, northern Australia. Journal of Archaeological Science, 79:73–85.

Mathieu, James R.

2002 Introduction. In Experimental Archaeology: Replicating Past Objects, Behaviors, and Processes (BAR International Series 1035). J.R. Mathieu (ed.). Pp. 1-11. Oxford: Archaeopress.

Matsumoto, Nobuhiro

1939 Problems of Shouldered Axes. Shigaku (The Historical Science), 18(2/3):297-328.

Meacham, William

1996 Defining the Hundred Yue. Bulletin of the Indo-Pacific Prehistory Association (Journal of Indo-Pacific Archaeology) 15(2): 93-100.

Michczyński, Adam and Danuta J. Michczyńska

2006 The effect of PDF peaks' height increase during calibration of radiocarbon date sets. Geochronometria, Vol. 25:1-4.

Midoshima, Tadashi

2005 Study on the use wear of stone tools. Tokyo, Japan: Douseisha.

Millhauser, John k.; Enrique Rodríguez-Alegría and Michael D. Glascock

2011 Testing the accuracy of portable X-ray fluorescence to study Aztec and Colonial obsidian supply at Xaltocan, Mexico. Journal of Archaeological Science 38 (11):3141-3152.

Miyamoto, Nobuhito

1939 A outline of Taiwan Prehistory. Anthropology - Prehistory Lecture, Vol. 10:1-57. Tokyo: Yuzankaku Inc.

Miyamoto, Nobuhito

1992 Taiwanese Aborigines. Taipei: Morning Star Publishing.

Mizuno, Seiichi

1933 Shouldered Axe: stone tools from South Manchuria. Anthropological science [Journal of the Anthropological Society of Nippon] 48(10):595-598.

Moholy-Nagy, Hattula; James Meierhoff; Mark Golitko and Caleb Kestle

2013 An analysis of pXRF obsidian source attributions from Tikal, Guatemal. Latin American Antiquity, 24(1) pp. 72-97.

Muyard, Frank

2016 Taiwan Archaeology and Indigenous Peoples: Cross-perspectives on Indigenous Archaeology and Interactions Between Archaeologists and Indigenous Communities in Taiwan. Archaeology, History and Indigenous Peoples New Perspectives on the Ethnic Relations of Taiwan, Li-wan Hung (ed.), pp. 195-262. Taipei: Shung Ye Museum of Formosan Aborigines.

Newlander, Khori Newlander; Nathan Goodale; George T. Jones and David G. Bailey

2015 Empirical study of the effect of count time on the precision and accuracy of pXRF data. Journal of Archaeological Science: Report 3:534-548.

Nezu, Masashi

1943 Primitive civilization of Indochina.Tokyo: Kawade Shobo Shinsha Publishers Inc.

Nordqvist, Kerkko and P. Häkälä

2014 Distribution of corded ware in the areas north of the Gulf of Finland - An update. Estonian Journal of Archaeology 18(1):3-29.

Obayashi, Taryo

1982 Hoa-Loc Culture in the Prehistory of Vietnam. Bulletin of the Department of Archaeology, University of Tokyo 1:21-60.

Oda, Shizuo

2010 The Discovery of the Yuan Shan Shell Mound: Reassessment of the Archaeological Research in Taiwan under Japanese rule. Journal of Southeast Asian archaeology (30), 45-67.

Odell, George H.

1975 Microwear in perspective: a sympathetic response to Lawrence H. Keeley. World Archaeology 7:226-240.

2004 Lithic Analysis. Springer US.

Odell, George H. and Frieda Odel-Vereecken

1980 Verifying the reliability of lithic use-wear assessments by blind tests: the low-power approach. Journal of Field Archaeology 7(1):87-120.

Olausson, Deborah

1980 Starting from scratch: the history of edge-wear research from 1838 to 1978. Lithic Technology 9:48-60.

1990 Edge-wear analysis in Archaeology: the current state of research. Laborativ arkeologi 4. p.5-14.

Ollé, Audreu and Josep Maria Vergès

2014 The use of sequential experiments and SEM in documenting stone tool microwear. Journal of Archaeological Science 48:60-72.

Osterrieth, M.; Marco Madella; Debora Zurro and M. Fernanda Alvarez

2009 Taphonomical aspects of silica phytoliths in the loess sediments of the Argentinean Pampas. Quaternary International 193(1/2):70-79.

Outram, Alan K.

2008 Introduction to experimental archaeology. World Archaeology, 40(1): 1-6.

Overholtzer, Lisa

2014 A new Bayesian chronology for postclassic and colonial occupation at Xaltocan, Mexico. Radiocarbon 56(3): 1077-1092.

Peng, Jia-Hong

2012 The Research of Plant Remains at the Shiqiao Site, Niao-sung Culture of Taiwan. Taiwan Natural Science, Vol.31, No.4, pp.56-59.

Peng, Shifan

1987 Ancient impressed (stamped) pottery in South China. Beijing: Cultural Relics Publishing House.

Phillips, S. Colby and Robert J. Speakman

2009 Initial source evaluation of archaeological obsidian from the Kuril Islands of the Russian Far East using portable XRF. Journal of Archaeological Science 36 (6):1256-1263.

Portillo, Marta; Seiji Kadowaki; Yoshihiro Nishiaki and Rosa M. Albert

2014 Early Neolithic household behavior at Tell Seker al-Aheimar (Upper Khabur, Syria): a comparison to ethnoarchaeological study of phytoliths and dung spherulites. Journal of Archaeological Science, 42:107–118.

Reimer, Paula J.; Edouard Bard; Alex Bayliss; J Warren Beck; Paul G Blackwell; Christopher Bronk Ramsey; Caitlin E. Buck; Hai Cheng; R. Lawrence Edwards; Michael Friedrich; Pieter M. Grootes; Thomas P. Guilderson; Haflidi Haflidason; Irka Hajdas; Christine Hatté; Timothy J. Heaton; Dirk L Hoffmann; Alan G. Hogg; Konrad A. Hughen; K. Felix Kaiser; Bernd Kromer; Sturt W .Manning; Mu Niu; Ron W. Reimer; David A. Richards; E. Marian Scott; John R. Southon; Richard A. Staff; Christian S. M. Turney; Johannes van der Plicht

2013 IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal. BP. Radiocarbon 55(4):1869-1887.

Renfrew, Colin and Paul Bahn

2012 Archaeology: Theories, Methods and Practice. 6th Edition. Thames and Hudson.

Richards, M.; S. Oppenheimer, and S. Skyes

1998 mtDNA suggests Polynesian origins in eastern Indonesia. American Journal of Human Genetics 63(4): 1234-1236.

Rolett, Benjamin W. and M. Vander Linden

2011 Investigating archaeological cultures: material culture, variability, and transmission. In Investigating Archaeological Cultures, Roberts and M. Vander Linden (eds.). Pp. 1-21. New York: Springe.

Roberts, Berry V.; Wei-Chun Chen and John M. Sinto

2000 Taiwan, Neolithic seafaring and Austronesian origins. Antiuquity: 74:62-74.

Rots, Veerle

2010 Prehension and Hafting Traces on Flint Tools: A Methodology. Belgium: Leuven University Press.

2014 What method to study hafting? The potential of use-wear and residue analysis confronted. In An Integration of the Use-Wear and Residue Analysis for the Identification of the Function of Archaeological Stone Tools, Proceedings of the International Workshop, Rome, March 5th–7th, 2012 (BAR International Series 2649). Cristina Lemorini and Stella Nunziante Cesaro (eds.). Pp. 27-41. Oxford: Archaeopress.

2015a Toward a More Behavioral Approach. The Contribution of Wear Studies. In Works in Stone. Contemporary Perspectives on Lithic Analysis, Shott Michael (ed.), pp96-115. The University of Utah Press.

2015b Keys to the Identification of Prehension and Hafting Traces. In Use-Wear and Residue Analysis in Archaeology, Marreiros J., Gibaja Bao J., Ferreira Bicho N. (eds), pp.83-104. Manuals in Archaeological Method, Theory and Technique. Springer.

Rots, Veerle; Louis Pirnay; Philippe Pirson; Odette Baudoux and Pierre M. Vermeersch

2001 Experimental Hafting Traces Identification and Characteristics. Notae Praehistoricae, 21: 129-137.

Roy, Sankar Kumar

1981 Aspects of Neolithic Agriculture and Shifting Cultivation, Garo Hills, Meghalaya. Asian Perspectives, Vol. 24:193–321.

Sand, Christopher; Yvonne Marshall; Peter Sheppard; Matthew Spriggs; Scarlett Chiu

2013 Ritually breaking Lapita pots: or, can we get into the minds of Oceanic first settlers? A discussion. Archaeology in Oceania 48 :2-12.

Sáez, Carmen Gutiérrez and Ignacio Martín Lerma

2015 Traceology on Metal. Use-Wear Marks on Copper-Based Tools and Weapons. In Use-Wear and Residue Analysis in Archaeology, João Manuel Marreiros, Juan F. Gibaja Bao and Nuno Ferreira Bicho (eds.). New York: Springer International Publishing. Pp. 171-188.

Schmidt-Vogt, Dietrich

1995 Swidden farming and secondary vegetation. Two case studies from northern Thailand. In Counting the costs: Economic growth and environmental change in Thailand, J. Rigg (ed.). Singapore: Institute of Southeast Asian Studies.

Semenov, S.A. (translated by Thompson M.W.).

1964 Prehistoric Technology: An Experimental Study of the Oldest Tools and Artifacts from Traces of Manufacture and Wear. London: Cory, Adams & Mackay.

Shackley, M. Steven

2012 Portable X-ray Fluorescence Spectrometry (pXRF): The Good, the Bad, and the Ugly. Archaeology Southwest Magazine 26 (2). Available at: http://www.archaeologysouthwest.org/pdf/pXRF_essay_shackley.pdf

2015 Chronology, Stratigraphy, and Dating Methods in Archaeology. International Encyclopedia of the Social & Behavioral Sciences (Second Edition). Pp.562-567.

Shaw, Cheng-long; Mong-Whay Su; Ping-Mei Liew

1999 Subsurface Geology of Taipei Basin - The Palynological Study. Special Publication of the Central Geological Survey, MOEA 11:145-157.

Shea, John J.

1985 Experiments in Debitage Analysis: Some Testable Hypotheses. Bulletin of the Massachusetts Archaeological Society 46 (2): 44-50.

Shea, John J. and Joel D. Klenck

1993 An Experimental Investigation of the Effects of Trampling on the Results of Lithic Microwear Analysis. Journal of Archaeological Science 20(2):175-194.

Shellnutt, J. Gregory; Alexander Belousov; Marina Belousova; Kuo-Lung Wang; Georg F. Zellmer

2014 Generation of calc-alkaline andesite of the Tatun volcanic group (Taiwan) within an extensional environment by crystal fractionation. International Geology Review 56(9):1156-1171.

Shen, Chen and Chun Chen

2001 Use-wear Analysis (Low Power Method): Research and Practice, and a Use-wear Examination of the Xiaochangliang Lithic Artifacts. Archaeology 7:62-73.

Sheng, Ching-Yi

1962 Report of surveying the prehistoric sites in the north coast of Taiwan. Taiwan Historica. Vol.13, No.3, pp.60-152.

Shennan, S. J.

2003 Archaeological approaches to cultural identity. Routledge.

Sheppard, Peter; Barbara Trichereau and Cristany Milicich

2010 Pacific obsidian sourcing by portable XRF. Archaeology in Oceania, 45(1):21-30.

Sheppard, Peter; Geoff J. Irwin; Sam C. Lin and Cameron P. McCaffrey

2011 Characterization of New Zealand obsidian using pXRF. Journal of Archaeological Science 38 (1):45-56.

Shi, Mengyi and Xianzhu Wu

2011 The microscratch trace of animal bone surface and human behaviour study of Kua Hu Qiao site in Xiaoshan District, Zhejian Province, Quaternary Science 31(4):723-729.

Shih, Chang-ju

1950 The economical stage of the shouldered axe and stepped adze of Taiwan. The Quarterly Review of Taiwan Culture [Taiwan Culture Journal] 6(2):11-12.

1954a Overview of the Yuanshan shell mound excavation. Taipei Cultural Relics 3(1):8-13.

1954b Excavation and discovery of the Yuanshan shell mound. The. Continent Magzine 9(2):27-34.

1957 Excavation of the Yuanshan Site. Bulletin of the Department of Anthropology [Journal of Archaeology and Anthropology] 3:62.

1962 Transportation between Taiwan and the Mainland China in the prehistoric time. aipei Historical Documents Quarterly, No.2: 1-9.

Sillar, B.; M.S. Tite

2000 The Challenge of 'Technological Choices' for Materials Science Approaches in Archaeology. Archaeometry 42(1):2-20.

Schmidt-Vogt, Dietrich

1995 Swidden farming and secondary vegetation. Two case studies from northern Thailand. In Counting the costs: Economic growth and environmental change in Thailand, J. Rigg (ed.). Singapore: Institute of Southeast Asian Studies.

Shaw, Cheng-long, Ping-Mei Liew and Mong-Whay Su

1999 Subsurface Geology of Taipei Basin: the Palynological Study. Special Publication of the Central Geological Survey, No.11, pp. 145-157. Taipei: Central Geological Survey, MOEA.

Solheim, Wihelm G. II

1969 New directions in Southeast Asian prehistory. Anthropologica, N. S. Vol. 11(1): 30-44.

1988 The Nusantao hyposthesis: the origin and spread of Austronesian speakers, Asian Perspectives 26(1): 77-88.

1996 The Nusantao and north-south dispersals." Indo-Pacific Prehistory Association Bulletin 15: 101-107.

Spriggs, M.

2007 The Neolithic and Austronesian expansion within Island Southeast Asia and into the Pacific. In From Southeast Asia to the PacificArchaeological Perspectives on the Austronesian Expansion and the Lapita Cultural Complex, S. Chiu and C. Sand (eds.). Pp. 104-140. Taipei: Academia Sinica.

