THE TIKAL EARTHWORKS REVISITED

BY

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PREFACE

In 2001 the senior author, after a long detour from his early career focus on Maya fortifications, decided that the most celebrated purported example of such defenses---the great Tikal earthwork---deserved reexamination. The timing was propitious. Two of his colleagues (and former students) had developed skills highly pertinent to such research. Jay Silverstein nurtured a long-standing interest in ancient warfare and had recently completed a dissertation on defensive systems along the Tarascan/Mexica frontier (Silverstein 2000). Timothy Murtha had years of experience mapping natural and cultural landscapes at Caracol, Piedras Negras, and San Lorenzo, and could provide much of the necessary technical expertise (and, as it turned out, the actual equipment). More generally, we understand Maya warfare in ways not even imagined when the earthworks were first discovered in 1967, and our grasp of Tikal's culture history is impressively detailed.

Guatemalan colleagues were extremely encouraging, and in 2001 Webster and Silverstein made a brief field reconnaissance to Tikal, accompanied by Hector Escobedo, Stephen Houston, and Zachary Nelson. This trip was a humbling experience. Our short (and very rainy) foray in search of the north earthwork demonstrated just how elusive this feature was, even when we knew its rough position on our maps. It also helped us to understand why we could find practically no one — at least in the United States – who had seen the earthworks in the last 30 years. All the more reason, we thought, to put our knowledge of this archaeological will-o-the-wisp on firmer ground. We accordingly submitted a proposal titled *A Re-evaluation of the Earthworks at Tikal, Guatemala* to the National Science Foundation in December of 2001. Support was requested for the first of several contemplated field seasons, and funding was provided for 2003 (NSF BCS 02-115). This report provides an extensive overview of our research during that year, including abundant presentation of the spatial data recovered. What we learned and recorded during the 2003 field season more than met our expectations, and sets the stage for future fieldwork.

Our research would have been impossible without the support and skills of our Guatemalan representative and colleague, Lic. Horacio Martinez (Universidad de San Carlos), who along with Irinna Montepeque facilitated administrative and logistical preparations. Martinez also participated in all stages of the fieldwork. Another invaluable participant during the 2003 season

was Kirk Straight, a graduate student newly recruited into our department who was a veteran of many field seasons at Caracol and Palenque.

We are indebted to the Pennsylvania State University and to many officials and individuals of the Instituto de Antropología e Historia de Guatemala and the Parque Tikal who contributed immeasurably to the success of our research. At the end of the season Horacio Ernesto Martinez Herrarte kindly took a series of highly professional photos of the earthwork. Our project also benefited from the suggestions of many old Tikal hands, including Donald Callender, Marshall Becker, T. Patrick Culbert, William Haviland, Chris Jones, Robert Sharer, Robert Fry, and Richard E. W. Adams. Princeton University kindly gave us access to Puleston's archived papers. Hector Escobedo, Stephen Houston, and Zachary Nelson greatly facilitiated our 2001 visit to Tikal. Many people such as Stephen Houston and Gerardo Gutierrez offered helpful comments on our manuscript. Finally, a great debt is owed to our six Guatemalan workmen who performed so effectively under grueling field conditions.

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INTRODUCTION

In 1966 University of Pennsylvania archaeologists discovered a puzzling landscape feature near the huge Maya center of Tikal in northeastern Guatemala (Puleston and Callender 1967). About 4.5 km north of Tikal's Great Plaza was an earthwork consisting of a deep ditch backed by an embankment and spanned by causeways (Fig. 1). The ditch did not follow topographic contours and so seemed to be a human construction. Dennis Puleston and Donald Callender made a pace-and-compass map tracing the earthworks for a distance of 9.5 km before losing each end in large logwood swamps, or *bajos*. Shortly thereafter, in 1967, they also recorded a short section of a similar feature to the southeast of Tikal near the satellite site of Ramonal. Archaeologists later assumed that this Ramonal ditch turned west and paralleled the northern earthwork (Fig. 2). Tikal thus appeared to be delimited on the north and the south by earthworks, and on the east and west by *bajos*, creating a vast enclosure variously estimated at 120 or 167 sq km (Puleston 1983; Culbert et al. 1990; Haviland 2003). Limited test excavations (Fig. 3) showed that a segment of the northern ditch was originally about 3.53 m wide and 3.12 m deep, confirmed that the earthworks were indeed made by the Maya, and suggested that the many gaps, especially where the ditch passed through low areas, were caused by later infilling by erosion. Because these excavations produced few chronologically sensitive artifacts, archaeologists could only surmise that the earthworks were probably built between about A.D. 250-750, with an Early Classic date before A.D. 550 most probable (a more complete and current review of chronology is given below).

The earthworks excited much interest because of their scale, and because they constituted a very rare "emic" boundary that revealed what part of the landscape was important to the ancient builders. Archaeologists had long been frustrated by the dispersed spatial pattern of dwellings and other structures that typically radiated outward from major sites like Tikal. Because big centers are often quite close to one another, especially in the northeastern Petén, it is difficult to determine the extent of their territories and the larger geopolitical relations among them. The earthworks have accordingly loomed large in reconstructions of Tikal's demography, political organization, and culture history. In fact, they have become essential components of site and even "urban" definition. As Culbert and his colleagues noted in an overview of Tikal's demography, "An area of 120 sq km is defined by the combination of lower-structure density, earthworks, and *bajo*.... This is what we consider the site of Tikal" (Culbert et al. 1990: 115). More recently, "The *city's* limits were marked to the north and the

south by the presence of two defensive trenches or moats during the Early Classic (Valdes and Fahsen 2004: 156; emphasis ours).[1]

During the 1960s many archaeologists still believed that the Classic Maya lacked intense forms of warfare. Puleston's and Callender's contention that the earthworks were fortifications was an early challenge to this "peaceful Maya" perspective.[2] They assumed that Uaxactun, an impressive neighboring center to the north, was the main enemy of Tikal, and that the earthworks were used in local wars between the two polities. The defenses, moreover, were clearly designed as protection against conflicts more serious than mere ritual raids for sacrificial victims. Many archaeologists accepted the fortification idea, including Webster, whose subsequent excavations of the earthworks at Becan were stimulated by the Tikal discoveries (Webster 1976).[3] The importance of the earthworks notwithstanding, they have since been virtually ignored, gradually assuming the character of a sort of archaeological "elephants' burial ground"---often cited but seldom visited.

In 2001 we decided that the earthworks deserved reexamination. They had never been adequately mapped, and the Ramonal segment was practically unknown (although see Ford 1986 for a brief reconnaissance). Mapping technology has matured remarkably since the original field research was completed, and we reasoned that if our GPS equipment could receive signals under the forest canopy we could track the feature with centimeter accuracy. Today there are also new interpretive possibilities. Some archaeologists believe that the ancient Maya engineered their landscapes to control water, and that elites managed hydraulic resources (e.g., Scarborough 1996, 2003). Might the earthworks be canals or drainage features? And now that Maya texts can be effectively understood, we have a fine-grained culture history for Tikal and her neighbors, much of which has to do with war. During the sixth and seventh centuries the Maya Lowlands were convulsed by great geopolitical struggles

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[1] Discussions of exactly what the earthworks delineate and Tikal's population estimates are often muddled and inconsistent. For example, Valdes and Fashen (2004:156) first describe the "city", with a population of 62,000, as limited by the earthworks, and then go on to extend the diameter of the "urban center" to a 10 km radius, with 90,000 inhabitants.

[2] They speculated about other ancillary functions as well, such as regulation of commerce.

[3] About the same time Baudez and Bequelin (1973) described another set of large-scale earthworks at Los Narajanos, Honduras. At least parts of this system appear to be quite early, but the earthworks have received little study and exactly how they were used remains unknown.

(Martin and Grube 1995, 2000). Chief among the antagonists were Tikal and her perennial enemy Calakmul, each abetted by allies or proxies. It might be possible to link the fortifications, if such they were, to specific military events. Finally, while we have today a much more refined understanding of the political organization internal to Maya polities than available to Puleston and Callender, there is still considerable debate concerning the physical boundaries (if any) of specific kingdoms (Culbert 1991; Chase and Chase 1998). Better documentation of the Tikal earthworks promises to help clarify such issues.

FIELD RESEARCH IN 2003

Following a short field reconnaissance in 2001, we returned to Tikal in 2003 for the preliminary phase of a larger project (Estudios de las Fortalezas Arqueologicas de Tikal, or EFAT). Our Penn State University research was funded by National Science Foundation grant BCS 02-11579 (*Re-evaluation of the Earthworks at Tikal, Guatemala*). Fieldwork was completed between March 17, 2003 and June 2, 2003.[4] It was designed as the first stage of a larger project and had five main purposes:

(1) To locate and map, using modern technology, those sections of the northern Tikal earthwork (Fig. 1) recorded by personnel of the University of Pennsylvania in the mid-1960s (Puleston and Callender 1967);
(2) To determine whether other segments of the earthworks exist---particularly that said to extend southwest from the outlying site of Ramonal that lies to the southeast of Tikal's epicenter---and to map these if possible;
(3) To assess whether re-mapping confirms the interpretation that the earthworks functioned as a defensive system;
(4) To locate and map settlement features lying within 50 m of the inner and outer edges of the earthworks, and
(5) To determine which segments of the earthworks might in the future yield the best artifact samples or other data that would inform us about the chronology of construction and the functions of the earthwork.

[4] EFAT is the acronym for the project as submitted to the Guatemalan IDAEH. It stands for Estudios de las Fortalezas Arquelogicas de Tikal, and this label appears on many of the associated images.

Our proposal explicitly omitted any test excavations or collections of artifacts or soils during the 2003 season in order to facilitate mapping, to simplify the conditions of the initial permit, and to defer the expenses of laboratory work and artifact curation. Webster's (1976) experience with the Becan earthworks showed that excavations can only be effectively planned once construction details have been adequately mapped.

Scheduling, Personnel, and Logistics

Fieldwork was initially scheduled for one two-month season during January and February of 2003, the coolest time of the year. Other professional commitments of Jay Silverstein (project co-PI) and Timothy Murtha (chief project mapper) necessitated rescheduling of fieldwork, which was accomplished in two sessions between March 17--April 27, and May 18 -- June 2. Prior to the beginning of fieldwork all necessary permits and permissions were obtained through the efforts of Lic. Horacio Martinez, our attached Guatemalan representative, who along with Irinna Montepeque also made many of the logistical arrangements necessary for the success of the project. Martinez also took an extremely active role in all phases of fieldwork

In addition to the primary field crew of Silverstein, Murtha, and Martinez, we recruited Kirk Straight, a graduate student at Penn State University with considerable previous mapping experience at Palenque. The presence of an extra mapper proved extremely fortunate. Not only were logistics difficult and time-consuming (as we expected), but the earthwork proved to be much longer than anticipated. Straight's participation also allowed us to expand the width of our northern settlement survey corridor, as explained below. Webster as principal investigator was in overall charge of the project and made a short trip to Tikal in late April to view all the sections mapped to that point. Actual fieldwork operations, however, were entirely carried out by Silverstein, Murtha, Martinez, and Straight, aided by a crew of six Guatemalan workmen. Prof. Richard Terry, a soils scientist from BYU University who has recently worked at several Maya centers including Piedras Negras and Aguateca, briefly visited the earthwork in early June.

General Mapping Procedures

Access even to the closest segments of the known earthwork was, as anticipated, difficult except where it crosses the Uaxactun road. During our 2001 reconnaissance we found the North Transect (cut in the 1960s to delimit the park,

and used by Puleston as a main arm of his cruciform settlement survey) to be heavily overgrown (Fig. 1). Fortunately, by 2003 park personnel had cleared the north *brecha* as a fire road, and with a little more work we were able to drive the project vehicle about 2 km along it, thus eliminating considerable walking time. Once GPS positions of the northern ditch segments were obtained, we were also able to cut a direct path to the northeastern part of the earthworks. A major concern was whether we could acquire GPS fixes under the tropical forest canopy. Fortunately our equipment worked very well, enabling rapid and accurate mapping not only of the earthwork itself, but also of settlement in the adjacent survey corridor.

We intensively mapped the northern earthwork and also reconnoitered segments of the feature to the west and southeast of central Tikal. We used a variety of equipment and field mapping methods as discussed below:

Software:

- ArcGIS 8.3.
- ArcPad 5.0.1.
- ArcGIS extensions: Spatial Analyst and 3D Analyst.
- Ashtech Solutions.
- ExpertGPS 2.0.
- Foresight 2.21.
- Survey Link 7.1.
- AutoCAD.
- Garmin Mapsource 3.02.

Equipment:

- Thales Navigation/Ashtech – ProMark2 GPS surveying system with kinematics capabilities.
- Topcon GTS 210 – Total Station.
- Magellan SportTrak Pro – Handheld GPS.
- Garmin GPS III plus handheld GPS.

Base Datums and Reference to True North: We established known base datums for the survey using the precision GPS ProMark2 survey system. Two existing base points were chosen from those shown on the Tikal site map near the northern end of the Maler Causeway and preserved on cement monuments in the epicenter -- BM44 and Group P (see Fig. 4). From these established monuments we acquired five fixed points that served as our local base stations

for all subsequent mapping (see Fig 5). These points also provided us with a reference to true north.

Base station points were established and numbered sequentially as follows:

0001: Intersection of the Uaxactun road and the North Transect, roughly 14 m north of the road's centerline.
0002: Intersection of the North Transect and the ditch, roughly 20 m sout of the ditch.
0003: Intersection of the ditch and the Uaxactun road, roughly 300 m south of the ditch along the eastern edge of the road.
0004: roughly 50 m north of 0002 along the North Transect.
0005: roughly 50 m south of 0002 along the North Transect.

We used a 'static survey' method in order to ensure the highest accuracy when establishing the known points. The points were triangulated using the ProMark2 and each point was acquired for a minimum of twenty minutes. [5] Afte processing, Ashtech Solutions reported a <5 mm horizontal and vertical softwar accuracy for all five points, and equipment accuracy is within 5 cm. These firml anchored points subsequently served as our base stations for ground survey of the earthwork and settlement north of central Tikal. As this ground survey of th feature progressed, fifteen additional fixed points were added to this list at convenient locations along the earthwork. These points were used as an independent test of survey accuracy. Using the GPS we were able to triangulate our traverse without completing a second loop (see triangulation below). Survey of this kind results in a large number of data points. When using the GPS for 'static' survey, a point is acquired by each unit every three seconds. A 20-minute survey thus results in a total of 400 data points for each unit or an overall total of 800 points for both. After processing, we estimate that we collected over 15,000 data points while mapping the earthworks, using both the Topcon GTS 210 and Ashtech Precision GPS.

Triangulation of the Data: Placement of earthwork and settlement features in their proper spatial contexts was critical to our project goals from the very beginning, so accuracy was an important concern. Typically, for a feature as long

[5] Triangulating GPS points is similar to traditional survey. Each point is typically occupied twice by each machine for a minimum of 20 overlapping minutes. A total occupied time of more than 40 minutes is thus acquired for each base point.

as the northern earthwork (> 12 km), one would have to run two independent ground survey loops totaling more than double the length of the single survey line (> 24 km). Fortunately the precision GPS system provided us with a rapid and dynamic accuracy check. As the earthwork was mapped, end points on the survey and a handful of additional points were tied in using the 'static survey' method discussed above. In total, more than 15 tie-in points were surveyed for accuracy. Without adjustment, all tie-in points reported a < 20 cm error range . With adjustment, the estimated error was reduced to less than 10 cm.

Ground Survey of the Northern Earthwork

After our base station points had been established we initiated ground survey. All points were recorded using a reference to true north (i.e., tied into local UTM coordinates).[6] During this first phase of the survey we divided the team into two units. One was dedicated to finding the earthwork, cutting a trail along it, marking the trail with survey tape, and recording its bearing on a handheld Garmin GPS. The second unit followed up and mapped the feature using the Topcon Total Station and the Promark 2 GPS surveying system.

Once the initial point of intersection of the earthwork and the North Transect was located, the exploration team began by following the earthwork to the west (i.e., toward the Uaxactun road). Whenever the exploration team encountered a gap where the feature was no long visible, they estimated the bearing of the missing section by extrapolating from the bearing of the known portion of the earthwork already mapped behind them, and then searched in a zigzag pattern until the feature was encountered again. The lead team then backtracked, cutting and marking a trail so that the mapping team could follow up and make the connection with the newly discovered sections of the earthwork. This procedure was used during the investigation of the entire northern earthwork. A similar method was used during the settlement survey phase of the research. One mapping team was dedicated to finding and marking sites, while the second team followed along and mapped each of them.

We used a standardized data collection notation so that all points were coded for context (*i.e.*, their relationship to the earthwork). As a general rule, transit stations were set up every 35 – 40 m (on average) where a full cross section of the earthwork was recorded. Between each base station we established

[6] True north was acquired once the GPS points were processed.

a number of other points, including centerline measurements every 10-15 m. also recorded a variety of additional points between the base stations because were interested in documenting all changes in the local character of the earthwork. We began the survey at the North Transect by mapping west for tv days, during which time we recorded more than 1 km of the feature. Next we followed the earthwork east from the North Transect to the furthest point originally reached by Puleston, a distance of roughly 4.5 km. We then resume work west of the North Transect.

THE NORTHERN EARTHWORK AND ITS ASSOCIATED SETTLEMENT

We located and remapped the entire 9.5 km segment of the earthwork originally reported by Puleston and Callender.[7] On the east our map stops jus about where theirs did (Fig. 6). It turned out, however, that Puleston had underestimated the length of the northern earthwork because he did not follov far enough to the west. Our new map shows that it is roughly 12.8 km long (counting its numerous gaps), extending some 3.5 km farther than he believed. Its western end does not simply terminate in a *bajo*, but instead reappears on tl other side and bifurcates just before reaching the higher ground that runs up toward Uaxactun. At this point one short section turns north and runs into a small *aguada*, locally called the Aguada El Duende, and a slightly longer one turns to the south.[8] This latter section suggested that a western earthwork mig exist, and as we shall see shortly this turned out to be the case.

Early on we found Puleston's old trenches, which he had never backfill They are in remarkably good condition after almost 40 years of exposure, and during future seasons we hope to reopen and extend them to verify and expan his original artifact sample.

Puleston and Callender discussed and illustrated details of only very sh segments of the earthwork. Our own more precise mapping of the northern segment reveals a pattern of considerable variability among its several components (Fig. 7 shows a section of the ditch as a contour map). The most

[7] While the figure of 9.5 km is often given in the literature as the length of the northern earthwork, in fact this was an extrapolation from shorter mapped sections interrupted by gaps

[8] This little water source is shown on some park maps; our workmen knew that it was sometir used by *chicleros* and looters.

persistently identifiable component is the ditch, which in most places appears to have a fairly uniform width of 4-6 m (Fig. 8). The inner embankment is sometimes very pronounced, running along the inner edge of the ditch for as much as 1 km. Elsewhere it is very faint or even disappears over considerable distances (Fig. 9). Puleston and Callender's description of this feature as "continuous" is thus somewhat deceiving.

Many parts of the ditch are fortunately well-preserved and are still several meters deep even after centuries of infilling. Some of these sections resemble the profile illustrated by Puleston and Callender. Where the bedrock is still visible (Fig. 10), what appear to be tool marks can still be seen on the comparatively flat, vertical faces of the cut limestone, which is quite soft.[9] Even the comparatively hard capstone can be easily cut with a knife, and the underlying marl layer (*sascab*) has the familiar plaster-like consistency so often found in such deposits in the Maya Lowlands. Basically the problem facing the builders of the ditch was to cut through a layer of surface limestone a meter or so thick. They then struck the *sascab* that rendered digging much easier. Although many segments of the ditch walls appear to be purposefully undercut as shown in Fig. 10, a more probable explanation is that the softer *sascab* underlying the capstone simply has weathered more rapidly. In many places large slabs of stone have broken off from the original sides and slumped toward the center of the ditch, possibly as a result of such undercutting. Slumping probably makes the ditch often look somewhat wider than the section excavated by Puleston and Callender, which measures about 3.53 m. Figure 11 illustrates some representative cross-sections of the northern earthwork.

Ditch segments are usually pronounced on slopes or high ground and less obtrusive in low areas. For long stretches the ditch takes the form of a barely visible, low swale, with no associated inner embankment. In such areas it is impossible to determine from surface inspection how deep it originally was. In very low terrain or *bajos* the ditch sometimes disappears altogether----in one zone near the west end for a distance of as much as 800 m (this is where Puleston thought it ended). It remains to be seen whether there were formal constructions in such places.

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[9] We are not absolutely certain about the tool marks, which appear as long vertical striations. Silverstein thinks they might alternatively have been caused by water dripping or running over the face of the stone. Most probably they are groves made by tools that were then eroded by water naturally channeled along them during heavy rains.

Puleston and Callender identified four basic components of the northern earthwork (Figs. 2, 12, 13): 1) the ditch; (2) the inner embankment; 3) artificial earthen causeways that extended across the ditch, and 4) gaps in the embankment that were apparently purposefully made. It is unclear from their presentation exactly how many of the latter two construction components they found. In the short time available to them, Puleston and Callender excavated into one artificial causeway and also trenched the ditch and embankment. The causeway, it turned out, had been inserted into the ditch at some time after it was dug, because about 0.75 m of soil had accumulated on its floor before the later causeway fill was laid down in two separate stages. The causeway in its last stage was a narrow, rubble-capped passage only about 1-2 m wide at the top. After it was used for some time a much wider section of the ditch was filled in, burying the narrower old causeway.

Webster later mapped and explored the same basic components at the Becan defenses, which were, however, significantly different in some respects. First, Becan's ditch is much deeper, wider, and more continuous, and its inner embankment is correspondingly more massive and more obvious for most of the 1.8 km length of the earthworks. Second, the causeways at Becan are not artificial, but consist instead of natural bridges of bedrock left in place when the associated ditch segments were dug.[10] The builders of the Tikal earthworks seem never to have left such natural bridges. Third, there is always an artificial gap in the embankment at the inner end of each Becan causeway that allows direct access to the site. Causeways and gaps, in other words, are functionally and hence spatially related features. And because of the scale of all these components, there was absolutely no difficulty in detecting them. Few habitation sites or other structures encroach directly on the Becan ditch as they do at Tikal's.[11] And finally, the biggest difference is that Becan's fortifications were designed to protect a very small area---essentially the regal-ritual apparatu of the polity, along with its associated elite residences. If the Tikal earthwork is fortification, it had very different strategic purposes.

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[10] More accurately, the Becan causeways as *originally designed* were natural stone bridges. Later some of them were partly cut, probably in a military emergency, and then repaired with artificia materials.

[11] Because the Becan ditch turned out to be of Late Preclassic date, the visible architecture, most which is much later, was necessarily designed to conform to the ditch layout.

The Tikal situation is somewhat different both with regard to the presence or location of these components and our ability to detect them. Even where the ditch is obvious it is so much narrower than Becan's that recognizing artificial earthen causeways is difficult. Breakdown from the ditch sides, tree-fall, and silting all create accumulations that can look like causeways, but probably are not. In places where groups or individual buildings are close to the ditch, it is also possible that refuse disposal or structure collapse has created such accumulations. Because the Tikal embankment is so much smaller and less continuous than Becan's, it is also hard to decide whether low areas are really purposeful gaps, rather than products of erosion or tree-fall, or even later cultural modifications, such as mining for construction fill, etc. The situation is complicated by the fact that at Tikal there is no necessary connection between the positions of artificial gaps in the embankment and earthen causeways. The ditch is so narrow that it could easily have been bridged by perishable log constructions. In fact, if the main purpose of the earthworks was defense, such bridges would have been tactically very sensible because they could be quickly erected and just as quickly removed. The many places where recently fallen trees span deep sections of the ditch (and can be used to cross it today) show how feasible such perishable structures would have been (see Fig. 14).

Bearing all these complications in mind, we did identify three fairly wide breaks and one narrower one in the northern embankment that might have served as access points for crossing the earthworks. The three breaks are about 10 m wide and their locations are shown in Fig. 15. Two of them, labeled A and B in Fig. 15, are associated with what appear to be filled-in sections of the ditch that possibly represent causeways. Point C is more problematical because the break in the embankment here seems to be more associated with drainage, and is not necessarily accompanied by a raised platform/causeway. Point D indicates the narrow break, which is roughly 2 m wide. The ditch appears to be filled in at three additional locations along the northern earthwork, and each of these sections could conceivably have provided access (Fig. 16). The other three sections appear less formally constructed, however, and are found near or adjacent to plaza groups. At this point, we can only speculate that these are less formal 'bridges' associated with later occupations that required local crossing facilities. It is also quite possible that these "filled-in" portions result from natural processes of debris accumulation and/or dumping of cultural material.

Not every break in the embankment or ditch is definitively associated with a causeway or point of access. The differential preservation of the ditch is a factor that must be critically evaluated. That said, we are confident that there are

at least two locations (in addition to that excavated by Puleston) where a causeway existed on the northern earthwork.

Puleston and Callender found many places where the ditch disappeared, particularly in low spots. They sank a deep trench into one such gap, but its walls unfortunately collapsed before the stratigraphy could be recorded and studied carefully. They nevertheless concluded that the ditch was continuous and that the apparent gap was produced by later erosion or other infilling. We also believe that some sort of continuous feature ran across the gaps, but for two different reasons. First, ditch construction seems to be quite uniform over long distances, and is essentially the same on either side of the gaps. Second, as already noted above, wherever a gap occurred a compass bearing from a known section to the rear always directed us to a continuation of the ditch just about where we would expect it.

We now have accurate vertical fixes for the northern earthwork. Various ditch segments may be as low as about 245 m asl or as high as 308 m asl. Elevation generally increases toward the west as the earthwork approaches the high, hilly topography stretching north toward Uaxactun. As Puleston and Callender observed, the line of the ditch does not conform coherently to the natural contours of the landscape, nor are changes in elevation necessarily gradual. In many places the ditch elevation rises or falls significantly over horizontal distances of 100 m or even less (Fig. 17). The western earthwork shows a similar pattern, although there is, especially on its northwest end, a long downhill run (Fig. 18).[12]

Functions of the Northern Earthwork

Any ancient feature interpreted as an ostensible fortification must meet several criteria. Its original form must have presented a reasonable physical obstacle at any particular point to attackers, given the weaponry, organization, and tactics of the times. Its overall design must also have rendered it strategically defensible, given these same factors. No doubt there were many poorly designed defensive systems in the ancient world, and others that were not in any sense formally designed at all---the ramshackle defenses thrown up in and

[12] No direct topographic information exists for the gap shown between the two sections of the western earthwork in Fig. 6. Vertical variation for the approximately two km long section shown in dashed lines in Fig. 18 comes from the local contour map, not GPS readings.

around the Maya centers of Dos Pilas and Aguateca are probably cases in point. The Tikal earthworks certainly represent formal design and, given their scale, something other than desperate emergency constructions. Deciding whether the earthworks in fact represent a defensive system, given all these considerations, is not straightforward. In some respects they do not conform to our expectations, and of course we cannot observe or as yet reconstruct all of their original features. Nor do we adequately understand how the Maya organized themselves for war.

One's impressions of the possible functions of the visible portions of the northern earthwork depend on exactly where one stands. Long stretches are consistent with the defensive role championed by Puleston and Callender: a deep ditch is backed by an embankment on the inner (south) side, and these elements are found on high ground or associated with a north-facing slope. Elsewhere the same construction elements are visible, but are situated in topographically inappropriate positions that would provide attackers coming from the north with a tactical advantage (Fig. 19). Still other segments of the ditch look like shallow channels or canals, and they lack an inner embankment. As indicated above, however, such sections would usually provide only short drainage runs. That visible sections of the embankment are always on the inner side of the ditch is consistent with a defensive function; in the case of a canal or drain the location of the spoil pile would presumably have been irrelevant.

Topographic irregularity has important implications for drainage, and water control has recently emerged as an issue in reconstructions of Maya political ecology (Scarborough 1996, 2003). While there seems little doubt that the Classic Maya, at Tikal and elsewhere, sometimes devised elaborate water catchment and drainage systems, there is a real danger of over-generalizing this pattern by extending it to any canal-like feature or depression. For example, Scarborough (2003: 80-81) implies that patterns of drainage associated with the Becan ditch and embankment, along with levels of regional rainfall, indicate a hydraulic function. Unfortunately he does not tell us how such a system could have worked, given its distinctive configuration, nor why Webster, who trenched the ditch to natural sascab in many places (and certainly had a hydraulic possibility in mind, given the fact that Becan means, quite inappropriately as it turns out, *"ditch or canyon created by water"* in Maya), failed to find deposits or stratigraphy consistent with standing or flowing water. That water drained into the Becan ditch is clear---how could it not? That the ditch was excavated to catch, hold, or channel water, however, is extremely unlikely and unsupported by any evidence currently available. During much of the year the inhabitants of

the Becan epicenter could have obtained water from a shallow *bajo* to the west of the site, and from an *aguada* within the earthworks, both perched above the base level of the ditch.

Seen in longitudinal cross-section, Tikal's northern ditch has such a jagged configuration that it creates many local micro-drainage patterns.[13] Obviously any ditch-like feature in an environment with almost 1800 mm of annual rainfall will catch and drain runoff, just as do the many natural *arroyos* in the vicinity that look so deceptively similar to the artificial ditch. A lively debate developed among the field staff concerning the alternative functions of drainage and defense. Some sections of the ditch certainly channeled water into low spots, although whether they were designed to do so remains unclear. Just as clearly the northern ditch never functioned as any kind of "moat" as Valdes and Fahsen label it. Only the short arm of the bifurcation at the west end of the north earthwork that debouches into the Aguada El Duende seems presently to be some kind of intentional drainage feature (Fig. 20). Murtha thinks this segment is ideally positioned to drain water from the surrounding low-lying land into the *aguada*, and speculates that it might be a late addition to the main earthworks.

Settlement Survey Adjacent to the North Earthwork

Critical to our eventual understanding of the earthwork is how the ancient Maya used the nearby landscape, especially for residential purposes, and how associated settlement might help us date its construction. Puleston's North Transect ran perpendicular to the ditch, so he only surveyed a narrow 500 m wide segment of settlement at the intersection. He accordingly recorded just a few sites in close proximity to the proposed defenses, and these might not be at all representative of the larger distribution. Obviously it was desirable to greatly enlarge this sample by examining a continuous strip of settlement along the whole length of the northern earthwork.

Our original goal was to locate and record all sites visible on the surface within 50 m of either side of the northern earthwork. Not only would this survey provide a new settlement sample for the Tikal near periphery, but it would also allow us to assess the accuracy of the extrapolations made by Puleston and other Tikal researchers based on the old transect surveys. Because the GPS and mapping equipment worked so efficiently, Silverstein and Murtha decided to

[13] The vertical variation shown in Fig. 17 charts the outer (north) edge of the ditch.

expand the survey corridor to 125 m on either side. The northern earthwork thus served as an east-west survey line for a transect measuring 250 m in width. The survey was completed for the entire documented length of the earthwork (12.8 km), or a total area of about 3 sq km (Fig. 21). Puleston originally finished a survey along his northern transect line that was 12 km long and 0.50 km wide. Our new survey covers an area equivalent to roughly 50% of his, counting a little overlap where the two intersect.

The survey was carried out using two different search strategies. Along most of the length of the earthwork to the east of the North Transect we cut *brechas* 125 m long perpendicular to the line of the feature every 100-150 m. Reconnaissance teams of at least five individuals then walked at evenly spaced intervals between the *brechas*. West of the transect most reconnaissance was carried out by teams of 5-6 workmen evenly spaced in a line 125 m long and perpendicular to the ditch. These workmen scoured the terrain, anchored on one end by a guide walking along the ditch. Our survey primarily recorded mound groups, as well as other incidental cultural features such as *chultunes* and *aguadas*.

Every observable feature encountered was cleared, tagged, and prepared for survey and mapping. Field map notation or a GPS point was taken to ensure coverage of all features. Each flagged feature was evaluated and recorded using two different methods. The vast majority (90%) of the settlement features were surveyed using the Topcon GTS 210 total station. True north angle measurements were used throughout the settlement survey, with all compass bearings immediately adjusted for true north by adding 4.30 degrees. All data were recorded in three dimensions.

Once identified, groups were cleared and sketched by Murtha or Straight, and were tied into the overall map using stakes established for the earthwork survey. This procedure allowed us to carry our reference to true north to each group. Once a site was tied into the overall earthwork map, center stakes were established within the group from which additional data points were acquired for each structure or other feature encountered. At least three basal and summit points were acquired for each regularly shaped structure, and more points were acquired for more complicated features or structures. Data points were transformed into line drawings by using the standard Maya (Maler) conventions, except that the line drawings do not necessarily illustrate absolute elevations of structures or features. Such information is available in three-dimensional form and need not be directly represented on the site maps.

A small subset of sites was mapped using the ProMark 2 GPS system and a Brunton compass set on a tripod. As in the first method, each group or feature was accurately positioned using a static survey technique. Each was sketched, and bearings and measurements were taken using a compass and tape (these data primarily served as a check for the GPS data, whose accuracy was not immediately available in the field). The ProMark 2 was then set up in the group and we used a 'stop and go' method to establish the corners of features in the same fashion as with the total station. While the first of the two methods is the more efficient, each provided us with extremely accurate settlement maps.

Enlargement of the survey corridor width from 100 to 250 m captured a larger sample of peripheral settlement than originally proposed. Detailed maps of 39 mound groups with 159 structures were made using the total station.[14] Fig. 22 shows the distribution of these groups, which are listed by provisional site field number and UTM coordinates in Table 2. Miscellaneous *chultunes* and *aguadas* were also recorded. There is some overlap at the intersection between our survey corridor and Puleston's north survey transect. The imposing Group 1 (our field number), located right on the line of the ditch, corresponds to his Group NW (N) 185-194.[15] The Settlement Atlas section (Appendixes 1 and 2 at the end of this report) provides separate maps of each group found near the earthwork, and elevation data for them.

Settlement density along our northern survey corridor averages 13 mound groups and about 53 structures per sq km. Such figures are somewhat higher than observed during earlier surveys of Tikal's near periphery. Those sections of Puleston's radial survey zone located beyond the earthworks and *bajos* have an estimated density of 39 structures per sq km (Culbert et al. 1990:116)

The 39 groups we identified are generally similar in form and distribution to those mapped by Carr and Hazard (1961) in the more distant quadrats of the 16 sq km Tikal epicenter map (Fig. 23 illustrates the range of groups encountered). Most of them consist of three to five structures arranged around a single plaza, although at least one is a single mound site. About 13 of the smaller

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[14] As a useful point of comparison, recent settlement surveys by Webster's students of a zone of comparable size---3 sq km--around the peripheries of Piedras Negras, Guatemala, recorded 89 sites with 254 structures. This survey zone was, however, generally closer to the Piedras Negras epicenter than the earthwork zone is to Tikal's.

[15] See Puleston 1983: 8 for the rather cumbersome numbering system used in the original survey.

groups appear to be associated with little residential terraces that leveled the local hillside terrain. Four groups (1, 32, 34, 45) were significantly larger, with eight or more structures and sometimes multiple plazas. Such variation is consistent with that reported by Puleston (1983) and Ford (1986) for peripheral areas of Tikal, and also with the scale of labor investment reported by Arnold and Ford (1980). Some groups are isolated from their neighbors, while others appear in little clusters (e.g., Groups 48-50).

We have not quantified our new settlement data in detail, but it appears that most groups are located on moderate to high ground, with comparatively few on hill slopes or in *bajo* locales. While the clustering of groups along hilltops is exaggerated by the severely undulating topography of the region, the character and density of groups is similar to patterns reported for other large Late Classic polities, such as Caracol in Belize (Murtha 2002). This pattern not only reflects adaptation to environmental characteristics, but also possibly subsistence activities (Puleston 1983) and a concern for defense. Until further subsurface data are available, however, it will be impossible to decide whether the elevation bias in the settlement pattern reflects cultural choices or preservation.

In several instances the spatial relationships between the earthwork and nearby plaza groups appear to be more than incidental. For instance, Group 1, located immediately north of the earthwork and west of the North Transect, consists of a multi-plaza settlement with at least three *chultunes* and an adjacent stone quarry. The location of this group---immediately north of the earthwork---seems counterintuitive to any putative defensive functions. At this location, however, the earthwork is unusually shallow and poorly preserved considering the relative elevation of the site, suggesting that this section was either never very substantial or that it was purposefully (or otherwise) diminished. A very different situation is seen at Group G5, a small plaza group located just north of a well-preserved and quite substantial portion of the earthwork. Group G5 appears to be tactically well situated on the summit of a hill facing north and east, but again its position north of the earthwork seems a poor defensive location (although one can imagine various stratagems that would integrate such settlements as bastions in a larger defensive system).

RECONAISSANCE OF THE RAMONAL EARTHWORK

A major goal of our project was to locate and map unreported segments of the earthwork, or those insufficiently examined in the 1960s. Puleston and Callender concentrated their work on the northern part of the system. At the time an informant reported another section near the site of Ramonal, located about 9 km southeast of the Tikal epicenter and just south of the east survey transect (Fig. 1). Very little is recorded in the literature about this feature, or about Ramonal itself. A section of the ditch was apparently mapped with compass and tape during the final stages of the Penn project, showing that it runs in a basically northeast-southwest direction. Anabel Ford (1986) later relocated this southern earthwork and mapped a short section of it (about 125 m), but just how long or continuous it was remained unclear. If it continued for any significant distance and turned to the west, as archaeologists working at Tikal have long assumed, it would indeed constitute a southern emic boundary on the Tikal near periphery that roughly parallels the northern one (Fig. 2). The Ramonal feature is accordingly often called the "southern" earthwork in the literature, despite its eastern location and its compass bearing, and the fact that if it did turn west it would have to cross two of the major drainages in the region—the Arroyo La Pava and the Arroyo Holmul. Survey teams saw no sign of a ditch crossing the South Transect at the appointed distance from the epicenter (although the northern earthwork cannot be seen where it crosses the North Transect either).

We scheduled a brief reconnaissance to Ramonal, where we hoped to augment the information from the Puleston and Ford projects by using modern technology to better position the earthwork and to record more of it. A special concern was to ascertain how the earthwork articulated with the site itself, and with the Bajo Santa Fe, the apparent eastern terminus of the north earthwork.

We visited Ramonal as the field season was winding down in the early part of June and found the earthwork very close to where it had been placed on Puleston's survey map, running southwest to northeast at a bearing of 21 degrees. Its configuration is identical to that of the northern earthwork---a trench or ditch dug into the soft limestone with an embankment on the inner (northwest) side. Perhaps due to the local topographic context, the section we saw was extremely well preserved. The ditch had an average depth of 2-2.5 m. We mapped roughly 1 km of the earthwork, separated into two sections by a small gap of 50 m. At its southwest end the earthwork terminates in a large *bajo* that we did not fully traverse because it is more than 1.5 km wide. The northeast

end also ends in a narrow finger-like extension of Bajo Santa Fe. Ramonal itself, which has been placed in slightly different locations on various earlier Tikal maps, is now firmly positioned by GPS data on our own map. We also fixed the locations of Corozal and other large sites in the region.

Ramonal is an impressive architectural complex situated on the northern edge of a small hill overlooking the Arroyo Negro and the Bajo Santa Fe. To our knowledge the site has never been mapped; it is not shown as one of the mapped peripheral centers in Puleston (1983). The group consists of more than 15 structures of significant size situated around at least four formal plazas, and unfortunately it has been severely looted. The ditch itself does not seem to articulate directly with the major architecture of Ramonal, which appears instead to be situated about 100 m 'inside' the associated section of the earthwork. There might be a still undetected articulation along the southern edge of the site.

We did not systematically survey the landscape adjacent to the Ramonal earthwork, but we made notes on settlement and collected positional data for many groups to facilitate future mapping in this part of the park. Settlement density around Ramonal is clearly very high. The currently mapped portions of the earthwork run adjacent to an 'island' surrounded by two large *bajos* and the Arroyo Negro, and this high ground was apparently very attractive for the establishment of *plazuela* groups and structures of considerable size. We estimate a settlement density of 22-25 *plazuela* groups per sq km, significantly higher than that found along the northern earthwork. Many groups are 'outside' the ditch, which seems to bisect the local settlement distribution. Further inspection of the Ramonal locale is clearly critical because of the proximity of earthwork and settlement.

The presence of an earthwork extending southwest from Ramonal makes it more likely that other unknown segments might lie along the eastern margins of the park. For reasons made clear shortly, we prefer to label the existing section the "eastern" earthwork, and suspend judgment about the presence or position of the long-postulated southern arm.

A hint that the earthwork might be a more encircling feature than Puleston envisioned was the bifurcation mapped at the western end of the north earthwork, where one short section runs northeast into the shallow Aguada El Duende (Fig. 6), and another longer one turns to the south. Even though we could not trace this south-turning section for very far before losing it in a *bajo*, we later found clear evidence of a previously unsuspected western boundary.

RECONNAISSANCE OF THE WESTERN EARTHWORK

Silverstein and a local informant first identified the western earthwork far to the southwest, where it crosses the western border of the park (today delimited by a *brecha*). Silverstein traced the feature for roughly 800 m to the northeast before losing it in an area of high elevation. Murtha and Martinez made another reconnaissance in late April, this time approaching the feature from Puleston's western survey transect. They found a section of earthwork crossing the transect roughly 8.8 km from the center of Tikal, and from this intersection they followed it to the northeast and southwest. While tracing the western earthwork, which is in very rough country, they determined that although the feature sometimes disappears where it crosses *bajos* or other terrain, it in fact maintains a generally consistent bearing (as does the northern earthwork) that enabled them to pick it up again.

The segment running northeast from the West Transect terminates in a logwood swamp about 4 km southwest of where the earthwork had been lost during the northern survey. We cannot at this point link up the western and northern earthworks. Moving to the southwest, Murtha and Martinez traced its course for more than 3 km, at which point it climbs over a very precipitous ridge that is twice cut by deep *arroyos*. They lost the ditch in this area, as indicated by the large gap of about 2 km shown in Figs. 6 and 18. Either the ancient Maya deemed a ditch here unnecessary, and/or they erected some other form of barrier. At the other end of the gap Murtha and Martinez picked up the southern section originally located by Silverstein. They followed it to the southwest for some 800 m beyond the boundary of the park, where it terminated in a large *bajo*. During this survey they also found a large Ramonal-scale site (nicknamed the Southwest Group) whose coordinates are listed in Table 2. Unfortunately it appears to lie just outside the southwest corner of the park boundary.

Handheld GPS units, along with WAAS correction, allowed us to record the position of the centerline of the western earthwork with one-meter horizontal accuracy.[16] We did not have time to follow up with the total station, so our map is not as detailed as it is for the northern earthwork. Because of temporal and geographical constraints we were also unable to follow the western feature for any great length beyond the park boundaries, but nevertheless we mapped 5.22

[16] The term centerline refers to the visually apparent center of the ditch.

km of it. Unfortunately, we did not have time to return to this section for a more thorough inspection of the region. We were, however, able to pick up and record another section of the earthwork somewhat over 2 km long farther to the south. In total, we directly mapped about 7.3 km of the western feature, not counting the section branching off the north earthwork near the Aguada El Duende. If we include this latter section, the total extrapolated length of the west earthwork is about 14.6 km, assuming that the present gaps were originally components of it. Our local informant told us that the earthwork continued for some distance even farther to the southwest. Future reconnaissance will be necessary to test this possibility, although it will also create a problem because we will have to operate outside the area of the Parque Tikal, and thus enter a separate archaeological jurisdiction.

An unexpected attribute of this newly discovered earthwork is the bearing of its two mapped sections. The northern one is roughly perpendicular to the line of the northern earthwork. The southern section, however, takes a rather abrupt swing to the west and leads almost directly away from Tikal's epicenter as it crosses the boundary of the park. If there were a southern earthwork in roughly the position long imagined by archaeologists, we would instead expect this section to turn toward the east. The general bearing of the western earthwork more closely approximates the dominant "grain" of the larger Tikal landscape (Fig. 6), including the direction of the major seasonal drainages, than that of the northern earthwork. As we have already seen in Fig. 18, however, the two mapped sections of this new earthwork also exhibit considerable shifts in elevation over short distances that again make them problematical as artificial watercourses.

Although the western earthwork is identical in form to the northern one, preservation is variable and there are places where it disappears for hundreds of meters. Elsewhere there are portions where the cut limestone bedrock is visible on the ditch walls. The inner embankment is generally more impressive than its northern counterpart, in some places standing as much as several meters high. The width of the ditch also varies considerably, widening to between 5 and 10 m at its maximum. The earthwork is particularly well preserved at the point where its western branch crosses the park's west perimeter boundary trail. The ditch, approximately 2 m deep at some points, extends both northeast and southwest from this junction. Just to the east of the trail lies the best preserved of the causeways thus far encountered, which spans an approximately 8 m wide section of the ditch. Some *chultunes* and structures were observed adjacent to the western earthwork, but we have not systematically collected settlement data

from this sector, so the overall density of buildings or features is difficult to estimate. Murtha's impression is that settlement density is quite low--probably less than 10 *plazuela* groups per sq km. Silverstein thinks it might be higher.

While we identified specific sections of the earthwork in these distant forays, it is also important to note that we also covered a great deal more of the peripheral Tikal terrain while attempting to trace it (minimally the cross-hatched areas shown in Fig. 24). Our reconnaissance cannot be considered in any sense systematic, but we did form impressions and record information about local settlement. The resulting data, while admittedly incomplete and qualitative, do provide good impressions about the general context of the earthworks, and will serve as a useful framework for the development of future research projects.

CHRONOLOGY OF THE EARTHWORK SYSTEM

No new artifact data exist that enable us to refine the original age estimates for the earthworks made by members of the Tikal project. Nevertheless, knowledge of the general chronology of the site and kingdom, the associated dynasty, and the interactions of Tikal within its larger geopolitical setting is much more precise than in 1967. In this section we accordingly review the basis for the early estimates and offer some more current perspectives. We use the ceramic complexes listed in Table 1 (adapted from Sabloff 2003: xxiv), but readers should bear in mind that this sequence differs slightly from some older versions.

Table 1: Tikal Ceramic Sequence

Lowland Maya Periods	*Ceramic Complexes*	*Calendar Dates*
Postclassic	Caban	A.D. 950-?
Terminal Classic	Eznab	A.D. 825-950
Late Classic	Imix	A.D. 700-825
"Intermediate"	Ik	A.D. 550-700
Early Classic	Manik	A.D. 200-550
Terminal Preclassic	Cimi	A.D. 125-200
Late Preclassic	Cauac	0-A.D. 125
Late Preclassic	Chuen	350-0 B.C.
Middle Preclassic	Tzek	600-350 B.C.
Middle Preclassic	Eb	1000-600 B.C.

