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Total Station Mapping: Practical Examples from Alta and Baja California

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The use of electronic total data stations for mapping archaeological sites is examined through two California case studies. Mission Santa Catalina, located in the high desert of Baja California, and a cluster of three shell mounds, located in a forest in the San Francisco Bay area, represent two different examples of organizing and implementing a mapping program using a total station. In this article, we will discuss the basic use of total stations for mapping archaeological sites and provide an overview of the process of creating digital maps from data obtained using a total station. The two case studies will offer in-depth consideration of different data collection strategies and techniques used for the production of digital maps, and we stress the broad application of total stations for accurate and efficient mapping in a variety of study settings.

From the earliest days of the discipline, archaeologists have relied on maps to better understand the spatial attributes of archaeological sites and to convey such information to other scholars. Accordingly, survey and systematic mapping of archaeological sites is a practice with considerable antiquity and development. From mechanical transits and plane tables to robotic total stations and the Global Positioning System (GPS), a quick survey of archaeological site mapping literature from the past twenty years reveals a florescence in technology available to archaeologists (e.g., Dibble 1988; Kidder 2002; Kvamme and Ahler 2007; Kvamme et al. 2006; McPherron 2005; Rick 1996a, 1996b; Searcy and Ure 2008). While many archaeologists working in California employ one form of mapping or another in their research, the speed of technological development in the field has outpaced the publication of technical reports detailing the use and rationale behind some of the newer and more popular mapping techniques, such as the use of electronic total stations.

Our goal in this paper is to outline two strategies for designing and implementing a mapping program using an electronic total station. We present two case studies that are intended as practical examples of total station use in two very different environments: the desert of Baja California, Mexico, and a forest in the San Francisco Bay area of California. A Sokkia SET510 electronic total station was used to map the archaeological site of Mission Santa Catalina in northern Baja California and a cluster of three shell mounds in China Camp State Park, Marin County, California (Fig. 1). In each case study, we discuss the project area, our project goals, the data collection strategies we employed and the reasoning behind them, as well as the techniques used for the production of different digital mapping products. We conclude with a discussion of our findings, including the benefits and shortcomings of our survey strategies.

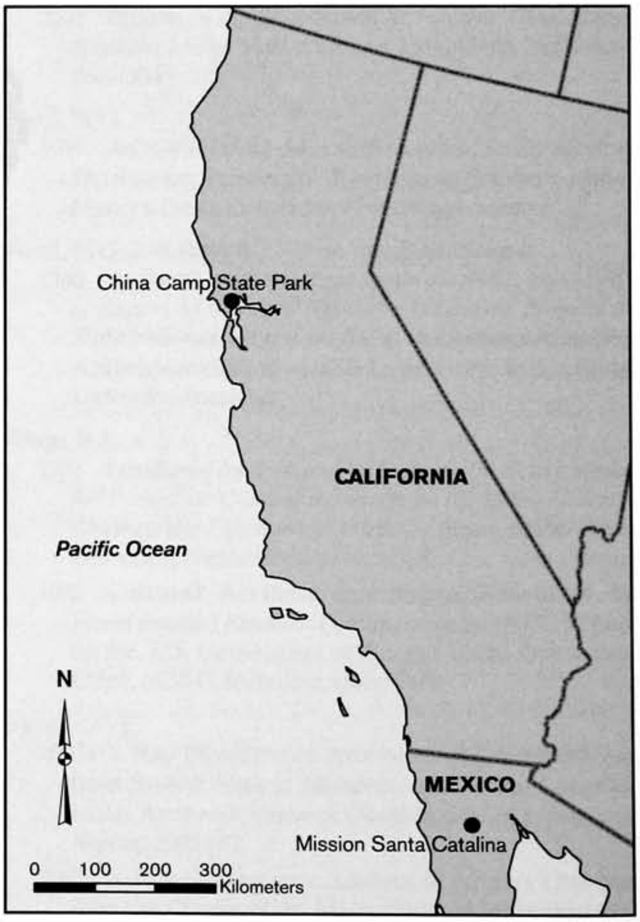

Figure 1. Locations of archaeological sites described in this article.

TOTAL STATION AND SOFTWARE BASICS

It goes without saying that maps are an important part of most archaeological projects. With map in hand, archaeologists can reduce "a vast and complex environment to a set of symbols in a manageable paper space, something [to] fold up and throw into our field pack" (Collins and Molyneaux 2003:99). In this article, we will focus our attention on the survey and recording of archaeological sites using an electronic total data station—an instrument that combines an electronic theodolite with an electronic distance measurement device (EDM). A typical total station uses an infrared laser to measure distances and uses an on-board electronic theodolite to calculate angles to reference points. It is used for a variety of survey purposes, including the mapping of archaeological sites and features, as well as the laying out of datum points and excavation grids. With careful set-up and ideal conditions, the use of a total station allows archaeologists to collect geographic data with extreme accuracy (0.001 meter) over distances of several hundred meters.

In short, the advent of total stations has revolutionized the practice of recording and mapping archaeological sites. While the cost of total station instruments—and of the software packages with which they are associated—are often high, the benefits of using a total station far outweigh any technological hurdles associated with "going digital" (Howard 2007:5). For excellent detailed summaries of the range of mapping instruments available to archaeologists, see Hester et al. (1997) and Howard (2007), and see Rick (1996b) for a detailed discussion of total station capabilities. Howard (2007) also presents case studies and techniques for producing digital depictions of archaeological sites, features, and landscapes using CAD software.

While many recent publications include archaeological plan maps derived from data collected using total stations, few examples exist in the archaeological literature that explicitly relate how and why these data were collected. In the remainder of this article, we outline our general mapping strategy, and then present two brief case studies from Alta and Baja California that will demonstrate the steps involved in collecting digital elevation data in two different environmental settings. The site of Mission Santa Catalina, for example, is characterized by sparse, low vegetation and minimal topographic relief, which occurs primarily in the form of wall foundation remnants. The shell mound cluster, however, is located in a wooded setting and comprises three discrete areas including two satellite shell middens and a large shell mound that rises more than five meters above the modern ground surface.

Setting Up a Grid System

The physical characteristics of a given archaeological site will determine in large part the manner in which data are collected for a particular map, but there are some constant fundamentals of total station use. For instance, we recommend the use of the coordinate mapping function of the total station, which enables researchers to record a range of points—from across an archaeological site—that conform to an X, Y, Z coordinate system. To allow for the possible expansion of a site map at a later date, we follow a conventional method which involves setting the primary datum point to an arbitrary coordinate, such as 1000 meters north, 1000 meters east, and 1000 meters in elevation (Hester et al. 1997:208–209). This "false-origin" system is simple and relatively flexible, in that it limits two-dimensional points to a northing and easting—positive integers in an X, Y, Z coordinate system. The total station's user interface also allows data points to be changed as a batch if needed. For example, you may decide to use the site's true elevation gathered from a known local datum or benchmark; shift points in space to accommodate data more than 1000 meters south or west of the original arbitrary datum; or correlate local, site-specific coordinates with a larger, universal grid system such as UTMs for use in GIS programs.

Like most total stations, the Sokkia instrument used for these studies does not contain an internal compass. Accordingly, one must manually set the horizontal angle through the use of a back sight. Care must be taken to ensure that one's grid system aligns with true north rather than magnetic north, which changes from year to year. Several internet sites provide easily accessible information on current magnetic declinations for any geographical setting. We suggest the use of a traditional optical transit to establish a line running true north (or other cardinal direction) from the primary datum. A stake placed along this line at a known distance from the primary datum can be used as a back sight to establish the horizontal angle for the total station. This process, in which the user defines the cardinal directions for the total station, is essential to the use of the coordinate function of the instrument. The use of a point along one of the cardinal directions from the primary datum also has the advantage of being useful for other aspects of field research that may need a physical grid system, such as geophysical prospection or surface collection.

Field Mapping Techniques

Once the instrument has been successfully set up and oriented, the process of data collection can begin with at least two crew members—a stadia rod-holder and total station operator. We recommend at least one more crew member to help record point data in a notebook in the event that the total station is lost or destroyed. This third crew member can additionally help facilitate the survey by removing items that block lines of site between the total station and stadia rod. In this scenario, several hundred points can be collected in just one day of mapping. However, as most archaeologists can attest, no two archaeological sites are alike, especially the arid and forested sites discussed in our case studies. The site and its features, post-depositional conditions, and the physical environment will in large part guide specific data collection methods and will be discussed below.

