ABSTRACT

Team 6 investigated the disappearance of an ancient people, the Guangalans, who were the ancestors of the Manteños, a powerful maritime people that inhabited the coasts of Ecuador when the Spanish conquistadores arrived in AD 1526. Archaeological evidence suggests that the Guangalan civilization expanded considerably over the course of 800 years, thrived agriculturally, and spread to areas previously unsettled. Around AD 600, the Guangalans vanished but the reason for their disappearance is a mystery. The region was not resettled for at least 300 years, until the arrival of the Manteños. To investigate the cause of the disappearance of the Guangalans, Team 6 analyzed charcoal samples from an excavation site near El Azúcar, a modern village located where the Guangalans once lived. The analysis of the samples would optimally give team members insight into the Guangalans’ use of the environment and whether misuse or destruction of the forest could be a cause for their sudden settlement abandonment.

INTRODUCTION

The Guangalan civilization was one of the ancient cultures that flourished in the coastal region of Ecuador from circa 200 BC to AD 600 (1). This time period is known as the Regional Development Period, due to the cultural developments in trade, technology, and agriculture across Ecuador. The Guangalans inhabited a region of the southwest coast where their close relatives, the Manteños, and their modern descendants can still be found in modern villages, such as El Azúcar, the site of the archaeological excavation of interest for our project. The remains of the ancient Guangalan settlements are found on hills around the modern villages. Although extensive investigations have been made of cultures of South America like the Inca, very little is known of the Guangalans. Remains of the Guangalan settlement near El Azúcar have been excavated and studied by teams from Drew University. The goal of the team project is to investigate the cause of the decline of the Guangalan civilization.

The Guangalans arrived in the coastal Ecuadorian region around 200 BC and were able to live successfully for approximately 800 years before disappearing for unknown reasons. They were very prosperous farmers, expanding into areas that were previously unsettled. Little is known about the Guangalan civilization so it is unclear as to why the Guangalans experienced such a favorable period of agriculture yet still left so suddenly. It is thought the Guangalans created a successful strategy for expertly using and settling semi-arid coastal plain valleys. This strategy would have required the use of coastal resources, and it is thought that this contributed to the inter-dependence of the coastal plain and coastal settlements. This suggests a model of Guangalan society as a regional organization where settlements were located in a range of microenvironments on the coast and inland with trade between villages. Guangala farms around
El Azúcar would have provided agricultural products, game meat such as deer, and crafts such as cotton textiles and shell beads. Evidence of all these activities has been found at their settlements near El Azúcar (2).

El Azúcar is situated along the Río Azúcar around 25 km from the modern coastline. Characterized today as a semi-arid region, the land around El Azúcar is mainly composed of savanna grasslands, scrub vegetation, and thorn forests (3). Up through the late 1960s, the area was heavily forested with dense, dry tropical forest vegetation, but environmental changes caused by deforestation and mistreatment of the soils have greatly changed the vegetation of the area. The fertile forests in the region were reduced and the area became drier, leading to the fragile, semi-arid environment of today. Tropical forests are characterized by rapid, heavy growth year round but extremely thin soil, as nutrients from dead organic matter are quickly cycled back into the plants. While these forests are very productive, their soils are not ideal for farmland unless there is careful stewardship and scheduled fallowing periods. Did the Guangalans misuse their environment like the 20th century villagers? Did they leave the area a desert like that which exists today? This region was not used extensively by the Manteño, but the Spanish found a region of dense forest when they arrived. That forest was possibly a regrowth occurring many years after the Guangalans left. Subsequent settlers of the region also cyclically misused and deforested the land until the forest once again had returned in the mid 20th century, only to be destroyed again.

One way to understand the waxing and waning of any civilization is to analyze the remnants of their society recovered through the archaeological excavation. Even now, the land in and surrounding El Azúcar is being misused and is once again in peril. If continued destruction is to be avoided, demonstrating and understanding the destructive cycles of the past could be invaluable. The current inhabitants of El Azúcar, who have ancestral ties to the Guangalans and the Spanish colonists, are becoming increasingly aware of the negative effects of depleting forests in their area. They are attempting to raise awareness about their environment and get the people to care for the land again. They look to their ancient ancestors for lessons to motivate the villagers of today. These potential lessons are the focus of this project.

The disappearance of the Guangalans is unresolved and we hope to reconstruct their history in order to understand why they left. Since they thrived as a civilization with advanced methods of agriculture for 800 years, their sudden and complete desertion is difficult to explain. The reason that they left could be accredited to several different causes, including anthropogenic climate change. This project focuses on how human interference can alter the natural vegetation to such an extent that it becomes uninhabitable and leads to abandonment. The issues of deforestation and overuse of resources still apply today as current day inhabitants are struggling with the consequences of the environmental decisions of the mid 20th century. They are not willing to make sacrifices and lifestyle adjustments to repair the environment, but the lesson from the Guangalan disappearance may prompt reform and awareness.

