Spring 2001

Obsidian Quarries in Melos, Greece & Their Effect on the Economy of the Agean Sea

Jessica Allen
University of Pennsylvania

Follow this and additional works at: http://repository.upenn.edu/anthro_seniortheses

Part of the Anthropology Commons

Recommended Citation

This paper is posted at ScholarlyCommons. http://repository.upenn.edu/anthro_seniortheses/23
For more information, please contact repository@pobox.upenn.edu.
Obsidian Quarries in Melos, Greece & Their Effect on the Economy of the Agean Sea

Disciplines
Anthropology
Obsidian quarries in Melos, Greece & their effect on the economy of the Aegean Sea

Jessica Allen
ENVS-Senior Thesis
Dibble/Giegengack
Spring 2001
Introduction:

Flaked stone tools are the only information we have to many parts of the past. Many archaeological sites are completely littered with the flakes and debris of stone tool assemblages. Obsidian is a very common, glassy rock that can be flintknapped in order to make flakes, blades and other tools. Its durability is excellent for preservation, hence these pieces of rock are sometimes the only link we have to entire regions of the ancient world. One of these regions is the Aegean Sea during the Neolithic Era. In this area obsidian is one of the most prevalent artifacts, since it was found in every site in or around the Aegean. Since obsidian only appears in recently volcanic active areas, most of this obsidian found in the Aegean was transported by humans. The movement of obsidian can tell us much about the economy and trade of the region.

Raw obsidian is located on the island of Melos. Melos lies in the southeast of the Aegean Sea within the Cycladic island region. It is one of the smaller islands that lies west of Antiparos. There are two volcanic outcrops on Melos, Sta Nychia and Demenegaki (Figure 1&2). These quarries have obviously been pillaged for raw material (Figure 3). The raw material was flintknapped to make flakes, blades and other tools. The cultures vary between islands and mainland; we see early Neolithic and late Neolithic cultures represented. The obsidian taken from Melos is the only link between some prehistoric Greek sites.

There have been many attempts to explain how the obsidian was moved, starting at the turn of the century. At this time, two men took an interest in prehistoric Greece. More specifically, Bosanquest and Mackenzie started to
investigate the settlement of Phylakopi on the island of Melos. The island of Melos was special that it was home to a very valuable natural resource, possibly controlled by the settlement Phylakopi. Upon first appearance of the value of obsidian stone tools it all fits together: the settlement had a monopoly over the obsidian and traded it for profit, which resulted in the success of its reign. Although this seems like a convincing hypothesis, it is not the case. Bosanquet and Mackenzie forgot to analyze many all aspects of the success of Phylakopi. They implied that all the obsidian that they found came from Melos when there are other quarries around, albeit further away. They also forgot to compare the time frames of the city at its strongest to the time when obsidian was the most valuable. The veracity of their conclusions has been questioned and attacked by those following in their footsteps.

In reaction to this work, Colin Renfrew did a great deal of his own research. Renfrew conducted studies to determine the source of the obsidian. Bosanquet and Mackenzie implied that all the surrounding obsidian came from Melos. This was their first mistake. Renfrew backtracked and identified obsidian from sites and compared it to natural sources of obsidian. After that was accomplished he could began investigating the trade systems. Renfrew, knowing the area well, was able to create a method to predict how obsidian was moved and traded. His work is invaluable in this area. While there is very little data, he managed to get a great deal of information out of it. He was helped by a number of people in his theories and methods. Ian Hodder is very active in conducting trade system analysis. His methods corresponded very closely to Renfrew’s and when they were conducted on Aegean obsidian the results were very similar.
This work, by both Renfrew and Hodder, is not without critique. Despite the strength of both conclusions, they are still attacked. Ammerman believed that both methods look over two very important aspects of trade analysis. One of these was time and the other was when a settlement will drop its objects to be picked up, when the objects became trash. He developed his own methods which accommodate for these two factors. However, since these studies have not been implemented on the Aegean obsidian, we do not know whether it makes a difference or not.

Melos, although it may be a small island, was and is of huge importance. The natural resource of obsidian on it makes it valuable to the Greek settlement and the archaeologists studying it. Obsidian is the key to understanding the economy and trade system of the area. With this knowledge it will better help us understand the culture of the Aegean as a whole.

Chapter Two: Background-The Culture that used Melos Obsidian, Neolithic Greece.

Like the rest of the world, Greece and the Aegean went through a transition approximately 10,000 years ago from Paleolithic to Neolithic culture. This change was the development from nomadic hunters and gatherers to permanent settlements, farms and domestication of animals. Permanent settlements became much more prevalent as people learned cultivation and husbandry. This is excellent news for archaeologists since after this point we can investigate lifetime civilizations rather than the remains of the temporary settlements of nomads. However, what’s been preserved is still limited.
Since clay does not decompose, pottery shards are crucial to the excavation and understanding of Neolithic culture. The styles can indicate changes and new technologies within prehistoric Greek culture. As settlements get bigger we find house posts and foundations of walls. Obsidian is also preserved well and was a prominent natural resource for Neolithic Greek cultures. Thus, not surprisingly, the quarries on Melos were pillaged for tools. However, with the advent of the Bronze Age and metallurgic technologies, obsidian was not used as frequently, even on the island itself where it is readily available. During its prime, in the early Neolithic, obsidian’s influence was absolute and far reaching. However, its demand declined as Greece approached the Bronze Age.

