The Suitability of List LaTeX Text Formatter for Thesis Preparation by Technical and Non-technical Degree Candidates

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Abstract

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Chair of the Supervisory Committee:
Title of Chair Name of Chairperson
Department of Chair

This sample dissertation is an aid to students who are attempting to format their theses with LaTeX, a sophisticated text formatter widely used by mathematicians and scientists everywhere.

- It describes the use of a specialized macro package developed specifically for thesis production at the University. The macros customize LaTeX for the correct thesis style, allowing the student to concentrate on the substance of his or her text.[1]

- It demonstrates the solutions to a variety of formatting challenges found in thesis production.

- It serves as a template for a real dissertation.

[1]See Appendix A to obtain the source to this thesis and the class file.

Table of Contents

List of Figures

Figure Number Page

List of Tables

Acknowledgments

The author wishes to express sincere appreciation to University of Washington, where he has had the opportunity to work with the TEX formatting system, and to the author of TEX, Donald Knuth, *il miglior fabbro*.

Dedication

to my dear wife, Joanna

1

Subsistence change, Emergence of agriculture, and Rice

Introduction

In this chapter, I will briefly discuss about the past and current archaeological approaches in relation to the emergence of agriculture. Then, the topic will be narrowed down to the central part of the Korean peninsula and traditional perceptions about transition from foraging to farming among the Korean archaeologists will be mentioned. Lastly, I will clarify the goal and methods of this thesis.

The transition from foraging to farming and the emergence of agriculture

The process of the transition from foraging to farming and the emergence of agriculture are long standing topics of archaeological investigation (Binford, 1968; Childe, 1951; Flannery, 1972, 1976; Redman, 1978). The emergence of agriculture and its role in subsistence is one of the most studied domains in the academic field of archaeology. The intensification of agriculture and the control over agricultural surpluses have been linked to the origins of socio-political complexity (Childe, 1951; Earle, 2002; T. Douglas Price, 1995; B. D. Smith, 1989; Welch & Scarry, 1995). A recent collection of papers in Current Anthropology (Vol. 52, 2011) indicates the importance of this topic and diversity of approaches to the transition from foragers to farmers. Current approaches to understanding the subsistence change from foragers to farmers would fall into four categories: (1) population pressure model, (2) climatic fluctuation model, (3) cultural or social model, and (4) evolutionary model.

One of the most well-known approaches is the population pressure model (Binford, 1968; M. N. Cohen, 1977, 2009; Flannery, 1972, 1976). This approach starts with the idea that farming is backbreaking, time-consuming, and intensive-labor work. Based on the ethnographic analysis in the Kalahari Desert of South Africa, Binford suggested that even in a marginal area, food collecting was a successful adaptation (1968). Therefore, he argued that human groups would not have become farmers, unless they had no other choice. Population pressure was therefore suggested as a proper agent for the origin of agriculture: more people required more food. The best solution to the problem, according to Binford, was farming, which provided a higher yield of food per a unit of land. However, at the same time, the intensification of agriculture required more labor to harvest food. Cohen (1977, 2009) argued for an intrinsic tendency of growth of human population, which is responsible for the initial spread of the human species out of Africa, and the subsequent colonization of Asia, Europe, and the Americas. Along with this population growth, after about 10,000 BC there was an increase in the use of less desirable resources in many areas. Cohen argued that the only successful way to cope with increasing population and declining resources was agriculture.

The second approach emphasizes climate fluctuation. The role of the rapid climate change in the process of subsistence change is certainly a factor to be considered at various specific points in time (Belfer-Cohen

& Goring-Morris, 2011). Bar-Yosef (2011) argued for rapid climatic fluctuation as the main factor in the origin of the cultivation of various wild plants in East and West Asia. The model is based on the idea that the origin of cultivation was motivated by the vagaries of the climatic fluctuation of the Younger Dryas around 10,000 B.C. within the context of the mosaic ecology which affected the communities that were already sedentary or semi-sedentary. By examining paleoclimatic records with available archaeological phenomena, Bar-Yosef proposed that while the rapid climatic fluctuation served as a trigger of the beginning of cultivation at the end of the Younger Dryas, such changes continue to influenced the Holocene period of both East and West Asia.

The third category of approaches focuses more on cultural or social aspects. Cauvin (1994) argued that the important changes associated with the subsistence change from foraging to farming were conceptual as much as, or more than just material (i.e. food production). Specifically, he suggested that farming was led by the emergence of new conceptual ideas such as new cosmology, religious practice, and symbolic behavior. For Cauvin, this transition allowed foragers to view their habitat in a different way and promoted a more active exploitation on their environment. Based on the archaeological phenomena of four cultural areas in China, Cohen (2011) argued that the Early Neolithic culture in China, which involved the farming of millet and rice, was invented and spread with a wide range of information exchange and broad social networks rooted in the interactions of Late Paleolithic hunter-gatherer societies (D. J. Cohen, 2003). Recent studies showed that the agricultural origins took place in relatively abundant environments, not in places where little food was available(1995). This partially supports the idea that the subsistence change from foraging to farming might not be solely explained by the economic aspect.

More recent approaches are based on evolutionary perspectives (Gremillion & Piperno, 2009; Winterhalder & Kennett, 2006, 2009). Among them, the most prominent one is based on the evolutionary ecology. The evolutionary ecology emerged from an earlier perspective known as 'cultural ecology', which focused on the dynamic relationship between human society and its environment (Steward, 1972). Evolutionary ecologists have emphasized human ability to reason and optimize their behavior. In this view, the cultural and behavioral change is explained as a form of phenotypic adaptation to changing social and ecological conditions, applying the assumption that organisms are designed by natural selection to respond to their environment in 'fitness-enhancing ways' (Boone & Smith, 1998, p. 141; Cannon & Broughton, 2010); Winterhalder & Smith, 1992). Hunter-gatherers operate based on the premise of efficiency to obtain sufficient food. Food is ranked by the energy value it contains; and lower-ranked resources such as seeds are demanded, only as higher-ranked ones become unavailable. In this view, the subsistence change to farming is explained as adding new resources. Current evolutionary approaches to the subsistence change from foragers to farmers have expanded to sub-disciplines such as Niche construction Theory (Bleed & Matsui, 2010; Crawford, 2011).

What we know so far? The facts

The studies that I have mentioned above show that in some parts of the world, farming spread rapidly and patchily from one place to another. However, it spread very slowly in other areas; in some places people did not become farmer for up to a millennium after their initial contact with agriculture, or never became farmers at all. Sometimes these areas are environmentally segregated (e.g. Alps or Pyrenees), but can be also defined by social factors (Robb, 2013). If we think of places that show evidence of farming (for example, Europe, which is the most thoroughly studied region in relation to the emergence of agriculture and spread of farming), there are several underlying characteristics these areas have in common [Robb (2013); Whittle & Cummings (2007)).

Migrations of farmers

Though it is highly varied in form, it is true that there were actual movements of farmer/farmers from one place to another. However, at the same time, there is no real evidence for massive migration in terms of single big wave of movement that covered large landscape. In fact, most archaeologically traceable human movements are 'opportunistic leap-frog' (Boland, 1990; Robb, 2013, p. 658) migrations. These movements seem to involve small group of people with no typical single origin, resulting in a complicated form of migration without homeland.

Genetic studies

Unfortunately, unlike the initial optimistic views (Cavalli-Sforza, Menozzi, & Piazza, 1994), the results of genetic studies are quite ambiguous and inconclusive. Though several researches showed that there is genetic discontinuity between hunter-gatherers and early farmers and between hunter-gatherer and modern populations in some places (Malmström et al., 2009; Rowley-Conwy, 2009), other studies suggest that both incoming and indigenous peoples contributed to the gene pool of modern population (Bramanti et al., 2009; Richards, 2005).

First contact

In many cases, when there is contact between foragers and farmers, the former often adopt new subsistence strategies (such as farming) little by little for their own sociopolitical purposes (Robb, 2013). This is somewhat different from the traditional view that new economic practices (based on the farming and the animal domestication) with innovative technologies (notably, pottery and new types/forms of stone tools) rapidly spread into the foraging context as a 'package', completely transforming society to fully farming community (Childe, 1951).

Summing up, if there is any conclusion that archaeologists can reach would be the transition from foragers to farmers and spread of farming occurred in a 'mosaic way' (Robb, 2013, p. 659). This means the transitions occurred around the world had various and diverse pathways. This diversity motivates us to investigate the specific manifestations of this transition in different parts of the world and better understand the different ways that people made this profound transformation.

