

A Preliminary Report on the

2006 GEOPHYSICAL SEASON AT GIZA

A Ground-Penetrating Radar Study

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INTRODUCTION

From October 28, 2006 until November 25, 2006, the Glen R. Dash Charitable Foundation, in cooperation with Ancient Egypt Research Associates (AERA), conducted a ground penetrating radar survey over selected areas of the Giza Plateau. This report details the preliminary findings from that study.

This work was performed by Glen Dash (Dash Foundation/Boston University Center for Remote Sensing/AERA), Benjamin Vining (Boston University Department of Archaeology), Dr. Joan Dash (Dash Foundation), David Crary (Dash Foundation), Brian Hunt (AERA) and Matthew McCauley (AERA).

SURVEY EAST OF KHENTKAWE TOWN

The region known as “Khentkawes Town” (KKT) is a set of well organized mudbrick structures lying east of the tomb of Khentkawes. It was excavated by the Egyptian archaeologist Selim Hassan in 1932 and 1933 (Hassan 1943). Our first task was to map buried features at the eastern edge of this town.

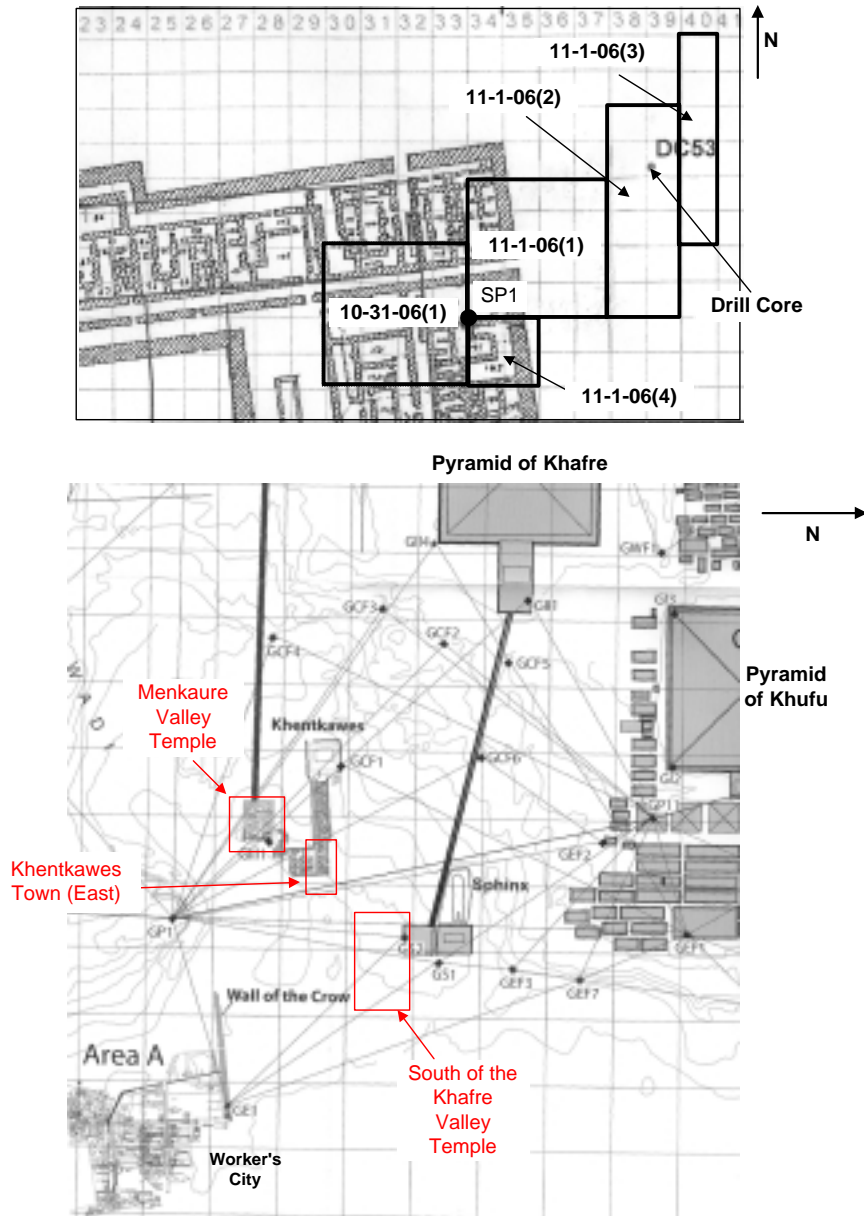


Figure 1: We have located three of the four areas we surveyed on this plan map of the Giza necropolis. The first region we surveyed was Khentkawes Town (East). A close up is shown the top. For the purposes of this survey, we divided this region into five “Geophysical Survey Areas.”

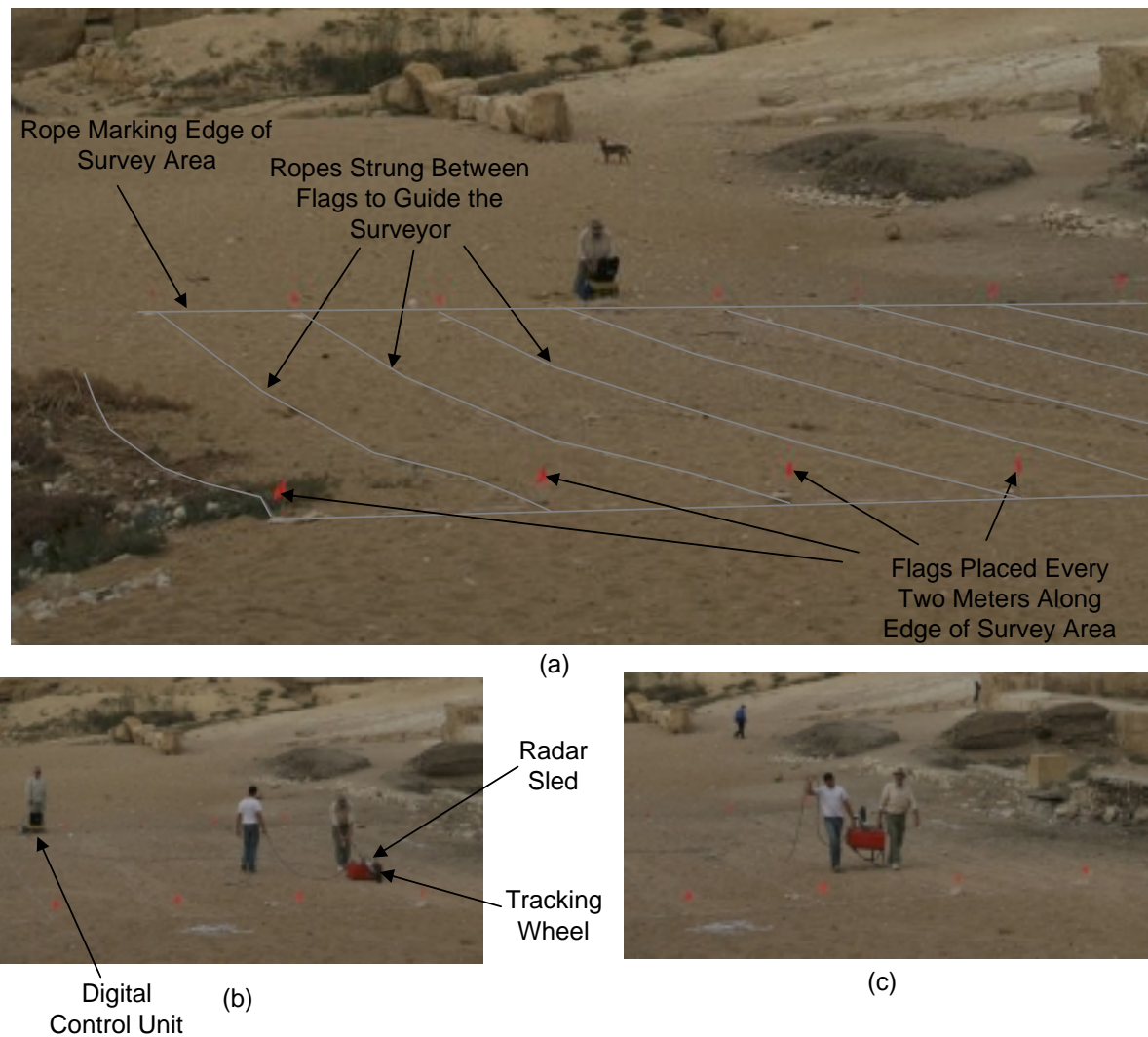


Figure 2: To conduct a survey, we first mark the edges of the Geophysical Survey Area with rope, place flags every two meters and run additional ropes between the flags as a guide (a). We take the data while walking backwards, using the ropes as a guide (b). When we conduct a “unidirectional survey”, we pick up the radar sled and carry it back to the next starting point at the end of each transect (c). When we conduct a “bidirectional survey”, we reverse the direction of the radar sled at the end of each transect (not shown). While bidirectional surveys are faster, they are prone to greater errors especially when operating on a slope.

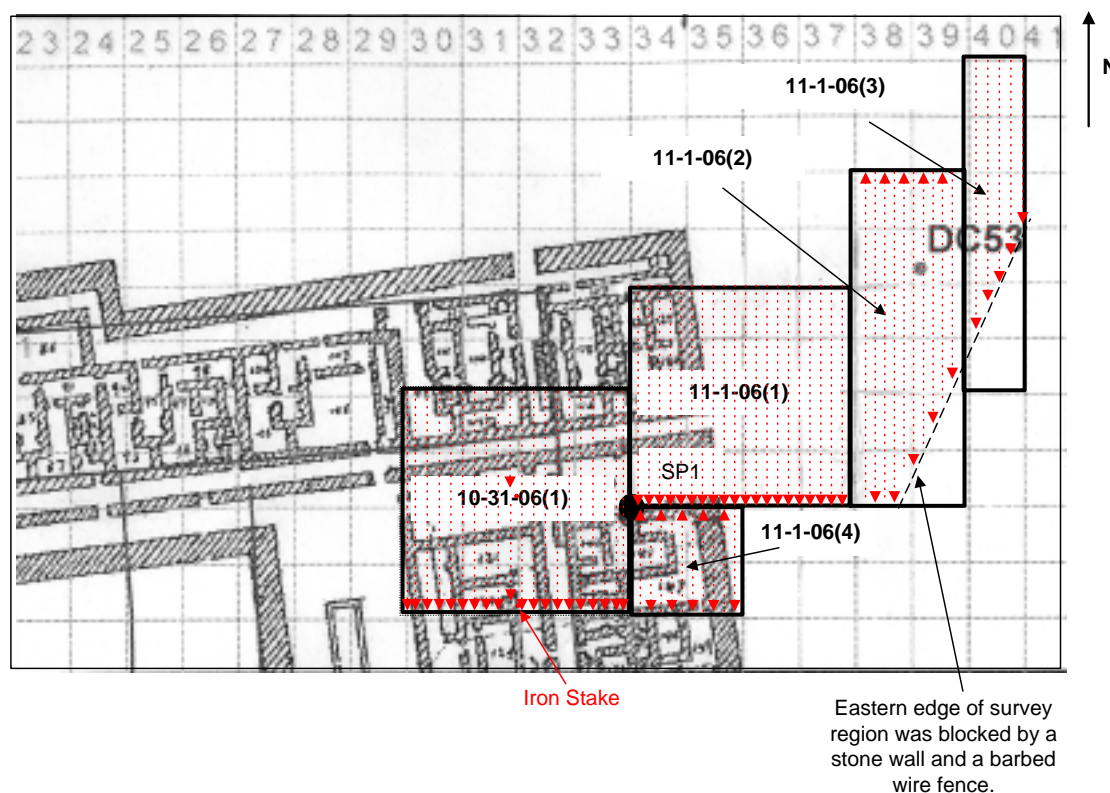


Figure 3: The red lines demark the pattern of the transects we used to map survey areas at the eastern edge of Khentkawes Town. Transects lines in the middle of the Geophysical Survey Area 10-31-06(1) were interrupted by two iron stakes. We chose a bidirectional traverse pattern for survey areas 11-1-06(2) and 11-1-06(4), and a unidirectional traverse pattern for survey areas 10-31-06(1), 11-1-06(1) and 11-1-06(3).

We set an initial control point (SP1) at the eastern edge of KKT at E500295.035 and N99354.986 on the Giza Plateau Mapping Project (GPMP) control grid (Goodman and Lehner 2007). Using SP1 as a reference, we then staked out five areas to survey. The first of these, designated Geophysical Survey Area 10-31-06(1), consisted of a 20 x 20 meter square covering E500275 to E500295 and N99345 to N99365.

We used a GSSI SIR 2000 ground penetrating radar system to conduct this study. The system consists of a radar sled, a cable and a control unit. To conduct this survey, we dragged the radar sled along predetermined transects as shown in Figure 2.

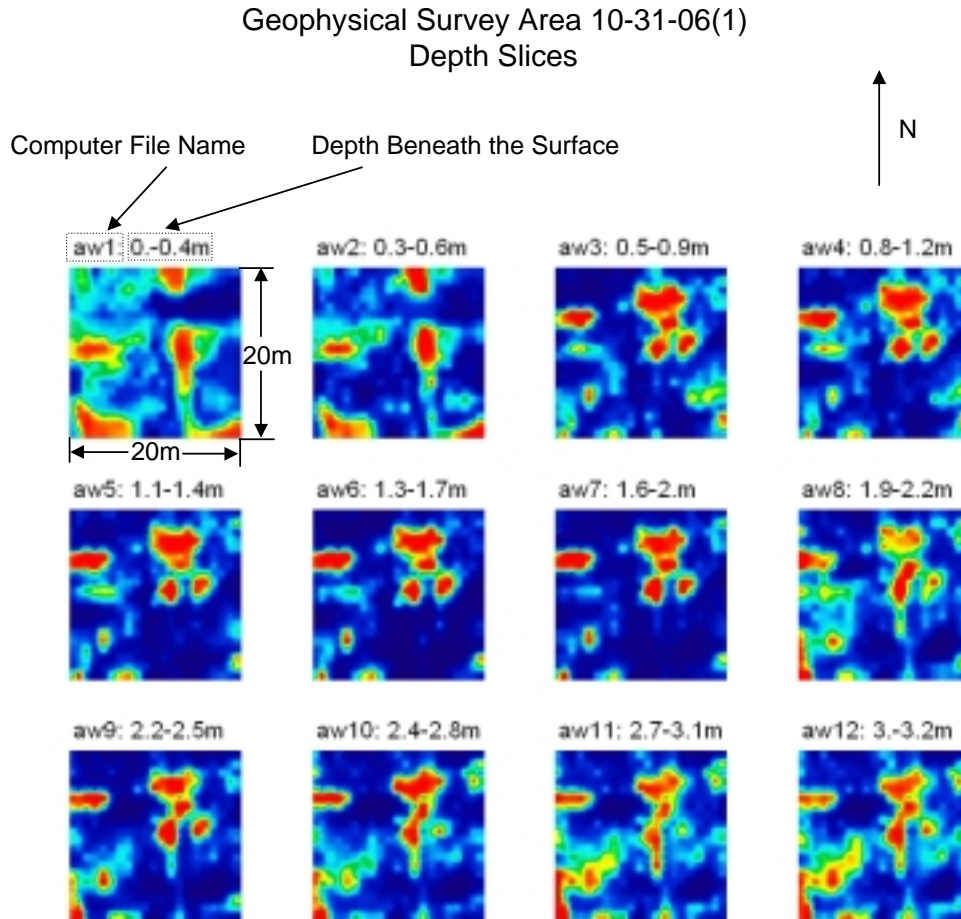


Figure 4: Each image above is a “depth slice” of Geophysical Survey Area 10-31-06(1). Each slice measures 20 meters in length, 20 meters in width and 0.4 meters in depth. The red, orange and yellow areas represent strong to medium radar reflectors respectively. The blue areas represent weak reflectors.

Once the mapping of a particular area is completed, data processing begins. For this study, we used a software program known as GPR-SLICE. This software allows us to produce virtual images of the subsurface at selected depths. For example, Figure 4 shows a set of “depth slices” for survey area 10-31-06(1). These are slices of the soil parallel to the surface each about .4 meters thick. Areas shown in yellow, orange, and red exhibit moderate to strong radar reflections respectively, while areas shown in blue exhibit little or no reflection.

Geophysical Survey Area 10-31-06(1)
Overview

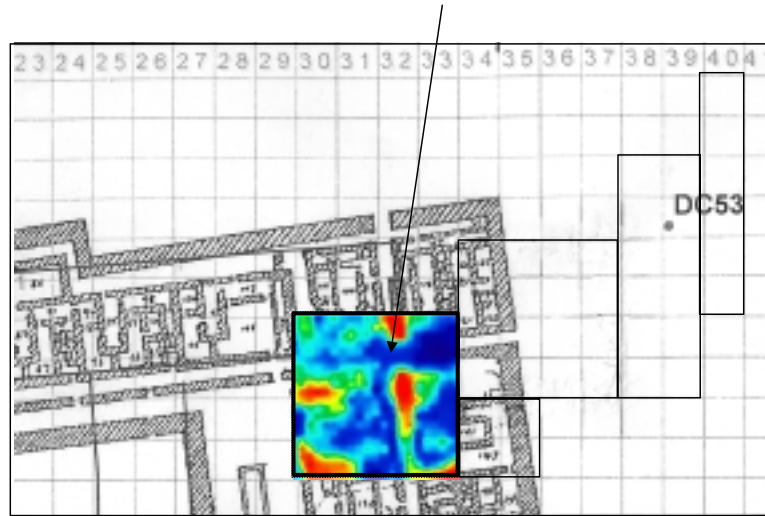
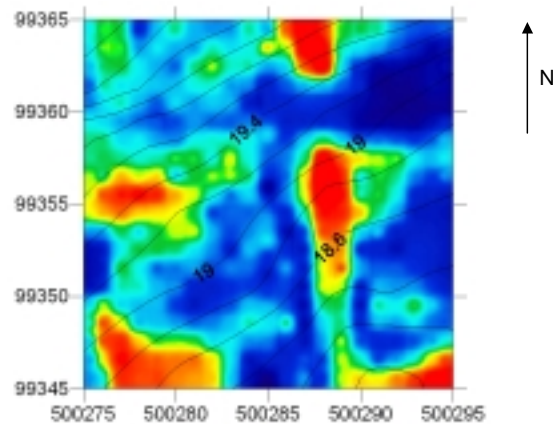


Figure 5: At the top, we combine the first two depth slices from Figure 4 to produce an “overlay.” We have added elevations as well. At the bottom, we place the overlay on Selim Hassan’s map of Khentkawes Town.

The data represents, in effect, a map of differing soil types. Ground penetrating radar detects changes in soil types by transmitting a brief pulse of radio frequency energy into the soil. As the radar pulse travels downward, it encounters differing soil types, each with differing electrical characteristics. Where changes are encountered, some of the pulse’s energy is reflected back to the surface and is picked up by the radar sled’s receiving antenna. Where the soil is uniform, there are no changes in soil types and no radar reflections. The same is true where the soil type changes slowly with depth.

Electrically, we can characterize most soil types by their “conductivity” and “dielectric constant.” Conductivity is a measure of how freely electrical current moves through the soil. Dielectric constant is a measure of how easily the soil can be electrically charged. An abrupt change in either can cause a reflection.

The first two depth slices in Figure 4 (designated by their computer file names aw1 and aw2) show buried walls of Khentkawes Town. The walls trending north-south appear to have survived the travails of time better than those trending east-west. The next four slices show different features, probably those associated with the floor beneath the walls. We find no useful information beyond a depth of 1.9 meters.¹ Here, most of what we see are “ghosts” of near-surface features.

Ghosting is a common problem in GPR interpretation. It is caused by multiple reflections of a radar pulse between two surfaces. For example, when a radar pulse reflects off a dense object, such as the top of a wall or a floor, it travels upward to the surface where it encounters another object – the surface itself. That causes the radar pulse to be reflected downward again, where it encounters the same wall or floor and is reflected up again. It is these “multiple reflections” that cause ghosting. Most of what we see in slices aw8 through aw12 are ghosts.

In Figure 5, we have taken the data from depth slices aw1 and aw2 and created an “overlay”. We produce overlays by combining the strongest reflectors from two or more depth slices. The process allows us to see the strongest reflectors over a range of depth. We have also added surface contours to the image. Finally, we have placed the overlay on a map of Khentkawes Town created by the Selim Hassan. The features match well.