There is some evidence that obsidian was used before the Neolithic around 7000 BC, in what Papathanassopoulos calls the 'Protoneolithic' (Papathanassopoulos 1981). At this time there is no evidence of pottery or animal domestication. However there is evidence of the transport of obsidian. Obsidian was just as valuable for hunter and gatherers, thus its use is not anticipated to correspond solely with the Neolithic. The earliest dated pottery of Neolithic Greece is from Nea Nikomedeia in Macedonia in 5620 BC (Renfrew 1972: 67). Pieces are found at this site dated between 6200 and 5300 BC (Rodden 1965: 83). The Middle Neolithic is represented by more growth throughout all of Greece from around 5000 to 4000 BC (Papathanassopoulos 1981:104). This was followed by the late Neolithic, which was a time of diversity. The popularity of black burnished and red painted pottery’s popularity declined while matte-painted and polychrome pottery took its place on mainland Greece in the late Neolithic. In the style of pottery, the change in
mainland Neolithic culture can be seen. Yet not all of Greece share these styles and changes.

Island cultures varied greatly from those of mainland Greece. Many islands of the Aegean, including the Cyclads, were not inhabited until the Middle Neolithic; though we know that there was access to these islands since Melos obsidian was being quarried, transported and used at this time. Island culture is dependent on fishing and nautical technologies for success unlike the mainland. The island of Crete shows that there was very little outside influence. Crete, lying south of all of Greece, took on its own culture. It has its very own distinctive pottery styles that are not found anywhere else in Greece. The only evidence that links it to the rest of Greece is the Melos obsidian that was used there. Like Crete, the Cyclads, had their own characteristic pottery styles, including incised and painted pottery. In the beginning of the Bronze Age around 2800 BC, these islands were prosperous.

The Cycladic settlement of Phylakopi on the island of Melos is the most successfully preserved stratigraphically. The site is separated into layers of the city; there is the first, second and third city. The settlement happens to be located on the same island as the highly valued obsidian quarries. However, the time of the height of its wealth was well past the beginning of the Bronze Age. The second city and most prosperous existed during the middle Bronze Age. This was determined by the pottery found at the second cities stratigraphic level. The matte-painted designs that were common in Phylakopi on this level corresponded with the designs of other mainland Bronze Age sites. At this time the city was so advanced that it had a planned design of roads and walls, very rare in poor settlements.
Papathanassopoulos 1981: 189). All this indicates that it was a prosperous city of the Bronze Age.

There is still so much that is unknown about prehistoric Greece. As you have seen in this chapter, Neolithic sites are very limited. Thus, all archaeologists have to analyze is mostly the pottery and obsidian left behind. By looking at the all the aspects available, they will tell us more about the culture as a whole. For instance, pottery styles can help us interpret how the obsidian was used or transported because their styles record the advancement of technology through time and growth in diversity of culture throughout the Neolithic. Furthermore, pottery allows us to compare various cultures and interpolate which sites were communicating with each other. Throughout mainland Greece the styles of pottery remain fairly consistent, which indicates communication. However, the similarities decline between the mainland and the Cyclads, demonstrating that there was less interaction overseas.

But we know that there was some seafaring since obsidian is found everywhere. It is found on mainland Greece in sites along the coast and inland; it is also found in the Cyclads, and the larger islands including Crete. This movement does not necessarily prove that there was the sharing of ideas. This lack in stylistic similarity between the mainland and the Cyclads supports the idea that there was no trade and very little communication going on between them. However, overall, these cultures are sharing pottery. All cultures are using pottery and there is the same general shape and function. For this reason, Renfrew later clumped these cultures together. In an entire region like Greece it is difficult to assess the
interaction between hundreds of miles. One fact that we do know is that at one point in history obsidian was a valuable commodity and being traded. This is a starting point in which we can examine the trade and communication of the Aegean through obsidian.

Chapter Three: How do we know that there is trading?

Obsidian can only be found in areas of recent volcanic activity. Volcanic eruptions are excellent dating events since they are infrequent and leave very explicit deposits. Therefore, obsidian deposits or quarries are restricted to specific areas. In the ancient Mediterranean the locations of obsidian quarries are known and usually a couple of hundred miles away from each other, although they may be from the same volcanic activity. The island of Melos has three quarries on it. There are also quarries 240 kilometers east of Melos on Giali (Dixon 1968: 40). The central section of the Mediterranean has a number of quarries including the islands: Lapari, Pantelleria, and Palmonola among others (Dixon 1968: 40). Despite only having these natural sites of obsidian, obsidian stone tools are found in every single archaeological site in the entire Mediterranean. This proves that there was transportation of materials, which opens up a world of possibilities of trade and communication. Determining how and where these artifacts traveled is the first dilemma faced when investigating trade in this ancient civilization.

There are many methods of identifying the original source of an artifact, or piece of float obsidian. Since there are pieces found in sites hundreds of miles away
from the closest quarry we cannot assume the people used the most convenient location. Thus, the obsidian must be traced to a source. The first and most obvious physical or chemical property used to distinguish various obsidians is the color or visible appearance (Dixon 1968: 41). Depending on its molecular structure, obsidian comes in many different colors spanning the spectrum. However, one quarry can consist of many different colors and looks of obsidian. Likewise many different and distant quarries can have the same appearance. The analysis must go down to a smaller level; unfortunately, obsidian is uniform even at the microscopic level. Its cryptocrystalline structure makes it useful for flaking and thus not useful for this study.

While appearances and cryptocrystalline structure reveal nothing about the origin of the obsidian, chemical properties do vary between each quarry and within quarries. The question is whether each quarry is individual enough to be contrasted to the others. Chemical analysis of the obsidian based on its trace elements is done through spectroscopy. This method is successfully used for determining natural sources of obsidian throughout the Neolithic Mediterranean. When it does not work, however, there is another method of analysis, fission track analysis. This process ages the rock and plots the Uranium content (Durrani 1972: 243). With this information, quarries that have two similar spectroscopic pictures are separated through fission track analysis. The rest of this chapter will examine these two processes, how they work, and what they reveal about the transport of obsidian in Neolithic Mediterranean.
Spectroscopy is a method used to determine the trace elements within a material, in this case, obsidian. A small amount of the sample is ground up into a fine powder. This powder is mixed with carbon and heated. Once completed, a spectrographic picture displays the wavelengths of the elements in it. Each element emits a specific wavelength when it is heated to incandescence. These wavelengths are sent through a prism that separates each element so that each is individually identifiable, even when they only occur at a few parts per billion. This process gives us the tools for analyzing and comparing obsidian found at an outcrop by their natural source and also as artifacts in Neolithic sites.