The role of the intensive rice agriculture in the central part of the Korean peninsula

According to the recent report from the Food and Agriculture Organization of the United Nations (FAO), the average annual rice consumption per person in Brunei and Vietnam is 245 Kg and 166 Kg

(Faostat 2011). These two countries mark the 1st and 2nd in rice consumption in the world. The average annual rice consumption per person in South Korea in 2011 was 88 Kg (the Korea National Statistical Office). However, according to historical records, the annual South Korean rice consumption per person around the 18th century was about 173 Kg. Though the westernized life style of South Korea reduced its annual rice consumption rate, rice is still the mainstay of its modern diet, and has been so for at least 2,000 years. The Koreans' attachment to rice is remarkable. The word for 'meal' in Korean is 'bab', which also and originally means 'steamed rice'. Regardless of their economic status, way of life, or ideological inclination, steamed rice was and is an essential dish throughout the nation. For the Koreans, 'A bowl of rice is equivalent to love and affection' (Woo, 2012). In this regard, one of the main topics of Korean archaeology over the last 50 years has been investigating the process of the subsistence change from hunter-gatherers to intensive rice farmers. However, despite continuous attempts to reveal the overall pattern of the change and accumulations of data, we still lack information on some of the most basic parameters involved in the role of the intensive rice agriculture in the prehistoric Korean Peninsula.

The central part of the Korean Peninsula (Figure 1.1) contains a vast amount of archaeological data related to subsistence change in the deeper past. This region has provided rich archaeological records documenting its general culture history. Its earliest known occupants were Paleolithic foragers dated as old as about 200,000 years ago (J. C. Kim et al., 2010). Clear evidences show that the full-dress farming was practiced in this region around 3,400 BP (G.-A. Lee, 2003, 2011). Solid evidences of dry fields, irrigated rice paddies and harvesting tools have been found (T. Yoon and J. Bae 2010). However, due to the lack of paleobotanical evidences from this period, the detailed information about when rice became the mainstay of the Korean diet is not yet known. Therefore, the study of the transition from hunter-gatherers to farmers and the role of the intensive rice agriculture in this transition has been integral to anthropological debates.

The transition from foragers to farmers in the Korean peninsula has been described as the subsistence change from hunter gathering to intensive rice farming around 3,400 BP (B. Kim (2006); Ahn (2000); J. Kim (2003), J. Kim (2006); Norton (2000), Norton (2007)). B. Kim (2006) argued that an agricultural economy based heavily on rice spread suddenly and swiftly into the foraging context with few evidences of a transitional period. However, recent paleobotanical data on the southern part of the Korean peninsula have revealed that people were more dynamic and varied than is posited by the models focused on the intensive rice farming (Crawford and Lee 2003; G. Lee 2003, 2011). For example, along with rice, they utilized other crops such as millet, soybean, and azuki for their subsistence. These new data require an alternative model which could explain the role of the intensive rice agriculture in this period.

This thesis investigates the role of the intensive rice agriculture as a subsistence strategy in the central part of the Korean peninsula, contributing new data that will establish the chronology of subsistence over the last 3,400 years. This research will provide an insight into when rice became the mainstay of the Korean diet. Low hills with gentle slopes embracing meandering rivers in this region were continuously occupied for as much as 4,000 years, and large inland habitation sites developed in this condition provide the multiple lines of subsistence data that are required for this study. The central hypothesis in this research is that a wide range of resources were utilized along with rice between 3,400 and 2,000 BP. This hypothesis contrasts with the rice-centered models, which assume rice to be the most dominant subsistence resource since 3,400 BP.

The primary goal of this research is re-evaluating the conventional rice-centered models to better understand the overall pattern of subsistence strategies and assess the weight of rice in it. To achieve this goal the study (1) tests the hypothesis that a wide range of resources were utilized along with rice between 3,400 and 2,000 BP., and (2) establishes a general chronology of subsistence during this period, incorporating in that work the organic geochemical analysis and luminescence dating of the pottery excavated from four large inland habitation sites in the central part of the Korean peninsula.

In Korean archaeology, pottery is one of the primary analytical resources, being abundant in almost every archaeological assemblage in the Korean Peninsula since 6,000 BP. However, despite intensive relative chronology-building, almost no attention has been given to analyzing the fabric of the pottery itself. Studies have showed that high-temperature boiling using pottery is particularly effective in the preparation of various resources (Stahl 1989; Wandsnider 1997). This represents a serious gap in our understanding of prehistoric subsistence in Korea during the critical time of the transition from foragers to farmers. The methods proposed here allows me to test prevailing rice-centered models, first by identifying what was stored and cooked in the pots, and second by dating the pots directly and absolutely. By doing so, the study establishes a general chronology of subsistence between during 3,400 and 2,000 BP. The results of my research provide critical information about the role of intensive rice agriculture in the prehistoric Korean diet.

In this thesis a total of 138 potsherds were collected for the organic geochemical analysis and eight sherds were dated with luminescence dating. Based on the results of organic geochemical analyses, each potsherd was assigned to a different food class. Then, these potsherds were be placed in time, based on the results of luminescence dating and available AMS radiocarbon dating. By doing so, I was able to achieve the primary goal of this research: re-evaluate conventional rice-centered models to better understand the overall pattern of subsistence strategies and assess the weight of rice in it.

Summary

In this chapter, I have briefly discuss about various approaches in relation to the origin of agriculture. Then, the focus was narrowed down to the central part of the Korean peninsula. The traditional perceptions about transition from foraging to farming among the Korean archaeologists was state, and the goal as well as methods of this thesis were clarified.

Figure 1.1: Location of the sites mentioned in the text

2

Background and Central Hypothesis

Introduction

In this chapter, first I will discuss the history and social context of Korean archaeology focusing on Japanese annexation of the country. Then, I will elucidate the current views on the transition from foragers to farmers and development of rice agriculture in the Korean Peninsula in detail. The problems with these existing studies will be stated based on the recent scientific evidence. Lastly, I will clarify main hypothesis of this thesis.

Archaeology in Korea - Its brief history and social context

The whole Korean peninsula is populated with Koreans. Though there are some regional dialects, in regard of its culture and language Korea includes no recognized minorities. Therefore, traditionally, the Korean prehistory is frequently formulated in Korea with reference to ethnicity, perceiving the elucidation of the formation of the Korean people to be the chief purpose of archaeology. In the twentieth century, the Korean peninsula underwent a series of dramatic political upheavals. This political fluctuation began with the Japanese annexation of the country in 1910. The liberation of the Korean peninsula in 1945 after the end of the World War II was followed by the Korean War (1950–1953) and the subsequent establishment of two competing states: the Republic of Korea (South Korea) and the Democratic People's Republic of Korea (North Korea). This political context established a particular and unique social milieu, which critically influenced archaeological practices. The modern practices of archaeology in Korea were first conducted by Japanese archaeologists such as Tadashi Sekino, Ryuzo Torii, and Ryu Imanishi during the colonial period. Archaeological remains, which are inherently subject to a variety of interpretations, were easily exploited to justify the Japanese colonization of Korea (Kim, 2008). Through this, Japanese archaeologists tried to claim that the Korean people were characterized by "a lack of independence" and "a servile attitude towards bigger nations." Though it seems that this is a typical example of "Colonialist archaeology" of Trigger (1996; 2008), there is a huge difference between the one and the other. The colonizers were Japanese, not Europeans. Though one might argue this is unimportant, in fact, it is. While European colonizers did not have any cultural or historical similarities with Native Americans, Japan and Korea have actively been interacting to each other since the Late Neolithic Age. For this reason, the archaeological phenomena of Korea and Japan are quite similar. Therefore, Japanese archaeologists who practiced archaeology in Korea argued that all prehistoric/historic material cultures were handed down from the Japanese isles to the Korean peninsula. The primary character of the "Colonialist archaeology" defined by Trigger is denigrating native peoples by presenting the primitive aspects of their archaeological phenomena. However, in this case, the Japanese justified their colonization by emphasizing the overall similarities and excellences of the prehistoric/historic material cultures of Korea and Japan.

As in many postcolonial nations, the Korean archaeology after the liberation from the Japanese colonization has taken a central role in refashioning national identity and restoring national pride (Kim, 2008). Especially in South Korea, archaeological phenomena have been being interpreted as evidences of migration and cultural diffusion throughout the Eurasian continent. Highlighting harmonious blending of different cultural traits and emphasizing cultural interactions over a vast region may appear to contradict nationalism which assumes the ethnic superiority. However, it should be noted that such interpretations describe the ancient Koreans as a people with a grandiose geographical scope whose life was not confined to a small peninsula. The interpretations of the archaeological phenomena in Korea often intentionally aim at suggesting creativity and superiority of the Korean people. Based on this, some archaeologists have recognized nationalism in the Korean archaeology and have described the current Korean archaeology as "nationalist archaeology" (Kim, 2008; Trigger, 2008).