Spurrell, F.C.J.

1892 Notes on early sickles. Notes on Early Sickles. Archaeological Journal 49:53-59.

Stemp, W.J.

2014 A review of quantification of lithic use-wear using laser profilometry: a method based on metrology and fractal analysis. Journal of Archaeological Science 48:15-25.

Stevens, Chris J.; Dorian Q. Fuller

2017 The spread of agriculture in eastern Asia-Archaeological bases for hypothetical farmer/language dispersals. Language Dynamics and Change 7:152-186.

Su, Pin-Ju, Andrew T Lin, Jyr-Ching Hu

2015 T Upper Pleistocene to Holocene sequence stratigraphy of a sea-connected inland collapse basin: The Taipei Basin, Taiwan. L Book of 31st IAS Meeting of Sedimentology, 22-25 June, 2015, Kraków, Poland.

Sung, Wen-hsun

1952 Cultural layers of prehistoric Taiwan. Taiwan Historica Special Issue 3(3/4): 59-62. Nantou: Taiwan Historica.

1954a Production of the Yuanshan Cultural People. Taipei Cultural Relics 3(1):2-7.

1954b Departmental collection of Yuanshan stone tools (1). Bulletin of the Department of Anthropology [Journal of Archaeology and Anthropology] 4:28-38.

1955a Departmental collection of Yuanshan stone tools (2). Bulletin of the Department of Anthropology [Journal of Archaeology and Anthropology] 5:44-58.

1955b Departmental collection of Yuanshan stone tools (3). Bulletin of the Department of Anthropology [Journal of Archaeology and Anthropology] 6:34-45.

1956 Prehistoric Archaeology Work of Taiwan in Recent Years. Collection of Archives from Taipei County 2: 7-20. New Taipei City.

1964 Stone and bone tools industry of Yuanshan Shell Mound. Annual Bulletin of The China Council For East Asian Studies No.3: 56-57. Taipei: The China Council For East Asian Studies..

1965 Pottery of Yuanshan Shell Mound. Annual Bulletin of The China Council For East Asian Studies No.4: 174-177. Taipei: The China Council For East Asian Studies.

1980 Taiwan: from Archaeological perspective. Taiwan of China. Pp. 93-220. Taipei.

Sung, Wen-hsun; Kwang-chih Chang

1964 Chronology of the Yuan-Shan Culture. Bulletin of the Department of Anthropology [Journal of Archaeology and Anthropology] 23/24:1-11.

1966 Errata in the “Chronology of the Yuan-Shan Culture”. Bulletin of the

Department of Anthropology [Journal of Archaeology and Anthropology] 27:36.

Sung, Wen-hsun and Chao-mei Lien

1987 Working report of the 9th and 10th excavation of Peinan Site. Taipei: Department of Anthropology, National Taiwan University.

1988 Working report of the 11th and 13th excavation of Peinan Site. Taipei: Department of Anthropology, National Taiwan University.

Sweeney, Megan and Susan Mccouch

2007 The Complex History of the Domestication of Rice. Annals of Botany 100(5):951-7.

Tan, Chang-kuo

2007 Paiwan Zu. Taipei, Taiwan: San Min Book Co. Ltd.

Teng, Louis S.

1999a Speaking of natural environment changes in Taipei.Museology Quarterly 18(1): 4-17. Taipei: National Museum of Natural Science.

2006 Geologic Research of Taipei Basin. Western Pacific Earth Sciences, Vol. 6, pp. 1-28.

2007 Quaternary Tectonics of Taiwan. Special Publication of the Central Geological Survey, MOEA, No. 18, pp. 1-24. Taipei: Central Geological Survey, MOEA.

Teng, Louis S., C.T. Lee, Chih-Hsiung Peng, Wen-Fu Chen and Chien-Jen Chu

2001 Origin and Geological Evolution of the Taipei Basin, Northern Taiwan. Western Pacific Earth Sciences, Vol. 1, No. 2, pp. 115-142.

Teng, Louis S., P.B. Yuan, P.Y. Chen, C.H. Peng, T.C. Lai, L.Y. Fei and H.C. Liu

1999b Lithostratigraphy of Taipei Basin Deposits. Special Publication of the Central Geological Survey, No.11, pp. 41-66. Taipei: Central Geological Survey, MOEA.

Teng, Louis S., Chyi-Tyi Lee, Ping-Mei Liew, Sheng-Rong Song, Shuh-Jong Tsao, Huan-Chi Liu and Chih-Hsiung Peng

2004 On the Taipei Dammed Lake. Journal of Geographical Science, Vol. 36, pp. 77-100.

The Archaeological Team of Guangxi

1982 Excavation of a Neolithic Site at Dalongtan, Long'an, Guangxi. Kaogu 1(1982): 1-7.

The Provincial Museum of Guangdong

1983 Excavation of the Xiqiaoshan Site at Nanhai, Guangdong. Kaogu 12(1983): 1085-1091.

Tree Valley Foundation

2012 Mid-term report of Talongtong Site rescue excavation and construction monitoring plan, Taipei. Taipei: Department of Cultural Affairs.

Torii, Ryuzo

1897 Comunication: Yuanshan shell mound. The Journal of the Anthropological Society of Tokyo 19(141):116-118.

1911 Yuanshan shell mound in Taipei, Taiwan. The Journal of the Anthropological Society of Tokyo 27(1):56.

Tsai, Cheng-Hao

2009 Research of the Taiwan Rice Technology evolution (Prehistoric ~1950 ages). PhD dissertation, Department of history, National Taiwan Normal University.

Tsai, Chia-Min, Wen-Jeng Huang, Pei-Chen Chan and Shih-Ting Lu

2014 Topographic change and potential inundation hazard in the Greater Taipei area and Coulomb stress on neighboring faults induced by the reactivation of the Shanchiao fault in northern Taiwan. Special Publication of the Central Geological Survey, No.28, pp. 105-128. Taipei: Central Geological Survey, MOEA.

Tsai, Yu-Wei; Wen-Jin Lai; Wei Lo

2009 A Study on chemical composition variations of weathered andesite. Mining & Metallurgy 53(3):87-92.

Tsang, Cheng-hwa

1992 Archaeology of the P'eng-hu Islands, Special Publications, No.95. Taipei: Institute of History and Philology, Academia Sinica.

1999 Taiwan Archaeology. Taipei: Artist Publishing.

2006a Looking at Taiwan from archeology perspective. In Eleven lectures on Taiwan history. M.-C. Lee (ed.), Pp. 7-33. Taipei, Taiwan: National Museum of Hisotry.

2006b Prehistoric cultural relations between South China, Taiwan and Southeast Asia: ecological location, cultural interaction and historical process. In Archaeology in the New Century—Multicultural Interaction of

Culture, Location and Ecology. Hsu, Cho-yun and Zhongpei Zhang (eds.), Pp. 71-89. Beijing: Fobidden City Press.

2012a Once Again on the Austronesian Origin and Dispersal. Journal of Austronesian Studies 3(1):87-119.

2012b Issues Relating to the Ancient Rice and Millet Grains Unearthed from the Archaeological Sites in Tainan Science Park. Journal of Chinese Dietary Culture 8(1):1-24.

2013 New lights on the archaeological discovery of Baxiandong site, and discussion of the chronology and analogy of Palaeolithic culutre in Taiwan. In Papers from the Religion Section of the Fourth International Conference on Sinology: New Lights on East Asian Archaeology. Chen and Tsang (eds), pp. 379-416. Academia Sinica, Taipei, Taiwan.

2016 Archaeological Perspectives on the Origins of the Indigenous Peoples of Taiwan. Archaeology, History and Indigenous Peoples New Perspectives on the Ethnic Relations of Taiwan, Li-wan Hung (ed.), pp. 33-72. Taipei: Shung Ye Museum of Formosan Aborigines.

Tsang, Cheng-hwa and Kuang-ti Li

2013 Archaeological Heritage in Tainan Science Park of Taiwan. Taitung, Taiwan: National Museum of Prehistory.

Tsang, Cheng-hwa and Yi-chang Liu

2001 Rescue exavation of Shihsanhang Site and preliminary research. New Taipei City: Cultural Affairs Department.

Tsartsidou, Georgia, Simcha Lev-Yadun, Rosa-Maria Albert, Arlene Miller-Rosen, Nikos Efstratiou and Steve Weiner

2007 The phytolith archaeological record: strengths and weaknesses evaluated based on a quantitative modern reference collection from Greece. Journal of Archaeological Science 34 (8):1262-1275.

Tseng, Mei-Huei and Ping-Mei Liew

1999 A Preliminary Probe on Sporo-Pollen Assemblages and Paleoenvironments of the Recent 20 ka in Taipei Basin. Central Geological Survey Special Publication, No.11: Subsurface Geology and Engineering Environment of Taipei Basin. Pp.159-179. Taipei, Taiwan: Central Geological Survey.

Tsien, Hsien-Ho

2003 Prehistoric jade carving technology. Taipei, National Taiwan Museum.

Tsung, Yu-shuan; Wen-Lien Chen and Cheng-hwa Tsang

2017 Preliminary Research on Experimental Archaeology of Making and Using Changpin Cultural Stone Flake Tools. A poster presented to the Annual conference of Taiwan Archaeologists 2016. Taichung, Taiwan: National Museum of Natural Sciences.

Tu, Cheng-sheng

1998 Aborigine Tribal Panorama Prints (1744-1747) by Liu-Shi-Qi. Taipei, Taiwan: Academia Sinica. [番社采風圖，1744-1747]

Tumung, Laxmi; Behrouz Bazgir and Andreu Ollé

2015 Applying SEM to the study of use-wear on unmodified shell tools: an experimental approach. Journal of Archaeological Science 59:179-196.

Tykot, Robert H.

2017 A Decade of Portable (Hand-Held) X-Ray Fluorescence Spectrometer Analysis of Obsidian in the Mediterranean- Many Advantages and Few Limitation. MRS Advances 2(33/34):1769-1784.

Van Driem, George

2017 The domestications and the domesticators of Asian rice. In Language Dispersal Beyond Farming, Martine Robbeets and Alexander Savelyev (eds.), pp. 183-214. Amsterdam: John Benjamins.

Van Gijn, Annelou

2014 Science and interpretation in microwear studies. Journal of Archaeological Science 48:166-169.

Van Gijn, Annelou and Aimée Little

2016 Tools, use wear and experimentation: extracting plants from stone and bone, by Annelou van Gijn and Aimée Little. In Wild Harvest: Plants in the Hominin and Pre-Agrarian Human Worlds. Karen Hardy and Lucy Kubiak-Martens (eds.). Oxford: Oxbow books. Pp. 135-153.

Van Gijn, Annelou and Yvonne Lammers-Keijsers

2010 Toolkits for ceramic production- informal tools and the importance of high power use-wear analysis. In Bulletin de la Société préhistorique française, tome 107, n°4, pp. 755-762.

Vaughan, Patrick C.

1985 Use- Wear Analysis of Flaked Stone Tools. University of Arizona Press. Tucson.

Vieugué, Julien

2014 Use-wear analysis of prehistoric pottery: methodological contributions from the study of the earliest ceramic vessels in Bulgaria (6100e5500 BC). Journal of Archaeological Science 41:622-630.

Walker, Mike

2005 Quaternary dating methods. UK: John Wiley & Son Ltd..

Walter, R. C.

1997 Potassium-Argon/Argon-Argon Dating Methods. In Chronometric Dating in Archaeology. Advances in Archaeological and Museum Science, vol 2. R.E. Taylor and M.J. Aitken (eds). Springer, Boston, MA.

Wan, Yusheng; Kungsuan Ho; Dunyi Liu; Hongying Zhou; Chunyan Dong; Mingzhu Ma

2012 Micro-scale heterogeneity of andesite from Chilungshan, northern Taiwan: Evidence from melt inclusions, geochronology and Hf-O isotopes of zircons. Chemical Geology 328:244-258.

Wang, Chiang

1983 Speaking of the Peinan site. Man and Culture, No.18, pp.36-49.

Wang, Hsiang-Hua and Yu-Chuang Tien

2009 Swidden Agriculture and Associated Traditional Ecological Knowledge of Six Aboriginal Tribes in Taiwan. Journal of National Park, Vol.19, No.4, pp.10-20.

Wang, Kuan-wen and Caroline Jackson

2014 A review of glass compositions around the South China Sea region (the late 1st millennium BC to the 1st millennium AD): placing Iron Age glass beads from Taiwan in context. Journal of Indo-Pacific Archaeology 34:51–60.

Wang, Jerry Liang-Shing

2001 Traditional Economy of Taiwan's Aborigines before the Dutch Rule. Chung-Hsing Journal of History, Vol. 12:75-98.

Wang, Renxiang

1987 Some Questions Concerning Two-Shouldered Stone Tools in Neolithic China. Southern Ethnology and Archaeology, Vol. 1:21-35.

Wang, Xiaoqin

2005 Research on the methodology of Micro observation using marks of used stones. Agricultural Archaeology 1:176-178. Jiangxi, China: Jiangxi Academy of Social Sciences.

Wang, Ying-Hao

2007 The preliminary notes on the ancient rice grains excavated in Taiwan (Unpublished). Department of Agronomy, National Taiwan University. Taipei, Taiwan.

Wang, Ying-Hao, Cheng-yi Chu, Kuang-ti Li, Cheng-hwa Tsang, Whei-li Chu, Chuan-kun Ho, Yue-ie Hsing and Jaw-shu Hsieh

2006 Preliminary research on the ancient rice grains in Taiwan. A paper presented to the Annual Conference of Taiwan Archaeologists, 2005. Taitung, Taiwan: National Museum of Prehistory.

Wei, Kuo-Yen

2007 Quaternary Mammalian Fossils of Taiwan: An Eclectic Overview and Prospects for Future Study. Special Publication of the Central Geological Survey, MOEA, No.18, pp.261-284. Taipei, Taiwan: Central Geological Survey, MOEA.