Renfrew performed spectroscopy on the obsidian from many quarries throughout the Mediterranean (Dixon 1968). He found 16 elements present. And of those 16, barium and zirconium were the best means of distinguishing each natural source, since their concentrations varied the greatest in the samples taken. Each quarry had a characteristic amount of these elements in it. By plotting this amount, each quarry’s samples would be restricted to one area (Figure 4). If there are two quarries where zirconium and barium are too similar, such as Lipari, Giali and Melos, another trace element could be used to separate the two quarries. Giali and Melos were eventually differentiated by an alternative method, fission track analysis, which will be discussed later on in this chapter.

The plotting of trace elements does provide an excellent foundation to build on by comparing artifacts with their possible natural source. Tools from Malta were traced to Lipari and Pantelleria, and tools from Crete were traced to Melos. It was discovered that tools came from the quarry of its region. Most tools found in the
eastern Mediterranean were obtained in the quarries of the eastern Mediterranean. By doing this study Renfrew first began to understand the magnitude of Neolithic trade. While the obsidian of Melos remained on the eastern part of the Mediterranean, it still traveled a great distance. Map 1 demonstrates the spread of obsidian from Melos and other location. This method was crucial in the analysis of Aegean trade. Spectroscopy enabled us to trace routes and see where and how far the obsidian actually traveled.

Unfortunately, there are still certain quarries, like Giali and Melos that are indistinguishable by spectroscopy. The answer for this is fission track analysis. Renfrew and Durrani conducted another investigation on obsidian which again included the Aegean Sea. Fission track was used to determine ages of obsidian and calculate its Uranium content. Since many of these volcanoes were too close in age, Uranium count must also be used. Both age and Uranium are represented in a material as an equation:

\[
\text{Age (in years)} = \left( \frac{p_n}{p_i} \right) 5.01 \times 10^{-6} F \]

\[
\text{Uranium (p.p.m.)} = 9.445 \times 10^7 \left( p_i / (D.R_a \cos^2 \theta_c \cdot g \cdot f(l)) \right)F
\]

(Dixon 1968: 42). \((p_n/p_i)\) are the densities of these etch pits per centimeter. The \(F\) represents the amount of thermal neutrons per cm. Uranium content is based on the same principle with a few more factors. Critical angle of the etch pits and the surface is taken into account in \(\theta_c\). The amount of uranium is also compared to a reference point \(D.R_a\), which is the density multiplied by the apparent range of the average fission fragment. Natural constants are also part of the equation. Both these equations seem complicated at first glance. What they represent, however, is not.
As obsidian ages, etch pits are produced by fission. The equations measure the amount of fission pits a piece of obsidian has accumulated since it was formed. Fission track is based on the natural aging of the rock. One problem with using these equations is that they assume that there is no intrusive rock within the obsidian, meaning that it remains in this protected environment undisturbed as it ages. This is not usually the case since many other minerals become included as the glass is cooling or after it forms. Either way, extraneous intrusions can create etch pits of their own that are quite indistinguishable from a naturally occurring pits. These “dirty” obsidians can greatly skew the results.

Renfrew took samples from Hungary, Central Anatolian and the Aegean. I am interested in the three quarries on Melos and the quarry on Giali. Most of the ages from the Aegean were dated between 8 and 9 million years ago. However, there were also samples from both islands that were dated around 2 m.y.a. This indicated that all of these quarries spurned from the same series of volcanic events. While this is pertinent to the history of the earth, it is not to our studies. Luckily, there is another characteristic that fission track analysis calculates, which is the uranium count of a rock. Three samples from Demenegaki on Melos were extremely close and distinct from those found on Giali. All the others were too similar to classify, though at no point do both age and Uranium count overlap. When the ages are too similar, the Uranium content is different or vice versa. Thus, using both we can successfully conclude from which natural source, Melos or Giali, an artifact was taken.
Like the spectroscopy work, Renfrew now chose a site to test. In this case it was Franchthi Cave, which is located on the mainland. The cave lies approximately 100 kilometers northwest of Melos. The pieces of obsidian found there were dated to 6500 BC. This predates both the Protoneolithic and the Neolithic. Using the spectrographic pictures of the sample they took, they discovered that the obsidian was obtained from Melos. This is a remarkable find, since it dates obsidian use as well as seafaring.

Obsidian was being transported all over the Aegean Sea in the Neolithic. As a natural resource, it was very limited. Yet, all of the ancient Aegean settlements found a way to overcome this, since obsidian artifacts are found abundantly all over the Mediterranean. Spectroscopy and fission track analysis are tools in understanding the spread and trade of obsidian through the Aegean. Furthermore, these studies definitely show that it was not only transported over land but also water. The ancient Aegean settlers were traveling great distances or trading the obsidian in order the move the rock as far as they did. More importantly, they were moving it over water. Seafaring must have had a major role in Aegean settlements, since most obsidian is on islands. Because the evidence shows that people were able to travel over land and water, a degree of sophistication can be inferred.