However, in the middle of the 1990's, archaeology in Korea started to make various voices. The 2nd generation Korean archaeologists who were educated in the United Kingdom and the United States as 'graduate students' began to conduct their own researches in Korea. Though they were highly influenced by the nationalism of the Korean archaeology from the first generation archaeologists, they also learned major theoretical frameworks and empirical methodologies from decent universities in US and UK. Currently, on one hand, these scholars are trying to avoid an extreme nationalism, and on the other, they are also concerned about the imperialist aspect of their knowledge originated from UK and US.

"Chulmun" foragers and "Mumun" farmers - where everything started

This dissertation investigates the process of transition from foraging to farming and the role of agriculture as a subsistence strategy during this transition in the central part of the prehistoric Korean Peninsula (Figure 2.1a). The period in question has been called the Mumun pottery period (c.f. Bale 2011: 3390-2290 calibrated years (cal.) B.P.). The traditional periodization scheme of the prehistoric Korea is based on the decorative attributes consistently found on the potteries that existed over specific time periods: 9950-3390 B.P. is the Chulmun (or 'comb-pattern') Pottery Period and 3390-2290 cal. B.P. is the Mumun (or 'undecorated') Pottery Period (Norton 2007; Bale 2011). Sometimes the former and the latter are respectively regarded as the Neolithic and Bronze Age of Korea (Ahn 2004; Norton 2007). The be-

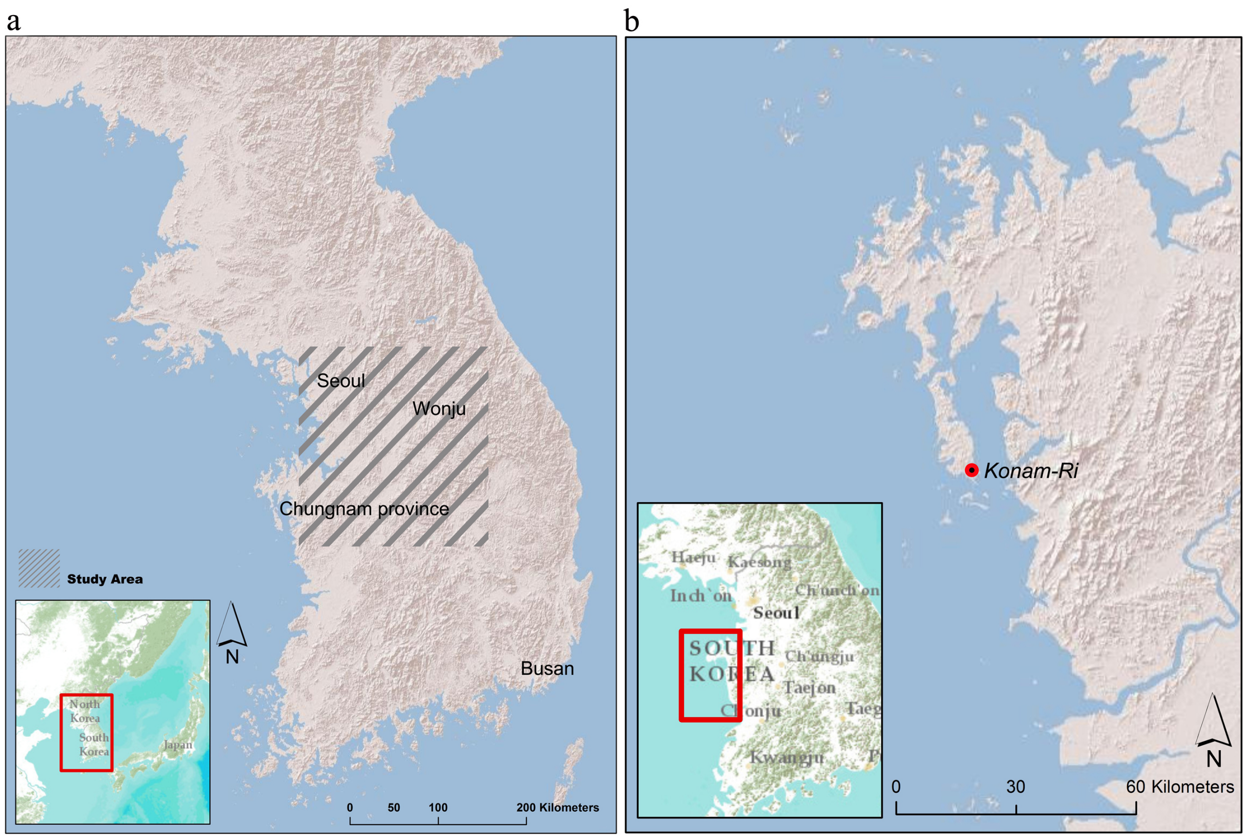

Figure 2.1: (a) The indication of the central part of the Korean Peninsula (b) The location of the Konam-Ri shell midden

ginning of the Mumun Period has an important role in the Korean archaeology, for it has been linked with the beginning of the agricultural society. The Mumun Period, named after its representative patternless feature of pottery, is known for intensive rice farming, instead of hunting and gathering of the Chulmun Period. Also, with this economical evolution, the society became more complex and social hierarchy emerged. 'Mumun', term meaning 'undecorated', is the most common feature of the pottery in this period. Ahn Jae-ho devised this influential 'Chulmun-Mumun' periodization based on diagnostic changes in pottery decoration, pit-house architecture, interior pit-house features, and stone tool types (J. Ahn 1991, 2000, 2001). Ahn's chronology assumes that changes in pottery decorative attributes and plan-shapes of pit-houses are time-sensitive. According to him, the Mumun periodization scheme has the following internal stages: Incipient, Early, Middle, and Late.

Korean archaeologists have been focusing on the differences between the overall archaeological assemblages of the Chulmun and Mumun periods. Now, I will briefly examine the different aspects of the archaeological assemblages from the two periods.

To begin with, in the case of pottery, the fundamental characteristics of the Chulmun Period pottery are the comb-shape pattern and the pointed bottom, which show some variations as the phases go by (Figure 2.2a). Some pieces of the Chulmun Period pottery from the Gangwon province (Figure 1.1) have the flat bottom, but this shape is considered as an exception to the general form of the Chulmun Period pottery. On the other hand, all the Mumun Period pottery have the flat bottom; the major part of their body does not have any pattern. Some patterns still existed, but confined to the extreme upper body. During the incipient stage of Mumun, potteries had a pinched clay strip attached to the outside of the rim and body (S. Cheon 2005; 1.1; 2.4a). Early Mumun potteries have both rim-punctuations and lip-scoring. This combination of attributes is sometimes referred to as Yeoksam-dong-style pottery (B. Lee 1974; Figure 1.1; 2.4c) after the site where they first uncovered. Another pottery style of the Early Mumun, Garak-dong (B. Lee 1974; Figure 1.1; 2.4b), is named after a site in Seoul, but settlements with this pottery tradition are found clustered in the tributary valleys of the Geum-gang River. Garak-dong style deep-bowls have appliqué rims (or double rim) with short slanted lines that are incised just below where the rim attaches to the body. The last type of the Early Mumun potteries is the Heunam-ri-style pottery, which is a combination of Yeoksam-dong and Garak-dong styles (J. Ahn 2000:49; J. Kim 2001; S. Lee 2005; Figure 1.1; Figure 2.4d. From the Middle Mumun Period, potteries become completely undecorated. The most dominant one is Songguk-Ri-style pottery (Figure 1.1; Figure 2.4e) which has elongated and curved shapes with everted rims in comparison with Early Middle Mumun pottery (Norton 2007).