Wicks, Karen and Steven Mithen

2014 The impact of the abrupt 8.2 ka cold event on the Mesolithic population of western Scotland: a Bayesian chronological analysis using ‘activity events’ as a population proxy. Journal of Archaeological Science 45:240-269.

Williams, Alan N.

2012 The use of summed radiocarbon probability distributions in archaeology: a review of methods. Journal of Archaeological Science 39:578-589.

William-Thorpe, Olwen

2008 The Application of Portable X-ray Fluorescence Analysis to Archaeological Lithic Provenancing. In Portable X-ray Fluorescence Spectrometry Capabilities for In Situ Analysis, Philip J. Potts and Margaret West (eds.). Pp.174-205.

Wu, Cheng-Mau; Hung-Teh Tsai; Kai-Hsing Yang and Jet-Chau Wen

2007 How Reliable is X-Ray Fluorescence (XRF) Measurement for Different

Metals in Soil Contamination. Environmental Forensics 13:110–121.

Wu, Chih-Wen

2007 Study on Variations of Growth, Grain Appearance, Amylose and Storage Proteins of Wild Rice in Taiwan. Unpublished PhD Dissertation. Department of Agronomy, National Taiwan.

Wu, Chunming

1999 Archaeological Observation for the History and Culture of Indigenous People in Southeast China. Xiamen: Xiamen University Press.

2011 Prehistoric cultural contact between the Philippines and South China. Chinese Archaeology 11: 142–147.

Wu, I-Lin

2017 Technical tradition of pottery production in eastern Taiwan: from microwear perspective. Newsletter of National Museum of Prehistory vol. 338. Available at http://beta.nmp.gov.tw/enews/no338/page_02.html

Wu, Wen-cheng

1998 The Rice. In: Rationalized fertilization of crops (rice, grains, vegetables, fruits and vegetables), Special Issue No. 2 of the Tainan Distric. Agricultural Research and Extension Station. S.-N. Huang and H.-Y. Huang, eds. Pp. 10-16. Tainan, Taiwan: the Tainan Distric Agricultural Research and Extension Station, Council of Agricultural Executive Yuan.

Wu, Xianzhu

2017 Study on Microscratch Archaeology. Beijin: Science Press.

Wu, Xianzhu; Yujie Li; Shuwen Pei and Xiujie Wu

2008 Surface marks on fossil bones at in Bailong Cave site, Yunxi, Hubei. Quaternary Sciences 28(6):1023-1033.

Wu, Xianzhu; Yunfu Wang; Shuwen Pei and Xiujie Wu

2009 Virtual three dimensions reconstruction and isoline analysis of human marks on the surface of animal fossils. Chinese Science Bulletin, Vol. 54(12):1736-1741.

Xie, Liye; Steven L. Kuhn; Guoping Sun; John W. Olsen; Yunfei Zheng; Pin Ding; and Ye Zhao

2015 Labor Costs for Prehistoric Earthwork Construction- Experimental and Archaeological Insights from the Lower Yangzi Basin, China. American Antiquity 80(1):67-88.

Xie, Liye; Xuejiao Lu; Guoping Sun; Weijin Huang

2017 Functionality and Morphology: Identifying Si Agricultural Tools from Among Hemudu Scapular Implements in Eastern China. Journal of Archaeological Method and Theory 24:377-423.

Yang, Feng-ping

1997 The Inheritance and Changes of Fengpitou site during its early and the late stage: A Case Study of Pottery (Unpublished). Department of Anthropology, National Taiwan University.

Yang, Nanjun

2012 Travelling around the aboriginal tribes: the adventure of Ushinosuke Mori. Taipei: Yuan-Liou Publishing Co. Ltd.

Yang, Shiting

2007 Important discoveries at the prehistoric of Hedang in Foshan. Lingnan Wenwu 3: 25-31.

Yang, Shu-ling

1997 Jade artefacts unearthed at the Peinan site. Taitung, Taiwan: the National Museum of Prehistory.

Yang, Xiaoyan; Z. Ma, Quan Li, Linda Perry, Xiujia Huan, Zhiwei Wan, M. Li, Jingyun Zheng

2014 Experiments with Lithic Tools: Understanding Starch Residues from Crop Harvesting. Archaeometry 56 (5): 828-840.

Yang, Yi-min; Yi Guo, Yao-ting Xie, Ji Xia, Chang-sui Wang

2008 Microwear analysis by digital microscopy of Turquoise from Peng Nation Tombs, West Zhou Dynasty. Sciences of Conservation and Archaeology 20(1):46-49.

Yao, Shao-Ji

2018 Wilhelm Joest's Stay on Formosa in 1880: Introduction, his Collection of Formosan Heritage and Translation of his Travel Memories. Taipei: National Museum of Taiwan History.

Yeh, Mei-chen

2001 Research on Huakangshan Culture. Taitung: National Museum of Prehistory.

Yin, Yi-Chih

2008 Prehistoric Taiwan Jade Industry: A Case Study at the Ping-Lin Site

(Unpublished). Taipei, Taiwan: Department of Anthropology, National Taiwan University.

Yu-fu

2017 A world of Tea Merchants in Dadaocheng. Taipei Pictorial, No. 596, Pp.58-59. Department of Information and Tourism, Taipei City Government. Available at https://www.travel.taipei/zh-tw/featured/details/11587

Yoneda, M.; Atsushi Suzuki; Yasuyuki Shibata; Masatoshi Morita;Kazuhiro Uzawa; Masashi Hirota and Masao Uchida

2002 Radiocarbon Marine Reservoir Effect in Human Remains from the Kitakogane Site, Hokkaido, Japan. Journal of Archaeological Science 29 (5):529-536

Yoneda, M,; Hikaru Uno; Yasuyuki Shibata; Ryo Suzuki; Yuichiro Kumamoto; Kunio Yoshida; Takenori Ssaki; Atsushi Suzuki and Hodaka Kawahata

2007 Radiocarbon marine reservoir ages in the western Pacific estimated by pre-bomb molluscan shells. Nuclear Instruments and Methods in Physics Research B 259 (1):432-437.

Yoneda, Minoru; Kikaru Uno; Yasuyuki Shibata; Ryo Suzuki; Yuichiro Kumamoto; Kunio Yoshida; Takenori Sasaki; Atsushi Suzuki; Hodaka Kawahata

2017 Radiocarbon marine reservoir ages in the western Pacific estimated by pre-bomb molluscan shells. Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms 259(1):432-437.

Yoshida, Shouichi

1994 Fundamentals of Rice Crop Science. Tokyo: Hakubunkan Shinsha Publishers, Ltd.

Zeder, Melinda A.

2015 Core questions in domestication research. Proceedings of the National Academy of Sciences of the United States of America, 112 (11):3191-98.

Zeng, Zhigang; Chen-Tung A. Chen; Xuebo Yin; Xueying Zhang; Xiaoyuan Wang; Guoliang Zhang; Xiaomei Wang; Daigeng Chen

2011 Origin of native sulfur ball from the Kueishantao hydrothermal field offshore northeast Taiwan: Evidence from trace and rare earth element composition. Journal of Asian Earth Sciences 40(2):661-671.

Zhai, Shaodong

2015 Replication Experiments on Lithic Products from the Taosi Site Including Analysis of Production Techniques for Ground Stone Tools. Acta Anthropologica Sinica, Vol.34, No.2, pp.192-201.

Zhong, Liqiang

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Appendix 1. Names of archaeological sites found shouldered axes and ordered alphabetically by using official spelling with the Traditional Chinese in this thesis.

Name in characters	Name in official spelling	Name in pinyin
斬龍山	Chanlungshan	Zhanlongshan
劍潭	Chientang	Jiantan
芝山岩	Chihshanyen	Zhishanyan
植物園	Chihwuyuan	Zhiwuyuan
清水	Chinshui	Qingshui
狗蹄山	Chiuchashan	Goutishan
竹山神社	Chushan	Zhushan Shenshe
鳳鼻頭	Fengpitou	Fengbitou
鵠尾山	Huweishan	Guweishan
關渡	Kuantu	Guandu
南關里	Nankuanli	Nanguanli
雙龍社	Shaunlungshe	Shuanglongshe
十八份	Shihpafen	Shibafen
潭頭	Tantou	Tantou
大坌坑	Tapenkeng	Dabenkeng
大埔	Tapu	Dabu
圓山	Yuanshan	Yuanshan
員山子	Yuanshantzu	Yuanshanzi
忠義山	Zhongyishan	Zhongyishan

Appendix 2. Attributes data of 325 shouldered axes.

Code	Site	Mateiral	Modification Method	Shouldered	Symmetry of Shoulder	Amount of Shoulder	Condition of Shoulder	Type of Shoulder	Condition of Edge	Possible Function	Preservation Condition
ZLS-001	Chanlungshan	Meta Sandstone	Peck Grind	uncertain	no	0	Fair	2	Poor	Axe-Hoe	Good
ZLS-002	Chanlungshan	Andesite	Grind	yes	yes	4	Fair	2	Good	Axe-Hoe	Good
ZLS-003	Chanlungshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
ZLS-004	Chanlungshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
ZLS-005	Chanlungshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
ZLS-006	Chanlungshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
ZLS-007	Chanlungshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
ZLS-008	Chanlungshan	Andesite	Grind	uncertain	no	0	Poor	2	Good	Axe-Hoe	Good
ZLS-009	Chanlungshan	Sandstone	Peck Grind Fine Polished	uncertain	no	0	Poor	2	Fair	Axe-Hoe	Poor
ZLS-010	Chanlungshan	Andesite	Grind	no	uncertain	0	Poor	7	Fair	Suspected Axe-Hoe	Poor
ZLS-011	Chanlungshan	Sandstone	Grind with Fine Polished	yes	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Poor
ZLS-012	Chanlungshan	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Poor
CT-001	Chientan	Basalt	Peck Grind	uncertain	no	2	Fair	2	Fair	Axe-Hoe	Poor
CSY-001	Chihshanyen	Andesite	Peck	uncertain	uncertain	1	Poor	2	Good	Axe-Hoe	Poor
NMP-20011000317	Chihshanyen	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Fair
NMP-20011000318	Chihshanyen	Andesite	Grind with Fine Polished	yes	yes	2	Good	1	Good	Axe-Hoe	Fair
NMP-20011000319	Chihshanyen	Andesite	Grind with Fine Polished	yes	yes	2	Fair	1	Fair	Axe-Hoe	Fair
NMP-20011000322	Chihshanyen	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Fair
NMP-20011000324	Chihshanyen	Sandstone	Grind	yes	no	2	Good	2	Fair	Axe-Hoe	Fair
NMP-20011000381	Chihshanyen	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Fair
NMP-20011000386	Chihshanyen	Andesite	Grind	yes	yes	2	Good	2	Fair	Axe-Hoe	Fair
NMP-20011000401	Chihshanyen	Andesite	Grind	yes	uncertain	1	Poor	3	Poor	Suspected Axe-Hoe	Fair
NMP-20011000414	Chihshanyen	Andesite	Grind	yes	uncertain	1	Poor	7	Poor	Suspected Axe-Hoe	Fair
NMP-20011000415	Chihshanyen	Andesite	Grind	yes	no	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NMP-20011000416	Chihshanyen	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000421	Chihshanyen	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000423	Chihshanyen	Andesite	Grind	yes	uncertain	0	Poor	7	Poor	Axe-Hoe	Fair
NMP-20011000425	Chihshanyen	Andesite	Grind	yes	yes	2	Poor	1	Poor	Suspected Axe-Hoe	Fair
NMP-20011000426	Chihshanyen	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000427	Chihshanyen	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000428	Chihshanyen	Andesite	Grind with Fine Polished	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000429	Chihshanyen	Andesite	Grind	yes	yes	2	Fair	1	Good	Axe-Hoe	Fair
NMP-20011000430	Chihshanyen	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000431	Chihshanyen	Sandstone	Grind	yes	no	2	Fair	4	Good	Axe-Hoe	Fair
NMP-20011000432	Chihshanyen	Andesite	Grind	yes	yes	2	Poor	2	Good	Axe-Hoe	Fair
NMP-20011000433	Chihshanyen	Andesite	Grind	yes	yes	2	Poor	2	Good	Axe-Hoe	Fair