Mapping Software

This article will also address how digital elevation data can be manipulated to create digital maps that show the site in different configurations and views. The specific process of transforming raw data into a particular mapping format varies between software platforms and will not be discussed in detail here. In general, however, data collected from an archaeological site must be first downloaded from the total station, typically using proprietary software supplied by, or purchased from, the instrument's manufacturer. Once the data have been retrieved from the instrument, it is usually possible to export them from the instrument's software package into a text file that can be read by standard spreadsheet applications, such as Microsoft *Excel*, or can be imported directly into a mapping software package.

Most software packages will create a topographic map by extrapolating or interpolating the data points collected in the field. For example, in *Surfer*, Version 8 (Golden Software, Inc. 2003), this function is called "gridding," and it will create a new file, leaving the raw data in the original worksheet unmodified. The new grid file (.GRD) can then be used to create different visual representations of the data. Specific algorithms (e.g., local polynomial, kriging, natural neighbor, nearest neighbor, etc.) can be used to create grid files, depending on speed requirements, analytical techniques to be employed, and the need for exact reproduction of data versus the smoothing of data during the gridding process.

Creating Digital Raster Maps

Through the process of gridding, X, Y, Z data are transformed to create a number of different raster map formats, including contour maps, surface maps, post maps, image maps, and shaded relief maps. Contour maps, for example, are useful for displaying topographic data in two dimensions, particularly in combination with other site features such as architectural remains or excavation units. Accordingly, one map can be created that contains all the relevant geographic data about a site, and distinct features can be added or deleted according to the purpose of the map. Software programs such as *Surfer* can also add other attributes to the final map, such as scales and north arrows.

One drawback of using interpolated point data and certain gridding algorithms is that subtle topographic features can be flattened. For large sites, or for ones with multiple components, it may be best then to create individual maps for particular areas or components if one is interested in subtle topographic changes. Also, depending upon the interpolation technique used for the gridding process—the difference, for example, between kriging and natural neighbor algorithms—non-existent features, called "artifacts," are sometimes added to the resulting maps. Some experimentation with the gridding process may be necessary to achieve desired results. Nevertheless, mapping software is an invaluable tool for creating topographic maps, surface artifact density maps, and other forms of spatial data (Bruseth et al. 2007).

While the exact needs and goals of any given archaeological project will vary, accurate and efficient site mapping is a critical component of archaeological field research. The following two case studies will highlight how digital elevation data can be collected using a total station in different environmental settings. In doing so, each example considers three fundamental elements: site history, including post-depositional factors;

conditions affecting data collection methods; and the creation of digital maps from data collected in the field. Firm knowledge of post-depositional factors, or specific cultural and natural transformation processes, is important to understand any archaeological site and to implement a mapping methodology for the collection of culturally relevant geographic data. Each archaeological site, moreover, will require specific adjustments to the basic techniques of data collection and the creation of digital maps, and this article should accordingly be seen more as a jumping-off point rather than a how-to manual. We merely hope to demonstrate the utility of such techniques, as well as the relative ease of creating accurate plans maps through the use of a total station.

MISSION SANTA CATALINA

Mission Santa Catalina was founded in 1797 as part of a series of Dominican missions that were intended to extend Spanish colonial control into the territories of the last remaining unmissionized indigenous groups of northern Baja California. In the case of Santa Catalina, the mission was founded in the homeland of Paipai-speaking people. Over the course of its brief history, the mission was home to several hundred native neophytes, many of whom appear to have continued certain hunting and gathering practices. The mission is located in the Paipai community of Santa Catarina, which is largely composed of the direct descendants of the mission's native inhabitants. In 1840, the mission was burned in an Indian uprising, and today, the remains of the Mission Santa Catalina are little more than low mounds where the mission's adobe walls once stood. One primary goal of creating a detailed map of the mission site, therefore, was to aid in the mapping of mission walls and other architectural features.

Prior to the current fieldwork, only one complete map of Mission Santa Catalina was known to exist. As part of his seminal investigation into the Dominican missions of northern Baja California, geographer Peveril Meigs III created a sketch map of the Santa Catalina Mission compound (Meigs 1935; see Fig. 2). Nevertheless, Meigs noted that he could not reproduce the mission plan accurately due to the amount of damage to the walls. His map, therefore, may be little more than an idealized vision of the mission's original state. More than seventy years later, during our initial research at the site in 2005, the walls had deteriorated even further and the condition of the site's architectural remains posed further challenges to the creation of a site map. However, through the use of modern technology, such as the total station and computer mapping software, we believe that it is possible to create an accurate map that reflects the site as it is today—one that can then be used to understand better the original layout of the mission compound.

Post-Depositional Factors

Before we began collecting data for the map of Mission Santa Catalina, we first examined the history of the site itself in order to account for post-depositional factors that may have transformed the site during the century and a half since its abandonment. The extent of the conflagration that ended the mission's use in 1840 is unknown, but test excavations in and around the mission walls suggest that supporting timbers and roof thatching likely burned in the room blocks of the mission quadrangle, leaving the adobe structure exposed to the elements (Lightfoot et al. 2006). Archaeological and archival evidence indicates little sustained use of the mission site itself after the attack of 1840. Indeed, information from Mexican-period documents as well as Paipai oral traditions suggests that many of the former neophytes and their descendants left the lands directly adjacent to the mission and moved to a nearby valley. In the twentieth century, the Paipai returned to Santa Catarina, although no households are located in the immediate vicinity of the mission.

Two other significant disturbances are known to have taken place at the mission site. The first took place in 1949 when American treasure hunters dug several holes in the mission site, at least one of which was excavated to the original level of the mission floor (McDonald and Oster 1968:14). Using a photograph taken during the looting of the mission site, we have been able to tentatively locate one area of disturbance in the northern corner of the mission compound, although the locations of the other holes remain unknown. The second event occurred in 1959 during field research by a team of American archaeologists. Records of the exact locations of the excavations have not been found, but based on the descriptions given in the brief published account of this

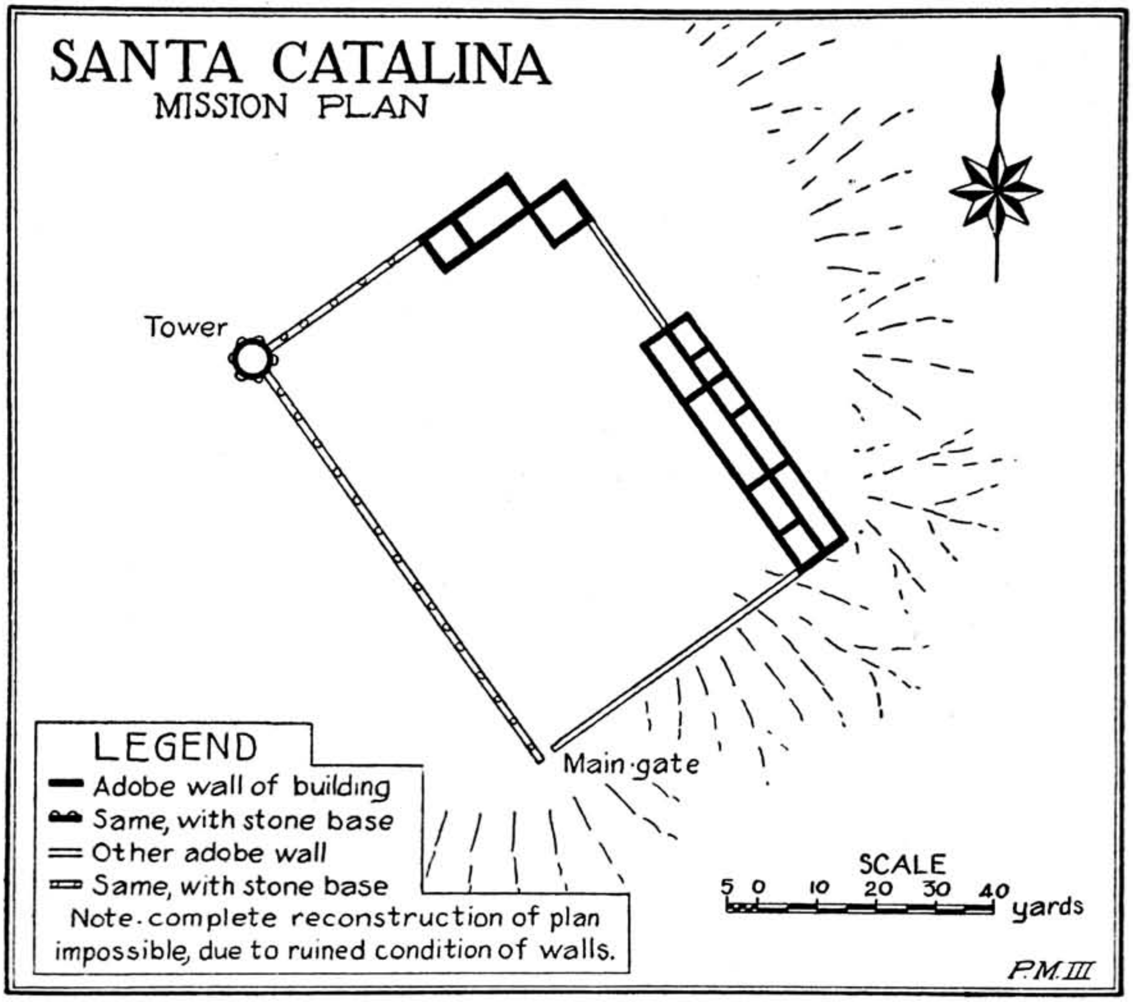

Figure 2. Original map of Mission Santa Catalina as drawn by Peveril Meigs III (1935).

work, it appears that excavations were only conducted in the open, interior space of the mission quadrangle (McKusick and Gilman 1959). Today, no indications of these two disturbances are visible on the surface of the site, the walls of which vary in height from less than a centimeter to approximately 40 centimeters.