Earthworks, like drained fields and agricultural terraces, are notoriously difficult to date, as Puleston and Callender found. Such features are often far from residences or other activity areas, so chronologically sensitive artifacts—particularly ceramics-- are characteristically absent or recovered only in low densities. There are usually no "sealed" surfaces such as plaster floors that protect potsherds from deteriorating and that ensure good chronological control. Ditches are simply huge holes in the ground that can fill up with artifacts of any age through a variety of re-depositional processes. Only very large samples of well-preserved and well-stratified artifacts, or sizable pure deposits from restricted time periods, are very useful in determining even their minimal ages. Webster's experience at Becan shows that even where artifacts are abundant, such informative samples are rare.

Earthwork components at Tikal provide particularly vexing challenges. Artificial causeways might have been built at any time after the ditch was dug, so the latest artifacts from their fill, or those on the old pre-causeway surface or the accumulated soil beneath them, provide only a minimal age. Deposits near the sides of causeways in the adjacent ditch (a convenient dumping ground) may be numerous, but tell us about when the causeway was used, not when the ditch was created. Even where the fill of the inner embankment is obtrusive and intact, various forms of bioturbation can insinuate later artifacts. By far the best samples potentially come from the old soil levels beneath the fill of the embankment, or from buildings or other cultural features buried beneath it. The strongest evidence for the age of the Becan ditch derived from just such a buried building, but none are so far known at Tikal. And while all the earthwork segments at Becan were probably contemporary, it is unsafe to make the same assumption about all parts of the much longer Tikal system (see Fry 2003: 146 for some properly cautious remarks about this issue).

Chronological Implications from the University of Pennsylvania Excavations

Chronological conclusions of the original project derive mainly from sherds recovered in two excavations, the first a 4 m section through the causeway, and the second a longer trench that sectioned both the nearby ditch and the inner embankment (Figs. 3, 13).[17] The 1967 publication gives only a very

[17] A few sherds were also recovered from the collapsed trench dug into the *bajo* deposits (Haviland: 2003: 137). Some of this sample was impossible to identify, but it did include Late Preclassic and Terminal Classic (Cimi Phase) materials.

brief and sketchy account of these operations and what was found in them, one that in some ways contradicts later summaries.

Virtually no sherds were recovered from the old eroded soil underlying the first phase of causeway construction, which seems to have only slightly preceded the second and final phase. Most of the ceramic material retrieved by Puleston and Callendar was deposited off the sides of the causeway while it was in active use (Becan yielded very large samples from similar contexts). Some also came from the final fill that buried the whole structure, or from scatters on its surface. Robert Fry found that 90% of the sample discarded alongside the causeway consisted not of domestic pottery as expected, but instead of impressively decorated ware including vases, dishes, and pottery drums. Puleston and Callender speculated that the causeway was a "funnel for trade", apparently because the shapes and consistent paste variety of the pottery suggested discard of one or several loads. Robert Fry (1979) suggested instead that the sherds were byproducts of the use of the ditch as a "firing channel".

Puleston and Callender describe sherds from the collective causeway excavations as predominantly "early and middle Late Classic" with some admixture of Early Classic. Absent were any "late Late Classic" sherds, presumably implying that the collection fell squarely into the eighth century or before. They present no discussion of any stratigraphy of the deposits found alongside the causeway, nor is this material distinguished from that in the later overburden or the fill. Their inference was that the causeway must have been built sometime after A.D. 700, and that it clearly long postdates the original excavation of the ditch. No Postclassic sherds were recovered so the whole crossing point apparently fell into disuse during or before Terminal Classic times. The excavation thus provided few good clues concerning the original date of the ditch---only that the causeway was present by the eighth century.

In the second trench only one "definite Early Classic rim sherd" was found in a chronologically sensitive context---buried under the fill of the embankment. This sherd (from a basal flange bowl) has never to our knowledge been illustrated or described in detail, nor its exact position specified. On this slender reed depends the entire direct dating of the ditch. Puleston and Callender concluded cautiously that "...the earthworks were constructed sometime within the range of Early Classic and early Late Classic times"(1967: 46). In terms of the current ceramic chronology this would be roughly between A.D. 200-750, although their presumptions about the Tikal/Uaxatun wars clearly inclined them toward an Early Classic (Manik Phase) origin. It is this

interpretation that has become enshrined as conventional wisdom in the subsequent literature. A further conclusion was that the presence of this single Early Classic sherd ruled out a Preclassic date for the earthworks.

Re-evaluation of the Chronology

William Haviland , along with Robert Fry (who analyzed the ceramic materials from the 1966 excavations) have recently reassessed the chronological implications of the original research. Haviland (2003: 137-141) favors an Early Classic (mid-Manik Phase) date for the ditch, and specifically around A.D. 537. He believes that the final filling-in of the causeway must have been done in late Imix times (thus a bit earlier than Puleston and Calendar suggested)---about A.D. 682 when Tikal was regaining its confidence and power under the aegis of her new king Jasaw Chan K'awiil ("Ruler A"), who finally defeated Calakmul thirteen years later.[18] Fry (2003: 146) describes all the redeposited sherds on the flanks of the causeway as being "...uniformly from the Ik ceramic complex", and for reasons not clear to us thinks that these accumulations show that the causeway fell into disuse for defensive purposes by the beginning of Ik times (A.D. 550). Construction of the ditch must be earlier, which puts his estimate reasonably in line with Haviland's — the northern earthwork dates to the Early Classic. Both reject a Preclassic date.

More indirect evidence comes from Robert Fry's test pit operations on the peripheries of Tikal:

> "Sampling of structures to the north of the earthworks shows that many of them—including the largest complexes of mounds, bordering in size on that of Minor Centers—show initial construction during the later portion of the Early Classic. These continued to be occupied throughout most of the Late Classic. This pattern would also support an inference of a middle Early Classic date for construction and major use of the northern earthworks" (Fry 2003: 146).

By "middle Early Classic" Fry presumably means here the mid-sixth century or slightly earlier, but this is puzzling, given Tikal's political history as

[18] Haviland (2003: 141) goes so far as to assert that *all* of the "access causeways" were widened at this time. Valdes and Fahsen (2004: 156) suggest that this supposed event is a "...reflection of the stability reached during the Late Classic..." Surely these are premature conclusions, considering that only one causeway has been excavated and we do not even know how many others exist!

now known. Why would people continue to live in zones outside the ditch in the face of major hostilities with Calakmul (see below)? Haviland (2003: 140) notes the "counterintuitive" relationships among population distribution, political history, and the presumed Early Classic date of earthwork construction.

Such torturous reexamination of the original collections notwithstanding, it seems fair to say that convincing evidence concerning the original construction of the earthworks is feeble to nonexistent and its presentation sometimes confusing. For now, it seems safest simply to suspend judgment, while admitting the attractiveness of an Early Classic date sometime around the mid-sixth century. Even so, our much better knowledge of general Lowland Maya culture history at least allows more plausible speculations than possible in the 1960s.

Warfare shows up as an explicit topic in Tikal's inscriptions only at the end of the fifth century (Martin 2003: 47), and references to it continue for several centuries, with a notable gap during the 130-year "hiatus". [19] Despite the many conflicts in which Tikal was embroiled, her apparent enfeeblement between A.D. 562 and the late seventh century, and suggestions that she was twice attacked between A.D. 657-677 (Martin 2003: 28), we know of no signs of internal destruction comparable to those found at Becan, Piedras Negras, Dos Pilas, or Aguateca. Admittedly such evidence might still lurk somewhere in the unexcavated precincts of this huge site, but even the Central Acropolis, probably the primary target of successful invaders, appears to have weathered all Tikal's political vicissitudes intact (at least until the ninth century).

Puleston's and Callendar's original suggestion that the ditch was designed to protect Tikal against attacks from Uaxactun now seems quite unconvincing, although the idea of a Uaxactun/Tikal conflict is still frequently repeated (e.g., see Montgomery 2001: 53). In fact, whether the oft-touted Tikal-Uaxactun wars of the fourth century ever occurred looks increasingly doubtful. Political relations between the two centers were complicated both before and after A.D. 378, when "strangers" with apparent Teotihuacan connections influenced the region, led by Siyaj K'ak (Stuart 2000). Stuart himself was careful not to rule out a war at this time. More recent studies of the "star-war" glyph at Uaxactun that supposedly records this conflict suggest instead that it is a *huli* (arrival) verb. Whatever

[19] Of course military (or possibly associated sacrificial) scenes show up in Tikal's iconography much earlier, and some Mayanists interpret the "Teotihuacan intrusion" of A.D. 378 as a warfare event.

happened in the late fourth century, Valdes and Fahsen (2004) envision a subsequent interval lasting right up into Terminal Classic times when the dynasties of Tikal and Uaxactun had close and presumably amicable relationships.

Historical evidence makes an early sixth century construction date most likely *if* the earthworks were designed for defense against adversaries other than Uaxactun. The 20th ruler, Wak Chan K'awiil, came to the throne in A.D. 537 under circumstances suggestive of political intrigue (Martin and Grube 2000). He initially enjoyed patronage over the rising capital of Calakmul to the north. Soon Calakmul turned on him, and he was also faced with other nearby foes such as Naranjo. Enemies, probably Calakmul and/or her proxy Caracol, defeated Tikal in A.D. 562 in a "star-war" confrontation that probably culminated with the ritual killing of Wak Chan K'awiil (Martin and Grube 2000: 39). Assuming that the earthworks are related to these struggles, the most likely interval of construction is between about A.D. 550 and A.D. 695, when a resurgent Tikal finally got the upper hand over Calakmul.[20] Wars continued thereafter, especially with local centers in the Petén lake region, but Tikal seems no longer to have been vulnerable to a major enemy. All things considered, what we have learned from the inscriptions does seem to best accommodate a mid-sixth century date as long suspected, and the most likely royal patron of the earthwork project was the ill-fated Wak Chan K'awiil. Tikal's kings raised few dated monuments during the 130 years following his demise, and it seems doubtful that they would have had the wherewithal to undertake such an ambitious project.

Another possibility is the Late Preclassic (A.D. 150-250) when impressive centers in the Mirador Basin north of Tikal collapsed, presumably with widespread political and demographic reverberations.[21] Such an early construction date is impossible according to Haviland and Fry, but given the feebleness of the existing evidence it seems best to retain an open mind. However unlikely it seems, a Late Preclassic date would nicely align the Tikal earthworks with those at Becan, which were clearly responses to intense forms of

[20] Between A.D. 657-677 the military fortunes of Tikal's ruler Nuun Ujol Chaak waxed and waned in struggles against several enemies.

[21] Unfortunately, and perhaps suspiciously, no intact monuments at Tikal predate the A.D. 378 event (Martin: 2003: 15).

warfare whose character and protagonists (in the absence of dated inscriptions) remain uncertain.

Any of these early dates would account for the non-strategic distribution of our newly mapped sites. Judging from Fry's test pitting elsewhere on the Tikal peripheries, many sites (or at least their principal occupations) probably post-date A.D. 700 (Fry 2003), and were built after there was a pressing need for defense. Whether the earthworks have any implications for the settlement distribution of the mature, Late Classic Tikal polity, or for the considerable and fractious populations that survived in the lakes region into Postclassic times (Rice and Rice 2004) remains to be seen. And all of this surmising presupposes a primary defensive role for the earthworks. If they were made for some other reason, then all chronological bets are off.

DISCUSSION

Results of our project during the 2003 field season exceeded the goals stated in our original proposal. We now have a much more complete map of the full 9.5 km extent of the northern earthwork originally recorded by Puleston and Callender (although in fairness we found that Puleston's mapping, including unpublished sections in his notes, was very accurate). The earthwork can now be effectively tied into the Tikal contour map because our UTM fixes are very numerous and precise, as are our elevations (Fig. 25). We also completed a considerably larger settlement survey than originally planned.

Puleston underestimated the length of the northern earthwork. Our new map shows that it is roughly 12.8 km long, continuing some 3.5 km farther to the east than he believed. It does not simply end at a *bajo*, but extends some 800 m across it (or alternatively begins again on the opposite side) and then bifurcates, with its main course turning to the south. We also provisionally mapped other distant sections ---especially on the west---of what clearly is a much larger and differently configured landscape feature than heretofore imagined. Lumping together all mapped sections of the earthwork, as well as the gaps between them, the plausible length of the system is approximately 25.9 km, or just over two and a half times longer than the original estimate for the northern segment.

Although its general functions remain debatable, there is no doubt that the Tikal hinterland had some sort of boundary system that was much larger than previously imagined. Discovery of the western earthwork was unanticipated, but makes sense in retrospect. The *bajos* that reputedly

constituted eastern and western adjuncts to the north and (putative) south earthworks were probably not serious obstacles to attackers (see below). In fact, it is not even correct to say that there is an extensive "western" *bajo* boundary. Fig. 1 clearly shows that much of the region to the southwest of Tikal's epicenter (i.e., between the West and South Transects) is high ground. Why the idea of a natural *bajo* barrier on this side of the site became so commonly accepted is puzzling.

With respect to the many gaps that we (and Puleston and Callender) recorded, it is useful to differentiate between areas where the earthwork, and especially the ditch, might be *invisible* on the one hand, or *missing* on the other. The former situation probably pertains to many sections that extend through low ground or *bajos* where sedimentation has been particularly rapid. As we have seen, one of Puleston's excavations (unfortunately collapsed before adequate documentation) apparently exposed part of a ditch segment that was invisible on the surface. In other places the earthwork appears to be missing even on high ground (this is particularly true of the west earthwork). What to make of these sections is still unclear, but one possibility is that other kinds of barriers protected these gaps, as suggested below.

What does the Earthwork Delineate?

The earthwork as currently known forms a clear boundary on both the north and west sides of Tikal's hinterland, but our new map poses some interesting questions about other possible perimeter features. The short Ramonal section has long been thought, without any direct evidence, to bend westward and form a southern earthwork roughly parallel to the northern one, and functionally equivalent to it. Despite the fact that such a course would make the feature cut across Puleston's southern survey transect, no one has ever detected any trace of an intersection there. Restating the earlier conventional wisdom, Haviland (2003) speculates that this imagined southern boundary was about 6.5 km south of Tikal's Great Plaza.

We now have more precise information about the Ramonal section, which basically runs on a northeast to southwest bearing along the "grain" of the topography, as shown by the courses of the nearby Arroyo Holmul and Arroyo La Pava (Fig. 2). This bearing roughly parallels the newly documented western earthwork. While the Ramonal section could of course somewhere take the proposed westward bend, the known pattern raises the alternative possibility (which we favor) that it is part of an *eastern*, rather than a southern perimeter. If

so it might continue to the northeast to link up somewhere with the northern earthwork, or disappear into the Bajo Santa Fe. It might also extend farther to the southwest, paralleling the western earthwork far beyond its known position near Ramonal. One bit of hearsay evidence hints at the existence of such a southeastern extension. During their approach to Ramonal, Murtha and Martinez were told that a local person had actually seen a section of earthwork to the south and west of the known Ramonal one. Only future ground survey and/or scrutiny of a new generation of remote sensing images will resolve these issues. In any case, the documented sections of the earthwork quite conceivably represent no more than half of a much longer system.

Wherever the boundary is eventually fixed, it was probably always inappropriate to use the known (or imagined) sections of the earthwork, along with the *bajos*, to define the "site" of Tikal, however convenient this might be for archaeologists attempting to deal with the perennial problems of Classic Maya site (or polity) delimitation, distribution of settlement features, and population reconstructions. *If* the earthworks were built as one sustained effort, the boundary definition scenario holds true *only for that particular period of time,* because Tikal's political fortunes manifestly waxed and waned, and so too undoubtedly did the territorial reach or ambitions of her rulers. This is why determining the chronology of the earthworks is so important. If the system is early, as seems likely, it might not have any relevance for Late Classic Tikal, the period for which it has been integral to so many settlement and demographic reconstructions.

Maya archaeologists have always been divided on the issue of boundaries of kingdoms. Some envision them as fairly fixed, while others think that they were more fluid, extending only so far as the situational influence of a local ruler or dynasty and not corresponding to any "line-on-the-ground" territorial principle. Although there exist some very impressive Lowland Maya "connective" features, such as the Coba-Yaxuna *sacbe*, there is nothing comparable to the Tikal boundary, which regardless of its putative defensive or other functions seems to be a clear emic hinterland demarcation *as the Maya planners conceived it at the time of construction.* This is just the conclusion that Puleston and Callender championed: "....the upper eschelons of nobles and priests, who must have had the power to order the construction of such a defense, were interested in protecting the agricultural resources upon which they ultimately depended" (Puleston and Callender 1967: 48).

Webster believes that a similar impulse lay behind the dedication of seven widely spaced stelae by Copán's twelfth ruler in A.D. 652. These monuments symbolically incorporated the most extensive and productive agricultural zone of the valley, as well as the region that contained most of the population. They demarcated a core sustaining district as perceived by a ruler, not a "site" in any conventional meaning of the term. Fortunately the king who created Copán's boundary system dated it for us. Furthermore, Copán's core sustaining area had rather clear topographic and geographic limits that incorporated the alluvial deposits on the valley floor, along with the lower slopes of the flanking hills. At present it seems safe to attribute a similar function to the Tikal earthworks, while admitting that it applies to the political geography of an as-yet unknown period of the kingdom's history. At no time did it serve as the limits of a "city" as Valdes and Fahsen state, but rather of some larger territorial entity. When, or whether, the boundary encompassed what we can reasonably call the whole "Tikal kingdom" remains to be seen.

Having made this Tikal-Copán comparison, it is only fair to point out the obvious difference between the two systems. Copán's boundary stelae were largely symbolic markers, essentially equivalent to territorial scents left by dogs pissing on trees. They might have sent a powerful cultural signal, but they were certainly not "expensive" to create in terms of time, labor, or materials, nor did they constitute any kind of physical barrier. Tikal's earthwork represents an effort of a very different kind. While it might have had some of the same functions as Copán's boundary markers, the earthworks required much more labor and so must have had other functions too.

William Sanders has suggested to us that although the earthwork might not have been very defensible in purely military terms, it was a boundary that still could be patrolled. The idea here is basically a "judicial" one --- that unwelcome individuals or social groups found "inside" the barrier would have transgressed a clear territorial marker, and could be ejected if they tried to settle on, or cultivate, or otherwise use Tikal's lands. Similarly, the boundary could have controlled trade or taxation, as others have imagined. But these explanations meet the same objection --- why not create a "cheap" symbolic boundary, rather than a comparatively expensive one that constitutes only a feeble physical impediment?

Puleston and Callender found that section of the boundary closest to Tikal's epicenter (ca. 4.5 km). The newly discovered western segment is about 8.8 km west of the Great Plaza, and if the Ramonal earthwork is part of a longer

eastern boundary, it would lie at a roughly similar distance in that direction. Assuming that the latter earthwork does eventually turn to join the western one, the most logical east-west line would be somewhere beyond the current southern limit of the Parque Tikal (see Fig. 3). Such a hypothetical boundary would be over 13 km from the epicenter. In this case the whole system would bound an area larger than the proposed old north and south perimeters, variously conceived to enclose (along with the flanking *bajos*) 120 or 167 sq km (Puleston 1983; Culbert et al. 1990: 117; Haviland 2003). It is on the north, of course, where Tikal was confronted with other nearby centers of considerable size, so there might well have been both political and environmental reasons for a set of boundaries that incorporated a large southern hinterland. Lest we perpetuate a long-standing misperception, however, it cannot be too strongly emphasized that there is *absolutely no trace of any southern earthwork that parallels and complements the northern one*. The fourth side of our boundary system is simply lacking given the evidence in hand.

For the present, we suggest that the Tikal landscape can be partitioned in the following manner in terms of its demographic, settlement, and political components. First, there is the *epicentral core* of large buildings – what is commonly called the site of Tikal—that extends over an area of (generously) 4 sq km. Beyond this architectural core is the *demographic core*, which is subsumed by the 16 sq km Carr and Hazard map (and which may be itself subdivided into "peripheral Tikal" and other zones as suggested by various Tikal publications). If one wishes to call any part of Tikal a "city", it would include the epicentral core and some subset of the demographic core. We prefer to think of Tikal's epicenter as the regal-ritual (or court) apparatus of the ruling dynasty rather than an urban conurbation (Sanders and Webster 1988; Webster and Sanders 2001).

Farther out, and encompassing the first two zones, is the *territorial core*, which as we have seen has often been imagined (incorrectly) as the 120 sq km zone delineated by northern and southern earthworks and flanking eastern and western *bajos*. Our new earthwork configuration hints that the Maya originally conceived of this territorial core in very precise terms. Although its full extent remains unknown, it was obviously much larger than the putative 120 sq km. If we are correct that the earthwork is an early construction, the territorial core of the mature eighth century polity might have been considerably larger, spilling out well beyond this set of boundaries. On the other hand, the Late Classic rulers of Tikal could hardly fail to recognize that the zone encompassed by this still-impressive boundary traditionally defined their most politically, strategically,

and agriculturally essential hinterland, whether they kept the old perimeter system in repair or not.

Finally, there is the whole Tikal polity or, if one prefers, the Tikal kingdom. This is obviously the most dynamic and extensive of all the components, expanding and shrinking with the political fortunes of Tikal's rulers and the strengths of her enemies. We envision the polity not in terms of lines on the ground, but rather as a network of political and economic relationships, although there is of course a landscape element associated with them. Which outlying centers and elites did Tikal's kings at any given time control reasonably well? Whom could they visit with impunity? From whom could they expect military support or tax or tribute? With whom did they exchange spouses? These questions are central to our concept of the larger Tikal polity, but they will never be comprehensible in terms of fixed territories or physical boundaries.

Settlement, Landscape, and Defensibility

Turning to the associated settlement, various Tikal publications have estimated structure densities beyond the northern earthwork to be on the order of 39 per sq km. We observed significantly higher densities along our corridor. If the corridor were somewhat enlarged---say to a full 500 m so that it is the same width as Puleson's transect--- these densities would rise because the ditch often lies below ridges or hilltops that are especially favorable for habitation. We have, of course, no current information on the phasing of any of our sites, although we suspect that most of them will not only be of Classic date, but especially Late Classic.

Webster, based on his work at Becan, hoped that some Tikal groups would be found so close to the inner embankment that buildings were wholly or partially buried beneath it, providing good contexts for chronologically sensitive excavations. So far no such situations have been observed. The Settlement Atlas (Appendix A) shows that eleven of the 39 groups (1, 4, 8, 24, 32, 44, 45, 46, 48, 49, 50) mapped along the northern earthwork fall reasonably close to the ditch itself. These sites will hopefully be important in our later attempts to date various sections of the earthwork because the ancient inhabitants might have thrown domestic trash into conveniently close sections of the ditch.

Several groups stand out in this respect. The large group G1, in the overlap zone between our survey and Puleston's, is outside the ditch but its southern perimeter lies right over the course of the ditch where there is an

apparent gap of 50-60 m (Puleston's map plots the line of the ditch somewhat more to the south). If future testing shows that the ditch is continuous in this area, then the southwestern buildings of the site must overly it and so will provide sound stratigraphic context (this is a good example of how adequate mapping is desirable to plan future excavations). Another example is the set of Groups 48, 49, and 50, which are very close to one another but lie on either side of the ditch. It is extremely unlikely that all of them predate the ditch and that builders threaded their earthwork through the narrow gap between Groups 48 and 49. These are instead probably later residences, and so we have a good chance of finding domestic trash in this gap.

Twenty-three of the 39 mapped groups are located "outside" of the north earthwork (i.e., to the north), and only 16 are found "inside" (to the south). Our brief observations suggest that the same imbalance is found around the southeast earthwork near Ramonal. This pattern is the opposite of what we would expect in the case of a fortified settlement zone, but we cannot be sure what it means in the absence of chronological information about settlement history and construction of the earthwork. If the north earthwork is an early construction (i.e., Early Classic), as Puleston and Callender maintained, and if it became militarily irrelevant after Tikal defeated Calakmul in AD 695, then Late Classic settlement might have quickly extended beyond the earthworks during the eighth century. In fact, settling near the ditch probably had some attractions. Rock and *sascab* could be mined from it, water might have collected in parts of it, and deep, moist soils might have supported some kinds of special cultivation.[22] These possibilities remind us that the earthworks were possibly multifunctional both in synchronic and diachronic terms, and in ways not necessarily anticipated by their original designers.

Another possibility is that settlement outside the ditch reflects cost/benefit decisions by rural farmers, who were willing to trade off the risk of occasionally losing a house or a crop to attackers against the convenience of being near their fields. One might even see in outlying settlement a tactical advantage as well, a kind of early warning "screen" against the approach of enemy forces. Rural householders could not only give the alarm, but they could also fall back and help man the defenses. All this is currently sheer conjecture, however, because

[22] It is even possible that parts of the bottom of the ditch were locally reconfigured for hydrological or agricultural purposes, although at present this is pure conjecture.

we lack a firm grasp of the chronology of the earthworks and associated settlement.[23]

While the earthwork probably had some kind of defensive functions, we are unsure about the nature of the defensive strategy. As already noted, there are some very counterintuitive juxtapositions of earthwork and topography, such as the three locations along the north earthwork where the natural slope would have conferred tactical advantage to anyone outside the wall, as opposed to inside (Fig. 19). In these sections the earthwork is located at the base of steep, south-facing inclines. Nor is it clear exactly how even short sections of the barrier were originally configured to form defensible barriers. It has always been obvious that the ditch *by itself* constitutes a feeble horizontal obstacle to would-be attackers. It is so narrow that Puleston and Callender felt obliged to insist that attackers could simply not *jump* across its width as exposed by the Penn excavations. At Becan, by contrast, the horizontal barrier averages some 16 m (not counting the inner parapet) and the ditch is about 7 m deep. Because the Becan earthworks had a very short perimeter (1.8 km) that was far easier to man with defenders, one would expect almost the inverse conditions---i.e. that the Tikal barrier should be the more formidable one at any given point. There is no evidence that either the Tikal or the Becan ditches were ever "moats" (by implication filled with water), although this label is sometimes used to describe them (e.g., see Valdes and Fashen 2004: 156; Harrison 1999: 75; Fry 2003: 144).

Some other possibilities come to mind. One is that there is not just one line of earthworks, but instead two or more that run parallel to one another. That is, a feature like the northern earthwork could have multiple or in-depth lines of defense. Anyone who has not moved across the outlying Tikal landscape might think it fanciful to imagine that such ancillary earthworks remain undetected, but those of us who have traced the known one are not so sure.

Based on his research on defensive gardens, Gerardo Guiterrez (2004) suggests to us several additional ways in which the earthworks could have been used, especially if supplemented by barriers of dense vegetation. He thinks they might be a component in an active rather than passive defensive strategy,

[23] Given what we know from earlier settlement surveys, most of the groups we recorded probably have predominantly Late Classic components. The real question is how much of this late architecture masks earlier components, as Fry's test pitting shows is common in other parts of the periphery..

forming a screen behind which mobile Tikal forces could move, from which they could unexpectedly emerge to engage enemies, and as a refuge into which they could retreat. Gutierrez points out that the real danger to attackers of a major center such as Tikal is the subsequent withdrawal. This is the interval when enemy forces are most vulnerable. The barrier they originally penetrated might become a tactical obstacle during their retreat, creating a vast trap, or killing ground. Gutierrez also draws our attention to the effects that sociopolitical arrangements have on defensive strategies. Many Old World territorial states like those of medieval Europe erected massive static defenses, most conspicuously major wall systems around towns or cities. They protected strong points from being rapidly taken by enemies, and enabled defenders to withstand lengthy sieges. Most important from a strategic perspective is that the time thus gained could be used to mobilize supporting forces from elsewhere in the system to relieve the threatened strong points. Very different sociopolitical conditions obtained in Mesoamerica, and especially in the Classic Maya Lowlands---one reason why so few centers *per se* were strongly fortified (e.g., Xochicalco or Becan). The more common strategy seems to have been a distant defense of centers or territory on open ground, with serious fighting at the political capital only a desperate last resort and, in effect, a harbinger of ultimate defeat.

We should bear in mind that our current impressions of the earthwork might be very misleading because of human and natural modifications since their original construction. Puleston and Callender assumed that the spoil from the ditch excavation was heaped up immediately adjacent to the inner face, with the loose earth probably held in place by retaining walls of rough stone from the cap rock, thus increasing the strength of the horizontal barrier. This inner embankment was possibly augmented with some other sort of barrier feature, such as a timber palisade or a tangle of dense vegetation. We saw no signs of any such stone facing. The "parapet" is so low in most places that the addition of some sort of perishable palisade would have been a great improvement, but there is no direct evidence for this either. Webster's experience with fortifications at Becan and elsewhere shows that finding remains of timber adjuncts is admittedly very difficult (although we know the Maya used them in the sixteenth century and signs of ancient ones have been detected at some sites [van Tuerenhout 1996: 130-172]).

Puleston placed his own trench (Fig. 3) through one of the most obtrusive sections of the earthen embankment found anywhere along the northern earthwork. Elsewhere it is not very visible for much of its course, and over long stretches disappears altogether even where the ditch itself remains pronounced.

Puleston's excavations showed that the ditch is substantially filled by material that washed or eroded in after it was dug. Given the thin soils of the region, the earth of the embankment must have been a main source of this fill, one reason for its generally low and unimpressive appearance. Nevertheless, one would expect a well-constructed defensive embankment to have survived in a more obtrusive form, especially if supported by stone retaining walls (of which we saw no obvious traces). This was certainly the case with major sections of Becan's embankments. If the Tikal earthworks represent early fortifications that later fell into disuse, it is possible that people building nearby houses, residential terraces, or other structures mined the parapet for construction material. That the embankment is always on the inner side of the ditch wherever it is visible supports the defensive interpretation. If the original ditch had some other main function, such as drainage, the location of the spoil pile presumably would have made no difference and should be more variable.

Just what to make of those portions of the ditch that appear only as low swales is puzzling. While they might originally have been much deeper, and simply silted in as Puleston proposed, such silting would not obliterate all remnants of any associated embankment. Yet in most places no such remnants are evident. The same logic applies to the places where the line of the ditch crosses a *bajo* and completely disappears.

The earthworks would only be effective as military barriers if properly manned at the point of enemy attack, because defending the whole perimeter was patently impossible. Even in Late Classic times Tikal could probably have mustered no more than 7000-8000 warriors if Haviland's (2003: 129) estimate of the Imix Phase core population (45,000 people) is correct.[24] If only elite warriors were mobilized, the whole available force would have amounted to a couple of thousand men at most. Even the most optimistic of these numbers could never have defended the very long perimeter we have detected, much less one of possibly even greater length. The only way they could have done so is by advance warning of the whereabouts of enemy forces, which in turn would have required an effective signaling system.

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[24] Other authors give different figures for the Imix Phase occupation. Culbert et al. 1990 think there were 62,000 people within the 120 sq km core zone, and that the total population within a 10 km radius of the site center was about 92,000. A 12 km radius would incorporate about 120,000 people. This reconstruction seems to be the most oft-repeated one (see for example Valdes and Fashen 2004: 156). If we accept these higher figures there would be more labor for earthwork construction.

Murtha performed a preliminary visibility analysis of the earthworks and surrounding settlement using standard viewshed methods (Fig. 25). For exploratory purposes the visibility point chosen was the highest natural elevation in Tikal Group P, on the northern edge of the epicenter. He added 10 m to this elevation as a conservative estimate of what would be visible from a tall building, and also assumed that there was no high forest to impede visibility. While still provisional, the results of this exercise are interesting. Very little of the earthwork itself is actually visible from the observation point—roughly 10% if the northern earthwork and 20% of the Ramonal one. None of the western earthwork can be seen. While these data are not very promising considering the challenge of defending the earthwork, a more important pattern is revealed: all of the large outlying architectural groups in the vicinity of the earthwork are visible.[25] For example, Groups 45 and 1 can both be seen, as can Ramonal, Corozal, and the newly discovered Southwest Group, which lies a full 12-13 km away. Future analyses will evaluate the visibility of the earthworks from the perspective of these large groups, rather than from Tikal proper.

Puleston and Callender surmised that the northern earthwork ended on its eastern and western peripheries in large *bajos* that would have constituted natural barriers to attackers. We now know that this is not true, at least at its western end, although the line of the ditch is frequently interrupted by *bajos*. Our experience suggests that if ancient *bajos* were similar to modern ones in their hydrology and vegetation, they would not have been effective barriers because they become so dessicated during the dry season, the very time when most Maya military campaigns were probably undertaken (Schele and Freidel 1990: 62; Webster 2000). Although natural *bajo* vegetation is unpleasant to walk though, it would not by itself have discouraged determined enemies. And, as other archaeologists have observed, if the ditch were excavated through *bajo* soils it would require frequent maintenance because it would silt in rapidly each rainy season. Clearly such a ditch might now be completely invisible. Still, traces of an original embankment should be evident, but they are not. Only future augering,

[25] As Puleston's surveys progressed he tried to locate and fix large outlying sites that had previously been encountered near Tikal. Ramonal was one of these, and is properly located and named on his map and our own. Another site named Corozal had long been known as well. Puleston relocated this site and called it Corozal A. This relabeling was necessary because he took compass bearings on another nearby site of considerable size, which he called Corozal B. Corozal A is apparently the site called simply Corozol on later maps produced by Anabel Ford.

excavation, or remote sensing will reveal whether a ditch actually existed in many places, and if so its depth.

Another possibility, Gutierrez's main insight, is that the Maya cultivated dense hedges of impassable or toxic vegetation as adjunct barriers (for a hypertrophied example of this surprisingly effective kind of territorial barrier in India, see Moxham 2001).[26] Such barriers are known from ethnohistoric accounts (Gutierrez 2004) and would have been most useful in closing some of the long gaps that occur between sections of the earthwork, such as that separating the two mapped western segments. More importantly, if such vegetation were established in the ditch itself it would have been a much more impressive obstacle.

In some places along the northern earthwork there might have been other kinds of defensive potential offered by strategically placed architectural groups. For example at the NW/W corner of the northern earthwork the large, multi-plaza group G-45 (Fig. 22) is situated on a ridge overlooking the western logwood *bajo*.

An important byproduct of our surveys is a conclusion about something that does *not* seem to be present on the Tikal peripheral landscape--- agricultural terracing. In a review of slope management features, Dunning and Beach (1994) remarked on the spotty distribution of agricultural terraces in the central Maya Lowlands. Such features have been detected in several other regions, most notably on the Vaca Plateau to the east of Tikal, and in the Río Bec region to the north.[27] They seem to be missing in the northeastern Petén around Tikal. Given the apparent density of population (and by inference intensity of ancient cultivation) as well as the steepness of many hillsides and the thinness of the upland topsoil, this absence is puzzling. Dunning and Beach (1994: 52) suggest that terraces were in fact built on many slopes in the Petén, but that they are now difficult to detect because of dense vegetation cover. Our surveys make this

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[26] Gutierrez reminds us that many kinds of toxic Mesoamerican plants might have been used as parts of barriers. *Chechen negro* comes to mind to anyone who has worked in the Lowlands, as does the poisonous nettle nicknamed *mala mujer*.

[27] Terracing in these two regions is markedly different, and given descriptions of the Rio Bec terraces (e.g., Turner 1994) it is difficult to imagine how they functioned and how they would have boosted the production potential of the region---although they might have increased sustainability (see Murtha 2002).

explanation extremely unlikely. Murtha's (2002) dissertation focused on the large terrace systems at Caracol, Belize. He mapped such features for many years, and excavated several of them. He and his crews (including Kirk Straight, who also mapped at Caracol) traversed much of the landscape near the Tikal earthwork, which rambles over a wide range of topographic relief, but even his trained eye detected no agricultural terraces. Moreover, visibility of archaeological features is surprisingly good because the understory vegetation is not very dense in many places.

We know that terracing was used to create ambient space for residential facilities near Tikal, so lack of technological know-how was not a factor. It might be, as Dunning and Beach further surmise, that agricultural terracing is found in abundance only where geological structures produce the proper regional landforms, and these are not found around Tikal. Finally, as Fedick (1994) suggests for the Belize Valley, if effective terracing depends on a combination of factors (especially slope angle and bedrock type), it might exist only in such restricted locales that we have simply not detected it. For whatever reasons, the Tikal Maya appear not to have used agricultural terracing on any scale on those parts of the landscape that we have traversed.

Construction Costs

Haviland (2003: 136) calculated that the northern earthwork required the excavation and movement of about 114,000 cu m of stone and earth. Exactly how he derived this figure is unclear to us. He probably estimated the area of the ditch cross-section illustrated by Puleston and Callender (Fig. 3) and then extrapolated it for the whole 9.5 km distance. Webster's recalculation using the same method gives a lower estimate of about 90,000 cu m for the earthworks as originally mapped in 1966, on the assumption that the northern ditch was everywhere as wide and deep as in the cross-section. Using a series of more local cross-section measurements, Murtha calculated that the amount of material excavated from the ditch fell between Haviland's and Webster's figures---about 110,000 cu m. The Becan ditch by comparison required the excavation and transport of roughly 117,600 cu m (Webster 1976: 99), somewhat more material than Haviland calculates. Using figures derived from Erasmus's (1967) excavation experiments, Webster thinks that 353,000 person-days were required for this task, which could have been accomplished by a work force of 10,000 adult males in about four months. While we project no such estimates yet for the longer Tikal earthwork system, construction costs were obviously much greater.

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Whichever of these estimates one prefers (and they are all pretty close) the effort must be evaluated in the proper perspective. Each of them is roughly comparable in volume to that of ~~a single~~ 4-5 large construction project undertaken during Classic times at a major Maya center such as Tikal or Copán (Abrams 1994; Webster and Kirker 1995). Our simulations reveal that even impressive temple structures, though much more complicated than earthworks, absorbed surprisingly modest inputs of time and labor. Earthworks simply required the excavation and minimal movement of unworked materials (ignoring hypothetical adjuncts made of perishable materials such as timber). Transport costs (a major energetic input) were thus minimized, as was the need for skilled labor. Moreover, some of the extracted materials might have done "double-duty" in the sense that they were used to build nearby residences or other structures. If it turns out that the earthworks are 40-50 km long and enclose the entire territorial core, the costs of construction would still not be enormous in absolute terms, even if the entire system were created as a single effort.

Such costs, however, are not only energetic, but also political and social. If the earthworks, or large segments of them, turn out to be of Late Classic date (i.e., post-A.D. 695, when Tikal's political recovery was underway), the considerable population then available to her rulers (both locally and in terms of the kingdom's larger political influence) would have provided plenty of labor with little political strain.[28] If, as seems more likely, they were built in the mid-sixth century or somewhat earlier, the effort is more impressive because the core population was then roughly 18% smaller (see Haviland 2003, Fig. 4.3), Tikal's political reach more circumscribed, and her rulers apparently much weaker.

Webster (1976) argued that the much more massive, but shorter, Becan earthworks were probably built very rapidly because an incomplete fortification is not much better than none at all. Assuming that the Tikal earthworks had defensive functions, the same logic does not apply. They are not a fortress in the strict sense of the word. They do not protect a small concentration of elite facilities as at Becan, but rather a sprawling hinterland. Surely they could not have been manned or defended in the same manner as Becan's shorter and more imposing perimeter, and so they must have been used tactically in some other way. Although the rather consistent width of Tikal's ditch suggests some kind of

[28] In his most recent overview of the demography of Tikal, Haviland (2003: 129) has reaffirmed his earlier conclusion that the core population of Tikal was about 45,000 people. This figure presumably refers to the area bounded by the *bajos* and by the original conception of the earthworks.

unified design, various earthwork segments might have been finished over much longer intervals than Becan's, thus reducing the political and social costs of construction.

Maintenance would have been necessary if the earthworks were fortifications and if they were used for a long time, and would have imposed additional costs. Ditch segments that extended through low spots or *bajos* (if they exist) probably silted in fairly rapidly and would have required frequent cleaning. Although there are presently deep eroded deposits in upland sections of the ditch, as visible in the Penn excavations (see Fig. 3), this infilling must have been slow, judging from Puleston's and Callender's deep trench across the ditch which is still virtually intact after almost 40 years.

SUMMARY

Successful though it was, our 2003 field research leaves several issues in doubt. Exactly when were the earthworks built? How long did they continue in use? When (or if) were they were abandoned? What were their functions? What we can say at this point is that they are not what we thought they were. We do know now that the earthworks are larger and differently configured than previously suspected, and that many of our assumptions about how they related to Tikal's political history, demography, and urban character are incorrect or at least misconceived. Only more research will answer the more detailed questions listed above.

Several goals for the next stage of research are obvious:

(1) Continued survey to identify as yet undocumented sections of the earthwork, including gaps in sections already recorded, tracing the Ramonal earthwork farther to the north and southwest, and exploring the possible existence of a southern earthwork.
(2) Excavation of selected portions of the known earthwork to more fully document its configuration (and especially to discover if ancillary defensive features such as palisades were present) and to sort out chronology of construction.
(3) Additional settlement survey in and around the western and Ramonal earthworks. We believe that future surveys—as for example around Ramonal— would be better carried out as block rather than transect surveys, thus producing a less biased sample.

(4) Test excavations in groups associated with the earthworks to determine if, or how, the earthworks conditioned settlement history and distribution.
(5) Studies of soils both in and around the earthwork to detect how they might have historically influenced land use and the processes of infilling.

An obvious approach to objective 1 is remote sensing. So far as we have been able to determine, no one has ever discerned any of the earthwork features on existing remote sensing images. When we began the pilot phase of our project we contacted T. Patrick Culbert, who along with Thomas Sever of NASA has recently examined a new generation of such images. Culbert informed Webster that he had never noticed the ditch on any of these. Such invisibility is not surprising in heavily forested landscapes. Webster well remembers flying at low altitude over the partly cleared Becan earthworks and noting how difficult it was to see them unless one knew just where to look. The much smaller Tikal earthworks are covered by a taller and denser forest, and so would not show up well (or at all) on standard photos. A joint NASA/NSF (AIRSAR) project is currently experimenting with archaeological applications of new synthetic aperture radar equipment that can record variations in vegetation and potentially penetrate the forest canopy to detect landscape features (Jeffrey Quilter, personal communication). Flights were recently made over several parts of northern Guatemala, including the region of the earthworks, but their images are not yet available. Two of the bands recorded information about the canopy vegetation, while a third might provide ground contour resolution on a scale of 1-3 m. The latter band might show the line of known parts of the earthwork and help us in visual prospecting for as-yet unmapped sections.

Multi-band satellite imagery might also be useful. Soils in the ditch are much deeper than surrounding ones and probably retain more soil moisture and support distinctive local vegetation. Now that we know precisely where the ditch is located, it might be possible to use multi-spectrum satellite images to detect a faint linear pattern for the mapped parts, and on this basis to prospect for similar patterns not yet mapped on the ground. Such imagery is expensive, however, and we did not budget for it. We have examined a LANDSAT 7 image taken on 3/27/2000 that is a composite of bands 7, 4, and 2, with a nominal ground resolution of 30 m. This is very coarse given the scale of the ditch, and no obvious alignments are visible, although there are some suspicious ones. This LANDSAT image does give a good impression of the topography, however, and is included here as Fig. 27, with the mapped portions of the earthwork superimposed on it.

Locating all the unknown segments of the earthwork is likely to be easier than dating the system as a whole, and the next phase of our research, hopefully also funded by NSF on the basis of a new proposal now being prepared, will be largely devoted to this effort.

In conclusion, every professional archaeologist knows how easily superficial field observations and anecdotal accounts are constantly repeated (and often embellished) until they become conventional wisdom. Maya archaeology provides particularly rich examples of this phenomenon. Webster, who has taught Maya archaeology for many years, remembers how he uncritically internalized and repeated the conventional wisdom concerning the Tikal earthworks and their political, demographic, and military implications. Much of this information is now suspect. Whatever the earthworks represent, we can only be sure at this point that they are big and getting bigger.

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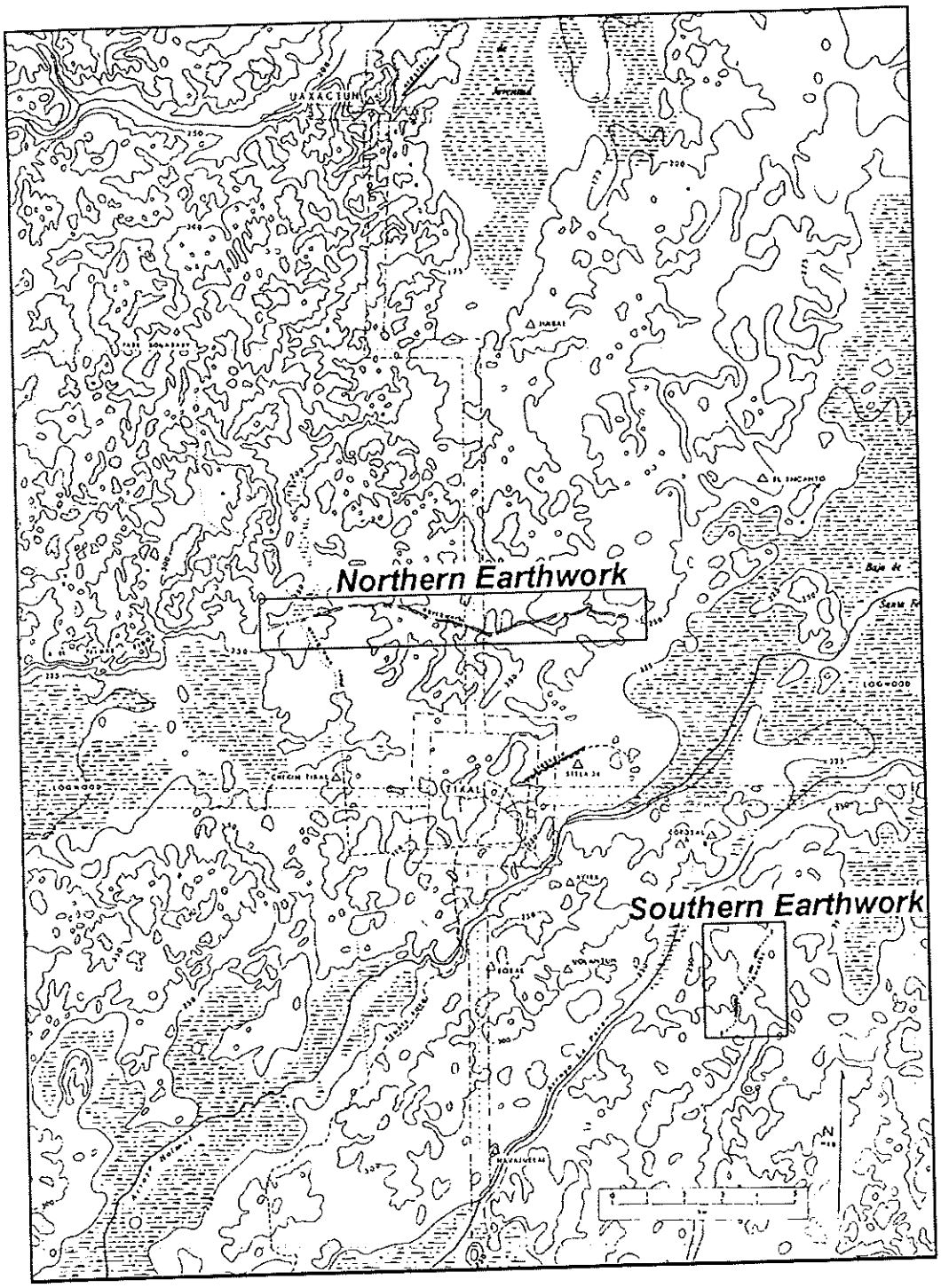


Figure 1—The Tikal epicenter and the four transects radiating from it. Portions of the earthwork identified in 1966-67 identified in red.

