1. Introduction

For three decades one of us (PS) has been collecting cases of ancient Middle American societies affected by explosive volcanic eruptions. Sheets began with cases in southern Mesoamerica because he was doing his doctoral research in El Salvador. The sample of cases expanded to cover much of Mesoamerica because there were so many examples of eruptions affecting ancient societies in Central Mexico and the Gulf Coast area. He found that complex societies were often quite vulnerable to the unanticipated great stresses. Because complex society emerged early in Mesoamerica, compared to the surrounding culture areas, the sample was weak in egalitarian societies. Sheets therefore turned to Costa Rica to try to correct that imbalance, by adding cases involving less complex societies. Egalitarian societies predominated in the Arenal area of Costa Rica. We have yet to find clear evidence of that egalitarian/ranking boundary having been crossed at any time in the Arenal area.

We began the “Proyecto Prehistorico Arenal” in the 1980s with the objective of exploring the reactions of egalitarian societies to the sudden massive stresses from the ten explosive eruptions of Arenal volcano during the past 4000 years. We were surprised to find these “simple” but clearly very sophisticated societies were exceptionally resilient to the disruptions caused by the big eruptions. We have expended considerable efforts to try to understand why and how these egalitarian societies could have developed such resiliency. Based on our efforts to date, we believe the key factors were (1) low regional population densities and availability of uncontested refuge areas in times of emergency, (2) alliances from exogamy and from multiple community feasting, (3) reliance on wild foods rather than a domesticated dietary staple, and (4) the household or sometimes the village was the decision-making unit rather than having centralized authority. Sedentary villages have been dated to as early as 3000 BC, with sophisticated ceramics and at least some maize agriculture. Secondary burials were placed with the households. A major cultural change occurred around 500 BC when villagers began burying their dead in cemeteries that were located at a distance from the village. Ethnographic accounts by traditional Cuna and Bribri Indians of lower Central America describe the spirits of the deceased needing separation from the noise of villages. That may provide a reason for that separation. And the spirits of the dead are powerful, and are better kept at a distance from the functioning community. The archaeological evidence is clear that people walked single-file in their processions to and from the cemeteries, but the reasons for that are unknown. The routes they followed were strikingly straight, as we found from mapping the ancient paths, and traditional ethnographic accounts may shed light on the reasons for that. Bribri accounts mention stretching a string to help guide the spirit from the community to the grave. An unanticipated consequence of generations of people following the same path is entrenchment, often to 2 to 4 meters below the surrounding ground surface. Using entrenched entrances into special places must have become a cultural standard. And such entrenched paths certainly focus one’s attention on the objective, as the surrounding countryside disappears on both sides of the path. When one enters the cemetery it opens up to view, very much like emerging from a tunnel. All Arenal area societies apparently were egalitarian from the earliest (Clovis horizon, about 11,500 years ago) to the Spanish conquest about 500 years ago.

More complex societies did emerge to the east of the Arenal area, by about AD 500, as exemplified by the Cutiris chiefdom. What could be called the “mentality of monumentality” develops when egalitarian principles no longer govern society, and the chiefly elite seeks ways to physically express their centralized authority. The chiefs at Cutiris apparently chose the entrenched straight entryways that became so important in the Arenal area as something to magnify immensely in their search for monumentality. Chiefs mobilized large
workforces to construct and maintain deep and wide entryways that connected satellite communities some 6-10 km distant with their site center. And we can only imagine the processions of people using the huge sunken entryways into the site center. The entryways are almost 50 meters wide, and many meters deep, as they disgorge their participants into the site center. Ring roads allow processional participants to connect with the radial entryways without being seen from the site center. The radial principal entryways and the ring roads are almost exclusively of earthen construction. As this is a tropical wet rainforest environment, with some 3000 mm of annual mean precipitation, it is unknown how erosion and water management were achieved.

The emergence of complex society at Cutris was followed by other chiefdoms emerging, including Fortuna, Las Mercedes, and Guayabo de Turrialba. These largely date from AD 1000 to 1500. The favored construction material of the entryways changes to stone, perhaps because of possible erosional problems of the earlier earthen construction. This later monumentality was achieved by slightly different means, but the net effect was quite similar to Cutris.