The evidence here proves that obsidian was being quarried and moved. Everyone agrees that it was being moved. The next pertinent question is how it was being traded. The next three chapters will cover various methods that have been used to research the many theories on trade systems in the Aegean.
Chapter Four:
The Beginning: The First Excavation of Melos by Bosanquet and Mackenzie (At Least It's A Start)

The first excavations of Melos began in the turn of the 19th Century with the British School of Athens. Two men, Bosanquet and Mackenzie (Bosanquet 1904), discovered a significant urban center on the island, known as Phylakopi. Thus, in 1895-96 they excavated the site. They discovered that it is an ideal site of the Cycladic Bronze Age. It is well known that Phylakopi was a large and wealthy city. Its reign spanned from the Early Bronze Age in its “First City” and remained prosperous throughout the middle of the Bronze Age during its “Third City”. In the layer of the “Second City” Bosanquet found fortified walls and highly skilled level craft in pottery, indicators of a wealthy city. Their next step was to find a reason why such a successful city would be located in such an isolated area like Melos, an island. The volcanic glass, obsidian, was thought to be highly valued in the Neolithic Age and Early Bronze Age. Phylakopi was located near both of the obsidian quarries on the island of Melos, Sta Nychia and Demenegaki. According to Mackenzie and Bosanquet, the location near the quarries and the value of stone tools were responsible for Phylakopi’s success. Thus, they named it “the great Aegean obsidian emporium in Melos” (Bosanquet and Mackenzie 1904: 221). They concluded that the need for obsidian lead to more growth of its “First City” which continued to the success for its “Second City”.

Bosanquet and Mackenzie formulated a profit-oriented trade system for Phylakopi. The people of this Melos settlement possessed a valued resource. This
control over a wanted or needed substance gave them power and thus, money. This translates into the success of their city, an ideal capitalist society. (Bosanquet 1904). This need for obsidian, however, did not last long. With the advent of the Bronze Age, obsidian lost its value. The metal bronze was being used rather than the rock obsidian. And when obsidian lost its value, Phylakopi lost its power. Bosanquet and Mackenzie relate the decline of Phylakopi to the decline of the use of stone tools.

There are many problems with this analysis of the settlement and obsidian exchange. Bosanquet and Mankenzie severely overestimate the value of obsidian at the wrong time. They claim that the decline of obsidian started in the Late Bronze Age, when it actually happened in the Early Bronze Age, since the height of success of the city was during the Middle Bronze Age. Simply based on the dates of the city, Renfrew found the “demand for obsidian slowing at the height of the civilization” (Bosanquet 1904: 32). Regardless of this fact, obsidian was never valuable enough to make a significant impact on the economy of a major city. Well into the Bronze Age, the second city was filled with the pottery and metals of foreigners, not the rocks of natives. Another problem with Bosanquet and Mackenzie’s excavations was the implementation of their modern capitalist views on an ancient society. Economies of the past could and very well might be dramatically different than what they are today. However, since capitalism is all that Bosanquet and Mackenzie were familiar with, they forced their biases into their research. Renfrew responds “professional trade and commerce was probably absent from most prehistoric communities” (Renfrew 1969a: 152). For these reasons Bosanquet and Mackenzie’s interpretations are considered erroneous. They did, however, serve a purpose. They incited
interest and laid the foundation to start more research in the Aegean exchange system. While they may be refuted by their successors again and again, Bosanquet and Mackenzie provided a much-needed starting point.

Chapter Five:  
Down-the-line Exchange vs. Direct Access Model: 
Renfrew’s Interpretation

Colin Renfrew has done a great deal of research on obsidian, not only in the Aegean but also in the Near East. He has established many theories on prehistoric trade systems that are adaptable to the Aegean and many other regions of the world. Also in doing this, it has helped him develop a realistic view of the economy in prehistoric Aegean. He began by analyzing Bosanquet and Mackenzie’s conclusions on trade. Recognizing their faults covered in the last chapter, he wanted to do an investigation of his own. Although he disagreed with them, he did use these past studies as a foundation to develop his own theories on the subject. The one point that Renfrew agreed with the previous research was that obsidian was definitely being quarried and moved from Melos. Archaeologists differ in how the obsidian was being transported. In this chapter we will discuss Renfrew’s theories; the Law of Monotonic Decrement (LMD), direct access model and down-the-line exchange and how they are researched in an entire region. Renfrew formulated a system in which to study these theories on regional exchange and adapted them to investigate prehistoric Greek economy in sites in and around the Aegean.
The LMD, direct access, down-the-line exchange (Renfrew 1975:42), and balanced reciprocity (Sahlins 1972:194-5) are simple theories that explain the ancient transportation of obsidian. The LMD is the relationship between the size of obsidian assemblages and the distance from the source. It predicts the decrease in assemblage size the further away from the source the site is located (Renfrew 1968). Direct access does not necessarily create the curve that the LMD predicts. It is simply as it sounds; any group with access to the quarry is allowed to go there and take what they please. This is limited to those who live close. Therefore, the direct access area for Melos is much larger than most other quarries, since it is on the island. Thus, it was easily accessible for most of coastal Greece.

However, once the obsidian is on the mainland it is more likely to be traded by down-the-line exchange. Down-the-line exchange is the process of a group taking what they need from an assemblage and trading the rest to another group. This trading is through balanced reciprocity as one group gives the other something back in return for the obsidian. Down-the-line exchange implies that the closer groups pass the obsidian to further away groups, abiding by the LMD. Down-the-line exchange is also nearly impossible over water; once at sea there is little interaction between groups (Renfrew 1975: 45). These basic concepts are broad enough to cover an entire trade system. Using them, Renfrew developed a process to measure and analyze the trade of Melos obsidian.

Renfrew takes these concepts of trade and plots the predicted outcome of obsidian quantity compared to the distance away from its source. In order to do this, Renfrew used the LMD, which is represented in a fall-off curve (Figure 5). A
fall off curve is composed of two zones, a supply and contact. The supply zone is the distance or area around the source where the obsidian is easily accessible. The contact zone represents the groups of people that had contact with the supply zone, however, economically speaking could not reach it. Direct access has a fairly linear fall-off curve, like the supply zone, since it exists in the area closest to the source. Down-the-line includes a contact zone as well as a supply zone. The contact zone has a much steeper slope since much more obsidian is being consumed in respect to distance.