¹ In Figure 4, as well as elsewhere in this report, we provide estimates for the depth of various features. These are rough estimates. Depth estimates depend on assumptions surveyors make regarding the speed of radiofrequency pulse propagation through the soil. In air, the speed of radiofrequency pulse propagation is the speed of light, 3×10^8 meters per second. In soil, however, the propagation is slower. How much slower is very difficult to measure. However, based on the methodology we use here, and which is described in the Technical Appendix, we can say that it is unlikely that the objects shown are any deeper than indicated. They may, however, be up to 50% shallower.

Geophysical Survey Area 11-1-06(1) **Depth Slices**

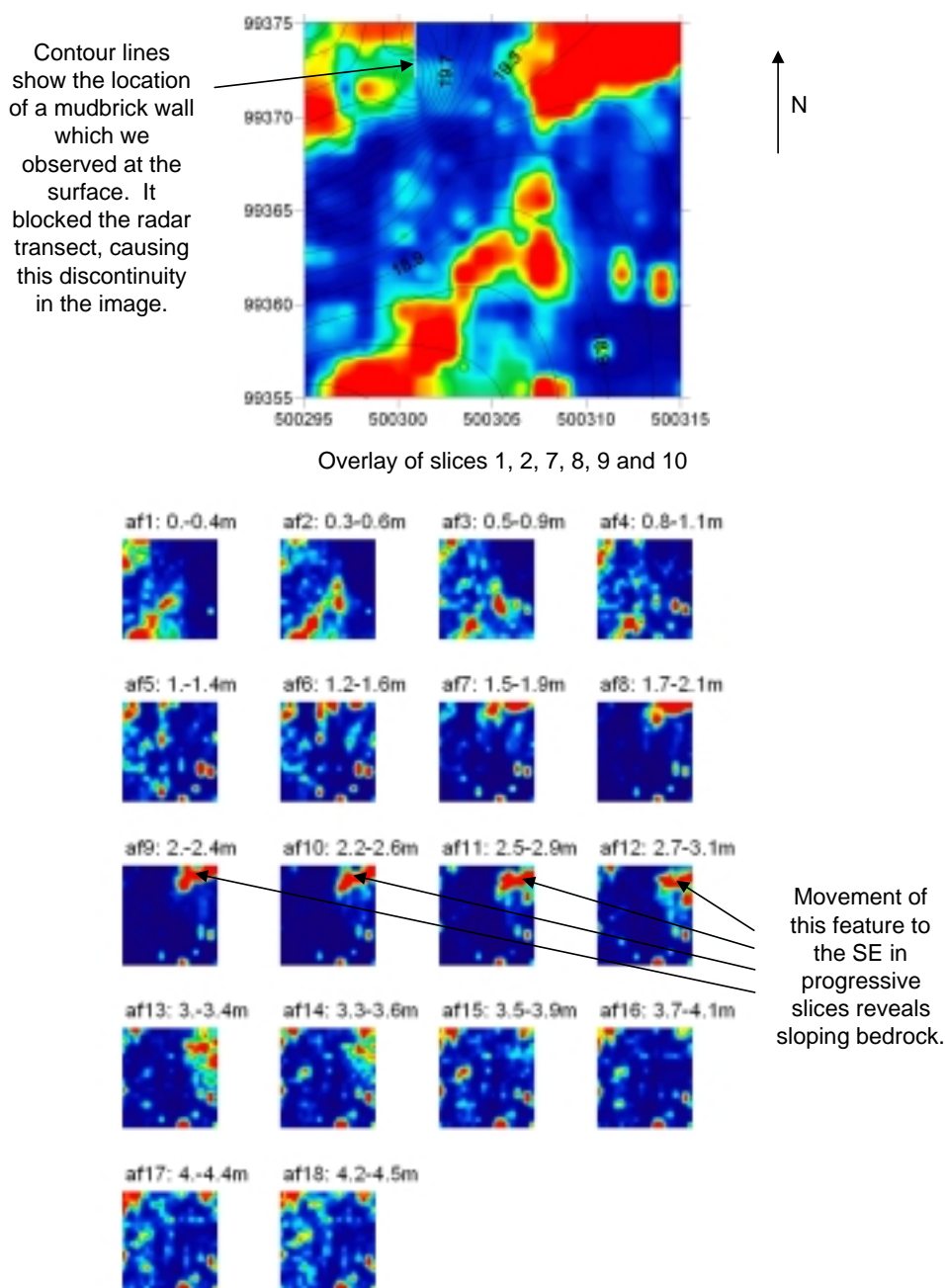


Figure 6: We show depth slices for Geophysical Survey Area 11-1-06(1), and produce an overlay (top). The feature which appears to move to the southeast in slices 9 through 12 represents bedrock sloping away in that direction.

Moving to the north and east, Figure 6 shows the data from Geophysical Survey Area 11-1-06(1). Here there are few rectilinear features evident in the eastern half of the survey area, a sign that we have reached the eastern end of Khentkawes Town. Note the abrupt discontinuity in the upper left hand corner of the overlay. We encountered a mud brick wall protruding through the surface here which kept us from pulling the radar sled to the end of our predetermined transect. This wall is likely part of the Khentkawes Town enclosure wall.

A bright red (and therefore highly reflective) feature emerges in the upper right hand corner of slice af9 in Figure 6. This is bedrock. Looking at the individual depth slices, we see that this bright red feature appears to move to the southeast with depth. This is, in fact, how sloping bedrock should appear on radar. Because the contrast between the bedrock and the fill material above it is great, bedrock reflects nearly all of the radar energy back to the surface. That means that the area under the bedrock does not get illuminated and appears dark in subsequent slices. In depth slice af10, for example, only the portion of the bedrock not imaged in slice af9 appears. The same is true for depth slices af11 and af12, resulting in an image of the bedrock that appears to move down slope with depth.

Figure 7 contains an overlay of the depth slices from survey area 11-1-06(1) together with its placement on Hassan's maps.

In Figure 8, we render some of the data from Figures 6 and 7 in a "sectional" form. This section is aligned with N99372 and covers the range from E500295 to E500315. The bright red band in Figure 8 is the surface of the bedrock. Because bedrock reflects virtually all of the radar energy back to the surface, the volume beneath it appears dark. The thickness of the red band is a function of the strength of the reflection, not the thickness of the bedrock.

Geophysical Survey Area 11-1-06(1) Overview

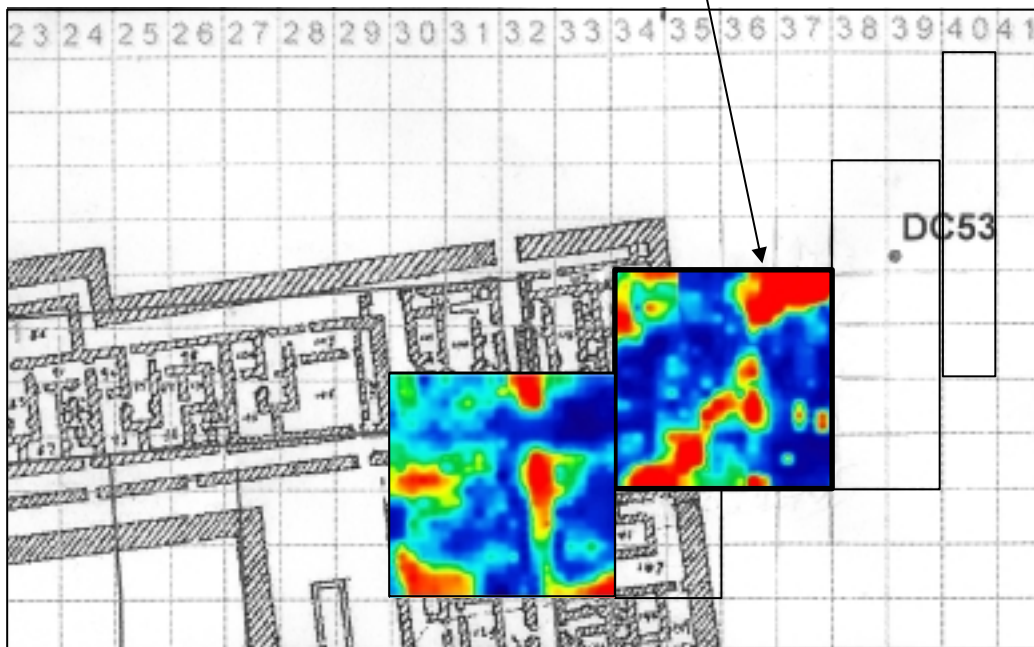
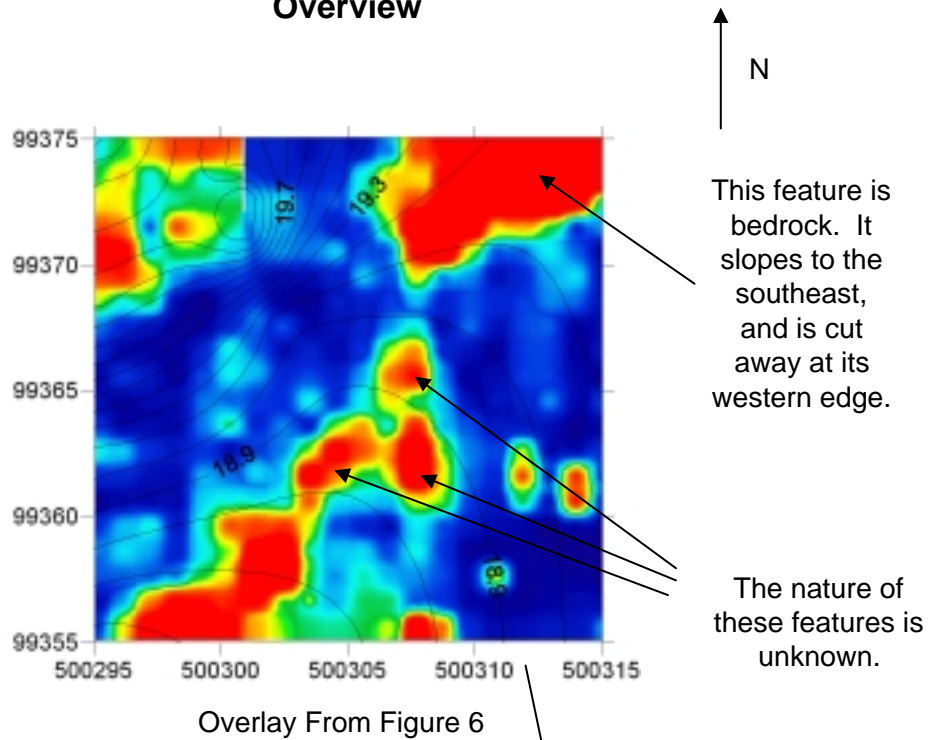


Figure 7: The overlay at the top represents the most relevant features of Geophysical Survey Area 11-1-06(1). It is placed on Selim Hassan's map at the bottom.

Geophysical Survey Area 11-1-06(1)
Sectional Cut at N=99372

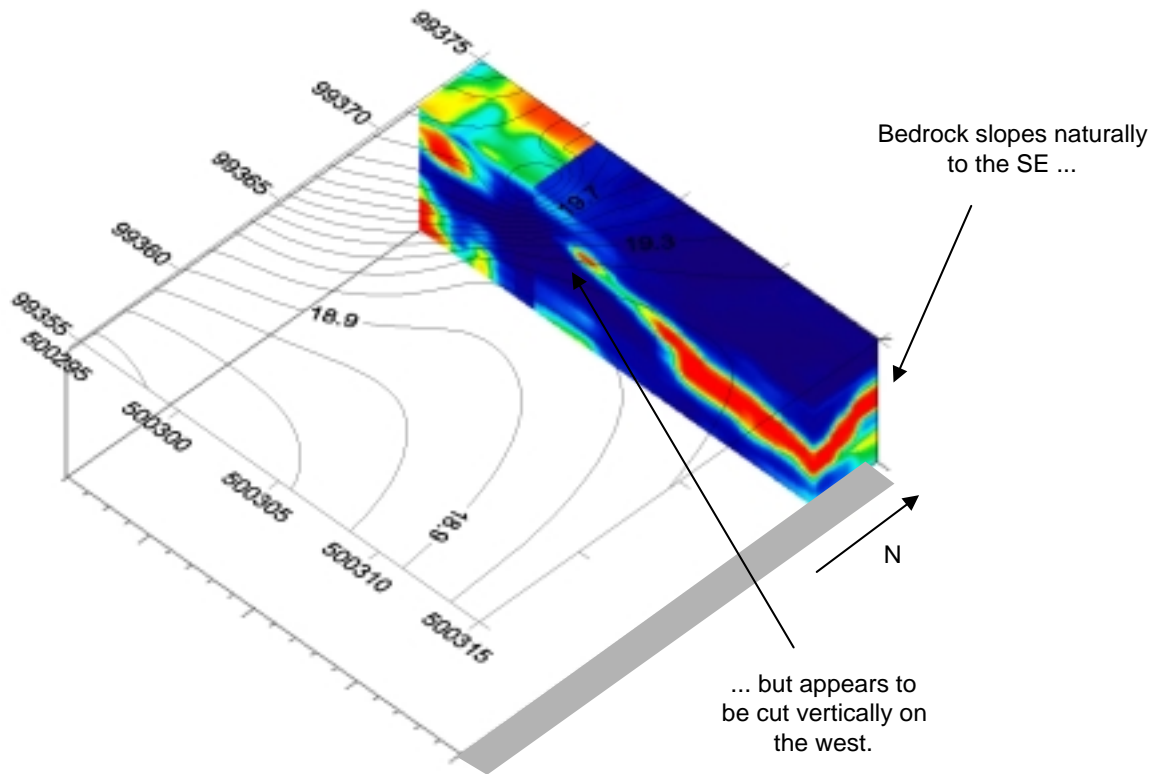


Figure 8: This 3D view of survey area 11-1-06(1) gives us another way of looking at features. Here, in section, the bedrock appears to slope away to the southeast. The bedrock blocks the entire radar signal, so only blue, indicating a lack of radar returns, appears beneath it. The western edge of the bedrock is either vertical or concave. Either way, the radar cannot detect it.

The section reveals that the bedrock slopes to the southeast. At its western edge the bedrock ends abruptly. This is a vertical or concave face. The vertical face is not detected by the radar because the radar's antenna is "horizontally polarized" which simply means that it is insensitive to vertical features.

Geophysical Area 11-1-06(2) Depth Slices

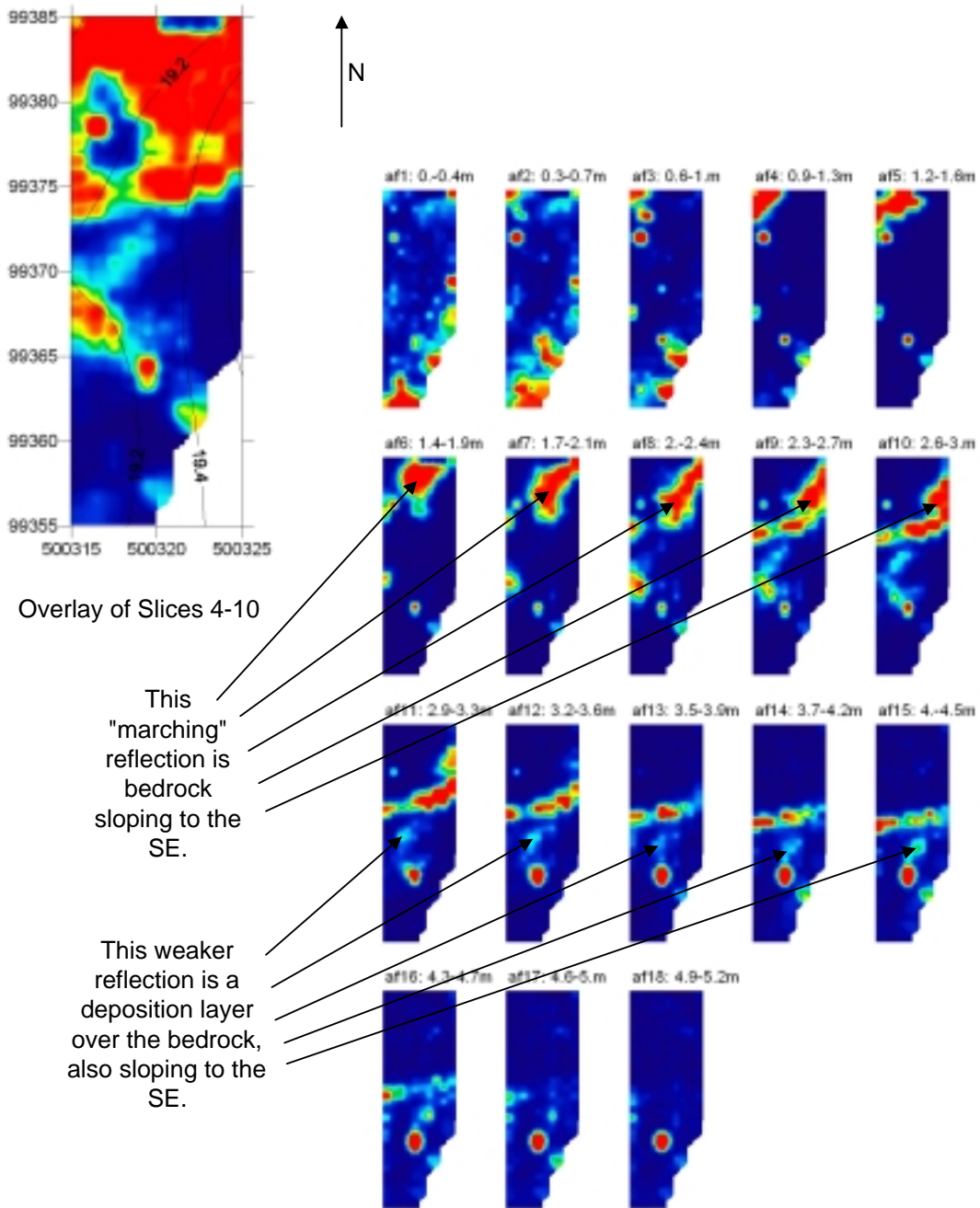


Figure 9: Depth Slices from Geophysical Survey Area 11-1-06(2).

Geophysical Area 11-1-06(2) Radargrams

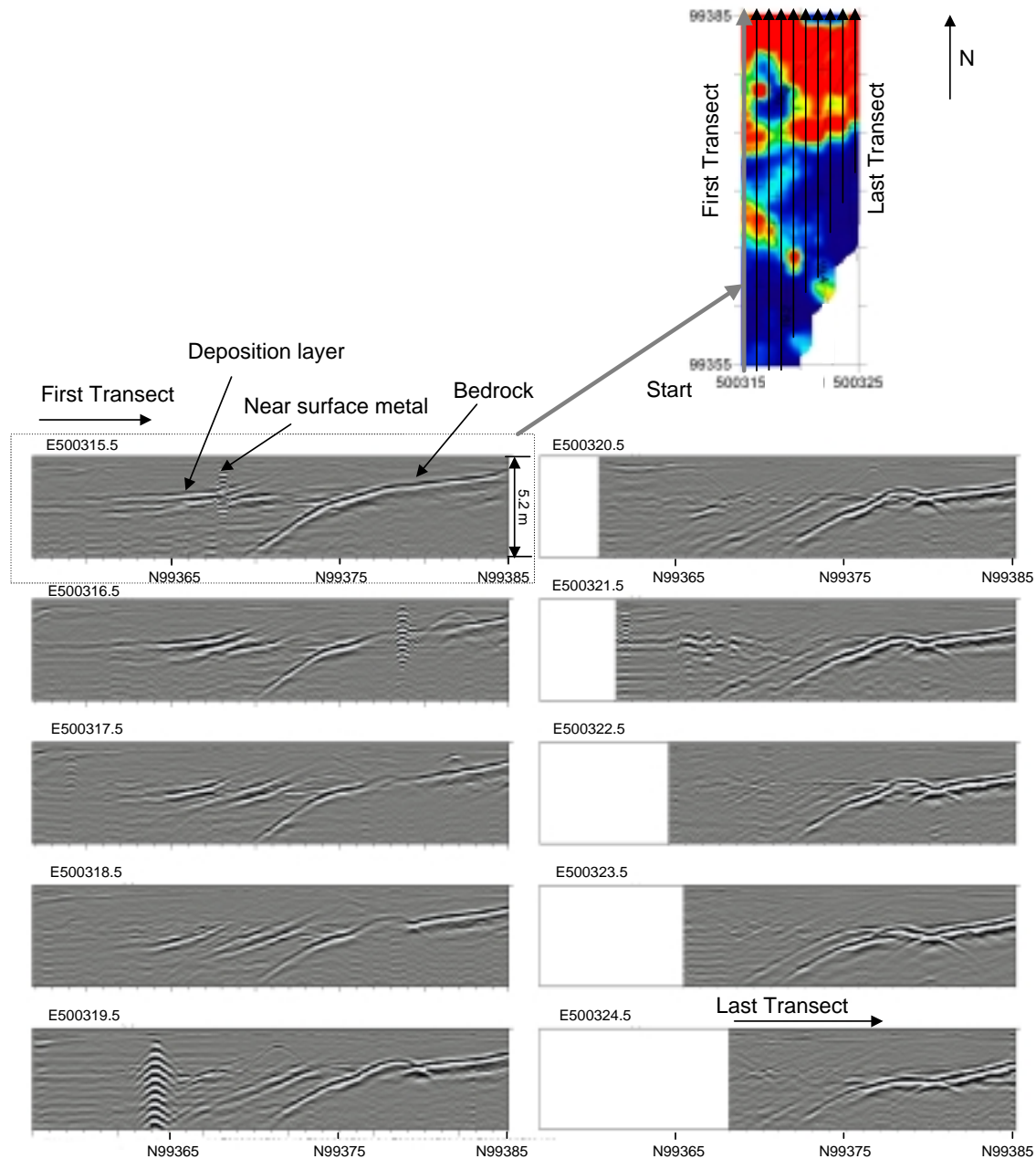


Figure 10: We need to consult the radargrams from Geophysical Survey Area 11-1-06(2) to determine the nature of the rectilinear features which appear on the slope of the bedrock in Figure 9. We show here ten radargrams for this area, corresponding to the ten transects we used to map it. The first of these, taken at the location identified with the gray arrow, is shown at the upper left. The linear features appear to be caused by a natural layer of deposition on the bedrock's slope.