NMP-20011000435	Chihshanyen	Sandstone	Peck Grind	uncertain	uncertain	0	Poor	7	Poor	Suspected Axe-Hoe	Fair
NMP-20011000437	Chihshanyen	Andesite	Grind	yes	uncertain	1	Poor	2	Fair	Axe-Hoe	Fair
NMP-20011000451	Chihshanyen	Andesite	Grind	uncertain	uncertain	0	Poor	2	Poor	Axe-Hoe	Fair
NMP-20011000468	Chihshanyen	Andesite	Grind	uncertain	uncertain	0	Poor	7	Poor	Suspected Axe-Hoe	Fair
NMP-20011000479	Chihshanyen	Andesite	Grind	yes	uncertain	1	Poor	7	Good	Axe-Hoe	Fair
NMP-20011000480	Chihshanyen	Andesite	Grind	yes	no	2	Fair	4	Poor	Suspected Axe-Hoe	Fair
NMP-20011000481	Chihshanyen	Andesite	Grind	yes	no	2	Fair	6	Poor	Suspected Axe-Hoe	Poor
NMP-20011000482	Chihshanyen	Andesite	Grind	yes	uncertain	1	Poor	7	Poor	Suspected Axe-Hoe	Fair
NMP-20011000484	Chihshanyen	Andesite	Grind	yes	no	2	Poor	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000485	Chihshanyen	Andesite	Grind	yes	yes	2	Poor	2	Poor	Suspected Axe-Hoe	Poor
NMP-20011000486	Chihshanyen	Andesite	Grind	yes	no	2	Poor	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000668	Chihshanyen	Andesite	Grind	yes	no	2	Poor	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000681	Chihshanyen	Andesite	Peck	uncertain	no	0	Poor	2	Good	Axe-Hoe	Fair
NMP-20011000316	Chihshanyen	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Fair
NMP-20011000327	Chihshanyen	Andesite	Grind	no	uncertain	0	Poor	7	Good	Axe-Hoe	Fair
NMP-20011000342	Chihshanyen	Sandstone	Raw rock	uncertain	uncertain	2	Fair	2	Poor	Axe-Hoe	Fair
NMP-20011000418	Chihshanyen	Sandstone	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20011000460	Chihshanyen	Sandstone	Peck Grind	yes	uncertain	2	Poor	2	Poor	Axe-Hoe	Fair
NMP-20011000483	Chihshanyen	Andesite	Grind	no	uncertain	0	Poor	2	Poor	Suspected Axe-Hoe	Poor
NMP-20011000508	Chihshanyen	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NTU-C08g_TP5L5	Chihshanyen	Andesite	Grind	yes	no	2	Fair	1	Poor	Suspected Axe-Hoe	Fair
NTU-C08g_01	Chihshanyen	Andesite	Grind	yes	yes	2	Fair	2	Fair	Axe-Hoe	Fair
NTU-C08g_02	Chihshanyen	Andesite	Grind	yes	no	1	Fair	7	Fair	Axe-Hoe	Fair
CWY-001	Chihwuyuan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
CWY-002	Chihwuyuan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0516	Chinshui	QuartzSandstone	Grind	yes	yes	2	Fair	4	Good	Axe-Hoe	Good
NMP-20041500732	Chiuchashan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NTU-A5189	Chungho Chienshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NTU-KN0604	Chushan	TuffSandstone	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Fair
NTU-1597	Dazhi Taiepi	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NMP-20041701137	Fengpitou	Sandstone	Peck Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20041701145	Fengpitou	OlivineBasalt	Grind with Fine Polished	yes	uncertain	2	Fair	2	Poor	Axe-Hoe	Fair
NMP-20041500306	Huweishan	MetaSandstone	Peck	uncertain	uncertain	0	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20041500315	Huweishan	MetaSandstone	Peck	yes	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Fair
NMP-20041500323	Huweishan	MetaSandstone	Peck	uncertain	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010800202	Kuantu	Andesite	Grind	yes	yes	2	Fair	7	Good	Axe-Hoe	Fair

NMP-20010800203	Kuantu	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010800204	Kuantu	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010800205	Kuantu	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010800206	Kuantu	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010800207	Kuantu	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010800208	Kuantu	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20041500623	Kuantu	Andesite	Grind	uncertain	no	0	Fair	2	Good	Axe-Hoe	Fair
NMP-20041500648	Kuantu	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010800069	Kuantu	Andesite	Grind	yes	yes	2	Good	2	Fair	Axe-Hoe	Fair
NMP-20010800062	Kuantu	Andesite	Grind	uncertain	uncertain	0	Fair	2	Poor	Axe-Hoe	Fair
NMP-20010800063	Kuantu	Andesite	Grind	uncertain	uncertain	0	Fair	2	Good	Axe-Hoe	Fair
NMP-20010800065	Kuantu	Andesite	Grind	uncertain	uncertain	0	Fair	2	Fair	Axe-Hoe	Fair
NMP-20010800071	Kuantu	Andesite	Grind	uncertain	uncertain	0	Poor	2	Fair	Axe-Hoe	Fair
NMP-20010800083	Kuantu	Andesite	Grind	uncertain	uncertain	0	Poor	2	Poor	Axe-Hoe	Fair
NMP-20010800088	Kuantu	Andesite	Grind	uncertain	uncertain	0	Fair	2	Poor	Axe-Hoe	Fair
NMP-20010900113	Kuantu	Andesite	Grind	no	uncertain	0	Poor	7	Good	Axe-Hoe	Fair
NTU-KN0555	Kuantu	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Good
NMP-STSP-NKL01	Nankuanli	OlivineBasalt	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Good
NMP-STSP-NKL02	Nankuanli	OlivineBasalt	Grind	yes	yes	2	Fair	1	Fair	Axe-Hoe	Fair
NTU-4000	Shaunlungshe	Serpentine	Peck Grind	yes	yes	2	Fair	2	Fair	Axe-Hoe	Fair
NMP-20041500002	Shihpafen	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NMP-20041500031	Shihpafen	Andesite	Grind	yes	yes	2	Poor	2	Fair	Axe-Hoe	Good
NMP-20041500034	Shihpafen	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Poor
NTU-KN0519	Tantou	Andesite	Grind	yes	yes	2	Fair	2	Fair	Axe-Hoe	Good
NMP-20010700140	Tapenkeng	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NMP-20010700144	Tapenkeng	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Fair
NMP-20010700145	Tapenkeng	Andesite	Grind	yes	yes	4	Good	2	Fair	Axe-Hoe	Fair
NMP-20010700148	Tapenkeng	Andesite	Grind	yes	uncertain	2	Poor	7	Good	Axe-Hoe	Fair
NMP-20041500120	Tapenkeng	Andesite	Grind	yes	uncertain	1	Fair	1	Poor	Suspected Axe-Hoe	Fair
NMP-20010700101	Tapenkeng	Andesite	Grind	yes	uncertain	2	Fair	2	Good	Axe-Hoe	Fair
NMP-20010700127	Tapenkeng	Andesite	Grind	uncertain	no	1	Poor	2	Good	Axe-Hoe	Fair
NMP-20010700141	Tapenkeng	Andesite	Grind	uncertain	uncertain	2	Fair	7	Poor	Suspected Axe-Hoe	Poor
NMP-20010700142	Tapenkeng	Andesite	Grind	yes	no	2	Good	3	Poor	Suspected Axe-Hoe	Fair
NMP-20010700143	Tapenkeng	Andesite	Grind	yes	uncertain	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NMP-20010700146	Tapenkeng	Argillite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Fair
NMP-20010700147	Tapenkeng	Sandstone	Peck Grind	uncertain	uncertain	2	Poor	2	Poor	Axe-Hoe	Fair
NMP-20010700149	Tapenkeng	Andesite	Grind	yes	uncertain	2	Poor	2	Poor	Suspected Axe-Hoe	Poor
NMP-20041700374	Tapu	TuffSandstone	Grind	yes	no	2	Poor	2	Poor	Suspected Axe-Hoe	Fair

NTU-T002	Unknown Site	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-T003	Unknown Site	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-T004	Unknown Site	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-T005	Unknown Site	Andesite	Grind	yes	uncertain	2	Fair	2	Good	Axe-Hoe	Fair
NTU-404-1	Unknown Site	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-404-2	Unknown Site	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-404-3	Unknown Site	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NTU-404-22	Unknown Site	Andesite	Grind	yes	yes	2	Good	1	Fair	Axe-Hoe	Good
NTU-T001	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-T006	Yuanshan	Andesite	Grind	yes	yes	2	Fair	1	Poor	Suspected Axe-Hoe	Poor
NTU-T007	Yuanshan	Andesite	Peck Grind	yes	no	2	Good	2	Good	Axe-Hoe	Good
NTU-T008	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NTU-T009	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Suspected Axe-Hoe	Good
NTU-T010	Yuanshan	Andesite	Grind	yes	yes	2	Fair	1	Good	Axe-Hoe	Fair
NTU-T011	Yuanshan	Argillite	Grind	uncertain	yes	2	Fair	1	Good	uncertain	Good
NTU-T012	Yuanshan	Possible Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NTU-T013	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	1	Poor	Suspected Axe-Hoe	Poor
NTU-T014	Yuanshan	Andesite	Grind	yes	uncertain	1	Fair	2	Poor	Suspected Axe-Hoe	Poor
NTU-T015	Yuanshan	Andesite	Grind	yes	yes	2	Good	4	Poor	Suspected Axe-Hoe	Fair
NTU-T016	Yuanshan	Schist	Grind	uncertain	yes	2	Fair	7	Poor	uncertain	Fair
NTU-T017	Yuanshan	Andesite	Grind	yes	uncertain	1	Fair	2	Poor	Suspected Axe-Hoe	Poor
NTU-T018	Yuanshan	Andesite	Grind	yes	uncertain	2	Poor	3	Poor	Suspected Axe-Hoe	Poor
NTU-T019	Yuanshan	Andesite	Grind	yes	uncertain	2	Poor	7	Poor	Suspected Axe-Hoe	Poor
NTU-T020	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Poor
NTU-T021	Yuanshan	Andesite	Grind	yes	uncertain	2	Poor	7	Poor	Suspected Axe-Hoe	Poor
NTU-T022	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Poor
NTU-T023	Yuanshan	Andesite	Grind	yes	uncertain	2	Poor	2	Poor	Suspected Axe-Hoe	Poor
NTU-T024	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-T025	Yuanshan	Possible Andesite	Grind	uncertain	uncertain	1	Fair	2	Poor	uncertain	Poor
NTU-T026	Yuanshan	Andesite	Grind	yes	uncertain	2	Poor	2	Poor	Suspected Axe-Hoe	Fair
NTU-T027	Yuanshan	Possible Andesite	Grind	yes	yes	2	Fair	7	Poor	Suspected Axe-Hoe	Fair
NTU-T028	Yuanshan	Andesite	Grind	yes	uncertain	1	Fair	5	Good	Axe-Hoe	Fair

NTU-YS-87-019	Yuanshan	Andesite	Grind with Fine Polished	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Poor
NTU-YS-88-1093	Yuanshan	Andesite	Grind with Fine Polished	uncertain	yes	2	Fair	2	Good	Suspected Axe-Hoe	Fair
NTU-YS-87-112	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Poor
NTU-1399-13	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	7	Poor	Suspected Axe-Hoe	Fair
NTU-1984-40	Yuanshan	Andesite	Grind	yes	yes	2	Fair	7	Poor	Suspected Axe-Hoe	Fair
NTU-1984-27	Yuanshan	Andesite	Peck Grind	no	yes	0	Poor	7	Good	Axe-Hoe	Good
NTU-1984-28	Yuanshan	Andesite	Grind	uncertain	no	1	Fair	2	Good	Suspected Axe-Hoe	Fair
NTU-1984-30	Yuanshan	Andesite	Grind	yes	uncertain	1	Fair	2	Poor	Suspected Axe-Hoe	Fair
NTU-1984-34	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NTU-1984-35	Yuanshan	MetaSandstone	Grind with Fine Polished	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NTU-1984-36	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NTU-1984-37	Yuanshan	Andesite	Grind	uncertain	yes	2	Fair	2	Good	Suspected Axe-Hoe	Good
NTU-1984-39	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NTU-1984-42	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Fair
NTU-3082	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-3529-1	Yuanshan	Andesite	Grind	yes	yes	2	Fair	1	Poor	Suspected Axe-Hoe	Fair
NTU-3529-3	Yuanshan	Andesite	Grind	yes	uncertain	2	Poor	1	Poor	Suspected Axe-Hoe	Poor
NTU-3529-2	Yuanshan	Andesite	Grind	yes	uncertain	1	Fair	1	Poor	Suspected Axe-Hoe	Fair
NTU-3529-4	Yuanshan	Andesite	Grind	uncertain	uncertain	0	Fair	2	Good	Axe-Hoe	Good
NTU-3530-5	Yuanshan	Andesite	Grind	yes	yes	2	Poor	3	Poor	Suspected Axe-Hoe	Fair
NTU-3539-1	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NTU-3539-2	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Poor
NTU-3539-3	Yuanshan	Andesite	Grind	yes	yes	2	Fair	3	Poor	Suspected Axe-Hoe	Fair
NTU-3539-4	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Poor
NTU-3539-7	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Fair
NTU-3539-9	Yuanshan	Andesite	Grind	yes	uncertain	2	Poor	2	Poor	Suspected Axe-Hoe	Fair
NTU-3542-19	Yuanshan	Andesite	Grind	yes	yes	2	Poor	1	Poor	Suspected Axe-Hoe	Fair
NTU-3542-30	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Poor
NTU-3543-1	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	3	Poor	Suspected Axe-Hoe	Poor
NTU-3819-4	Yuanshan	Andesite	Grind	uncertain	no	2	Fair	2	Poor	uncertain	Poor

NTU-3820-3	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NTU-3820-4	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Fair
NTU-3823-25	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Fair
NTU-3823-27	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Fair
NTU-3823-28	Yuanshan	Andesite	Grind	yes	uncertain	2	Poor	2	Poor	Suspected Axe-Hoe	Fair
NTU-3823-30	Yuanshan	Andesite	Grind	no	uncertain	0	Poor	7	Good	Axe-Hoe	Fair
NTU-3823-41	Yuanshan	MetaSandstone	Grind with Fine Polished	no	uncertain	0	Poor	7	Poor	Axe-Hoe	Fair
NTU-3823-50	Yuanshan	Andesite	Grind	uncertain	uncertain	0	Good	2	Fair	Axe-Hoe	Good
NTU-3823-69	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	3	Poor	Suspected Axe-Hoe	Poor
NTU-3823-72	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-3825-3	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-3826-5	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NTU-YS-33-670	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NTU-72	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NTU-A5548	Yuanshan	Andesite	Grind	uncertain	yes	2	Poor	7	Fair	Axe-Hoe	Fair
NTU-YS-87-SC-5	Yuanshan	Andesite	Grind	yes	yes	2	Fair	1	Fair	Axe-Hoe	Fair
NTU-1029	Yuanshan	Andesite	Grind	yes	uncertain	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
IOE-00112	Yuanshan	Andesite	Grind with Fine Polished	yes	yes	2	Good	1	Good	Axe-Hoe	Good
IOE-00113	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
IOE-00114	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
IOE-00115	Yuanshan	Andesite	Grind	yes	yes	1	Fair	2	Good	Axe-Hoe	Good
IOE-00116	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Fair	Axe-Hoe	Good
IOE-00117	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
IOE-00118	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00119	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00120	Yuanshan	Andesite	Grind	yes	yes	2	Good	3	Good	Axe-Hoe	Good
IOE-00121	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
IOE-00122	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00123	Yuanshan	Andesite	Grind	yes	yes	2	Good	7	Good	Adze	Good
IOE-00124	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00125	Yuanshan	Andesite	Grind	yes	yes	2	Good	7	Good	Axe-Hoe	Good
IOE-00126	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
IOE-00127	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00128	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
IOE-00129	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00130	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00131	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00132	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Good
IOE-00133	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00134	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
IOE-00135	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Good
NMP-20010900136	Yuanshan	Andesite	Grind with Fine Polished	yes	yes	2	Fair	2	Good	Axe-Hoe	Fair
NMP-20010900145	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Fair	Axe-Hoe	Fair