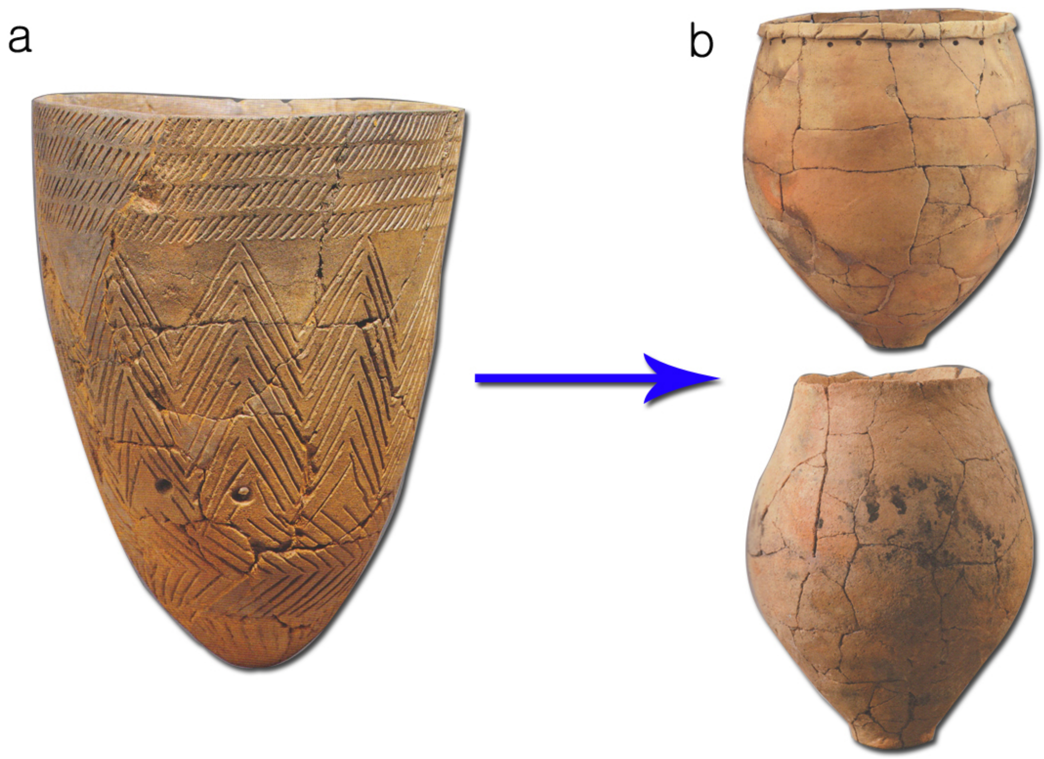

Figure 2.2: The Chulmun and the Mumun Period Potteries (a): Chulmun pottery with comb-shape pattern and the pointed bottom (b): Mumun potteries with patterns mostly on rim (upper-right; Heunam-ri-style pottery) and with no pattern (down-right; Songguk-Ri-style) (modified from T. Yoon and J. Bae 2010)

The manufacturing technique of stone tools shows too discrepancies between the two periods. Though polished stone tools started to be used in the Chulmun Period, their qualities and the skill of their production are relatively poorer than those of the Mumun Period (Figure 2.3a). The stone tools of the Mumun Period including the polished stone arrowhead and dagger, which were excavated in the central part of the Korean peninsula, are very elaborate and exquisite (Figure 2.3b). Also, from the middle of the Mumun

Period, we begin to observe bronze ware.

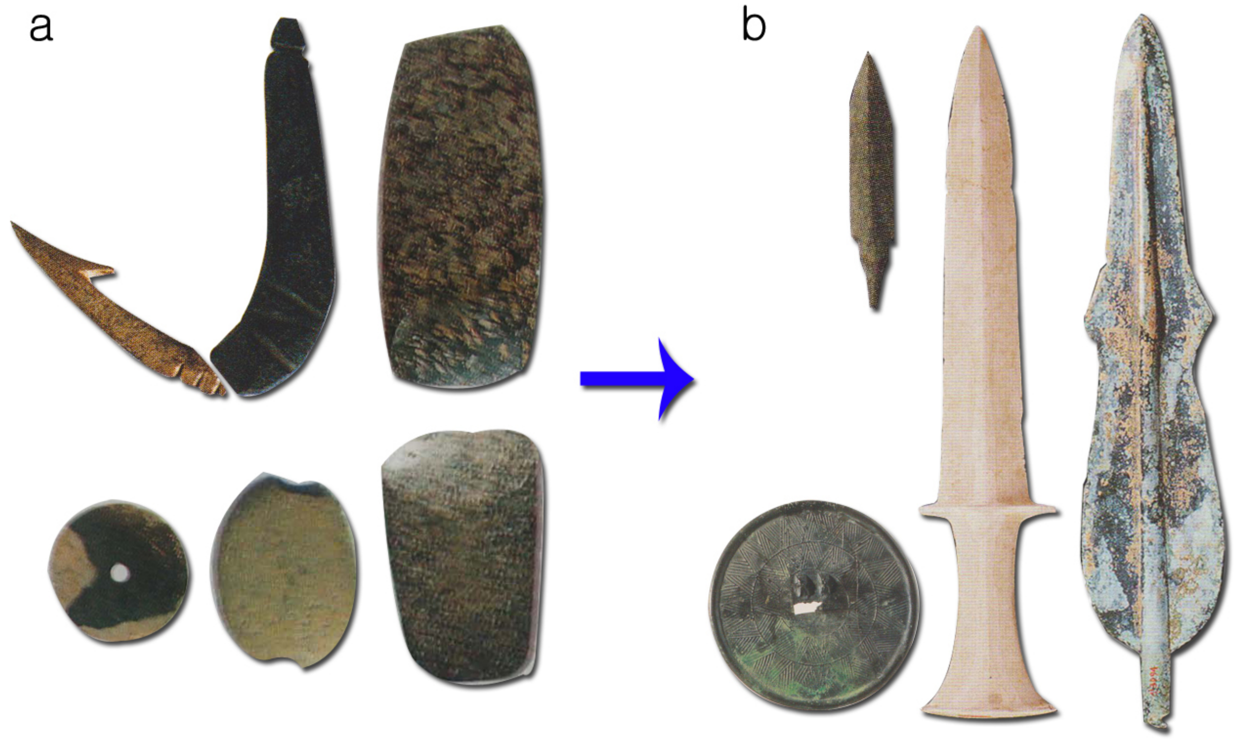

Figure 2.3: The Chulmun and Mumun Period tools (modified from T. Yoon and J. Bae 2010)

The form of habitations also changes. The Chulmun Period's houses have generally a round shape, but this shape was transferred into a rectangular style longhouse in the Mumun Period (Figure 2.5). Inside the longhouse, we can observe a row of 3 or 4 hearths for warming/cooking, which are not seen in that of the Chulmun Period. In a few words, the Chulmun Period's pottery with the pointed bottom and comb-shape pattern, and its polished stone tools and round-shape habitation were changed into the patternless flat-bottom pottery, elaborate polished stone tools and rectangular-shape habitation.

Together with these differences in characteristics of the archaeological assemblages of the two periods, Korean archaeologists assume that the most distinctive difference between the two periods consists in their subsistence strategies. Agriculture brought a great change into human life. Engaging in farming, human beings settled down for the first time. In the Korean Peninsula, it is argued that in the Mumun

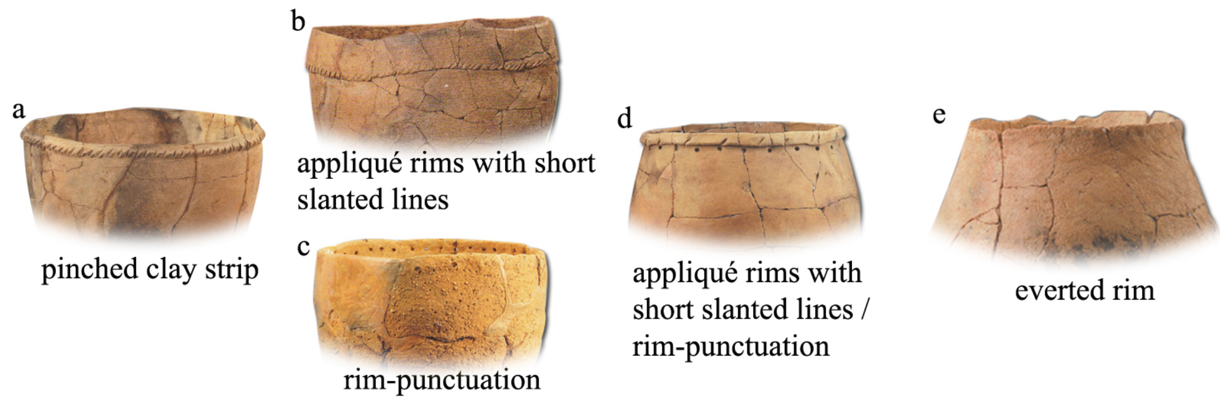

Figure 2.4: The patterns on Mumun potteries (a): pinched strip pottery (S. Cheon 2005) (b): Garak-Dong style pottery (B. Lee 1974) (c): Yeoksam-Dong style pottery (B. Lee 1974) (d): Heunam-Ri style pottery (Ahn 2000) (e): Songguk-Ri style pottery (Norton 2007)

period agriculture became the main means of living due to rice. Clear evidence including stone sickles (Figure 2.6a), "semi-lunar shaped" stone knife (Figure 2.6b), as well as dry field (Figure 2.6c) and irrigated rice paddies (Figure 2.6d) shows that full-dress farming was practiced in this region around the beginning of the Mumun Period (G. Lee 2003; 2011; T. Yoon and J. Bae 2010). Korean archaeologists think that agriculture was introduced in the Chulmun Period's late phase and the rice agriculture spread widely in the Mumun Period's early phase to be the principal subsisting way in the Mumun Period's middle phase. They think that though agriculture was introduced during the Chulmun period, the main subsistence in this period was confined to hunting, fishing, and gathering. Normally, the start of the rice agriculture is treated as being very important; and the site that gave initially grains of rice, burned or not, is thought to have a critical meaning. However, what matters is not the start of the rice agriculture, but its general practice. Korea is an agrarian country even nowadays, and rice is still the staple food of the Korean people. Therefore, it is essential to know when the ancients of the Korean peninsula started to eat rice as staple food.