Geophysical Survey Area 11-1-06(2) **Overview**

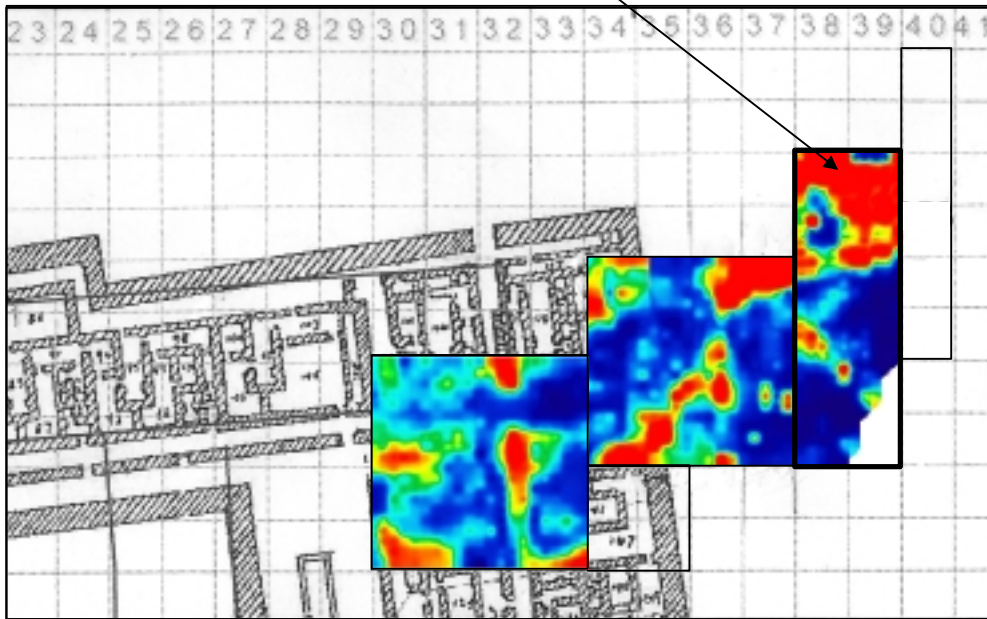
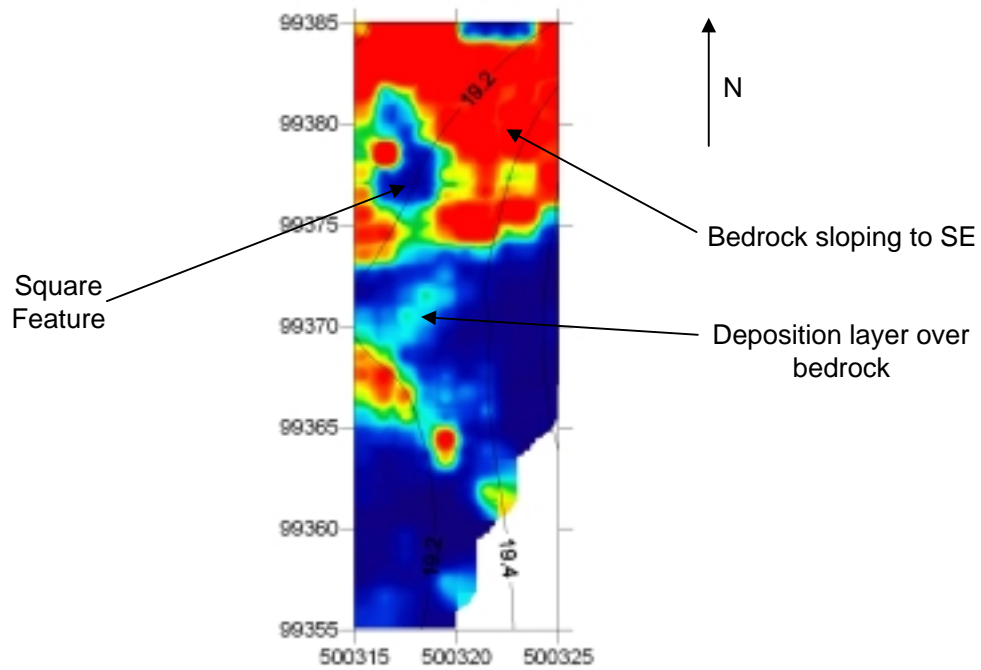


Figure 11: An overview of the data from Geophysical Survey Area 11-1-06(2).

Further to the east, Geophysical Survey Area 11-1-06(2) encompasses a 10 x 30 meter area whose southeast corner was obscured by a stone wall and barbed-wire fence (Figure 9). Detectable subsurface features here include bedrock and a set of rectilinear features on the bedrock's southern slope. These rectilinear features appear to march to the southeast with depth, right along with the bedrock. To better classify these features, we need to look at the raw data generated by the radar in the field, data which is in the form of a "radargram."

A radargram is a kind of electrical section of the soil. One radargram is produced for each transect that is run. Since each transect is stored in a separate computer file, transects are sometimes referred to simply as "files."

In Figure 10, the bedrock stands out clearly. Indeed, the surface of the bedrock appears to have three distinct layers, one bright, one dark and one bright. However, this is a radar artifact. Because of certain antenna limitations, the transmitted radar pulse has three parts, one positive, one negative and the next positive, or vice versa. Therefore, what is reflected also has three parts.

From the radargrams, we can see that a layer of soil has apparently been deposited over the bedrock. This deposition layer appears to be the cause of the faint rectilinear features in Figure 9.

The square feature in Figure 11 appears at first to be a cut in the bedrock, perhaps a shaft tomb or the foundation of a building. Here again the radargrams are helpful. The feature appears at the junction of two layers of bedrock. What appears to be a square shaft in the bedrock in Figure 11 may in fact simply be a natural feature, the place where one layer of bedrock slips under another. On the other hand, the mounded debris around the feature visible on the radargrams may indicate the presence of eroded manmade structures here, perhaps walls.

Geophysical Survey Area 11-1-06(3) Depth Slices

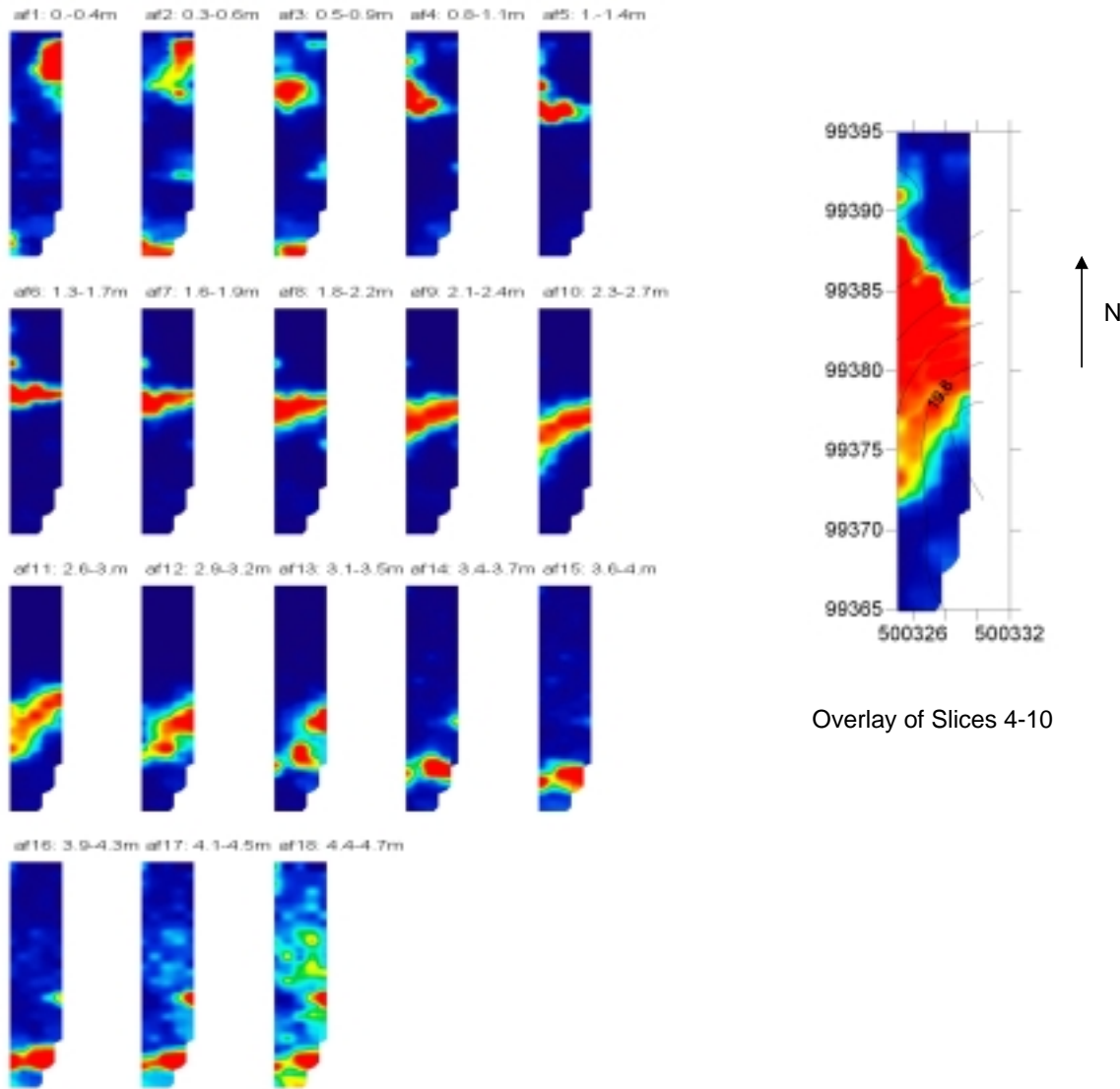
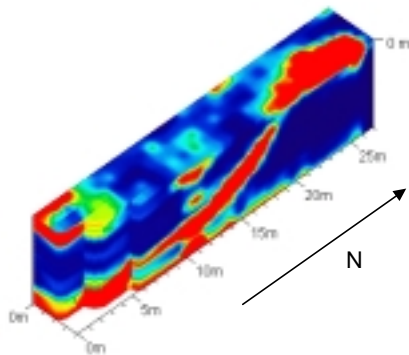


Figure 12: Depth Slices from Geophysical Survey Area 11-1-06(3).

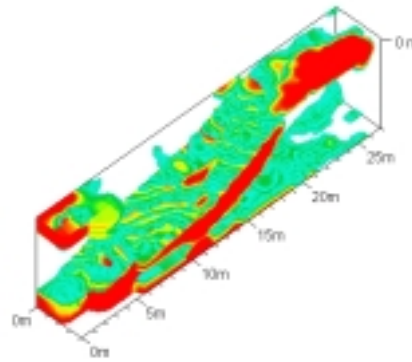
Farthest to the east is Geophysical Survey Area 11-1-06(3), an irregularly shaped survey area of approximately 5 x 27 meters (Figure 12). We find nothing here but bedrock, shaped either by natural features or by human activity. From the depth slices we can see that the bedrock slips to the south and east. Since the bedrock is the only distinctive feature in area, we can create an image of it in isolation (Figure 13).

Imaging in 3D



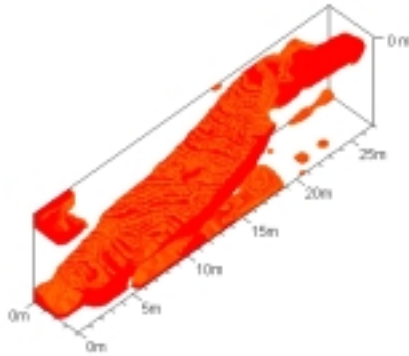
The GPR SLICE software can produce a 3D image of the subsurface.

(a)



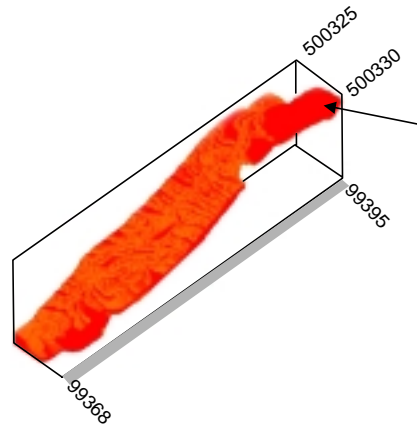
Here we strip away the weakest reflectors (in blue).

(b)



In this image we strip away all but the strongest reflectors.

(c)



Using Photoshop, all but the desired features can be stripped away and the image can be annotated.

(d)

Here the bedrock slopes to the north and may form part of a road or causeway

Figure 13: By selectively stripping away the weaker reflectors we can obtain an image of the bedrock in isolation. While the overall shape of the bedrock is true, the fine texture is sampling noise.

To create the image in Figure 13, we started with the subsurface data in sectional form in Figure 13(a). We then programmed GPR SLICE to remove all of the volume in blue, that is, all the areas that exhibited little of no reflection (Figure 13(b)). Using the same process, we then progressively removed all but the strongest of the reflectors. Once that was done, we used Adobe Photoshop to remove any other spurious reflections.

Finally, in Figure 14 we have combined our results for the area east of Khentkawes Town and superimpose them on Selim Hassan's map.

East of Khentkawes Town -- A Summary

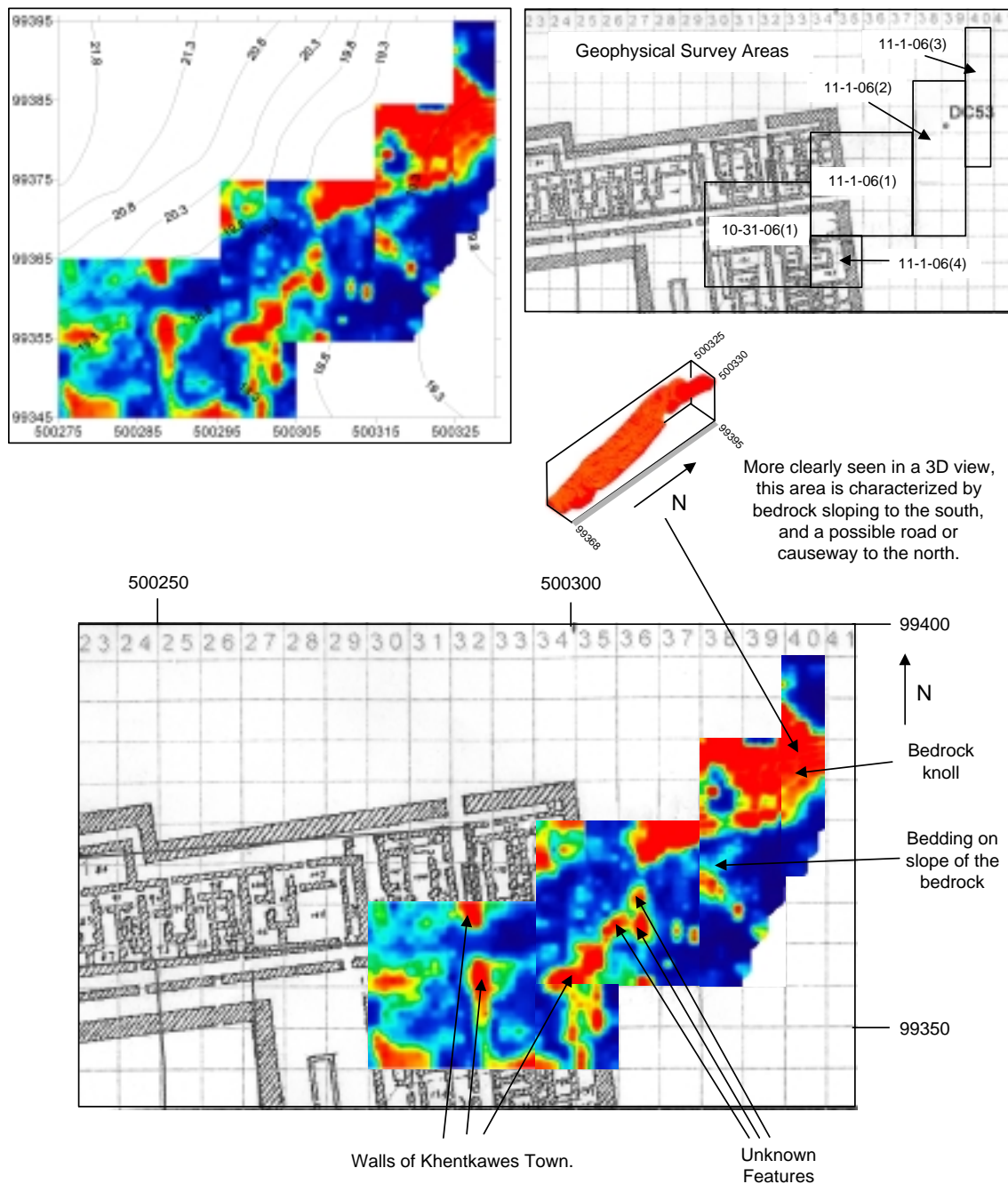


Figure 14: A summary of the major features found in the region to the east of Khentkawes Town.

THE MENKAURE VALLEY TEMPLE

The Menkaure Valley Temple (MVT) was excavated by George Reisner beginning in 1908. His plan map can be found in Figure 15 (Reisner 1931: Plan VIII and X). An “ante-town” just to the east of the Valley Temple was excavated by Selim Hassan in the 1932 (Lehner 2002).