NMP-20010900146	Yuanshan	Andesite	Grind with Fine Polished	yes	yes	2	Poor	7	Poor	Suspected Axe-Hoe	Poor
NMP-20010900148	Yuanshan	Andesite	Grind	yes	no	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010900149	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010900150	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Fair
NMP-20010900151	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010900153	Yuanshan	Possible Andesite	Grind with Fine Polished	yes	uncertain	1	Fair	1	Poor	Axe-Hoe	Fair
NMP-20010900160	Yuanshan	Andesite	Grind with Fine Polished	yes	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Poor
NMP-20010900170	Yuanshan	Andesite	Grind with Fine Polished	yes	uncertain	1	Poor	7	Poor	Suspected Axe-Hoe	Poor
NMP-20010900185	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	1	Poor	Axe-Hoe	Fair
NMP-20010900214	Yuanshan	Possible Andesite	Grind with Fine Polished	yes	uncertain	1	Poor	2	Poor	Axe-Hoe	Fair
NMP-20010900215	Yuanshan	Andesite	Grind with Fine Polished	yes	no	4	Good	4	Poor	Suspected Axe-Hoe	Fair
NMP-20010900217	Yuanshan	Andesite	Grind with Fine Polished	yes	no	2	Good	3	Poor	Suspected Axe-Hoe	Fair
NMP-20010900218	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010900219	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010900223	Yuanshan	Possible Andesite	Grind with Fine Polished	yes	yes	2	Fair	7	Poor	Axe-Hoe	Fair
NMP-20010900300	Yuanshan	Andesite	Grind with Fine Polished	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NMP-20010900301	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NMP-20010900120	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	7	Poor	Suspected Axe-Hoe	Poor
NMP-20010900124	Yuanshan	Andesite	Grind	no	uncertain	0	Poor	7	Good	Axe-Hoe	Fair
NMP-20010900128	Yuanshan	Andesite	Grind	no	uncertain	0	Poor	7	Good	Axe-Hoe	Fair
NMP-20010900143	Yuanshan	Andesite	Grind	yes	yes	2	Fair	7	Poor	Suspected Axe-Hoe	Fair
NMP-20010900147	Yuanshan	Andesite	Grind	yes	no	2	Good	3	Poor	Suspected Axe-Hoe	Fair
NMP-20010900152	Yuanshan	Andesite	Grind	yes	yes	2	Good	7	Fair	Suspected Axe-Hoe	Fair
NMP-20010900192	Yuanshan	Andesite	Grind	yes	yes	1	Poor	2	Poor	Suspected Axe-Hoe	Fair
NMP-20010900222	Yuanshan	Andesite	Grind	uncertain	uncertain	0	Poor	2	Poor	Axe-Hoe	Fair
NTU-G01j_004	Yuanshan	Slate	Grind	yes	yes	2	Good	4	Good	Axe-Hoe	Good
NTU-KN0246	Yuanshan	Slate	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NTU-KN0247	Yuanshan	Slate	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NTU-KN0248	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0249	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Poor
NTU-KN0250	Yuanshan	MetaSandstone	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Good
NTU-KN0251	Yuanshan	Andesite	Peck Grind	uncertain	yes	2	Fair	2	Good	Axe-Hoe	Fair
NTU-KN0252	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0253	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0254	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0255	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Good

NTU-KN0256	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NTU-KN0257	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0258	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Fair
NTU-KN0259	Yuanshan	Andesite	Grind	yes	no	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0260	Yuanshan	Andesite	Grind	yes	no	2	Fair	2	Good	Axe-Hoe	Good
NTU-KN0261	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0262	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Fair	Axe-Hoe	Good
NTU-KN0263	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0264	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0265	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Fair	Axe-Hoe	Fair
NTU-KN0266	Yuanshan	Andesite	Grind	uncertain	yes	2	Good	2	Fair	Axe-Hoe	Good
NTU-KN0267	Yuanshan	Schist	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NTU-KN0268	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0269	Yuanshan	HardShale	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Good
NTU-KN0270	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Suspected Axe-Hoe	Good
NTU-KN0271	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Fair
NTU-KN0272	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Fair	Axe-Hoe	Fair
NTU-KN0273	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Fair	Axe-Hoe	Fair
NTU-KN0274	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NTU-KN0275	Yuanshan	Slate	Grind	yes	no	2	Good	2	Good	Axe-Hoe	Good
NTU-KN0276	Yuanshan	Andesite	Peck Grind	yes	yes	2	Good	2	Good	Knife	Poor
NTU-KN0277	Yuanshan	Andesite	Grind	yes	no	2	Good	1	Good	Axe-Hoe	Fair
NTU-KN0278	Yuanshan	Andesite	Grind	yes	no	2	Good	2	Good	Axe-Hoe	Fair
NTU-KN0279	Yuanshan	Andesite	Peck Grind	yes	uncertain	1	Poor	2	Poor	Axe-Hoe	Fair
NTU-KN0280	Yuanshan	Andesite	Peck Grind	yes	yes	4	Good	1	Fair	Axe-Hoe	Fair
NTU-KN0281	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Fair	Axe-Hoe	Fair
NTU-KN0282	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Fair	Axe-Hoe	Fair
NTU-KN0283	Yuanshan	Slate	Grind	yes	no	2	Good	1	Fair	Axe-Hoe	Fair
NTU-KN0284	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Fair	Axe-Hoe	Fair
NTU-KN0285	Yuanshan	Andesite	Grind	yes	no	2	Good	2	Good	Axe-Hoe	Poor
NTU-KN0286	Yuanshan	Basalt？	Peck Grind	yes	yes	2	Good	2	Fair	Axe-Hoe	Fair
NTU-KN0287	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Axe-Hoe	Poor
NTU-KN0288	Yuanshan	Andesite	Grind	yes	no	2	Good	3	Fair	Axe-Hoe	Fair
NTU-KN0289	Yuanshan	Andesite	Grind	yes	yes	2	Good	3	Poor	Suspected Axe-Hoe	Poor
NTU-KN0290	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Axe-Hoe	Poor
NTU-KN0291	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Axe-Hoe	Poor
NTU-KN0292	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Axe-Hoe	Poor
NTU-KN0293	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Axe-Hoe	Poor
NTU-KN0294	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Fair	Axe-Hoe	Poor
NTU-KN0295	Yuanshan	Andesite	Grind	yes	no	3	Fair	7	Fair	Axe-Hoe	Poor
NTU-KN0296	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Good	Axe-Hoe	Poor
NTU-KN0297	Yuanshan	Andesite	Grind	yes	yes	2	Good	4	Good	Axe-Hoe	Poor
NTU-KN0298	Yuanshan	Andesite	Grind	yes	no	2	Good	1	Fair	Axe-Hoe	Poor
NTU-KN0299	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	1	Poor	Suspected Axe-Hoe	Poor
NTU-KN0300	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Poor
NTU-KN0301	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Suspected Axe-Hoe	Good
NTU-G03b_017_01	Yuanshan	Andesite	Grind	yes	yes	2	Good	4	Fair	Axe-Hoe	Poor
NTU-G03b_017_02	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Fair
NTU-G03b_017_03	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Fair
NTU-G03b_017_04	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Good	Axe-Hoe	Fair
NTU-G03b_007_01	Yuanshan	Andesite	Grind	uncertain	yes	2	Poor	1	Poor	Suspected Axe-Hoe	Poor

NTU-G03b_007_02	Yuanshan	Andesite	Grind	uncertain	uncertain	0	Poor	7	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_03	Yuanshan	Andesite	Grind	yes	uncertain	2	Poor	7	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_04	Yuanshan	Andesite	Grind	uncertain	uncertain	0	Poor	7	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_05	Yuanshan	Andesite	Grind	yes	uncertain	1	Poor	7	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_06	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_07	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_08	Yuanshan	Andesite	Grind	yes	no	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_09	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_10	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_11	Yuanshan	Andesite	Grind	yes	yes	2	Good	1	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_12	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_13	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_14	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_15	Yuanshan	Andesite	Grind	yes	no	2	Good	2	Poor	Suspected Axe-Hoe	Poor
NTU-G03b_007_16	Yuanshan	Slate	Grind	yes	no	2	Good	2	Fair	Axe-Hoe	Fair
NTU-G03b_007_17	Yuanshan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Fair
NTU-G03b_007_18	Yuanshan	Andesite	Grind	yes	yes	2	Fair	2	Poor	Axe-Hoe	Poor
NTU-G03b_007_19	Yuanshan	Andesite	Grind	yes	no	2	Good	3	Poor	Suspected Axe-Hoe	Poor
NTU-3821-7	Yuanshan or Chientan	Andesite	Grind	yes	yes	2	Good	2	Good	Axe-Hoe	Good
NMP-20041500225	Yuanshantzu	Andesite	Grind	yes	uncertain	1	Poor	2	Poor	Suspected Axe-Hoe	Fair
NMP-20041500226	Yuanshantzu	Sandstone	Peck	uncertain	uncertain	0	Fair	2	Good	Suspected Axe-Hoe	Good
NMP-20041500397	Zhongyishan	Andesite	Grind	yes	yes	2	Fair	2	Poor	Suspected Axe-Hoe	Fair
NMP-20041500398	Zhongyishan	Andesite	Grind	yes	uncertain	1	Poor	7	Good	Suspected Axe-Hoe	Good

Appendix 3. Measurement data of 325 shouldered axes.

Code	Length	Width	Thickness (Height)	Weight	Shoulder Height	Shoulder Width	Shoulder Length	Shoulder Angle A	Shoulder Angle B	Edge Height	Edge Width	Edge Length	Edge Angle A	Edge Angle B
ZLS-001	117.47	95.56	24.6	406.45	3.4	2.95	4.5	49.1	40.9	0	0	0	0	0
ZLS-002	100.18	82.54	13.19	145.5	6.9	4.8	8.41	55.2	34.8	18.9	41.25	45.4	24.6	65.4
ZLS-003	86.96	47.7	9.03	57.65	6.4	3.8	7.44	59.3	30.7	9	23.8	25.4	20.7	69.3
ZLS-004	67.04	70.66	9.87	44.2	12.1	16.8	20.7	35.8	54.2	17.3	33.7	37.9	27.2	62.8
ZLS-005	79.65	61.57	12.93	83.7	3.4	6.2	7.07	28.7	61.3	17	30.75	35.1	28.9	61.1
ZLS-006	89.05	58.25	12.21	84.3	6.5	10.6	12.4	31.5	58.5	12.2	28.75	31.2	23	67
ZLS-007	79.82	50.9	9.88	54.4	2.8	8.3	8.76	18.6	71.4	11.2	24.75	27.2	24.3	65.7
ZLS-008	121.67	89.87	21.03	332.7	20.9	5.85	21.7	74.4	15.6	30.7	44.25	53.9	34.8	55.2
ZLS-009	109.78	84.06	24.62	285.1	12.2	3.85	12.8	72.5	17.5	15.7	41.95	44.8	20.5	69.5
ZLS-010	72.35	105.82	19.85	185.35	0	0	0	0	0	0	0	0	0	0
ZLS-011	76.81	54.05	11.95	55.9	6.9	7.6	10.3	42.2	47.8	0	0	0	0	0
ZLS-012	55.87	44.94	10.35	32.8	12.6	3.9	13.2	72.8	17.2	0	0	0	0	0
CT-001	106.98	83.24	19.68	234.4	15.7	11.3	19.3	54.3	35.7	0	0	0	0	0
CSY-001	119.98	81.42	15.87	247	2.6	5.2	5.81	26.6	63.4	19.8	40.05	44.7	26.3	63.7
NMP-20011000317	82	67.1	6.8	48	13.5	14.6	19.9	42.8	47.2	14.7	33.5	36.6	23.7	66.3
NMP-20011000318	104.2	54.9	12.6	90.5	1.7	5.5	5.76	17.2	72.8	15.3	27.3	31.3	29.3	60.7
NMP-20011000319	103.5	68.6	10	93	7.8	9.35	12.2	39.8	50.2	17.6	28.2	33.2	32	58
NMP-20011000322	137.5	87.4	26.4	486	14.6	8.35	16.8	60.2	29.8	22.3	43.25	48.7	27.3	62.7
NMP-20011000324	99.5	51	15.9	116.5	4.1	4.55	6.12	42	48	10.3	25.85	27.8	21.7	68.3
NMP-20011000381	170	123.8	27.5	1019	11.8	6.55	13.5	61	29	38.4	61.85	72.8	31.8	58.2
NMP-20011000386	178.5	135.2	23.4	772	21.9	40.3	45.9	28.5	61.5	0	0	0	0	0
NMP-20011000401	102	133	12	277.3	2.9	45.1	45.2	3.68	86.3	0	0	0	0	0
NMP-20011000414	78	93	18	162.3	2.4	10.6	10.9	12.8	77.2	0	0	0	0	0
NMP-20011000415	118.5	89	18	288.7	5.6	20.1	20.9	15.6	74.4	0	0	0	0	0
NMP-20011000416	106	100	20	355.5	12.2	21.95	25.1	29.1	60.9	0	0	0	0	0
NMP-20011000421	77	93	12	150.2	9.9	11.6	15.3	40.5	49.5	0	0	0	0	0
NMP-20011000423	90	82.5	9.5	81.5	0	0	0	0	0	17.5	41	44.6	23.1	66.9
NMP-20011000425	65	44	8.5	32.4	2.4	10.1	10.4	13.4	76.6	0	0	0	0	0
NMP-20011000426	43.5	52	10	35.9	10.7	7.45	13	55.2	34.8	0	0	0	0	0
NMP-20011000427	53	35	4	11.8	25	9.1	26.6	70	20	0	0	0	0	0
NMP-20011000428	37	34	8	17.8	8.3	4.15	9.28	63.4	26.6	0	0	0	0	0
NMP-20011000429	64	63	11	60.9	2.1	10.2	10.4	11.6	78.4	15.3	31.6	35.1	25.8	64.2
NMP-20011000430	60.5	45.5	10.2	44.6	29.7	4.6	30.1	81.2	8.8	0	0	0	0	0
NMP-20011000431	40	58	7	25.6	6.8	3.2	7.52	64.8	25.2	10.9	29.65	31.6	20.2	69.8
NMP-20011000432	58.5	51	9	37.8	6.8	7.75	10.3	41.3	48.7	18.2	25.7	31.5	35.3	54.7
NMP-20011000433	62	50.2	6	24.3	10.4	5.65	11.8	61.5	28.5	18.9	25.2	31.5	36.9	53.1
NMP-20011000435	50	43	15	45.2	0	0	0	0	0	0	0	0	0	0
NMP-20011000437	42	52	7.5	19.8	10.5	40	41.4	14.7	75.3	7.8	25.75	26.9	16.9	73.1
NMP-20011000451	108.8	126.9	13.3	341	32.3	9.45	33.7	73.7	16.3	13.4	64.4	65.8	11.8	78.2
NMP-20011000468	147.5	110	10	265.8	0	0	0	0	0	0	0	0	0	0
NMP-20011000479	75.2	78.5	14.5	137.6	12.2	26	28.7	25.1	64.9	21.4	39.25	44.7	28.6	61.4
NMP-20011000480	74.5	129	19	232	17.8	28.7	33.8	31.8	58.2	0	0	0	0	0
NMP-20011000481	58	94	20.5	154.9	5.3	29.1	29.6	10.3	79.7	0	0	0	0	0
NMP-20011000482	9.2	78	14.5	175.8	11.3	22.2	24.9	27	63	0	0	0	0	0
NMP-20011000484	66.5	78	13	87.1	10.8	17.45	20.5	31.8	58.2	0	0	0	0	0
NMP-20011000485	44	34	9	17.4	19.2	4.85	19.8	75.8	14.2	0	0	0	0	0
NMP-20011000486	75	80.5	11.2	87.2	8.1	16.9	18.7	25.6	64.4	0	0	0	0	0
NMP-20011000668	131	74.7	17.6	246.5	22.2	7.7	23.5	70.9	19.1	0	0	0	0	0
NMP-20011000681	133.3	119	24.5	534.5	7.2	9.05	11.6	38.5	51.5	23.8	60.05	64.6	21.6	68.4
NMP-20011000316	69.7	44.6	9.8	43	12.3	4.65	13.1	69.3	20.7	9.5	22.3	24.2	23.1	66.9
NMP-20011000327	231.5	124.5	23.4	1136.9	0	0	0	0	0	47.6	64.4	80.1	36.5	53.5
NMP-20011000342	263	104.6	32.3	1148.3	27.3	10.25	29.2	69.4	20.6	23	49.05	54.2	25.1	64.9