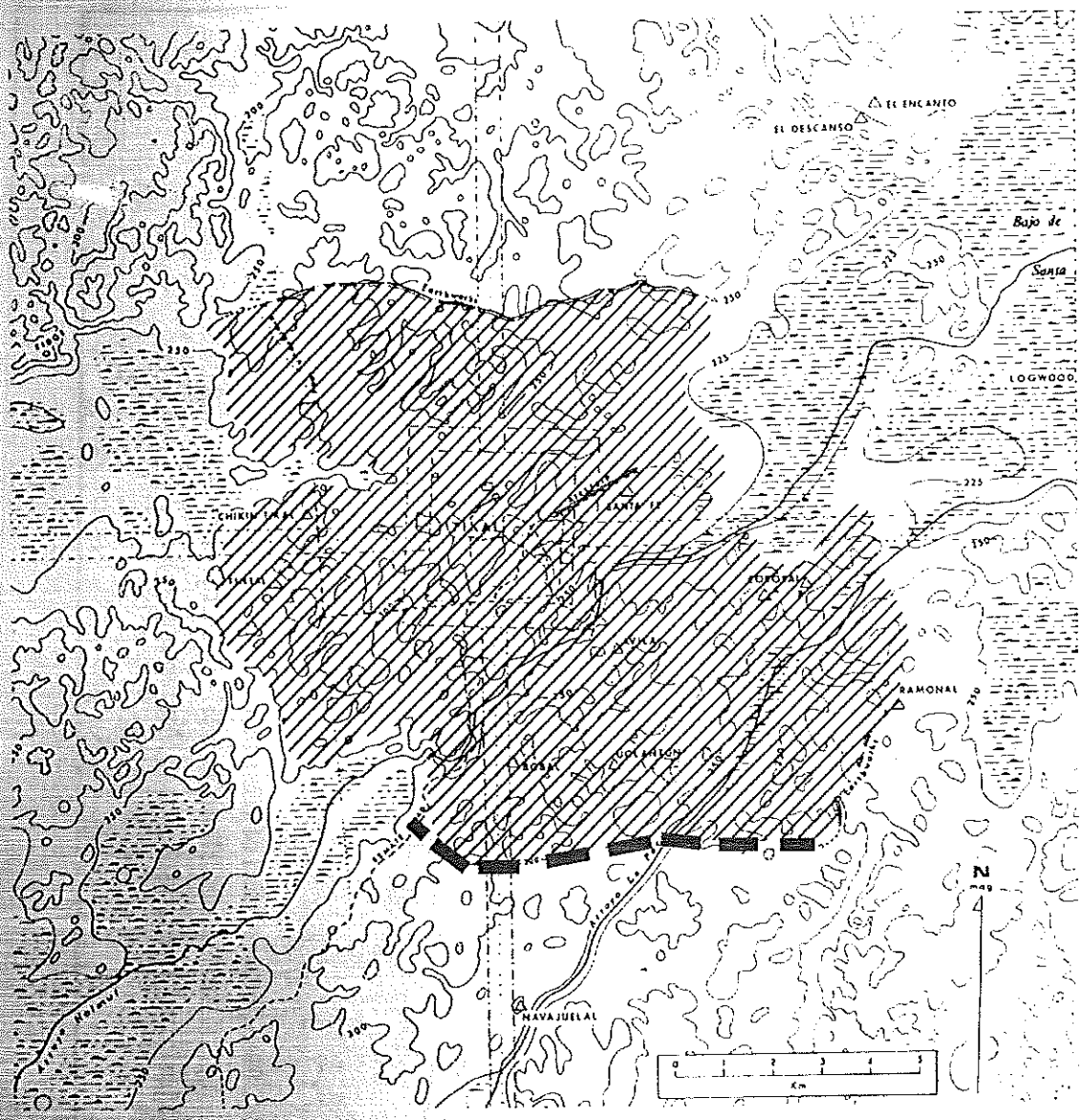


Figure 2 – Puleston's conception of the earthworks as boundaries of Tikal (modified from Puleston 1983: Fig. 20).

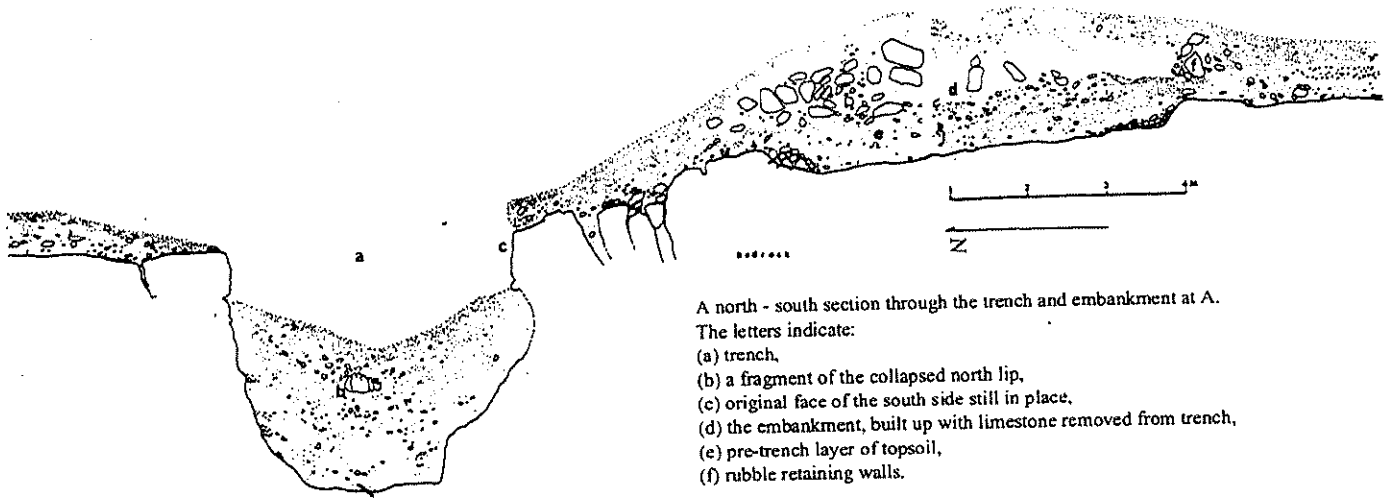


Figure 3 – Puleston's and Callender's section of the northern earthwork's ditch and embankment (Puleston and Callender 1967; used by permission of the University Museum, The University of Pennsylvania).

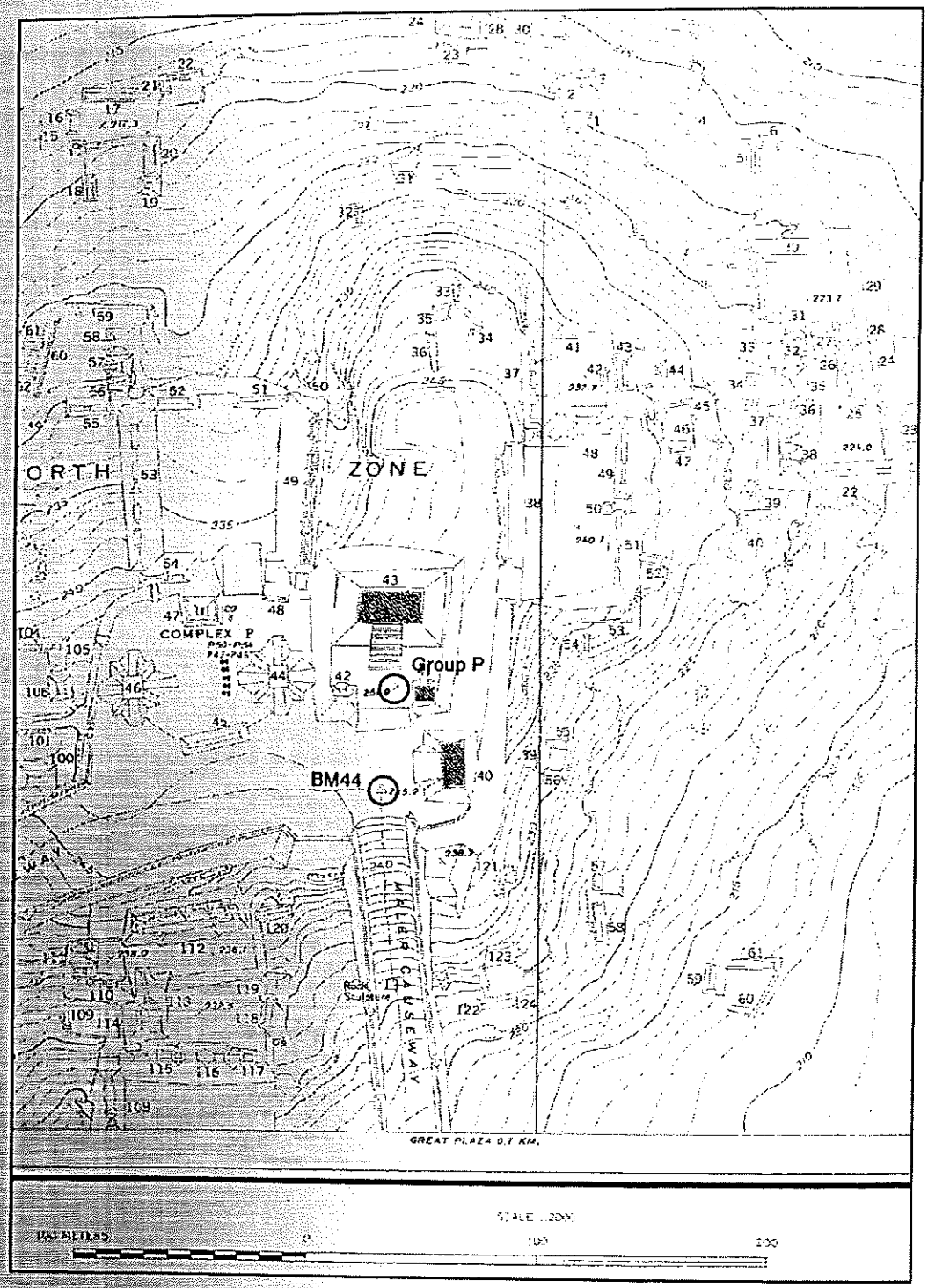


Figure 4 – Locations of base stations for the EFAT survey established near the north end of the Maler Causeway in Group P (modified from a section of Carr and Hazard 1961).

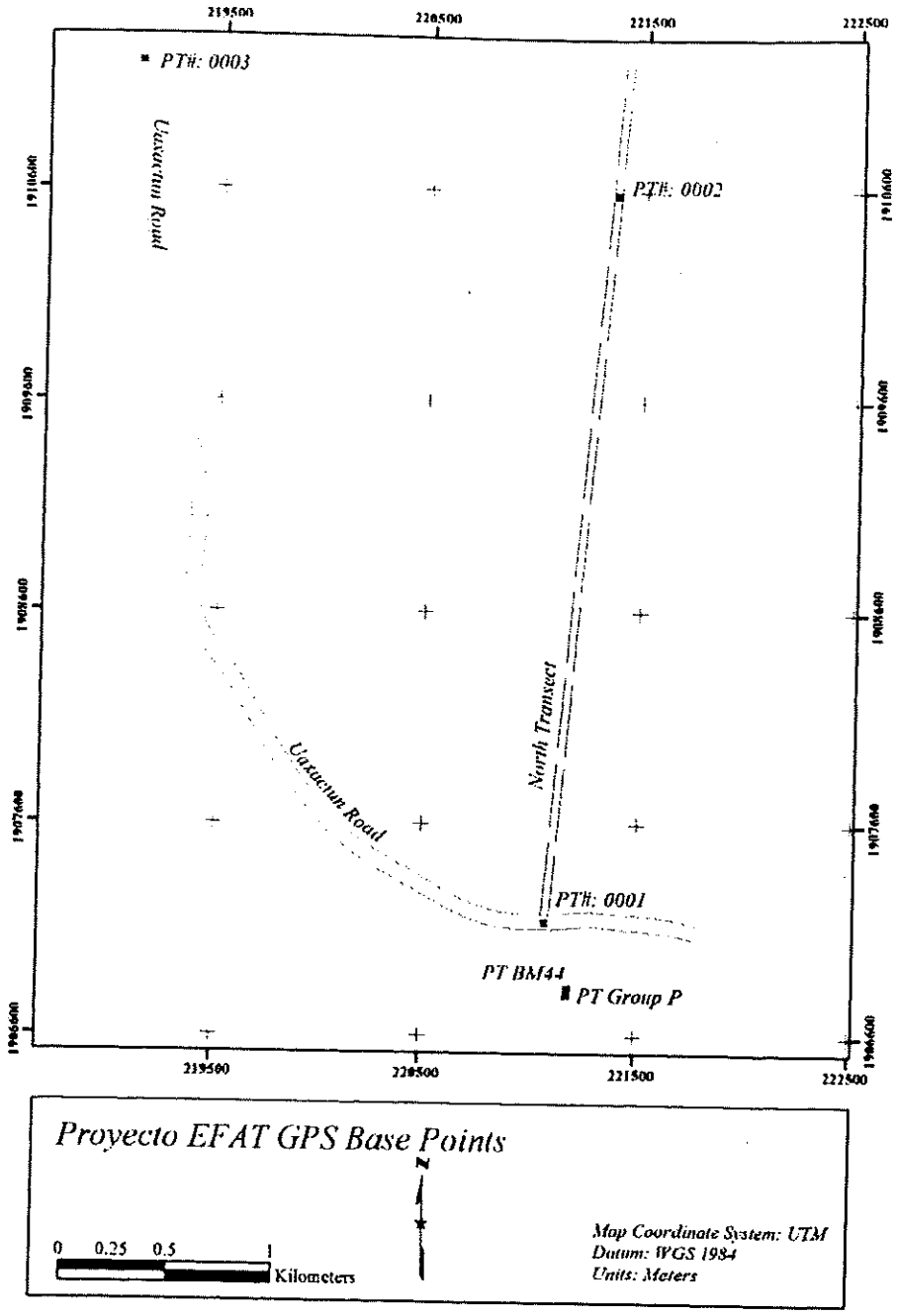


Figure 5 – Locations of the five fixed mapping points.

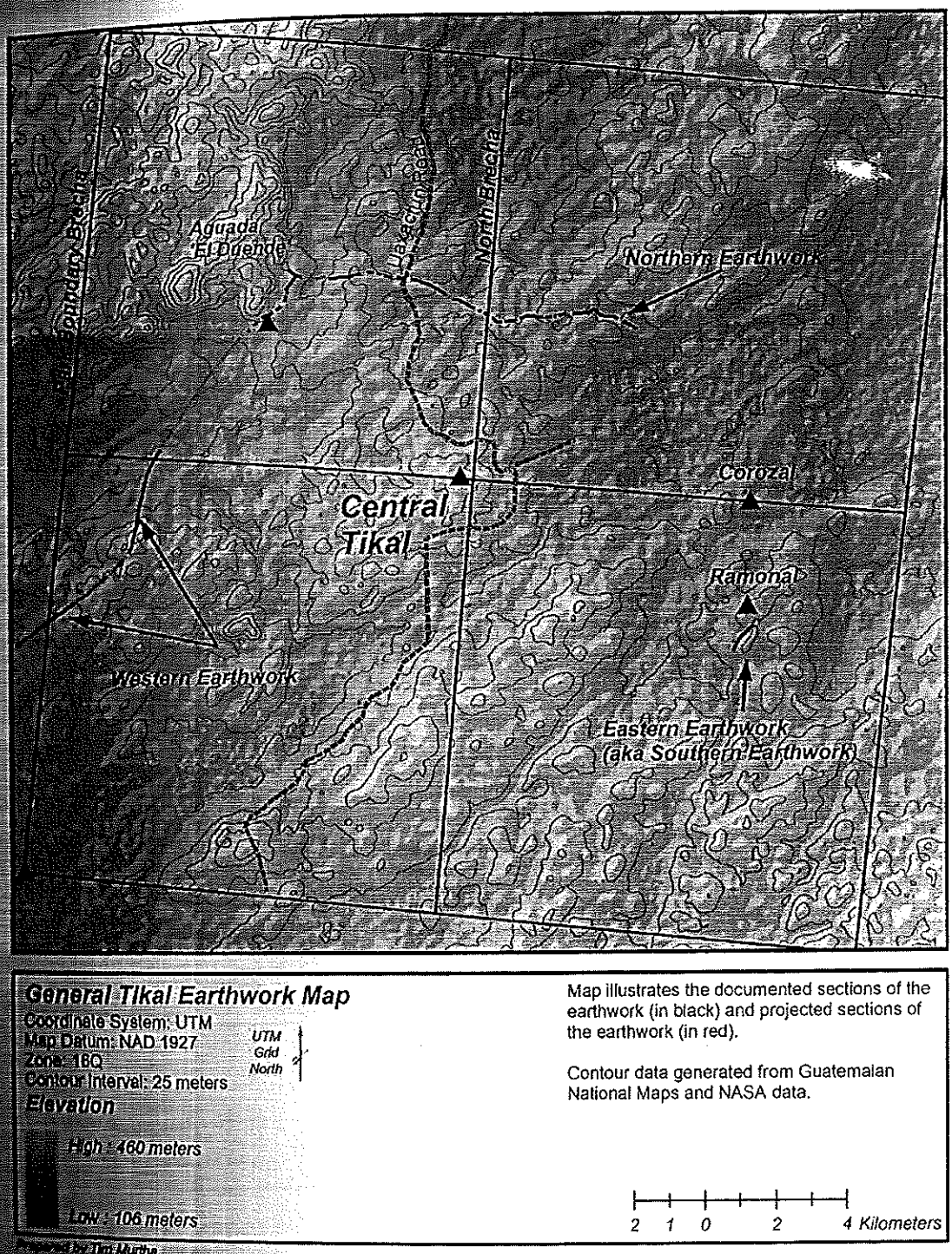


Figure 6 – Contour map of the Tikal Park, the Uaxactun road, and all known sections of the earthwork.

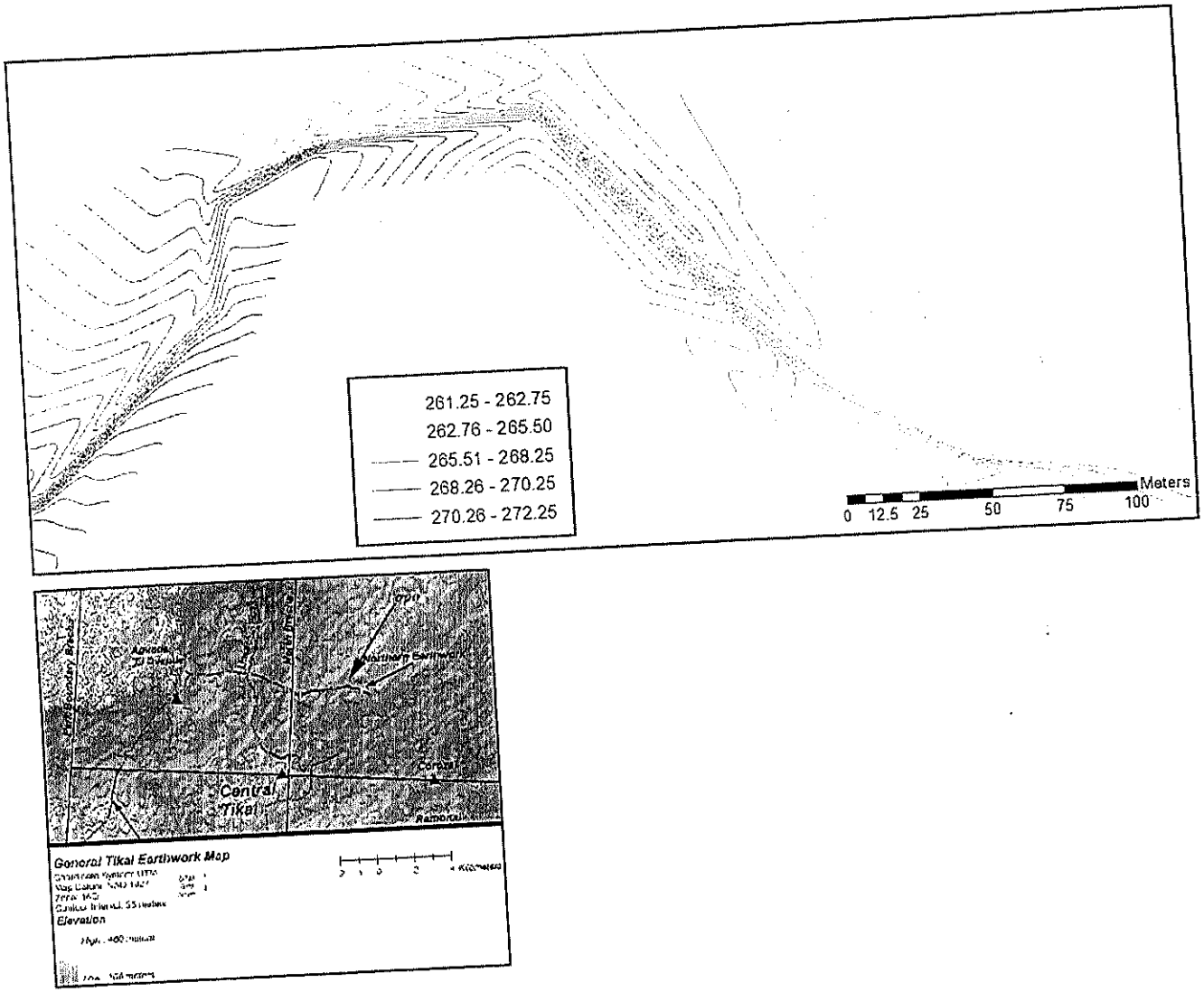


Figure 7 – 0.25 m Contour map of a ditch section.

Figure 7 – 0.25 m Contour map of a ditch section.

Figure 8 – A deep section of the northern ditch.

Figure 9 – Nearly invisible section of the embankment of the northern ditch.

Figure 10--Vertical face of hard limestone in the northern ditch; note the undercutting.

Figure 11 -- Sample cross-sections of the northern earthwork.

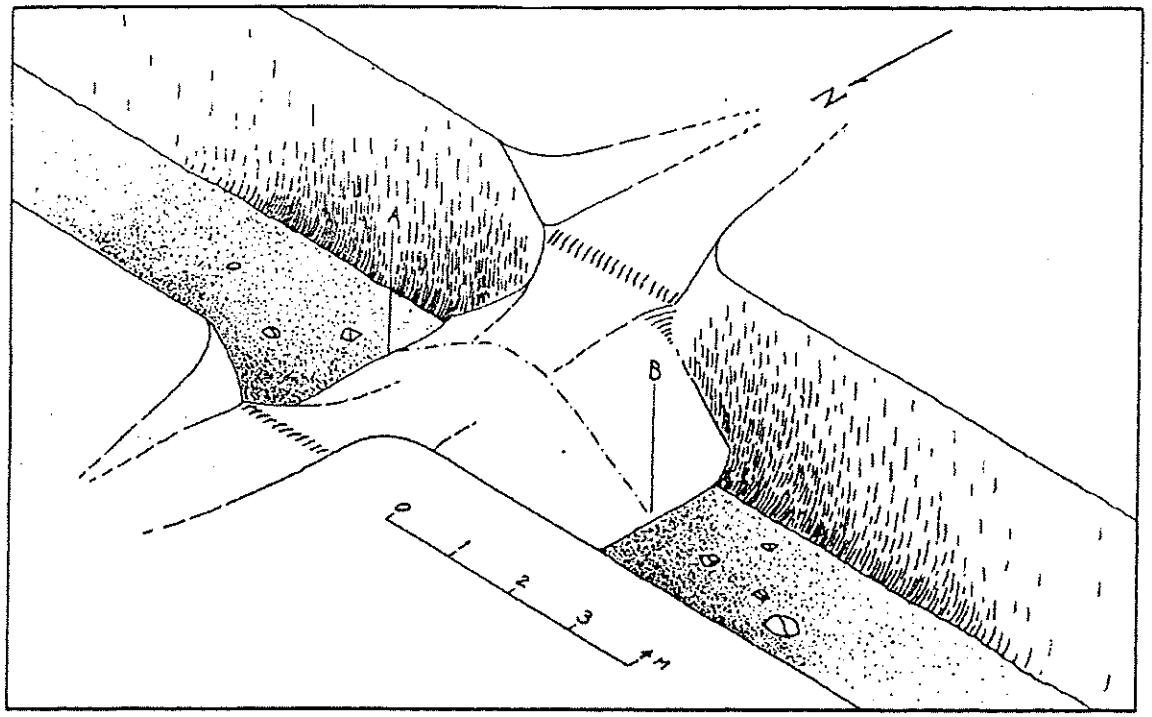


Figure 12 – Reconstruction drawing of the ditch and causeway embankment (from Puleston and Callender 1967; used by permission of the University Museum, The University of Pennsylvania).

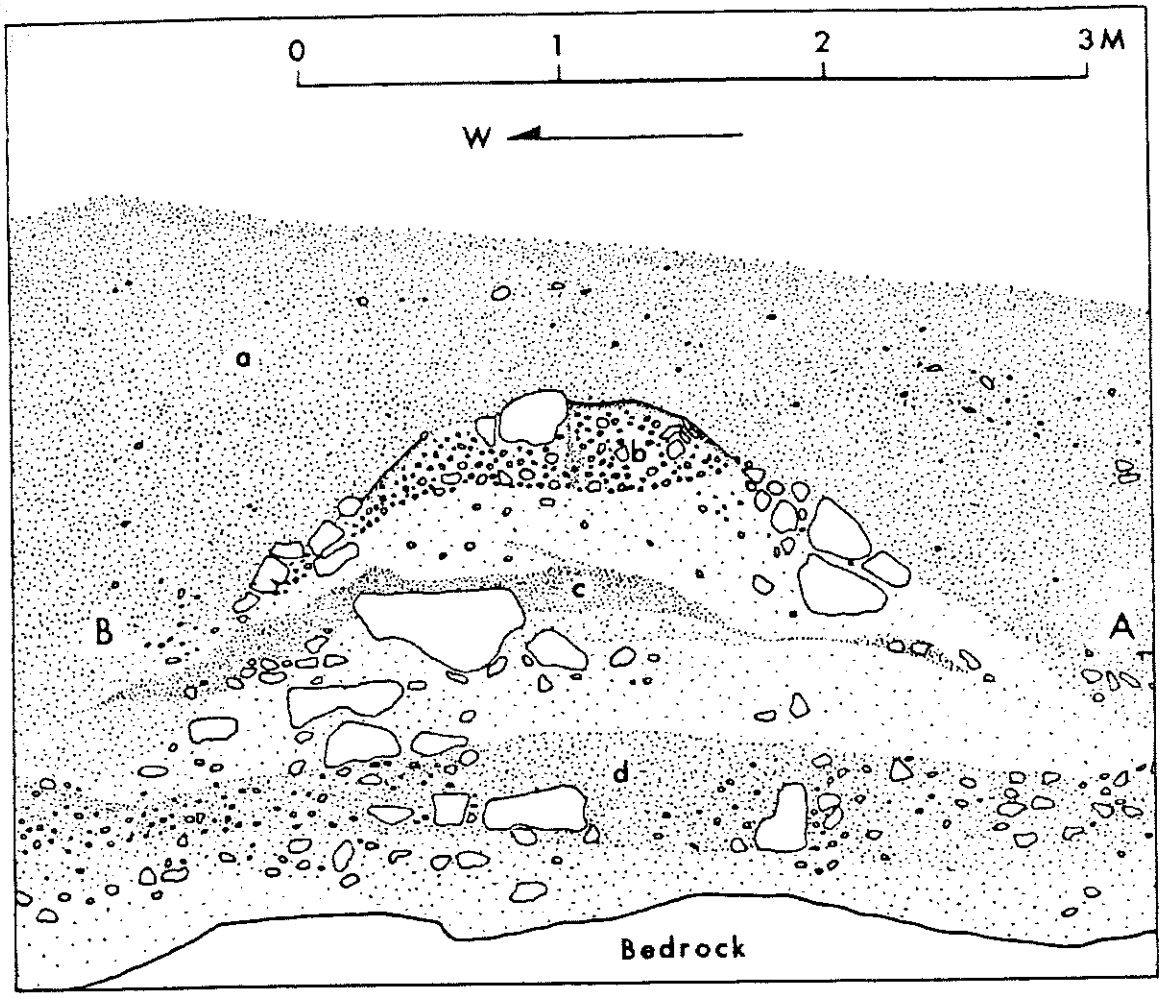


Figure 13 – Profile of trench excavated through a causeway on the northern earthwork (from Puleston and Callender 1967; used by permission of the University Museum, The University of Pennsylvania).

Figure 14 – Section of the northern ditch spanned by a fallen tree.

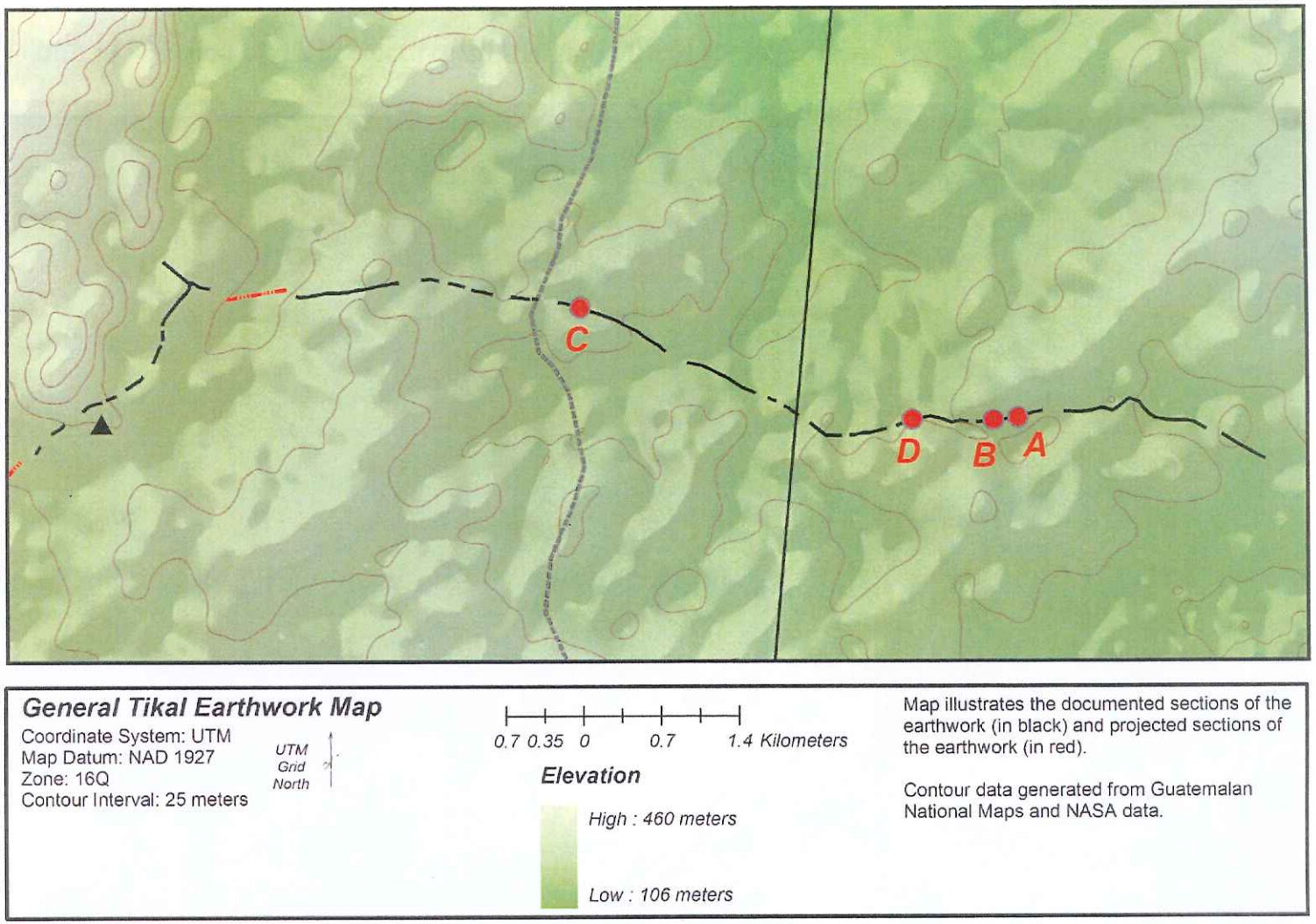


Figure 15 – Locations of known or probable artificial gaps in the northern embankment.

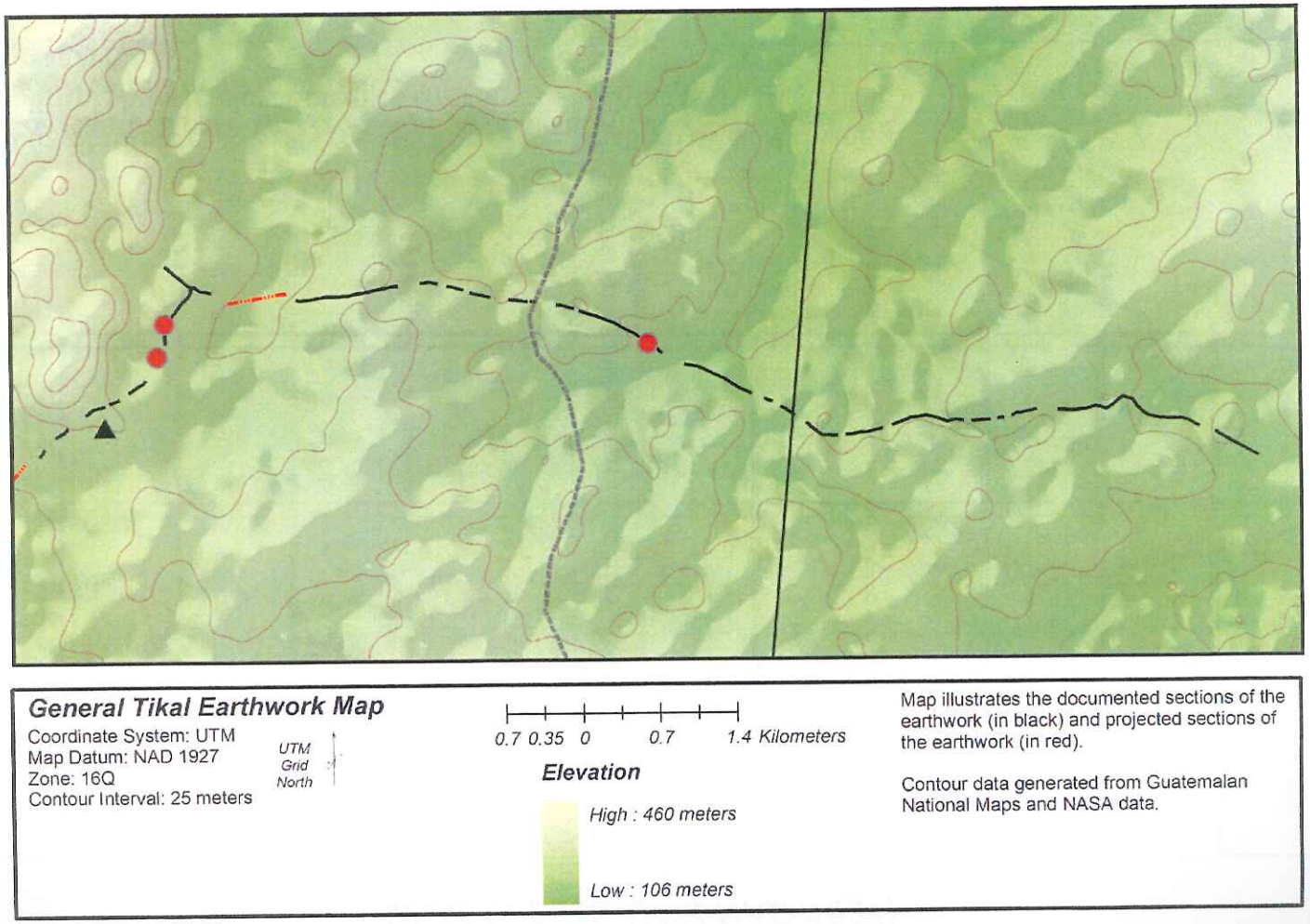


Figure 16 – Places where the northern ditch might be purposefully filled in.

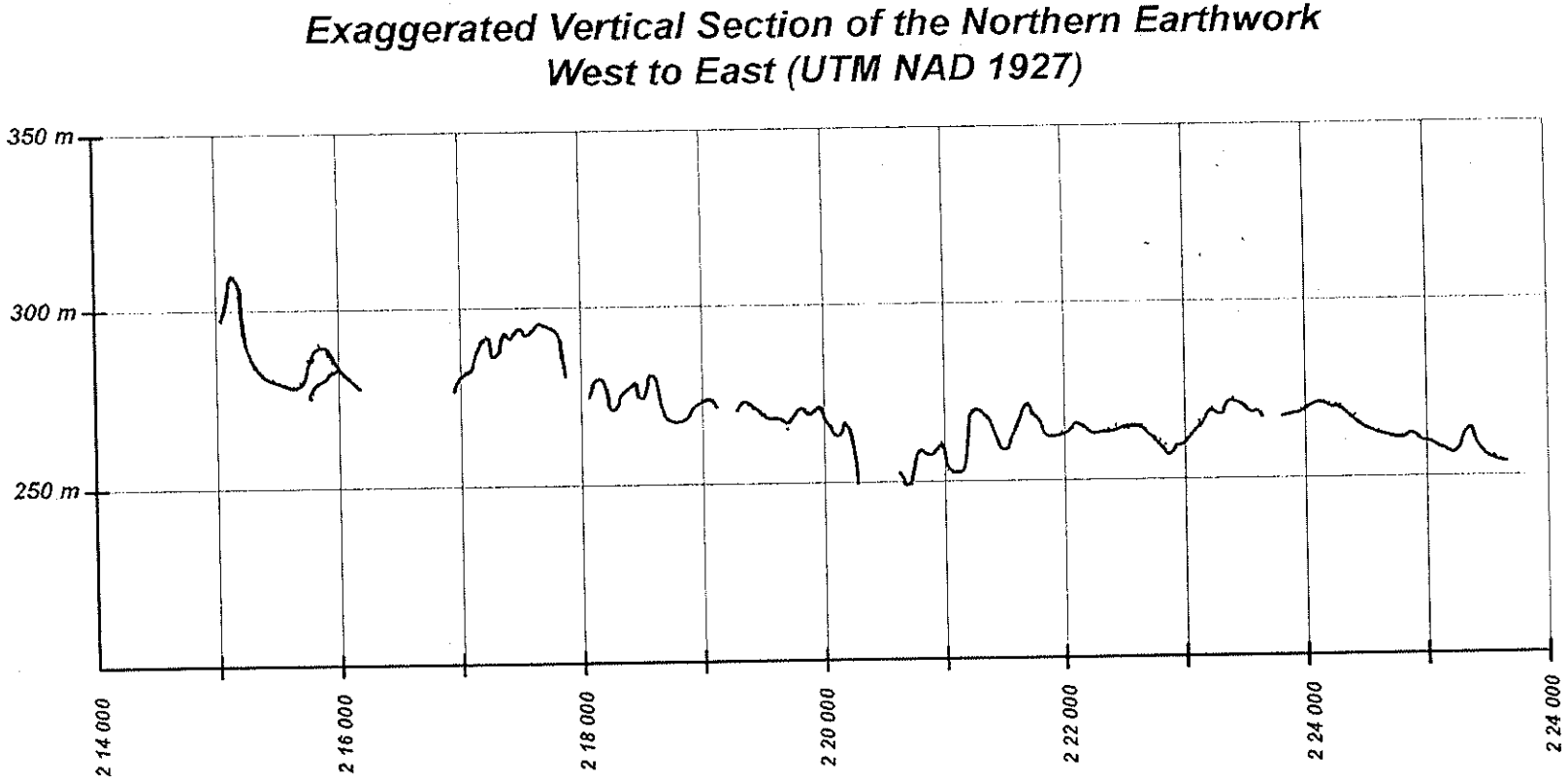


Figure 17 – Longitudinal east-west cross-section of the northern ditch showing abrupt shifts in elevation even over short distances (vertical scale exaggerated).

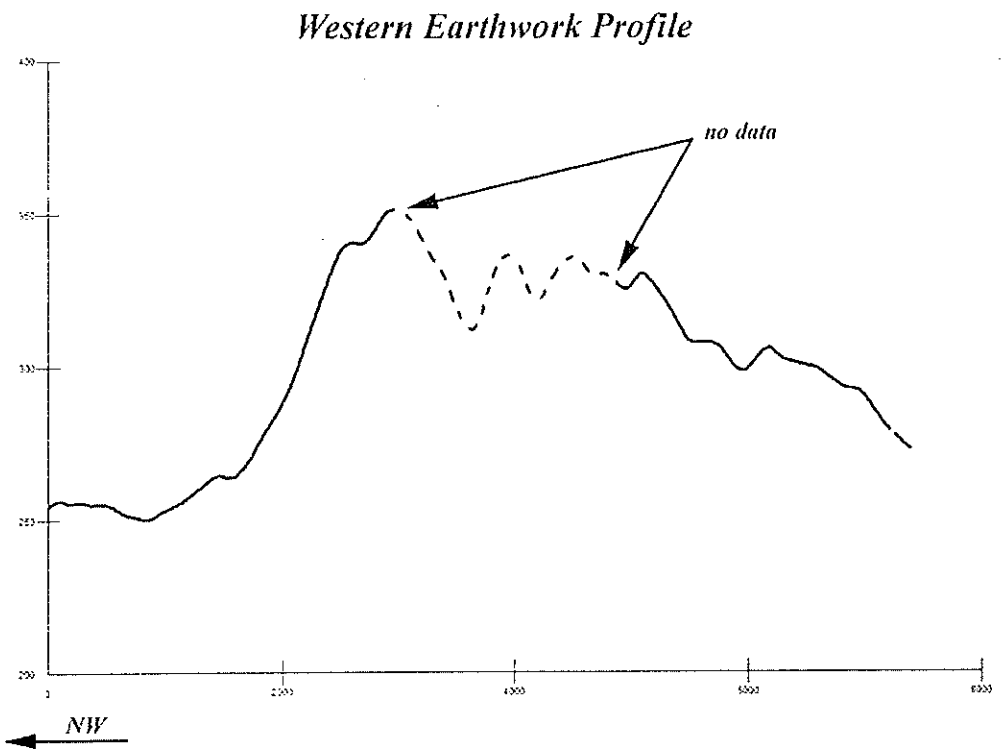


Figure 18 – Longitudinal northeast-southwest cross-section of the western earthwork showing changes in elevation (vertical scale exaggerated).

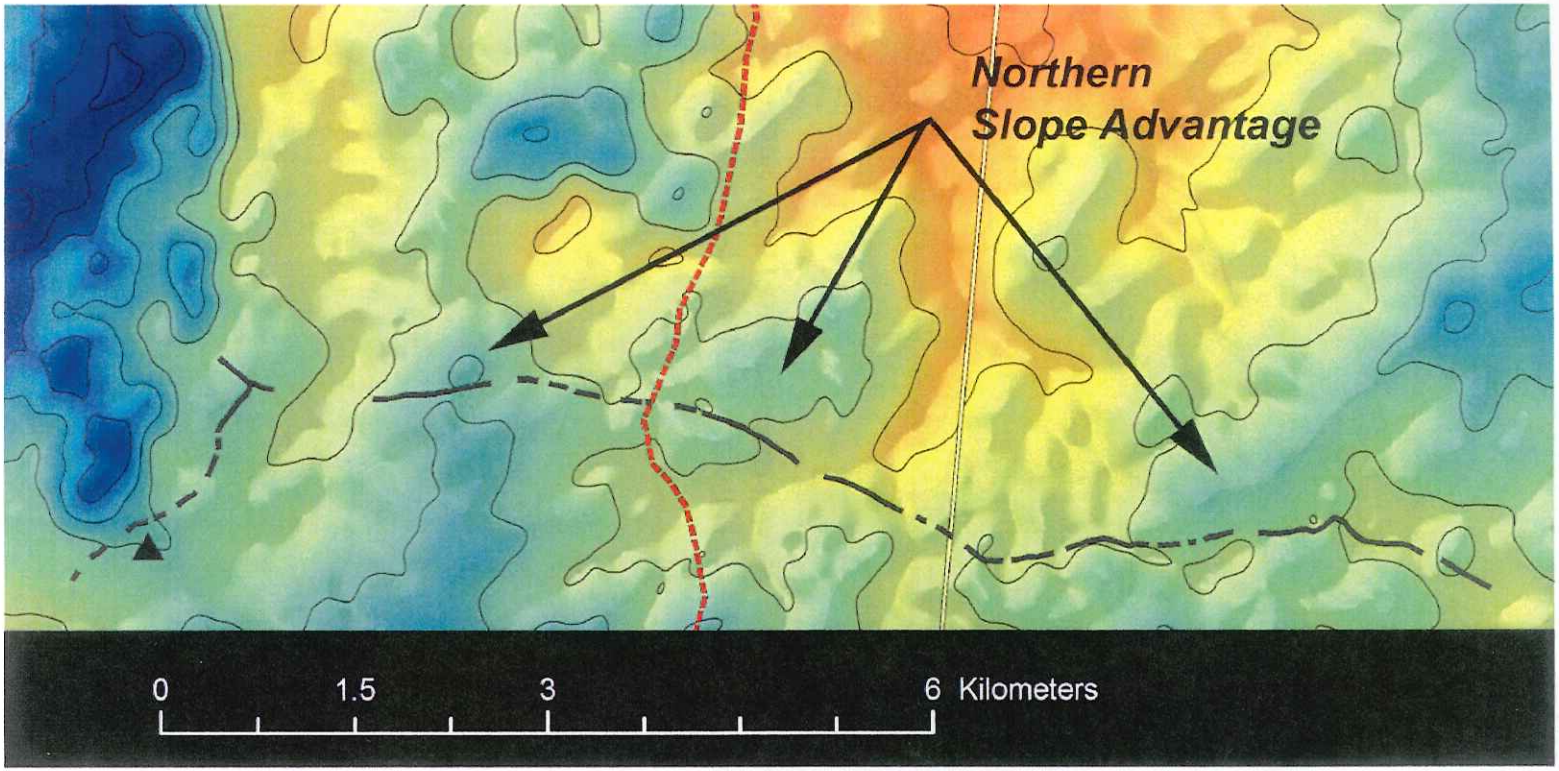


Figure 19 – Three places along the northern earthwork where topographic advantage would lie with attackers.