It is hypothesized that the Guangalans overused their natural resources by excessive logging and aggressive farming to the point where agriculture was no longer possible. This environmental damage would cause the forest vegetation to be altered, and the dominant old species of hardwood would gradually be replaced by shrubs and softwood. A difference in
vegetation types and species can be tested with the remains of wood that were found in carbonized form. The excavation from Site 47 revealed layers of charcoal, and this charcoal can be assumed to be wood from the Guangalan fireplaces. If they used the wood to burn, it would have most likely been wood that was cut down from the forest nearby, reflecting which species were most dominant. The succession of different species used as firewood used might show patterns in different wood types (i.e. softwood, hardwood, shrubs) present in the forest. A clear pattern in the succession of hardwood trees to small shrubs would suggest the changing environment affected by deforestation or other circumstances under which habitation would not have been ideal. Analysis was conducted using comparison of Guangalan charcoal to known wood types through the use of dissecting microscopes and the Scanning Electron Microscope (SEM). The eventual conclusion and resolution of the mystery behind the disappearance of the Guangalans may be useful to apply to society today.

BACKGROUND

The Excavation

The modern village of El Azúcar is situated along the Río Azúcar around 25 km from the modern coastline. Characterized today as a semi-arid region, the land around El Azúcar is mainly composed of savanna grasslands, scrub vegetation, and thorn forests. As recently as the 1960s, the region was covered with dense dry tropical forest. The environment and vegetation of the region at the time of the beginning and end of the Guangalan presence from 200 BC - AD 600 is not currently known but the analyses conducted by this project can provide information on the ancient setting.

The charcoal samples used in this project were recovered from the excavation of Guangalan settlements near El Azúcar. Two of these, Site 30 and Site 47, contain deep layers of Guangalan remains from early- to middle- Guangala (200 BC – AD 600). Site 47, a Guangalan farmstead, was located in 1986-87 during an archaeological settlement survey. It was chosen for further excavation because of the richness in archaeological material. The site contains 1 hectare of surface area covered with ceramics and other Guangala artifacts and has buried deposits of midden with a depth range from 25 to 200 cm. The site is approximately 40 meters above sea level and about 500 meters to the east of the river. The site only contains materials from the Guangalan phase, making analysis limited to this time period.

The site was excavated in 1-by-1 m units when stratigraphic divisions were visible and 5 or 10 cm levels when these divisions were not apparent. Fine mesh screens (1/8”) were used in the excavation of Site 47 to ensure that small artifacts would not be lost through the screen. At the bottom of this site was a house floor. Among these small artifacts were animal bones, ceramic fragments, and pieces of wood charcoal.

Site 30 is also located in the Río Azúcar valley, about 500 m to the west of Site 47 on the opposite side of the Río Azúcar. Deposits were found up to 70 cm deep. This location was divided into 5 cm levels and excavated using fine mesh screens (1/8”).
The excavation of both sites uncovered remains that showed little signs of disturbance, indicating that these were their initial deposit sites. Both sites were dense with artifacts, suggesting that they were placed there intentionally by the Guangalans. Based on this, the team concluded that the areas were used as a place to dispose of trash. The top levels of Sites 30 and 47 were dated using radiocarbon methods to between AD 400 and 600 and bottom levels to as early as 200 BC. Therefore the deposits cover the early and middle portion of the Guangalan civilization. There are no later settlements in the valley and the Guangalans appear to have abandoned the region.

Charcoal samples from two areas near El Azúcar which the Drew University archaeological team excavated were also added to the sample for this project. Site MV-C2-3a lies on the coast of Ecuador, and Site MV-C2-4f is located about halfway between the coast and the Río Azúcar Valley. The bottom levels of these sites contain remains from late- to post-Guangala. Therefore, these samples may provide data on what the environment in areas near El Azúcar was like after the Guangalans abandoned the region. The bottom level of Sites MV-C2-3a and MV-C2-4f were dated using radiocarbon methods to between AD 700 and 900, which means they represent the late- to post-Guangalan civilization.

The remains found at these locations include pieces of wood charcoal, assumed to have been used in the fireplaces of the Guangalans and deposited into the trash mound after they had been burned, as previously mentioned. The identification of charcoal remains from Sites 47 and 30 to tree species would be useful to investigate Guangalan resource use as well as reconstruct what the vegetation was like during the Guangalan occupation of the region. Species identified at Sites MV-C2-3a and MV-C2-4f would help determine what the vegetation was following the Guangalan abandonment of the region.