NMP-20011000418	115	56	15	116	29.3	10.95	31.3	69.5	20.5	0	0	0	0	0
NMP-20011000460	153	96.3	29	488.9	13.8	11.3	17.8	50.7	39.3	44	46.7	64.2	43.3	46.7
NMP-20011000483	48.5	54	13.5	43.4	47.8	3.65	47.9	85.6	4.37	0	0	0	0	0
NMP-20011000508	70.8	47.7	10.5	56.4	9.2	4.05	10.1	66.2	23.8	0	0	0	0	0
NTU-C08g_TP5L5	105.1	111.4	16.5	262.2	2.5	23.05	23.2	6.19	83.8	0	0	0	0	0
NTU-C08g_01	119.2	85.7	23.8	324.5	21	15.65	26.2	53.3	6.7	6.5	41.2	41.7	8.97	81
NTU-C08g_02	109.1	80.4	19.1	271.6	14.3	7.85	16.3	61.2	28.8	9.3	37.3	38.4	14	76
CWY-001	128.77	94.37	13.9	288.3	2.9	12.35	12.7	13.2	76.8	0	0	0	0	0
CWY-002	122.8	91.28	11.19	199.9	6.5	15.15	16.5	23.2	66.8	24.9	45.6	52	28.6	61.4
NTU-KN0516	120	84.4	11.7	141.2	17.4	18.05	25.1	43.9	46.1	18.3	38.3	42.4	25.5	64.5
NMP-20041500732	93.2	50.3	9.9	58.9	7.3	6.05	9.48	50.3	39.7	11.2	23.6	26.1	25.4	64.6
NTU-A5189	69.9	68.5	8.4	47.1	22.5	17.65	28.6	51.9	38.1	16.9	34.25	38.2	26.3	63.7
NTU-KN0604	76.6	75	16.6	124.2	5.7	6.05	8.31	43.3	46.7	23.8	35.85	43	33.6	56.4
NTU-1597	127.1	62.4	11.7	129.6	4.1	9.55	10.4	23.2	66.8	18.2	30.75	35.7	30.6	59.4
NMP-20041701137	87.4	56.2	8.9	59.8	10.1	4.95	11.2	63.9	26.1	26.2	27.6	38.1	43.5	46.5
NMP-20041701145	84.4	63.7	9.3	68.5	10.8	9.8	14.6	47.8	42.2	14.3	16.2	21.6	41.4	48.6
NMP-20041500306	90.8	64.8	17	139.1	32.6	2.8	32.7	85.1	4.91	0	0	0	0	0
NMP-20041500315	85.5	37.2	19.6	56.6	12.5	13.8	18.6	42.2	47.8	0	0	0	0	0
NMP-20041500323	72.6	53.1	16.5	79.3	33.8	7.8	34.7	77	13	0	0	0	0	0
NMP-20010800202	88.9	80.6	13.3	146	6.7	6.95	9.65	44	46	13	40.3	42.3	17.9	72.1
NMP-20010800203	76.9	52	10	59.8	10.3	5.35	11.6	62.6	27.4	9.1	19.55	21.6	25	65
NMP-20010800204	52	68	11.5	57.3	2.4	11.8	12	11.5	78.5	0	0	0	0	0
NMP-20010800205	57.7	43	18.5	32	4.2	3.95	5.77	46.8	43.2	0	0	0	0	0
NMP-20010800206	58	55.8	11.5	46.1	4.3	6.1	7.46	35.2	54.8	0	0	0	0	0
NMP-20010800207	71	40.6	11	50	4.9	3.15	5.83	57.3	32.7	0	0	0	0	0
NMP-20010800208	48	53.3	11.5	45.3	9.4	7.8	12.2	50.3	39.7	0	0	0	0	0
NMP-20041500623	102.6	89.6	14.7	189.4	14.3	9.75	17.3	55.7	34.3	31	44.6	54.3	34.8	55.2
NMP-20041500648	85.6	57.3	14.8	129.8	8.4	5.2	9.88	58.2	31.8	0	0	0	0	0
NMP-20010800069	113.6	69.6	16.6	114	42.3	13.1	44.3	72.8	17.2	20.5	35.2	40.7	30.2	59.8
NMP-20010800062	167.1	115.3	51.5	688	14.6	5.25	15.5	70.2	19.8	31.6	56.9	65.1	29	61
NMP-20010800063	130	94.3	22.8	376	18.6	5.6	19.4	73.2	16.8	19.4	46.95	50.8	22.5	67.5
NMP-20010800065	124.8	102.3	20	418	18.8	2.7	19	81.8	8.17	23.9	51.05	56.4	25.1	64.9
NMP-20010800071	121.3	87.9	22.3	310	23.9	5.65	24.6	76.7	13.3	16.7	44.2	47.2	20.7	69.3
NMP-20010800083	108.8	88.8	28.8	325	31.1	11.1	33	70.4	19.6	15.8	42.8	45.6	20.3	69.7
NMP-20010800088	116.2	82.3	22.6	348	21.5	3.85	21.8	79.8	10.2	11.1	40.45	41.9	15.3	74.7
NMP-20010900113	130	128.5	20.9	442	0	0	0	0	0	25.3	64.55	69.3	21.4	68.6
NTU-KN0555	78.7	71.7	12.7	108.2	12	10.4	15.9	49.1	40.9	0	0	0	0	0
NMP-STSP-NKL01	131.7	82.1	3.3	175.5	13.2	11.95	17.8	47.8	42.2	9.5	28.4	29.9	18.5	71.5
NMP-STSP-NKL02	8.75	6.13	1.06	78	11.3	10.15	15.2	48.1	41.9	17	30.75	35.1	28.9	61.1
NTU-4000	127.1	54.6	12.5	113.6	19.7	6.55	20.8	71.6	18.4	15	22.3	26.9	33.9	56.1
NMP-20041500002	64.6	63.8	9.7	46	12.6	12.6	17.8	45	45	15	31.8	35.2	25.3	64.7
NMP-20041500031	118.3	77.4	24.7	257.4	20.4	5.35	21.1	75.3	14.7	18.3	39	43.1	25.1	64.9
NMP-20041500034	67.2	71.9	10.5	64.4	13.7	12.5	18.5	47.6	42.4	0	0	0	0	0
NTU-KN0519	98.6	663.1	12.5	116.8	13.7	6.3	15.1	65.3	24.7	17.5	31.55	36.1	29	61
NMP-20010700140	78	60.5	10	69	20.8	7	21.9	71.4	18.6	0	0	0	0	0
NMP-20010700144	77.7	61.1	9	67	2.5	8.4	8.76	16.6	73.4	9.1	29.9	31.3	16.9	73.1
NMP-20010700145	108.1	61.8	12.4	121	2	5.55	5.9	19.8	70.2	8.9	28.8	30.1	17.2	72.8
NMP-20010700148	167	120	22.3	624.5	13.7	9.25	16.5	56	34	15.7	59.1	61.1	14.9	75.1
NMP-20041500120	58	47.8	14.9	58.9	1.8	4.3	4.66	22.7	67.3	0	0	0	0	0
NMP-20010700101	125	101	31	602.4	6.3	4.1	7.52	56.9	33.1	16	26.65	31.1	31	59
NMP-20010700127	117	87	24	330	11.2	2.95	11.6	75.2	14.8	11.4	31.25	33.3	20	70
NMP-20010700141	106.7	59	16.3	165.9	13.5	4.35	14.2	72.1	17.9	0	0	0	0	0
NMP-20010700142	124.8	86	20.5	286.5	1.1	21.85	21.9	2.88	87.1	0	0	0	0	0
NMP-20010700143	97.9	56	12.2	87.4	2.3	1.65	2.83	54.3	35.7	0	0	0	0	0
NMP-20010700146	65.6	45.8	7.6	26	7.9	4.15	8.92	62.3	27.7	7.1	22.05	23.2	17.8	72.2
NMP-20010700147	102.1	89.2	19.3	220.5	14.7	12.15	19.1	50.4	39.6	11.8	43.4	45	15.2	74.8