Figure 20 – Aguada 'El Duende'.

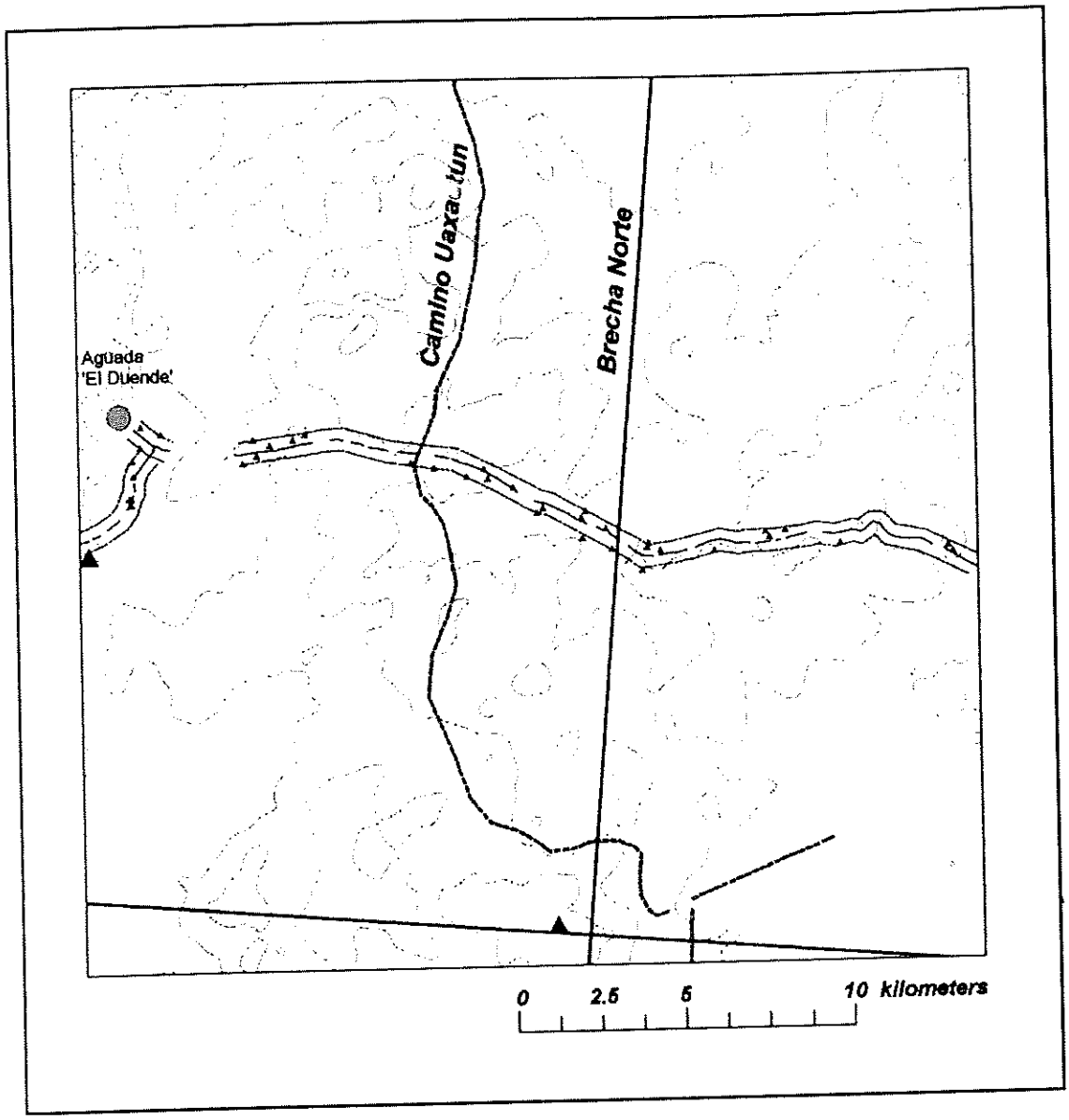


Figure 21 –Corridor of settlement along the northern earthwork

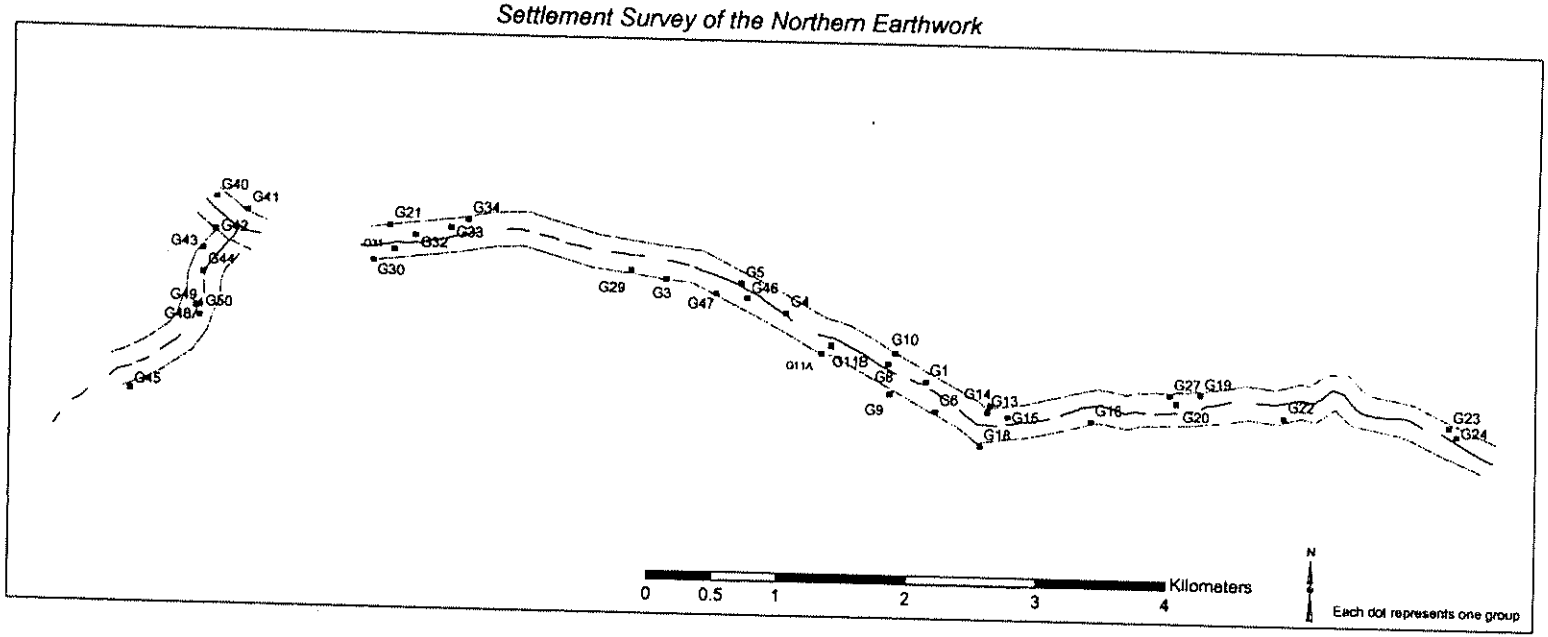


Figure 22 – The survey corridor along the northern earthwork showing locations of all mapped sites.

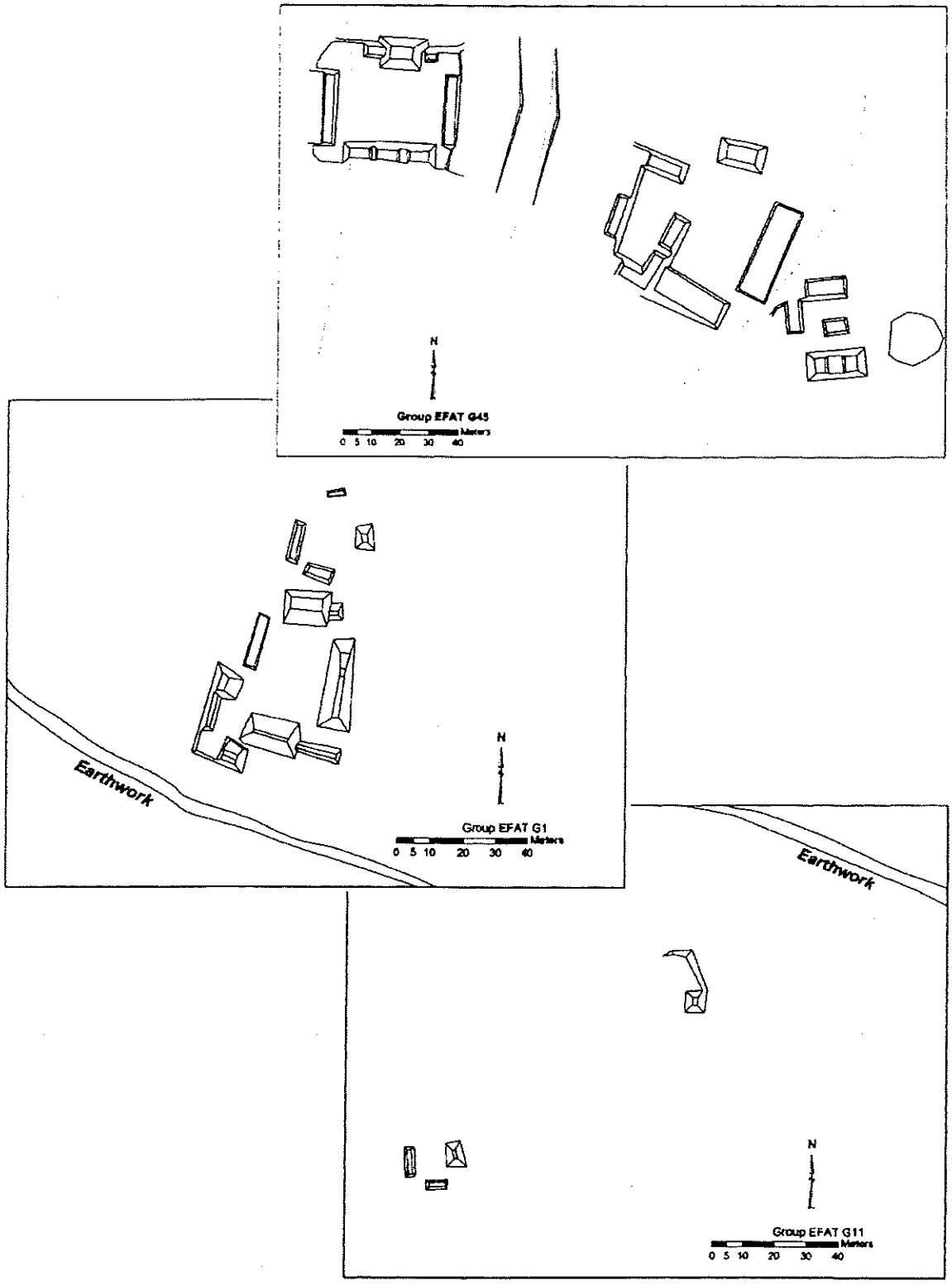
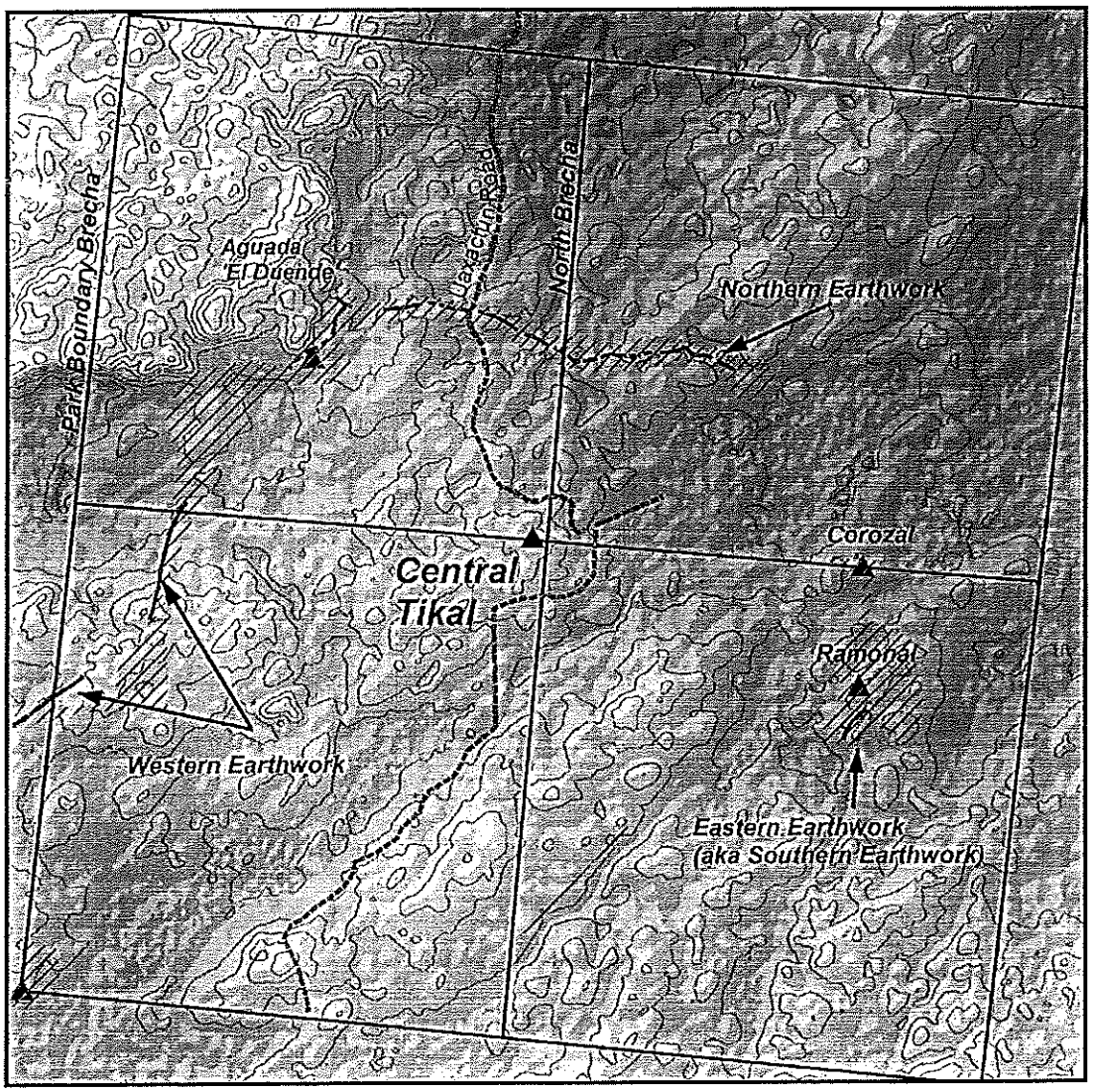


Figure 23 a-c – Representative sites in the settlement zone.



General Tikal Earthwork Map

Coordinate System: UTM
Map Datum: NAD 1927
Zone: 16Q
Contour Interval: 25 meters

UTM Grid North

Elevation

High : 460 meters

Low : 106 meters

Contour data generated from Guatemalan National Maps and NASA data.

Red shading indicates regions of Tikal reconnoitered during the 2003 field season.

2 1 0 2 4 Kilometers

Prepared by Tim Murtha

Figure 24 – Contour map showing all portions of the earthwork; red zones show the approximate areas over which survey crews ranged during the 2003 season.

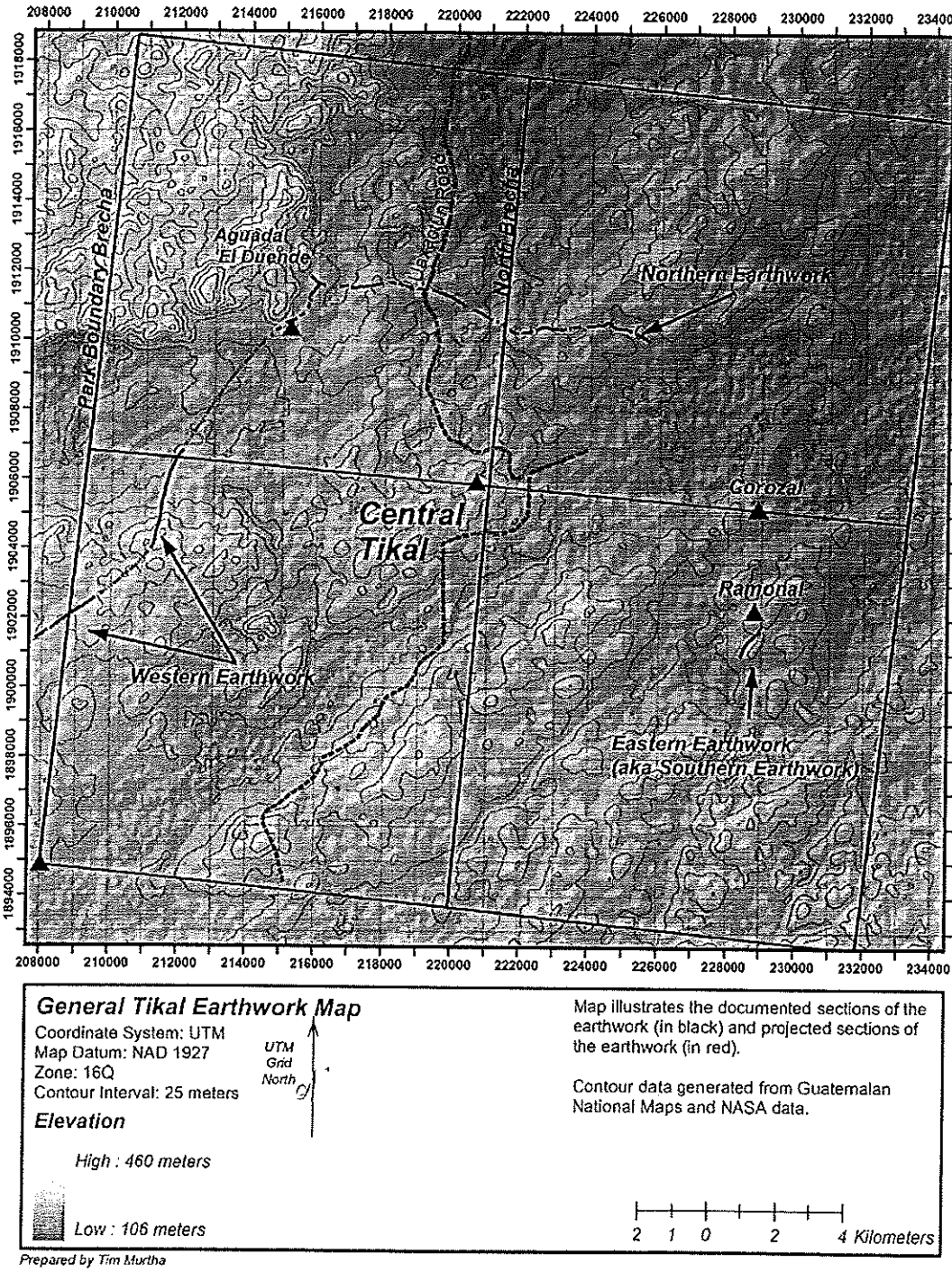


Figure 25 – Map of Tikal epicenter, Uaxactun road, and mapped portions of the earthworks with a superimposed UTM grid. Grid Datum = NAD 1927.

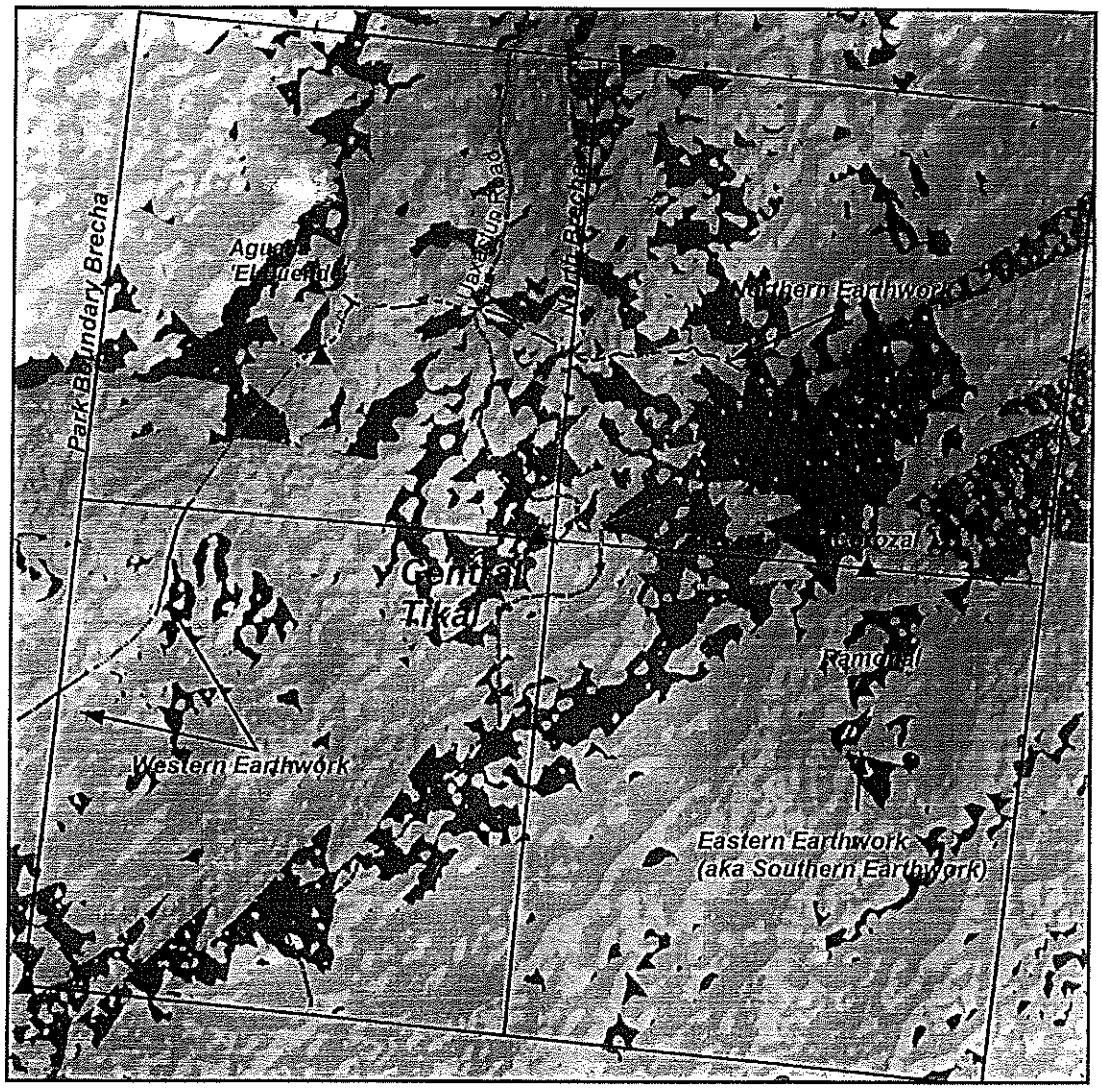
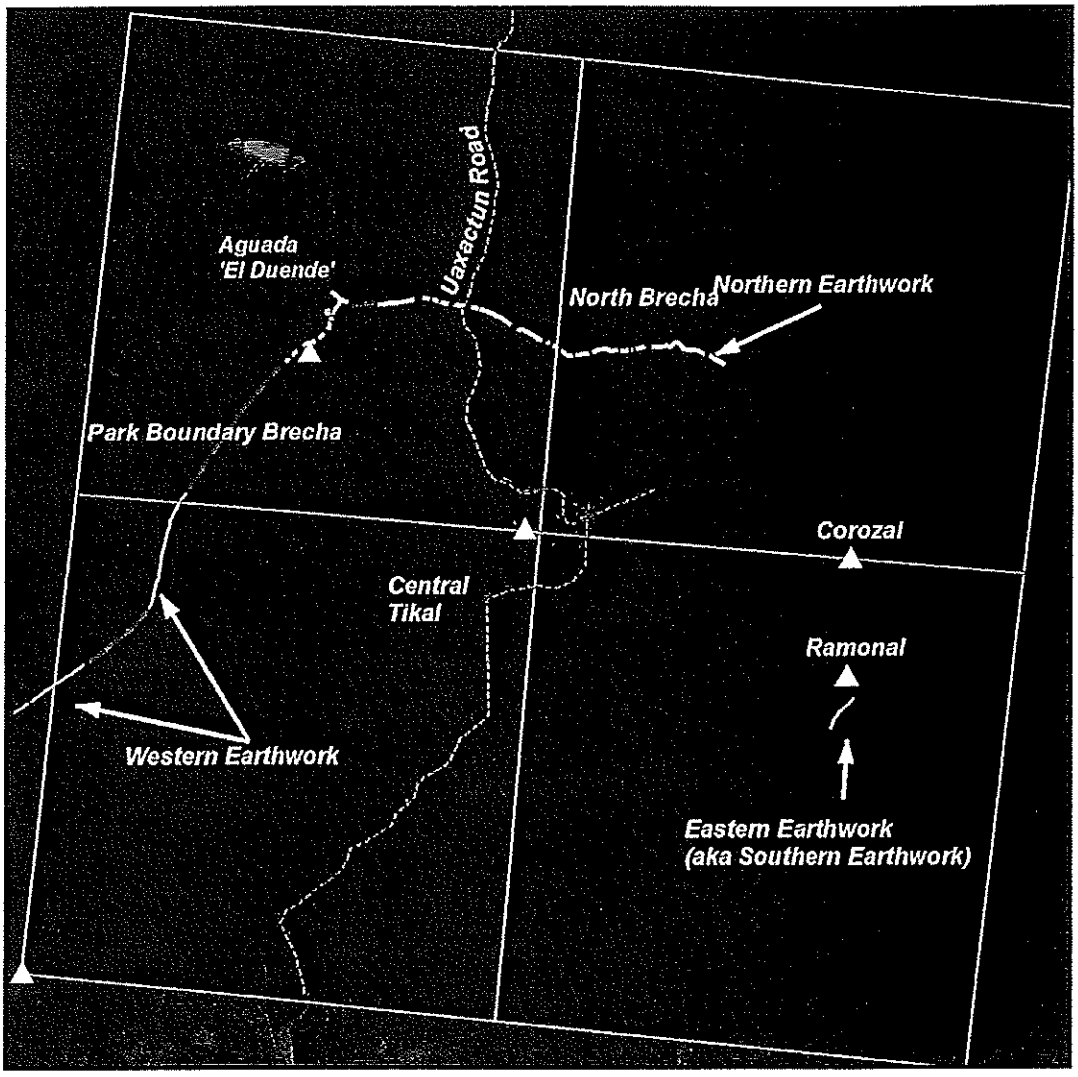


Figure 26 – Visibility map of greater Tikal. Areas visible from the observation point are shaded in blue.



General Tikal Earthwork Map

Coordinate System: UTM
Map Datum: NAD 1927
Zone: 16Q

UTM Grid North

Map illustrates the documented sections of the earthwork (in white) and projected sections of the earthwork (in red).

The features are placed over a LANDSAT - 7 image (Bands 2, 4, and 7) taken on 3/27/2000.

2 1 0 2 4 Kilometers

Prepared by Tim Murtha

Figure 27-- LANDSAT image with superimposed earthworks.

SETTLEMENT ATLAS

This section provides detailed maps of settlement along the northern earthwork in two forms. Table 2 lists all the sites recorded according to their UTM co-ordinates, and also provides information on numbers of structures, numbers of plazas, and their position with regard to the earthwork. Appendix A shows all of the groups located along the northern earthwork and their positions on the UTM grid. It also illustrates each group and its relationship to the nearby sections of the earthwork. Individual maps can be joined together to create a continuous survey transect image. In Appendix B we show each site at a larger scale.

Groups were numbered sequentially as they were found in the field, but there are gaps in the sequence (i.e., there are only 39 groups but numbers go up to 50). These gaps reflect field contingencies—e.g., what seemed to be a group or building was originally given a number, but was later found not to exist on closer inspection, multiple reconnaissance groups skipped numbers so as not to overlap with each other, or what were originally numbered as two groups were collapsed into one. The original field numbers are retained here for consistency with field maps and notes. Two small groups were given the designations 11A and 11B, and these are counted separately in Table 2.

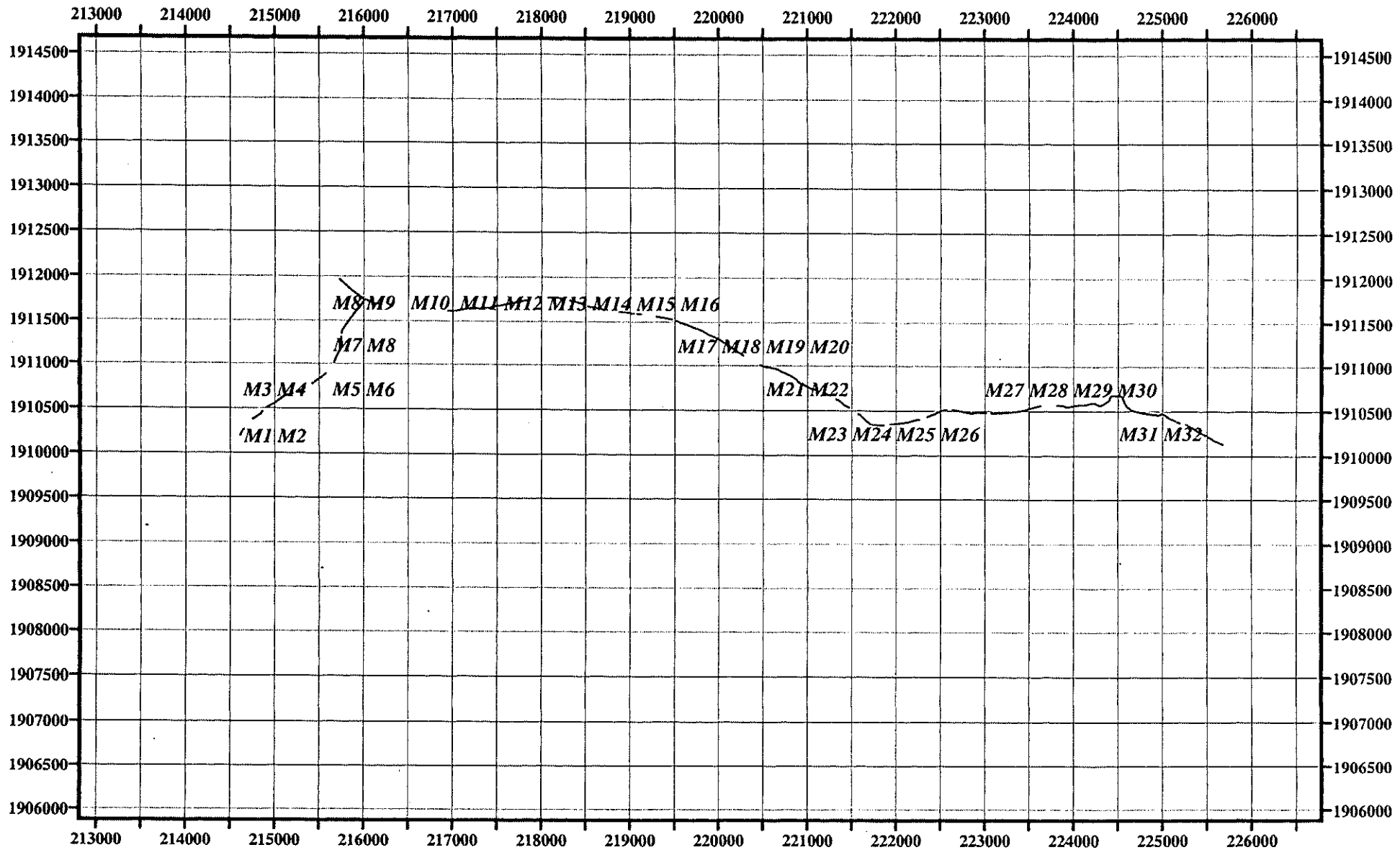
Table 2 – Sites along the northern earthwork and some other large outlying centers in the Tikal Region.

GroupID	Structures	Plazas	North or South*	East UTM	North UTM
G1	12	2	North	221303.689	1910562.263
G4	3	1	North	220217.060	1911059.019
G3	4	1	South	219290.374	1911301.967
G8	4	1	North	221012.445	1910692.608
G10	2	0	North	221062.836	1910774.520
G11A	1	1	South	220567.843	1910817.165
G11B	3	1	South	220493.208	1910760.052
G14	3	1	North	221802.883	1910387.485
G15	6	1	North	221939.324	1910300.958
G18	2	1	South	221723.845	1910066.709
G19	4	1	North	223422.063	1910504.333
G20	3	1	North	223233.102	1910433.736
G31	3	1	South	217200.890	1911488.413
G30	4	1	South	217041.223	1911399.197
G29	3	1	South	219020.343	1911369.035
G27	2	1	North	223185.584	1910495.425
G33	2	1	North	217631.925	1911663.521
G40	2	1	North	215830.423	1911858.200
G41	5	1	North	216070.008	1911764.189
G42	1	0	North	215824.316	1911615.581
G43	4	1	North	215731.499	1911463.039
G44	3	1	North	215738.042	1911279.894
G45	21	5	South	215189.217	1910376.687
G46	5	1	South	219914.339	1911167.685
G47	4	1	South	219679.387	1911197.780
G48	4	1	North	215683.033	1911018.697
G49	2	1	South	215713.036	1911020.941
G50	2	1	South	215714.718	1910943.551
G5	2	0	North	219868.611	1911281.323
G6	2	1	South	221377.576	1910331.651
G9	3	1	South	221024.734	1910455.521
G13	1	0	North	221779.216	1910335.404
G32	9	2	North	217357.829	1911605.679
G34	9	2	North	217765.162	1911726.782
G16	3	1	South	222580.608	1910280.632
G22	4	1	South	224067.100	1910340.471
G24	4	1	North	225393.261	1910216.255
G23	4	1	North	225337.429	1910288.296
G21	4	1	North	217163.776	1911673.629
*SW Group	14	3	-	208034.390	1894934.050
Corozal	-	-	-	228891.355	1905305.910
Ramonal	-	-	-	228843.053	1902262.860

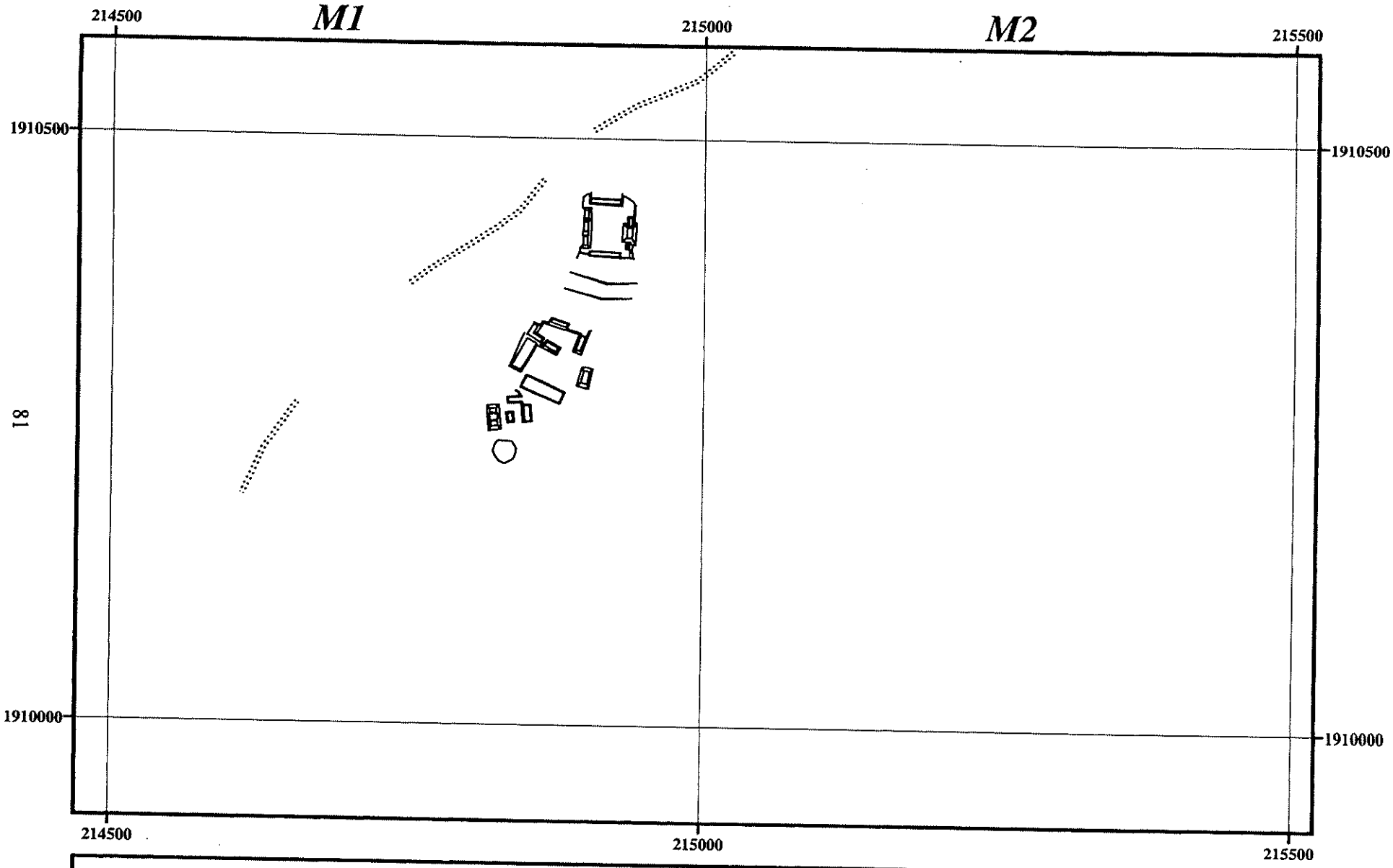
*North indicates "outside" the earthwork, while south indicates "inside".

Appendix A.