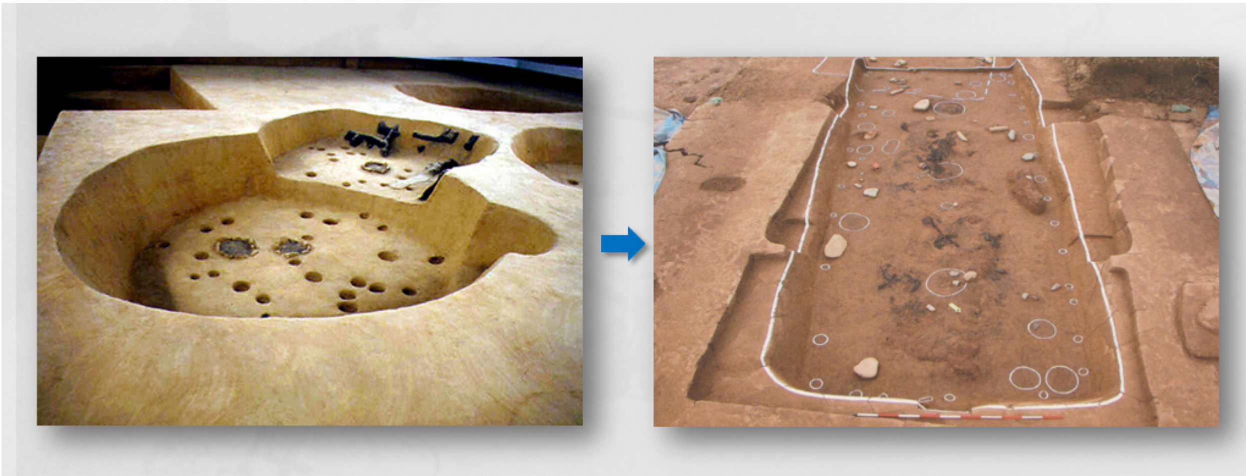

Figure 2.5: The Chulmun and Mumun Period habitations (modified from T. Yoon and J. Bae 2010)

Current views on the transition from foragers to farmers and development of rice agriculture in the Korean Peninsula

The transition from foragers to farmers in the Korean peninsula has been approached by assuming a strict dichotomy between Chulmun hunter-gatherers and Mumun full-dress rice farmers (J. Ahn 2000; B. Kim 2006a). The transition was linked with multiple migration events coinciding with climate change (J. Kim 2003; 2006), or assumed to be driven by population growth (Norton 2000, 2007), or regarded as consequence of a risk reduction strategy (J. Lee 2001).

Until recently, quantitative analyses of marine resources from coastal shell middens have been the primary data source for investigating patterns of subsistence in Korea (J. Lee 2001, 2006; Norton 2000, 2007; cf. G. lee 2011). For example, J. Lee (2001) argued that people used farming as a risk-reduction strategy against the declining sea level on the east and south coasts, as the ratio between the population and marine resources became imbalanced after 4,000 BP. By comparing the results of the analyses of marine resources from the shell middens of the west, east, and south coasts, J. Lee argued that farming emerged to overcome the loss of marine resources along the east and south coasts.

Similarly, Norton (2000) emphasized population growth as one of the key factors for the adoption of rice farming along coastal settings. He examined the remains of marine resources from the Konam-Ri shell midden (Figure 2.1b), located on the west coast of the Korean peninsula. Based on the result of this examination, he suggested that the differential processing of large fish might be an evidence of residential stability. Residential stability, he argued, led to the increased population throughout the hunter-gathering stage. This increase, and the associated increased human predation, caused a decrease in the size of fish and other favored taxa, and subsequently pushed the hunter-gatherers to adopt rice farming (Norton 2000).

J. Kim (2003, 2006) suggests a combination of environmental fluctuation and subsequent human migrations from northern latitudes as a major factor of the agricultural transition in the central part of the Korean peninsula. Based on paleoclimate data for the early Holocene East Asia, he argued that because of cooling climate and decreasing temperature around 4,000–3,000 BP, the farmers in the Jilin-Duman regions along the current border with China might have migrated to the central part of the Korean peninsula, which was better suited for farming. He presented a sudden change in household pattern and the presence of finely ground stone daggers around the central part of the Korean peninsula as evidences of these migrations. In addition, Kim assumes that the mobility of indigenous hunter-gatherers was constrained when immigrant rice farmers blocked their way to resource patches. The inaccessibility of foraging areas enhanced the transition of hunter-gatherers to farmers (J. Kim 2006).

Lastly, B. Kim (2005; 2006a; 2006b) focused on the emergence of a complex society associated with an intensive rice agriculture around 2,600BP. By correlating regional scale survey data from the south-eastern Chungnam province (Figure 1.1) with its soil productivity for rice agriculture based on a site catchment analysis of the region, Kim argued that the emergence of a social hierarchy and the subsequent social complexity were driven by the rapid spread of the intensive rice agriculture into foraging contexts. He asserted that this rapid transition is examplified by the sudden presence of harvesting tools of ground stone.

There are two underlying key ideas that these studies have in common, but both are problematic. The first two studies assume that shell middens can represent the general process of subsistence change from foragers to farmers in the central part of the Korean peninsula. Since a peninsula, consequently the Korean Peninsula is a part of a continent, the data from the coastal shell middens cannot represent the subsistence of the inland, which includes considerably large habitation sites. Next, all the four studies assume rice to be a dominant subsistence resource since 3,400 BP, without considering the possibility of the utilization of a more wider range of resources for subsistence.

According to archaeobotanical evidences from the southern part of the Korean peninsula, which includes the Daundong site in Ulsan and several localities within the context of the Nam River in Jinju (Oun I, Okbang 1,2,4,6 and 9, Sangchon B), the diet of the ancient farmers of the region included various resources such as millet, soybean, and azuki between 3400 and 2,600 B.P. (Crawford and Lee 2003; G. Lee 2003, 2011) (Figure 1.1). I assume the subsistence pattern might be similar in the central part of the Korean peninsula during this period, though we lack, for the moment, clear paleobotanical evidences to test this assumption. Therefore, the re-evaluation of those rice-centered models is required, and the general chronology of subsistence during this period has to be established.

The central hypothesis of this thesis

Studies have shown that in some cases, the initial domestication of crops and subsequent agriculture appeared as a part of the complex foraging economies in an affluent environment (Price and Bar-Yosef 2011; Price and Gebauer 1995) and hunting, gathering and fishing persisted well after farming was introduced (Boric 2002; Craig et al. 2011; Galili et al. 2002; Milner et al. 2004). In the Yangtze River Valley in China, for example, as well as in the Sub-Saharan Africa and the eastern North America, evidences of very early domestication come from settlements situated in zones with very rich resources which are associated with river valleys, and in none of these areas does domestication appear to have developed within a context of population growth forcing humans into marginal environmental zones (Smith 2007). New strategies such as agriculture were initiated by relatively complex hunter-gatherers in circumstances where risk is affordable. Then why did these foragers invest their efforts in agriculture when there was no immediate risk? The key idea for the reply to this question is that an increased sedentism was a "pre-requisite" for the advent of agricultural societies, for complex hunter-gatherers are characterized by a relatively large population and sedentism (Price and Gebauer 1995: 8). Recent case studies in the eastern North America by Smith (1995; 2007; 2011) are good examples. Smith argued that many of our present domesticated plants