NMP-20010700149	58.9	82.5	9	45.4	30.2	23.4	38.2	52.2	37.8	0	0	0	0	0
NMP-20041700374	86.7	87.8	20.3	197.2	16.2	9.35	18.7	60	30	0	0	0	0	0
NTU-T002	57.6	40.9	9.9	34.6	2.9	5.9	6.57	26.2	63.8	0	0	0	0	0
NTU-T003	121.9	61.3	11.92	110.8	4.2	7.25	8.38	30.1	59.9	20.5	30.5	36.7	33.9	56.1
NTU-T004	74	60.9	10.2	63	2.4	9.7	9.99	13.9	76.1	0	0	0	0	0
NTU-T005	54.9	50	9.2	39.4	3.3	4.5	5.58	36.3	53.7	10.9	25	27.3	23.6	66.4
NTU-404-1	53.3	46.5	10.3	38.3	2.6	7.75	8.17	18.5	71.5	0	0	0	0	0
NTU-404-2	73.8	52.8	8.3	41.5	1.6	7.45	7.62	12.1	77.9	0	0	0	0	0
NTU-404-3	85.3	54.4	11.4	76.5	7.7	5	9.18	57	33	0	0	0	0	0
NTU-404-22	110.1	65.9	13.3	140.2	5.7	12	13.3	25.4	64.6	15	32.8	36.1	24.6	65.4
NTU-T001	83.9	61.8	9.2	63.2	2.7	9.05	9.44	16.6	73.4	0	0	0	0	0
NTU-T006	36.3	48	8.5	23.4	7.5	10.4	12.8	35.8	54.2	0	0	0	0	0
NTU-T007	119.1	76.6	22.6	319.1	28.9	9.95	30.6	71	19	13.6	38.3	40.6	19.5	70.5
NTU-T008	93.4	47.7	8.6	53.6	13.5	4.15	14.1	72.9	17.1	0	0	0	0	0
NTU-T009	99.2	58.1	19.2	139.1	8.4	8	11.6	46.4	43.6	15.9	29.05	33.1	28.7	61.3
NTU-T010	90	54.7	9	68.6	3.4	9.1	9.71	20.5	69.5	10.6	23.05	25.4	24.7	65.3
NTU-T011	60.3	48.1	13	46.3	1.7	8.55	8.72	11.2	78.8	34	24.25	41.8	54.5	35.5
NTU-T012	71.6	60.6	20.5	146.4	4.4	3.8	5.81	49.2	40.8	0	0	0	0	0
NTU-T013	41.9	25.3	11.8	14.6	3.5	9.33	9.96	20.6	69.4	0	0	0	0	0
NTU-T014	82.5	42.1	7.7	33.2	7.8	16.6	18.3	25.2	64.8	0	16	0	0	0
NTU-T015	97.6	46.3	9.8	58.7	3.5	5.05	6.14	34.7	55.3	0	0	0	0	0
NTU-T016	84.7	41.8	8.9	48.5	6	3.7	7.05	58.3	31.7	0	0	0	0	0
NTU-T017	60.6	36.4	9.7	37.9	13.3	13.3	18.8	45	45	0	0	0	0	0
NTU-T018	64.1	61.7	10.2	52.2	2	9.3	9.51	12.1	77.9	0	0	0	0	0
NTU-T019	41.4	29.3	9.2	23.2	0	0	0	0	0	0	0	0	0	0
NTU-T020	48.3	32.1	7.1	20.8	10.1	4.4	11	66.5	23.5	0	0	0	0	0
NTU-T021	48	31.8	8.11	21.2	0	0	0	0	0	0	0	0	0	0
NTU-T022	75.9	40.5	9.2	38.2	28.9	11.9	31.3	67.6	22.4	0	0	0	0	0
NTU-T023	71.4	69.5	7.4	46	8.8	10	13.3	41.3	48.7	0	0	0	0	0
NTU-T024	90.1	58.1	12.2	88	3.2	6.1	6.89	27.7	62.3	0	0	0	0	0
NTU-T025	136.5	85.6	17.5	321.8	41.6	15	44.2	70.2	19.8	0	0	0	0	0
NTU-T026	113.7	68.2	15	186.5	15	7.55	16.8	63.3	26.7	0	0	0	0	0
NTU-T027	133.6	87.9	20.6	351	5.6	9.75	11.2	29.9	60.1	0	0	0	0	0
NTU-T028	82.6	63.6	14.6	107.8	24.6	7.6	25.7	72.8	17.2	15.6	31.75	35.4	26.2	63.8
NTU-YS-87-019	39.1	47.5	8.9	22	2.5	6.1	6.59	22.3	67.7	0	0	0	0	0
NTU-YS-88-1093	49.4	53	6.7	25.3	6.9	2.45	7.32	70.5	19.5	19.7	26.45	33	36.7	53.3
NTU-YS-87-112	33.6	56.4	7.4	21.8	6.9	9.95	12.1	34.7	55.3	0	0	0	0	0
NTU-1399-13	77.5	49	14.9	89.5	3.6	1.7	3.98	64.7	25.3	0	0	0	0	0
NTU-1984-40	56.8	66.2	15.4	83.9	5.7	4.7	7.39	50.5	39.5	0	0	0	0	0
NTU-1984-27	101.6	66.5	18	156	14.6	2.8	14.9	79.1	10.9	18.8	33.25	38.2	29.5	60.5
NTU-1984-28	67.9	78.6	8	49.9	14.1	12.3	18.7	48.9	41.1	11.9	30.3	32.6	21.4	68.6
NTU-1984-30	86	59.2	13.8	86.1	10.2	5	11.4	63.9	26.1	0	0	0	0	0
NTU-1984-34	83.2	74.7	21.2	126.3	7.9	9.55	12.4	39.6	50.4	0	0	0	0	0
NTU-1984-35	64	61	15.3	81.2	12.6	4.1	13.3	72	18	0	0	0	0	0
NTU-1984-36	81.6	53.7	8.4	56.4	2.9	6.55	7.16	23.9	66.1	0	0	0	0	0
NTU-1984-37	68	53.8	6.7	36	9.9	3.9	10.6	68.5	21.5	12.9	24.15	27.4	28.1	61.9
NTU-1984-39	65.1	70.4	9.7	64.2	7.1	10.5	12.7	34.1	55.9	0	0	0	0	0
NTU-1984-42	55.7	84.3	11.7	57.9	4	7.6	8.59	27.8	62.2	0	0	0	0	0
NTU-3082	81.8	69.4	13	106.7	6.7	11.25	13.1	30.8	59.2	0	0	0	0	0
NTU-3529-1	90.6	65.9	11	94.4	3.4	6.2	7.07	28.7	61.3	0	0	0	0	0
NTU-3529-3	71	56.8	12.6	59.7	3.25	8.1	8.73	21.9	68.1	0	0	0	0	0
NTU-3529-2	116.1	81.8	19	248.9	4.3	16.3	16.9	14.8	75.2	0	0	0	0	0
NTU-3529-4	138.5	101.7	21	472.5	33.7	0.8	33.7	88.6	1.36	30.7	50.75	59.3	31.2	58.8
NTU-3530-5	71.9	68.9	11.3	99.5	3.4	10.5	11	17.9	72.1	0	0	0	0	0
NTU-3539-1	102.1	59.4	10.7	84	4.7	4.83	6.74	44.2	45.8	0	0	0	0	0
NTU-3539-2	68.4	53.7	10.6	53.3	1.8	6.3	6.55	15.9	74.1	0	0	0	0	0

NTU-3539-3	131.7	108.3	13.4	289.4	5.5	33.85	34.3	9.23	80.8	0	0	0	0	0
NTU-3539-4	60.1	54.8	13	53.6	4	10.8	11.5	20.3	69.7	0	0	0	0	0
NTU-3539-7	111.1	46.7	9.3	87.2	4.9	3	5.75	58.5	31.5	10.2	22.2	24.4	24.7	65.3
NTU-3539-9	81.8	73.5	6.7	47.1	15.7	22.25	27.2	35.2	54.8	0	0	0	0	0
NTU-3542-19	56.1	52.9	9	37.1	3.8	7.7	8.59	26.3	63.7	0	0	0	0	0
NTU-3542-30	38.4	36.4	8.3	18.5	6.1	5.9	8.49	46	44	0	0	0	0	0
NTU-3543-1	123.6	108.5	18.8	194.8	11.8	26.2	28.7	24.2	65.8	0	0	0	0	0
NTU-3819-4	74.9	70.5	9.4	79.3	15	10	18	56.3	33.7	0	0	0	0	0
NTU-3820-3	79.7	41.4	6.8	31.2	4.6	2.9	5.44	57.8	32.2	0	0	0	0	0
NTU-3820-4	64	61.3	7.8	53.1	5.8	11.75	13.1	26.3	63.7	12.9	30.45	33.1	23	67
NTU-3823-25	72	79.1	15.1	126.5	10	12.2	15.8	39.3	50.7	21	39.4	44.6	28.1	61.9
NTU-3823-27	77.9	76	12.5	108.3	17.3	11.15	20.6	57.2	32.8	14.8	37.35	40.2	21.6	68.4
NTU-3823-28	87.8	56.6	8.8	74.6	2.3	4.55	5.1	26.8	63.2	0	0	0	0	0
NTU-3823-30	127.5	116.5	15.8	325.2	0	0	0	0	0	37.8	70.65	80.1	28.1	61.9
NTU-3823-41	125.4	78.3	21	294.7	35.1	0.55	35.1	89.1	0.9	0	0	0	0	0
NTU-3823-50	183.6	114.8	23.5	781.5	25.1	1.5	25.1	86.6	3.42	0	0	0	0	0
NTU-3823-69	101.7	98.1	16.6	137.5	13.2	42	44	17.4	72.6	0	0	0	0	0
NTU-3823-72	102.3	74.9	11.1	131.8	1	8.2	8.26	6.95	83	0	0	0	0	0
NTU-3825-3	82.2	80.6	12.1	105.5	3.6	9.1	9.79	21.6	68.4	0	0	0	0	0
NTU-3826-5	72.8	46.6	8.8	46	7.4	5.45	9.19	53.6	36.4	0	0	0	0	0
NTU-YS-33-670	78	46.6	10.1	57.3	3.5	4.9	6.02	35.5	54.5	0	0	0	0	0
NTU-72	61.3	52.7	9.8	41.5	3.8	10.55	11.2	19.8	70.2	0	0	0	0	0
NTU-A5548	46.3	58.3	9.2	35.6	0	0	0	0	0	18.9	29.15	34.7	33	57
NTU-YS-87-SC-5	82.4	57.7	7	46.4	6.6	7.9	10.3	39.9	50.1	18.8	29.25	34.8	32.7	57.3
NTU-1029	70.5	64.6	9	65	13.8	9.6	16.8	55.2	34.8	0	0	0	0	0
IOE-00112	120	78	11	144.1	5	11.7	12.7	23.1	66.9	21.8	38.8	44.5	29.3	60.7
IOE-00113	125	71	8	156.7	2.6	13.8	14	10.7	79.3	23.9	35.5	42.8	33.9	56.1
IOE-00114	138	62	4	130.7	5.9	8.55	10.4	34.6	55.4	29.8	33.1	44.5	42	48
IOE-00115	82	48	7	31.5	3.9	3.4	5.17	48.9	41.1	11.8	24.55	27.2	25.7	64.3
IOE-00116	120	55	7	106.4	19.3	8.05	20.9	67.4	22.6	14.6	27	30.7	28.4	61.6
IOE-00117	109	48	4	62	4.5	6.3	7.74	35.5	54.5	6.1	24.5	25.2	14	76
IOE-00118	112	56	6	111.9	6.9	7	9.83	44.6	45.4	17.3	29.5	34.2	30.4	59.6
IOE-00119	126	60	12	135.1	5.7	7.8	9.66	36.2	53.8	15.8	29.6	33.6	28.1	61.9
IOE-00120	112	60	8	113	1.1	10.2	10.3	6.16	83.8	13.2	30.85	33.6	23.2	66.8
IOE-00121	85	58	9	92.4	4.6	9.7	10.7	25.4	64.6	13.1	31.35	34	22.7	67.3
IOE-00122	95	62	2	56.3	10.7	10.2	14.8	46.4	43.6	12.2	32.6	34.8	20.5	69.5
IOE-00123	92	55	5	60.1	11.7	9.45	15	51.1	38.9	19.5	27.6	33.8	35.2	54.8
IOE-00124	92	58	6	63	6.2	6.3	8.84	44.5	45.5	16.3	28.9	33.2	29.4	60.6
IOE-00125	86	70	5	65.9	2.3	6.8	7.18	18.7	71.3	16.1	34.75	38.3	24.9	65.1
IOE-00126	90	54	8	63.8	2.8	9	9.43	17.3	72.7	10.6	26.8	28.8	21.6	68.4
IOE-00127	99	58	6	78.1	4.2	4	5.8	46.4	43.6	11.4	29.4	31.5	21.2	68.8
IOE-00128	92	54	10	86.8	1.7	5.05	5.33	18.6	71.4	14.4	26.25	29.9	28.7	61.3
IOE-00129	97	60	13	104.8	3.2	6.7	7.42	25.5	64.5	18.8	30.4	35.7	31.7	58.3
IOE-00130	80	53	4	48.3	6.2	4.15	7.46	56.2	33.8	11.8	27.3	29.7	23.4	66.6
IOE-00131	94	55	6	76.7	6.7	7.2	9.84	42.9	47.1	19.2	25.8	32.2	36.7	53.3
IOE-00132	71	63	3	50.2	9.1	11.85	14.9	37.5	52.5	11.7	31.7	33.8	20.3	69.7
IOE-00133	65	47	7	29	18.1	8.4	20	65.1	24.9	9.1	23.6	25.3	21.1	68.9
IOE-00134	72	63	5	41.3	14.1	17.2	22.2	39.3	50.7	18.9	31.4	36.6	31	59
IOE-00135	70	38	4	28	8.5	6.65	10.8	52	38	8.6	18.7	20.6	24.7	65.3
NMP-20010900136	76.5	65.5	8	57.3	6.9	6.25	9.31	47.8	42.2	16.1	31.05	35	27.4	62.6
NMP-20010900145	144.1	101.1	25.5	440.3	12.9	9.55	16.1	53.5	36.5	0	0	0	0	0
NMP-20010900146	90.9	89.2	15	192.1	7.9	13.95	16	29.5	60.5	0	0	0	0	0
NMP-20010900148	99	75.1	15.5	120.9	10.9	7	13	57.3	32.7	0	0	0	0	0
NMP-20010900149	80	59	16	113.1	5.6	8.2	9.93	34.3	55.7	0	0	0	0	0
NMP-20010900150	108	78.9	14.9	155.8	2.7	13.35	13.6	11.4	78.6	0	0	0	0	0
NMP-20010900151	77.8	45.8	9.8	56.3	2.2	4.25	4.79	27.4	62.6	0	0	0	0	0