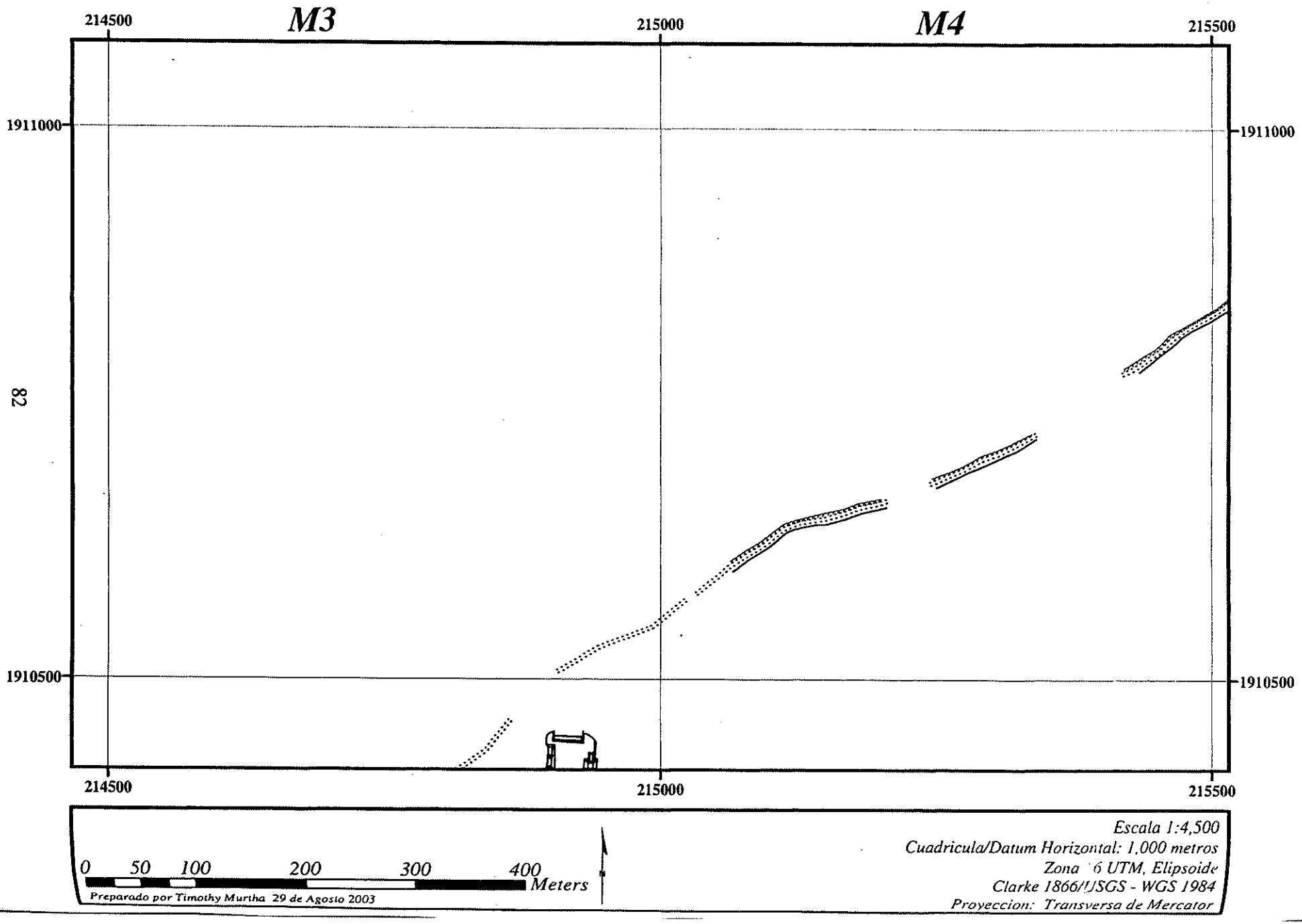
Atlas del Proyecto EFAT



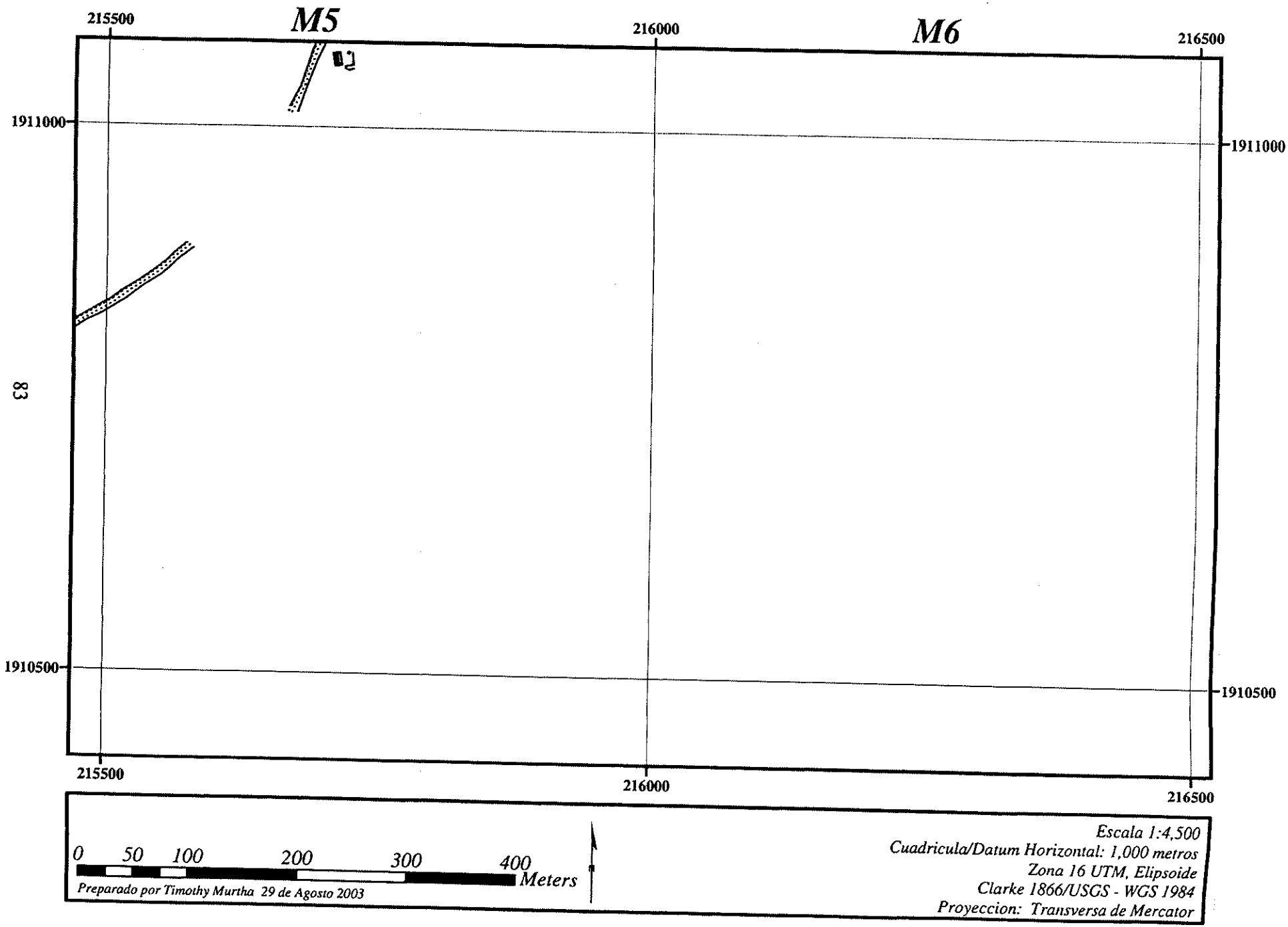
Atlas del Proyecto EFAT



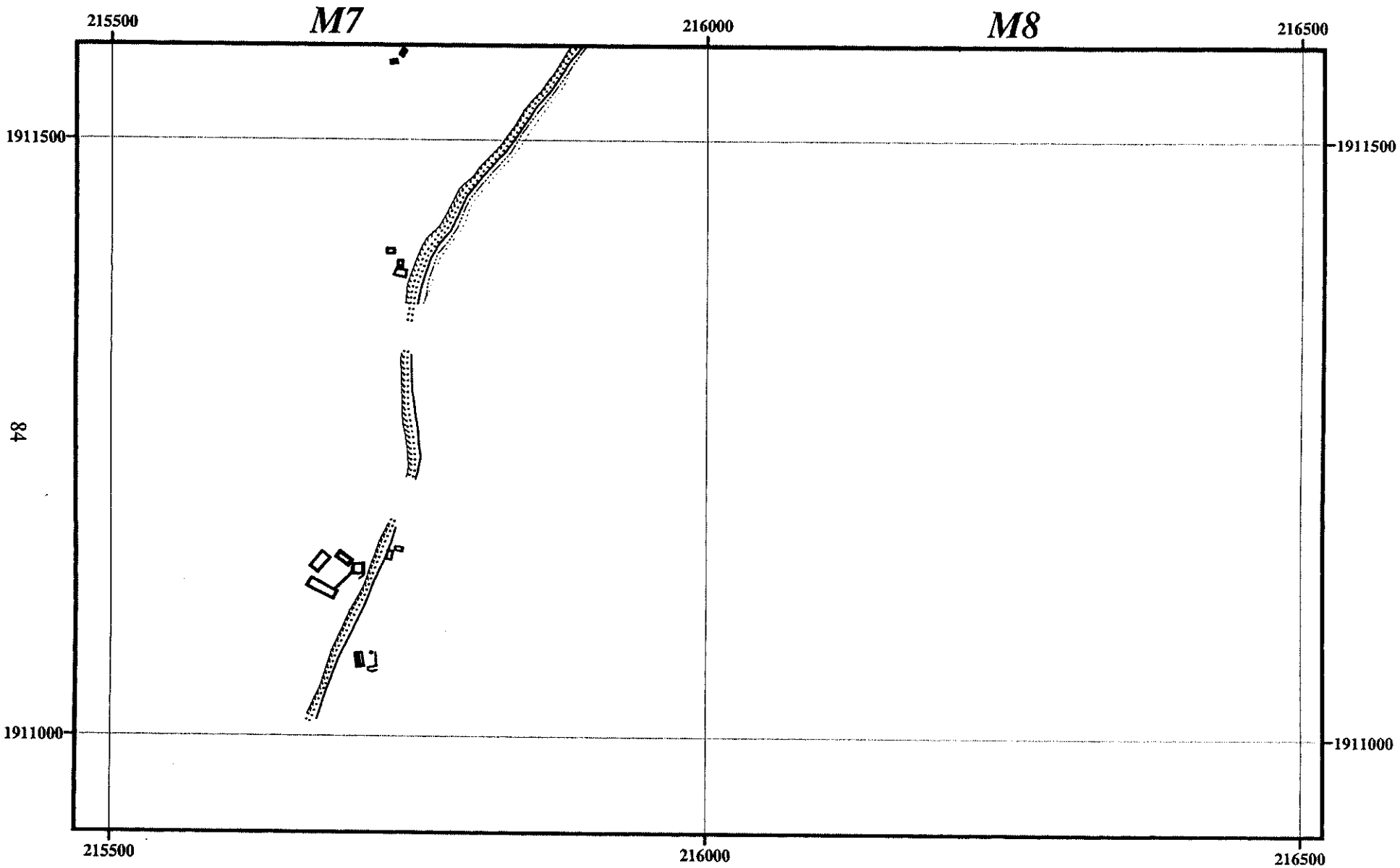
Atlas del Proyecto EFAT



Atlas del Proyecto EFAT



Atlas del Proyecto EFAT

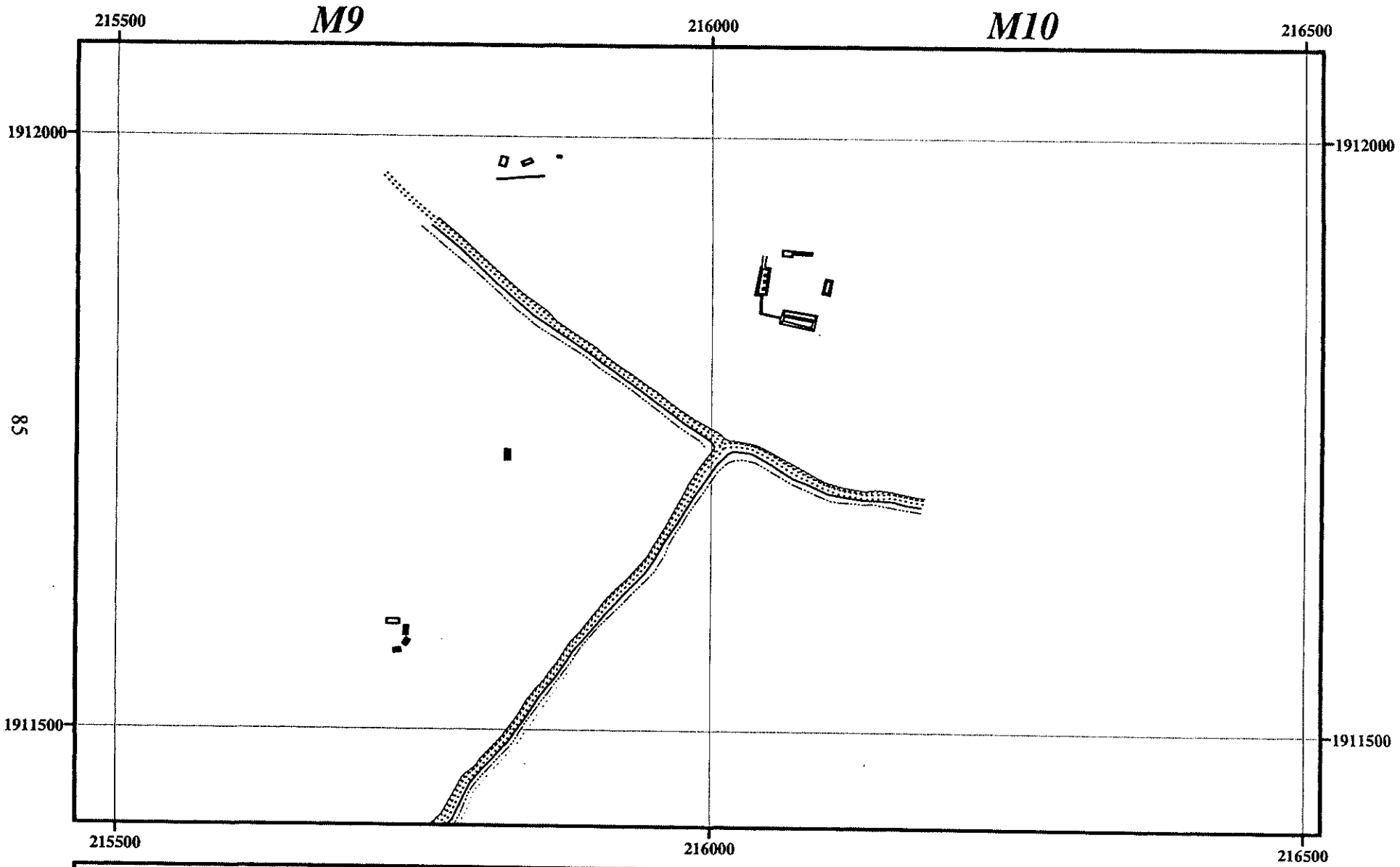


0 50 100 200 300 400 Meters

Preparado por Timothy Murtha 29 de Agosto 2003

Escala 1:4,500
Cuadricula/Datum Horizontal: 1,000 metros
Zona 16 UTM, Elipsoide
Clarke 1866/USGS - WGS 1984
Proyeccion: Transversa de Mercator

Atlas del Proyecto EFAT

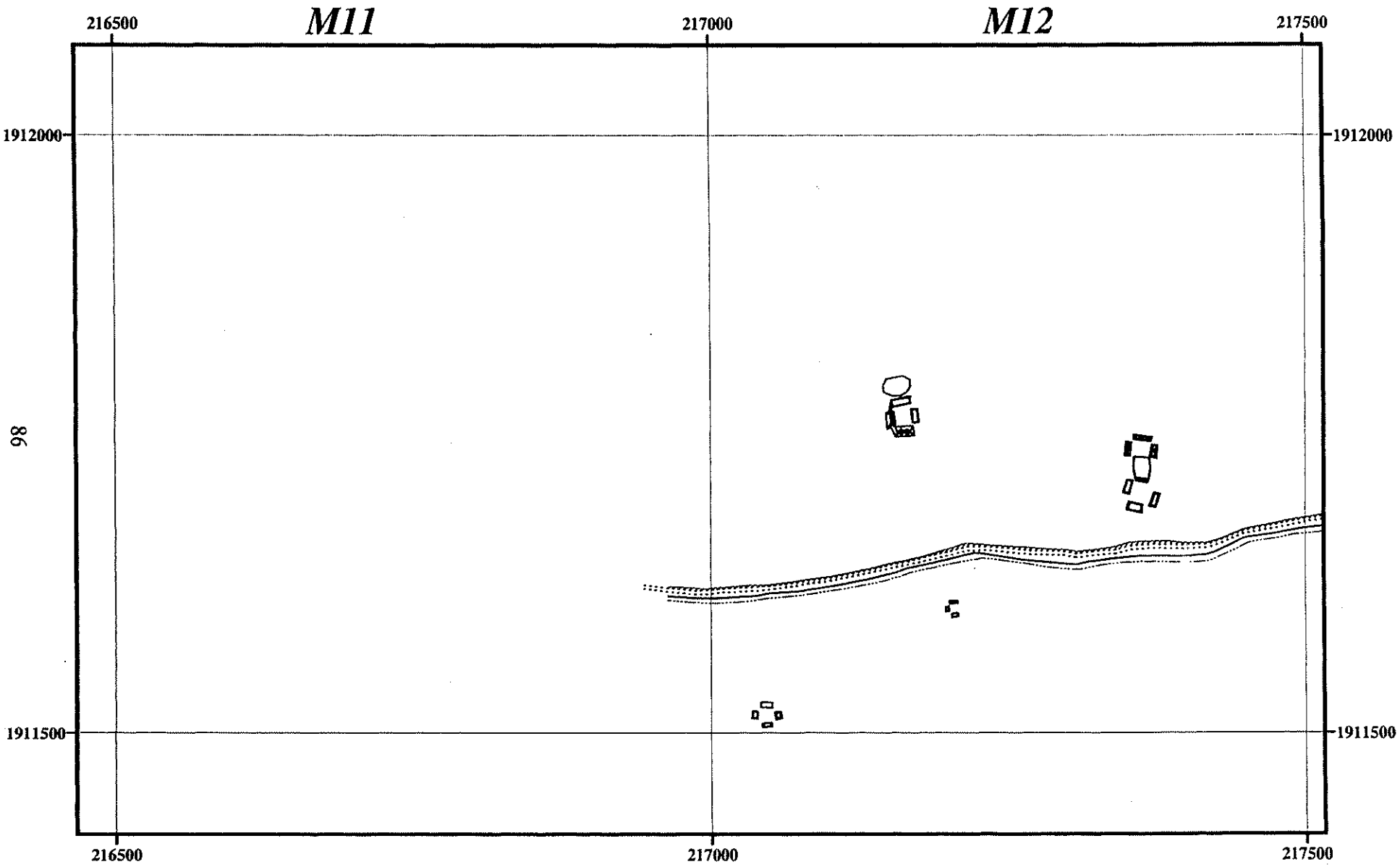


0 50 100 200 300 400 Meters

Preparado por Timothy Murtha 29 de Agosto 2003

Escala 1:4,500
Cuadricula/Datum Horizontal: 1,000 metros
Zona 16 UTM, Elipsoide
Clarke 1866/USGS - WGS 1984
Proyeccion: Transversa de Mercator

Atlas del Proyecto EFAT



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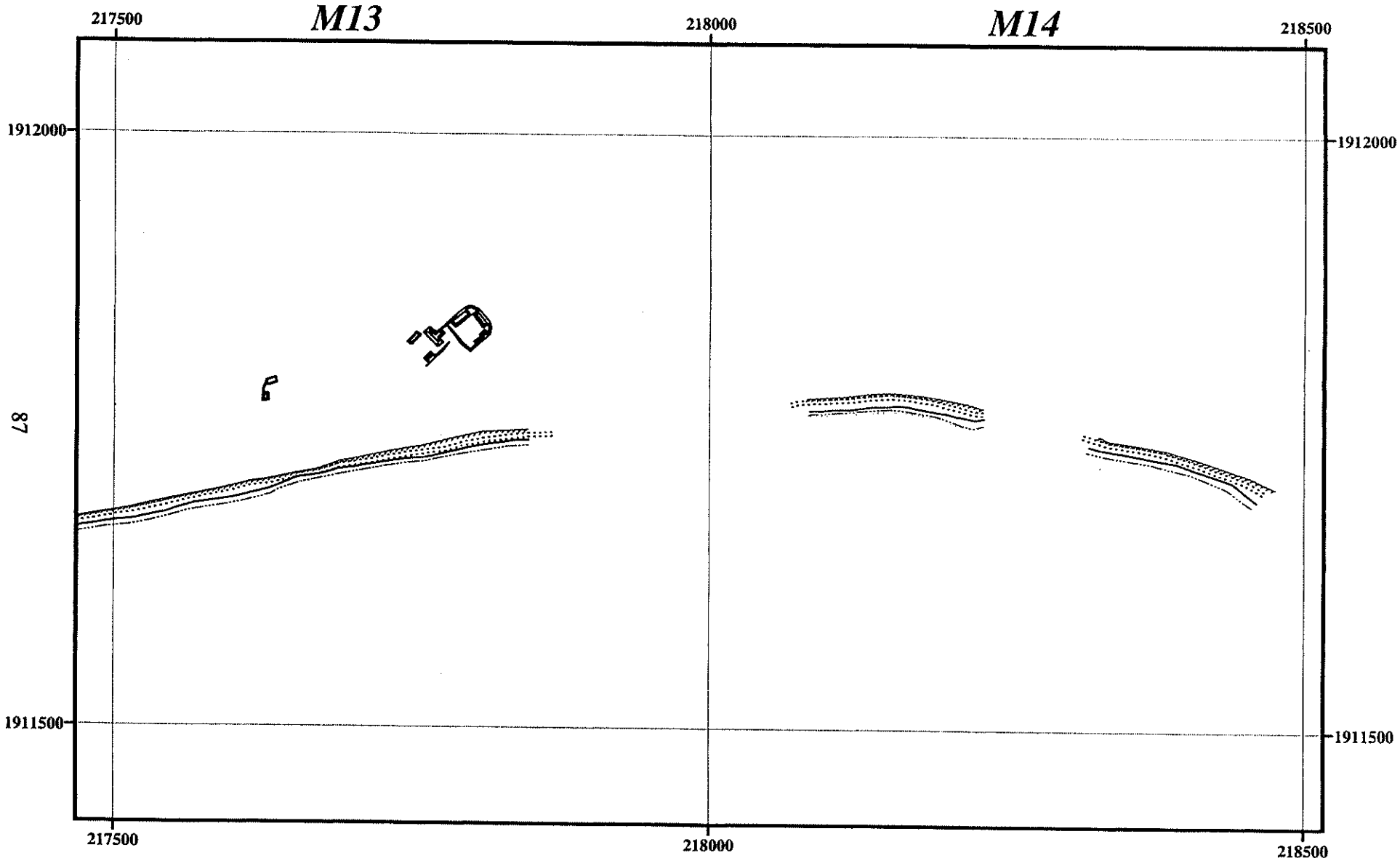

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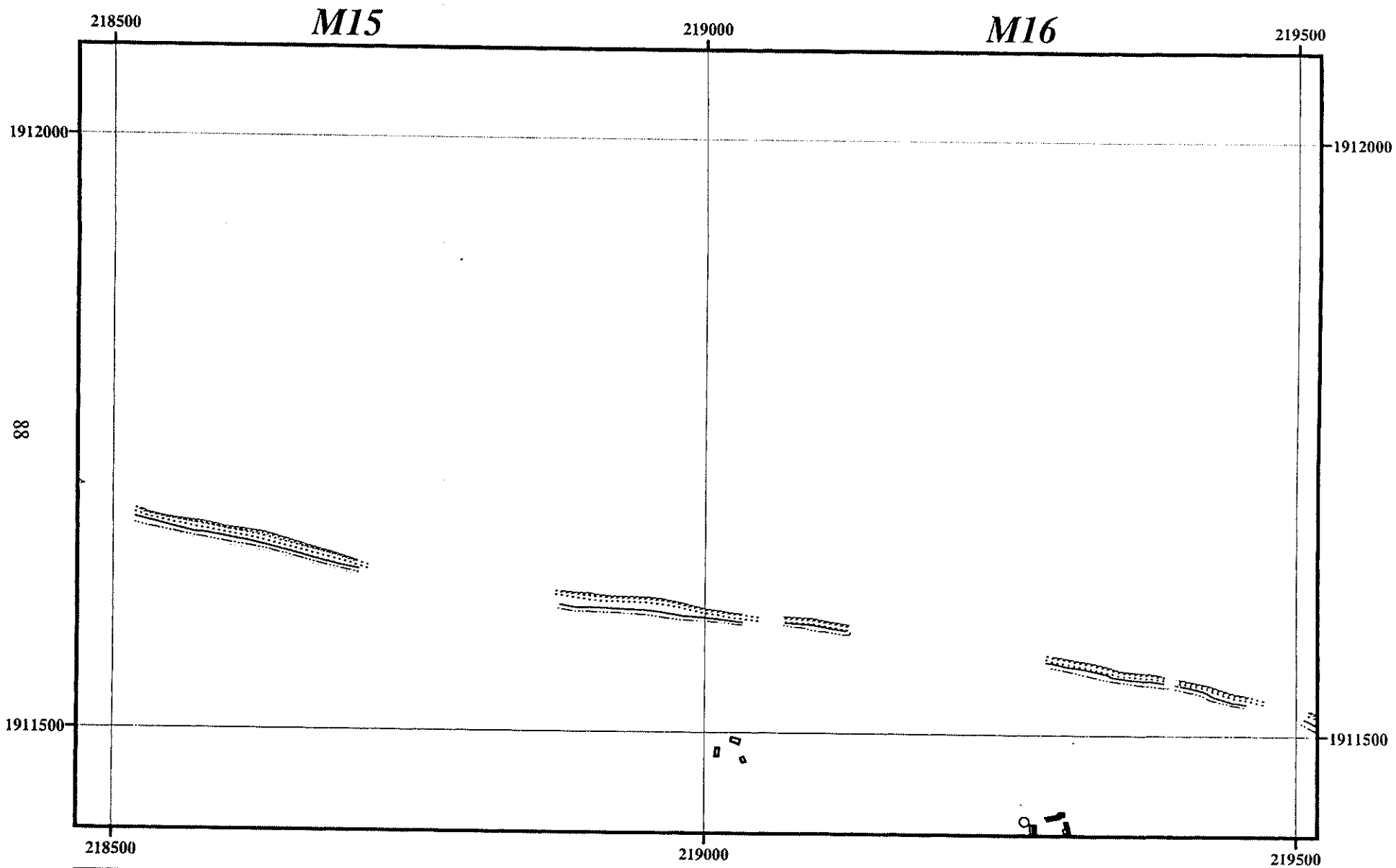
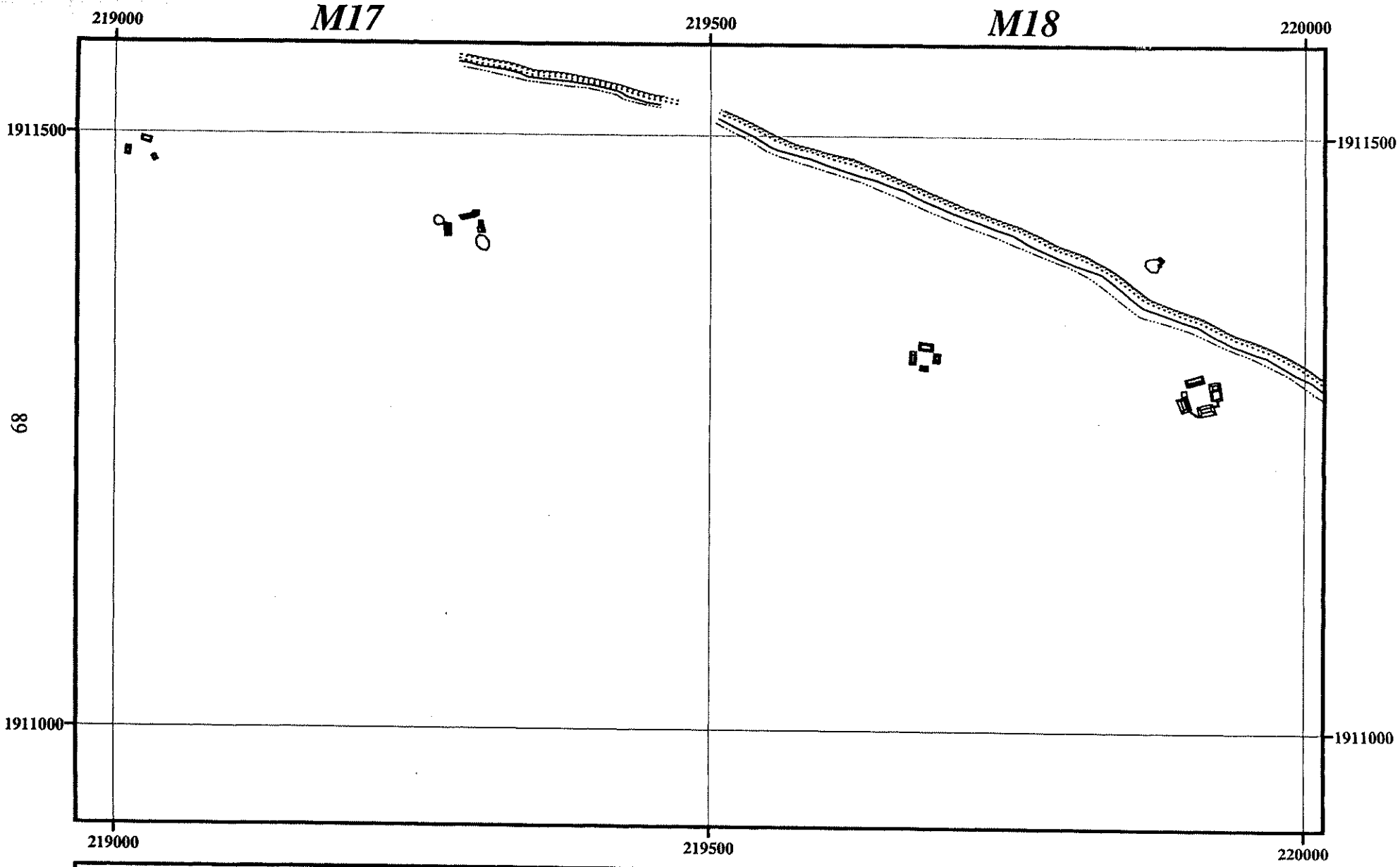


Atlas del Proyecto EFAT

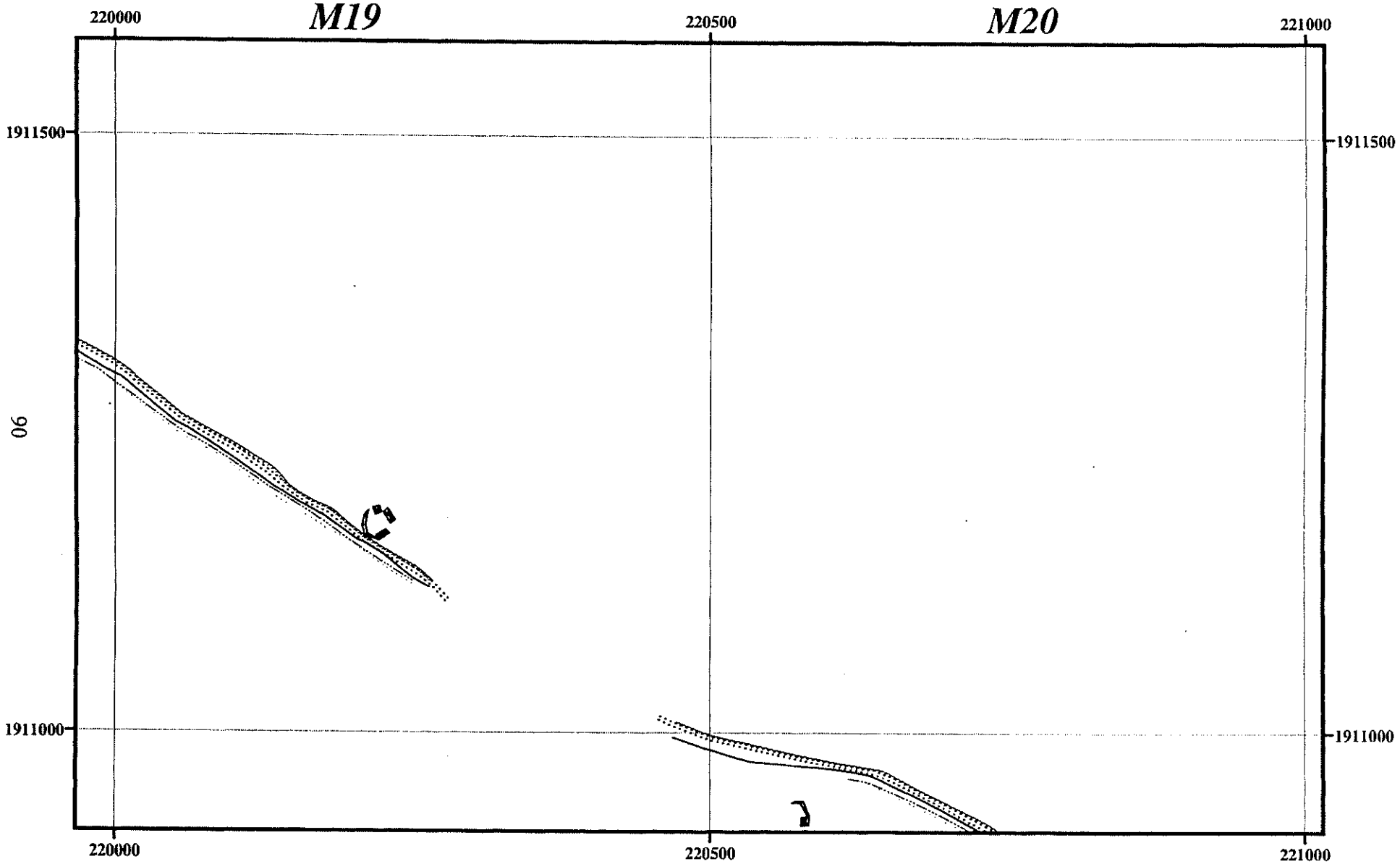


0 50 100 200 300 400 Meters

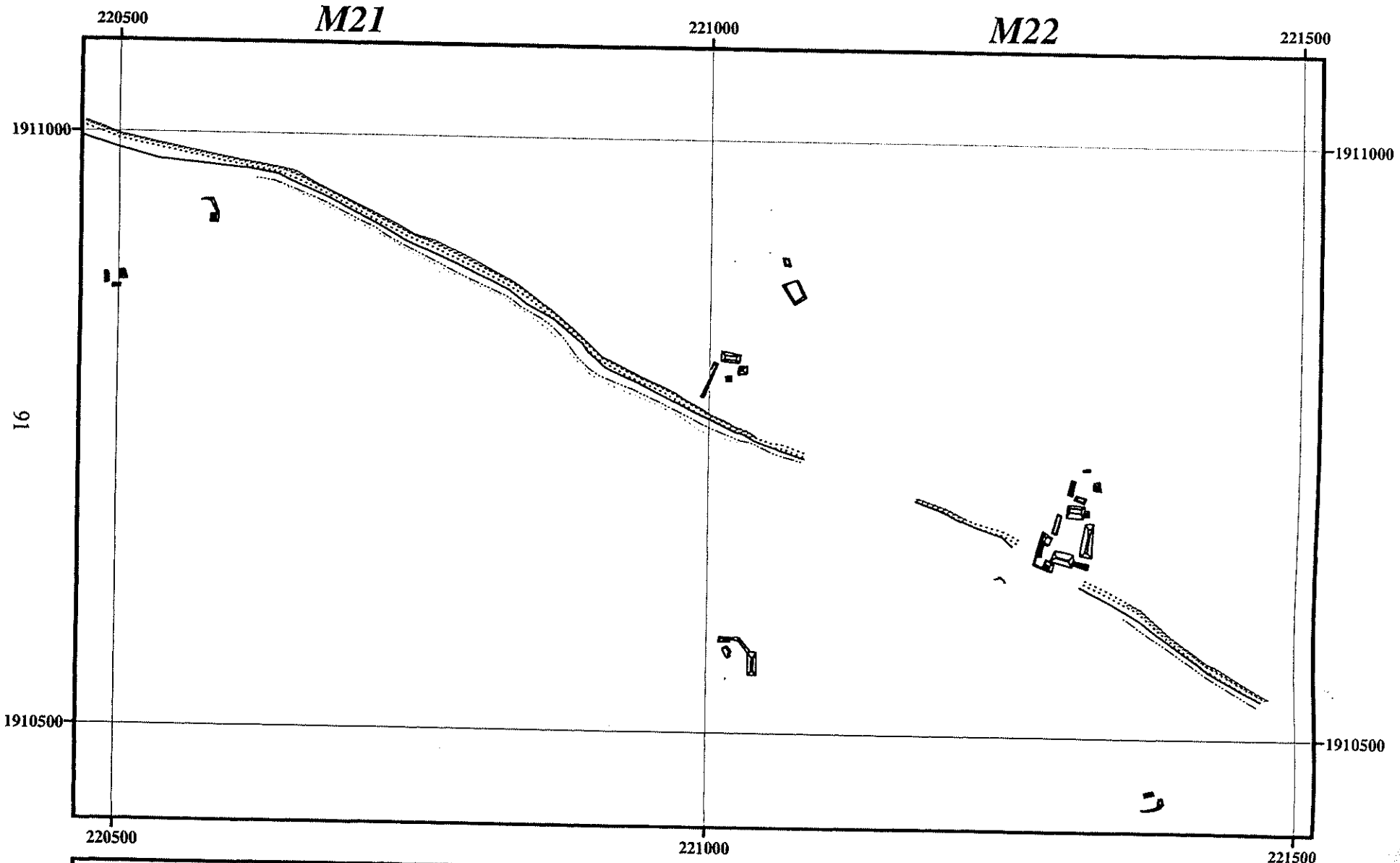
Preparado por Timothy Murtha 29 de Agosto 2003

Escala 1:4,500
Cuadricula/Datum Horizontal: 1,000 metros
Zona 16 UTM, Elipsoide
Clarke 1866/USGS - WGS 1984
Proyeccion: Transversa de Mercator

Atlas del Proyecto EFAT



Atlas del Proyecto EFAT



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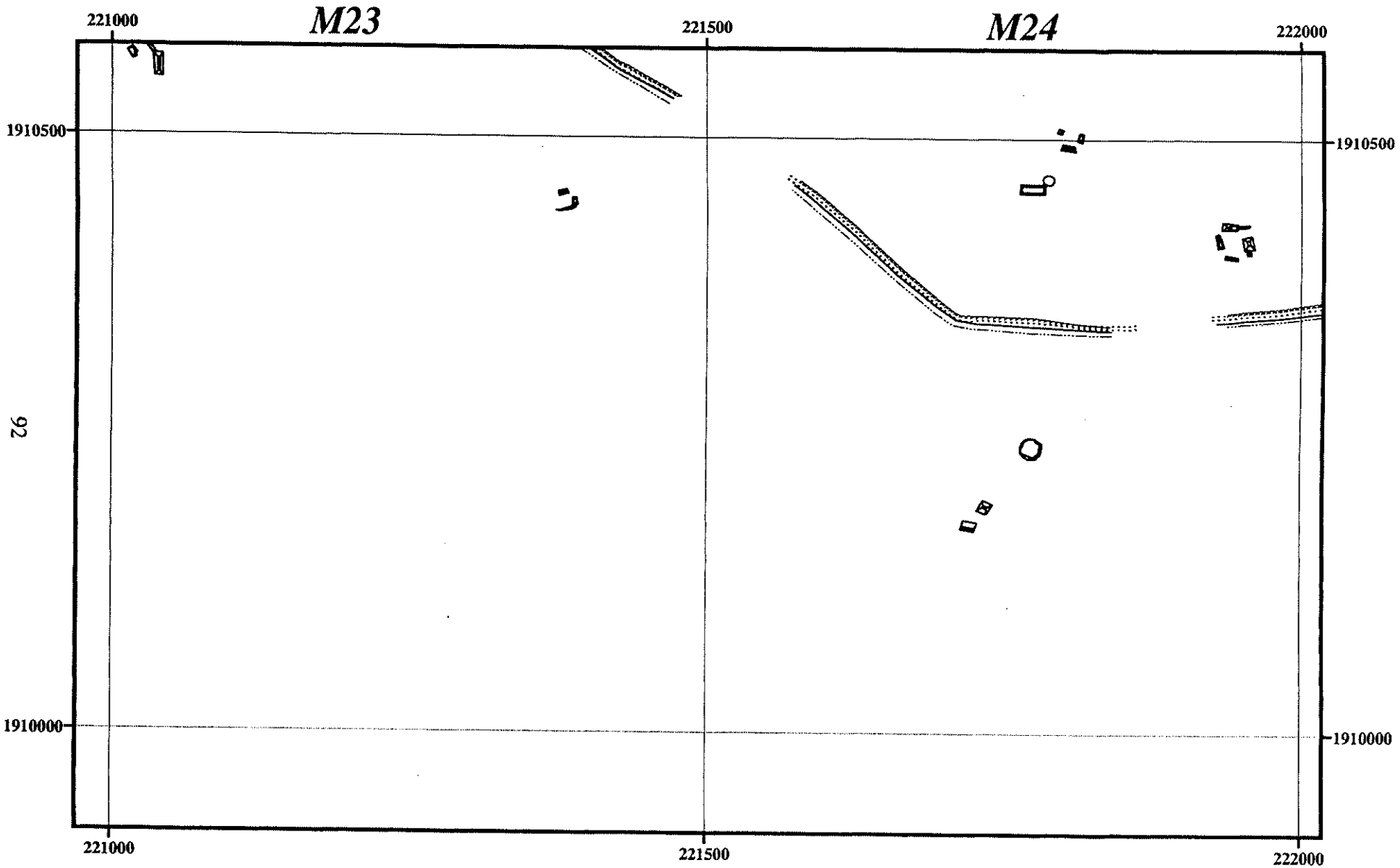
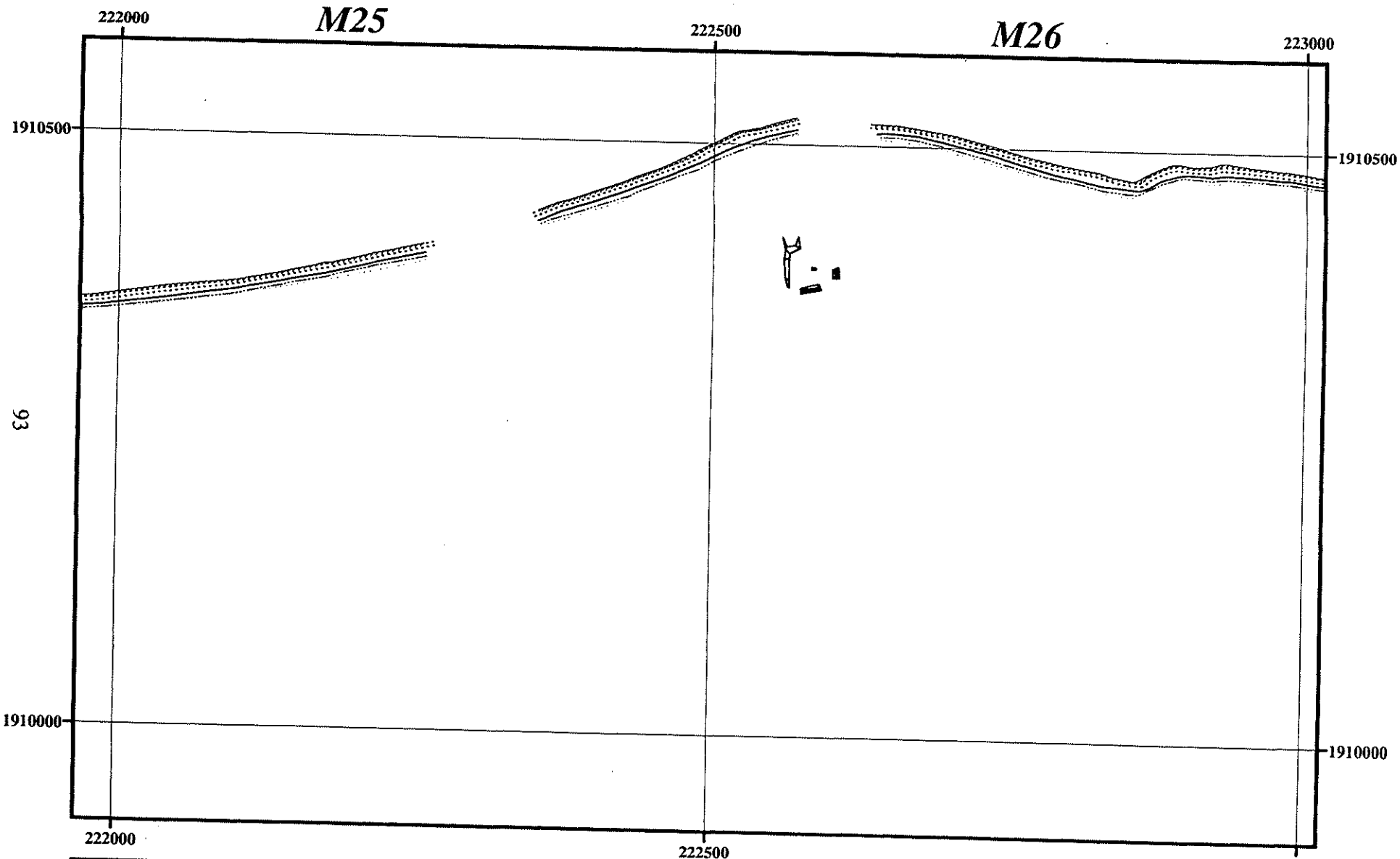


Meters
Preparado por Timothy Murtha 29 de Agosto 2003
Proyeccion: Transversa de Mercator

Atlas del Proyecto EFAT

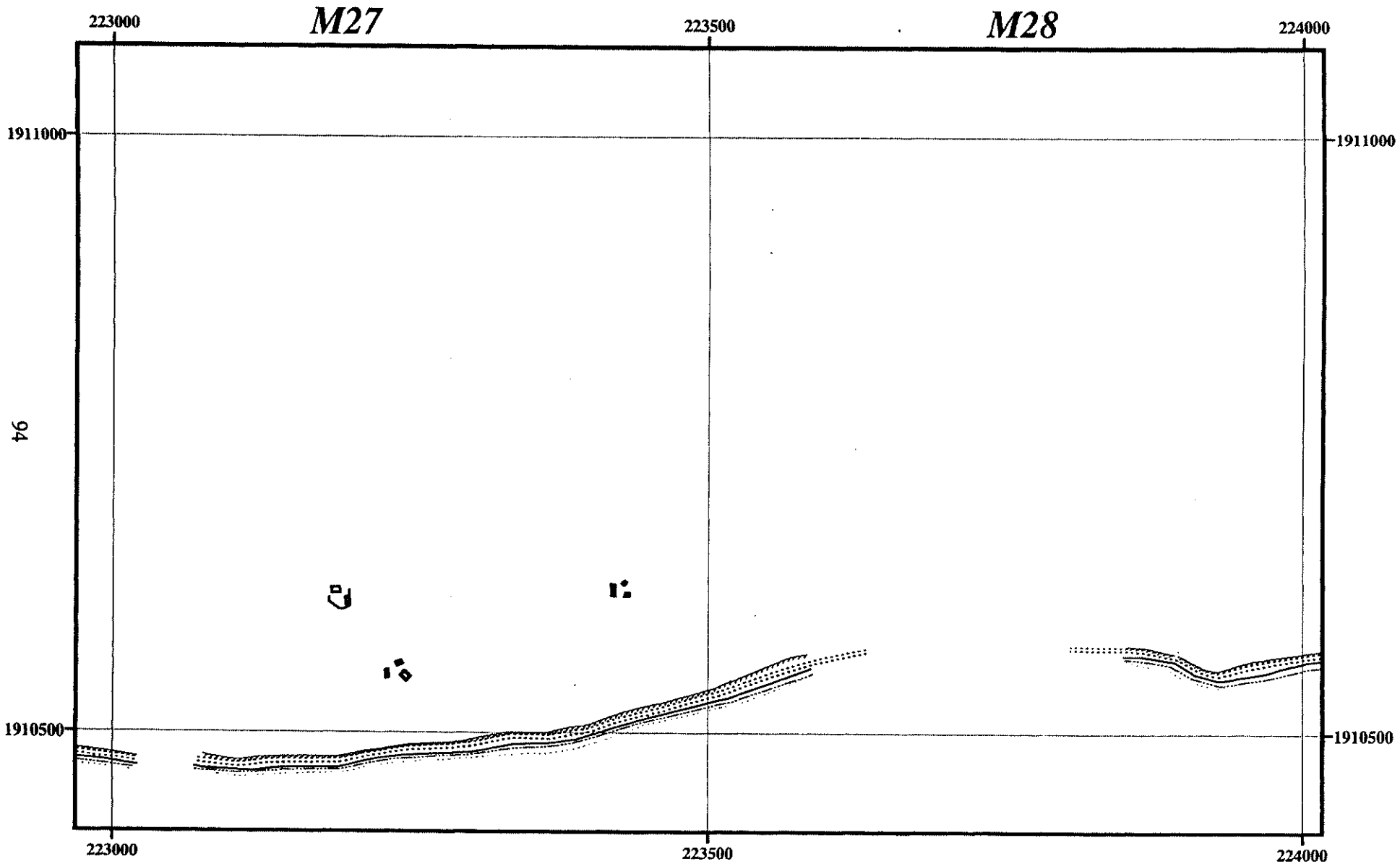


0 50 100 200 300 400 Meters

Preparado por Timothy Murtha 29 de Agosto 2003

Escala 1:4,500
Cuadricula/Datum Horizontal: 1,000 metros
Zona 16 UTM, Elipsoide
Clarke 1866/USGS - WGS 1984
Proyeccion: Transversa de Mercator

Atlas del Proyecto EFAT



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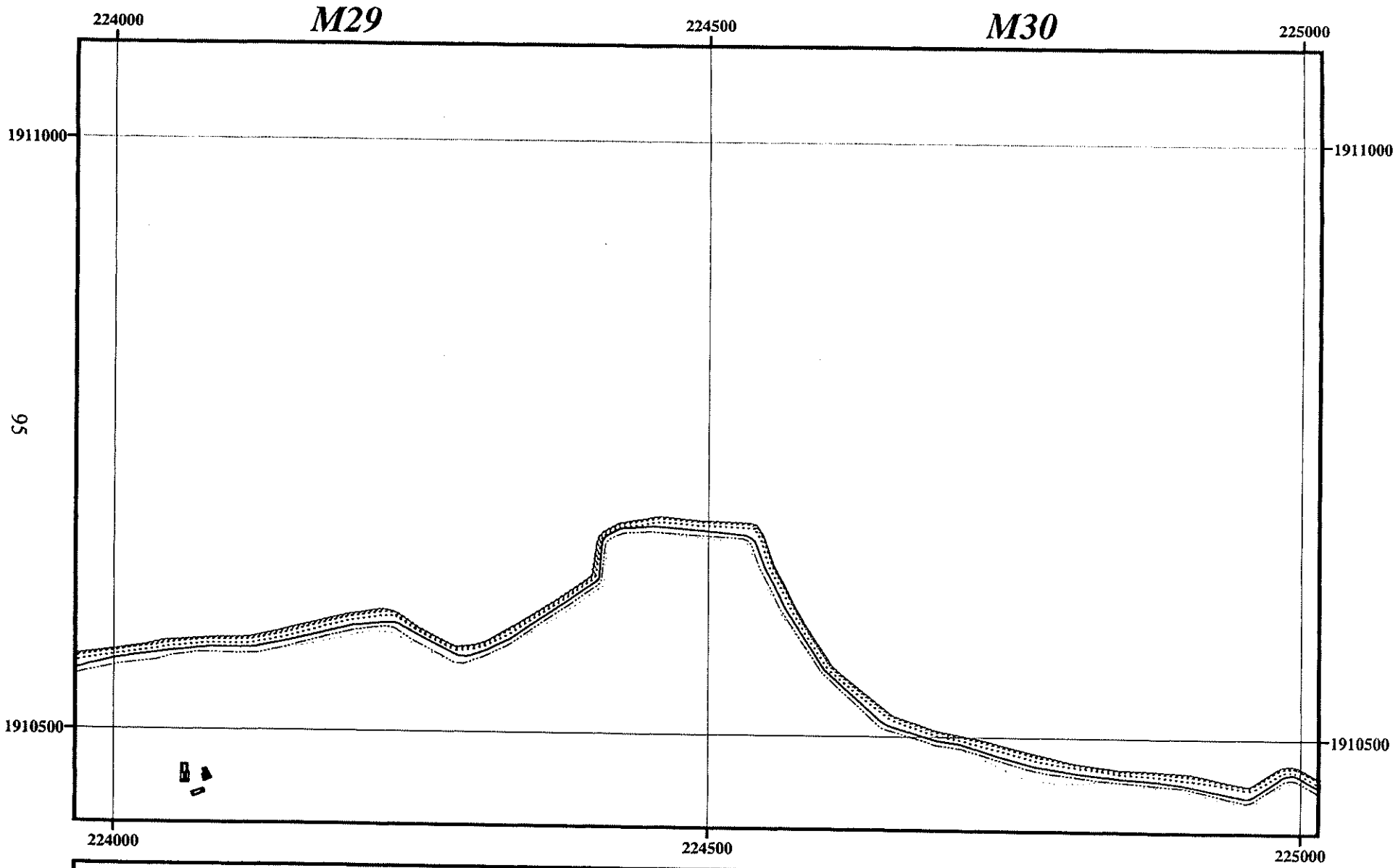