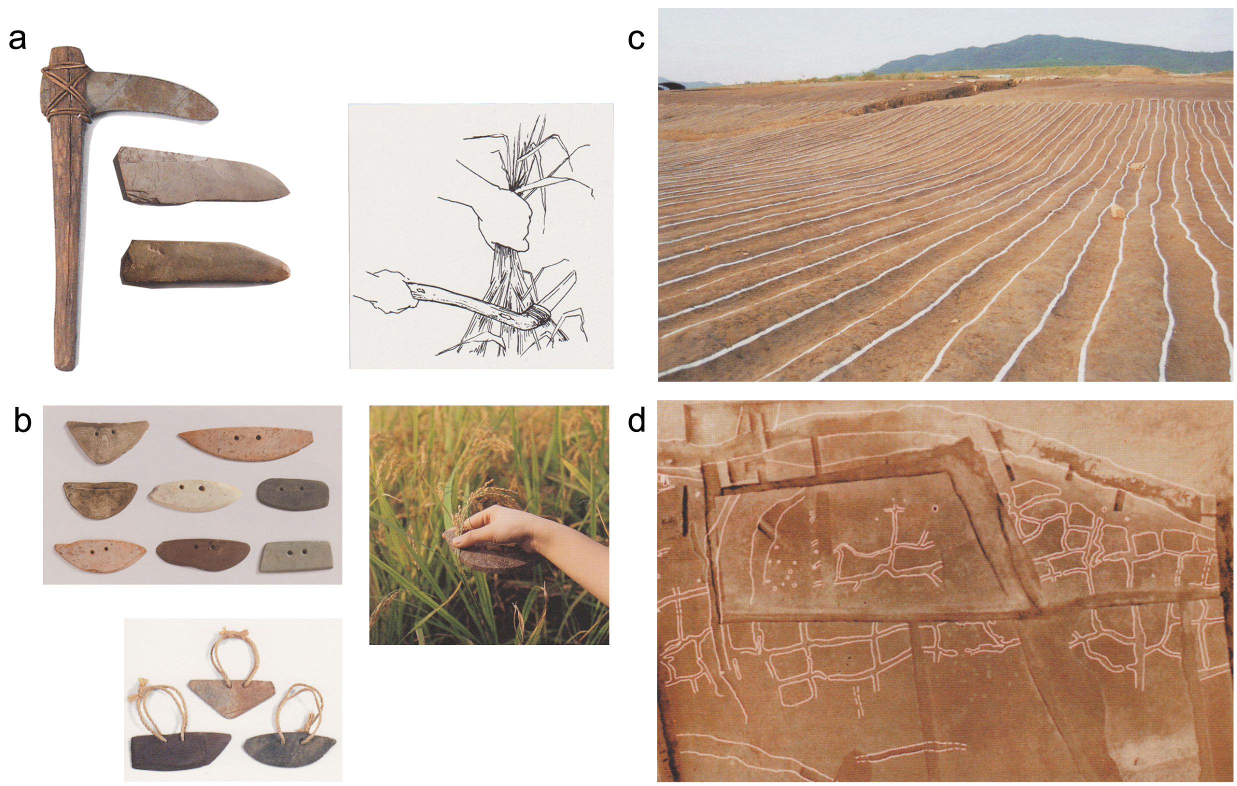

Figure 2.6: The evidence of full-dress farming in the central part of the Korean peninsula: (a) stone sickle, (b) semi-lunar shaped knife, (c) excavated dry field, and (d) irrigated rice paddy (all modified from T. Yoon and J. Bae 2010)

originated from the weeds growing in the open habitats created by rivers (e.g. floodplain), and they were easily adapted to open areas in the habitats disturbed by human sedentary settlements. Those weeds that invaded open areas in human settlements eventually became domesticated in conformity with the natural outcome of the selective relationship between people and plants within a stress-free environment (Smith 2007; 2011). Even the Jomon Japan, the period that is traditionally considered as giving an "affluent" hunter-gathering context based on sedentism, showed clear evidences of plant domestication (Obata et al. 2007). Recently, Crawford (2011) stressed that the orthodox view that the Jomon sustained hunting and gathering for millennia in a naturally rich environment is oversimplification if not correct.

This situation could have existed in the prehistoric Korea. We have solid evidences of a long-term, permanent occupation of the peninsula by complex hunter-gatherers at various places since around 6,000 BP. At the Amsa-Dong Site (Figure 1.1) in the south-east Seoul, at least 12 houses, a significant amount of pottery and different types of ground stone tools such as arrow points, spear points and sickles, were excavated (H. Lim 1985). Considering that the site was not fully excavated, and based on the scale of the houses as well as the diversity of ground stone artifacts, we can easily assume that this provides clear evidences for sedentism. The house structures and seasonality of the faunal assemblages at the Tongsam-Dong site (Figure 1.1) in the southern part of the Korean Peninsula indicate that people lived there year-round on a permanent basis (J. Lee 2001). We have pollen data from 5,500 BP to 2,600 BP showing that there were specific subsistence solutions which include distinctive combinations of wild (e.g. acorn (Quercusacutissima Carr.), Manchurian walnut (Juglans spp.)), possibly managed (e.g. chenopod (Chenopodium sp.), panicoid grass (Paniceae)), and domesticated (e.g. foxtail (Setariaitalica ssp. italica) and broomcorn millet (Panicummiliaceum), possibly soybean (Glycine max), azuki (Vignaaugularis) and beefsteak plant (Perillafrutescens (L.) Britt)) plants (G. Lee 2011: S326). On the other hand, though we lack the evidence of faunal remains due to the high acidity of sediment in the Korean peninsula, it is still possible that hunting and fishing may have persisted along with farming after its introduction (cf. Craig et al. 2011; Milner et al. 2004).

In this regard, the prevailing rice-centered models, which assume rice to be the most dominant subsistence resource since 3,400 BP., are misleading. My hypothesis is that there was utilization of a wider range of animals and plants resources along with rice among ancient farmers in the central part of the Korean peninsula between 3,400 and 2,000 BP. What is overlooked in the subsistence studies of the prehistoric Korea is the distinction between the first adoption of crops and the later development of intensive agriculture (G. Lee 2011). The migrants (cf. J. Kim 2006), if there were any, probably needed time to adjust themselves to the local environmental conditions, particularly for rice agriculture, which required complicated irrigation techniques. As G. Lee (2011) noted, rice may have played a minor subsistence role at this time, and it may not have served as a driving factor of the emergence of social complexity.

Summary

In this chapter, first I have discuss the history and social context of Korean archaeology focusing on series of political upheavals related to Japanese annexation. Next, I elucidated the current studies on the transition from foragers to farmers and development of rice agriculture in the Korean Peninsula. Then, the problems with these existing ideas stated based on the recent scientific evidence from the Korean peninsula and Japan. Lastly, I clarified main hypothesis of this thesis in detail.

3

Methodological background, Research design and analytical procedure of Luminescence dating

Introduction

To evaluate my hypothesis and to establish a general chronology of subsistence from 3,400 to 2,000 BP, I used the organic geochemistry and luminescence dating methods on the pottery excavated from three major inland sites in the central part of the Korean peninsula. In Korean archaeology, pottery is one of the main objects for archaeological analysis, being abundant in the Korean Peninsula in almost every archaeological assemblage in the sites that post-date 6,000 BP. This abundance allowed archaeologists to develop a detailed Korean archaeological chronology based on the pottery shape, size and decoration. Though this intensive chronology-building has much contributed to Korean archaeology, almost no attention has been given to analyzing the fabric of pottery itself. This is a surprising omission and represents a serious gap in our understanding of prehistoric technology and subsistence. The above methods allow us to identify what was stored and cooked in the pots as well as to date them directly, so that we can understand how subsistence changed over time. Accordingly they let me directly test the hypothesis posited precedently: that there was utilization of a wider range of resources among ancient farmers in the central part of the Korean peninsula between 3,400 and 2,000 BP and rice seems to have played no more than a minor role in subsistence during this period. In this chapter, I will discuss about the methodological background, Research design and analytical procedure of Luminescence dating. I will elucidate some of the main principles of luminescence dating and its application history to the Korean archaeology. I will also describe the laboratory analysis process in detail.

Luminescence dating in archaeology

In terms of pottery chronology, archaeologists have used stratigraphy that indicates a depositional event: when the artifacts were buried together, not specifically when they were manufactured. Dating these depositional events or "occupations" (Dunnell 1971: Raffeny 2008) is a usual goal but it is not quite same as dating manufacturing events. Archaeologists have not always distinguished occupational event and manufacturing event in practice (cf. Feathers 2009). In addition to stratigraphy, another method employed by archaeologists was seriation based on the physical characteristics of the potteries. However, this also has an inherent problem because transmission of the physical characteristics can occur across space (Dunnell 1970; Feathers 2009). To ascertain that seriations are mainly entangled to time, they must be restricted in space. Lack of control over spatial variation means it is difficult to tell whether there are sequential or special differences between each stage of seriation. The radiocarbon dating somewhat fitted with those traditional approaches, for this well-known absolute dating method mostly does not date the potteries themselves but nearby organic remains (e.g. Charcoal). This means the dating event inevitably has a variable relation to the target event of pottery manufacture.

Luminescence dating dates manufacturing event: when the pottery was made. To understand the chronology of subsistence, what archaeologists need to know is cooking event. Since cooking event is more likely associated with manufacturing event than depositional event, luminescence dating is probably the most suitable method for creating subsistence chronology.

3.3 Luminescence: the principals

Luminescence dating is an absolute dating method that has been used both intensively and extensively in the field of archaeology and earth sciences. It is based on the emission of light, luminescence, from minerals. In case of pottery, burnt flints, or burnt stones, the dated event is the last heating of the objects. Another common application is dating sediments. In this case, the event being dated is the last exposure of the mineral grains to light. The age range which the method can be applied is from a century or less to over one hundred thousand years.