Overall, the condition of the mission site poses a significant challenge to accurate mapping of architectural features. Meigs' (1935:122) original estimation that a "complete reconstruction of plan [is] impossible, due to ruined conditions of walls" was a significant challenge to us as we made preparations to map the site of Mission Santa Catalina. Furthermore, looting and other more scholarly excavations in the mission compound likely obscured foundation remnants and room outlines. The obstacles of poor preservation and major disturbances notwithstanding, the technological advances made in the seven decades since Meigs published his original map provided several advantages that allowed for the creation of a site map that more accurately reflects the conditions on the ground at the mission site.

Data Collection

The primary goal of a site map is to represent the current conditions of a particular site and to make it legible to others. In the case of Mission Santa Catalina, then, this meant that the reconstruction of architectural features—while a major interest from the standpoint of the authors—was necessarily a secondary consideration during the field stage of the mapping process. Instead, the goal was to produce a detailed raster image (similar to a digital elevation model or DEM) that would provide an objective representation of the site's surface. Architectural features could later be inferred and added as part of

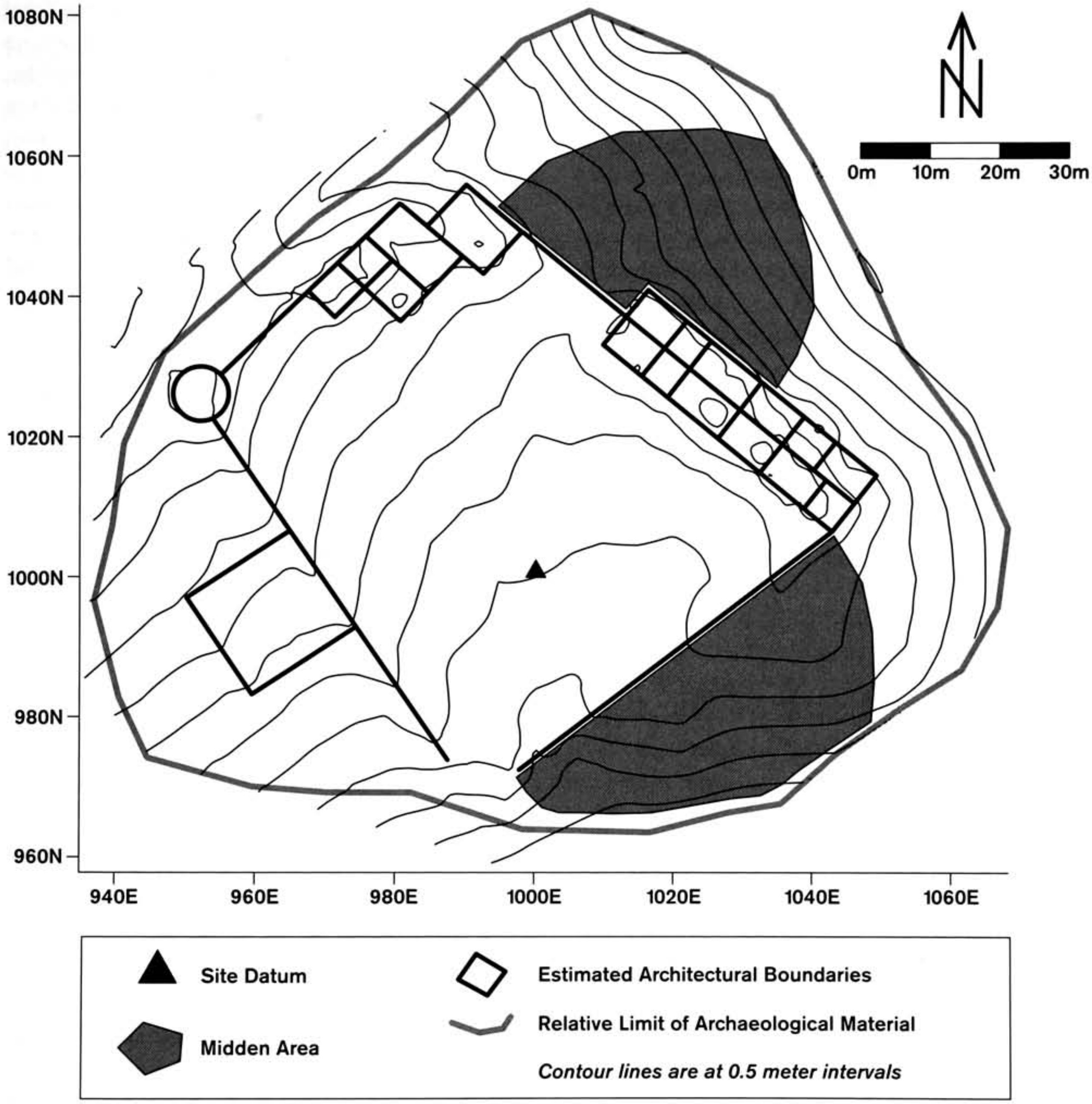

Figure 3. Site plan for Mission Santa Catalina, showing topography, estimated architectural footprint, midden features, and site boundary.

a broader map that would also record the location of modern disturbances and archaeological activities.

The resulting surface map can be used to plan future archaeological and preservation work at the site, measure further human disturbances to the site, and assess deterioration due to natural processes such as erosion.

The site of Mission Santa Catalina is located on a gentle slope, with an elevation gain of roughly 5 meters across the primary site area. The mission quadrangle itself is oriented about 45 degrees off of the cardinal directions and measures approximately 70 meters by 80 meters. Large middens, likely representing neophyte habitation areas, extend for about 30 meters from the southeastern and northeastern walls of the mission compound (Fig. 3). There is no standing architecture and the site is only sparsely covered with juniper trees and prickly pear cacti.

These conditions allowed for uninterrupted lines of sight across the entire site, and it was accordingly decided to place a single datum point located near the center of the mission compound. This was the primary reference point around which the map was created. In order to mark the datum point, a 50-centimeter-long piece of aluminum angle bar was driven into the ground so that only a few centimeters remained visible above the surface. Once the primary datum point was established, the total station was set up above the aluminum marker and the instrument was configured.

Because the mission site does not contain significant topographic features other than architectural remains, we conducted a stratified sample of data points spread out across the mission quadrangle and adjacent areas. Using fiberglass measuring tapes, a grid was established at five-meter intervals over the area for which we planned to collect data. Information was collected every five meters for areas of the site that held no architectural features visible on the surface. In areas where architectural features were present, we intensively sampled relevant topographic features following the basic strategy