Wood charcoal analysis is, however, still only a developing type of analysis in the field of archaeology. Some of the difficulties in the method are the lack of type collections or published images of wood charcoal for identification. This type of study has never been undertaken for the Guangala and only rarely in Ecuador. Therefore, the establishment of a type collection and methodology for the analysis will be a significant contribution to the field of archaeology.

**Characteristics of Wood and Wood Charcoal**

Wood charcoal is often found in excavation sites because it is capable of surviving in the ground indefinitely. This is due to the fact that carbonized materials are not subject to organisms that destroy organic materials (4). Carbonization occurs when wood is heated in a closed vessel without the presence of oxygen, which would allow the wood to burn and turn to ash. In the absence of oxygen, the wood is allowed to decompose into several products. The main product of carbonization is black porous charcoal. Other products of carbonization include a minimal amount of ash, bark, vapors, and contamination like sand and soil particles (5).

Since wood cells have rigid cell walls that retain their shapes through carbonization, cell patterns and structure remain largely intact and can be used to identify woods. The patterns of wood and wood charcoal are formed by longitudinal cells, ray cells, and growth rings. Most
wood cells run vertically and parallel to the tree stem. These longitudinal cells are responsible for
the wood grain. Ray cells, unlike longitudinal cells, run horizontally and perpendicular to the
stem. Both longitudinal cells and rays form patterns that are important in identifying wood.
Growth rings also create patterns in wood and wood charcoal. Some growth rings are obvious,
while others are distinguishable only through microscopy. Growth rings are formed by the
climate changes as the tree grows. Since the visibility of the growth rings depends on the species
of wood, growth ring patterns are useful in identifying wood. They are less useful, however, in
identifying archaeological wood charcoal since only fragments of the trunk or branches are
recovered.

There are three planes of charcoal that display the features of the structure of wood. The
cross-sectional or transverse plane is shown when the wood is cut perpendicularly to the stem.
This surface reveals the concentric growth rings as well as rays. The cross-sectional plane also
shows the shape and size of cells. The radial plane is shown when the wood is cut parallel to the
stem and through the pith, the center of the stem. In this view, the growth rings appear parallel
and longitudinal cells appear as vertical columns. The tangential plane is parallel to the pith and
is tangent to the growth rings, displaying longitudinal cells as vertical columns. Since each of
these planes displays the structure of wood charcoal from a different perspective, the patterns of
the same type of wood will appear differently in each surface.