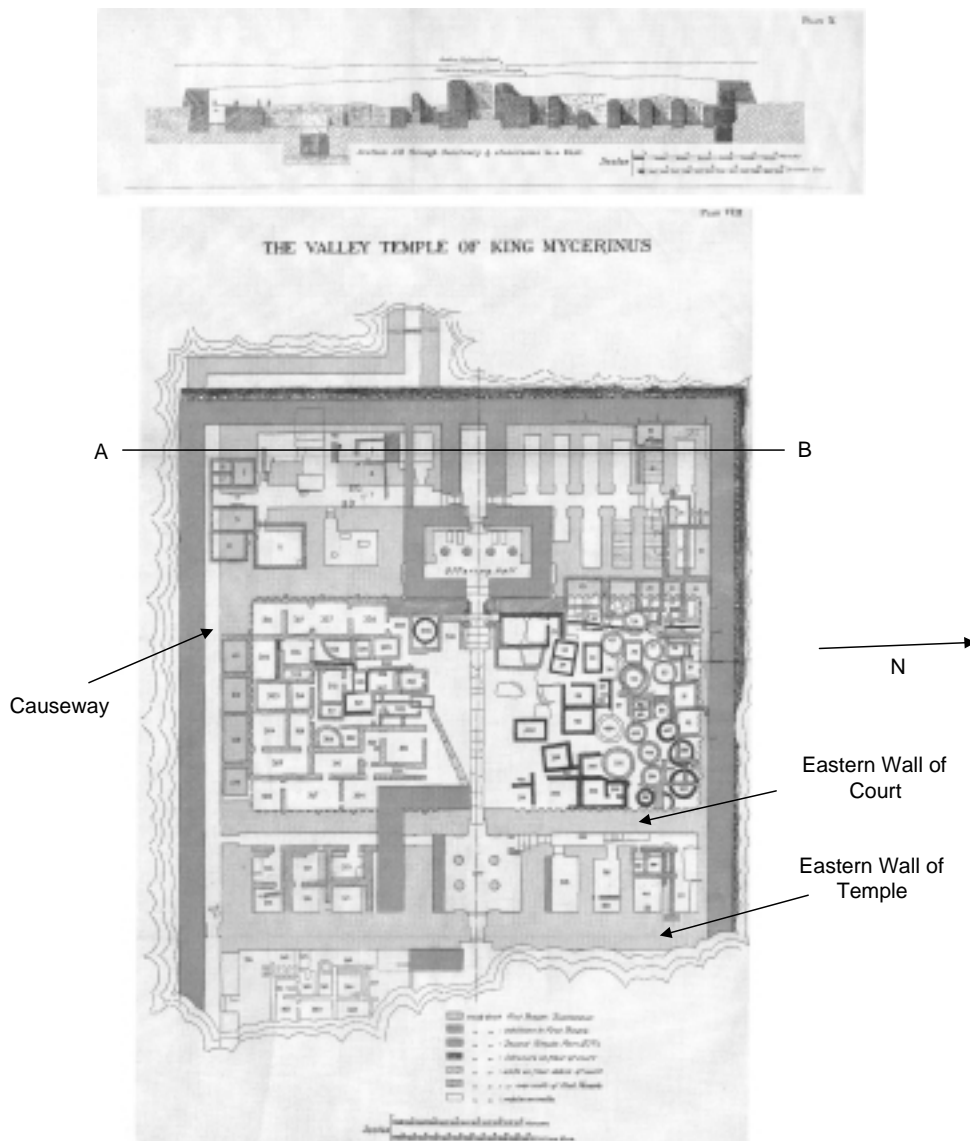
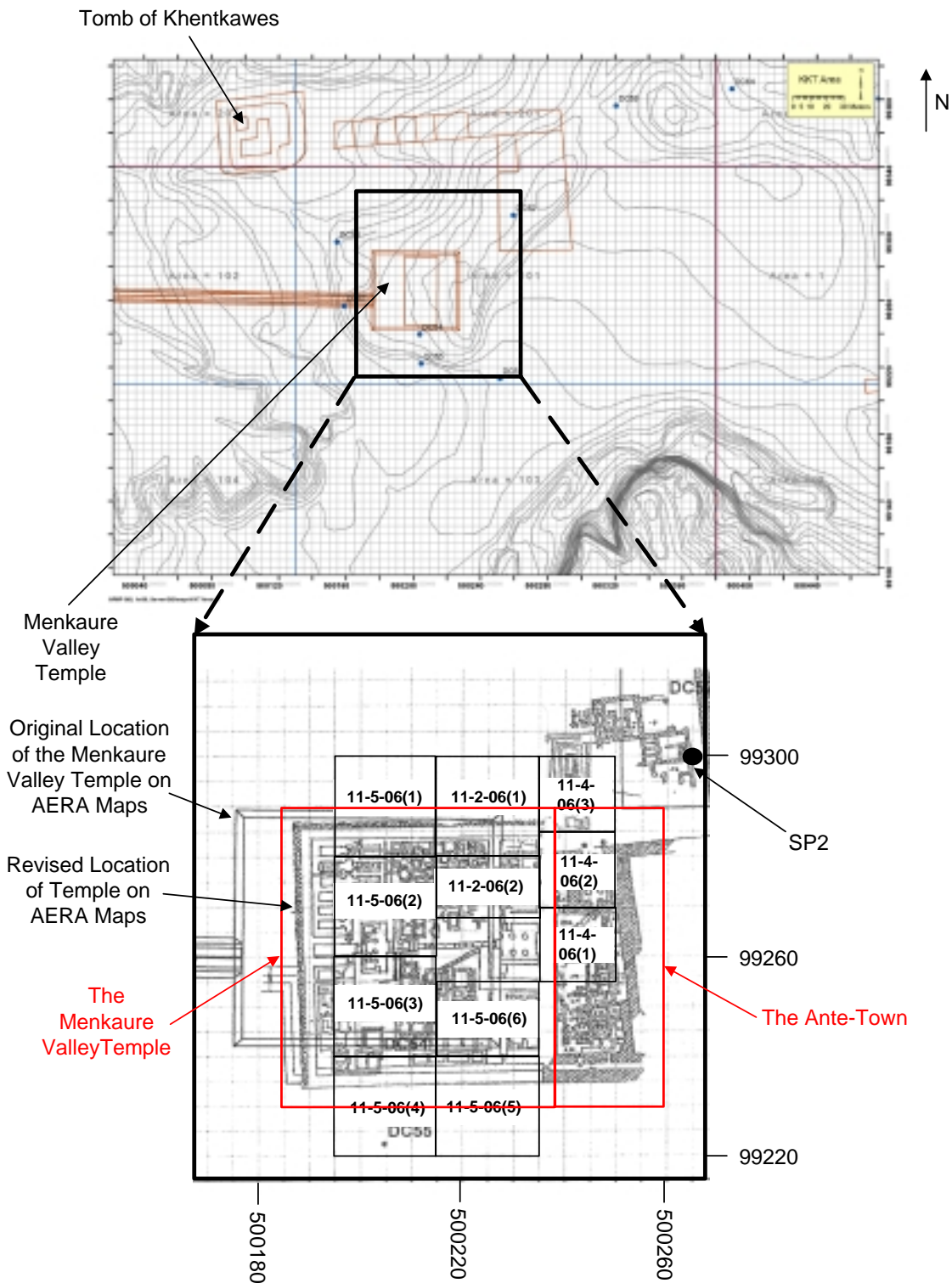


Figure 15: We show George Reisner's plan map of the Menkaure Valley Temple. At the top is a sectional view through the section A-B. (Reisner 1931: Plan VIII)



Geophysical Survey Area 11-4-06(1)
Depth Slices

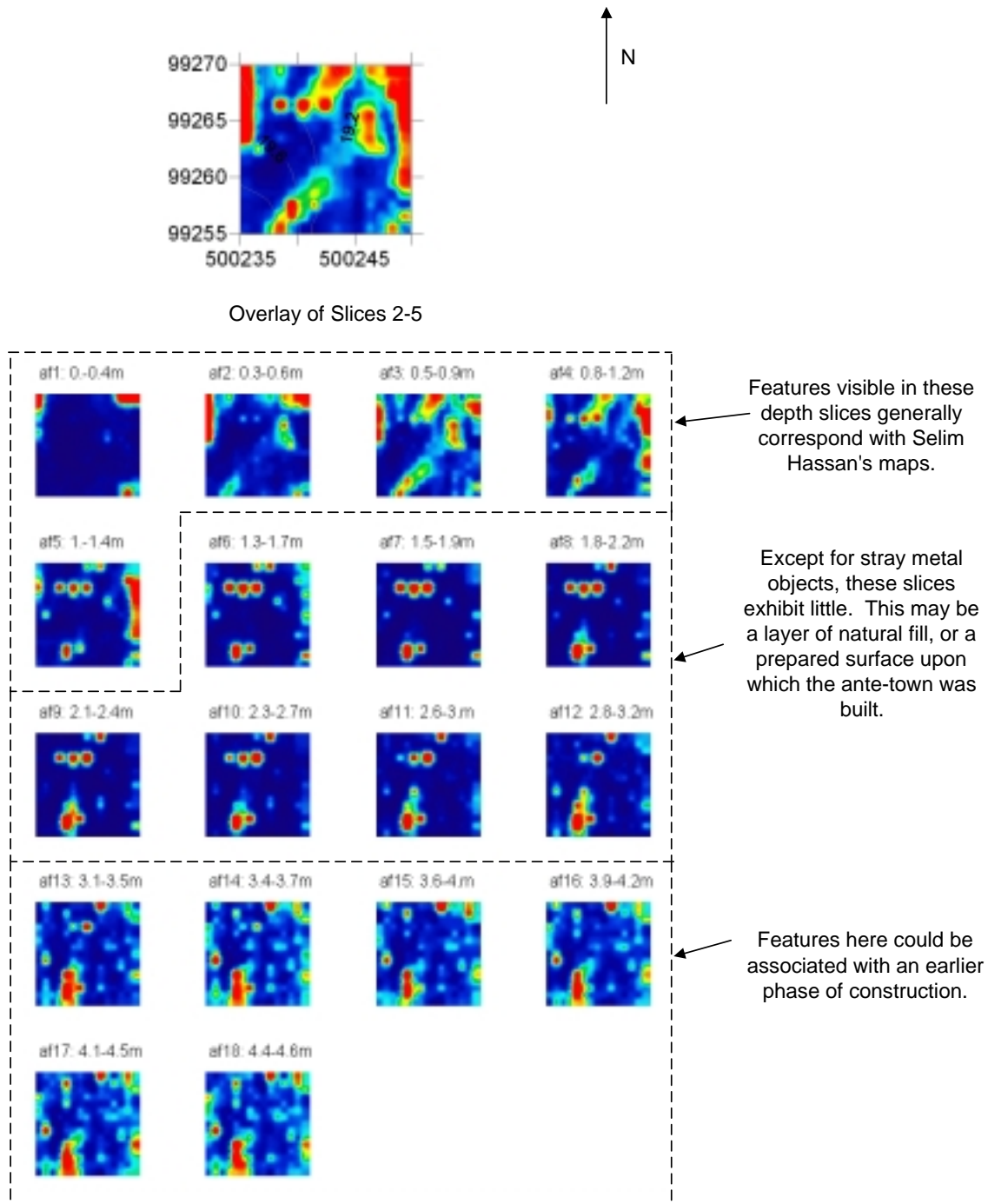


Figure 17: Depth Slices for Geophysical Survey Area 11-1-06(1).

We began by setting a second control point, SP2, at E500265.043 and N99299.998. Using this control point as a reference, we then laid out 11 survey areas (Figure 16). These included areas to the north, east and south of the temple, and as much of the interior as could be accessed. A rubbish pile prevented us from surveying over the center of the MVT.

Geophysical Survey Area 11-4-06(1) covers a portion of the ante-town. Figure 17 shows the depth slices from this area, as well as an overlay of slices 2 through 5. Figure 18 summarizes this data. The features visible in the overlay match some of the major features mapped by Selim Hassan. The radar was able to detect the eastern wall of the MVT and a portion of a major north-south wall at the eastern end of the survey area.

Depth slices 6 through 12 for area 11-4-06(1) (Figure 17) are largely devoid of reflective features other than three prominent horizontally aligned dots. These dots, however, are artifacts caused by near surface metal objects, probably horseshoes. We can observe this by looking at the radargrams (Figure 19). When metal objects are struck by a radar pulse, they ring electrically, much as a bell rings audibly when struck with a clapper. This electrical ringing goes on for many nanoseconds and results in a distinctive column-like feature on radargrams.

If we ignore these features, then there is little in depth slices 6 through 12 in area 11-4-06(1) (Figure 17) we can identify. It is possible that these slices consist of a natural deposition layer or a prepared surface upon which the ante-town was built. Indeed, the features visible in depth slices 13 through 18 may represent an earlier phase of construction in this area.

Geophysical Survey Area 11-4-06(2) also displays features associated with the ante-town. Once again, the most striking features are near to the surface (Figure 20).

Geophysical Survey Area 11-4-06(1) Overview

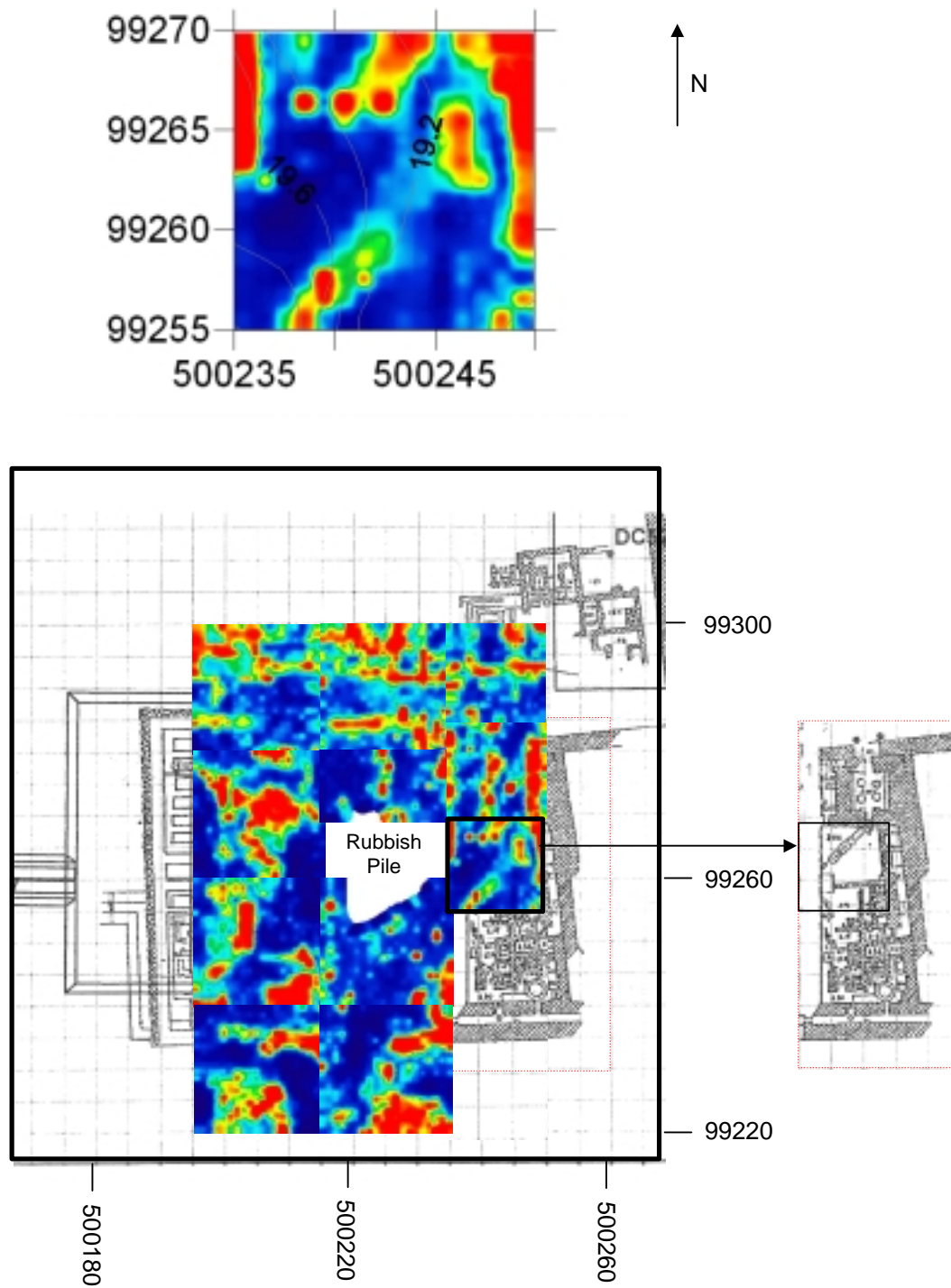


Figure 18: Overview of the data from Geophysical Survey Area 11-4-06(1).

Geophysical Survey Area 11-4-06(1) Radargrams

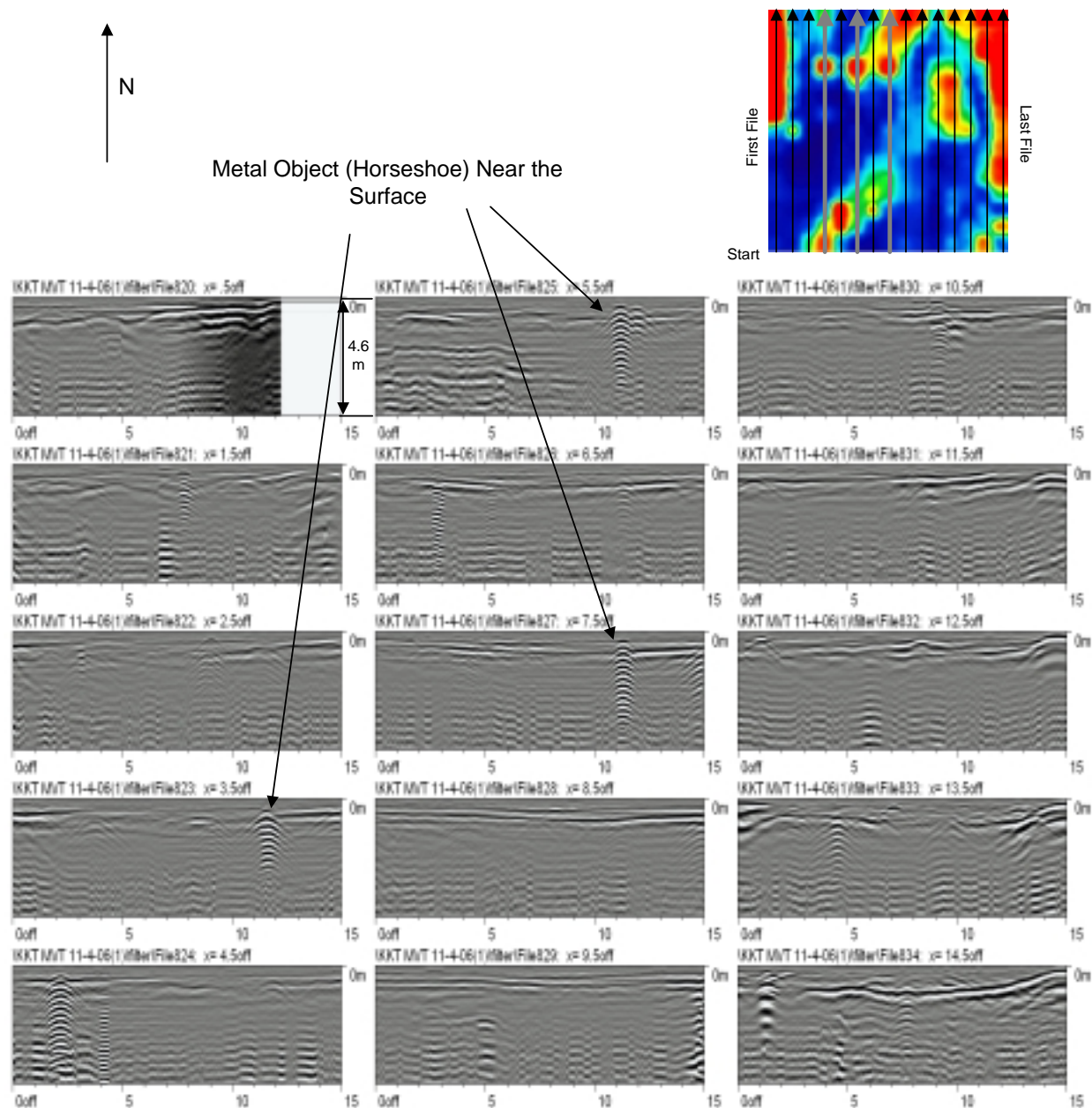


Figure 19: These column-like features are caused by metal objects near the surface, probably horseshoes. The gray arrows on the overlay at the upper right correspond to the 4th, 6th and 8th transects respectively.