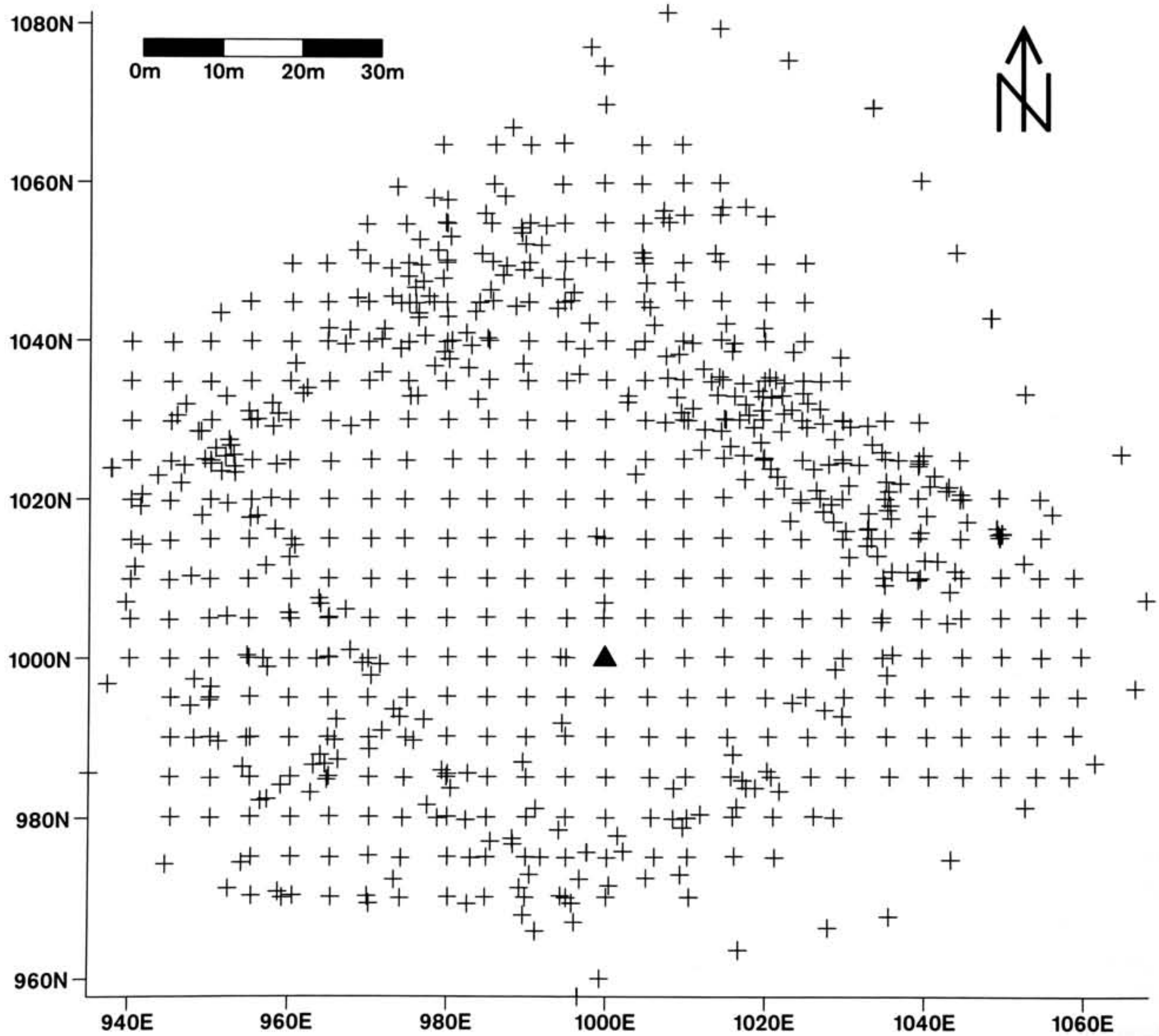

Figure 4. Post map showing all of the points collected for the site map of Mission Santa Catalina. Note the combination of systematically and judgmentally collected points.

suggested by Fletcher and Spicer (1988) and others (e.g., Kvamme et al. 2006:92–93), which involves a combination of uniform and irregular sampling of survey data (Fig. 4). In effect, the highest points of the wall remnants and other architecturally related features were collected every one to two meters, as were the lowest points in each potential room, enclosure, or looter's pit. These data provided the basic points from which we constructed the site map.

We also collected data from judgmentally defined points so that additional two-dimensional features, such as vehicle paths, could be included in the eventual site map that we created. Each of these was saved separately on the total station itself for ease of creating separate features on the map. During the collection phase of the mapping, we also discovered a previously unknown structure adjacent to the southwest wall of the mission quadrangle. The foundation remnants of this structure were flush with the modern ground surface and were consequently mapped in separately from the systematic data points taken from the rest of the site. This information was added to the basic raster image of the site's topography to show other features of the mission site. In all, we collected data from over 700 points across the mission site.

Creating Digital Maps

For Mission Santa Catalina, one of our primary goals was to create a site plan map showing the remnant architectural features of the site. Despite the poor preservation of the architectural remains, we were able to create a plan map of the mission quadrangle and surrounding areas from the digital elevation data we collected using the total station. To do so, we created a contour map that included all of the data points that we recorded in the field. Because the topographic relief of the architectural remains at the site is very slight, we then set the contour interval of the map to five or ten centimeters (Fig. 5). The resulting map provided the basic outline of the mission foundations, over which we added lines representing the approximate location of the mission walls and room divisions. Afterward, the contour lines were then reset to half-meter intervals. A similar technique involves increasing the vertical exaggeration in different digital map formats to highlight certain areas of the site, such as foundation remnants. In some cases, as with the newly discovered room along the southwestern wall, architectural features that were flush with the modern ground surface were added later. This was done by plotting the data points for those features, and then incorporating the data into the site plan map of the mission compound.

Another goal was to create a map that could be used to record modern disturbances, such as roads, as well as archaeological activities like excavation units. Once the basic outline of the mission compound was established, we added detail to the map, although many of these features did not have robust topographic signatures. In order to add these features to the map, we created a post map, which is simply a two-dimensional plotting of all the data points in a particular file. These points were overlain on top of the original contour map, and lines and polygons were added to represent each feature in the resulting vector image. In the map of Mission Santa Catalina, features such as vehicle paths, architectural remains, midden deposits, geophysical survey blocks, excavation units, and site boundaries are all part of the master digital map and can be turned on or off as necessary.

SHELL MOUNDS OF CHINA CAMP STATE PARK

CA-MRN-114, CA-MRN-115 (the Thomas site), and CA-MRN-328 are shell mounds found in China Camp State Park, which is located on the southwest shore of San Pablo Bay and about three miles from San Rafael, California. MRN-115 is approximately five meters tall, 30 meters long east to west, and 45 meters long north to south. Two smaller shell mounds—MRN-114 and MRN-328—are located nearby. MRN-114 is located about 20 meters north of MRN-115 and MRN-328 is found about 40 meters south of MRN-115. All together, the three sites form a shell mound cluster, one of many found along freshwater courses that empty into the broader San Francisco Bay area.

MRN-114 and MRN-115 were originally recorded and mapped in the early 1900s by Nels Nelson, who circumnavigated the San Francisco Bay surveying and recording over 400 shell mounds (Nelson 1907, 1909). As part of the University of California Archaeological Survey, Clement Meighan excavated twelve contiguous 1.5 meter units and one house pit approximately 2.5 meters in diameter at MRN-115 in 1949 (Meighan 1953). A radiocarbon sample collected from an approximate depth of three meters yielded an age range of A.D. 1100

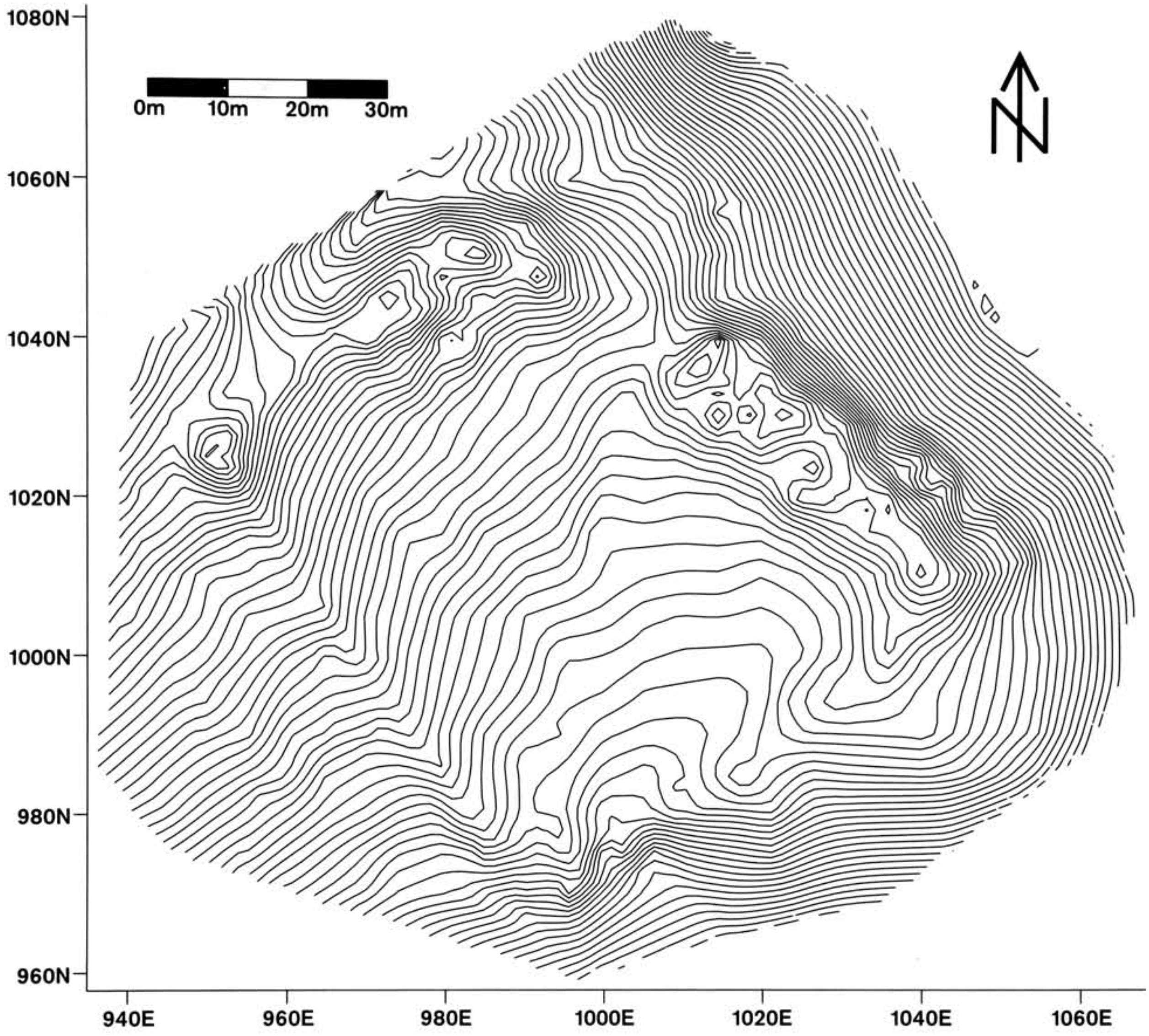

Figure 5. Base contour map of Santa Catalina mission site. Contour intervals are at ten centimeters.

to 1360. Archaeological deposits on top of the house pit excavation and a notched projectile point led Meighan to believe that the site was abandoned at about A.D. 1800. This time span has import for studies of complex hunter-gatherers and their later colonial interactions with Europeans in the Bay Area.

As part of his site report for MRN-115, Meighan published a site plan map, a plan drawing of the house pit excavation, profile drawings, and a cross-section of the site's basal deposits based on five test auger units (Meighan 1953) (Fig. 6). Meighan's plan drawing of MRN-115 appears similar to Nelson's map of MRN-115 produced forty years earlier, which depicts approximate site dimensions and site boundaries. However, while Meighan takes great care to indicate the location of his excavation units—a benefit in understanding the 1949 excavation and provenience of artifacts—it is difficult to relocate the twelve house pits using Meighan's approximate topographical contour lines. Thus, the first goal of mapping MRN-114, MRN-115, and MRN-328 was to create accurate site plan maps that could be used to identify site boundaries and to relocate surface features on MRN-115 (Fig. 7). Second, we wished to provide state park staff with an accurate depiction of the sites for help in monitoring natural and human disturbances. Third, after defining a manageable study area for the project,

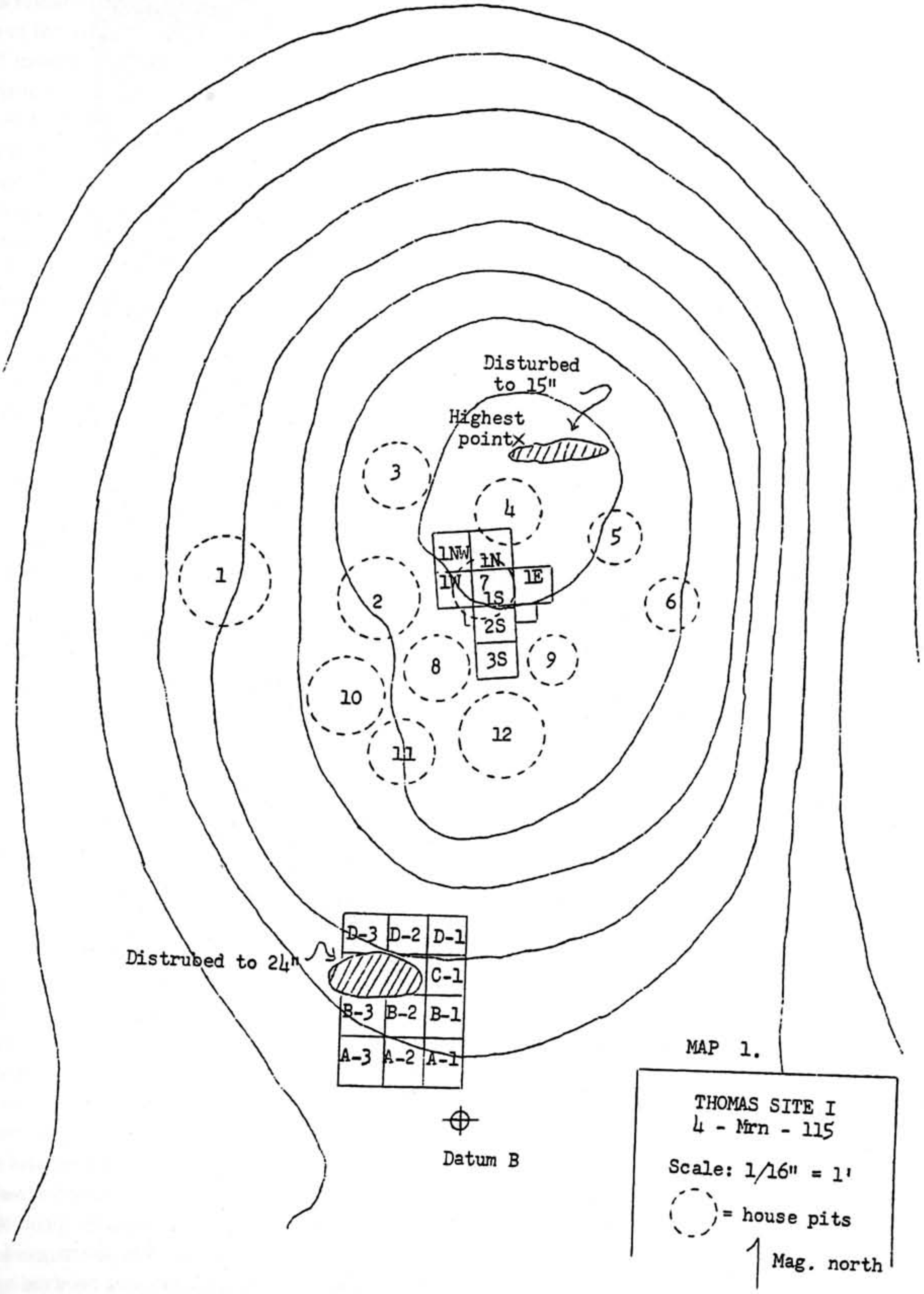

Figure 6. Original map of MRN-115 as drawn by Clement W. Meighan (1953)
(Courtesy of the Archaeological Research Facility, University of California, Berkeley).