Collection of Type Samples

Many regions have libraries of the native trees and plants and their characteristics. In
wood charcoal analysis, these libraries are used to compare to excavated charcoal. These types of
reference libraries have not been created for the coast of Ecuador. Therefore, a type collection of
wood species had to be created for this project. To compare the excavated charcoal to the wood
that would have been present in a dry tropical forest that may have been present at the time of the
Ancient Guangalans, samples from the dry tropical forests of the surrounding area had to be
collected. The Drew University archaeological team gathered samples from trees and shrubs
currently available near El Azúcar. El Azúcar is currently a semi-arid region, however, so very
few trees were available. The two most common species in El Azúcar today are the Mullullu
(Cordia lutea) and Algarrobo (Prosopis juliflora). Mullullu is secondary growth that takes over
land and inhibits the forest from growing back. Algarrobo is a very drought tolerant tree that can
survive in the semi-arid region. The keystone species for the dry tropical forest are rare or nearly
extinct in El Azúcar. Therefore, to find living specimens, the team went upland to Julio Moreno,
where the government protects an area of dry tropical forest. From this area, trees absent from El
Azúcar were easily located. The trees range from dense hard woods to small trees and shrubs and
are used by local people for a variety of purposes. They most likely would have been used by the
Guangalans for the same purposes (Table 1). When the team located one of these species, a small
section of a branch was cut so as to not harm the entire tree. The collected samples were then
burned and carbonized, as described previously, so that their structures are comparable to the
charcoal found in the excavation. These type samples provided the team with a reference library
to use for comparison. Of the collected species, the Guasango, Cascol, Ebano, Barbasco,
Licuanco, Sapote, Mullullu, and Algarrobo, are the “keystone” species. Each of these trees
creates an environment conducive to the growth of the surrounding plants. Therefore, the
survival of the dry tropical forest depends on the presence of these trees.
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Location Collected</th>
<th>Abundance in El Azúcar</th>
<th>Type of Wood</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mullullu</td>
<td><em>Cordia lutea</em></td>
<td>Near El Azúcar</td>
<td>Very common</td>
<td>Shrub; secondary growth</td>
<td>Fence posts; small household tools</td>
</tr>
<tr>
<td>Barbasco</td>
<td><em>Jacquinia pubescens</em></td>
<td>Near El Azúcar</td>
<td>Coastal</td>
<td>Shrub or small tree</td>
<td>Fishing</td>
</tr>
<tr>
<td>Licuancro</td>
<td><em>Coccoloba ruiziana</em></td>
<td>Near El Azúcar</td>
<td>Coastal</td>
<td>Shrub or small tree; many branches</td>
<td>Medicinal purposes; branches for charcoal</td>
</tr>
<tr>
<td>Guayancan</td>
<td><em>Tabebuia chrysantha</em></td>
<td>Near Julio Moreno</td>
<td>Rare</td>
<td>Strong, fine hardwood</td>
<td>Ornamental tree; honey, fruit, and herbal tea</td>
</tr>
<tr>
<td>Mata Sarna</td>
<td><em>Machaerium attenuatum</em></td>
<td>Near Julio Moreno</td>
<td>Rare</td>
<td>High tree; narrow trunk; many branches</td>
<td>House construction (planks and crossbeams); charcoal; cooking</td>
</tr>
<tr>
<td>Guachapeli Blanco</td>
<td><em>Machaerium attenuatum</em></td>
<td>Near Julio Moreno</td>
<td>Rare</td>
<td>Very large with many branches; moderately dense</td>
<td>Boat and house construction; edible pods; charcoal</td>
</tr>
<tr>
<td>Morocho</td>
<td></td>
<td>Near Julio Moreno</td>
<td>Rare</td>
<td>Small tree; few branches; softwood</td>
<td>House construction (planks and crossbeams); charcoal; firewood</td>
</tr>
<tr>
<td>Algarrobo</td>
<td><em>Prosopis juliflora</em></td>
<td>Near El Azúcar</td>
<td>Fairly common</td>
<td>Low tree or shrub</td>
<td>Fence posts; fuel; charcoal</td>
</tr>
<tr>
<td>Guasango</td>
<td><em>Loxopterygium huasango</em></td>
<td>Near El Azúcar</td>
<td>Almost extinct</td>
<td>Very tall tree with many branches; strong, fine, heavy hardwood</td>
<td>Highly prized for house construction</td>
</tr>
<tr>
<td>Sapote</td>
<td><em>Capparis angulata</em></td>
<td>Near El Azúcar</td>
<td>Almost extinct</td>
<td>Heavy, fine hardwood</td>
<td>Fruit; furniture; linen; soap; perfume; herbal medicine</td>
</tr>
<tr>
<td>Ebano</td>
<td><em>Zizyphus thyriflora</em></td>
<td>Near El Azúcar</td>
<td>Almost extinct</td>
<td>Soft wood with many branches</td>
<td>Soft charcoal and firewood</td>
</tr>
<tr>
<td>Cascol</td>
<td><em>Libidibia corymbosa</em></td>
<td>Near El Azúcar</td>
<td>Almost extinct</td>
<td>Shrub or small tree; hardwood; many branches</td>
<td>Tools; charcoal</td>
</tr>
</tbody>
</table>
METHODS

1. Establish a catalogue of native tree species that were most likely present during the period of investigation, using input from local people in the region, and gather samples of these trees from the area.

2. Carbonize these wood samples in individual fire pits: dig small holes in the ground (one per wood sample), place the sample in its respective hole, repeatedly light the sample until it is carbonized but not disintegrating (do not add any kindling or any other firewood to the pit; this will contaminate the sample). Label each sample before carbonizing by wrapping heavy wire around it and running a length of wire out of the pit. Attach a label with the sample’s name to the wire.

3. Examine the type samples under the dissecting microscope to find the distinctive features of each sample. Compare samples to find differences. Samples should be made along the horizontal (or cross sectional or transverse), tangential, and radial planes. (Fig. 1).

4. Look for distinctive patterns in rays, annual rings, pores, resin canals, cell size, cell density, and any other features (Fig. 2).

5. Sketch each type sample at the magnification where it is most distinctive.

6. Take photomicrographs of each type sample under different magnifications (10x, 20x, 30x, and 40x) with the dissecting microscope and mounted camera to create a reference library.

7. Mount each type sample on an SEM stub with graphite clay and sputter coat them. Take SEM photomicrographs of each samples’ distinctive features at 100x, 200x, 500x, and the instrument’s smallest and largest magnifications.

8. Examine archaeological samples under dissecting microscope to make an initial identification. Repeat step 5 with the archaeological samples to confirm identification: compare pictures taken of the archaeological samples with the SEM reference library of the type samples.