The paths were discovered in remote sensing imagery provided by Tom Sever of NASA. Particularly effective are color infrared aerial photography and IKONOS satellite imagery for discovery of the ancient paths. Other imagery that contributed include LIDAR, Radar, color and black-and-white aerial photography, and the Thermal Infrared Multispectral Scanner (TIMS). We have developed a field and lab methodology for confirming, and disconfirming, anomalies in the remote sensing imagery as ancient footpaths. The detailed tephrochronology of the ten large explosive eruptions of Arenal volcano assists in our dating the initiation and the cessation of use of a particular path or path segment.

One problem we have had is adequately conveying the nature of our discoveries to our colleagues and to the general public. In books, articles, and other printed media we use maps, drawings and photographs of stratigraphic sections, airphotos, and satellite imagery. However all these illustrative media are static. The 3-d visualization of the terrain, with paths and excavated features included, is the most dynamic and successful means of education that we have found to date. That is the focus of this paper. Unfortunately, there is no way to include an interactive, dynamic 3-d reconstruction in a static printed paper, at least not with any technology presently in existence.

2. Previous Research and Current Issues

The Arenal Research Project has been operating in northwestern Costa Rica since the early 1980s, with Sheets directing the archaeology (summarized in Sheets 1994, 2003) and Sever directing the remote sensing (summarized in McKee et al. 1994, and Sever et al. 2003). Funding from the National Science Foundation, National Geographic, and the University of Colorado has supported field and laboratory research. NASA has provided abundant remotely sensed imagery from aircraft and satellite platforms, in both analog and digital formats (McKee et al. 1994, Sever et al. 2003).

We believe this case of the small footpaths with the simple egalitarian Arenal societies being later “writ large” into monumental sunken entryways in chiefdoms is consistent with the practice theory espoused by Pierre Bourdieu (1977). He argues that repeated daily practices can result in large scale social structures. Thus the understanding of small-scale activities is necessary to understand the origins and functioning of large-scale social operations.

During the many season of field work we have discovered dozens of village and cemetery sites, along with some campsites, lithic sources, and other special-purpose loci. We have not detected any footpaths from our earliest time spans, from Paleoindian through Archaic and the early sedentary (Tronadora phase) occupations. That constitutes 79% of the time that we have documented people living in the area, from approximately 10,000 to 500 BC. It is apparent that the cultural prescription that certain kinds of travel needed to be along the same path did not exist during these occupations. Our assumption is that task-oriented travel predominated, wherein people perceiving a need to obtain a food or other resource, visit kin, or conduct a ritual, generally would travel least-cost routes on an individual task basis, therefore sufficiently randomizing foot travel across their countryside so that entrenched paths would not develop. It is indeed fortunate that every footprint of people moving across the landscape does not preserve,
or the life support capacity of a totally trampled world would be miniscule. Tronadora phase (c. 2000-500 BC) villages were small, evidently less than 100 people, characterized by round houses with (presumably) thatch roofs. Ceramics were highly sophisticated, and were accompanied by basic and efficient chipped and ground stone tool assemblages. The manos and metates probably were used for grinding maize and other seeds, and both macrofossils and pollen indicate minor gardening of domesticates was done. However, the bulk of the diet probably derived from wild species of trees, bushes, vines, and other plants, along with hunting and fishing. The deceased were placed in secondary burials, in small rectangular pits just outside the drip lines of house roofs, and often accompanied by ceramic vessels, including nicely decorated drums. It is important to emphasize the association of the deceased with a particular household in the Tronadora phase, because this changes so dramatically in the next phase. We have closely examined all film and digital remote sensing imagery in and around these early villages, as well as all earlier sites, and walked the territory around each early site, and found no linear anomalies that could be ancient footpaths. In terms of social organization, all material indicators consistently point toward egalitarian societies throughout the thousands of years from PaleoIndian through Tronadora times.