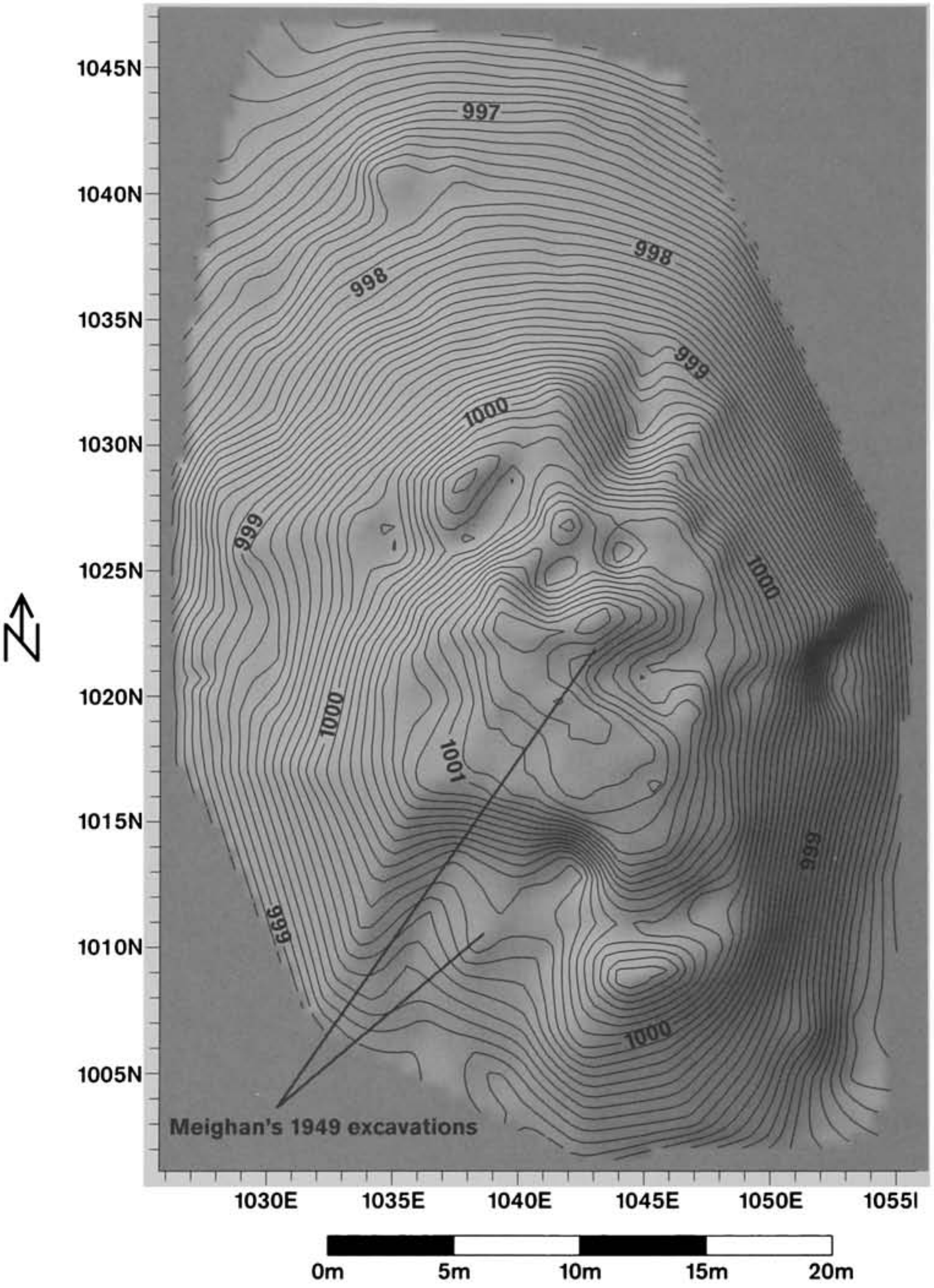

Figure 7. Shaded relief and contour map of MRN-115 showing surface depressions and the remains of Meighan's 1949 excavations.

we hoped to use the plan map to assess general site topography, creek drainages, shell mound subsidence, and other hidden features of the forested landscape.

Post-Depositional Factors

Before mapping could begin, however, it was necessary to assess the multiple cultural and natural transformation processes that might impact our interpretation of the shell mound surface models. In terms of the first mapping goal, most shell mounds are renowned for their complex stratigraphy and long-term records of past human activity. These palimpsests of history have long been the topic of study for understanding regional chronologies, because the stratigraphy of shell mounds can be quite complex, often revealing clear temporal changes in artifact types. One of the more famous shell mounds, the Emeryville shell mound, was 18 meters tall with a diameter of approximately 106 meters (Uhle 1907).

At MRN-115, Meighan (1953:4) believed that a foot of sediment containing artifacts rested on top of the burned remains of the conical bark house. To Meighan, this suggested occupation of the site even after a fire destroyed the house. A notched projectile point and obsidian flakes found on the surface of the three sites also supported use during the mission period. However, late nineteenth century Chinese porcelain fragments associated with a Chinese shrimp camp, the sundry trash attributed to illicit activities of some park goers, and looter's pits also hint at more recent periods of site "use." Understandably, at MRN-115 it is important to be able to distinguish Native American occupations from later activity.

Second, in a novel attempt to help curb the rate of human and natural disturbances to MRN-115, employees of the California Department of Parks and Recreation covered the entire mound in chain-link fencing, which was laid horizontally across the surface of the site. The fencing does appear to prevent looting. However, general weathering combined with the gradual accumulation of tree limbs and leaf litter on top of the fencing have smoothed some surface features, making the boundaries of some house pits less visible to the naked eye. Without the aid of a geophysical survey, we decided that closely spaced readings from an electronic total station could help to clarify the outlines of surface features on MRN-115. The final plan map is also intended as a tool to aid park staff and archaeologists in their efforts to monitor the park's cultural resources.

Third, a suite of natural disturbances can complicate our understanding of site topography at China Camp. In addition to the widespread destruction of shell mounds from urban development (Luby et al. 2006:197–98), shell mounds and loose shell-bearing soils bear the brunt of rodent disturbance, heavy rains, and coastal erosion, which can lead to slumping and possible subsidence. Additionally, at least two tree falls impact the study area. Nelson (1907:186) and Meighan (1953:1) noted a large buckeye tree that once grew out of MRN-115, but this tree has long since collapsed, taking with it a portion of the shell mound. At MRN-328, a similar tree fall gutted a portion of the site and fell on top of one of the more provocative areas of the site: a cluster of shallow depressions believed to be the remains of semi-subterranean house pits.

Data Collection

All three sites are located within a dense forest primarily consisting of California bay laurel, buckeye trees, and poison oak, and are nestled within a small, gradually sloping canyon that serves as the drainage for two creeks. Tree clusters, thick vines, dead branches, and spotty forest lighting hinder clear lines of sight and the possibility of connecting all three shell mounds to a single site datum (Fig. 8). Instead, we decided to establish a primary project datum and multiple subdatums.

Three subdatums were initially staked out from the primary datum at points around MRN-115 in order to map parts of the site and to break up the entire project area into manageable mapping strata. To reduce user error and for ease in setting up the instrument, ideally all of our subdatums would have been placed at coordinates with even integers (e.g., 1002.000 N, 1055.000 E, rather than 1002.154 N, 1055.673 E). Uneven station coordinates increase the chance of operator error and require careful attention when setting up and orienting the EDM at the start of each work day. However, subdatum location was wholly dependent upon clear lines of sight. Because of this, subdatums were placed where a back sight was possible. At times, some smaller tree branches were pushed aside or removed, while total station "trick shots" were often needed to successfully navigate small gaps between trees and branches. After establishing one primary project datum and three subdatums located at points thought to be ideal for mapping all three sites, we then proceeded to map MRN-114 and MRN-115.

Being on a relatively open area with a flat, gentle slope, MRN-114 was mapped with the total station by first laying out a north-south baseline with a measuring tape emanating from subdatum 3. Another tape measure was then placed perpendicular to the north-south baseline and moved at five-meter increments. The stadia rod was then moved systematically along the east-west line at five-meter intervals. The entire site was mapped using this method, while the looter holes and two large buckeye trees were mapped with additional points placed judgmentally for higher resolution.