9. Look for a trend in the identified archaeological samples from different strata.

ANALYSIS OF CHARCOAL

These methods listed above were applied to our study of wood charcoal excavated from Guangalan trash mounds at archaeological sites in El Azúcar and two additional Late Guangala to Early Manteño sites to the south of El Azúcar. The wood type samples we analyzed and catalogued were Algarrobo, Barbasco, Cascol, Ebano, Guachapeli Blanco, Guasango, Guayacan, Licuanco, Mullullul, Mata Sarna, Morocho, and Sapote. The type samples were distributed to

[6-7]
each team member, who used dissecting microscopes to look for the distinctive features of each tree, paying special attention to patterns in cell structure, growth rings, and rays. Due to the fact that cross-sections of charcoal best display its characteristics, most team members looked for pieces with a flat, cross-sectional surface. These were obtained by snapping the charcoal, as cutting or sawing it caused the cell walls of the charcoal to crumble, obscuring the distinctive features.

Through use of the dissecting microscopes, team members were able to supplement background research on the assorted trees with a firm knowledge of the appearance of the carbonized form of each tree. The dissecting microscopes magnified samples up to 45x, offering a better view than could be attained with the naked eye. Once patterns or distinct features were recognized in a type sample, a piece of charcoal that best displayed these patterns was selected from each sample to be used as a reference for later identifications. Ideal samples were acquired through extensive examination of the available collected samples. The sample, optimally, had a flat cross-sectional surface, which would make it easier to photograph under the dissecting microscope and the SEM. Samples with uneven surfaces do not provide enough uniform horizontal surface area to photograph and analyze. Cross sections were used because they offered a consistent and easy way of identifying the different trees.

Though each team member became well acquainted with her own type sample, the process of identifying the actual archaeological material required every member to be able to recognize the appearance of each type sample. To familiarize the entire team with the different type samples, each member first drew a rough sketch of her charcoal as viewed under the dissecting microscope. These drawings were basic representations of each wood type and thus did not offer enough detail or precision to aid in accurate identification. The drawings could not be used as the only resource, and, as a result, each type sample was photographed using the computer-dissecting microscope at four different magnifications: 10x, 20x, 30x, and 40x. The pictures obtained from the computer-dissecting microscope allowed each team member to share what she saw under the microscope with all of the other team members. The four images from each sample were compiled into a reference sheet, which was used as a comparative guide in the identification process.

Though the digital pictures acquired from the dissecting microscope were useful, the quality of the images taken was often inadequate in distinguishing all the features of the charcoal. Due to the reflective surface of the charcoal, the direct lighting of the microscopes obscured many details of the image. In order to create a better reference guide, the team used the Scanning Electron Microscope (SEM) to obtain clearer images. The SEM allowed the team to obtain pictures at a much greater magnification than the dissecting microscope or even the computer-dissecting microscope could have done. Whereas the dissecting microscopes use light that traverses a system of lenses to create a two-dimensional image, the SEM produces an image of much greater magnification by scanning an electron beam across each point of the sample.

The sample was limited in size by the SEM stub, on which the sample was mounted in order to hold it in place in the instrument. The sample was held in place and leveled on the stub by graphite clay. The mounted sample was then put in the sputter coater to ensure conductivity. Once coated, it was put into the Topcon ABT 32 SEM to be photographed and analyzed. The
sample was photographed with Evex VidxScan Digital Interface at magnifications ranging from very high to very low so that it would be easier to compare general and specific structures with the archaeological samples. The magnifications that were common to all type samples were the lowest and highest settings as well as 100x, 200x, and 500x. Pictures were also taken at other magnifications depending on what magnification produced the most distinctive photos. The lower magnifications allowed team members to view repeating patterns in the cell structure of the wood charcoal, and the higher magnifications allowed team members to look for distinctive features in cell patterns and size that had not been visible under the dissecting microscope. Each type sample photographed under the SEM was then compiled into a reference library of type samples that became invaluable during identifications. The reference library created using the SEM photographs became much more useful than the previous compilation of dissecting microscope images due to the clarity and magnification of the SEM images.

After the team compiled the reference library, archaeological samples excavated from several layers of Site 30, Site 47, Site MV-C2-3a, and Site MV-C2-4f were distributed to team members. In order to identify samples that would be useful to analyze, team members carefully scrutinized each fragment with the dissecting microscope. Samples that were covered in dirt were rinsed using fine brushes and distilled water, or broken in half if they were large enough to expose a fresh cross-section. Needle nose probes were used to break layers of soil off of the surface of the pieces. Then, team members examined each piece under a dissecting microscope, looking for characteristics of wood to determine whether it was a piece of wood charcoal. Once individual pieces of wood charcoal were identified, they were examined more closely under the microscopes. Team members looked for charcoal pieces with visible cross sections that displayed distinct patterns. When a distinctive sample was found, it was mounted to a stub with graphite clay and coated in the sputter coater. It was then analyzed in the SEM at the same magnifications as the type samples. Once the images were scanned, or even during the scanning, they were compared to the previously compiled reference library. Team members examined each individual archaeological sample and consulted the reference library images, looking for the distinctive patterns of the longitudinal cells, ray cells, and growth rings. The images of the archaeological pieces were scrutinized and compared by multiple team members until a consensus could be reached to confirm each identification.