Geophysical Area 11-4-06(2)
Depth Slices

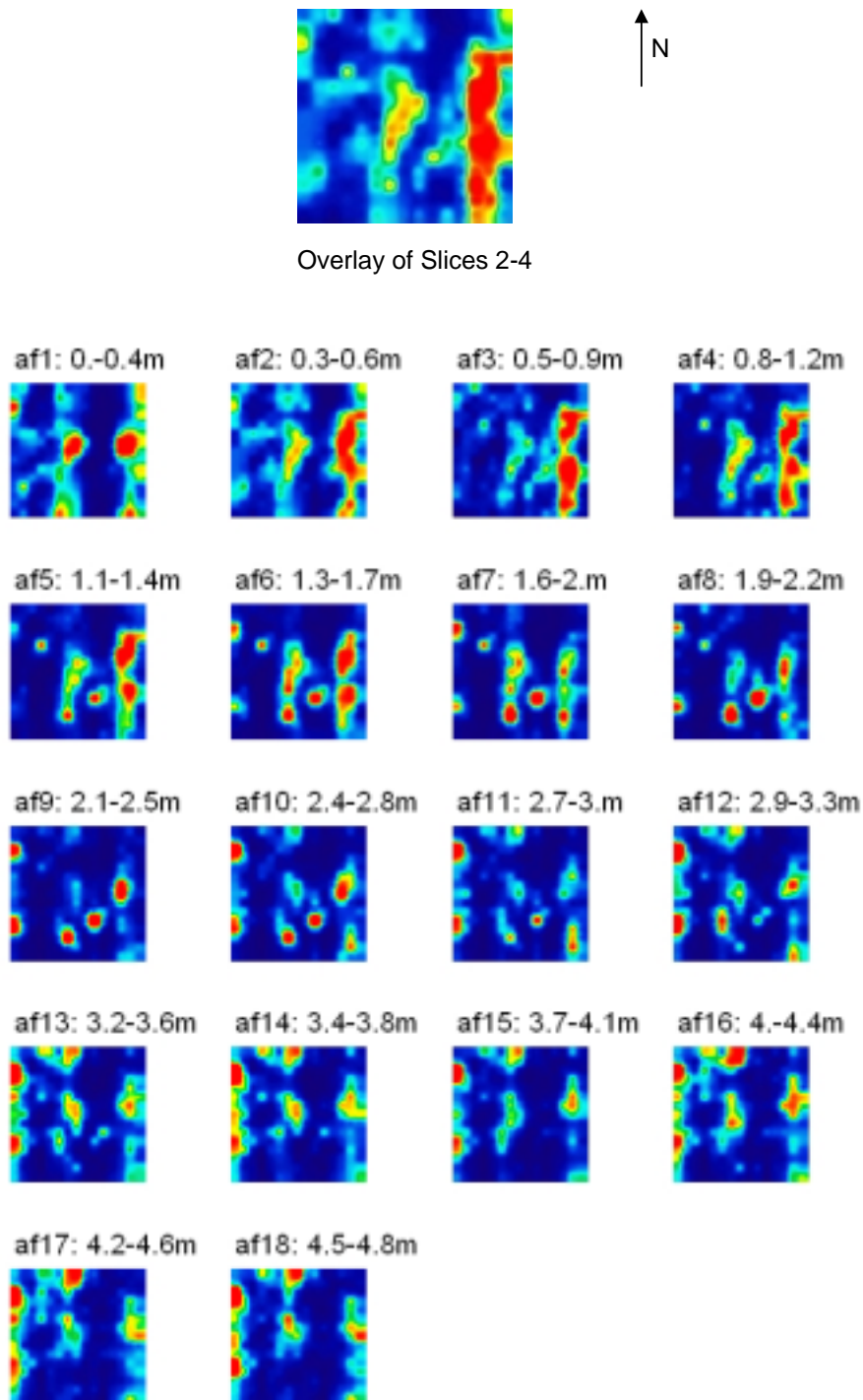


Figure 20: Depth Slices from Geophysical Survey Area 11-4-06(2).

Survey Area 11-4-06(3) lay to the north of the ante-town. An overlay of depth slices from this area reveals rectilinear structures, some of which match Selim Hassan's maps (see Figures 21 and 22). However, in addition to what Selim Hassan found, we find a prominent wall running directly east-west through the center of this area. Again, these features appear to be near to the surface.

Beneath the surface layers in area 11-4-06(3) we again find a layer largely devoid of reflectors. Deeper still, in depth slices 13 through 18, we find a feature which is likely the northeast corner of the Menkaure Valley Temple.²

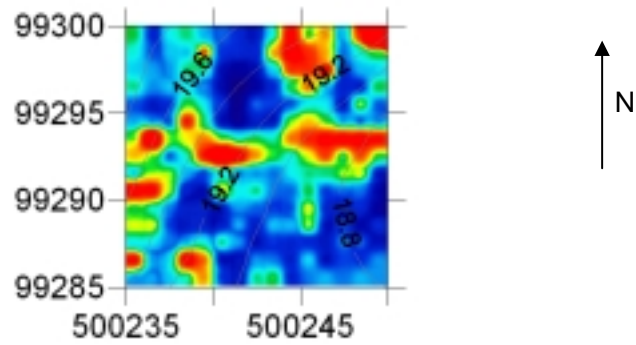
Geophysical Survey Area 11-2-06(1) is just north of the MVT. Depth slices 1 through 3 show near surface rectilinear features (Figures 23 and 24). Also clearly visible is a continuation of the central east-west wall in 11-4-06(3). A prominent causeway separates this wall from a second wall to the south. This second wall aligns with the remnants of the northernmost wall of the MVT. Once again, we see beneath this a layer largely devoid of reflectors (slices 5 through 9). Beneath this, however, a separate, different, and distinct set of rectilinear features emerge.

There appear to be two phases of occupation north of the MVT. We detect the earliest phase in depth slices 11-18 (most prominently in depth slices 11-16) and we detect the later phase in depth slices 1-3. These phases appear to be separated by a prepared surface or a layer of natural fill.

We laid out Geophysical Survey Area 11-2-06(2) just to the south of 11-2-06(1). Here, we are well inside the Menkaure Valley Temple. We can see some features associated with the MVT, including the eastern wall of the main court (Figure 25). According to Reisner's data, the eastern wall of the court stood approximately 2.4 meters high (Reisner 1931: Plan X, Figure 15 here).

² Note that GPMP Control Point GIII.1 is identified elsewhere as being the northeast corner block of the MVT. Apparently this is incorrect.

Geophysical Survey Area 11-4-06(3) Overview



Overlay from Figure 22

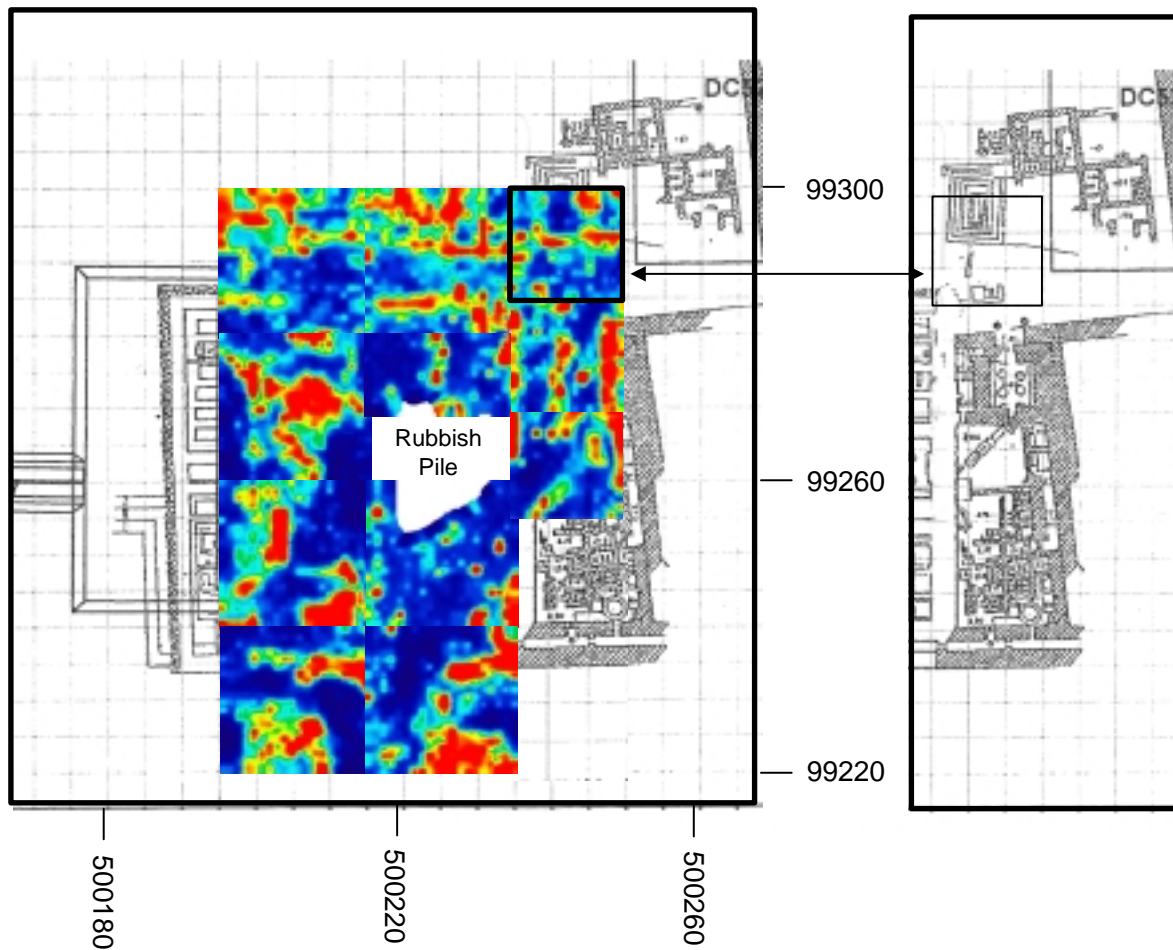
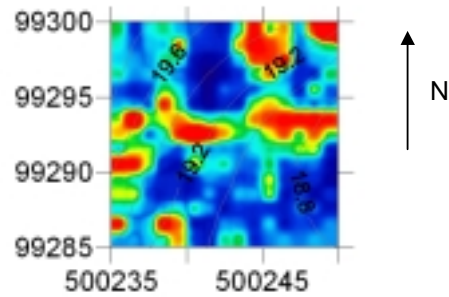
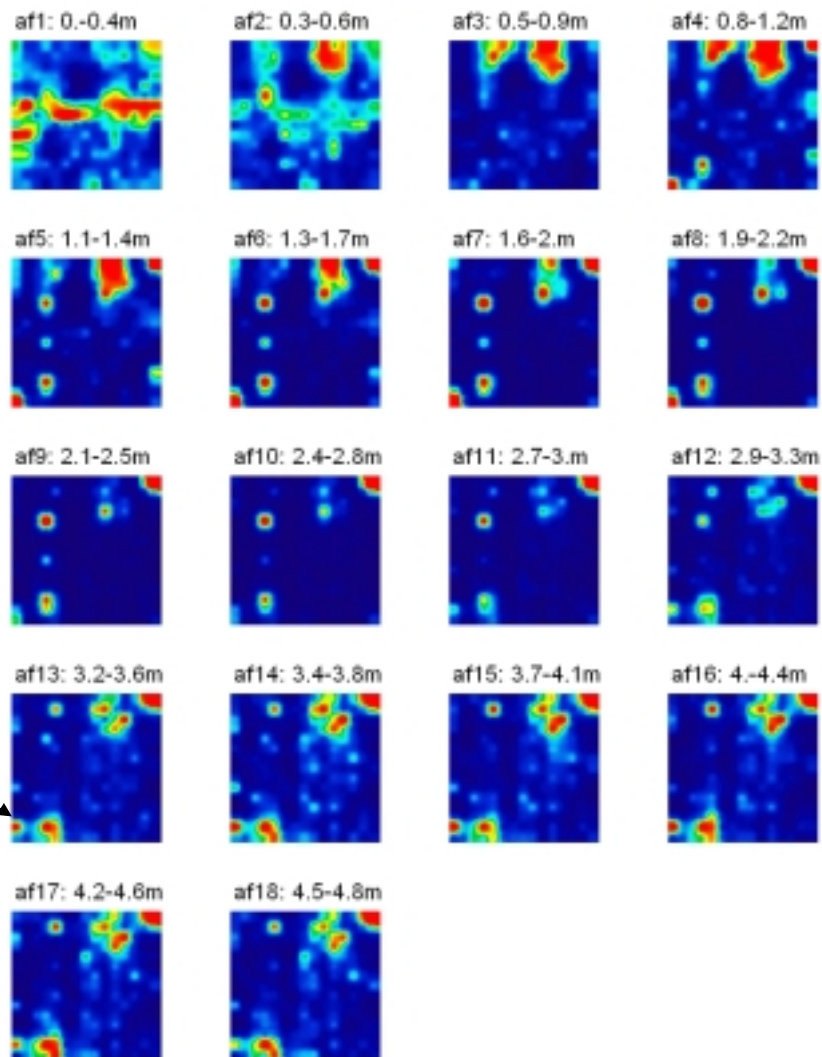


Figure 21: We show an overview of Geophysical Survey Area 11-4-06(3).

Geophysical Survey Area 11-4-06(3) Depth Slices



Overlay of Slices 1,2 and 13



This feature is likely the northeast corner of the MVT

Figure 22: Depth Slices for Geophysical Survey Area 11-4-06(3).

Geophysical Survey Area 11-2-06(1): An Ante-Town in Two Phases.

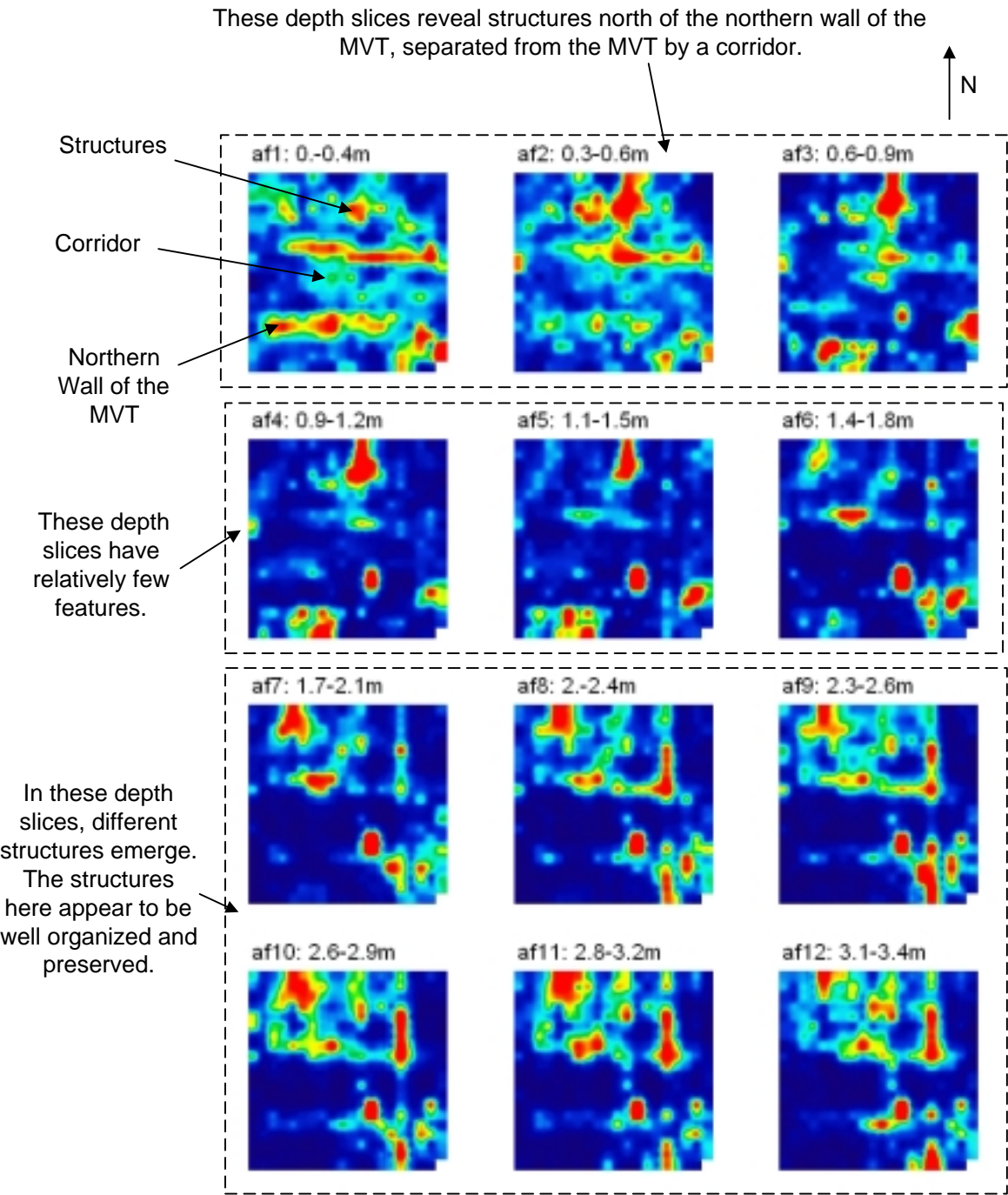
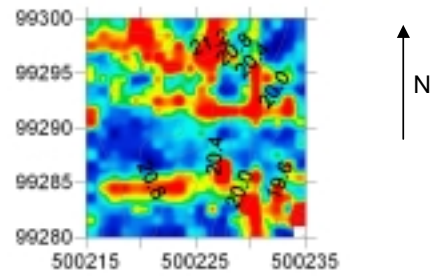
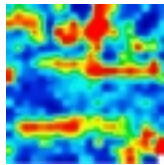


Figure 23: Depth Slices from Geophysical Survey Area 11-2-06(1).

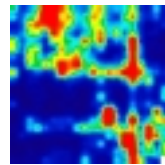
Geophysical Survey Area 11-2-06(1) Overview



Overlay of Slices 1-3 and 8-12



Overlay of Slices 1-3



Overlay of Slices 8-12

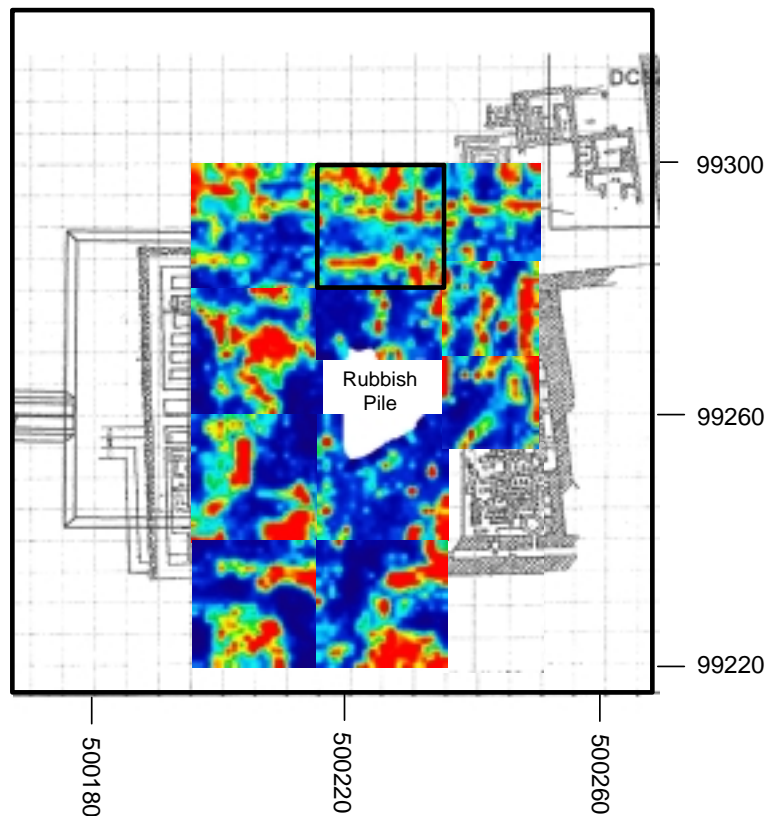


Figure 24: In Geophysical Survey Area we detected an ante-town in two phases.

Geophysical Survey Area 11-2-06(2) Depth Slices

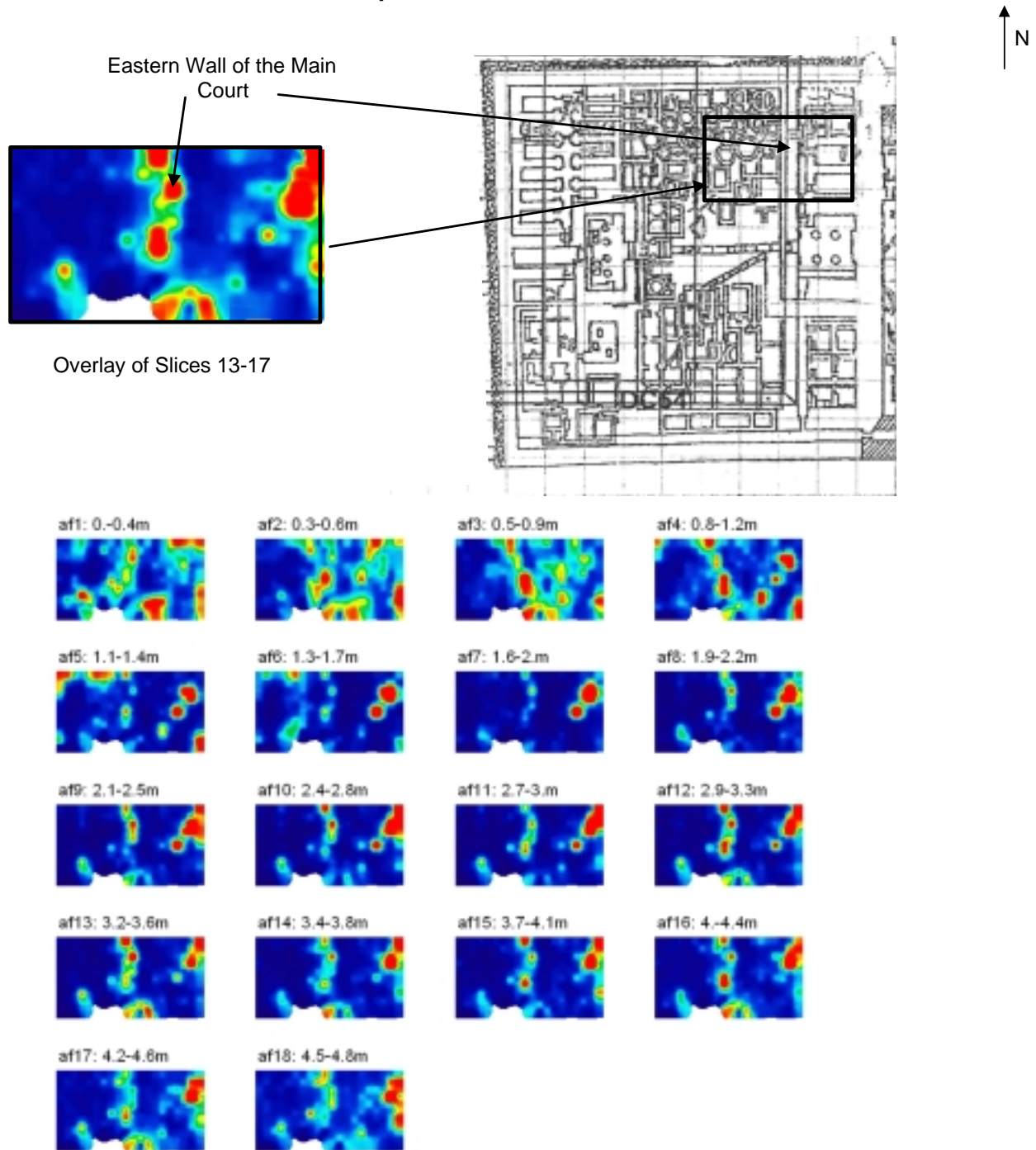


Figure 25: Depth Slices for Geophysical Survey Area 11-2-06(2).