The next step is to apply these fall-off patterns to the obsidian in the Aegean. Renfrew worked exclusively with the obsidian taken from Melos. The sites were located throughout Greece; most lie in a coastal area, whether on the mainland or an island (Map 2). They span in ages from Neolithic to Bronze Age. From each site there were two sets of data that must be taken for Renfrew to predict the fall-off pattern. The first was the effective distance from the site to the source which was calculated in terms of effort not actual distance. Second, was the efficiency of production, or in other words, the rate of consumption (Renfrew 1973: 72-73). For the Aegean, effort was considerably less than one might think. The convenience of boats allowed many more people to have access to the source at much less effort. This means that the supply area is much greater and might not correlate with Renfrew's predicted curves. Thus, to calculate the effective distance, Renfrew took the shortest route overseas and added it to twice the distance over land. In terms of effort, land travel was much more difficult. Effective distance was the easier of the two data sets to define and collect.
More complications arise when the efficiency of production was determined. Since most of the sites were almost entirely composed of obsidian flakes, it cannot be compared to other natural resources used there. Pottery shards do exist but clay was not a valuable enough resource to be comparable and thus was not helpful for this study. Renfrew had noted in the past that there was a correlation between the distance from a source and the artifact's size (Renfrew 1967:432). While this was interesting, it did not solve our dilemma in determining efficiency of production.

Taking the total weights of assemblages was data that can be collected for each site. Since down-the-line exchange was predicted, the total amount of obsidian found does not provide us with any information. We do not know how much was traded, thus we do not even have the total amount that was transported there. When taking the total weight of the artifact or debitage assemblage Renfrew was confronted with the same problem. Alone the weight of each total assemblage was not helpful; comparing the amount of artifacts, the amount of debitage, and the total amount was. This comparison represents the amount of usable tools a group made from the entire assemblage of obsidian. The more flakes and blades they had, the more sharp edges they had. In prior studies it had been discovered that there was a positive correlation between distance and cutting surfaces. Thus the knapper tried to make smaller blades rather than fewer larger blades the further from the source he traveled (Sheets and Muno 1972). Furthermore, debitage is an inevitable byproduct of knapping. If obsidian was very expensive and limited, certain techniques could be used to create more flakes and less debris. From this, Renfrew deduced that the further away from the source, the less available and more
expensive obsidian was. Likewise, the percentage of artifacts in the whole assemblage should increase with distance. The greater the distance from Melos, the more economical knappers were with their obsidian. In order to make any type of comparison over a region, Renfrew must assume certain ideas. He must assume that the whole region had the same general cultures, including style and needs. Any variations between sites must be eliminated to a certain degree. Renfrew considered the artifacts found over the whole region. Many styles were the same and evolved the same throughout the Aegean, thus he assumed that the styles of obsidian were similar enough to compare (Renfrew 1972). Thus, the weights can be compared to determine the production efficiency of a site.

The results of these measurements described above are on Table 1. They show that in the Neolithic, the further away a site was, the greater the total debitage weight compared to the total artifact weight (Torrence 129). This data was plotted the exact opposite of the predicted LMD, meaning that there is more waste. Furthermore, this indicated that distance was not a major factor in trading obsidian and Renfrew's curves were incorrect for this area. However, this pattern changed in the Bronze Age. Thus, Renfrew implied that when the LMD was restored at this time obsidian was so cheap that the cost, although small, was enough to limit the obsidian to those close by. This was supported by the fact that most obsidian found in Bronze Age sites is found in middens or discarded (Ammerman 1978: 184). During the Neolithic, direct access seems to be the only option using these results. Any group could come and take as much as they wanted, which accounts for the lack of efficiency further away. During the Bronze Age, down-the-line exchange
became more popular, since the value of obsidian was not worth the journey, but could still easily be traded for something of equal value.

Regional studies are easily skewed. Doing a study over a broad area, like this one, provides much opportunity for a large margin of error. In this case there were many issues that were not accounted for. Melos is an island and the cost of traveling was different than land. Especially since the location of most of the sites Renfrew studied were on the coast. Many of his predicted curves were based on land potentially altering the results. Also, all the sites were all within a hundred kilometers of Melos (Torrence 1986: 121) making them all in or near the supply zone. This may be another cause of the inverse LMD in the Neolithic. In order to do these comparisons Renfrew assumed a general style over the area. As we have seen in the second chapter this may be true for some areas, but not all. The island of Crete has two sample sites on it, Knossos and Pyrgos. In the Neolithic, Crete was only identifiable with the rest of Greece because it used the obsidian from Melos. In no way does this indicate that they shared either style or lithic technologies with mainland sites.

A problem with comparing artifacts and debitage weights is that it assumes no usage. A flake can be retouched many times until it is too small to be retouched anymore. When the archaeologist picks the obsidian off the ground, she has no way of knowing if it is a pristine piece or if it started much larger and had been used and retouched many times. Since the Neolithic had permanent settlements, retouching could have happened over and over in the same area making the amount of debitage greater and artifacts smaller. Thus, it is reasonable that the LMD is reversed and the
sites that were further away were actually recycling the obsidian they had and they were, therefore more economical. However, this retouching theory is only speculation and assemblages of retouched and non-retouched tools of the same size and shape can not be distinguished, making it impossible to prove. It is simply one possibility out of many. Renfrew's study was a very difficult and comprehensive one that described the economy of an entire region. These complications were unavoidable and even with them; Renfrew does an excellent job explaining the prehistoric Aegean trade system.