The population density during all Precolumbian phases of occupation of the Arenal area remained very low by Mesoamerican, Andean, and even by overall Costa Rican standards. It probably never exceeded a few people per square kilometer. However, comparatively within our area, the Arenal phase (500 BC to AD 600) had the largest settlements and the highest regional population density of any phase. Instead of burying the dead adjacent to each household, villages created separate cemeteries, in some cases only a few hundred meters away, but usually a kilometer to many kilometers distant. In terms of social organization, societies during all phases of occupation prior to the Arenal phase were egalitarian, based on the uniformity of housing, artifacts, and grave goods in the Tronadora phase as well as evident uniformity in the two earlier phases. Housing and household artifacts do not show any differentiation during the Arenal phase, supporting the interpretation that egalitarian societies continued. However, some evidence from Arenal phase cemeteries indicates that egalitarian societies might have been pushing the egalitarian boundary.

In the Bolivar site, as an example of an Arenal phase cemetery, the burials at the very top of the hill had more formal rock coverings and more feasting evidence and a lot more broken pots and metates than did the burials just downslope (Hoopes and Chenault 1994). If these differences are not reflective of variation in gender, age-grade, or other similar factors, they could be indicative of the beginnings of social inequality. The lack of any skeletal preservation in this, and in all other Arenal phase cemeteries, is due to high soil acidity and mean precipitation of approximately 3000 mm per year. Unfortunately, that means gender or age studies of the deceased cannot be performed. The habitation area was approximately 150 meters down slope to the northwest of the cemetery. No path was found connecting them, probably because the plowing for agriculture that has been done on this peninsula in recent decades destroyed it.

Although we detected no remains of a path at Bolivar, the cemetery itself is instructive as to burial procedures and post-interment rituals (Hoopes and Chenault 1994). The ridge-top cemetery received considerable pre-and post-interment attention. The primary burials were placed in pits dug about a meter below the ground surface, and occasionally accompanied with grave goods (stone axes). The pits were filled in with dirt and then outlined with elongated stones on the surface, and then rounded river stones were harshly smashed onto the entire surface, creating a low mound of rock. That was followed by extensive feasting and smashing of hundreds of complete pottery vessels and dozens of decorated metates and other artifacts in post-funerary rituals throughout the cemetery. Clearly this was the most prestigious area of the cemetery. Only ten meters down the gentle slope was a different kind of cemetery, but one that appeared similar at first glance as it was also covered with broken pottery and a few broken ground stone artifacts. However, the project ceramicist and the lithic analyst could get virtually no rejoins, and artifacts were smaller and had more rounded break edges than those atop the ridge. We concluded that people had scavenged broken artifacts from a midden, and scattered them over the burials, rather than being complete artifacts broken in place, and thus appears to be a “poor
person’s” imitation of the more elaborate cemetery with conspicuous consumption nearby. The closest midden was adjacent to the small village 150 meters away, and that presumably was the source of the “shortcut” grave-covering artifacts.

In other areas paths that date to the Arenal phase have been found. The shortest known path is only 250 meters long, and its positioning helped us understand how important entrenched paths were to ancient people in this area. It is between a cemetery (G-184) and a village (G-180) that are 1.1 km apart (McKee, Sever, and Sheets 1994:144-146). The easiest transit between the village and cemetery would be an almost straight line along the flat floodplain of the Rio Piedra. However, they routed their path up the hill, over the top, and down the other side, compellingly showing the deep cultural need for an entrenched path. By choosing the route up and over the hill they increased the distance of travel slightly, and the effort significantly. Traveling from the cemetery, one would be in the entrenched path up and down the hill, but as one reached the bottom of the hill and the entrenched path disappears, the village would open up to view. At Trench 37 the path had eroded down to about 1.5 m below the surrounding ground surface, while other parts of the trench on both sides of the hill had eroded down to an estimated 2 m deep below the surrounding ground surfaces.