Radioactivity is ubiquitous in the natural environment. Luminescence dating utilizes the radioactive isotopes of elements such as uranium (U), thorium (Th) and potassium (K) (Feathers 2003). Naturally occurring common minerals such as quartz and feldspars act as dosimeters, showing the amount of radiation to which they have been exposed (Duller 2008). A common characteristic of these naturally occurring minerals is that when they are exposed to the light emitted by radioactive decay, they tend to store some proportion of the energy delivered by the radiation within their crystal structure. The minerals accumulate this energy as exposure to radioactive decay continues through time. When this energy is released at some later date, these minerals release the energy in the form of light. This light is what we call luminescence.

Luminescence is explained by the solid state energy band theory (Aitken 1985; 1998; McKeever and Chen 1997). The interaction between radiation and the crystal structure provides energy to electrons that can be raised from valence band to the conduction band. Because of this stage, electrons become trapped within the crystal. In ideal situation, electrons cannot be trapped within the crystal structure, but this is possible because of defects within the structure. The electrons may be stored (and accumulated) at these defects for certain period. By the time these electrons are released, they lose the energy delivered by the radiation, and may emit part of that energy in the form of a single photon of light (Duller 2008).

The reason we can use this phenomenon for dating lies in the fact that this energy stored in minerals can be reset by two processes. The first process is by heating the material to the temperature above about 300°C: the process that occurs in a hearth or kiln during firing of pottery. The second is exposure to daylight, as may occur during erosion, transportation, or deposition of sediments. Either of these processes releases any existing energy, and thus set the 'clock' to zero (Duller 2008). Therefore, in luminescence dating, the event being dated is the last resetting of this clock, either by heat or light.

Measurements of the brightness of the luminescence signal can be used to calculate the total amount of radiation that the sample absorbed during the period of burial. If this can be divided by the amount of radiation that the sample receives from its surroundings per year, this will give the duration of time that the sample has been receiving energy: the age (Duller 2008).

$$\text{age} = \frac{\text{total amount of radiation exposed during burial (equivalent dose)}}{\text{amount of radiation recieved each year (dose rate)}}$$

There are a number of naturally occurring minerals that emit luminescence signals, including quartz, feldspars, and calcite. Among them, quartz and feldspar are the most suitable and ubiquitous material for dating (cf. Feathers 2003; 2009). The luminescence age is the period of time that has passed since the sample was heated or exposed to daylight. The age is given as the number of years before the date of measurement. Since there is no designate datum for luminescence ages, the date of measurement must be noted. The term BP (before present) should never be used for calculating luminescence age, for BP designates specific datum point and is only proper for radiocarbon ages.

The energy that stored within minerals' crystal structure can be released using a number of laboratory methods.

Thermoluminescence

Heating the sample at a certain rate from room temperature up to 700°C releases the trapped electrons within the crystal structure. The resulting signal from this process is called thermoluminescence (hereafter

TL). Typically the TL signal comes with a series of peaks (Figure 3.1). Each peak may indicate a single type of trap within the mineral, and commonly the signal is comprised of several traps. Although it is not always possible to identify the source of electrons precisely, in most cases TL signal observed at highest temperature originates from trap that is deepest below the conduction band (more energy is required to release electrons from deeper traps, and therefore this occurs at higher temperature).

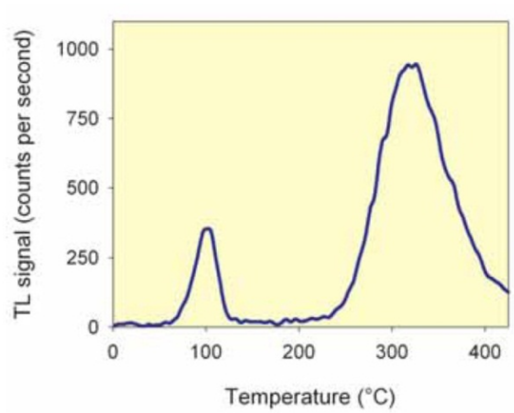

Figure 3.1: A typical thermoluminescence signal (commonly referred to as a "glow curve") that shows multiple traps (Duller 2008; cf. Feathers 2003:1495)

Optically stimulated luminescence

A second way of releasing the electrons stored within minerals is by exposing them to laboratory light (Huntley et al 1985). As soon as the mineral exposed to light, luminescence is emitted from the mineral grains. The signal is termed optically stimulated luminescence (hereafter OSL) and Figure 3.9 shows the signal from quartz during the stimulation. As measurement continues, the electrons in the traps are emptied away and the signal starts to decrease drastically (Figure 3.2).

A similar signal is observed from other minerals including feldspar. However, OSL signal from feldspars decreases more slowly than that from quartz (Duller 2008). Unlike TL, the OSL signal does not shows multiple traps. Thus, before measuring the luminescence signal, it is important to thermally pretreat the sample to make sure that the measured signal is from the deepest traps. This is achieved by heating

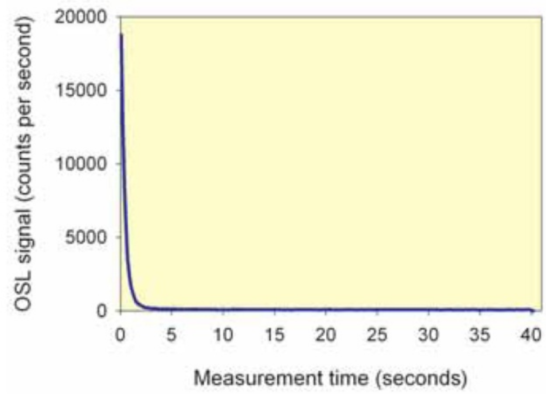

Figure 3.2: A typical optically stimulated luminescence signal from quartz grain (Duller 2008)

the sample before measurement so that the shallow traps (whose electrons are unstable over the burial period) are emptied, leaving only the electrons in deeper, stable traps – this heating is called a preheat (Duller 2008: 6; Feathers 2003).

The light used to stimulate the minerals is restricted to certain range of LED lights. Blue light emitting diodes are most widely used type for generating OSL signal from both quartz and feldspar. Another method of stimulation is using LEDs that emit beyond the visible part of the light spectrum: infrared stimulated luminescence (hereafter IRSL). IRSL is only observed from feldspars, for quartz does not produce an IRSL signal when the sample in room temperature (Duller 2008). Using these different characteristics of quartz and feldspar against the infrared light, a method for assessing the purity of quartz separated from feldspar for luminescence measurements can be provided.

Luminescence dating and its application to the Korean archaeology

The luminescence dating is a technique for dating once-heated materials, and is used by archaeologists primarily to date ancient ceramics and sediments (Feathers 2003). This technique can measure the time that has elapsed since the last exposure to heat and light of the materials constituting the object. As this exposure event generally occurred when pottery was made, the luminescence dating is ideal for dating archaeological ceramics (Feathers 2003). The optically stimulated luminescence dating (hereafter OSL), infrared stimulated luminescence dating (hereafter IRSL), and thermoluminescence dating (hereafter TL) methods employed for dating ceramics have been quite common in Europe and the United States for nearly two decades, but they are yet to be widely used in Korea. Given the abundance of ceramics in Korean archaeological records, it is surprising that the luminescence technique has not been more frequently employed. Though it has been mentioned considerably since its initial introduction (J. Choi et al. 2006; J. Choi et al. 2009), it has been used mainly in the field of geology (J. Bang et al. 2009). In archaeology, after its applicability was considered (D. Hong et al. 2001), it has only been employed to date sediments in Paleolithic archaeological sites (J. Kim et al. 2010). Probably the absence of archaeological luminescence dating of ceramics in Korea may be attributed to the uncritical acceptance of the relative chronologies. I partially agree to the detailed relative chronologies based on the decoration and style of potteries and their serviceable nature (H. Lee 2008; J. Bae 2007), but their applicability is quite low in subsistence change settings, for they are only based on the physical characteristics of pottery. Of course, the primary purpose of the luminescence dating in this research is to investigate the role of intensive rice farming and to establish the chronology of subsistence strategies over time by correlating the dates it obtained with the results of organic geochemistry analyses. However, with a systematic application of the luminescence dating, I was also able to grasp a glimpse of a more reliable chronology which can be easily applied to other archaeological studies. In 2011, I dated one potsherd from the archaeological deposit in Hongseong city, central part of the Korean peninsula. Using the thermoluminescence method, I was able to confirm that the potsherd was from the proto-historic period (280±86AD; U2516 in Table 3.1).