Geophysical Survey Area 11-5-06(1) **Depth Slices**

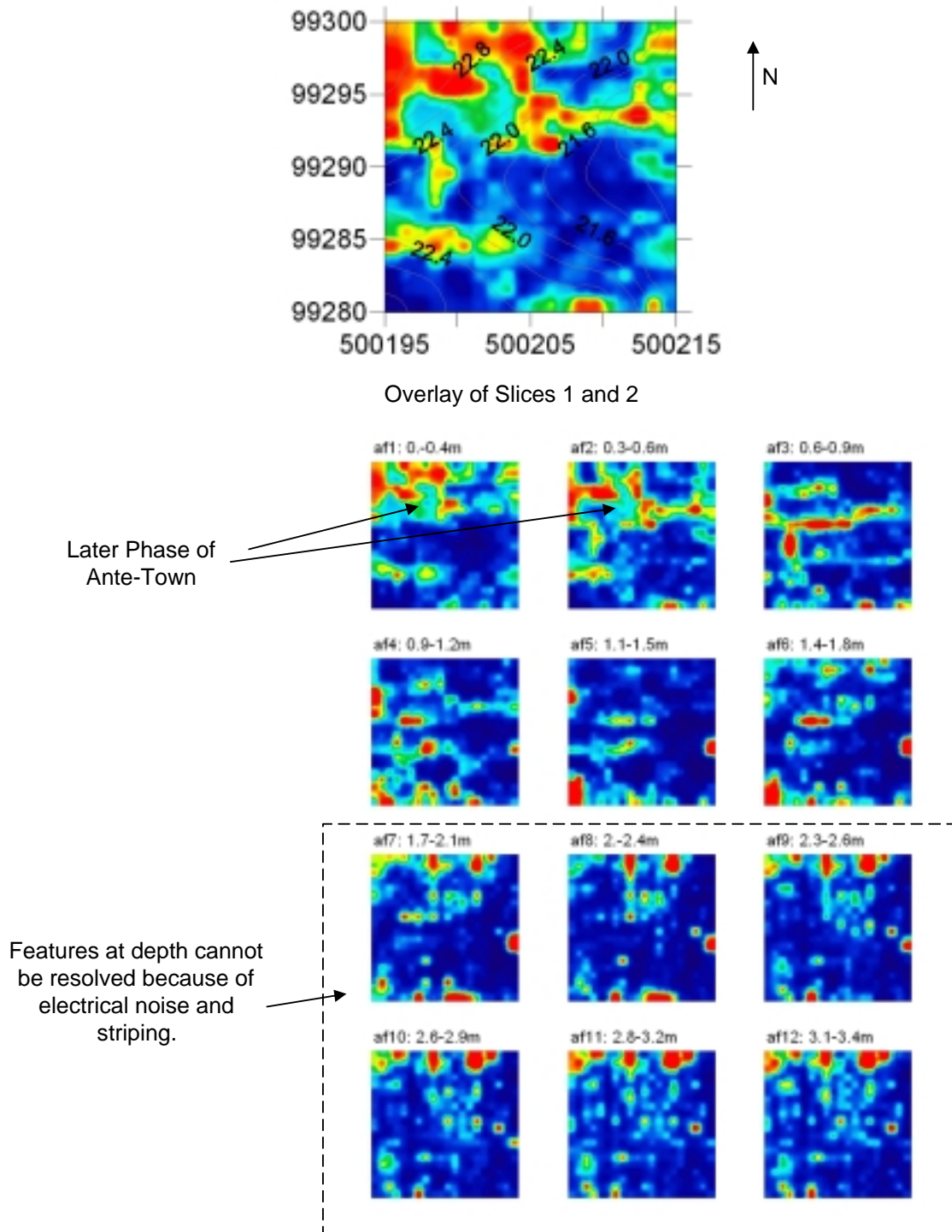


Figure 26: Depth slices for Geophysical Survey Area 11-5-06(1).

**Geophysical Survey Area 11-5-06(1)
Overview**

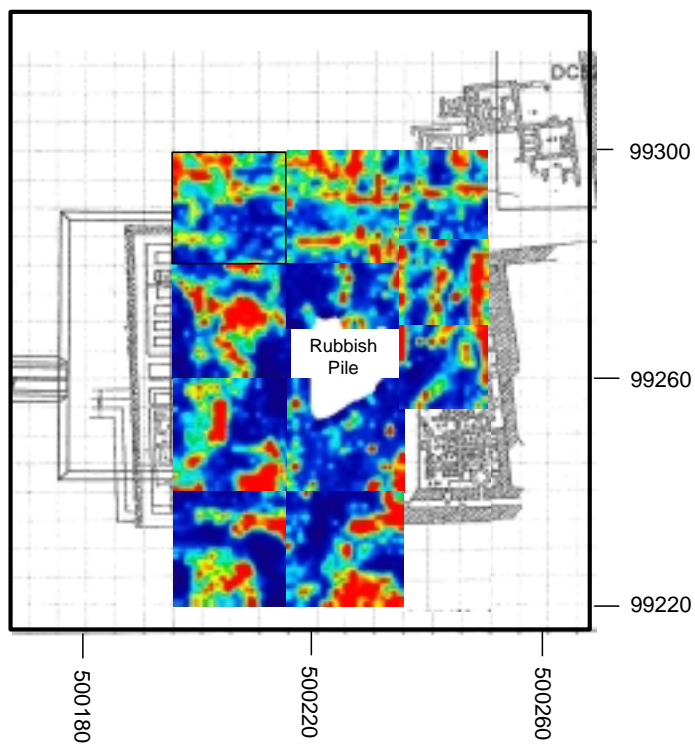
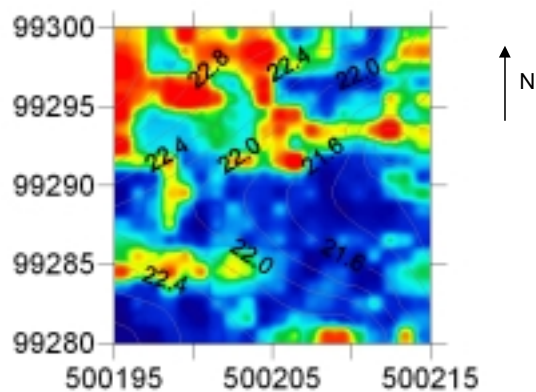


Figure 27: An overview of Geophysical Survey Area 11-5-06(1).

After a two day break, we returned to the field on Saturday, November 5, only to find a significant increase in electrical noise. We were not able to identify its origin. However, the electrical noise effectively masked the weakest part of the radar reflections and, hence, limited our depth of observation.

Complicating matters further, the overburden was thicker in this area. In area 11-5-06(1) elevations averaged approximately 22 meters above mean sea level, a height that rendered the even the top of the walls of the Menkaure Valley Temple invisible to us. Therefore, all we could detect in survey area 11-5-06(1) were walls associated with the later ante-town even though it is reasonable to expect that the earlier phase evident in 11-2-06(1) continues into this area (see Figures 26 and 27).³

The overburden and electrical noise also limited the depth of observation in Geophysical Survey Areas 11-5-06(2), 11-5-06(3) and 11-5-06(6). These survey areas lay within the MVT itself (Figure 16). Most of what we detected here probably resulted from the backfilling of previous excavations.

In Geophysical Survey Area 11-5-06(4) we detected features associated with the southern wall of the MVT. South of this wall there is a large reflective mass which can be seen in the lower left hand corner of the image in Figure 28. Although we know from Reisner's work that a causeway runs through this area, the size and elevation of this mass makes it more likely that it is a remnant of previous excavations. It may be a ramp to facilitate the removal of debris. The results from survey area 11-5-06(5) are similar.

The data we collected for the areas in and around the MVT is summarized in Figure 28.

³ The deeper depth slices in this area were also affected by a phenomenon known as striping. Striping occurs when a bidirectional pattern of survey is used on a relatively steep slope because the angle the base of the radar sled makes with respect to the slope changes depending on whether the sled is being pulled uphill or downhill. This slight, almost imperceptible change in angle changes the coupling characteristics of the radar antenna with the soil beneath it and changes the radar sensitivity just slightly. At the far end of the radar's range, this change becomes noticeable as striping.

The Menkaure Valley Temple -- A Summary

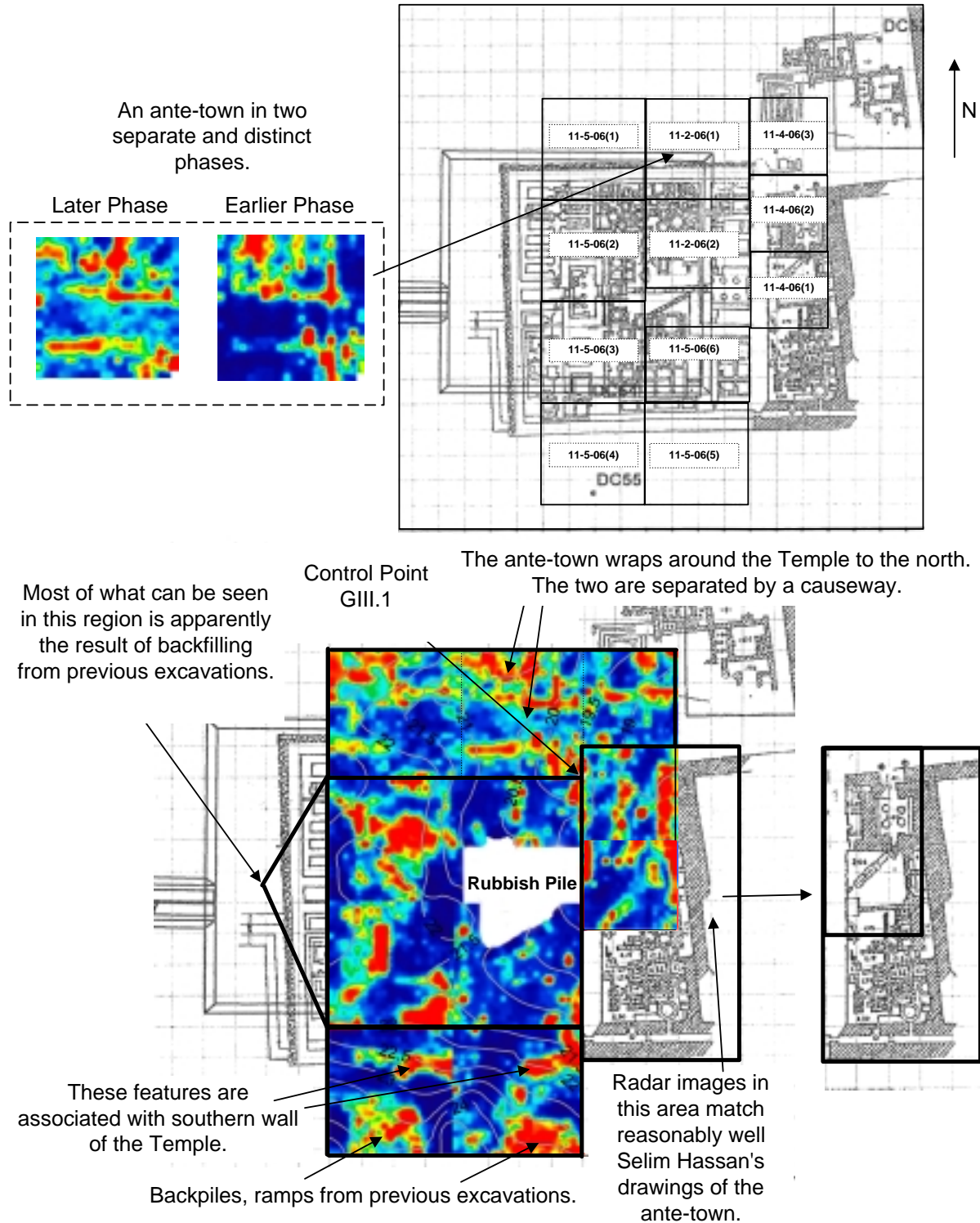


Figure 28: A summary of the features found in the region around the Menkaure Valley Temple.

SOUTH OF THE KHAFRE VALLEY TEMPLE

Just south of the Khafre Valley Temple lies a low, relatively unmapped depression. In order to facilitate surveying in this region, we established a control point, SP4, at E500390.022, N99459.759. We then set out 11 survey areas as shown in Figure 29.

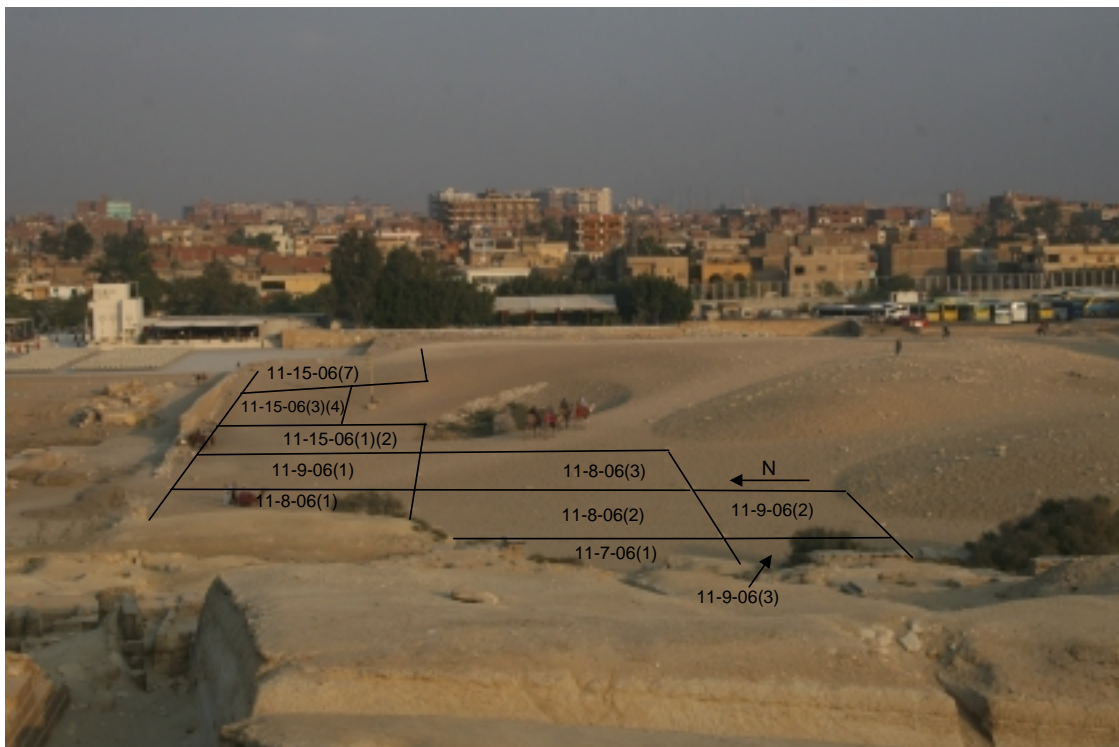
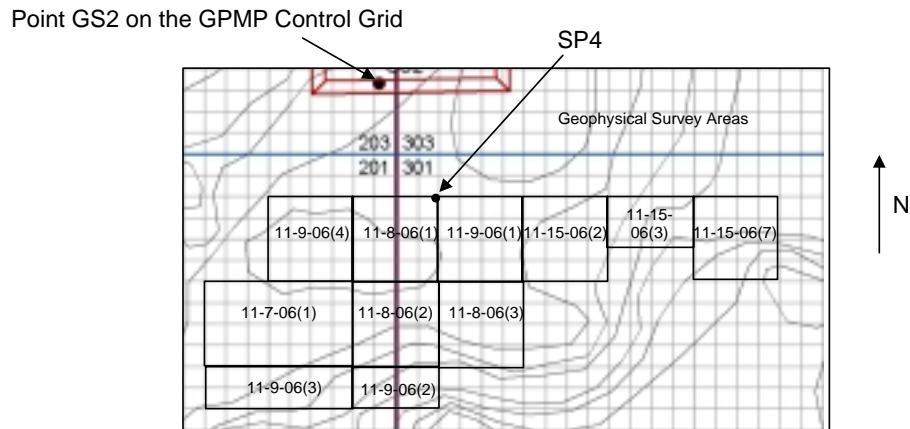


Figure 29: The region south of the Khafre Valley Temple viewed from the west.

Geophysical Survey Area 11-7-06(1)
3D View

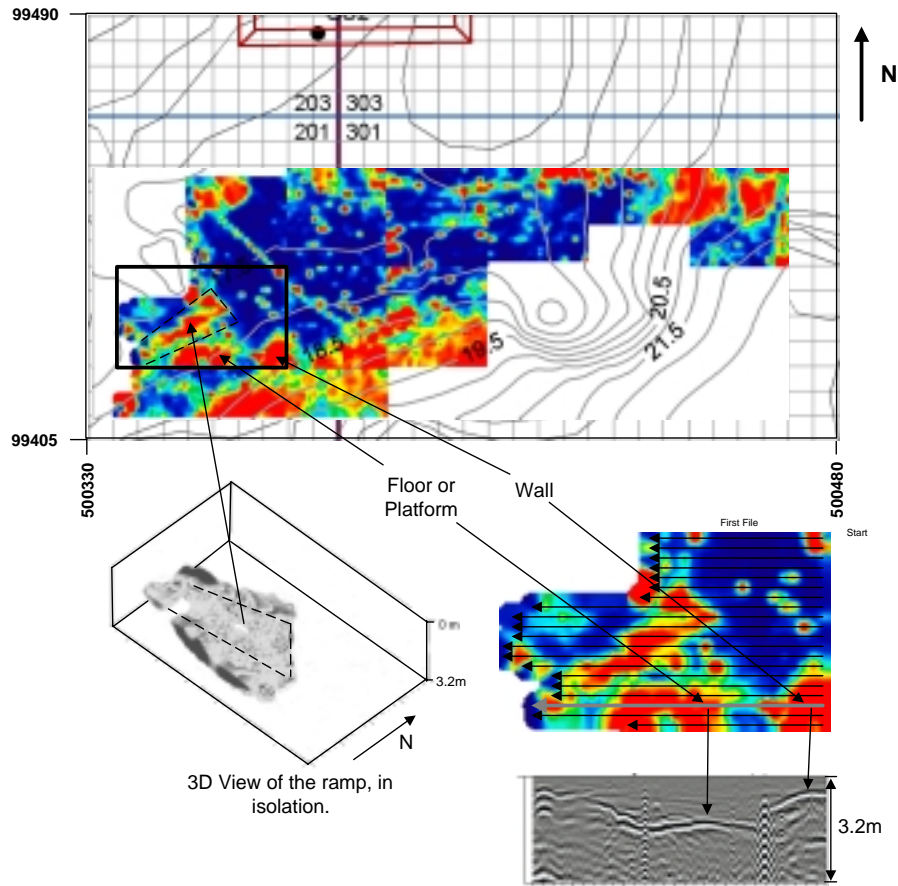


Figure 30: A ramp descends from the southwest corner of this area into what may be a harbor. We show the ramp in isolation at the lower left. At the bottom right, we overlay our transects on the radar image of the area. The radargram associated with the gray transect reveals a floor or platform and a wall.

We surveyed Geophysical Survey Area 11-7-06(1) first. The most significant feature found here was a ramp descending from the southwest corner of the survey area towards the north and east. In Figure 30 we have isolated this feature using the same techniques we used to isolate the sloping bedrock east of Khentkawes Town. The ramp, which begins at an elevation of 17.5 meters above mean sea level, descends 0.75 to 1.5 meters over a 20 meter run, ending somewhat abruptly in the middle of the survey area. In the southernmost five meters of this survey area we found a hard surface, probably bedrock, and what may be a mudbrick or fieldstone wall built upon or immediately to the north of it. The northeast portion of the survey area is largely devoid of features except for some near-surface metal objects, probably horseshoes.

Geophysical Survey Area 11-9-06(4)

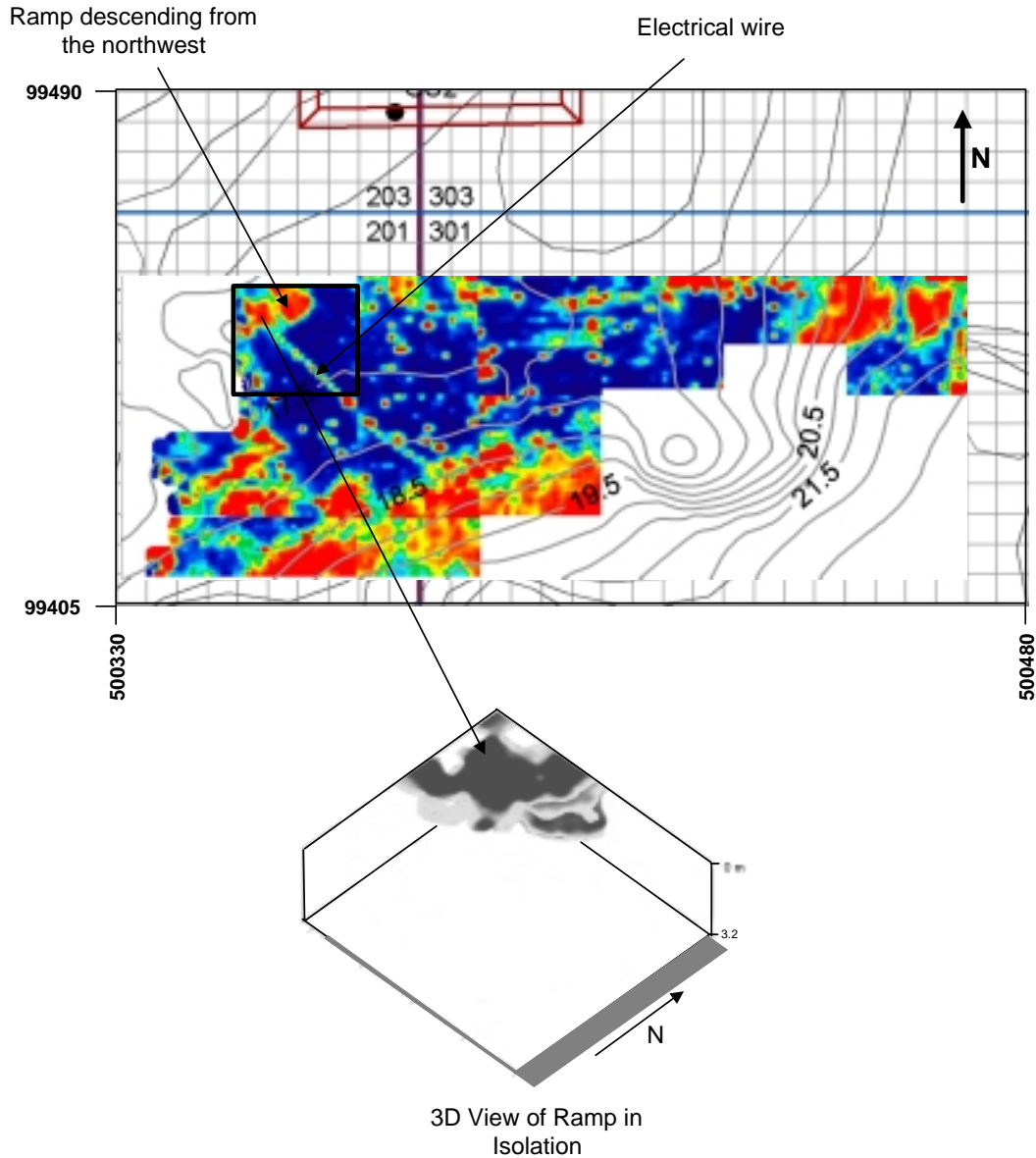


Figure 31: This ramp descends from the northwest corner of survey area 11-9-06(4) into what may be a harbor.

To the north, Geophysical Survey Area 11-9-06(4) also contains a ramp, but his one slopes to the southeast from the northwest corner of the area (Figure 31). It slopes less steeply than the ramp in area 11-7-06(1). This ramp terminates in an area nearly devoid of natural reflectors. The feature which appears like a string of pearls across the survey area is an electrical cable.

Geophysical Survey Area 11-8-06(2) and 11-8-06(3)

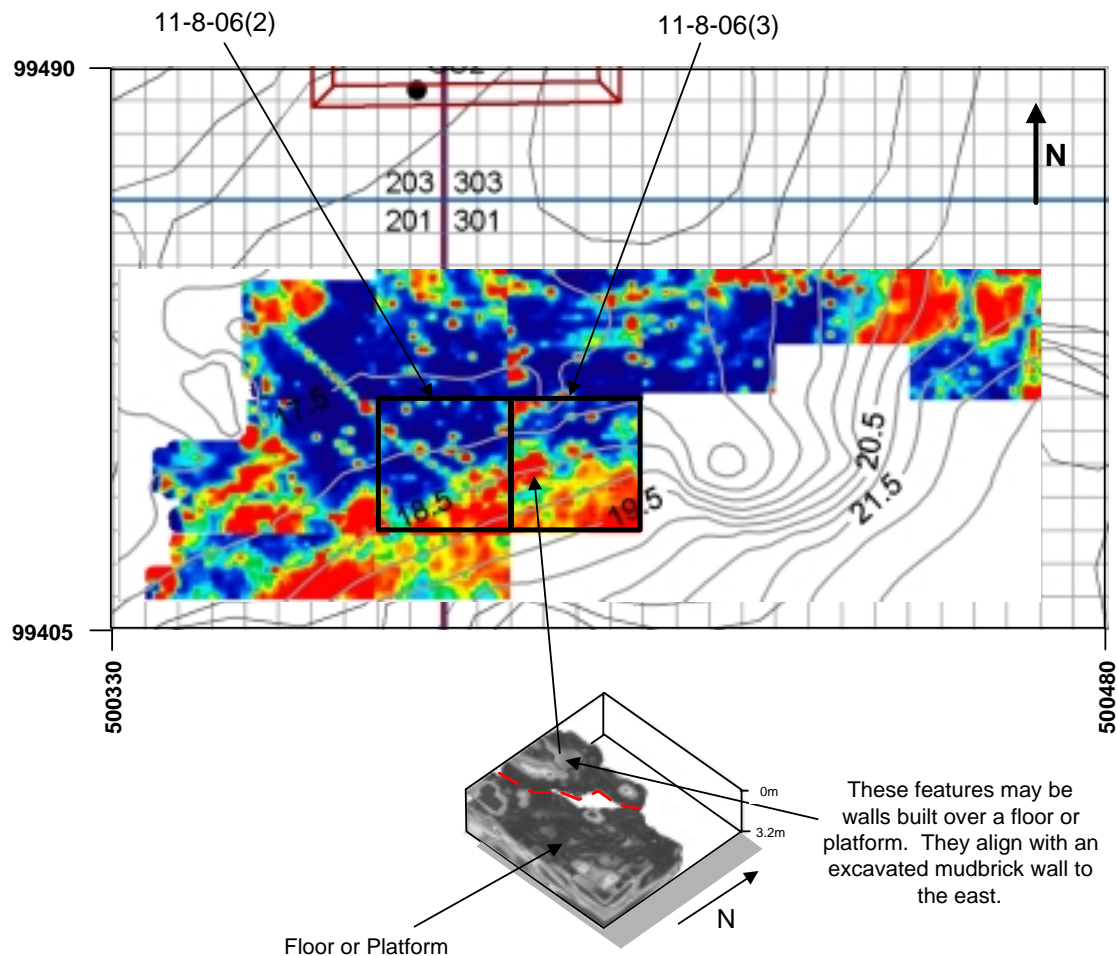


Figure 32: We find a hard, flat layer in the southern most five meters of these two survey areas. Walls appear to be built on to or just to the north of this layer.

To the east and south, a hard subsurface layer at elevation of approximately 16 meters above mean sea level occupies the southernmost five meters of Geophysical Survey Area 11-8-06(2) (Figure 32). This could be a floor, or a platform of hardpan or bedrock.

At the eastern end of this hard layer appears to be a fieldstone or mudbrick wall standing more than one meter high. The northern three quarters of this survey area is otherwise largely devoid of features. The hardened layer and wall appear to continue into Geophysical Survey Area 11-8-06(3), both progressing slightly to the north.

Geophysical Survey Area 11-9-06(3) 3D View

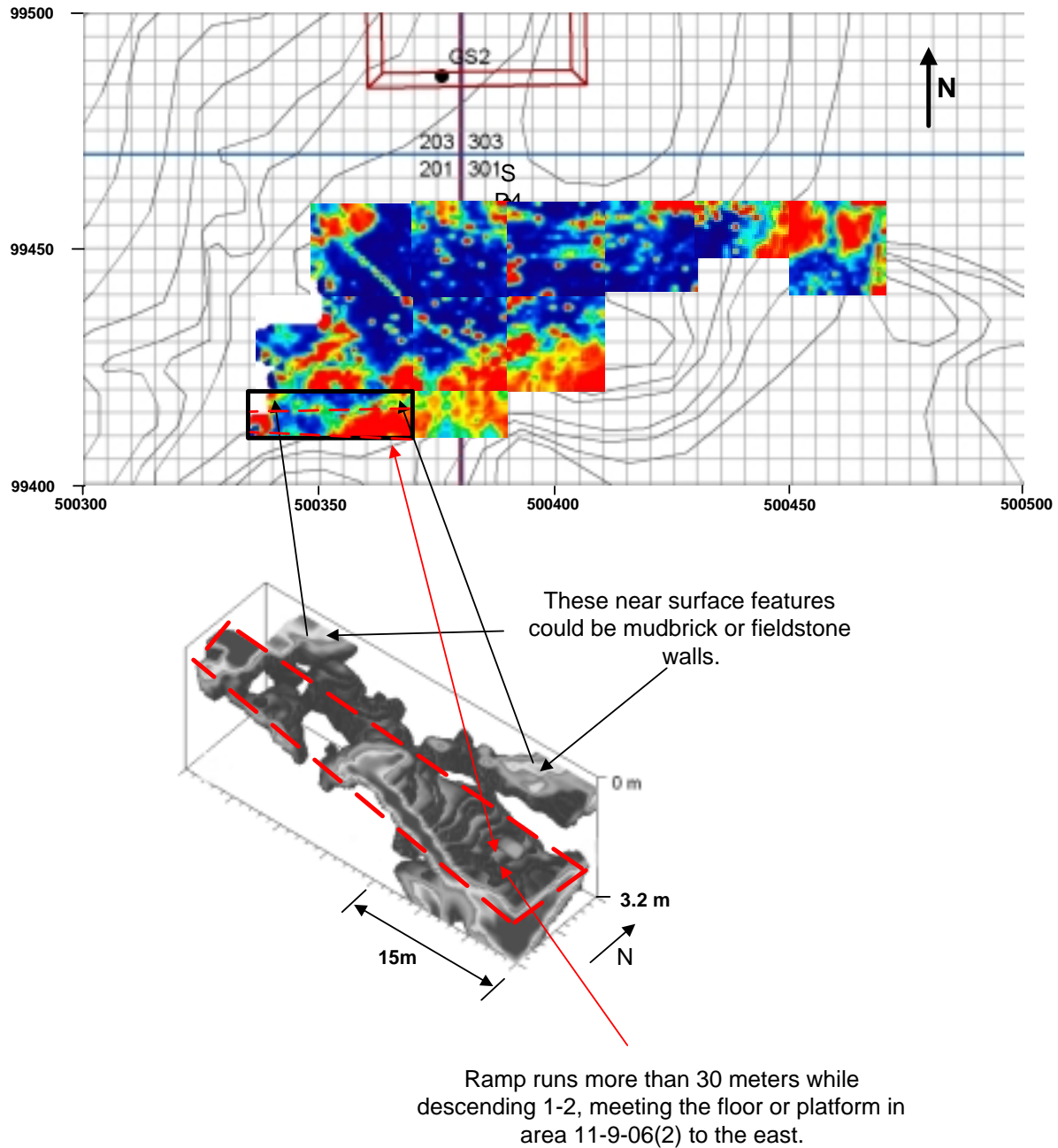


Figure 33: Here we have stripped away the surface layers revealing a ramp which slopes steeply to the east, meeting the floor or platform in area 11-9-06(2).

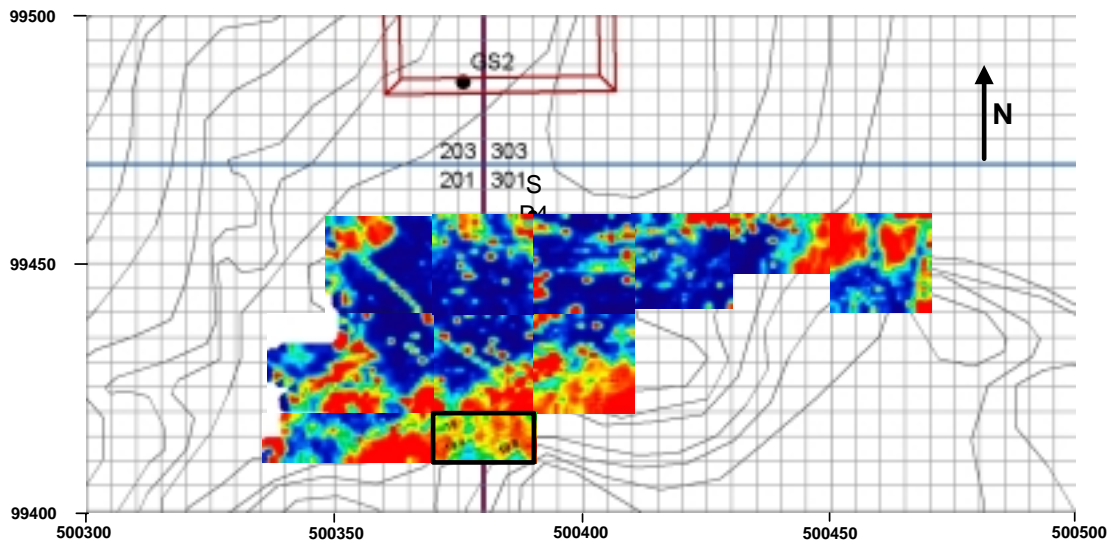
The two southernmost areas surveyed south of the Khafre Valley Temple were Geophysical Survey Areas 11-9-06(3) and 11-9-06(2). Geophysical Survey Area 11-9-06(3) contains a ramp or causeway descending to the east from an elevation of 18 meters to between 16 and 17 meters (Figure 33). This ramp meets a hard layer in Geophysical Survey Area 11-9-06(2), apparently the same layer found in area 11-8-06(2) (Figure 34). While this layer appears to dip to the south and east in Figure 34, in fact, the surface elevation in this area *rises* to the south and east. Since the software assumes that the radar is being dragged on a flat surface, a rising surface topology causes subsurface features to appear to dip. Therefore, this layer might have been purposely leveled. Unfortunately, we cannot determine that with certainty since we have only crude estimates for the radar pulse's velocity in this area and therefore only crude estimates of depth. Along northern end of 11-9-06(3) we find features which appear to be part of the presumed wall at the southern end of 11-7-06(1).

To the north, Geophysical Survey Area 11-8-06(1) is devoid of features other than scattered horseshoes and other near surface debris (Figure 35). The same can be said of Geophysical Survey Area 11-9-06(1) just to its east, except for some enigmatic linear features at an elevation of 16 to 17 meters above mean sea level. These features continue into Geophysical Survey Area 11-15-06(2) where a wall rises to the surface in its northeast corner. This wall, however, appears to be of modern origin.

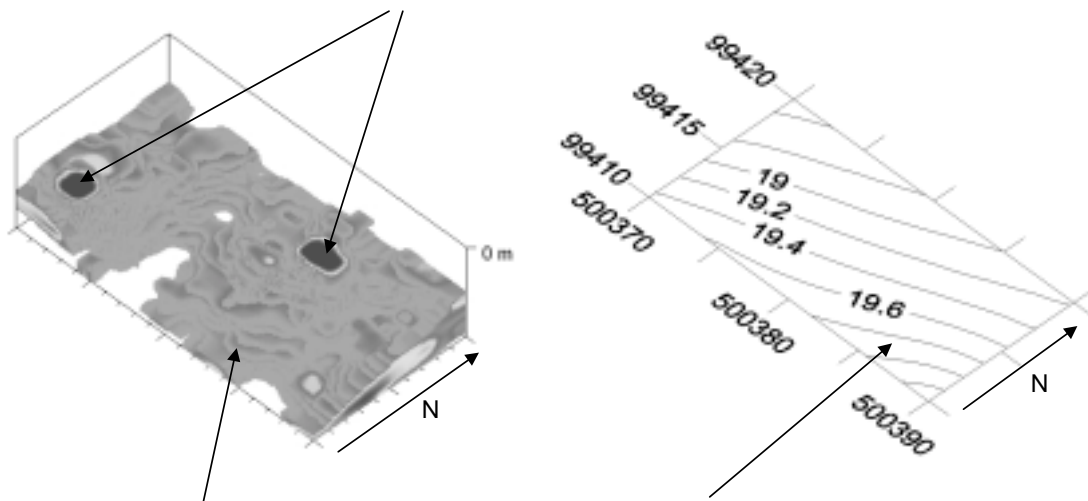
Moving further to the east, the surface elevation in Geophysical Survey Area 11-15-06(3) rises from 18.5 meters at its western edge to nearly 20.5 at its eastern edge (Figure 36). The rise coincides with the appearance of a hard buried surface, probably bedrock, in 11-15-06(3). The western edge of this surface has been cut away, either deliberately or through natural processes.

This surface continues to the east in Geophysical Survey Area 11-15-06(7) (Figure 36). It appears to slope to the east; however, the surface topology rises in this area. Therefore, this feature may represent a naturally sloping surface, or alternatively, one that has been purposely leveled.

Geophysical Survey Area 11-9-06(2) 3D View



Near Surface Metal Object Here (Probably Horseshoes)



This layer *appears* to dip to the south and east ...

... but since the radar assumes the surface it is dragged on is flat, a *rise* in surface topology causes the subsurface layer to *appear* to dip.

Figure 34: Here we have electrically stripped away the layers nearer to the surface, deriving an image of a hard subsurface layer. Though it appears to slope to the east and south, the surface elevation in this area rises to the south and east. Since the radar's software assumes that the radar is being pulled on a perfectly flat surface, the subsurface may have been purposely leveled.