RESULTS

Team six identified a total of eleven samples from the four archaeological sites. The samples originated from several different stratigraphic levels (Table 2). This accounts for samples from a range of time periods covering both the Guangalan civilization and post-abandonment; samples were identified from 210 BC to AD 600, as well as from AD 700 to AD 900.

From Site 47-V1, Level 23, one archaeological sample from the years of 210 BC to AD 90, was identified as Barbasco (Fig. 3). This identification was based on the arrangement of alternating diffuse/low density longitudinal cells with groups of densely packed longitudinal cells.
From Site 47-Y5, Mata Sarna was found in one archaeological sample in level 18, which dates the sample between AD 60 and AD 240. The archaeological sample and type sample both contain alternating regions of dense longitudinal cells with diffuse longitudinal cells, scattered resin canals, and ray cells perpendicular to the longitudinal cells (Fig. 3).

From Site 47-V0, one of the samples found in Level 14, aged from AD 195 to AD 365, was identified as Ebano. This is based on the presence of scattered resin canals located in regions that consist of longitudinal cells that have neither a distinct pattern nor density (Fig. 4).

From Site 47-V2, one of the archaeological samples from Level 8, dated between the years of AD 290 and AD 450, was identified as Cascol. The distinguishing feature of the charcoal samples is the alternating regions of extremely dense longitudinal cells with more diffuse longitudinal cells. However, despite the similarities in cellular structure, the two samples differ in their amount of resin canals. This might be a characteristic that differs from sample to sample and from tree to tree; however, there is also a chance that the sample is not Cascol (Fig. 4).

From the second level of Site 30-R4-2, two samples were identified as Sapote (Fig. 5). These samples, aged between the years of AD 400 and AD 600, have scattered resin canals and alternating diffuse and dense regions of longitudinal cells.

From Site MV-C2-3A Unit A7, one archaeological sample was identified. The sample from Level 17, aged between AD 700 and AD 900, was also identified as Algarrobo. It contained the same
characteristics as the previous samples identified as Algarrobo from Site MV-C2-4F Unit B1 Levels 16 and 17 (Fig. 5).

From Site MV-C2-4F, Unit B1, Levels 16 and 17, four samples from the time period of AD 700 to AD 900 were identified as Algarrobo. The key characteristics that are present in both charcoal samples include the following: many extremely diffuse ray cells that exist in narrow (1-3 cells wide) and short strips of parallel lines, randomly placed resin canals, and slightly diffuse longitudinal cells.

Charcoal samples from the following sites had distinct and unique patterns: 47-V1-Level 9, 47-V1-Level 23, MV-C2-4F-B1-Level 17, 17, 47-V2-level 9, 47-V0-Level 17, 47-V2-Level 19, and 47-V1-Level 23. However, Team Six was unable to identify any of them based on the collected type samples. Better samples may be needed or the reference collection may need to be expanded.

Table 2: Summary of Identifications of Charcoal

<table>
<thead>
<tr>
<th>Site</th>
<th>Unit</th>
<th>Level</th>
<th>Depth (cm)</th>
<th>Time</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV-C2-4f</td>
<td>B1</td>
<td>17 #1</td>
<td>AD 700-900</td>
<td>Algarrobo</td>
<td></td>
</tr>
<tr>
<td>MV-C2-4f</td>
<td>B1</td>
<td>17 #2</td>
<td>AD 700-900</td>
<td>Algarrobo</td>
<td></td>
</tr>
<tr>
<td>MV-C2-4f</td>
<td>B1</td>
<td>16 #1</td>
<td>AD 700-900</td>
<td>Algarrobo</td>
<td></td>
</tr>
<tr>
<td>MV-C2-4f</td>
<td>B1</td>
<td>16 #2</td>
<td>AD 700-900</td>
<td>Algarrobo</td>
<td></td>
</tr>
<tr>
<td>MV-C2-3a</td>
<td>A7</td>
<td>17</td>
<td>AD 700-900</td>
<td>Algarrobo</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>R4</td>
<td>2 #1</td>
<td>10-20</td>
<td>AD 400-600</td>
<td>Sapote</td>
</tr>
<tr>
<td>30</td>
<td>R4</td>
<td>2 #2</td>
<td>10-20</td>
<td>AD 400-600</td>
<td>Sapote</td>
</tr>
<tr>
<td>47</td>
<td>V2</td>
<td>8</td>
<td>35-40</td>
<td>AD 290-AD 450</td>
<td>Cascol</td>
</tr>
<tr>
<td>47</td>
<td>V0</td>
<td>14</td>
<td>70-80</td>
<td>AD 195-AD 365</td>
<td>Ebano</td>
</tr>
<tr>
<td>47</td>
<td>Y5</td>
<td>18</td>
<td>80-85</td>
<td>AD 60-AD 240</td>
<td>Mata Sarna</td>
</tr>
<tr>
<td>47</td>
<td>V1 #1</td>
<td>23</td>
<td>110-115</td>
<td>210 BC-AD 90</td>
<td>Barbasco</td>
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</tbody>
</table>
DISCUSSION