NMP-20010900153	93.1	53.2	10	72.6	12	6.7	13.7	60.8	29.2	0	0	0	0	0
NMP-20010900160	72.2	51.3	14.4	86.6	2	6.7	6.99	16.6	73.4	0	0	0	0	0
NMP-20010900170	67	73.7	15	90.3	6.8	6.4	9.34	46.7	43.3	0	0	0	0	0
NMP-20010900185	91.5	46	11.1	61.8	6.1	9.4	11.2	33	57	0	0	0	0	0
NMP-20010900214	78.9	87	9.1	88.5	11.4	11.5	16.2	44.7	45.3	32.7	43.5	54.4	36.9	53.1
NMP-20010900215	97.2	63	12.2	104	1.1	6.85	6.94	9.12	80.9	0	0	0	0	0
NMP-20010900217	89.8	55.5	7.8	56	1.9	9.5	9.69	11.3	78.7	0	0	0	0	0
NMP-20010900218	103.4	61.5	11.5	111.5	8.8	6.25	10.8	54.6	35.4	0	0	0	0	0
NMP-20010900219	64.9	50	10.5	50.5	6.2	5.6	8.35	47.9	42.1	0	0	0	0	0
NMP-20010900223	84.3	64.1	10.5	89	5.1	12.95	13.9	21.5	68.5	18.6	31.95	37	30.2	59.8
NMP-20010900300	97.3	63.7	8.7	74.5	3.1	8.15	8.72	20.8	69.2	7.5	31.8	32.7	13.3	76.7
NMP-20010900301	78.7	61.4	14	71.5	18.2	13.2	22.5	54	36	14.8	30.65	34	25.8	64.2
NMP-20010900120	95.5	106	21.9	355.2	0	0	0	0	0	0	0	0	0	0
NMP-20010900124	84.1	87.5	22.5	241.9	0	0	0	0	0	16.1	42.75	45.7	20.6	69.4
NMP-20010900128	49.5	66.5	9	45.6	0	0	0	0	0	16.7	33.25	37.2	26.7	63.3
NMP-20010900143	140.5	110.5	18.2	493.9	47.5	4.3	47.7	84.8	5.17	0	0	0	0	0
NMP-20010900147	103.2	122.9	13.1	236.3	6.8	39.4	40	9.79	80.2	0	0	0	0	0
NMP-20010900152	56	43.8	8	26.2	14.8	8.45	17	60.3	29.7	0	0	0	0	0
NMP-20010900192	161.5	84.5	20.8	402.1	3.8	4.05	5.55	43.2	46.8	0	0	0	0	0
NMP-20010900222	93.9	67.8	16.1	96.5	20.8	9.35	22.8	65.8	24.2	18.9	33	38	29.8	60.2
NTU-G01j_004	50.7	27.6	10.4	18.3	3.5	2.15	4.11	58.4	31.6	6.1	13.55	14.9	24.2	65.8
NTU-KN0246	256.4	85.1	28.2	764.5	31.8	14.7	35	65.2	24.8	39.5	38.2	54.9	46	44
NTU-KN0247	196.4	60.7	20.9	314	16.3	8.3	18.3	63	27	40.1	26.85	48.3	56.2	33.8
NTU-KN0248	160.4	93.1	14.5	291.1	3.4	12	12.5	15.8	74.2	22.3	46.55	51.6	25.6	64.4
NTU-KN0249	128.6	113.9	17.3	423.5	15	13.9	20.5	47.2	42.8	34.6	56.45	66.2	31.5	58.5
NTU-KN0250	127.8	75.2	9.9	144	18.7	7.2	20	68.9	21.1	32.7	36.6	49.1	41.8	48.2
NTU-KN0251	97.1	73.4	25.5	243.5	12.3	5.55	13.5	65.7	24.3	14.9	35.1	38.1	23	67
NTU-KN0252	113.6	74.2	10.3	136.8	1.9	11.05	11.2	9.76	80.2	17.3	37.1	40.9	25	65
NTU-KN0253	102.8	63.2	13	124.4	6.9	5.15	8.61	53.3	36.7	12.2	31.6	33.9	21.1	68.9
NTU-KN0254	105	74.6	14.1	150.4	6.1	10.7	12.3	29.7	60.3	19.8	36.4	41.4	28.5	61.5
NTU-KN0255	108.5	54.4	10.3	98.5	15	6.45	16.3	66.7	23.3	10.5	26.05	28.1	22	68
NTU-KN0256	94.8	84.9	9.9	84.5	21	19.55	28.7	47	43	16.2	40.45	43.6	21.8	68.2
NTU-KN0257	109.8	58.3	13.3	104	5.5	5.05	7.47	47.4	42.6	18	29.15	34.3	31.7	58.3
NTU-KN0258	100.3	65.1	10.6	102.1	2.3	11.45	11.7	11.4	78.6	16	32.45	36.2	26.2	63.8
NTU-KN0259	92.7	65.8	10.2	87.9	3.7	8.2	9	24.3	65.7	20	32.9	38.5	31.3	58.7
NTU-KN0260	79.3	72.3	8.5	66.1	9.3	10.2	13.8	42.4	47.6	20.4	36.15	41.5	29.4	60.6
NTU-KN0261	99.5	54.1	9.7	81.9	3.7	7	7.92	27.9	62.1	18.7	25.6	31.7	36.1	53.9
NTU-KN0262	88.2	57.3	9.6	68.5	6.1	11.15	12.7	28.7	61.3	15.6	28.15	32.2	29	61
NTU-KN0263	92.2	47.6	11.9	76.6	3.4	8.2	8.88	22.5	67.5	13	23.8	27.1	28.6	61.4
NTU-KN0264	88.3	41.2	10.5	62.7	2.5	3.45	4.26	35.9	54.1	10.9	20.35	23.1	28.2	61.8
NTU-KN0265	70.1	45.6	7.9	39.2	8.3	5.8	10.1	55.1	34.9	11.5	22.35	25.1	27.2	62.8
NTU-KN0266	74.1	67.9	7.9	50.6	11.6	5.9	13	63	27	10.3	33.95	35.5	16.9	73.1
NTU-KN0267	86.3	44.8	6.5	41.1	10.1	6.3	11.9	58	32	9.9	20.45	22.7	25.8	64.2
NTU-KN0268	97.3	47.5	8.4	48	9.1	7.45	11.8	50.7	39.3	14.3	23.75	27.7	31.1	58.9
NTU-KN0269	72.6	45.2	8.1	37.3	6.8	6.9	9.69	44.6	45.4	6.6	22.6	23.5	16.3	73.7
NTU-KN0270	73.1	58	10.8	49.4	12.4	5.85	13.7	64.7	25.3	3.4	28.5	28.7	6.8	83.2
NTU-KN0271	70.6	62.5	8.2	47.1	6.9	9.8	12	35.1	54.9	17.7	30.2	35	30.4	59.6
NTU-KN0272	64.9	62.9	8.4	48.3	6.1	9	10.9	34.1	55.9	15.4	31.45	35	26.1	63.9
NTU-KN0273	75.1	49.2	9.4	54	2.5	7.25	7.67	19	71	6.3	23.35	24.2	15.1	74.9
NTU-KN0274	57.5	554	7	25.8	24.1	14.15	27.9	59.6	30.4	5.8	25.4	26.1	12.9	77.1
NTU-KN0275	43.1	36.7	6.6	10	3.8	5.25	6.48	35.9	54.1	9.4	17.75	20.1	27.9	62.1
NTU-KN0276	257.3	94.7	19.2	608.3	13.4	17.1	21.7	38.1	51.9	60.4	47.35	76.7	51.9	38.1
NTU-KN0277	133.5	112.2	15.5	311	183	22.2	184	83.1	6.92	19.8	50.85	54.6	21.3	68.7
NTU-KN0278	109	68.9	14.9	170.5	14.9	9.55	17.7	57.3	32.7	7.7	33	33.9	13.1	76.9
NTU-KN0279	147.3	83.6	21.4	247.9	0	0	0	0	0	28.9	41.8	50.8	34.7	55.3
NTU-KN0280	111.5	66.4	11.6	115.4	8.6	11.1	14	37.8	52.2	14.8	33.2	36.3	24	66

NTU-KN0281	130.4	51.4	12.5	126.7	6.9	6.6	9.55	46.3	43.7	11	25.7	28	23.2	66.8
NTU-KN0282	94.5	62	14.9	102.5	12.9	6.9	14.6	61.9	28.1	16.9	31	35.3	28.6	61.4
NTU-KN0283	113	54.3	13.3	96.7	12.9	10.1	16.4	51.9	38.1	17.7	24.55	30.3	35.8	54.2
NTU-KN0284	93.3	54.6	10.4	64.5	10.6	5.5	11.9	62.6	27.4	20.6	27.3	34.2	37	53
NTU-KN0285	106.4	55.1	10.5	106.8	8.1	4.9	9.47	58.8	31.2	9.3	27.45	29	18.7	71.3
NTU-KN0286	100	70.3	8.9	77.1	18.8	8.15	20.5	66.6	23.4	14.1	35.15	37.9	21.9	68.1
NTU-KN0287	110.2	44.3	9.7	68.5	10.5	6	12.1	60.3	29.7	12.7	16.5	20.8	37.6	52.4
NTU-KN0288	105.6	56.8	12.1	106.8	3.4	8.1	8.78	22.8	67.2	18.5	27.05	32.8	34.4	55.6
NTU-KN0289	88.7	79	11.2	109.8	5.1	17.25	18	16.5	73.5	0	0	0	0	0
NTU-KN0290	95.3	47.8	10.7	61.6	8.1	5.7	9.9	54.9	35.1	0	0	0	0	0
NTU-KN0291	100	52	8	51.7	3.6	1.5	3.9	67.4	22.6	0	0	0	0	0
NTU-KN0292	68.4	68.1	9.5	58	6.6	10.75	12.6	31.5	58.5	14.2	24.15	28	30.5	59.5
NTU-KN0293	74.4	57.5	10.9	65	7.5	6.45	9.89	49.3	40.7	16.6	27.5	32.1	31.1	58.9
NTU-KN0294	79	57.7	13.2	86.6	9.4	6.4	11.4	55.8	34.2	7.6	28.85	29.8	14.8	75.2
NTU-KN0295	92.5	66.4	10.9	82.3	10.1	10.05	14.2	45.1	44.9	21.5	33.25	39.6	32.9	57.1
NTU-KN0296	87.2	58	10.9	70.2	10.5	13.05	16.7	38.8	51.2	13.6	29	32	25.1	64.9
NTU-KN0297	71.9	48	7.7	39.8	3.5	7.65	8.41	24.6	65.4	7.2	24	25.1	16.7	73.3
NTU-KN0298	63.5	50.9	7.2	35	1.6	7.6	7.77	11.9	78.1	8.1	24.05	25.4	18.6	71.4
NTU-KN0299	50.7	44.1	9.4	31.7	1.8	2.95	3.46	31.4	58.6	0	0	0	0	0
NTU-KN0300	56	41.4	10.2	39.2	10.5	4.2	11.3	68.2	21.8	4.9	17.1	17.8	16	74
NTU-KN0301	55.4	39.1	9.2	29.1	1.9	1.05	2.17	61.1	28.9	3.6	19.55	19.9	10.4	79.6
NTU-G03b_017_01	68.4	50.1	7.6	34.9	5.3	6.5	8.39	39.2	50.8	8.2	24.85	26.2	18.3	71.7
NTU-G03b_017_02	87.1	53.9	10.1	53	7.2	2.25	7.54	72.6	17.4	16.7	26.95	31.7	31.8	58.2
NTU-G03b_017_03	71.9	66.4	10.2	55.9	10.1	13.65	17	36.5	53.5	17	33.2	37.3	27.1	62.9
NTU-G03b_017_04	80.7	79.4	8.4	65.6	14.6	15.4	21.2	43.5	46.5	26.7	13.95	30.1	62.4	27.6
NTU-G03b_007_01	67.2	43.2	7.2	30.8	0	0	0	0	0	0	0	0	0	0
NTU-G03b_007_02	32.6	37.5	7.9	18.1	0	0	0	0	0	0	0	0	0	0
NTU-G03b_007_03	34.4	34.9	8.7	19.1	0	0	0	0	0	0	0	0	0	0
NTU-G03b_007_04	35.3	23.9	9.7	15.4	0	0	0	0	0	0	0	0	0	0
NTU-G03b_007_05	53.8	27.4	7.6	20.5	0	0	0	0	0	0	0	0	0	0
NTU-G03b_007_06	41.4	45.7	9.9	28.8	3.7	6.15	7.18	31	59	0	0	0	0	0
NTU-G03b_007_07	55.1	41.2	8.2	18.8	12.7	6.85	14.4	61.7	28.3	0	0	0	0	0
NTU-G03b_007_08	68.8	45.5	9.1	35.3	3.6	4.15	5.49	40.9	49.1	0	0	0	0	0
NTU-G03b_007_09	56.9	50.8	7.9	33.4	5.8	6.5	8.71	41.7	48.3	0	0	0	0	0
NTU-G03b_007_10	60.1	62.9	8.8	44	12.8	12.05	17.6	46.7	43.3	0	0	0	0	0
NTU-G03b_007_11	65.2	56.8	11.2	51.8	3.4	7	7.78	25.9	64.1	0	0	0	0	0
NTU-G03b_007_12	72.9	45.4	7.5	37.7	3.8	3.45	5.13	47.8	42.2	0	0	0	0	0
NTU-G03b_007_13	80.3	53.9	10.8	66.4	12.5	6.25	14	63.4	26.6	0	0	0	0	0
NTU-G03b_007_14	82.9	59.7	10.8	75.4	10	3.9	10.7	68.7	21.3	0	0	0	0	0
NTU-G03b_007_15	75.3	50.8	11.4	62.7	7	5.2	8.72	53.4	36.6	0	0	0	0	0
NTU-G03b_007_16	104.9	63.2	9	92.8	15.3	8.65	17.6	60.5	29.5	17.4	28.75	33.6	31.2	58.8
NTU-G03b_007_17	179.2	53.7	11.9	179.1	21.8	8	23.2	69.8	20.2	14.4	24.55	28.5	30.4	59.6
NTU-G03b_007_18	87.7	118	19.7	318.2	19.7	16.3	25.6	50.4	39.6	0	0	0	0	0
NTU-G03b_007_19	136.3	116.2	17.4	376.1	9	33.95	35.1	14.8	75.2	0	0	0	0	0
NTU-3821-7	89.8	55.5	13.8	109.8	8.5	4.95	9.84	59.8	30.2	0	0	0	0	0
NMP-20041500225	36.5	41.7	11.2	24.8	10.8	6.3	12.5	59.7	30.3	0	0	0	0	0
NMP-20041500226	129.5	69.2	15.6	150.9	14.7	9	17.2	58.5	31.5	27.2	32.6	42.5	39.8	50.2
NMP-20041500397	86.2	52.2	9.5	37.6	5.9	4.75	7.57	51.2	38.8	5.7	7	9.03	39.2	50.8
NMP-20041500398	113	78	20.9	252.6	4	14	14.6	15.9	74.1	10.8	18	21	31	59