Geophysical Survey Areas 11-8-06(1), 11-9-06(1) and 11-15-06(2)

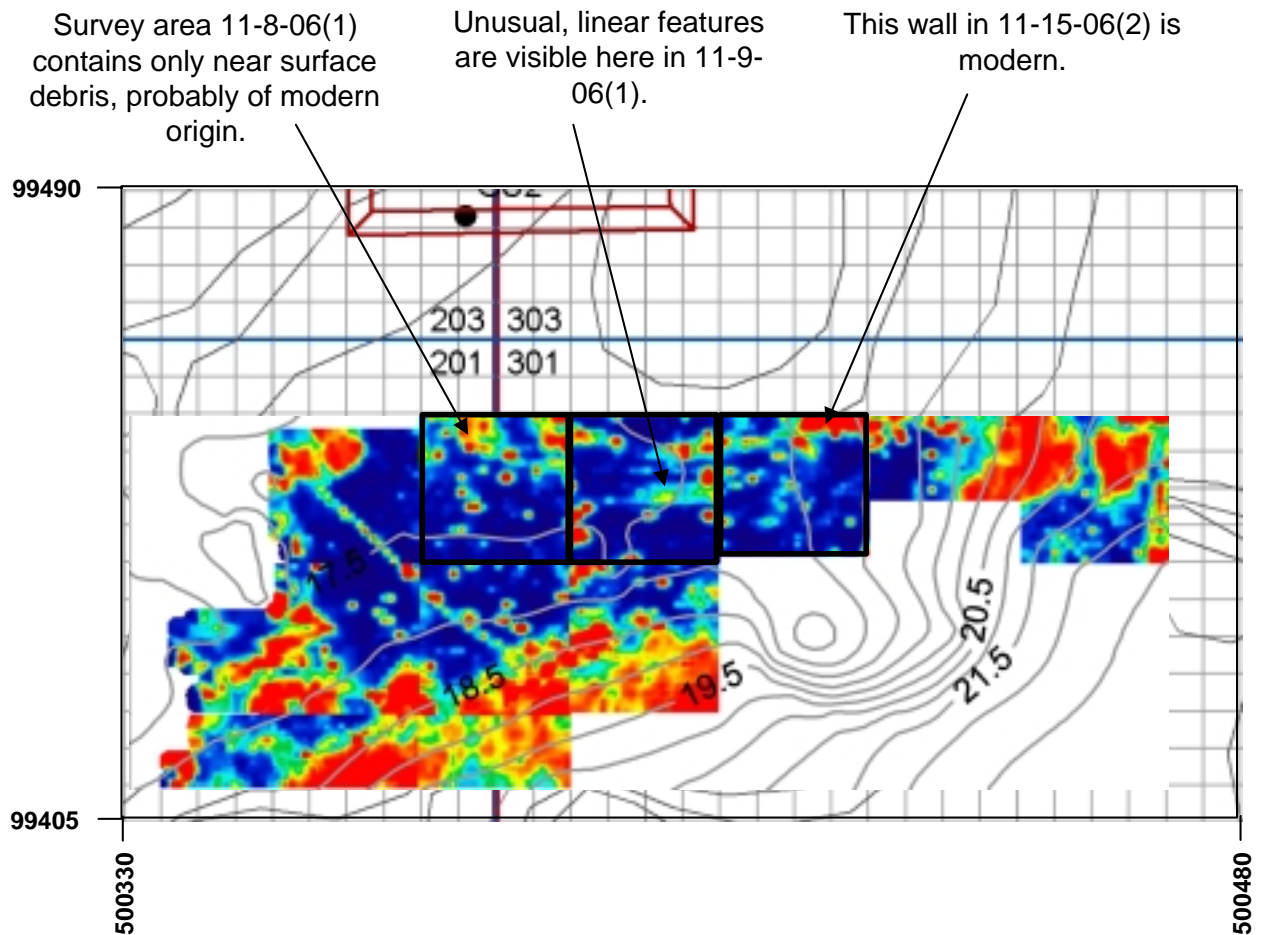


Figure 35: These three survey areas exhibit few ancient features. This is consistent with a harbor region

Geophysical Survey Areas 11-15-06(3) and 11-15-06(7)

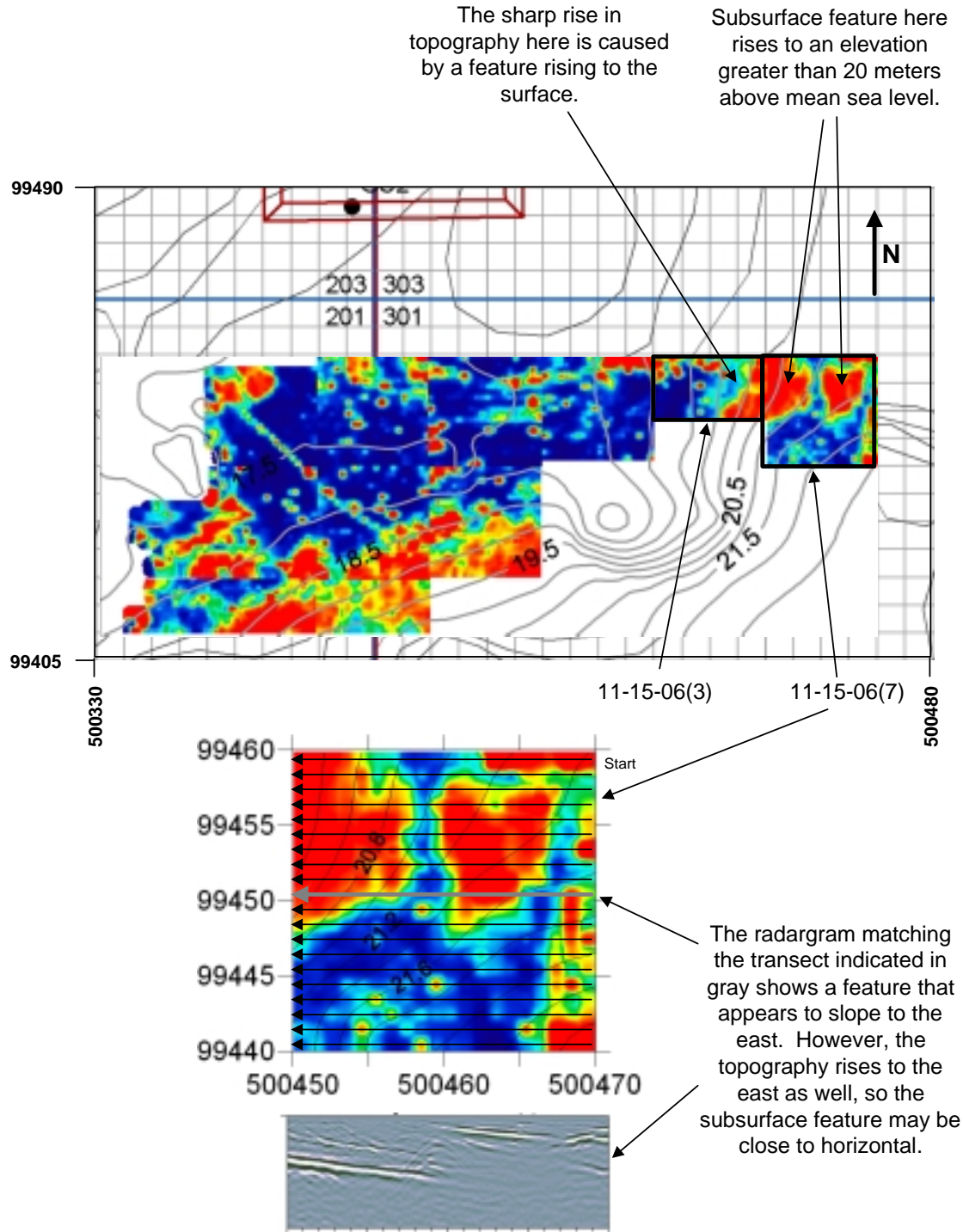


Figure 36: These two survey areas are characterized by a subsurface feature that rises to an elevation of more than 20 meters above mean sea level.

The data for the region south of the Khafre Valley Temple is summarized in Figure 37. Overall, the region has the appearance of a port facility. Ramps descend into this area from the northwest and southwest and perhaps from other directions as well. A hard layer at the southern end of this region provides a firm and relatively flat floor or platform. Facilities may have been built on the northern edge of this floor. The mudbrick wall exposed to the east of Geophysical Survey Area 11-8-06(3) may be part of these facilities

The northern portion of the area surveyed is largely devoid of ancient features. A hard subsurface layer rings the region on south and east, rising from an elevation of approximately 16-17 meters above mean sea level to 20 meters or more at the eastern edge. This layer appears to follow the surface contours visible today.⁴

⁴ The discontinuities between survey areas 11-9-06(3) and 11-7-06(1) in Figure 37 are an artifact of the radar survey. The gains chosen to survey the two areas were changed in order to better image different features.

South of the Khafre Valley Temple A Summary

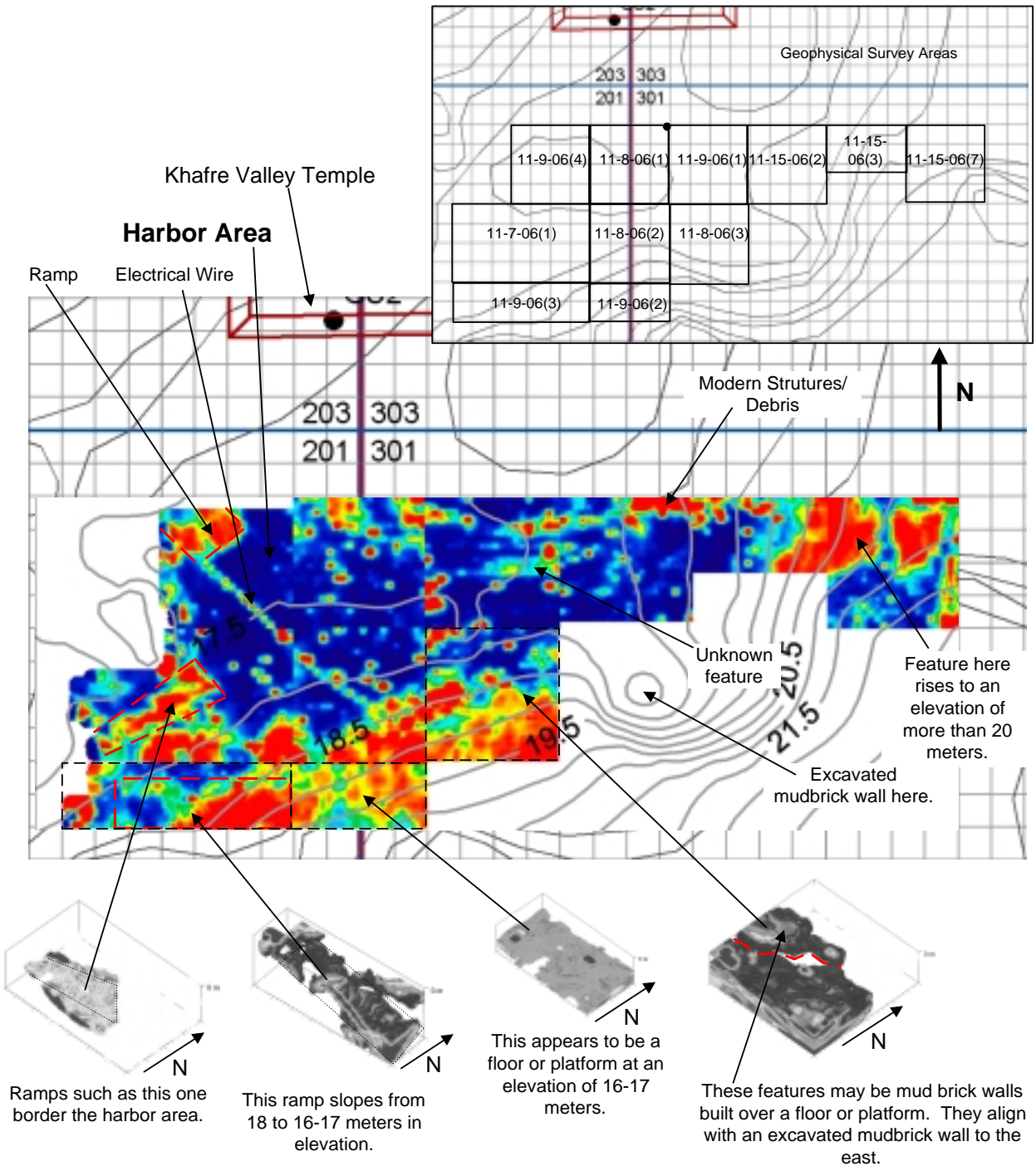


Figure 37: A summary of the region south of the Khafre Valley Temple.

THE SOCCER FIELD

We examined the soccer field using four Geophysical Survey Areas: 11-12-06(1) and (2) and 11-13-06 (1) and (2) (Figure 38).

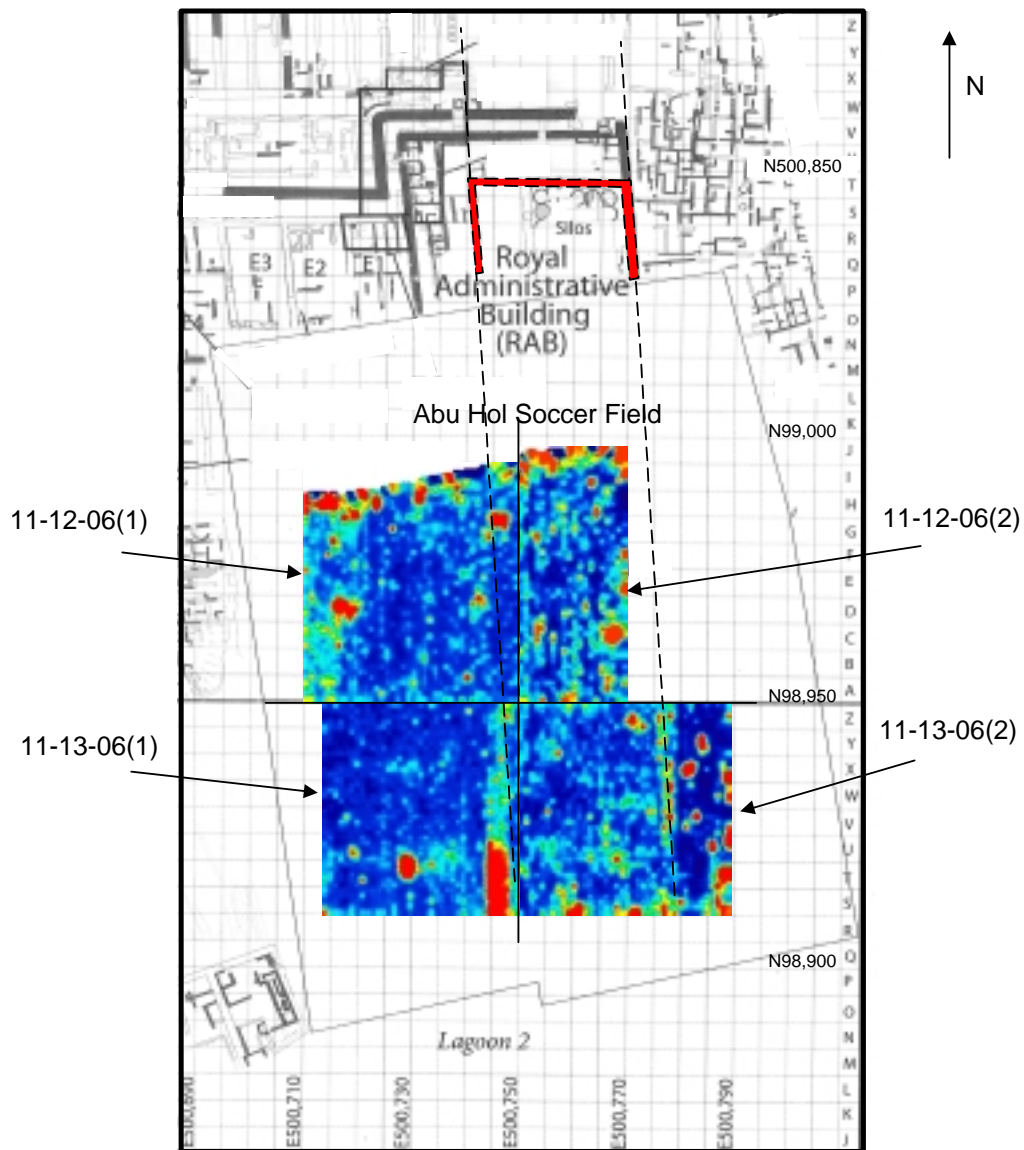


Figure 38: The Soccer Field. Four Geophysical Areas are shown. The two to the south, 11-13-06(1) and 11-13-06(2), display wall-like features that roughly align with walls in the "Royal Administrative Building."

While in the field we noticed that nearly all our radargrams here exhibited a reflection at the same depth. We determined that this was probably a reflection off of the water table. At this time, the water table was at 15.7 meters above mean sea level. Knowing that, and the elevation of the soccer field itself (17.8 meters above mean sea level), we could calculate the velocity of the radar pulse here (.075 meters per nanosecond). This allowed us to do what we could not do in the other areas in this study -- provide a reliable depth estimate for the features we detected.

As for the radar survey itself, most of what we found here appears to relate to recent work to build the soccer field. However, towards the southern end of the survey we detected two sets of linear features, perhaps walls (Figure 39). These features roughly align with walls within the excavated Royal Administrative Building to the north. These walls could be part of a massive structure under the modern soccer field, aligned roughly north-south.

On the other hand, these features may be of more modern origin. An examination of the radargrams reveals that these features rise nearly to the surface where they were cut off by the construction of the modern soccer field (Figure 39). Either these were truly massive walls standing two to three meters high, or something more mundane such as evidence of modern trenching. Ground truthing will be required to tell the difference.

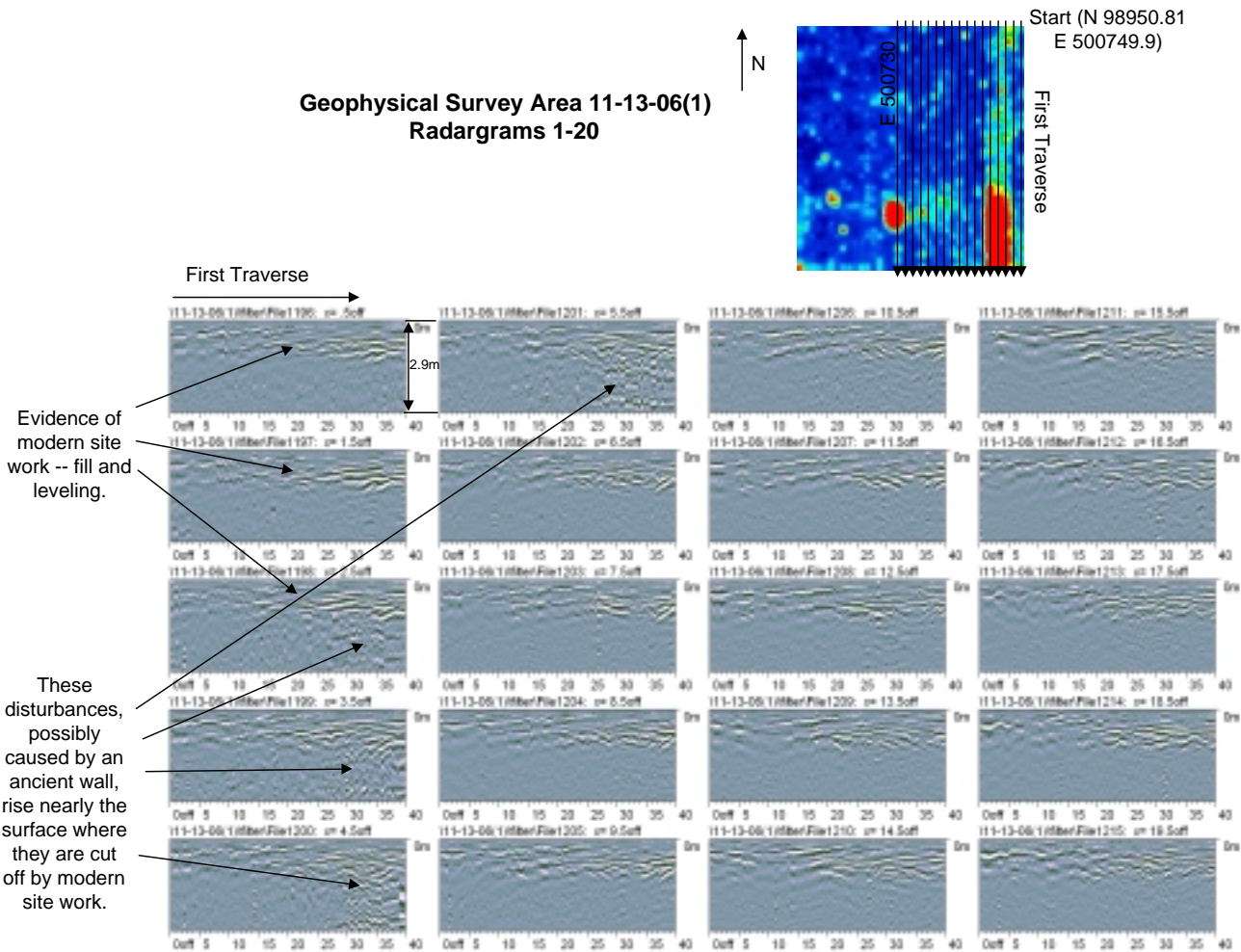


Figure 39: We show radargrams for the eastern portion of 11-13-06(1). The radargrams yield clues as to the nature of a wall-like structure visible in our data. This may be an ancient wall or evidence of modern trenching.

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