3. Ethnographic Considerations

In our Western culture we view a footpath as providing the most practical and economic (least-cost) route for people to walk from one place to another. However, ethnographic research has indicated that native peoples can imbue paths with powerful meaning, and we should not underestimate such meaning in the past. Why travel such a precisely prescribed route? James Sneed’s study of anciestral Pueblo trails of northern New Mexico (2002) suggests an answer. He found that much more than practical and economic factors were extant while people established and used ancient paths in the Bandelier area. The generations of use had endowed the paths with meaning. In a paradigm-changing insight into how differently Westerners and Native Americans can view a trail, Sneed (2002:756) provides a quote from Waterman about the Yurok of California: “Trails are sentient, and must be traveled with urbanity. If you step out of a trail and in again, and fail to preserve decorum, the trail becomes resentful.” This special sense of a trail, that channeled transit within a learned social memory, is what evidently developed in ancient Costa Rica. Generations of Arenal people were constructing meaning by single file path processions following precisely the same route. The spiritual aspects of the Arenal area paths probably were more important than their practical aspects, and the unforeseen consequences of sustained use developed into a treasured cultural value of entrenched entry into special places.

An initial necessary condition to form entrenched Arenal paths must have been the emergence of the cultural/ritual prescription of single-file travel along precisely the same path, year after year, from village to cemetery and back. That apparently began about 500 BC with the separation of cemetery from village. Ethnographic accounts of the Bribri (Skinner 1920, Bozoli de Wille 1975) provide possible clues as to why people would have done these processions. The Bribri believe the soul-spirit, after separation from the deceased, needs guidance between village and cemetery. The Cuna in Panama believe the soul-spirit appreciates the body being buried at a distance from the noise and busyness of the village (Dillon 1984). Whatever the reason, the actual first effect of sustained path use was linear compression, and where inclinations were greater than 5°, water from strong rainstorms began eroding and entrenching the path. The actual walked path surface is consistently only about ½ meter wide, and that can only be formed by single-file use. Because the tephra layers and the juvenile soils on them are so unconsolidated in the Arenal area, their angle of repose under these conditions is a slope on either side of the path of approximately 30° from horizontal. Thus, as the path surface erodes downward, it takes a broadened “V” shape of surrounding surface down with it. Centuries of use often result in the path entrenching to two, three, or up to seven meters below the landscape. Thus the prescription on path use in sloping areas resulted in the inadvertent entrenchment, which I believe became a cultural standard of the proper way to traverse between special places. To date, not a single instance of a constructed feature of any path itself has been found in the Arenal area. That contrasts dramatically with the constructed roads-entryways of the later chiefdoms. Only a brief mention of the later chiefdoms is warranted here.
4. Later Chiefdoms and Constructed Monumentality

Recent research by Vazquez et al (2003) discovered the emergence of the Cutris chiefdom between AD 500 and 1000, to the east of Arenal. The chiefs created monumentality by organizing large work gangs to dig four 6-10 km long deep roadways to enter the site center. We suggest the value of entrenched entryways was developed by egalitarian societies centuries earlier in the Arenal area and probably many other areas. Later chiefdoms continued making monumental entryways, such as at Guayabo de Turrialba (Fonseca 1981, Murillo 2002). They were less entrenched, and surfaced with stone, perhaps because of the difficulties in water management of entrenched earthen entryways. When the mentality of monumentality developed, it is not surprising that chiefs would turn to something that had deeply embedded itself into the egalitarian value system: entrenched entryways. People had for dozens of generations “bought into” the significance of those entryways. And the use of them, seeing important places open up in front of the person arriving, must have carried intense emotional reactions.

5. 3-D Visualization

Three-dimensional interactive visualizations have been constructed of the Arenal landscape, including the sunken pathways linking cemeteries with villages. The paths also link cemeteries with the sources of stone used in their construction. And the paths link cemeteries with springs, as people needed large amounts of water to support themselves in construction efforts and particularly in feasting and ritual. The 3-D visualization allows one to fly along or over a pathway and experience the topography in ways that can not be done by any other technology.

The Arenal 3-D visualization was part of a broader program including Mesoamerica and Central America. To create the terrain file for Mesoamerica and Central America the research team selected 15-meter resolution imagery from Landsat 7 that covered the entire region from southern Mexico to northern Colombia, plus selected IKONOS scenes, at one-meter resolution, for special areas of interest. The imagery was draped over 90 meter resolution elevation data from the Shuttle Radar Topography Mission (SRTM).