Implications

The large amount of Algarrobo found in the coastal, post-Guangalan levels could indicate that the region had become much drier, as Algarrobo is a drought-tolerant species. These samples could also indicate that deforestation had occurred after the Guangalans left their settlement, as Algarrobo can survive in much harsher conditions than the keystone species of the region’s forests. However, while the presence of Algarrobo is suggestive, it is not conclusive, as it is also present in forests under normal conditions. It may also be the case that Algarrobo is naturally more prevalent in coastal regions.

The presence of these types of charcoal in the archaeological samples, especially the presence of keystone species, indicates that the region around El Azúcar was once a dry tropical forest and not the semi-arid region it is today. It is known that the forest was present when the conquistadores made contact with the Manteños, and that the conquistadores cleared the forest, as they kept records of the events that transpired. It is also known that between the time the conquistadores left and today, the forests redrew. It is unclear what happened to the forests during the time of the Guangalans. However, the evidence the team collected cannot conclusively say whether or not the forests were destroyed, and, if they were, whether or not the Guangalans were responsible for the destruction of the forests in the region.

If the Guangalans had altered their environment in some way, there would have been a trend in their wood usage, from ideal firewood to increasingly less ideal firewood as they became more desperate as the forests dwindled. However, there was no definitive pattern of use over time in the charcoal samples analyzed. The samples vacillated between woods that were ideal for burning and woods that were not. The possible reasons for this are unclear, but one can be attributed to the small sample size. Therefore, more research with a larger sample size is necessary to determine whether or not they had changed their environment.

If the Algarrobo were to conclusively demonstrate that the region had become drier, as the present land around El Azúcar has, it would still be unclear as to whether this was a natural climatic change, or whether this was caused by the Guangalans. Therefore, the team could neither support nor refute its hypothesis that the Guangalans had abandoned their settlement as a result of overexploitation of the trees in the forest.

Methodology

While inconclusive, the team’s results prove that charcoal analysis is feasible. The field of charcoal analysis is still new, so the methodology is still in development at this point. Therefore, a major contribution of this project was the development of an effective way to analyze charcoal and the creation of type samples to be used for future research in the region, as well as the troubleshooting of potential issues involved in this process.

Different types of charcoal are distinctive at the cellular level when viewed even under low magnifications under a dissecting microscope; however, they can still be unclear. Therefore,
dissecting microscopes are best used as a means to make a preliminary identification: they can determine whether the substance being analyzed is even charcoal or some other substance and may indicate what type of charcoal the sample is. However, depending on the size of the sample as compared to the size of the type samples, identification may be difficult with the dissecting microscope if the charcoal came from different parts of the tree (i.e. the trunk, branches, or twigs).

The team was able to overcome much of these obstacles through use of the SEM, which became crucial to making identifications. When the project was first started, it was unclear, even to the project advisor, whether or not the SEM was necessary to the process of charcoal identification. However, it quickly became apparent that accurate identifications were only possible when using the SEM, because the archaeological samples were very small and were frequently obscured by dirt from the archaeological site.

The images produced by the SEM clearly showed the differences in cell size and compactness, growth rings, rays, and resin canals between the different type samples. However, while the SEM greatly helped in making identifications, using it was not always simple. There are many complications that are associated with this method. Definite identifications were possible; however, they were very time consuming to make with the SEM. The team had to prepare each sample, coat them in the sputter coater, and then analyze them in the SEM, which required a lot of unproductive time waiting for the vacuum to form and for scanning to take place. It was also possible to make a false identification based on images from different magnifications and angles. Team members sometimes thought an identification had been made only to discover that similar looking structures could look vastly different at varying magnifications. A slightly tilted sample could also obscure the distinctive features of a sample, making an identification difficult, if not impossible. For example, there was confusion over the identification of several samples from Sites 47 and MV-C2-4f that were determined to be wood charcoal, but appeared to be different type samples at different magnifications and angles.