Lab. No	Depth (m)	Water Content (%)	Dose rate* (Gy/ka)	TL (De)	OSL (De)	IRSL (De)	Age
U2516	0.36	20.4	5.532±0.277	8.712±0.91 11.665±1.423	8.586±0.331	7.215±0.361	280±86

Table 3.1. The result of the luminescence dating (*Dose rates are rounded to two decimal places, but calculation of the total dose rate was carried out prior to rounding)

All the samples for my research was dated at the Luminescence dating lab, Department of Anthropology, University of Washington. The Luminescence dating method enables the evaluation of the time that has passed since the mineral grains were crystallized, that is, since the grains were last exposed to daylight or heated to a few hundred degrees Celsius. Generally, as at the lab of the University of Washington, the method uses an optically and thermally sensitive light or luminescence signal emitted by minerals such as quartz and feldspar. For dating, the amount of absorbed energy (luminescence signal) per mass of mineral (1 J/kg= 1 Gray) due to the natural radiation exposure since the last zeroing - known as the palaeodose - is determined by comparing the natural luminescence signal of the sample with that which is induced by the artificial irradiation (Preusser et al. 2008). The time having passed since the last daylight exposure/heating (the date of the sample) is obtained through dividing the palaeodose by the dose rate, the latter representing the amount of energy deposited per mass of mineral by the radiation exposure on the sample over a certain time (Preusser et al. 2008). The potsherds in this thesis was dated by using this formula, and both of the two general methods, TL, OSL, and IRSL will be applied. For a further clarification, the dates from the luminescence dating were correlated with those from AMS radiocarbon dating.

Analytical procedure

The luminescence dating method enables evaluation of the time that has passed since mineral grains crystallized, which means it can measure the amount of time since the grains' being last exposed to daylight, or heated to a few hundred degrees Celsius. Its technique was developed in an archaeological context, in Europe in the 1960s and 1970s, as a method of dating heated materials, primarily ancient ceramics and potteries (Feathers, 2003). It has been applied to a wide range of Quaternary researches such as landscape evolution, palaeoclimate, archaeology, and has been being refined since its early days. It dates the past exposure to heat and light, and because the events of this exposure are the actual events archaeologists are interested in, it has a strong merit over other dating methods (Feathers, 2003). In other words, in the luminescence method, the dating event is often the target event that the archaeologists are looking for. In this thesis, the luminescence dating was applied to eight archaeological ceramic samples.

Sample preparation - grain size

For the luminescence dating, determining the grain size is quite important, for there are advantages/disadvantages as well as different methods it occasions. Generally, fine grains (1-8 µm) are more abundant than coarse ones; and they can be analyzed with samples of relatively small amount. They also require a relatively simple sample preparation process, and rely less on the external dose rate, which is often problematic in a complex ceramic environment. However, if samples include feldspar grains (which cannot be separated from other grains during the sample preparation procedure), one has to deal with the high fading rate of feldspar (Wintle, 1973).

One of the biggest advantages of using coarse grains (180-212 µm) is the single grain analysis, which can be done only with coarse grains. Quartz grains are generally used for the analysis of coarse grains, because of its well-known properties and low fading rate. Since it is possible to minimize feldspar inclusion during the sample preparation process of coarse grain, we do not have to consider the fading of feldspar as a major variable. Also, because of the larger grain size and etching process during the sample preparation, the contribution of alpha radiation (which has a short range: 50µm) is minimal. This is a huge merit, for alpha radiation is much less effective in producing luminescence than beta and gamma radiations. In case of analyzing fine grains, this 'low alpha efficiency' must be considered. However, using coarse grains for the analysis requires a complicated sample preparation process and a larger amount of sample. Also, it cannot be totally exempted from the high fading rate, because feldspar has to be used for the single grain analysis in some cases (feldspar typically has a bright luminescence signal, which enables dating older deposits than with quartz; Preusser et al. 2008) where quartz shows an extremely low luminescence signal. It has also been verified that the quartz of volcanic origin may show anomalous fading, just like feldspar (Bonde et al. 2001; Tsukamoto et al. 2007). In this Thesis, fine grains were used for the analyses, because of their small sample size and advantages that I mentioned above.

Glassware and reagents

All glassware was washed with Decon 90 (Decon laboratories), rinsed four times in distilled water. Analytical grade reagents (typically ≥98% purity) were used throughout.

Dose rate measurement

The dose rate is the amount of energy deposited per mass of mineral by the radiation exposure of the sample over a certain time (Preusser et al. 2008). For the dose rate measurement, the exposed parts of the potsherds were used (0.5-1 g). The dose rates were determined by alpha counting (Low level alpha counter 7286: Little more Science Engineering Co., DayBreak alpha counter 583: DayBreak), beta counting (Beta multi counter system RISØ GM-25-5: Risø National Laboratory), and flame photometry (Flame Photometer PFP-7: Jenway).

The water absorption percentages of the samples were measured. This is quite important for calculating the dose rate, as the attenuation of radiation is much greater if the sample is filled with water (Preusser et al., 2008). For measuring the water absorption percentage, the sample was saturated with deionizing water for several days. Then, the surface wetness was removed by gently dabbing it with a wet paper towel; and then it was immediately placed on the scale to weigh it. After the sherd was dried in a 50°C oven for several days to record its weight in its dry state. The water absorption percent is calculated as W = [(S/D)/D]*100, where S is the saturated weight and D the dry weight.

Some component of the dose rate is produced by the ionizing cosmic radiation, and could be by the geographic location and burial depth of the sampled material (Prescott and Hutton, 1994). All information related to the latter points was obtained from the excavation records of the sites where the samples came from.

Alpha counting gives the current alpha activity rate. And based on this rate and the assumption of secular equilibrium, one can calculate the beta and gamma dose rate. However, by using the beta counter and flame photometry as well, we can enhance the validity of the alpha counting and the total dose rate measurement. This sort of advantage is available only if we utilize multiple tools at the same time.

Equivalent dose measurements

For measuring the equivalent dose (paleodose) of the pottery samples, TL (Thermo luminescence; Day-Break 11000 Atomated TL system), OSL (Optically stimulated luminescence; RISØ TL/OSL system DA-15), and IRSL (Infrared stimulated luminescence; RISØ TL/OSL system DA-15) were utilized. Artificial laboratory irradiations were given by the Irradiator type 721/A (Little more Science Engineering Co.) and RISØ TL/OSL system DA-15. Fine grains (1-8 μm fractions) were used for dating. The grains were obtained from the core part of the potsherds more than 2 mm away from any exposed surface. This was done by drilling, using tungsten carbide drill bits. For the TL analysis, the equivalent dose was determined by the slide method to obtain both of the advantages of the additive dose method and the regeneration method (Prescott et al., 1993). The slide method can deal with the matter of extrapolation as well as the process of zeroing simultaneously. These two problems cannot be solved at the same time in case of using either the additive dose method, or the regeneration method solely. As I mentioned above, for dating fine-grained samples, one has to deal with the low alpha efficiency. This is taken into account by determining the alpha efficiency factor: "b-value (Huntley et al. 1988)". It has been known that the alpha efficiency varies between quartz and feldspar (Huntley et al. 1988). The typical b-value of quartz and feldspar is respectively about 0.5 and more than 1.5. IRSL was applied to reduce the feldspar signal, for feldspar tends to be stimulated by infrared light (Roberts and Wintle, 2001).

Determining age

The time having passed since the last daylight exposure/heating of the pottery sample (Hereafter: age) was calculated through dividing the palaeodose by the dose rate. The final date of the sample was obtained through calculating the average of the three dates from TL, OSL, and IRSL. Normally, when conducting the luminescence dating on a pottery sample, its associated sediment is required for the precise dose rate measurement. However, since there was no associated sediments on my samples, I relied on the dose rate of the sample itself. Therefore, it was assumed that the dose rate of the sample was the same as (or at least approximate to) that of the associated sediment.

Summary

In this chapter, I have discuss about the methodological background, research design and analytical procedure of Luminescence dating. Some of the main principles of luminescence dating and its application history to the Korean archaeology were elucidated. I also described the laboratory analytical process in detail.

Colophon

This document was typeset using the XeTeX typesetting system originally created by the Jonathan Kew, and the uwthesis class created by Jim Fox. Other elements of the document formatting source code have been taken from the Latex, Knitr, and RMarkdown templates for UC Berkeley's graduate thesis, and Dissertate: a LaTeX dissertation template to support the production and typesetting of a PhD dissertation at Harvard, Princeton, and NYU

The body text is set at 11pt with EBGaramond(3). The thesis was written as R markdown formatted documents, which was converted to PDF using pandoc using knitr with a custom R package.

This PDF was generated on 2015-05-06 02:43:22 in the following computational environment:

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## Running under: Windows 7 x64 (build 7601) Service Pack 1
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## [2] LC_CTYPE=English_United States.1252
## [3] LC_MONETARY=English_United States.1252
## [4] LC_NUMERIC=C
## [5] LC_TIME=English_United States.1252
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##
## other attached packages:
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