Chapter Six: New Approaches-Alternatives to Renfrew's Study

Renfrew has done most of the work on Aegean obsidian using his own theories of exchange. There are, however, many more methods and theories on exchange. An archaeologist must choose which method works the best for a given area. In the Aegean, water travel was an important factor in determining which exchange system was the most likely. I chose these two next studies because they were both in reaction to Renfrew's work. Ian Hodder, who worked along side Renfrew, created an equation that formulates fall off curves mathematically. With this equation, Robin Torrence studied the obsidian of prehistoric Greece. The other theory that I cover was one done by Ammerman. In his study he criticized both Renfrew and Hodder for ignoring the critical factor of time. He then created a method of study which has yet to be used in Aegean studies. The fact that these studies exist supports the research as a whole. Like this study, Hodder and
Torrence’s conclusion match Renfrew’s. This makes the validity of their argument that much more stronger. While Ammerman’s work has been done in the Near East, it has not been conducted on the Aegean. It would be interesting to see if time makes a significant difference.

Ian Hodder performed a methodical study before he predicted a certain fall off curve theory. He conducted a series of random walks. (Hodder and Orten 1976: 98-154) In these walks he retraced a variation of different walk processes of Neolithic settlers under various conditions. During these walks he recorded the amount of exchanged goods he encountered. By walking and recording numerous times, every time changing his route and thus altering the number of trades or steps that he encountered, he developed his own series of fall off curves. This series of data showed an exponential relationship between the number of trades made and the distance from the source. This relationship was used to formulate a equation. The fall off curves, created by this equation, were very similar to Renfrew’s predicted down-the-line fall off curve (Hodder 1978: 161) (Figure 6). By knowing the relationship between the two he could use one to calculate the other. More importantly he could use the number and length of trades to conclude which type of exchange system was being used. The relationship was exponential:

\[ \text{LOG } Y = a - bX^\alpha + c \]

(Torrence 1986: 117). The exponent represents the association of exchange with Y, Y representing the percentage of traded goods, including stone and pottery, to the total amount. \( X \) represents the distance from the source. This equation yields convex curves depending on the amount of steps taken; these curves are concave
when numbers are small (Hodder and Orton 1976: 142-5). The resulting exponent \( \alpha \) can be used to determine the distance traveled given the percentage of obsidian per assemblage. When \( \alpha \) is less than one, the exchange did not last a great distance. However, if it ranged between one and two the exchange continued over a large distance. Hodder determined the \( \alpha \) by calculating standard error between 0 and 2.5. The lowest error was the best-fit model for that exchange. By taking the best-fit model he determined the amount of trades that was most likely taken in this area.

The next step was to associate various exchange types to this equations using the \( \alpha \). When the \( \alpha \) is around 0 it represent a direct access exchange and a linear fall off curve. When \( \alpha \) is raised and the number of steps or moves the obsidian took was increased, the exchange curve became much steeper resembling Renfrew’s down-the-line exchange. Hodder’s theory can be used on any obsidian exchange system.

The theory was used by Torrence to analyze the obsidian exchange in the Aegean. Taking Renfrew’s initiative she researched Neolithic and Bronze Age sites. She took data that was needed for Hodder’s equation and blade dimensions from these sites and re-analyzed them using regression analysis. She used Hodder’s equation to calculate the standard error with each of the different percentages she collected (Table 2). She found that the total, primary, and tertiary flake had 0.1 for their best fit model. Only in secondary flakes was the linear model the best fit. The last category, shatter, had the only \( \alpha \) value above one at 1.5. Using Hodder’s theory above, Torrence suggests that these low \( \alpha \) values were because there was a small number of shor: moves. This data also indicated that the exchange system was direct access, which was in agreement with Renfrew’s work. She also took the
dimensions of flakes and blades and tried to correlate them to distance. As stated previously, the efficiency of production can be helpful in determining the cost of travel or distance. Unfortunately, there was no difference in the platform size or flaking technology in general to indicate economizing the obsidian. These conclusions sound all too familiar. Like Renfrew, she was dealing with a small quantity of data. However, having both types of analyses on Aegean obsidian concluding the same thing strengthened both arguments. The mathematical study does an excellent job supporting Renfrew and vice versa. Torrence did this study just for this reason.

Ammerman recognized two major flaws in all of this work. He recognized that neither Renfrew nor Hodder accounted for time. While the two of them do not think that time was an important enough factor to place in the equation, Ammerman did. He saw that at the time of the procurement of the source, all obsidian should be located in or around the quarry. However, as time passed you would expect to see more obsidian spread throughout the region (Table 3) (Ammerman 1978: 182). Figure 6 expresses the importance in time in a linear exchange system based on Renfrew’s contact zone. In this table you see that the closest site was able to replenish the amount they traded anytime they wanted. Consequently, this site continually traded obsidian, which caused a build up of obsidian at all of the sites (Ammerman 1978: 181). This model can only be used for a contact zone where obsidian was not a majority of the assemblage.

Ammerman addressed another good point about analyzing trade systems. Many forget that artifacts were usually dropped when they were not needed
anymore. Thus, the setting that they are found in is when they were no longer needed. This effects the trade and more importantly how the archaeologists see it (Ammeman 1978: 184). He still considered time a key factor as he aimed to determine the rate of dropping at a certain site. Using $d$ for the percentage of obsidian dropped and $p$ for the percentage of obsidian traded in a linear network, he created a formula for assessing the amount of obsidian being used at a certain site at a certain time. Table 4 (Ammnerman 1978: 184) shows how in a linear model of $x$, $y$, and $z$, he calculated this. At the beginning of the time interval, one site gave a proportion of its assemblage to the next site leaving it with $(1-p)y$ of obsidian.