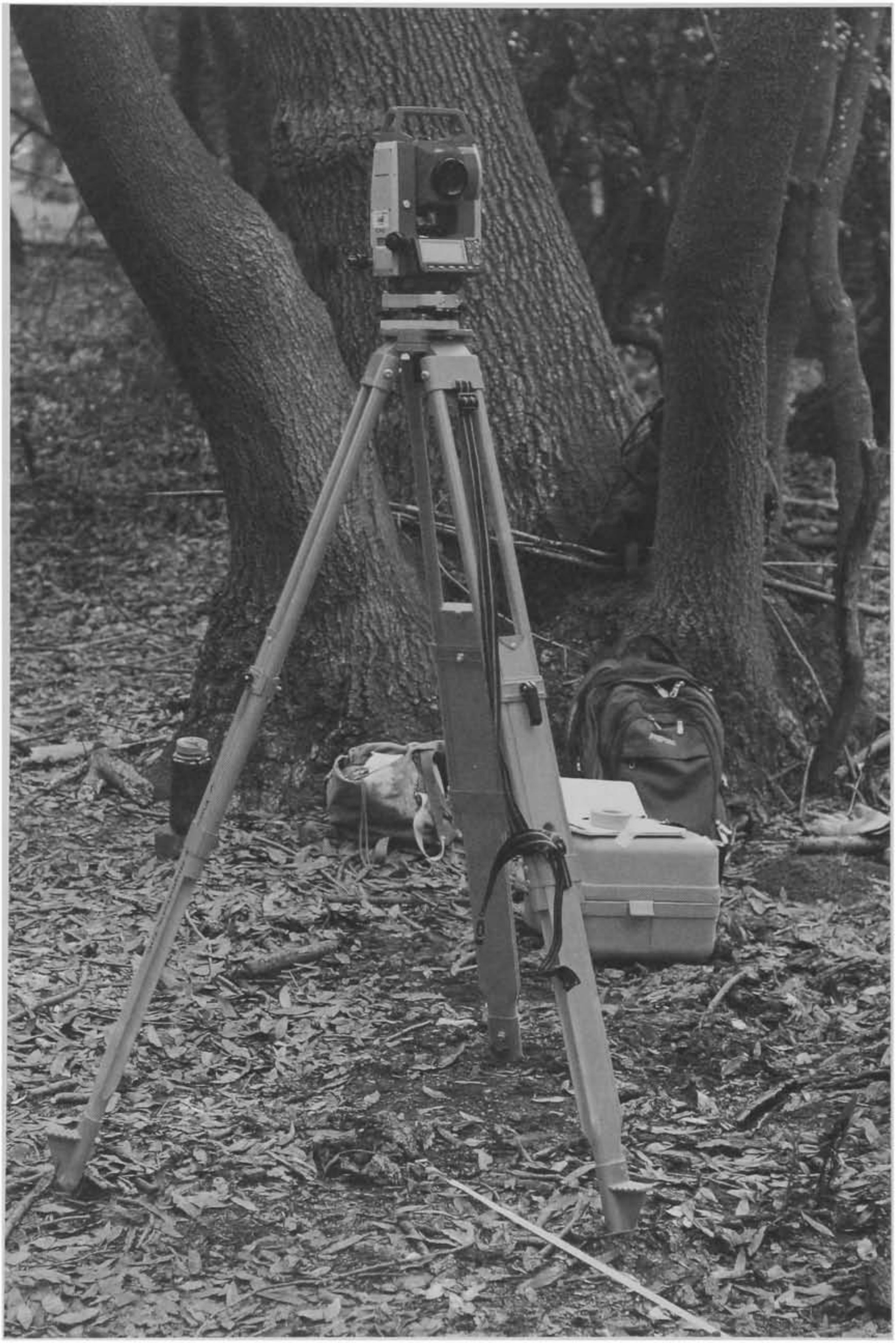

Figure 8. Sokkia SET510 total data station and wooded environment of China Camp State Park (Photograph by Lee M. Panich).

Collecting data between archaeological sites did not follow the method we used for mapping MRN-114. We found that stretching measuring tapes in the forest was a challenging and time-consuming task. Instead, we marked east-west transects every five meters off of a single north-south baseline using a compass and bright orange flagging tape. The flagging tape was used as a guide for the person holding the stadia rod. This person would walk towards the flagging tape, stopping approximately every five meters—and every ten meters in especially flat areas—for the EDM operator to record data. Points along the left side, right side, and bottom of both creeks were recorded at one-half-meter intervals in order to reduce angularity resulting from interpolation in our mapping software.

Using the three subdatums placed around MRN-115, the site could be divided into separate strata and mapped in the same manner as MRN-114. Baselines were extended from each datum and transects were created as before. However, as MRN-115 is a large shell mound approximately five meters tall, we opted not to use flagging tape to mark our transects as it became difficult for the person holding the stadia rod to see over the mound. A third crew member often helped guide the person holding the stadia rod and also removed branches for clear lines of sight.

Data were collected around the base of MRN-115 approximately every five meters, while most points on the sides and top of the mound were spaced every half-meter or meter to more clearly define pit features. Like our strategy for mapping room blocks at Mission Santa Catalina, additional data points were collected from each pit for greater resolution in the final plan map. Some data at the base of MRN-115 could not be recorded from any of the three total station subdatums as some trees were simply too large to negotiate. These missing data from areas behind some trees created tree "shadows" on the original surface map for MRN-115 and prompted the placement of a fourth subdatum closer to the site (Fig. 9).

Similar concerns led us to place three more subdatums closer to MRN-328 in order to collect data around the fallen tree and locate coordinates for subsurface test units. Data from MRN-328 were collected in a similar fashion as at MRN-114, except for a cluster of shallow depressions on top of the site that we recorded using tighter intervals between points. One primary datum, eight subdatums, and 1,936 data points later, our next step was to create a site map.

Creating Digital Maps

After collecting all data, we then set out to produce a digital map of the three sites and their immediate surroundings. As discussed above, we designed the mapping survey of the three shell mounds to accomplish three main goals: to collect digital elevation data that could be used to relocate the sites, to monitor disturbances, and to assess topographic features associated with the three sites.

As discussed earlier, different raster maps can be used to highlight specific natural and cultural components of the shell mound sites. House pits, and even the remains of Clement Meighan's 1949 excavation, are easily identified with the shaded relief map (Fig. 7), and when combined with two-dimensional contour and post maps, the shaded relief map is a powerful tool for archaeologists and park staff to relocate archaeological features and to monitor surface disturbances. A three-dimensional surface map was used to interpret site topography, creek drainages, shell mound subsidence, and other hidden features of the landscape (Fig. 10). A kriging algorithm was used to produce this particular map, and shading, color, and lighting can be adjusted to exaggerate vertical surface features. Unlike the shaded relief map, the surface map can also be rotated three-dimensionally to examine site topography close-up and from multiple angles.

Using the three-dimensional surface map, the two creek beds and the overall change in elevation across the study area lends insight to site formation processes and geomorphology. For example, we can see that the creek that runs along the base of MRN-114 is eroding the site. What is less clear is whether the same creek may have once flowed around the other side of MRN-115, creating the depression visible at the base of the site. This depression around MRN-115 might also be interpreted as subsidence associated with natural weathering and the sheer weight of the shell mound (Nelson 1909:329–330, 1910:364–365; Uhle 1907:11). At MRN-328, we also identified no fewer than three shallow, circular depressions that decrease in size from south to north. While clearly visible on the three-dimensional surface map of MRN-328 alone, the surface features become flattened when the data are combined and interpolated with the data points from all three sites.

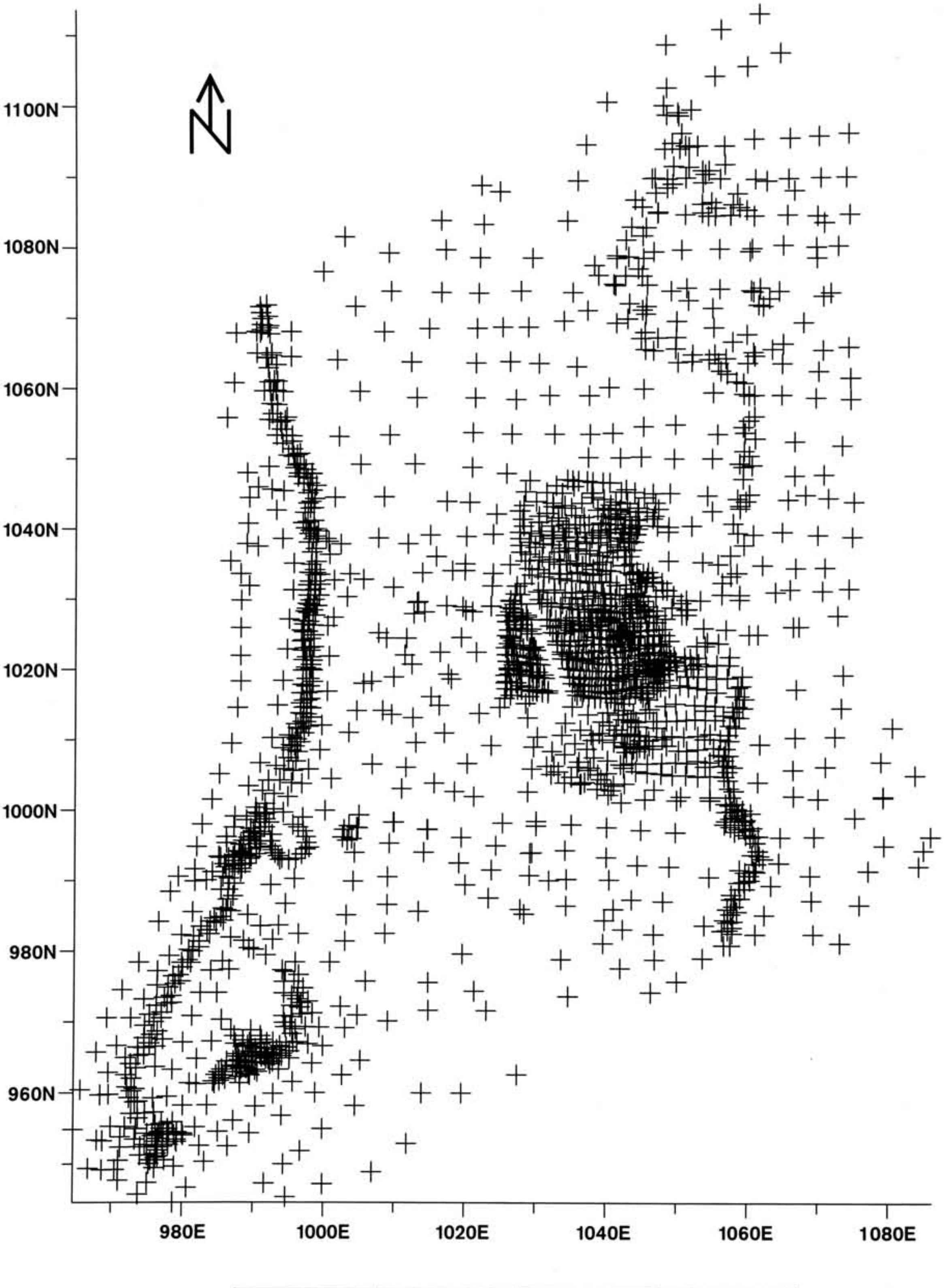

Figure 9. Post map showing all of the points collected for the project site map and tree "shadows" on MRN-115.