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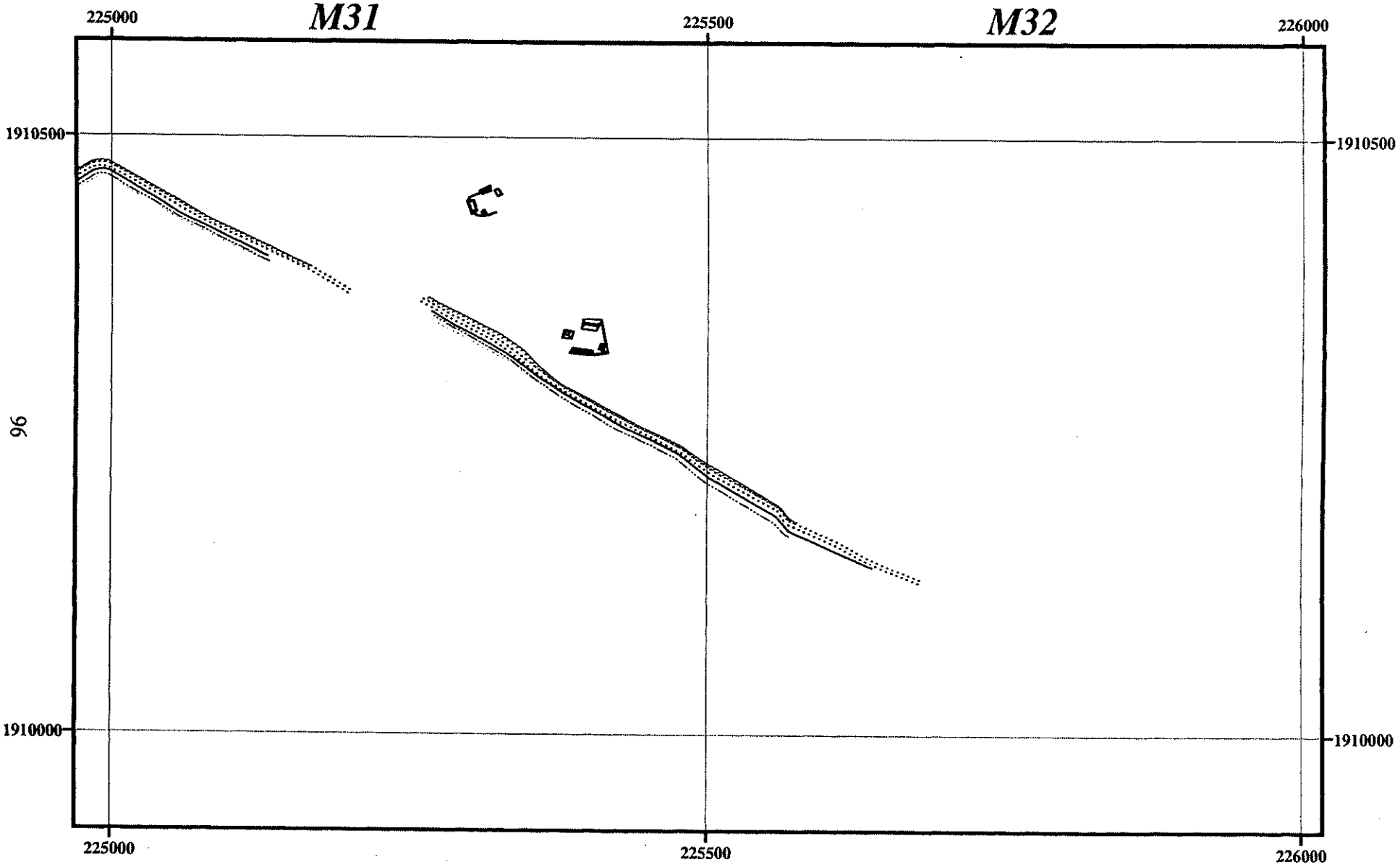
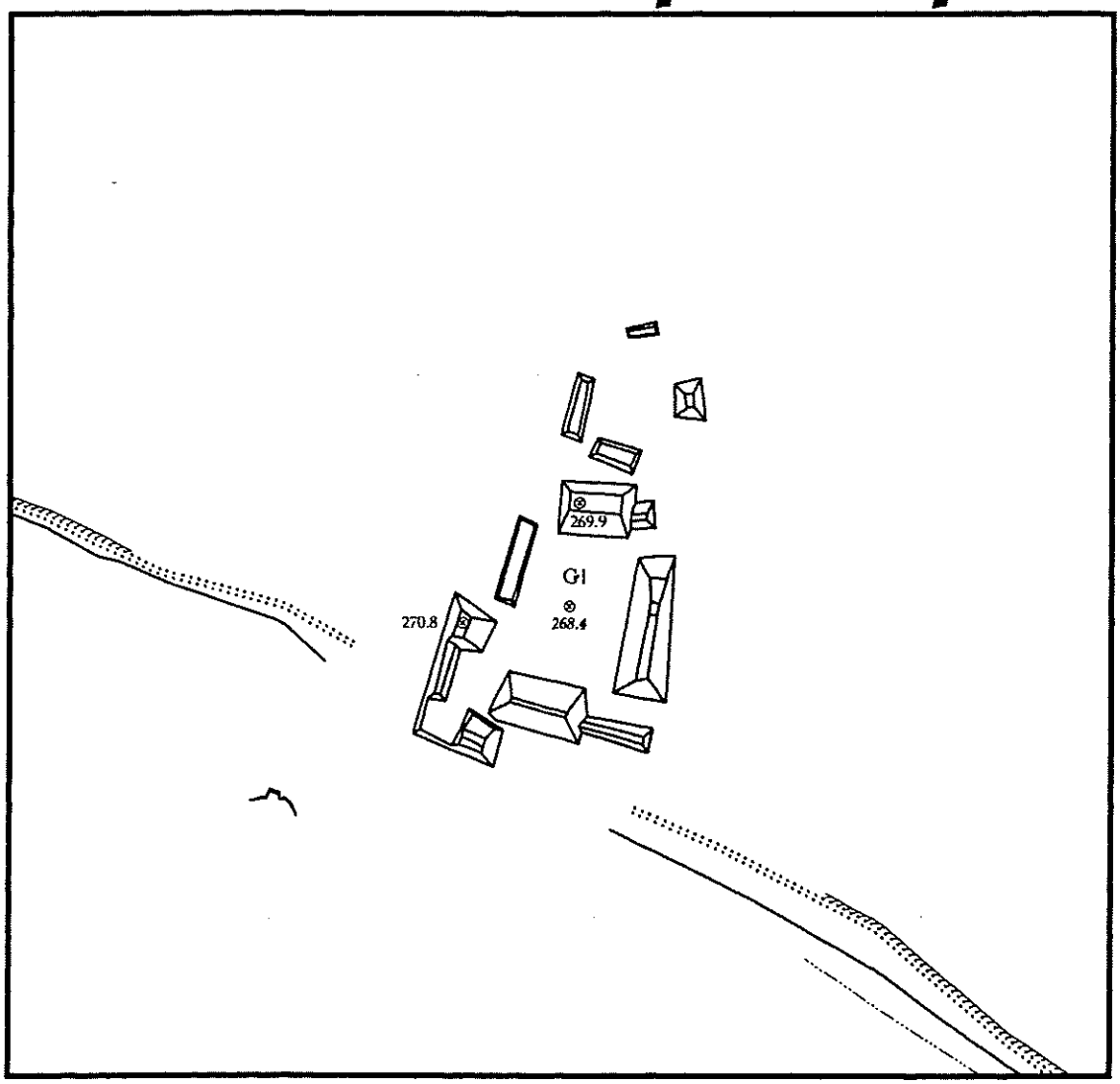


Appendix B.