Issues

The methodology of charcoal analysis poses a challenge due to the assumptions made, subjectivity of identifying and differentiating the charcoal samples that may lead to inconsistencies in results, and the time-consuming scanning electron microscope (SEM) procedure. One issue is the carbonization of charcoal, a method discussed earlier, and its effect on the viewing image. The charcoal has been carbonized, giving the sample a shine that may obscure the image when viewed under a dissecting microscope. A shiny image would gloss over the details of the pores and might obscure the interpretation of the pattern. It can be difficult to differentiate the various type samples as well as accurately identify the charcoal from the excavation material.

Another problem is the inconsistency of evaluating the charcoal with the two types of instrumentation: the dissecting microscope and the scanning electron microscope (SEM). The microscope and SEM are inconsistent because of different magnifications, as the regular microscope can only magnify to a maximum of 45x the original sample while the SEM can reach well up to 100,000x the sample. Images viewed under inconsistent magnifications cannot be
compared accurately because the defining features appear different and a connection between the type sample and archaeological evidence is difficult to make. However, it is best to use both instruments because both have their respective advantages and disadvantages. While the SEM is more accurate, it is a lot more time consuming. The entire process of sputter coating and placing the sample into the machine demands time and it becomes impossible to analyze each piece of the excavation under the SEM. If it were possible, the SEM procedure would be better to use because it provides better results.

There are also issues with the validity of assumptions that are made. One assumption is that the wood that was burned was from their fireplaces, which would imply that they themselves chose the wood they would use. If the trees were burned from a forest fire or in another natural way, the wood would be random and independent of any efforts for conservation or conscious use. The wood charcoal analyzed for this project was from the remains of ancient settlements and in some cases actual hearths and house floors therefore the assumption that the charcoal does represent fuel wood of the Guangalans is reasonable. The assumption that wood structures do not change is also necessary because the type samples that are found today are used for comparison with the archaeological excavation material. If the wood structure did evolve, the comparison wouldn’t be accurate and the correct trees could not be identified. Another aspect to consider is the hypothesis that the Guangalans disappeared due to environmental causes. More research is needed to test alternative models such as migration due to conflict or warfare or even to pursue economic activities present in other areas. Cemeteries or mass graves have never been located in the area to suggest that the Guangalans died of disease or conflict. Also, archaeological survey does demonstrate, however, that there are no domestic settlements in the Río Azúcar Valley or surrounding valleys between AD 600-800 when the Manteño establish a small settlement in the area. Therefore, further research is needed to test all of the alternative hypotheses.

The identification of the charcoal and establishment of type samples is difficult because not all species have clear defining features that are easy to distinguish. The interpretation of the pattern may differ from person to person, making it subjective when drawing a comparison. Repeated samples and multiple analysts are important to secure identifications and results. The handling of charcoal also poses challenges. Archaeological fragments are extremely fragile and will crumble easily and the sample is lost. This affects the integrity of the sample as does the fact that not all charcoal discarded by the Guangalans would have preserved and further it is impossible to insure that every fragment preserved is recovered in the excavation process. Therefore, quantification or statistical analysis of results is problematic.

Another issue is the difficulty in determining from the archaeological charcoal fragments what part of the tree was used. Other studies have found it useful to determine if twig or trunk wood was used in order to determine the type of resource exploitation. Trunk wood obviously would be a less sustainable use of the forest resources while twig wood would not damage the tree or the forest. Theoretically, the best results would be produced if the wood were analyzed for both type and parts used. By using the charcoal and SEM analysis, it is possible to deduce the succession of wood species used. However, the limited type samples and fragmentary archaeological samples make it difficult to connect the archaeological samples to the part of the tree used.
CONCLUSION

The goals of this project were to identify wood charcoal used by the Ancient Guangalans and to test the effectiveness of this method in archaeological research. Our objective was to look for trends in wood use, which would give insight into the lifestyle and environment of the Guangalans. These trends were used to answer the questions of why the Guangalans left the region. Our charcoal identification indicates the presence of dry tropical forest throughout the occupation of the Guangalans, but suggests that environmental change may have occurred in the post-Guangalan period.

Due to time restrictions, our sample size was rather limited. Therefore, definitive conclusions cannot be made. Given more time, a larger sample size may be analyzed to properly represent the resource use of the Guangalans. This would elucidate trends that would better depict the gradual changes in the availability of certain woods in the environment. This method may be utilized for further research of the Guangalans as well as other civilizations.

At the conclusion of this study, several unresolved questions remain. They include the cause of the disappearance of the Guangalan civilization and the cause of the hypothesized climate change indicated by the presence of Algarrobo in later levels. Due to the abundance of archaeological charcoal yet to be analyzed, the results of this study can be expanded by future independent research projects in pursuit of the answers to these persisting queries.

REFERENCES