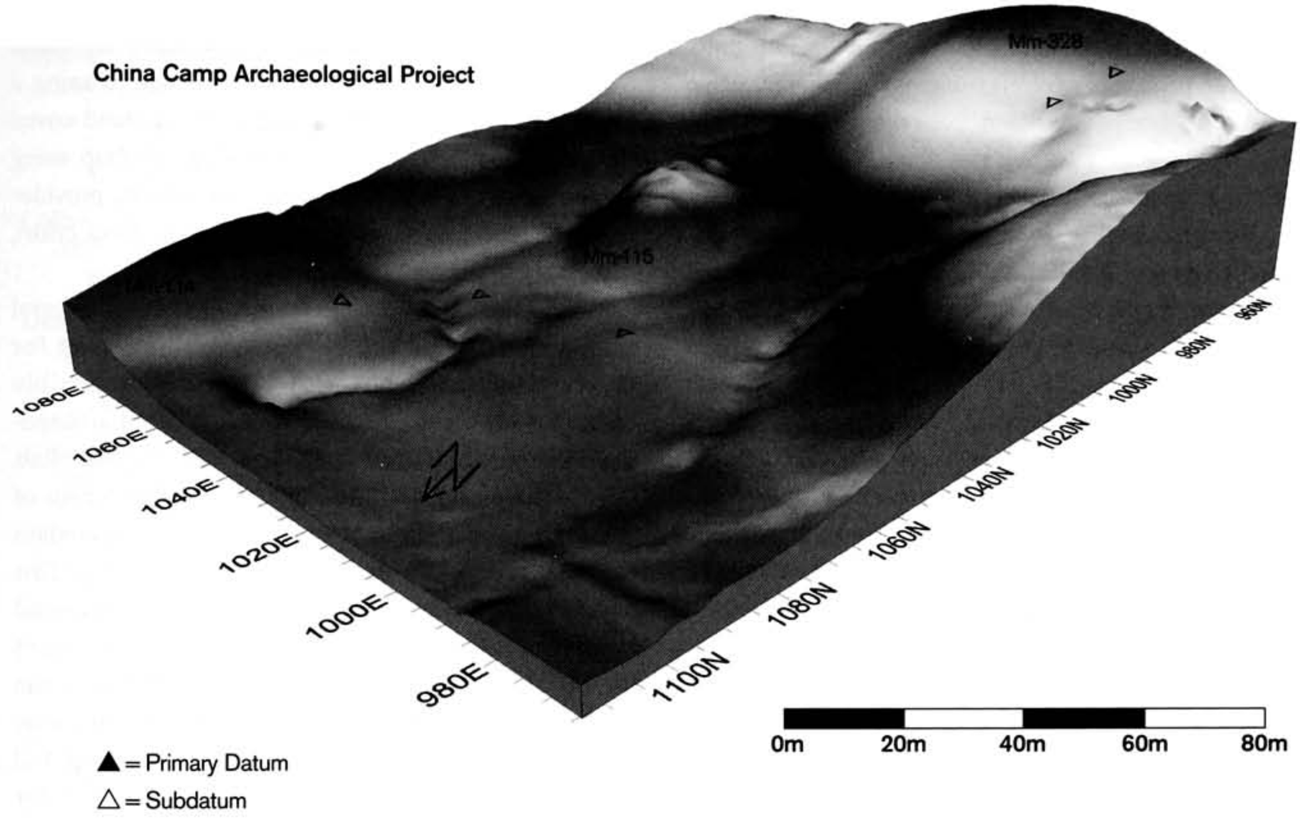

Figure 10. Three-dimensional surface map of project area, including MRN-114, MRN-115, and MRN-328.

DISCUSSION

In the foregoing sections, we have outlined the strategies we employed to collect topographic and other spatial data at sites with two very different natural and cultural environments. In both cases, the physical characteristics of the sites themselves determined how data were collected and used to create maps. At Mission Santa Catalina, the lack of vegetation or significant topographic features enabled us to collect data from across the site quickly and easily using the total station. However, at the same time, some relevant cultural features of the site—deposits, modern roads, and recent archaeological activities—do not have significant, if any, topographic signatures. Accordingly, data from many of these site attributes had to be collected separately from the overall site topography. In the case of the mission architecture, we used a combination of three-dimensional topographic data as well as two-dimensional point plots within the mapping software to more accurately reconstruct the mission's architectural footprint.

The China Camp shell mounds serve as a stark contrast to the desert setting of Mission Santa Catalina. In the dense forest of China Camp State Park, we encountered serious logistical problems in using the total station to collect topographic data from the shell mound sites. Clear lines of sight were rarely encountered, requiring the placement of several subdatums. Nevertheless, the precision of an electronic instrument such as the total station ensures that minimal error is introduced when multiple station coordinates are used.

Through the use of the total station, accurate topographic maps were created of the three shell mound sites that show important features such as looter's holes, previous archaeological excavations, and prehistoric house pits. The resulting raster images offer archaeological insights into the use and post-depositional history of the sites and can additionally be used to share important information about these sites with park officials. As is the case with the map of Mission Santa Catalina, other types of information can also be added to the basic topographic map, including park trails and surface collection units. However, problems were encountered in using mapping software to interpolate points from the area as a whole; small scale features such as the shallow depressions on MRN-328 were obscured by surface smoothing.

We also highly recommend that the X, Y, Z coordinate data for each point be physically recorded in a project notebook in order to protect against the loss of data due to instrument malfunction. Having a hard copy of data points is helpful for spot-checking project worksheets and for determining which points to use for the addition of non-topographic features. Increasingly, however, the advent of more streamlined interfaces between total stations and laptops allows for periodic digital backups and processing of geospatial data in the field (Searcy and Ure 2008:44–45). We also realize that there are a host of available computer programs that can be used to produce archaeological site maps. Our preference for *Surfer* is based largely on price and ease of use, although it should be noted that *Surfer* is well suited to creating topographic maps of discrete areas that do not need to be shown in relationship to larger geographic regions. *Surfer* also works well for sites—such as the China Camp shell mounds—where raster data are of paramount importance.

Like many GIS programs, *Surfer* can also add vector data—in the form of points, lines, and polygons—to an existing raster image such as a contour map. In fact, *Surfer* data are readily incorporated into a powerful landscape archaeology tool kit that pulls from raster data, GIS techniques, and remote sensing to evaluate regional spatial patterns. Our goal, however, is not to advertise a particular software package, as there are several options available; rather we simply hope to further the idea that researchers take seriously the process of creating archaeological site maps. They are one of the most important records of the work we conduct.

The advance of mapping technology employed by archaeologists is rapidly accelerating. Even as we were using a traditional total station to collect data for our maps in Baja California and the San Francisco Bay area, other archaeologists were busy with cutting-edge instruments such as robotic total stations (Kvamme et al. 2006). However, for many archaeologists working in remote areas or with limited field budgets, the electronic total station remains one of the best options for site mapping. This is not to say that it is perfect—the China Camp example demonstrates the downside to using a total station in hilly terrain with dense ground cover (although such a site would be difficult to map using any method)—but the total station, we believe, provides excellent results based on considerations of time, effort, and cost.

The mapping of archaeological sites is an integral aspect of field research. Several methods exist for creating site maps, but with new, easily accessible technology the use of a total station to map archaeological sites is becoming common across the discipline. Yet for many trained to use more traditional means of mapping, employing total stations and their attendant computer programs may appear intimidating. This need not be the case. The two case studies discussed here provide examples of two different strategies for the collection of three-dimensional data from archaeological sites and for using these data to create site maps that can convey information in a clear and concise manner. While the mapping of particular archaeological sites may require some innovation on the part of researchers, using a total station to create site maps follows the same basic principles as earlier methods and can be successfully employed by even the least "tech-savvy" among us.

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