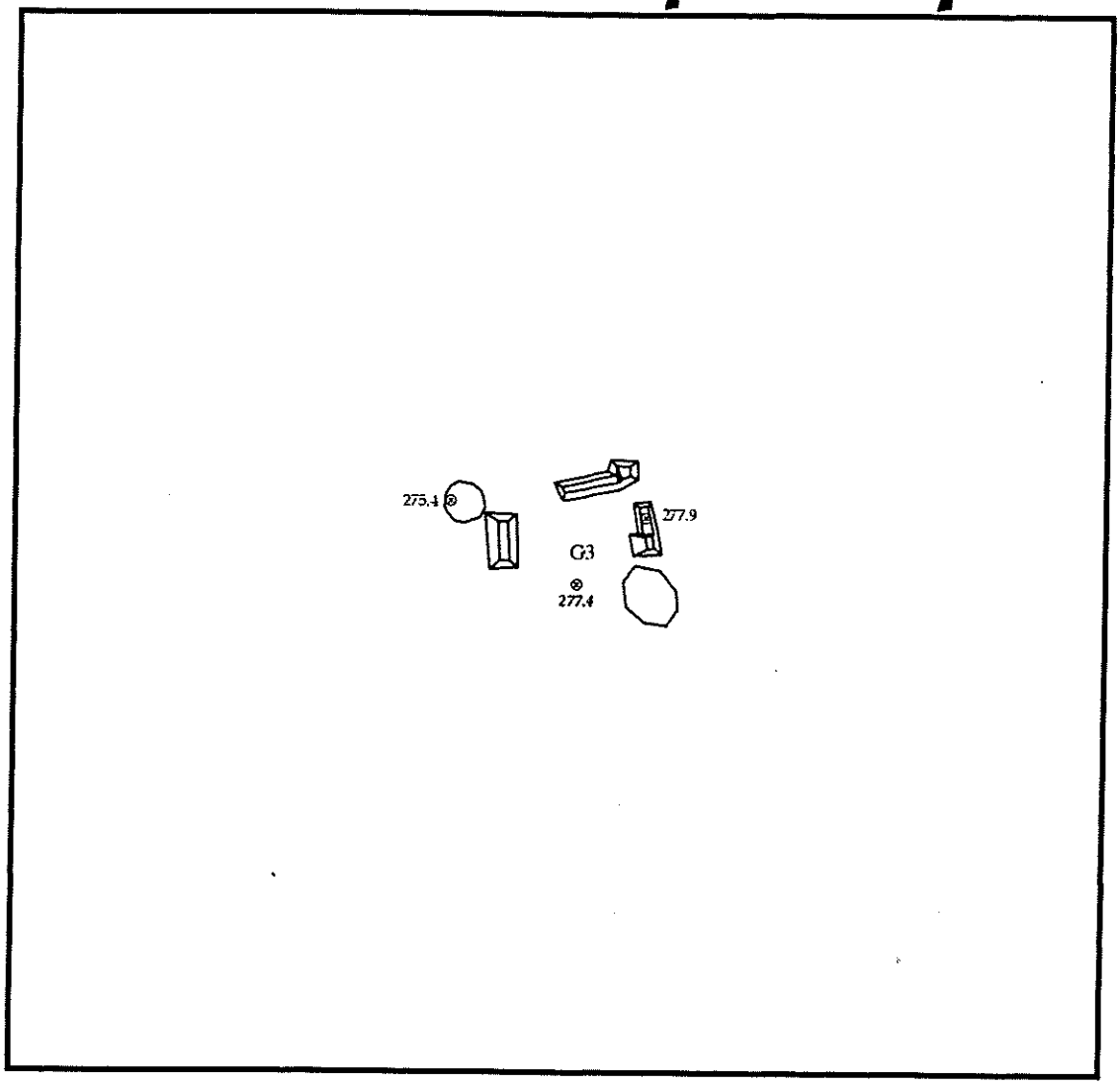
EFAT Group Maps



0 10 20 40 Meters

Grupo 1
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

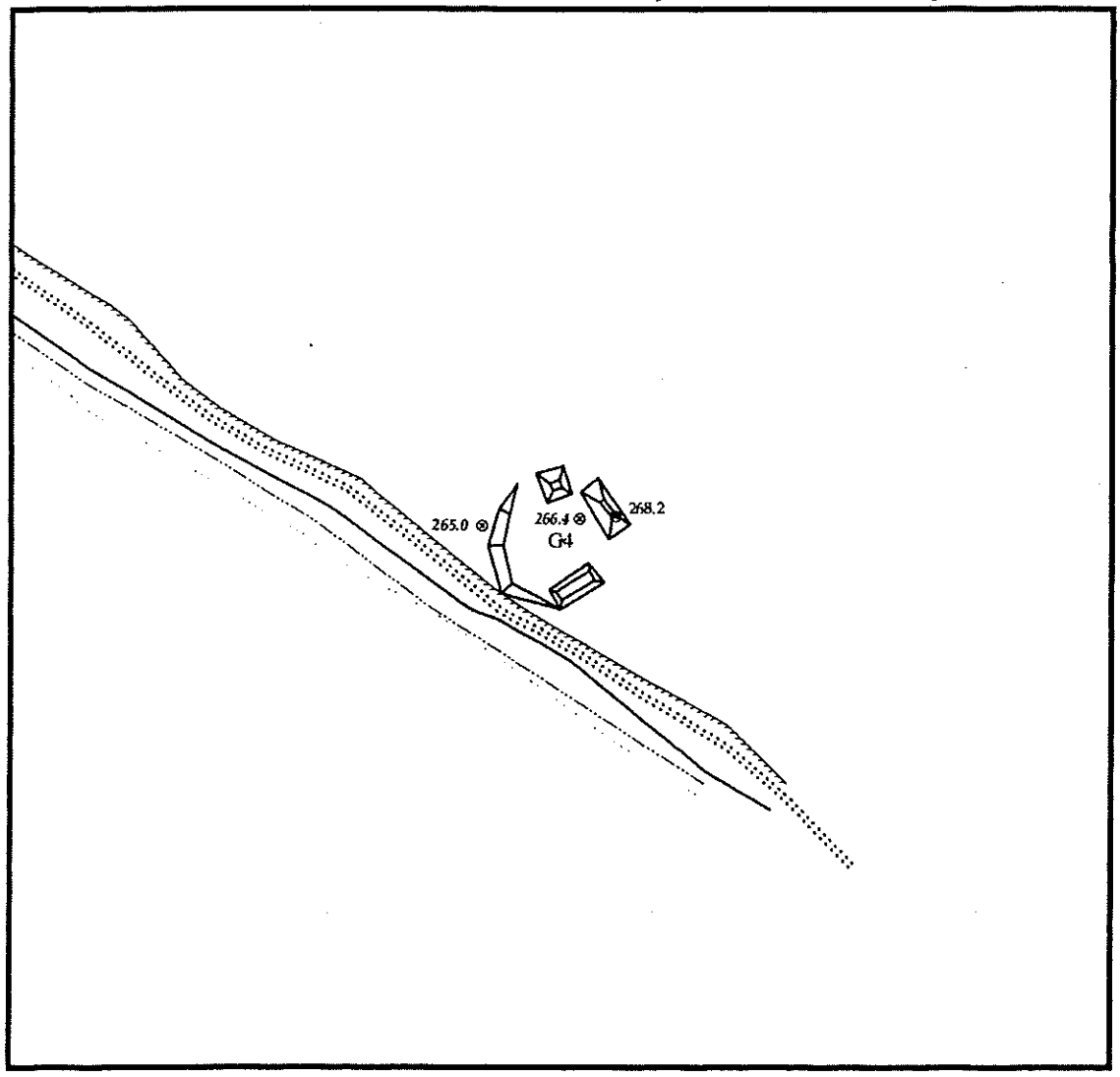
EFAT Group Maps



0 10 20 40 Meters

Grupo 3
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

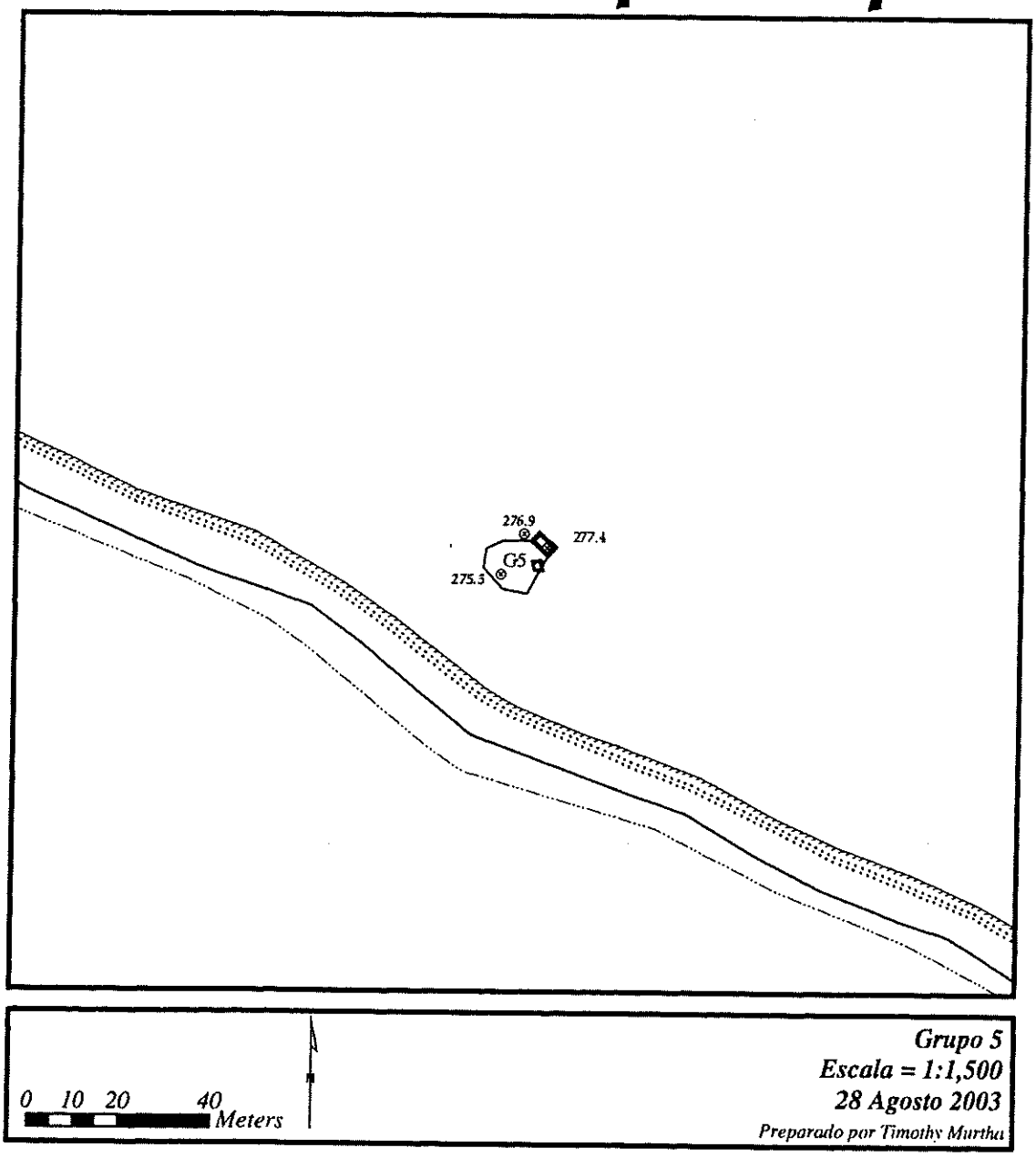
EFAT Group Maps



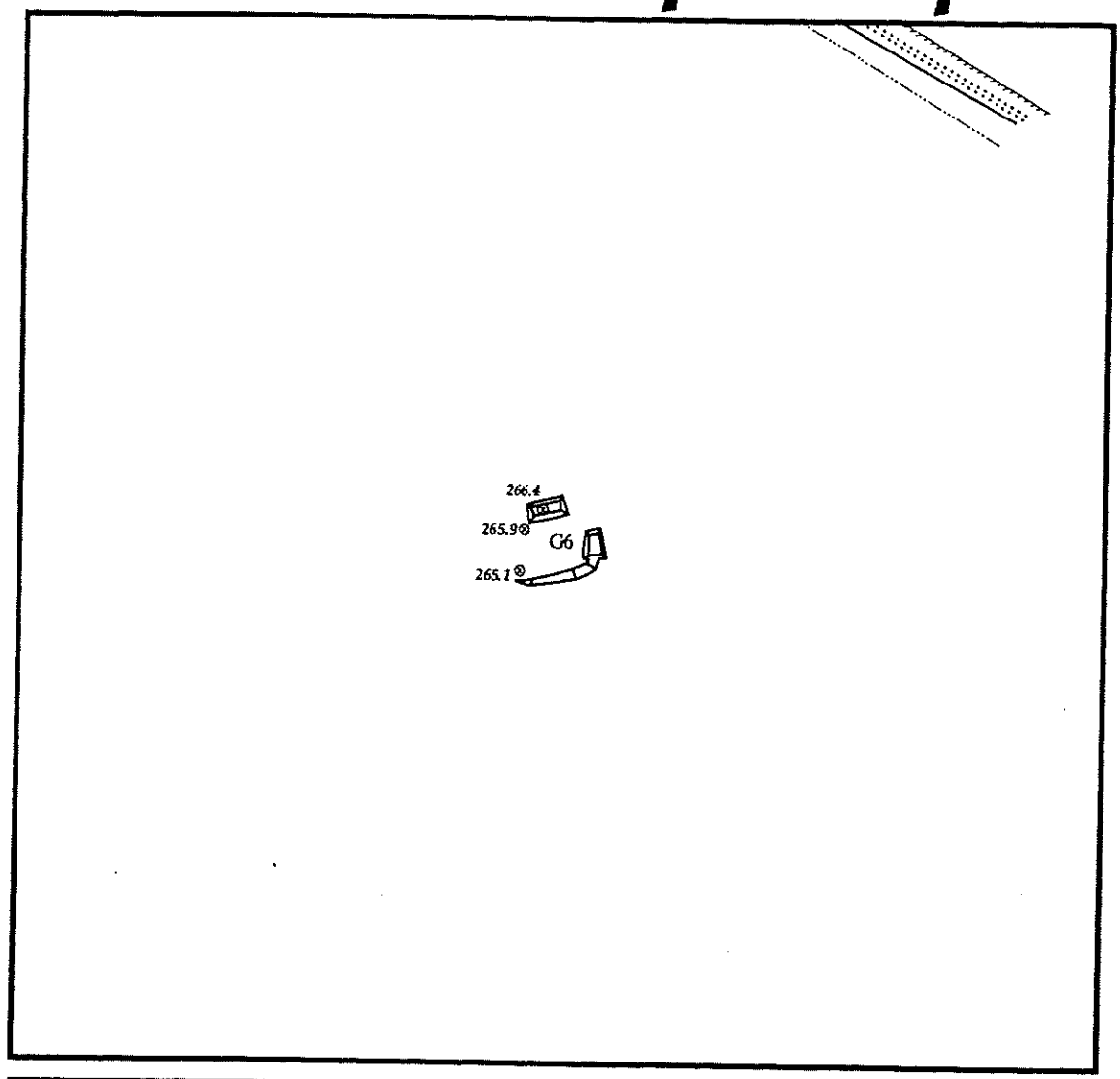
0 10 20 40 Meters

Grupo 4
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

EFAT Group Maps



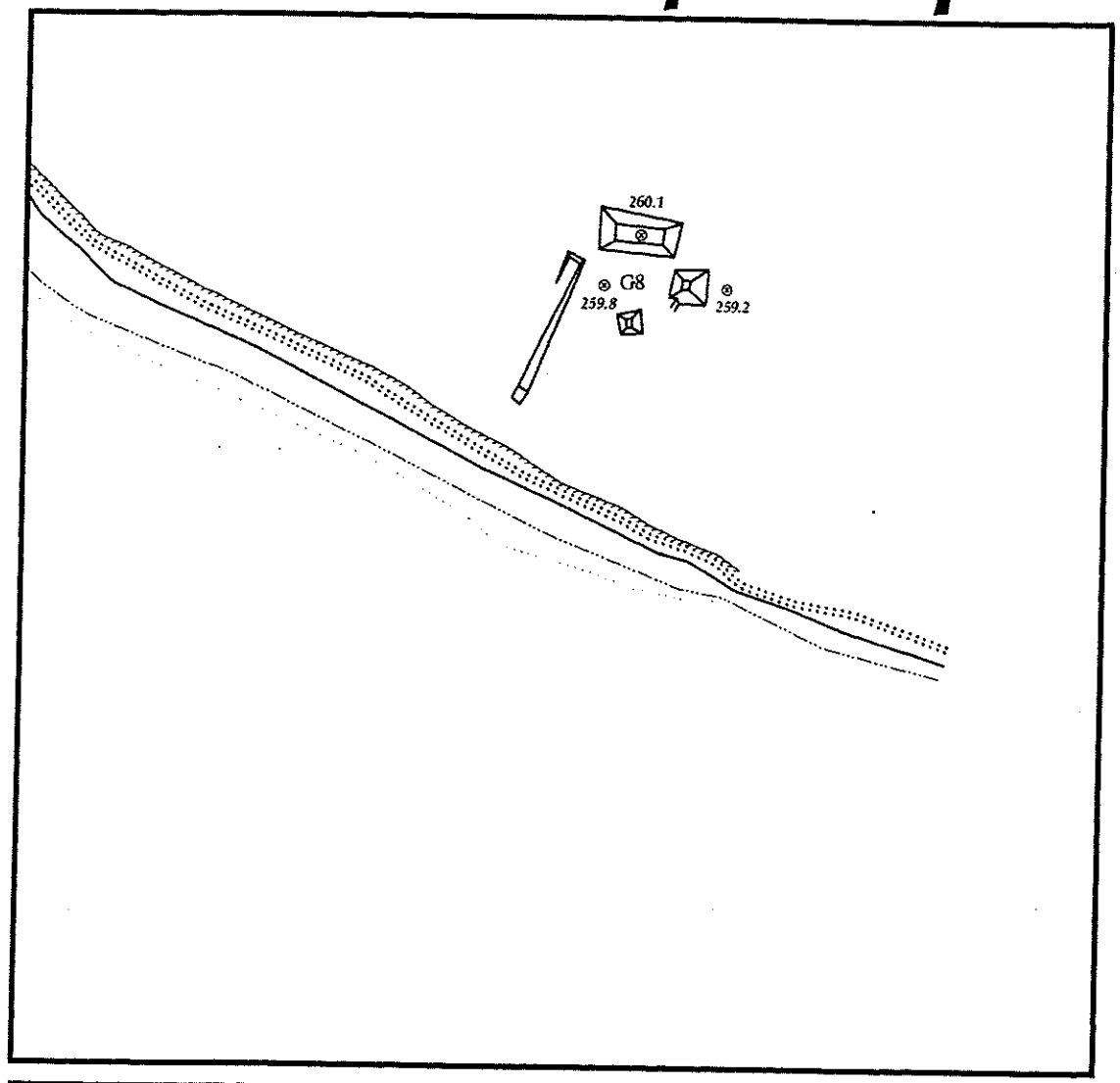
EFAT Group Maps



0 10 20 40 Meters

Grupo 6
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

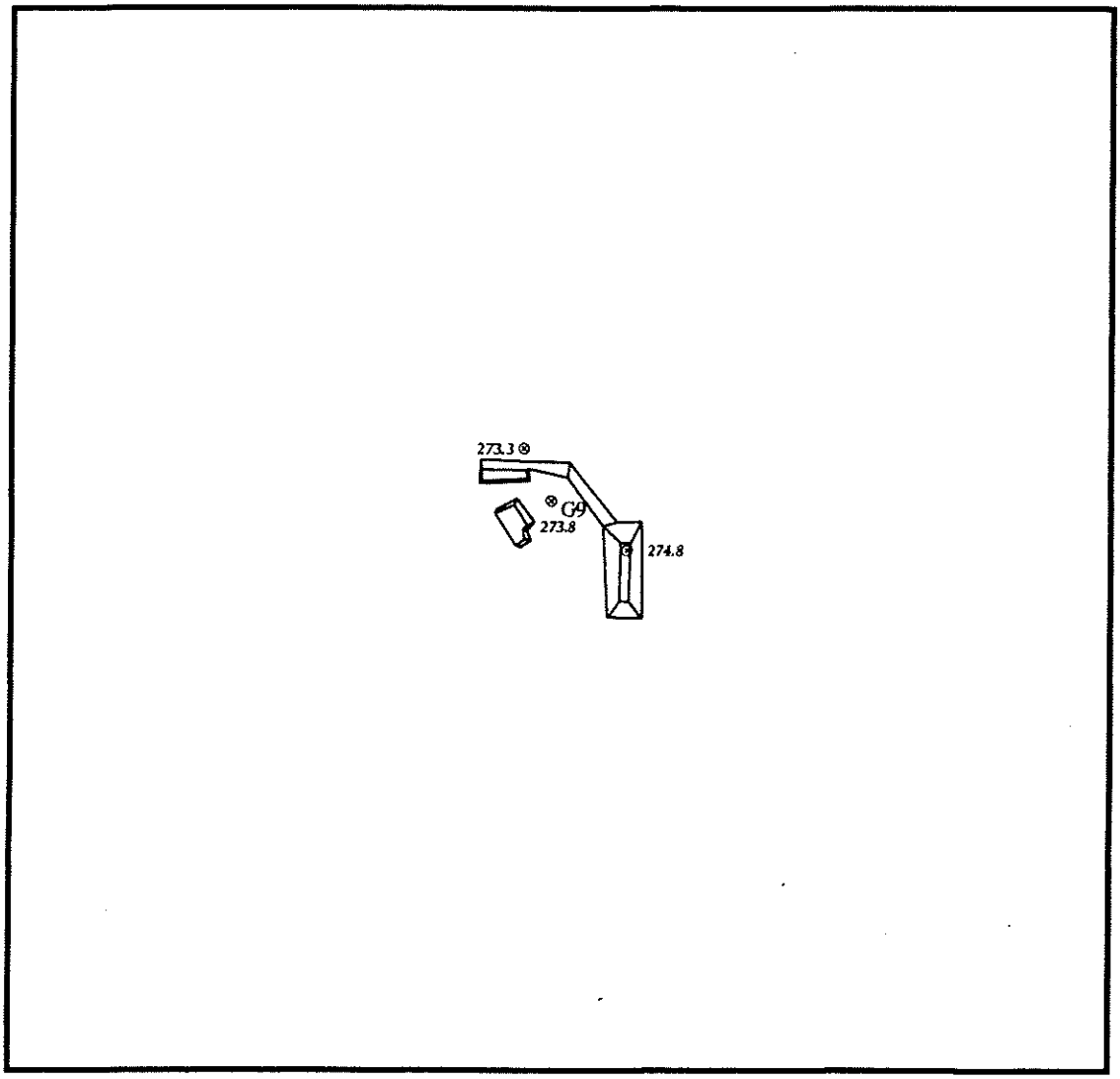
EFAT Group Maps



0 10 20 40 Meters

Grupo 8
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

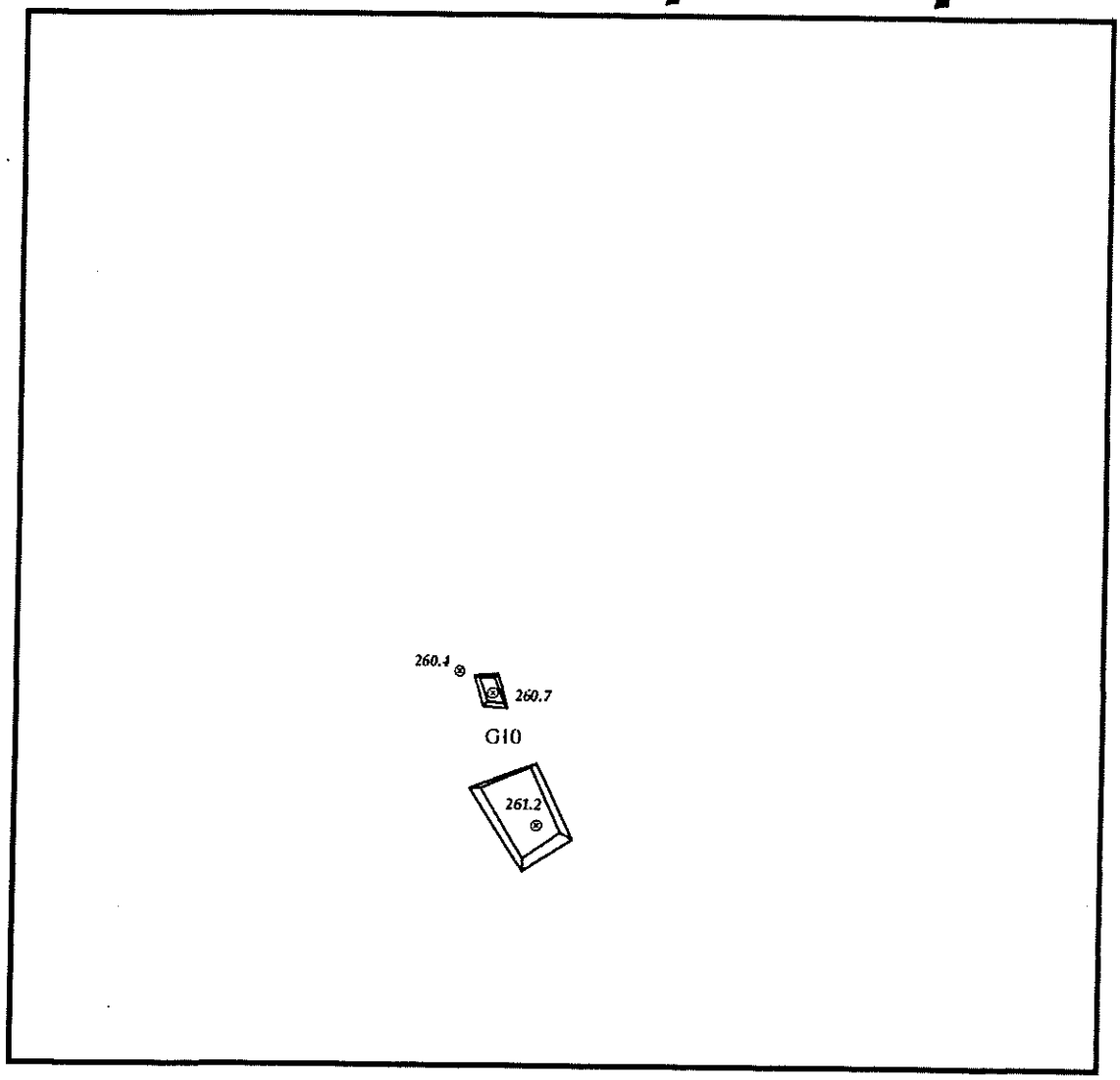
EFAT Group Maps



0 10 20 40 Meters

Grupo 9
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

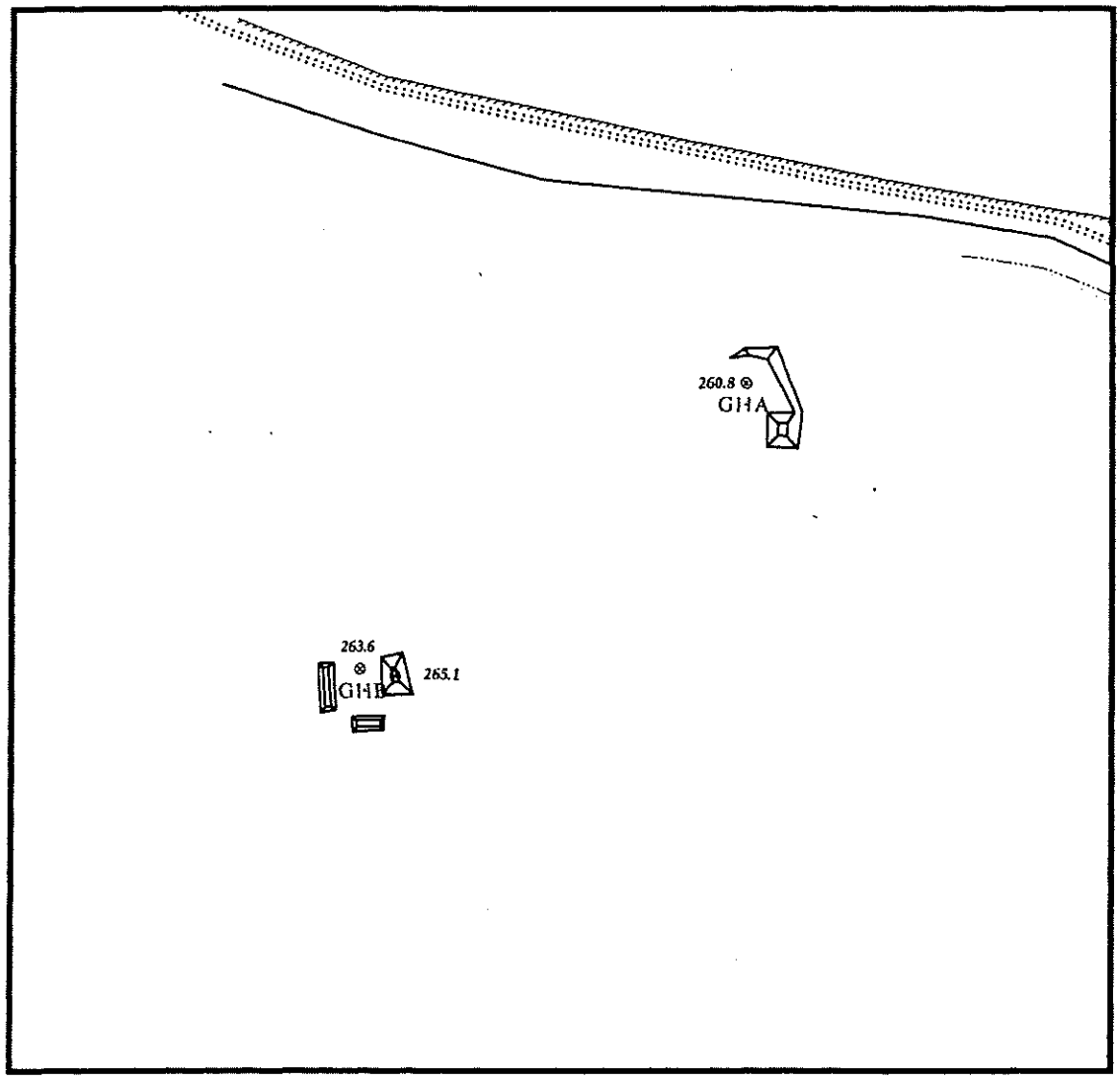
EFAT Group Maps



0 10 20 40 Meters

Grupo 10
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

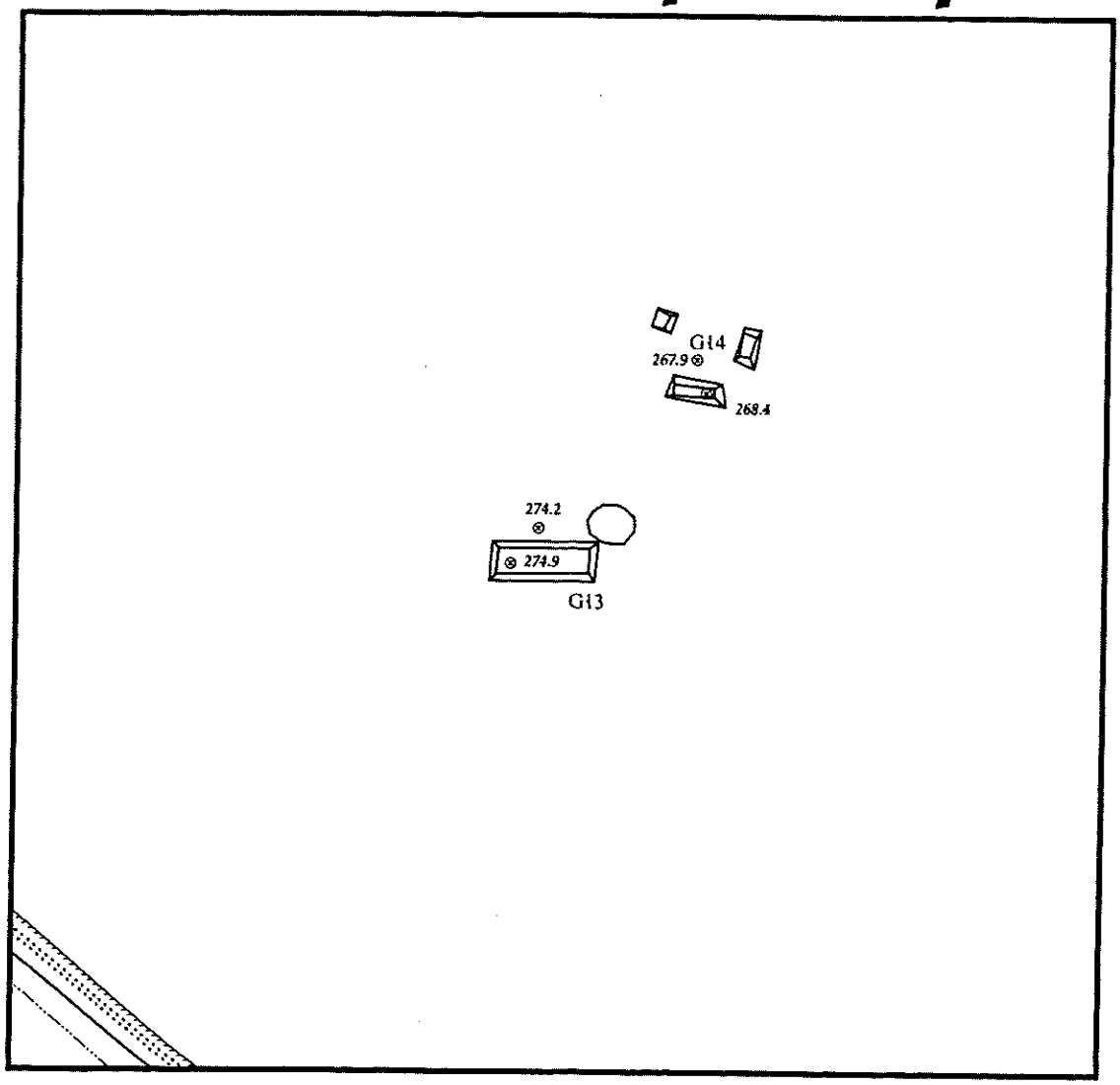
EFAT Group Maps



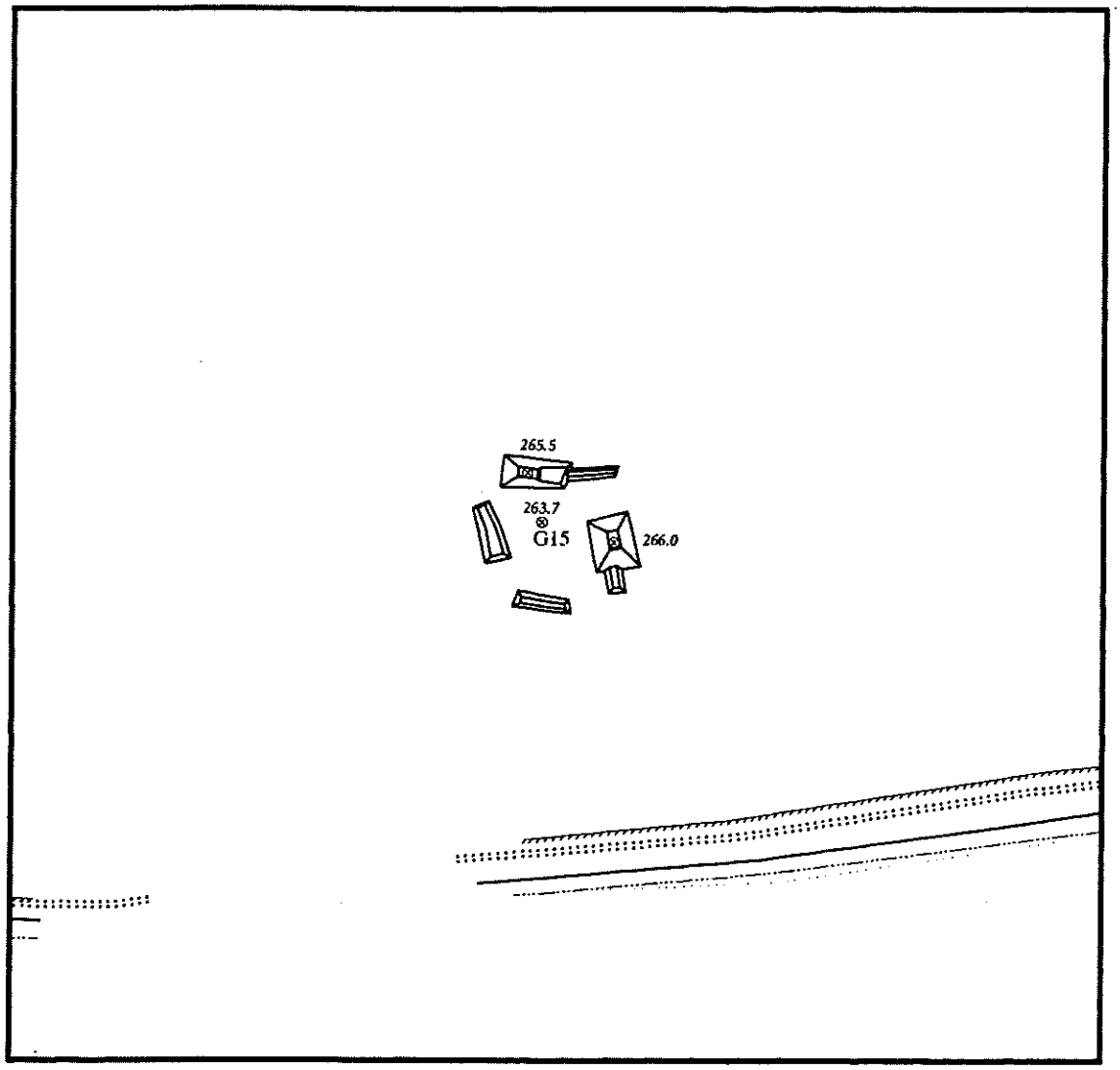
0 10 20 40 Meters

Grupo 11
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

EFAT Group Maps



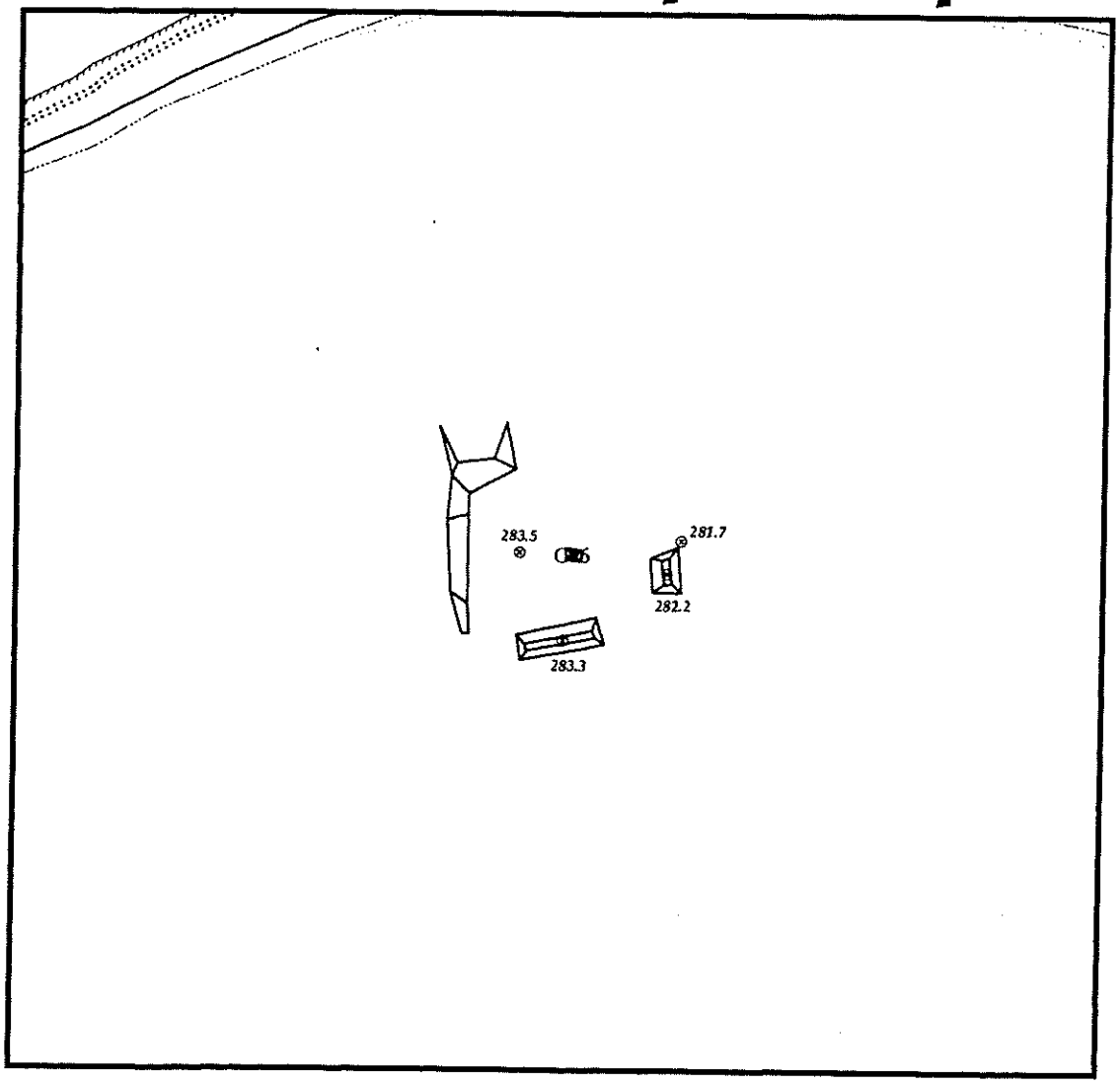
EFAT Group Maps



0 10 20 40 Meters

Grupo 15
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

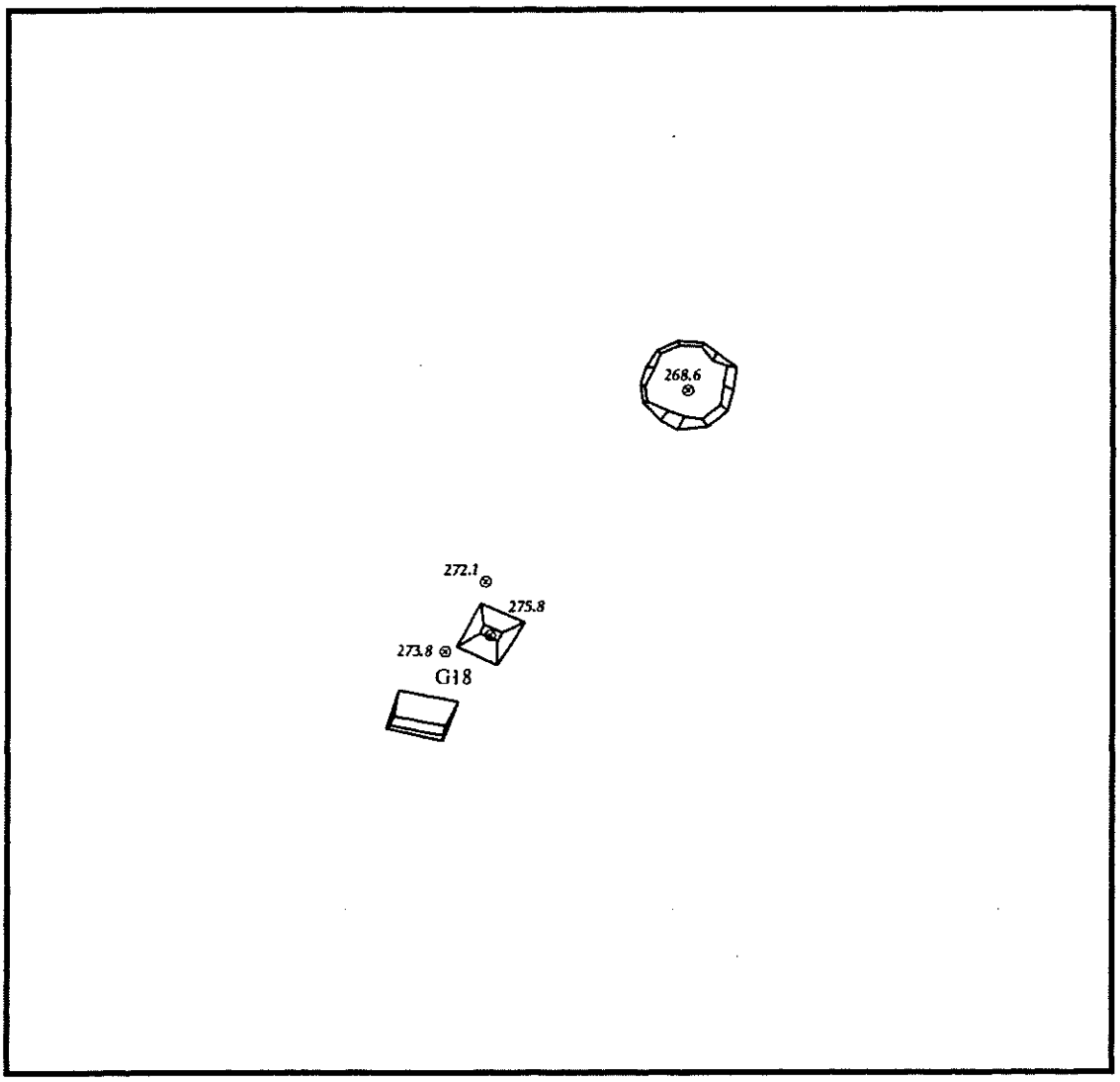
EFAT Group Maps



0 10 20 40 Meters

Grupo 16
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

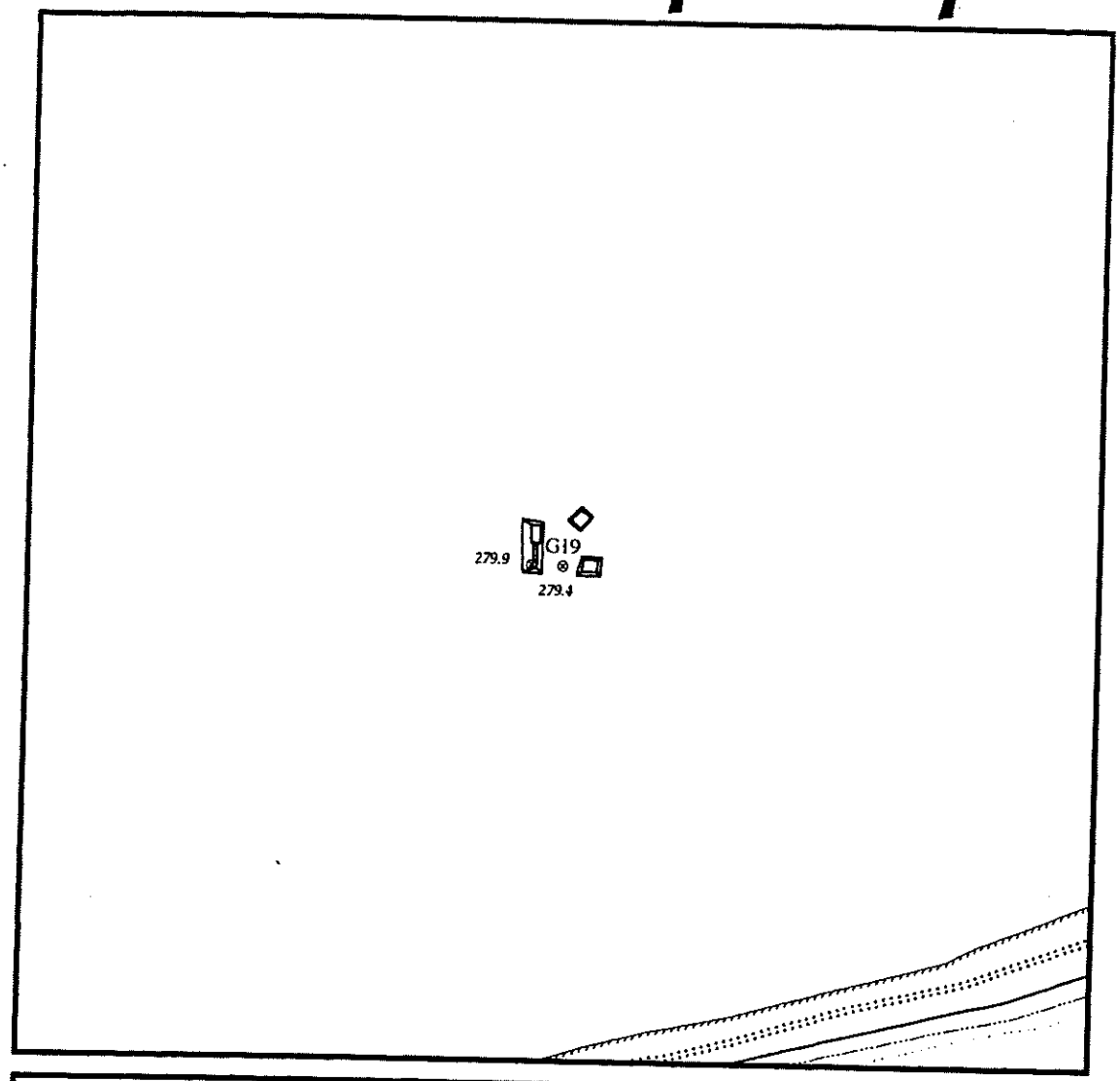
EFAT Group Maps



0 10 20 40 Meters

Grupo 18
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

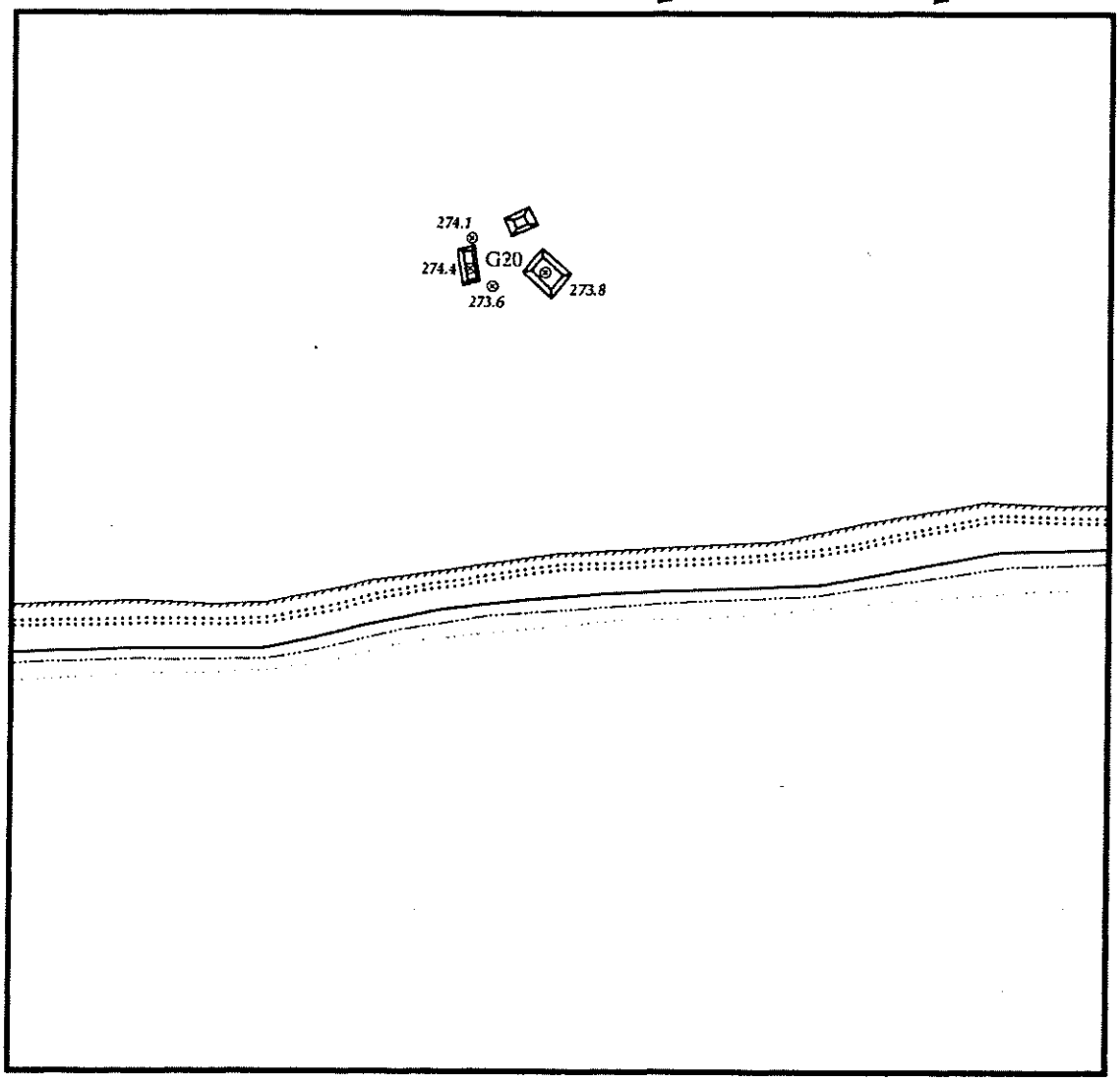
EFAT Group Maps



0 10 20 40 Meters

Grupo 19
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

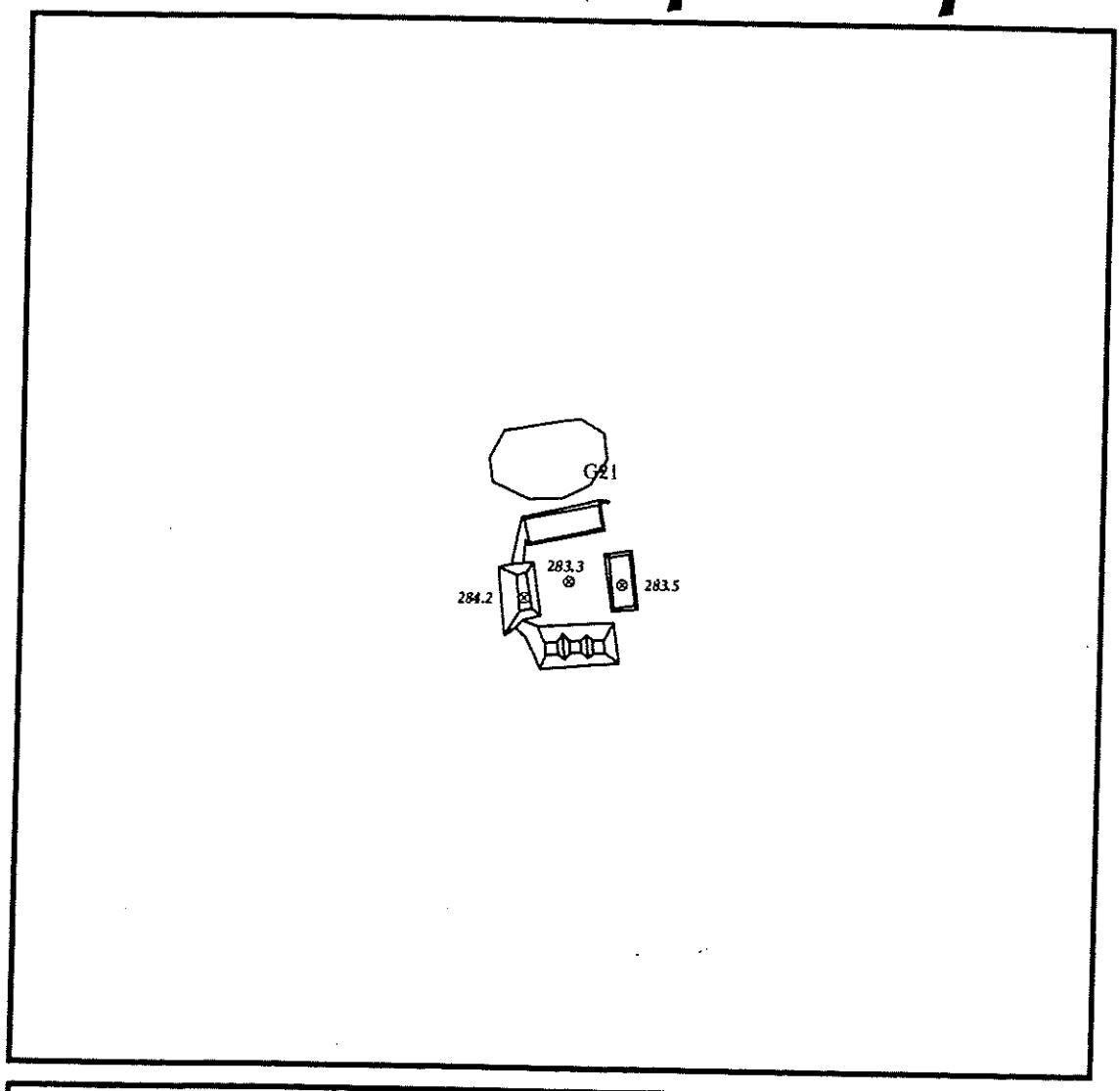
EFAT Group Maps



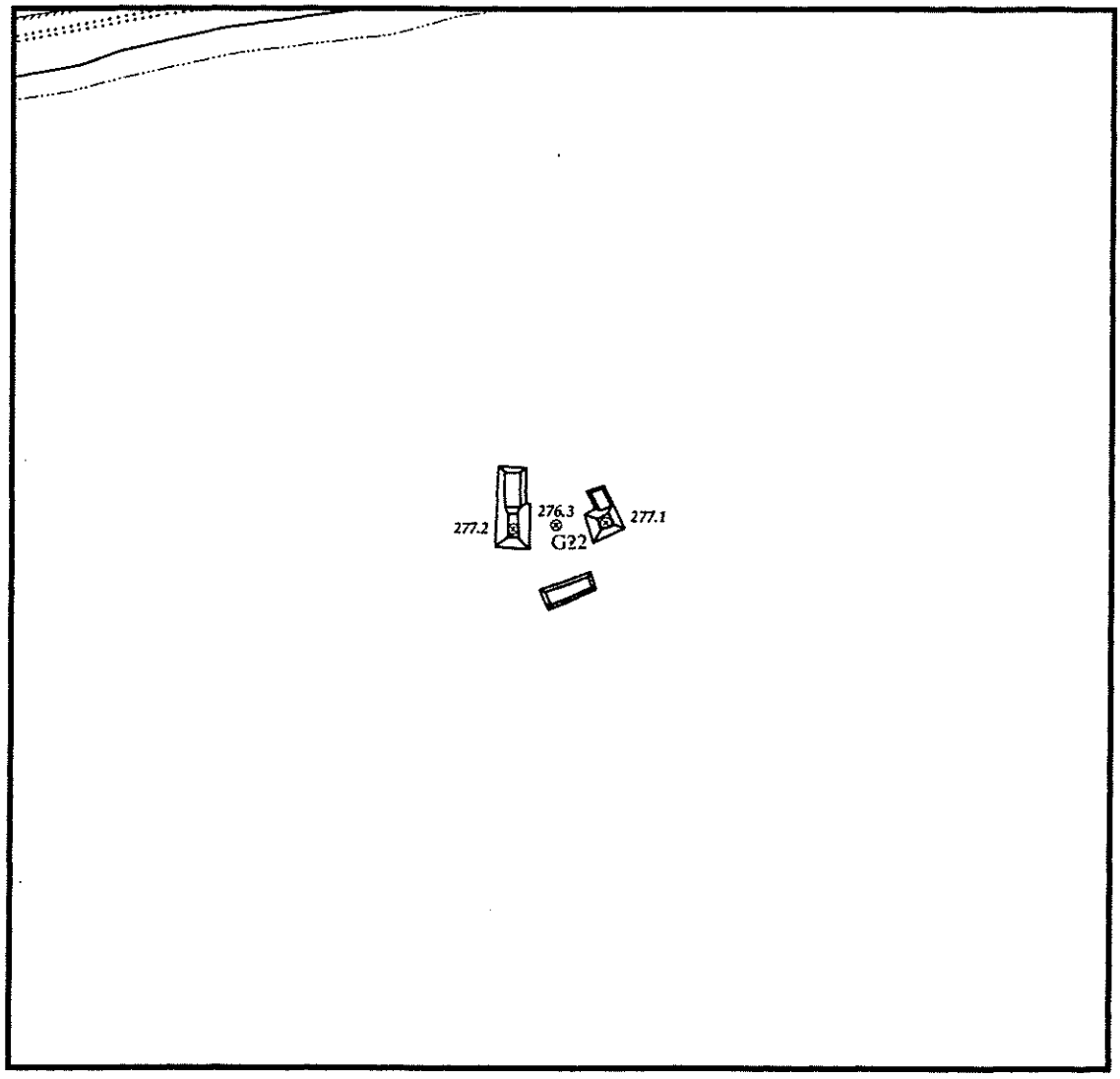
0 10 20 40 Meters

Grupo 20
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

EFAT Group Maps



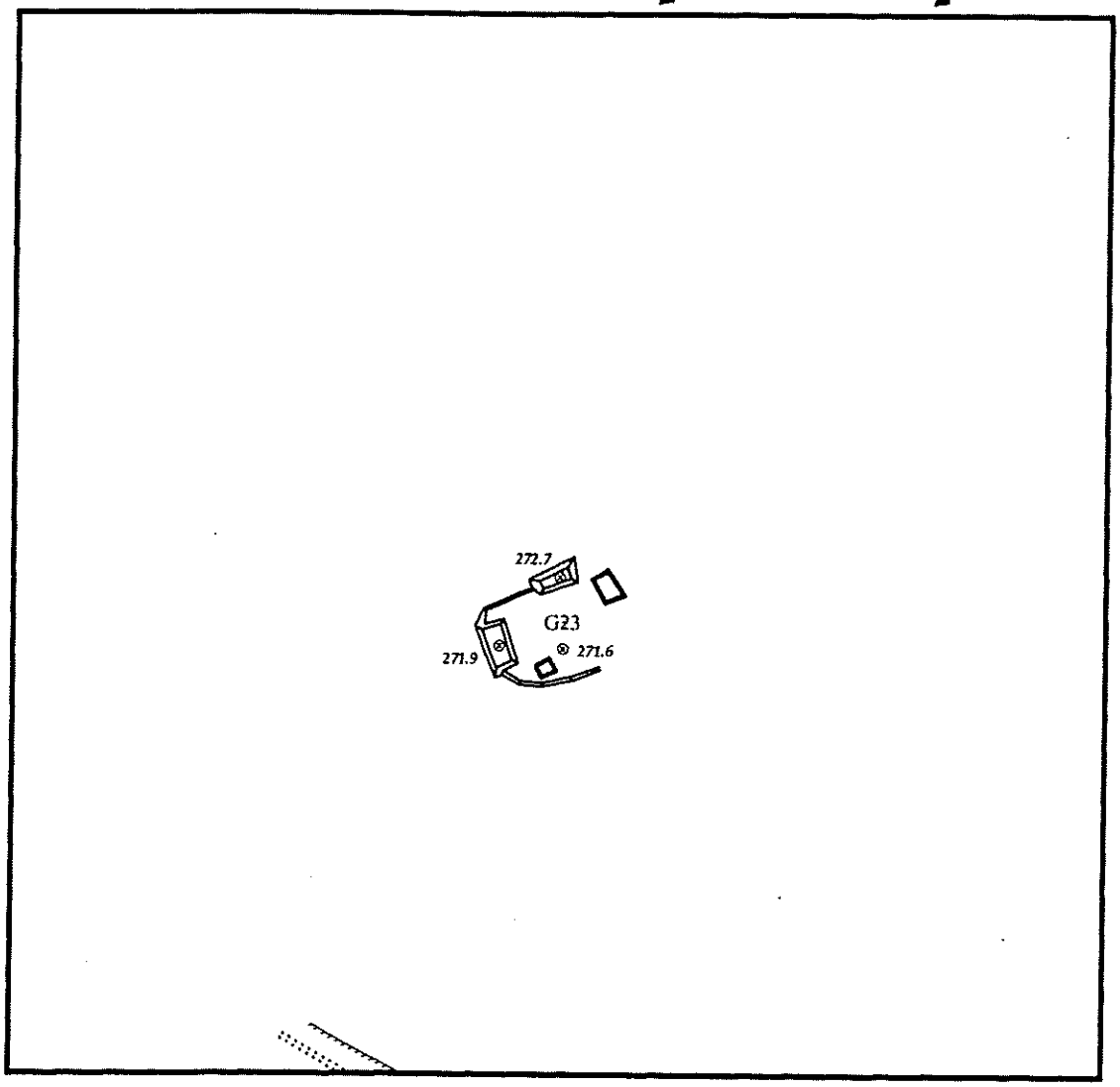
EFAT Group Maps



0 10 20 40 Meters

Grupo 22
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

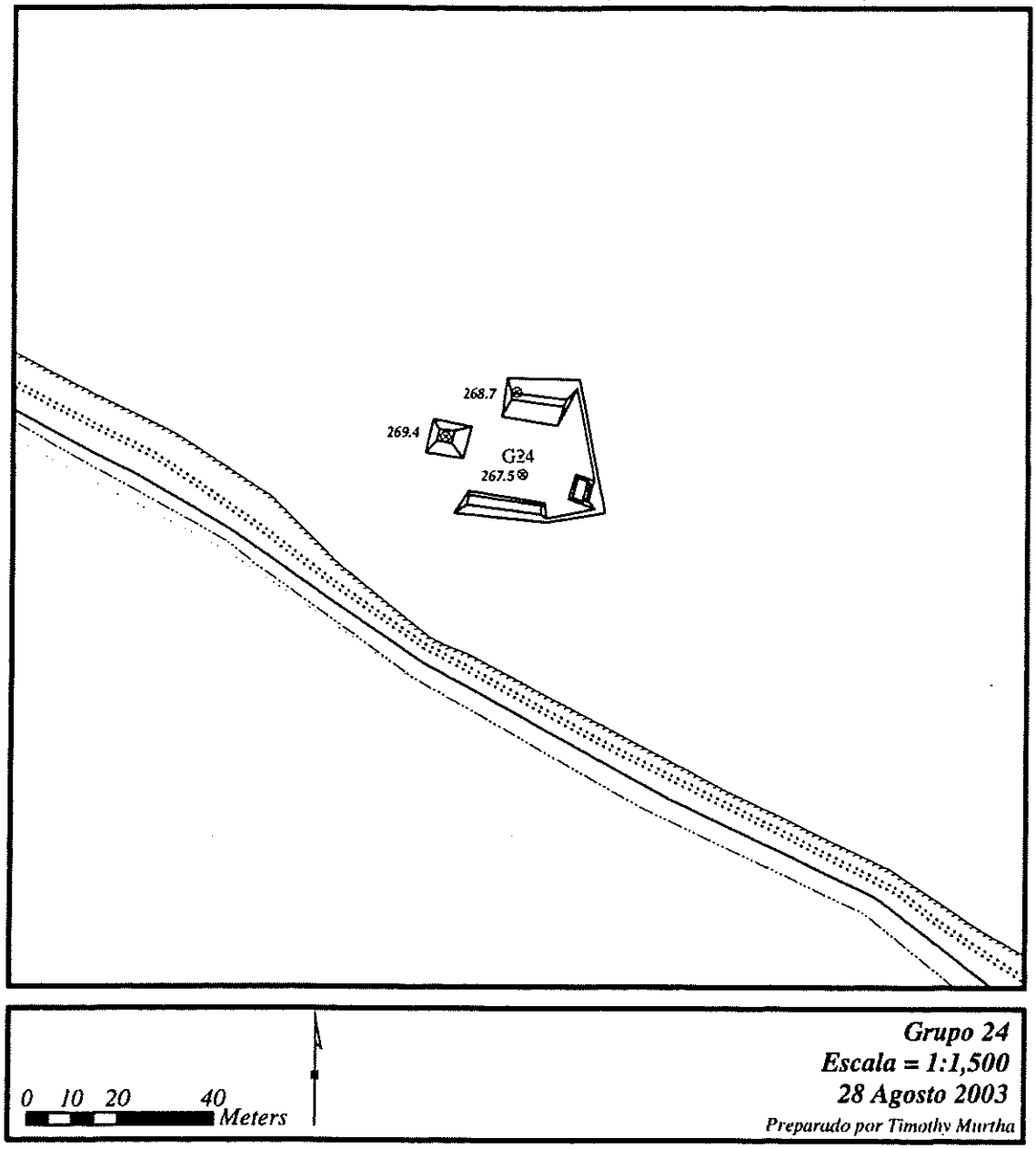
EFAT Group Maps



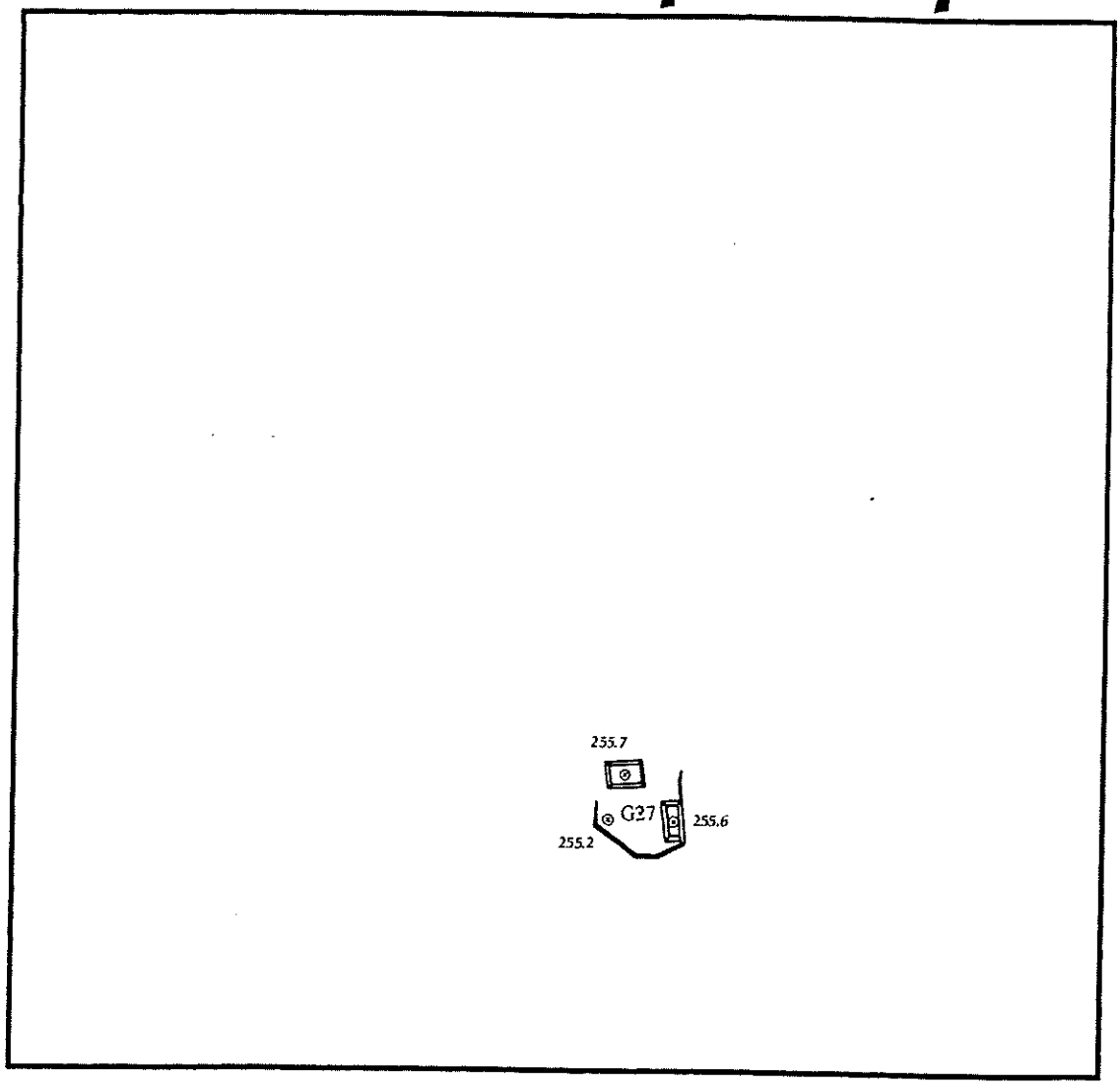
0 10 20 40 Meters

Grupo 23
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

EFAT Group Maps



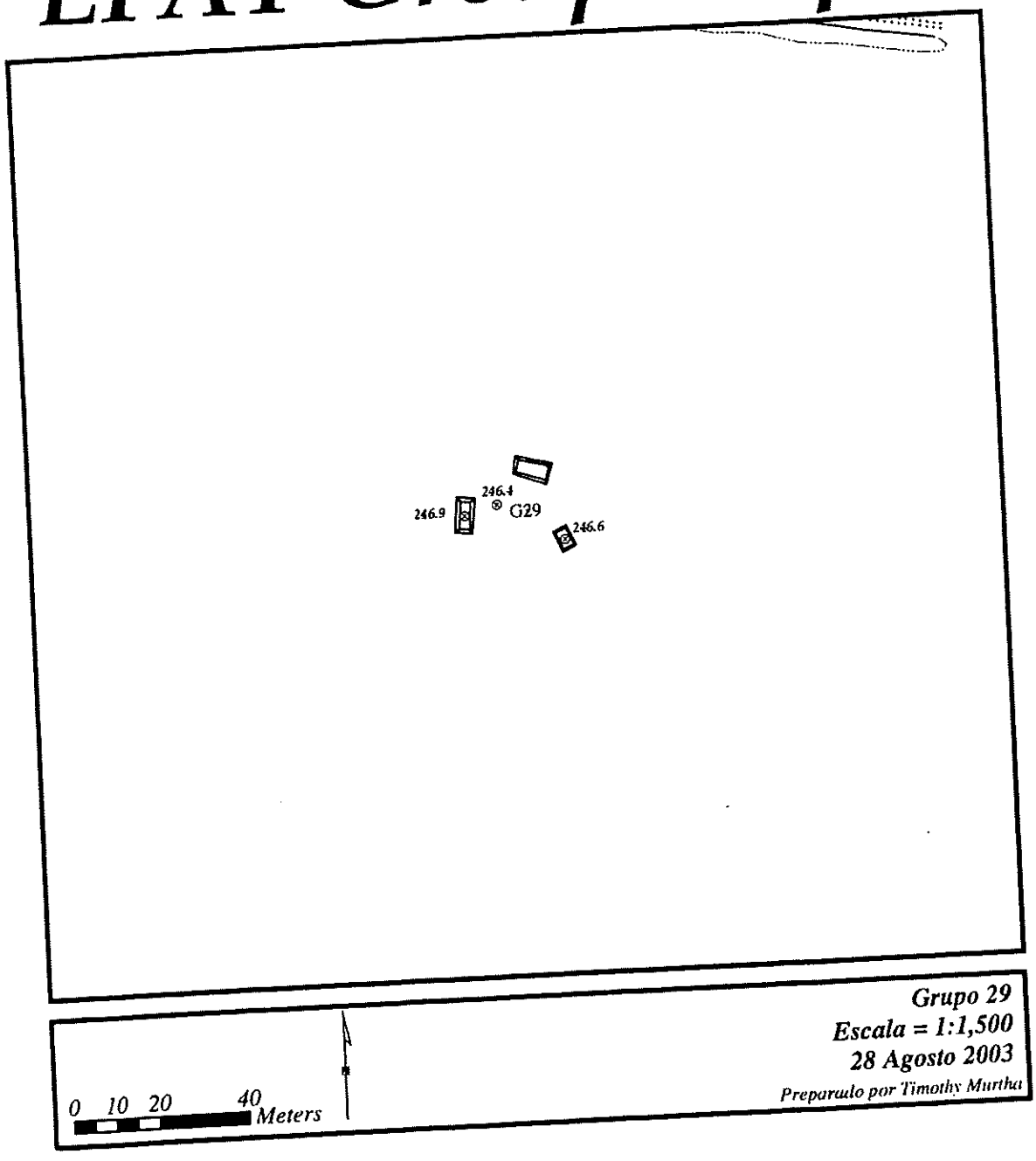
EFAT Group Maps



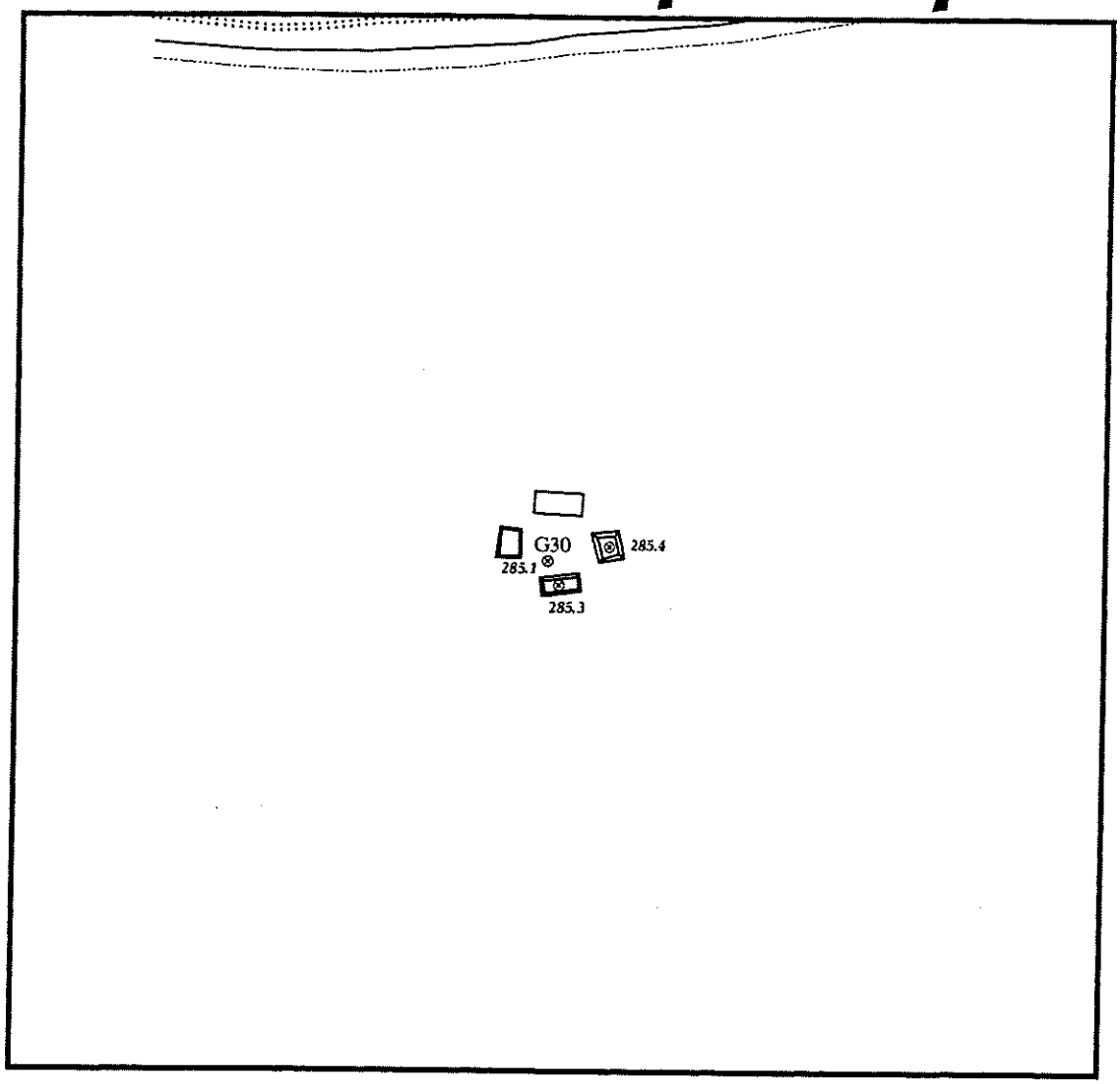
0 10 20 40 Meters

Grupo 27
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

EFAT Group Maps



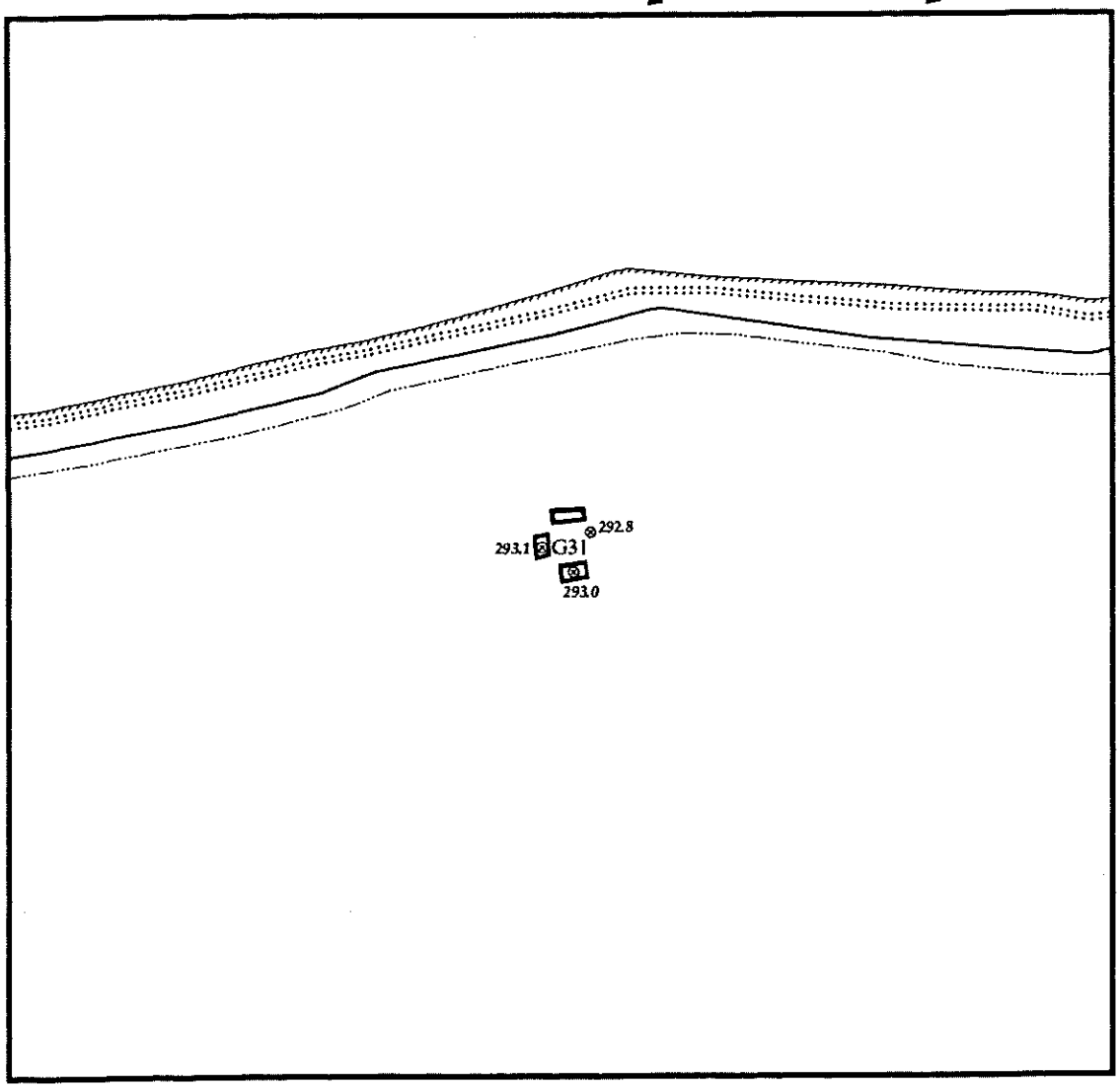
EFAT Group Maps



0 10 20 40 Meters

Grupo 30
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

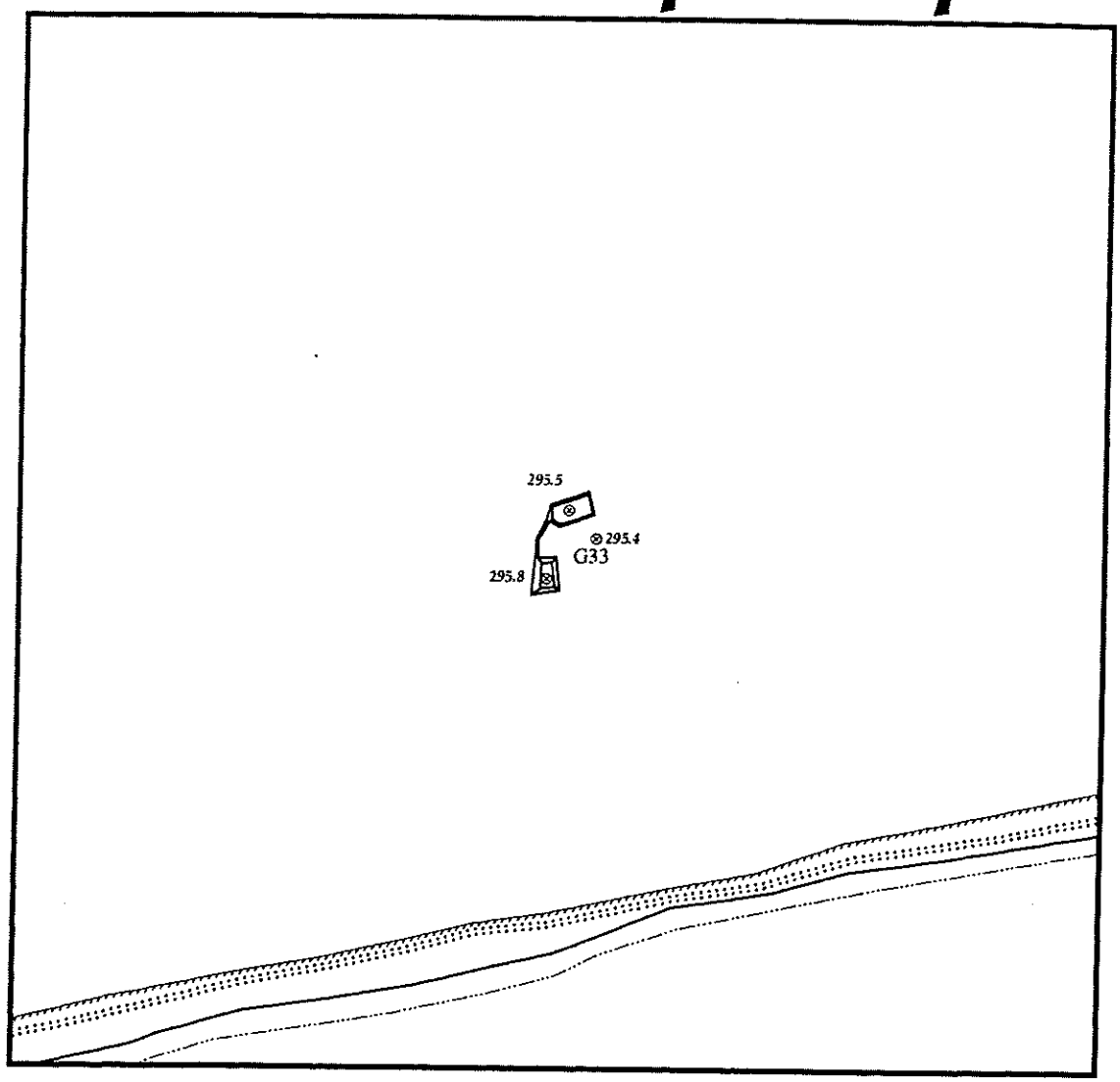
EFAT Group Maps



0 10 20 40 Meters

Grupo 31
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

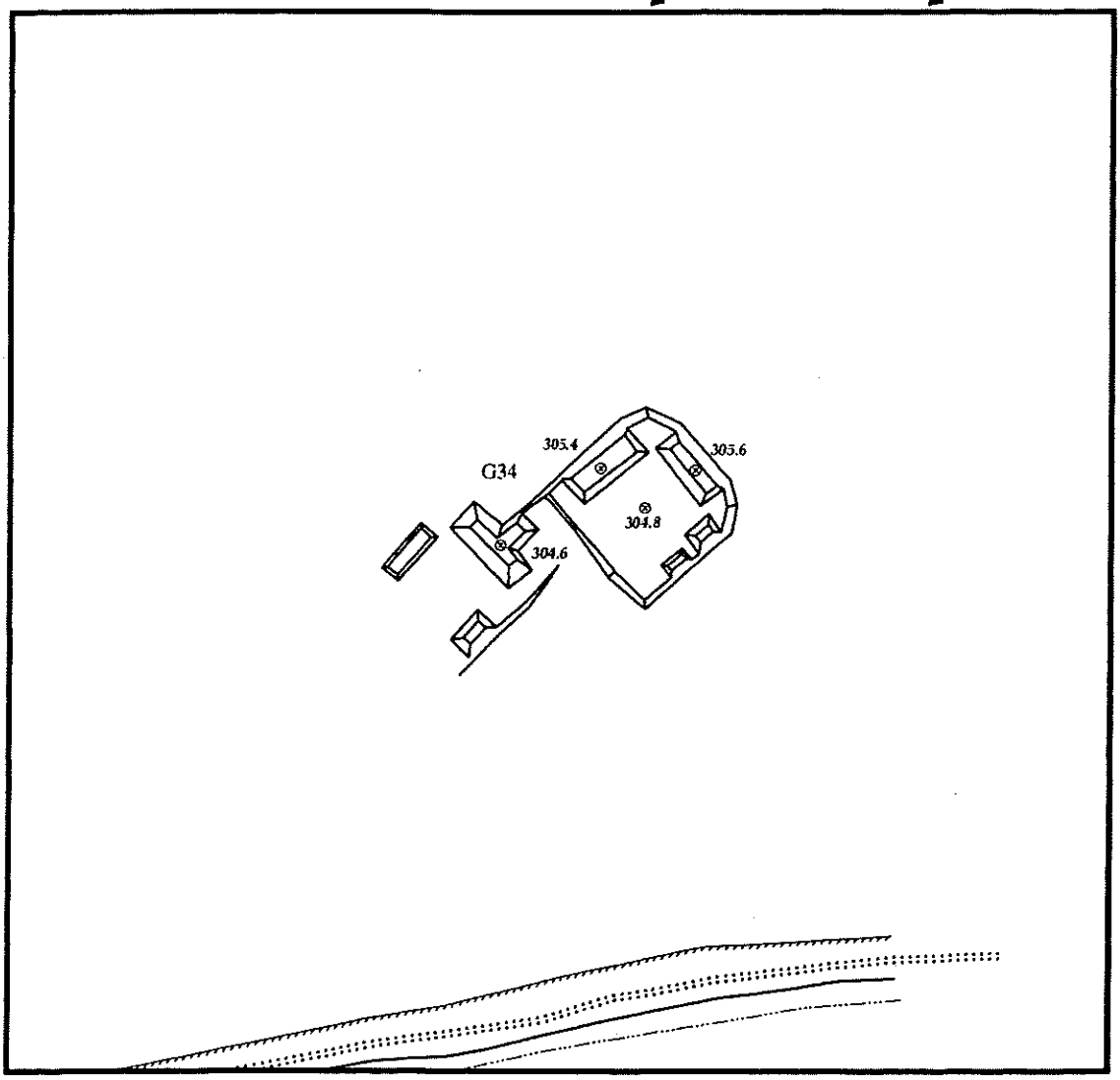
EFAT Group Maps



0 10 20 40 Meters

Grupo 33
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

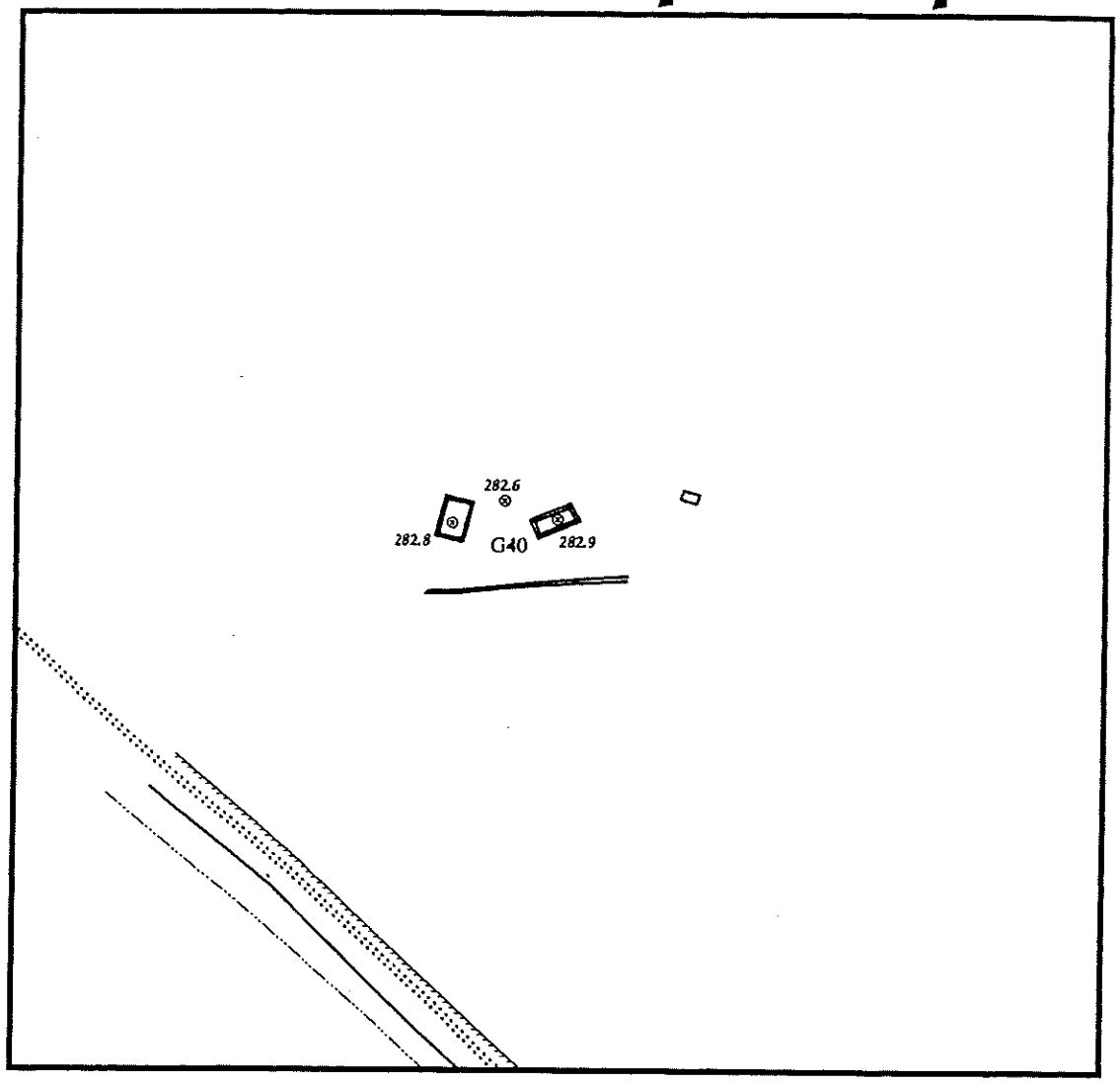
EFAT Group Maps



0 10 20 40 Meters

Grupo 34
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

EFAT Group Maps



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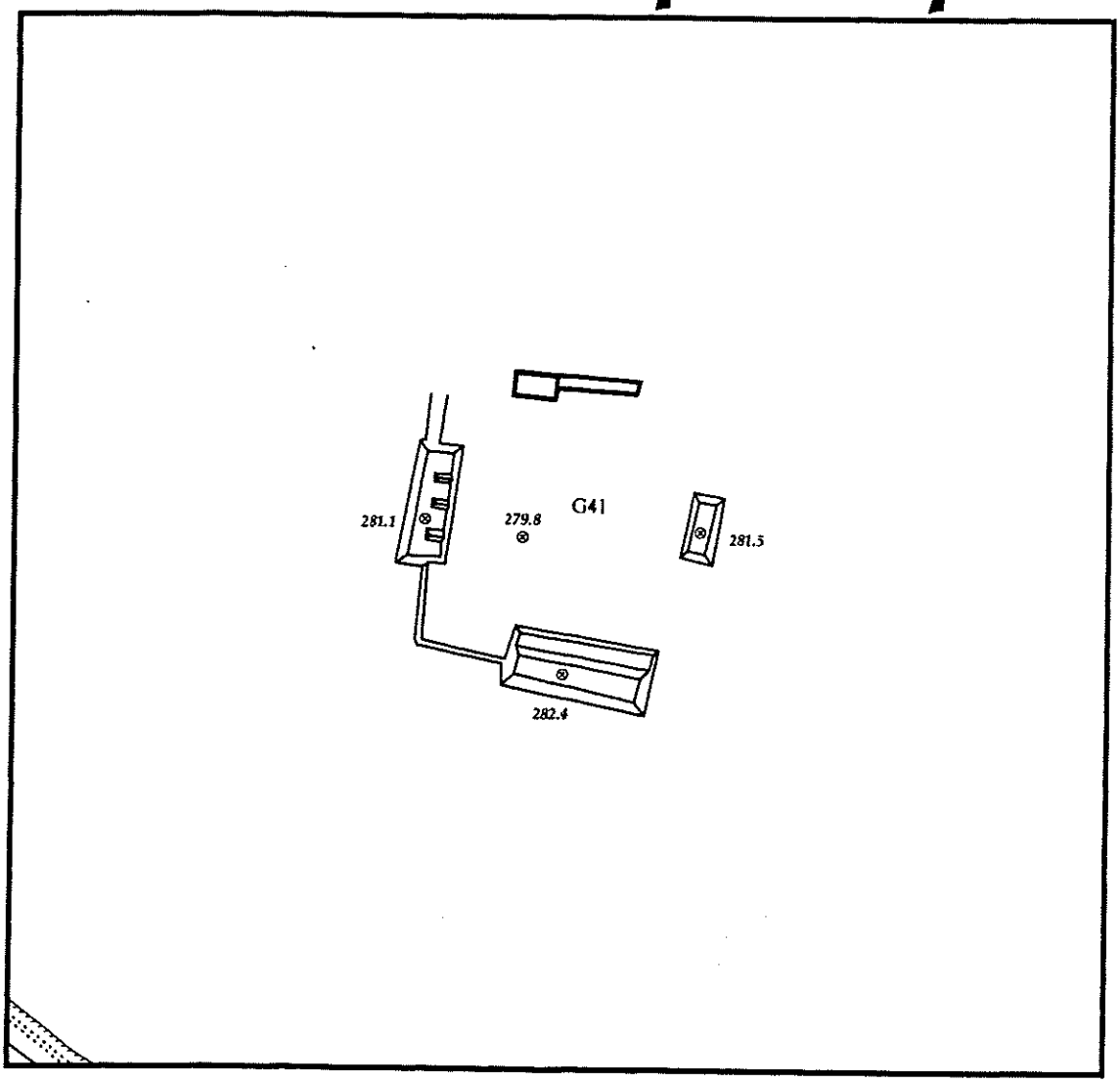
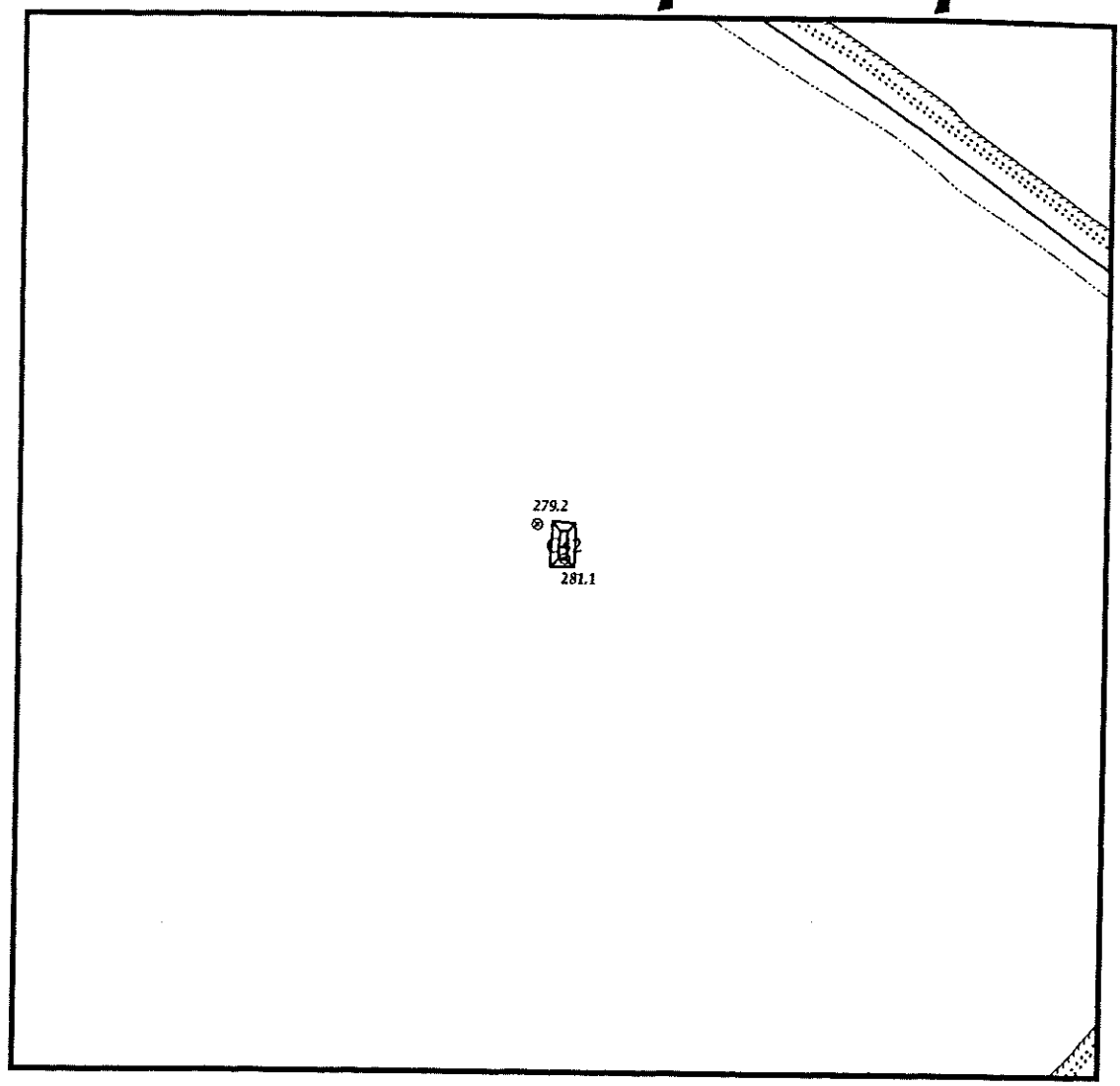


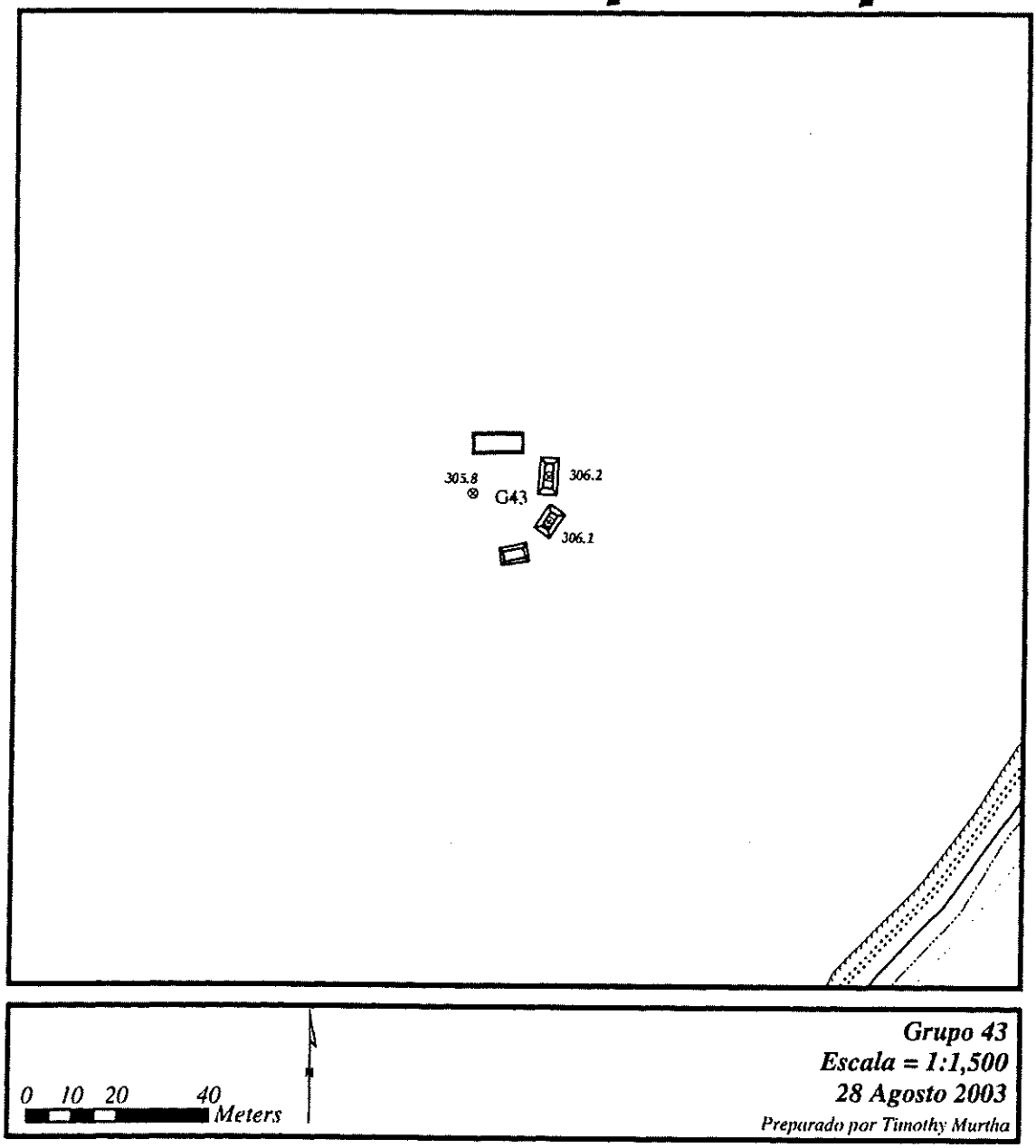
EFAT Group Maps



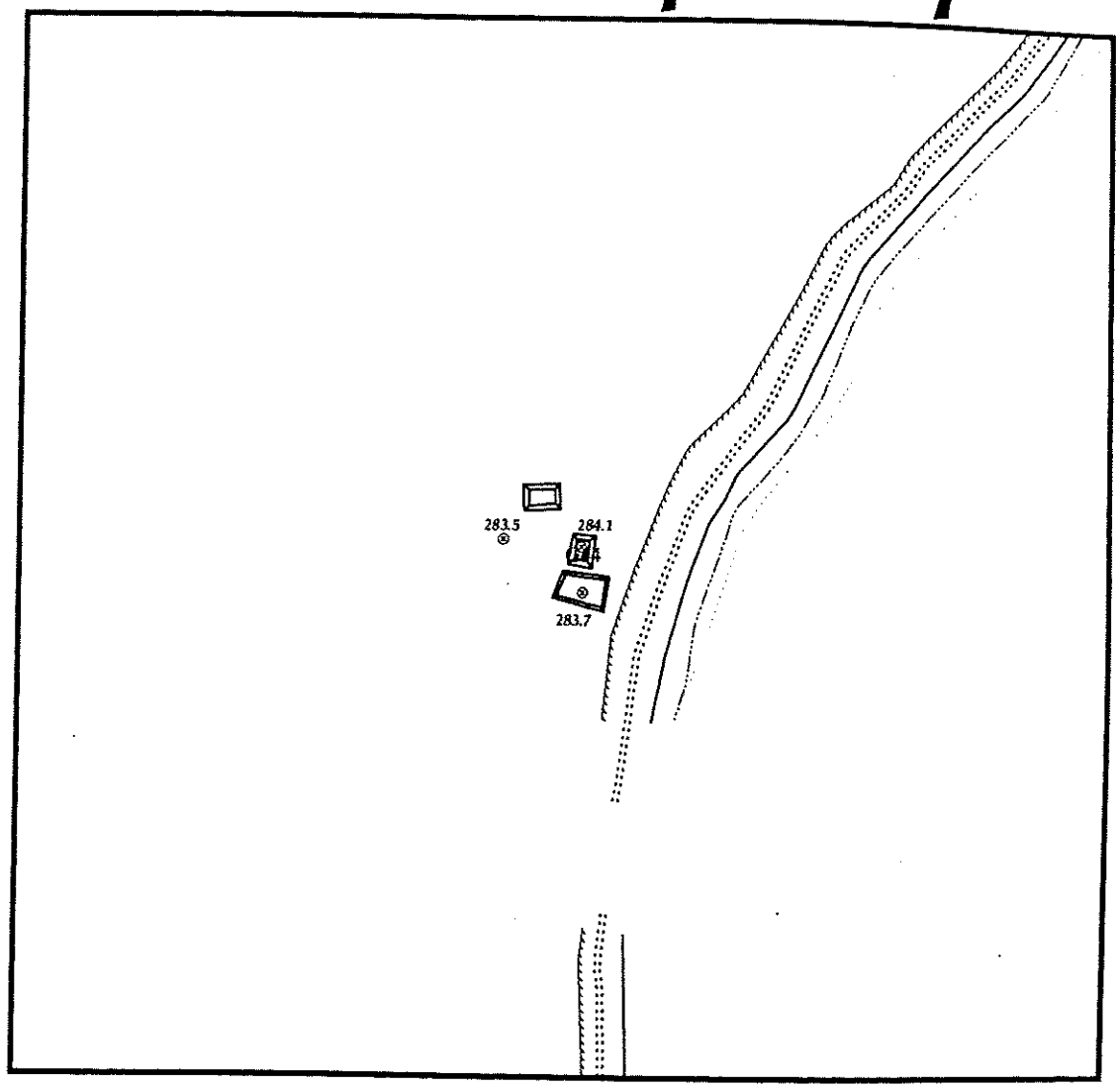
0 10 20 40 Meters

Grupo 42
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

EFAT Group Maps



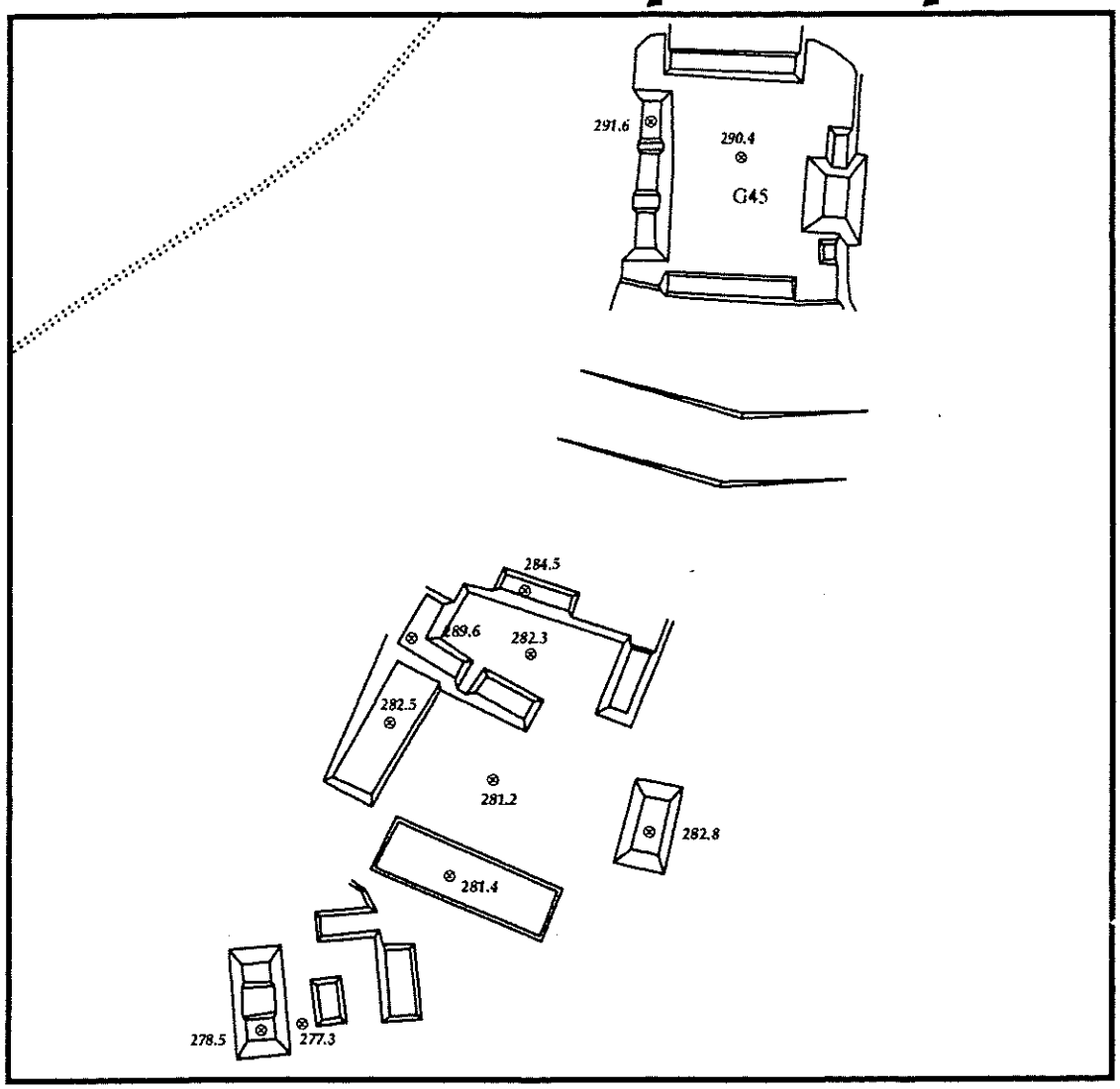
EFAT Group Maps



0 10 20 40 Meters

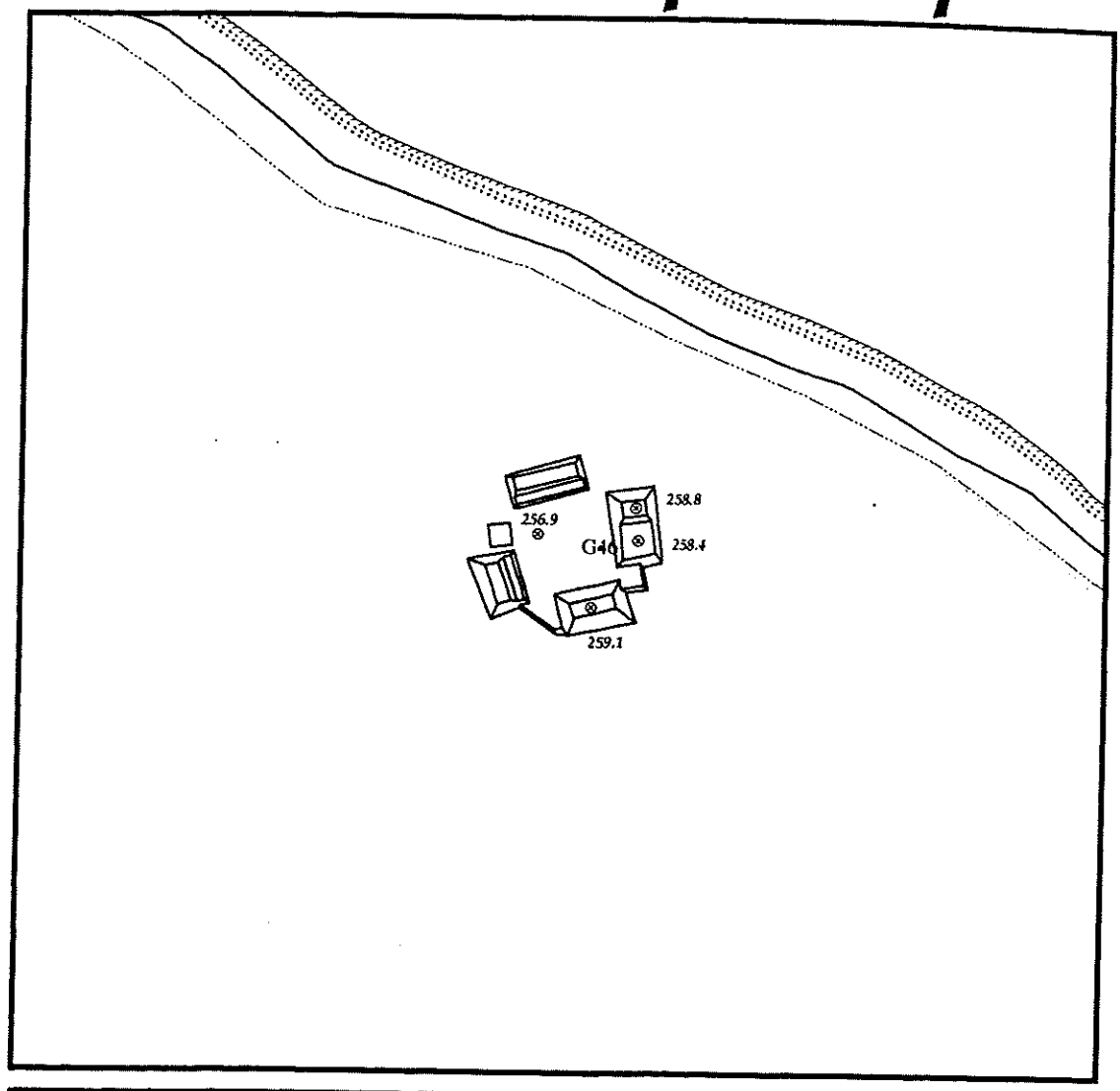
Grupo 44
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

EFAT Group Maps



Grupo 45
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

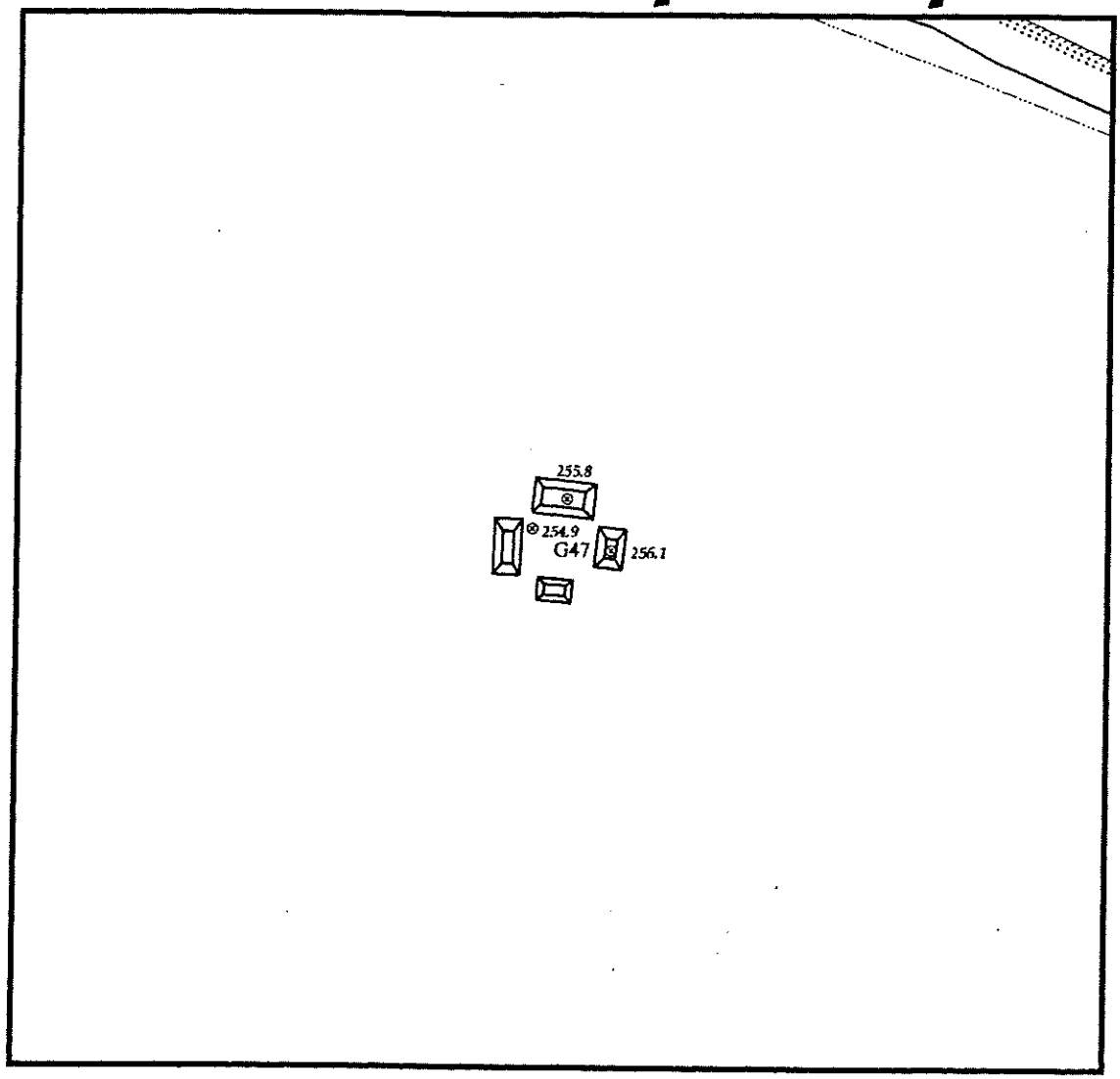
EFAT Group Maps



0 10 20 40 Meters

Grupo 46
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

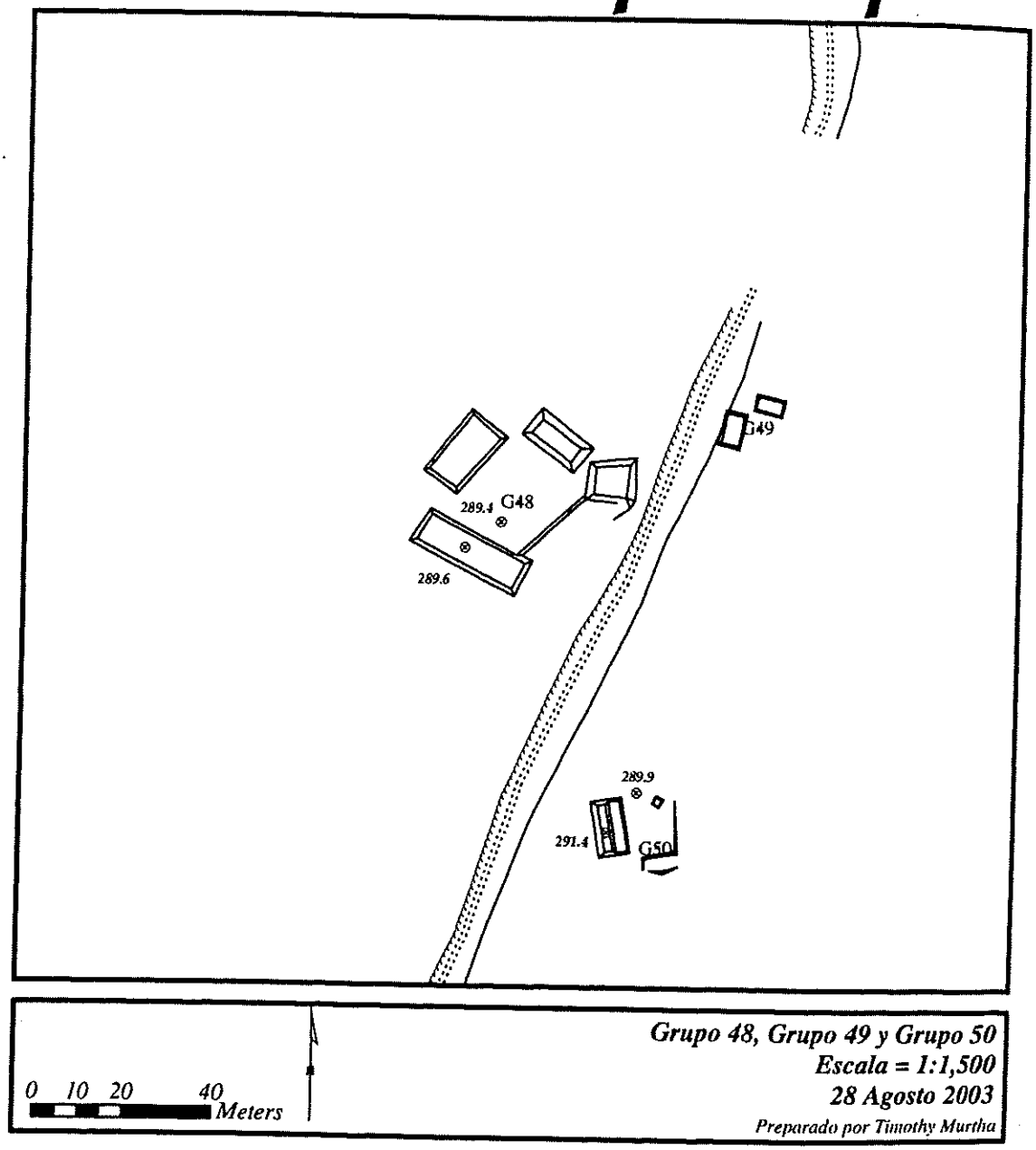
EFAT Group Maps



0 10 20 40 Meters

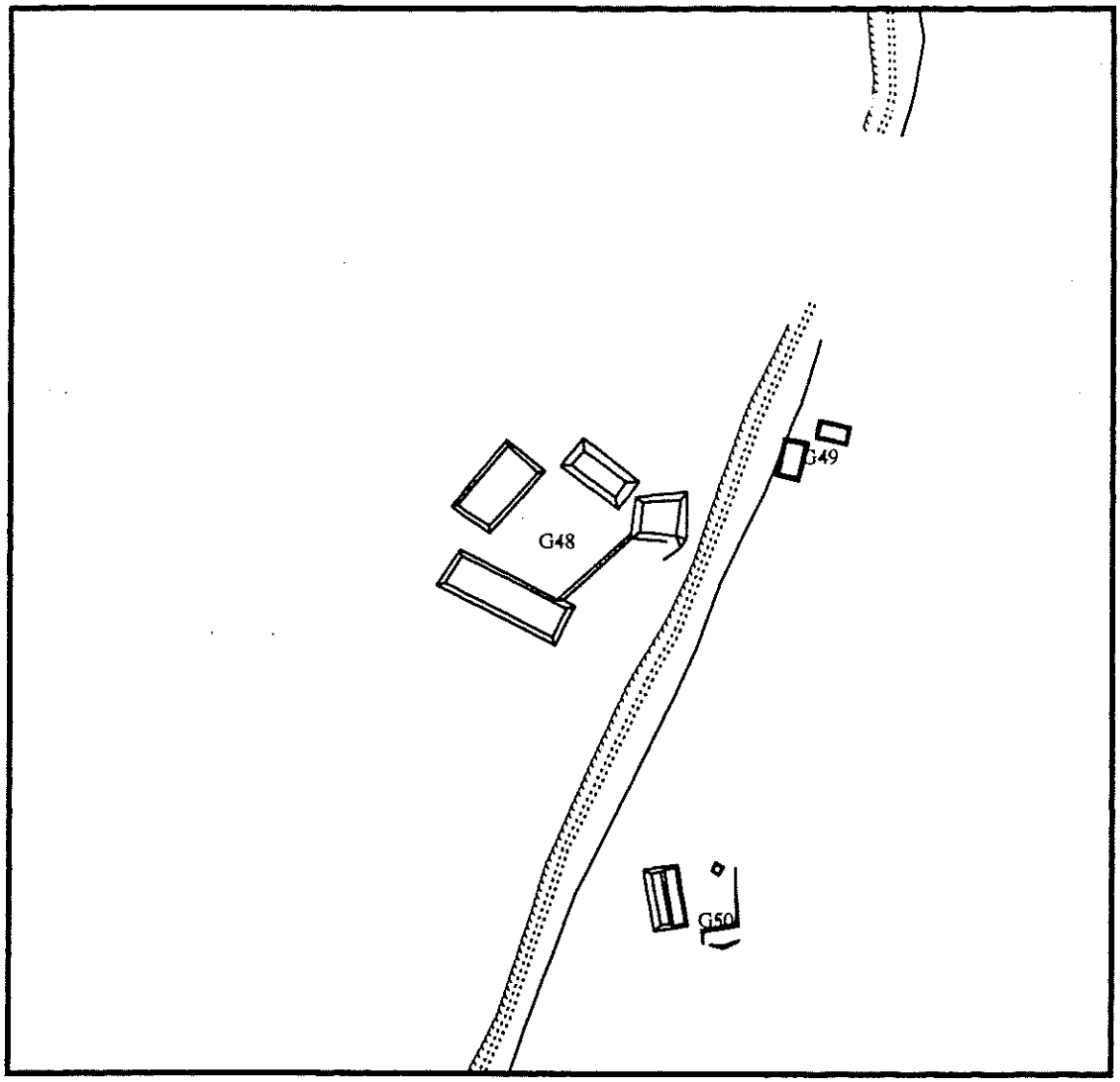
Grupo 47
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

EFAT Group Maps



Grupo 48, Grupo 49 y Grupo 50
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha

Proyecto EFAT
Mapas de los Grupos



0 10 20 40 Meters

Grupo 48, Grupo 49 y Grupo 50
Escala = 1:1,500
28 Agosto 2003
Preparado por Timothy Murtha