In order to better understand the context, function and relationship of ancient footpaths in the Arenal Region of northern Costa Rica and their evolution to the natural terrain and connectivity to ancient villages and sites, a three dimensional model of the terrain with overlaying features was developed. The resultant visualization allows the investigator to “fly over” the footpaths at various altitudes, directions, and tilt angles and zoom in upon features of interest upon the landscape. The aerial vantage point leads to the realization that everything observable in the ancient landscape has meaning and interconnection, factors that sometimes can not be appreciated from the ground. This gives the archeologist the ability to understand the complex evolution of human factors for settlement patterns, subsistence strategies, use of resources, and the social, political, religious, and economic relationships that connect the study of the past with the present.

The terrain model was produced from several data sources. High resolution, pan-sharpened IKONOS data were processed using ERDAS software to produce both natural and color infrared images at one-meter resolution. These high resolution IKONOS scenes and 30-meter resolution LANDSAT imagery were draped over a Digital Elevation Model (DEM) derived from digitized contour lines of the 1:50,000 scale topographic maps of Costa Rica using TerraBuilder - a 3D terrain construction application from Skyline Software Corporation.

TerraBuilder provides a three-dimensional spherical Earth with latitude/longitude coordinates as a base for holding imagery, elevation and vector data types. Because the IKONOS data were formatted using a UTM coordinate system, Terra Builder had to convert the files into latitude and longitude using built-in conversion procedures. (Terra Builder is quite versatile in it’s acceptance of a wide range of data formats including GeoTiff, .img files output by ERDAS Imagine, and MrSID compressed files to name a few.) The multi-resolution terrain file produced by TerraBuilder combines the imagery and elevation data with built-in imagery of the entire globe.

Using the resultant multi-resolution terrain file another Skyline application – Terra Explorer Pro
(TEP) - was used to interact with the file, add and remove vector data, and add or remove other assets such as labels, images, and icons. For example, the location of the ancient footpaths, determined from previous analysis of NASA airborne scanner data and color infrared photography, and ground verified using Global Positioning System (GPS) measurements, were input as vectors onto the terrain file. In addition, the location of ancient sites and cemeteries were also incorporated as vector layers. Terra Explorer Pro was also used to create and record animated “flights” over the terrain and support analyses of the terrain through a series of tools that measure distance, produce contour maps, and locate best path to name a few. Due to the flexibility of TEP other GIS data can be added to the mosaic and any of the existing data layers can be toggled on or off.

6. Summary and Conclusions

The Arenal Research Project, operating intermittently in northwestern Costa Rica since the 1980s, has documented human occupation for the past 10,000 years. During most of that time, people walking across the landscape were presumably task-oriented, and thus sufficiently randomized to leave no traces that we have been able to detect today. However, from about 500 BC to about AD 1200, people separated their cemeteries from their villages. The processions that regularly linked the two were by people traveling single-file in as straight of lines as possible. The unanticipated consequence, path entrenchment, apparently became a highly valued cultural standard. That was “writ large” when complex societies developed, and chiefs mobilized massive construction efforts to make monumental sunken entryways.

Until three-dimensional interactive visualizations were developed, we had only paltry, static ways of sharing the landscape, the locations of villages and cemeteries, and the paths that linked them. Now with the visualization one can fly over the processional landscape, following a path to its endpoint. One can sense the feasting done at the cemeteries and see how people got to them. One can see from where people obtained construction stone, and see the spring from which they obtained water for cooking and drinking at the cemetery. The landscape comes alive in a way not matched by any other graphic displays at our disposal.

The three-dimensional landscape of the Arenal area was constructed by draping high-resolution IKONOS satellite imagery over a Digital Elevation Model (DEM). The DEM was constructed from the 1:50,000 scale topographic maps from the Instituto Geográfico in San José. Specific locations of paths, cemeteries, and village sites were verified with the Global Positioning System (GPS). Terra Explorer Pro software allows us to fly over the terrain and sense movement from village to cemetery and back, along the ancient footpaths.

7. References Cited


Murillo Herrera, Mauricio 2002. Análisis critico de las investigaciones en el sitio Guayabo (UCR-43), de Turrialba y las repercusiones sociales con relación al manejo de sus recursos