However, it also received $px$ obsidian at the same time. Through the time interval obsidian is dropped leaving it with $(1-d)$ of obsidian. Using these simple equations, Ammerman predicted the percentage of obsidian at a site. He conducted this on a series of linear exchange sites. The results are shown on Table 5 (Ammnerman, 1978: 185). The first point that popped out was the similarity between these numbers and the time interval numbers. The first site has its steady supply and the sites following continued to build up obsidian. They do differ in the fact that with dropping rates the percentages never reach the amount that they did before. They are much lower and increase in much smaller increments. This is logical since each site was losing more obsidian than it was before.

In this chapter, two different ideas of analyzing trade are presented. Both theories began as a reaction to Renfrew. It is important to note that the data in the Aegean is very limited. This may skew conclusions enough so that they are seem similar. However, with the information that we have, these are our only options.
Furthermore, these studies have been very thorough. Renfrew has gotten as much information out of Aegean obsidian exchange that is possible to get. It would be interesting, however, to see if time and dropping rate made a large impact on the exchange system. We are left to ask whether what would make a difference with the lack of data and information that exists in prehistoric Greece sites.

**Conclusion:**

According to Renfrew and Torrence’s results, Melos obsidian was transported mostly by direct access. Direct access is a very simple form of exchange. Since Melos is an island, most of Greece could travel directly to the quarries and take what they pleased. With this system, very little communication and interaction between settlements occurred. Sea transport was economical and very familiar to most Greek settlements. All the Cycladic people were surrounded by the sea, meaning that seafaring was essential for any movement. Once at sea, the distance they traveled was a small detail. This is why Melos was accessible to such a great region.

Renfrew’s conclusions are logical, yet they are not undisputed. There are many aspects of Greek culture that he had to take into account in order to do his analysis. He assumed that all Greek cultures were similar enough to examine as one group. While there was similarities between the sites, he cannot make this general assumption. The Cyclads, the mainland, and each individual settlement had its own culture that changed over time. Time was another assumption made by Renfrew. In
order to do his studies he inferred that all these sites also change the same over time. In no portion of his study did time affect the trading between different settlements. These assumptions were unavoidable.

In Ammerman's work he also made a set of assumptions. In his theory, each settlement must be trading goods at a constant rate. Also, like Renfrew, they all must be growing at the same constant rate. In order to make these assumptions, it is important to understand the area. Renfrew was very familiar with the Aegean, thus he made assumptions that he was comfortable making. In prehistoric sites, there is so little data that assumptions are inevitable. While these assumptions weaken his argument, another group of assumptions would invalidate it completely.

It is easy to think that ancient economies were the same as ours today or simply did not exist. Bosanquet and Mackenzie made the mistakes of implementing modern though: on a civilization that thrived 5000 years ago. Renfrew and Torrence's work was careful not to assume the other easy alternative, that there was no economy in the ancient Greek world. Through their analysis, they adapted to all the possible systems that Renfrew predicted. It is not surprising that the simplest explanation is the right one. They did learn that the sea greatly affected the behavior of the settlements. In coastal and island settlement, direct access was the main system used for attainment of obsidian. Inland settlements were unlike coastal settlements, since travel was more expensive. Thus down-the-line trading was more economical. It is not surprising that it was used inland. The conclusions made by Renfrew and Torrence cohere with the expected results, since it is the logical explanation.
Even though Renfrew and Torrence share a strong conclusion, Ammerman did raise some interesting objections. The time and trash factors may severely skew the view of the archaeologist. By not taking these into account, it definitely weakens their conclusions. It would be interesting to see how Ammerman’s theories relate to Greek obsidian. Having this information would be extremely useful for nullifying assumptions as well as solidifying the conclusions, if they agree with Renfrew. If not, we know that time needs be taken into account when determining ancient economies and trades.

There is always more knowledge out there waiting to be learned. Renfrew has done an excellent job sucking the Aegean dry for information of its ancient economy. However, no one knows what actually happened in the past. And with the more research that is done, the closer we can come to piecing together the truth of what really happened. Thus, Ammerman’s work might shed some light on Neolithic Aegean trade and economy and therefore his theories should be implemented on this region. It would also increase knowledge on ancient economies as a whole and how we look at them. When this happens, we will be one step closer to the truth.
Figures 1 & 2: Density of surface obsidian in Sta Nychia and Demenegaki, respectively (Torrence 1986: 172-73).
Figure 3: Primary (top row), secondary (middle row) and tertiary (bottom row) flakes made from Melos obsidian (Torrence 1986: 209).
Figure 4: Amount of barium and zirconium, trace elements, in obsidian quarries throughout the Mediterranean. This method is used for identifying natural sources of stone tools found throughout the region (Durrani 1971: 42).
Figure 5: Fall of curve of down-the-line exchange (Renfrew 1975: 11).

Figure 6: Fall off curves predicted by Hodder from his set of random walks (Hodder 1978: 161).
Map 1: This map shows the range of Melos obsidian as well as all the other obsidian quarries of the Mediterranean. The obsidian from Melos is definitely the most prevalent in the Aegean Sea (Durrani 1971: 41).

Map 2: Sites used for Renfrew's and then Torrence's study (Torrence 1986: 121).
Table 1: Mean dimensions of blades found throughout the Aegean Sea Region. (Below) Mean weights of debitage in cm (Torrence 1986:129).

<table>
<thead>
<tr>
<th>Site</th>
<th>Effective distance</th>
<th>Width</th>
<th>Thickness</th>
<th>Length/weight</th>
<th>Platform length</th>
<th>Platform width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>x</td>
<td>N</td>
<td>x</td>
<td>N</td>
<td>x</td>
</tr>
<tr>
<td>Neolithic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saliagos</td>
<td>85</td>
<td>136</td>
<td>1.29</td>
<td>136</td>
<td>0.37</td>
<td>135</td>
</tr>
<tr>
<td>Kitos</td>
<td>120</td>
<td>238</td>
<td>1.17</td>
<td>238</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>Franchthi</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kephala</td>
<td>130</td>
<td>128</td>
<td>1.44</td>
<td>127</td>
<td>0.39</td>
<td>120</td>
</tr>
<tr>
<td>Anavolousa</td>
<td>130</td>
<td>14</td>
<td>1.21</td>
<td>14</td>
<td>0.36</td>
<td>14</td>
</tr>
<tr>
<td>Mavrispilia</td>
<td>110</td>
<td>135</td>
<td>1.15</td>
<td>135</td>
<td>0.35</td>
<td>134</td>
</tr>
<tr>
<td>Bronze Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phyliakopi</td>
<td>10</td>
<td>2,058</td>
<td>1.09</td>
<td>2,059</td>
<td>0.34</td>
<td>2,059</td>
</tr>
<tr>
<td>F32</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F20</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ayia Irini</td>
<td>130</td>
<td>1,003</td>
<td>0.97</td>
<td>995</td>
<td>0.29</td>
<td>996</td>
</tr>
<tr>
<td>Halieis</td>
<td>130</td>
<td>80</td>
<td>1.02</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Knossos</td>
<td>190</td>
<td>894</td>
<td>0.89</td>
<td>891</td>
<td>0.25</td>
<td>894</td>
</tr>
<tr>
<td>Nemea</td>
<td>220</td>
<td>79</td>
<td>1.11</td>
<td>79</td>
<td>0.30</td>
<td>79</td>
</tr>
<tr>
<td>Pyrgos</td>
<td>245</td>
<td>28</td>
<td>0.91</td>
<td>28</td>
<td>0.26</td>
<td>28</td>
</tr>
<tr>
<td>Lerna</td>
<td>305</td>
<td>1,038</td>
<td>1.05</td>
<td>1,057</td>
<td>0.29</td>
<td>1,038</td>
</tr>
<tr>
<td>Korakochorio</td>
<td>450</td>
<td>100</td>
<td>0.89</td>
<td>100</td>
<td>0.33</td>
<td>100</td>
</tr>
</tbody>
</table>

Notes:
1. Width, thickness, platform dimensions are in centimeters; length/weight is centimeters per gram; effective distance is given in kilometers as measured on a map with scale of 1:2,500,000.
2. All data gathered by author, except Kitos which is taken from Perles (1981).

<table>
<thead>
<tr>
<th>Site</th>
<th>Total sample</th>
<th>Primary flakes</th>
<th>Secondary flakes</th>
<th>Tertiary flakes</th>
<th>Shatter/chips</th>
<th>Flake cores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Saliagos</td>
<td>1,482</td>
<td>43</td>
<td>2.9</td>
<td>104</td>
<td>7.0</td>
<td>348</td>
</tr>
<tr>
<td>Anavolousa</td>
<td>63</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>7.7</td>
<td>23</td>
</tr>
<tr>
<td>Mavrispilia</td>
<td>893</td>
<td>73</td>
<td>8.1</td>
<td>97</td>
<td>10.9</td>
<td>356</td>
</tr>
<tr>
<td>Phyliakopi</td>
<td>2,26</td>
<td>126</td>
<td>5.8</td>
<td>841</td>
<td>39.6</td>
<td>528</td>
</tr>
<tr>
<td>Ayia Irini</td>
<td>1,825</td>
<td>78</td>
<td>4.3</td>
<td>450</td>
<td>24.7</td>
<td>715</td>
</tr>
<tr>
<td>Knossos</td>
<td>702</td>
<td>86</td>
<td>11.3</td>
<td>195</td>
<td>25.6</td>
<td>297</td>
</tr>
<tr>
<td>Nemea</td>
<td>97</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>9.3</td>
<td>34</td>
</tr>
<tr>
<td>Pyrgos</td>
<td>27</td>
<td>2</td>
<td>7.4</td>
<td>12</td>
<td>44.4</td>
<td>11</td>
</tr>
<tr>
<td>Lerna</td>
<td>1,507</td>
<td>46</td>
<td>3.0</td>
<td>217</td>
<td>14.4</td>
<td>514</td>
</tr>
<tr>
<td>Korakochorio</td>
<td>532</td>
<td>68</td>
<td>12.8</td>
<td>303</td>
<td>57.0</td>
<td>125</td>
</tr>
</tbody>
</table>

Table 2: Proportions of debitage types used in Torrence’s regression analysis (Torrence 1986: 128).
<table>
<thead>
<tr>
<th>Site</th>
<th>1</th>
<th>5</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>1</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>100</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>100</td>
<td>58</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>86</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>100</td>
<td>95</td>
<td>64</td>
</tr>
</tbody>
</table>

Table 3: Ammerman’s percentage of obsidian in lithic assemblages for certain sites as time passes (Ammerman 1978: 182).

<table>
<thead>
<tr>
<th>Site</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>End of time t:</td>
<td>x</td>
<td>y</td>
<td>z</td>
</tr>
<tr>
<td>Start of time t+1:</td>
<td>px + (1-p)y</td>
<td>py + (1-p)x</td>
<td></td>
</tr>
<tr>
<td>End of time t+1:</td>
<td>(1-d)[px + (1-p)y]</td>
<td>(1-d)[py + (1-p)x]</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Ammerman’s exchange model that encompasses time, trading rate and dropping rate (Ammerman 1978: 184).

<table>
<thead>
<tr>
<th>Time</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>36</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>52</td>
<td>19</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>63</td>
<td>35</td>
<td>16</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>65</td>
<td>42</td>
<td>26</td>
<td>16</td>
<td>9</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>69</td>
<td>45</td>
<td>30</td>
<td>19</td>
<td>13</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Percentages of obsidian, traded in a linear network, at sites further away from the source (Ammerman 1978: 185).
References:


