New York University
Excavations at Amheida 2010
Geological Investigations

LOCAL GEOLOGY

The geology of the Amheida area has been outlined previously by the site topographers; the general geomorphology and location of most exposed units has been identified with great accuracy. The description that follows is based upon observations during the 2010 season that have built upon, and in some cases have slightly altered the details of, this previous work. It should be noted that a Munsell color chart was not available during this survey, and colors are therefore described as closely as possible based on observer bias. In addition, because the region of Amheida is one of active dune activity, local geology has been described as best as possible using current sedimentary exposures. Future dune movements may provide additional opportunities to describe and correlate local outcrops. Also, this field report reflects initial data and impressions at the end of the 2010 season, which are subject to revision through additional data collection and analysis.

Topographically, the Temple and associated occupation areas at Amheida form a local high point. Surrounding land surfaces are lower but also exhibit variable geomorphologies and degrees of erosion. Beyond the Temple mound, local high points tend to be either spring mounds or exposures of local sedimentary units (Figure 1). In some cases it is difficult to distinguish between these two types of sediment from geomorphology alone, as the formation of yardangs and the degradation of previous deposits may take a variety of forms. For this reason, ground-truthing of presumed spring mound environments has revealed regular stratigraphy instead of spring sediments in two different areas around the site.

Geologic survey during 2010 revealed a fairly regular stratigraphy present where outcrops have been preserved. Generally, a series of cemented dune deposits (paleodunes) exist beneath and between silty deposits and localized evidence for standing freshwater. Elevations taken on these deposits match the elevations provided for sub-excavation cemented sand deposits (approximately 136.5 m asl), which supports the hypothesis that exposed outcrops outside the excavation area represent the stratigraphy beneath the Temple mound as well. Observations of the modern surface surrounding the excavation areas also reveal paleodune deposits forming the modern land surface, which is again confirmation that remnant outcrops reveal a regional stratigraphy that continues beneath and beyond the Temple mound. In an effort to correlate these stratigraphic units and provide a more detailed view of the environments represented by these sediments, geologic sections (GS, Figure 2) were described and drawn at a number of locales in and around Amheida.

STRATIGRAPHY

Southwest (GS001-GS006)

Several outcrops to the SW of the site proper (Figure 1) provide excellent exposures of the subsurface deposits and provide a small area for the correlation of stratigraphic units (Figures 2, 3). The basal unit exposed in some of these sections is well-sorted medium sand with limited fabric preservation, as significant biogenic overprinting has occurred since the original deposition of this sand. Root casts and burrows are common, but the sorting of the sand as well as the overlying deposits suggest that this unit represents a dune environment. Pottery found *in situ* and some small pieces of charcoal in this unit provide evidence for occupation within or on this unit, which may provide a means for dating this early dune environment through radiocarbon or relative dating via pottery fabric.

Above this "occupied" dune unit are a number of additional dune units, some with excellent cross-bedding and all composed of well-sorted medium to fine sand. Root traces are common, and several paleosurfaces can be identified via erosional (wavy) surfaces and the presence of mudcracks. The specific units present within each section vary, which is to be expected given the variable progression of dune deposits.

Above these dune deposits, there is sometimes preserved a moderately sorted, medium to fine sand with abundant bioturbation and root traces. This unit contains abundant gastropods of the species *Melanoides tuberculata* as well as at least two additional gastropod species, and pottery is also abundant. The presence of the gastropods in particular is indicative of standing freshwater, and the abundance of pottery suggests heavy human use of this area during this period. The presence of some pottery in the unit below may be indicate related occupation of upper dune units, and the presence of charcoal again may provide a means for dating this unit if relative dating of pottery does not provide an accurate date.

Above this freshwater deposit is another dune-sand, which sits below a unit composed of very fine silt to clay with well-developed angular-blocky peds, root traces, biopores and variable oxidation staining. The color of this unit is very similar to the Mut bedrock found elsewhere in the oasis, a reddish-purple. There is pottery within this silty layer in some areas.

Above this silt is yet another cross-bedded dune deposit that contains woody material in some areas. Finally, the cap of several outcrops consists of another silt/clay unit with ped formation, root traces, biopores and oxidation staining. This top unit in particular is extremely "chunky" and almost seems out of place or transported in some areas, with sand filling in around peds. Coloration is again a reddish-purple, with some areas of more gleyed greenish-gray. Charcoal is present as displaced pieces in at least one area within this unit.

The two silty layers, and in particular the well-developed peds found within them, indicate that these fine-grained units may represent paleosols, which would in turn indicate the presence of stable land surfaces in this area for relatively long periods of time, separated by a period of dune formation. The source of the silt is difficult to determine, though it may have accumulated during a period of slower erosion and increased vegetation. The similarity between these silts and the Mut formation may indicate that these units represent reworked Mut shales. A comparison between current bedrock and these units may clarify the degree to which these units are actually similar to bedrock.

Stratigraphic investigations of these outcrops (GS001-GS006) reveal occupation surfaces older than those currently under investigation, which may aid in the determination of the timing of paleodune and silt deposition. In addition, the close spacing of these six outcrops provided an opportunity for small-scale investigation into the paleoenvironments that preceded Roman occupation at Amheida, which are unsurprisingly punctuated by dune formation and movement. However, the evidence for stable surfaces and standing freshwater may provide additional insights into the hydrologic and geomorphologic history of the Amheida area, even if these deposits are too old to provide much information relevant to current excavations.

A secondary goal of the detailed descriptions provided here is to provide an understanding of the local stratigraphy and the extent to which the described units are representative of the geology of the Amheida area as a whole. With this goal in mind, additional sections were described in other areas of outcrop to the southeast and north of the Amheida excavations.

Southeast (GS007-GS010)

To the southeast of the Temple hill (Figure 2), two large hills reveal the same general stratigraphy found to the southwest. For both of these hills, the lower-most slope is covered by significant slope wash. Because an effort is being made to avoid significant digging or disturbance of potentially archaeological deposits on the Amheida site proper, minimal cleaning of this slope wash means that the stratigraphy has been reconstructed using minimal sedimentary exposures. The details of the units making up the bottom half of these sections should therefore not be taken as complete. It may be prudent to obtain permission to clear sections on these hills in the future in order to obtain a more accurate sedimentary description.

The eastern-most hill, described as GS007, and reveals a significant thickness of dune sand deposits. Limited exposure reveals cross-beds as well as the presence of flakes of shale and leaf litter preserved in the upper portion of the cross-bedded laminations. On top of this sand is bioturbated fine silt found in chunks that could be well-developed peds. These chunks of silt are often sandy on their surfaces and look like they have been transported or otherwise disturbed (conglomeratic). A thin sand unit separates two such units, similar to those found to the SW except that in this case they do not look like they are in place.

It is possible that the nature of the weathering of these pedogenic horizons has resulted in deposits that have been heaved and broken to the extent that they look transported. The stratigraphic context of these units and its similarity to that found elsewhere supports the idea of *in situ* silts, although it is also possible that these silt units were transported in this portion of the site during the same periods that they could be found *in situ* elsewhere.

The second hill, to the west of GS007, exhibits enough variation that two sections were measured. GS008 was measured on the northern side of the hill, and reveals a similar stratigraphy to GS007 except for a small area of Interbedded silt/clay and sand approximately 1.8 m above the modern surface. This unit pinches out to the south in this hill, and is not found on the eastern hill. Sand units in GS008 also contain shale flakes, and sit beneath conglomeratic silts. Farther to the south along this same outcrop, and additional section, GS009, reveals a slight variation in the upper stratigraphy. The lower units here were largely covered by slope wash, although a single piece of pottery was seen within the dune deposit. At the top, massive sand units are interbedded with chunky silts that break into subangular blocky peds and contain root traces. The top of this section is composed of a very colorful medium sand in black, orange, yellow and red. Gray silts are also present. This upper unit and the silts directly below it have a sulfurous smell to them when pieces are broken open.

The very local nature of this sandy unit as well as its significant oxidation and sulfurous smell support the presence of a spring vent on the southern portion of this hill, which would have altered the local stratigraphy in the immediate area of water discharge. There is a similarly localized patch of colorful coarser sand on the eastern hill, which again may indicate spring activity. Additional excavation into the tops and sides of these hills may reveal the presence of spring vents, though given the elevation of these units it is likely that any spring activity here would pre-date the time period of current interest to the Amheida excavations.

An isolated yardang present to the south of these large hills provides yet another outcrop, here described as GS010. A similar stratigraphy is revealed, although in this case the cross-bedding of lower dune sands is more obvious. Unit three contains some inclusions of sandy silt, presumably a portion of the upper-most unit here. Shale inclusions are also present in the upper-most sand, providing a correlation with the cross-bedded, shale-containing sands to the north. Finally, the uppermost unit here is again conglomeratic silt to fine sand, primarily of a pinkish color but more grayish-green is found toward the top of the unit. Chunks are subangular blocky with root traces when they are broken open. In this case there is no question whether this unit has been transported, as a ~10 cm. piece of limestone was present within the jumble of silt chunks.

The regularity of the stratigraphy across this southern portion of the Amheida site suggests a predictable "basement" beneath the occupation, and may also provide a means for determining the relative ages of various units found at the site. The transport of the upper silty units to the SE of the Temple mound is not currently well-understood. It may be that spring activation provided localized flows that transported silty units as peds without changing the overall stratigraphy. Further investigations of these units may be necessary to understand the history of their deposition.

East (GS011-GS013)

Stratigraphic exposures closer to the Temple mound and to the north of the site provide additional evidence that the stratigraphy described thus far continues beneath the site and throughout the immediate area. Three areas of stratigraphic exposure quite close to the excavation area reveal bioturbated, cross-bedded sands topped by silt deposits very similar to those found to the southeast of the site boundary. Dune sands sometimes include shale flakes, and here also the uppermost silty deposits look transported, with blocks of well-consolidated silt piled and loosely aggregated. The interface between sand and silt is rich in pottery, again suggesting an occupational surface within the uppermost dune layers or upon the surface represented by the dune deposits (Figures 2, 4). Collection of these materials, and potentially the clearing of better sections here, may elucidate finer-scale details regarding environmental change or the nature and timing of this occupational layer.

North (GS014-GS018)

Areas to the north and northwest of the site are difficult to see, due to extensive ground coverage by modern dune sands as well as the presence of Amheida Village. A few yardangs (GS014, GS015, and GS018) were described in order to examine the cemented sand in this portion of the site (Figure 5). These sections indicate that the dune deposits hidden under slope wash in other areas (GS007-GS009 in particular) may contain microstratigraphic details that are difficult to discern without clear exposures of sediment. Cross-bedded dune sands in these sections are variably cross-bedded and bioturbated, with a single exposure of a pebbly sand which may indicate limited water-related transport. The limited extent of these deposits makes this information of limited interest from a paleoenvironmental perspective, but the presence of these cemented sands to the north and northwest does support the idea of paleodune environments as the sub-occupation surface and the "bedrock" beneath the Temple Mound.

GS016 and GS017 were sections described within a series of mounded deposits that form a rough circle on the northeast side of the site (Figure 2). Although it was originally thought that these deposits might represent a spring mound, they instead reveal a similar stratigraphy to that found to the southeast at GS007 and GS008. Cross-bedded sands contain gray shale flakes and are overlain by silty deposits. The basal sands contained some pottery and charcoal as well, suggesting a potential link with the basal dune deposits found to the SW (GS001-GS006). The silty deposits capping GS016 and GS017 are variably pinkish to greenish-gray, and are not clearly in place, though they do not look as well-transported as those found to the southeast of the site.

South (GS019)

Digging was avoided during the current season, but in one instance a two-meter pit was discovered dug into the surface just north of the Second Pyramid (M2). This opportunity to investigate sub-surface deposits to the south revealed the presence of fluvial gravels in at least two individual units separated by an erosional boundary. These units sit on Mut Formation bedrock. The occurrence of fluvial deposits so close to obviously fluvial deposits associated with Spring Mound 2 (see below) is not particularly surprising, but the relationship between these deposits and anything described farther north is currently unknown.

The surface of the southern plain is covered in most places in a lag of silica gravel, which is likely sourced within the fluvial gravels described at GS019. This surface lag disappears on the south side of M1, just at the boundary of the site proper. The placement of this lag deposit may indicate areas of subsurface fluvial gravels; in this case fluvial activity would have affected only the southernmost portions of the area so far examined. A second possibility is that these fluvial gravels naturally underlie dune deposits throughout this area, and that moving north brings us up-section into the dune deposits. Other possibilities include land use within the site boundary removing any fluvial deposits. Only additional subsurface stratigraphic investigations will reveal answers to these questions.

SPRING MOUNDS

M1

The first spring mound examined within the Amheida area was the large horseshoe-shaped mound to the southeast of the site. The horseshoe itself seems to be composed of ironstone and sand, and may indicate an older and more extensive period of spring activation. Within the central horseshoe are much lower ridges of colorful sand, which preserves ceramics. These small ridges, one on each side of a central pile of vegetation-collected sand, were described as M1-01 to the west and M1-02 to the east. The various sandy units are consistent with spring-deposited sands found elsewhere in the oasis, and the presence of pottery within the sediment suggests that this spring was active during some period of human use of the area. A general age on the pottery may provide insights into the exact timing of this activation.

The southeastern extension of this horseshoe mound seems to be composed of a second spring "eye", with a higher concentration of ironstone and more consolidated sediment. No pottery or other material is present here to suggest an age of activation, but the higher elevation of these sediments suggest that it may represent an older period of spring activity than the sands described as M1-01 and M1-02.

M2

The second spring mound to be described in 2010, and therefore the mound designated as M2, is farther south and is the site of a tomb known as the Second Pyramid. This mound exposes a large central area that may have contained a vent of some sort. The sediment exposed on the sides of the interior of the "vent" is at the base variably oxidized and very colorful, containing yellow, red, and orange sediments. Silt and silty inclusions are present, supporting deposition by water as well as the presence of groundwater activation – these basal deposits are identical to spring-deposited silts and sands found elsewhere in the oasis. Above these obviously spring-related sediments is a significant thickness of oxidized, purplish fluvial sand and gravel, all highly bioturbated and indicative of flowing water. The source of the "fluvial" water may have been this spring itself, but the deposits are poorly sorted and course, indicating water flow. Elsewhere there are masses of iron-cemented root casts and other evidence of a highly vegetated area, supporting the presence of surface water.

The spring activity here may have been the source of both the deposits exposed at this spring mound, and additionally may have been the water source for fluvial deposition elsewhere in this southern plain. The activity of a spring here may explain the fluvial deposits at GS019, for example, making a stronger case for significant groundwater flow at some point in the past. The presence of the tomb built high on the side of the mound suggests that spring activity predated the related occupational period, but any finer dating would be difficult without organic matter for radiocarbon dating or artifacts found *in situ* in fluvial deposits.

M3

Mound 3 is a large pile of sand and ironstone to the south of M2. Very little sediment is visible, though there is a small exposure of yellow and orange sediment that is likely spring-related. Additional information may require the clearing of a stratigraphic section.

M4

M4 is a relatively small but round feature, with a depression in the center that may represent a spring vent. Infilling sand makes it difficult to determine what may be present in the center, but an exposure along the raised side was described as M4-01 (Figure 2). These sediments are water-lain, with highly and variably oxidized spring-related sediments as a cap. These sediments support M4 as a spring-related deposit beyond its suggestive morphology.

M5

Mound 5 is slightly larger than M4, to the northeast. It has a similar round morphology with a depression in the center, but exposed sediments are more variable. Cemented cross-bedded sands along the edges of M5 are well-sorted and suggest a dune environment, whereas sands found within the depression (potentially a vent) contain silty chunks and a lag of *Melanoides tuberculata*. Along the eastern edge of the mound are salt-cemented sands underlain by iron-cemented sand. These deposits suggest standing freshwater and evaporative conditions, with variable cement potentially determined by the variable influence of groundwater flow. While excavation would reveal a more useful stratigraphy, the surface expression of these deposits supports spring activity at M5 at some point in the past.

Spring Mounds as Water Sources

The investigations undertaken thus far at Amheida suggest that there are a number of spring-related deposits surrounding the site. The difficulty with spring "mounds" of this sort is that they may have been active at almost any time in the past, and any given spring mound not necessarily have been active at the same time as others. The mounded nature of the deposits is generally the result of the erosion of previously isolated deposits; presumably the more resistant iron-rich sediments deposited by the groundwater stood up to erosion far better than the surrounding landscape, resulting in mounds on the modern surface. The presence of a "spring mound" therefore tells us that groundwater-related deposition occurred in this place, but doesn't necessarily reveal the vent source of this water or the timing of spring activity.

There is some evidence of re-activation of springs. At M1 in particular, the elevation of the "horseshoe" is much higher than that of the sandy deposits that contain pottery. It seems that this area was subject to groundwater flow at some time in the distant past, followed by the lowering of the landscape and reactivation of flow more recently. Multiple periods of groundwater flow may have been initiated by climatic conditions in the region. However, it is difficult to say when any given mound may have been active unless we find direct evidence in the form of artifacts or architecture.

It is worth noting that many of the "regular stratigraphy" deposits described here, particularly GS017 and GS016, take the same erosional form as some of the spring-related deposits. This supports the idea that the modern form of spring deposits is related to erosional processes, and less dependent upon the nature of spring deposition and flow. It also suggests that ground-truthing will be required for the identification of any sediment, regardless of its morphological expression.

OTHER OBSERVATIONS

Limestone Gravel

A pile of gravel found near what has been magnetically interpreted as an area of pottery kilns (just south of GS009) is composed primarily of limestone, with some mudstone and chert present as well. All of these clasts are at minimum moderately rounded, and they are coated with a black substance on surfaces that face the interior of the pile. Even minimal digging into this gravel was avoided at present, but a limestone fossil of a marine bivalve was present in the surface gravel. Similar marine fossils can be found in the capping limestones on the Libyan Plateau to the north, which implies a Plateau source for the gravel pile. It should also be noted that some small piles of limestone can be found to the north of this area, closer to the road, and that a crushed gravel unit is commonly used as a subsurface before paving in this area (see road at entrance to site). Although these other limestone piles do not exhibit the same black coating, it may be prudent to investigate the possibility of a more recent source for this gravel pile.

Channeled Lands and Construction

Slightly south of GS009 and the limestone gravel described above, a series of channels have been dug into the land surface. While it is difficult to determine the extent to which erosion has affected the current land surface in some areas, the channeled land here may have been associated with irrigation at some point in the past. One intriguing feature in this area is a linear construction of mud built across two channels running N-S. Within this construction, a grass mat has been preserved within the mud mixture. The dating of this feature may provide some limitations in terms of when these channels were created and utilized in the past. This area has been identified by previous magnetometry survey as an area of pottery production; it would be interesting to pursue specific investigations of the usage of this portion of the site and the extent to which water use and pottery production may have been linked.

Preliminary Investigations: SE and E

Initial and limited investigations to the southeast of the site (east of the road, across from M2/Second Pyramid) suggest an area of uplifted Taref Formation sandstone and a visible (due to modern activities involving bulldozers) fault surfaces. This uplifted area was previously visited by Professor Ellen Morris, and contains scatters of paleolithic materials as well as carvings within the sandstone. In addition, there is evidence of at least two small basins where groundwater ponding occurred. The silica gravel in this area consists of pieces very similar to, but much larger than, that found throughout the southern portion of the study area to the west of the road, which suggests that this area may be a source of that gravel or at least is closer to that source than areas farther west. Detailed investigations of this area would be suggested for future seasons.

East of the road farther north, there are several large mounds. At least one of these is a spring mound, and one other is composed of fluvial deposits that contain pottery. Another mound seems to expose the regular dune-beneath-silt stratigraphy found elsewhere during the 2010 season. Detailed stratigraphy of these deposits should be included in plans for future investigations.

DISCUSSION AND CONCLUSIONS

Investigations into local stratigraphy have revealed evidence for occupation within dune/interdune environments, which likely predate Roman occupation at the site by a significant margin. Although there is evidence for standing freshwater as well as active spring discharge within the local area, preliminary opinions on the age of the pottery found within these deposits suggest that all evidence for surface water found thus far is relevant to periods much older than the Roman period of interest.

One of the more curious aspects of the local stratigraphy is the extent to which we find a regular sequence of dune sands beneath silts, while those silts seem variably disturbed. The variety of colors found within these silt units is also notable – in the more *in situ* deposits the color is a purplish red, very similar to the color of the local Mut siltstone bedrock. In those areas where these deposits look transported, the color is more frequently a greenish color. This coloration is also seen within the Mut bedrock but only along fissures and within spring mounds, presumably as a result of contact with groundwater. It is therefore possible that the color change supports the idea of water-related transport of these silty deposits, which may correlate with the *in situ* units found elsewhere. This would suggest localized reworking of silt deposits within very limited time frames, so that silt was reworked on the same land surface where it can be found in place.

Regardless of the specific environmental origin of these silt deposits, the regularity of the stratigraphy surrounding the Temple Mound suggests that the visible outcrops are in fact revealing the original stratigraphy of the area. This hypothesis is supported by the fact that excavations found cemented sandstone at an elevation of 135.5 meters above sea level (asl) beneath the Temple Mound, which matches perfectly with the elevations taken on sandstone units southeast of the site (GS001-GS006, see Figures 2 and 3). Sandstone beneath silts therefore appears to be the general stratigraphy of the area immediately surrounding the Amheida site proper, though the specific location of interdune freshwater deposits may be localized and difficult to determine without extremely clear stratigraphic exposures.

Overall, the 2010 geologic investigations at Amheida reveal a number of directions for potential future research at the site (see additional document), and indicate that the work done thus far in the area has been of high quality, providing a useful basis for the current study. Future work will hopefully elucidate sedimentary details in the deposits already examined while expanding the range of geologic investigations into areas farther east and north.

Katherine A. Adelsberger

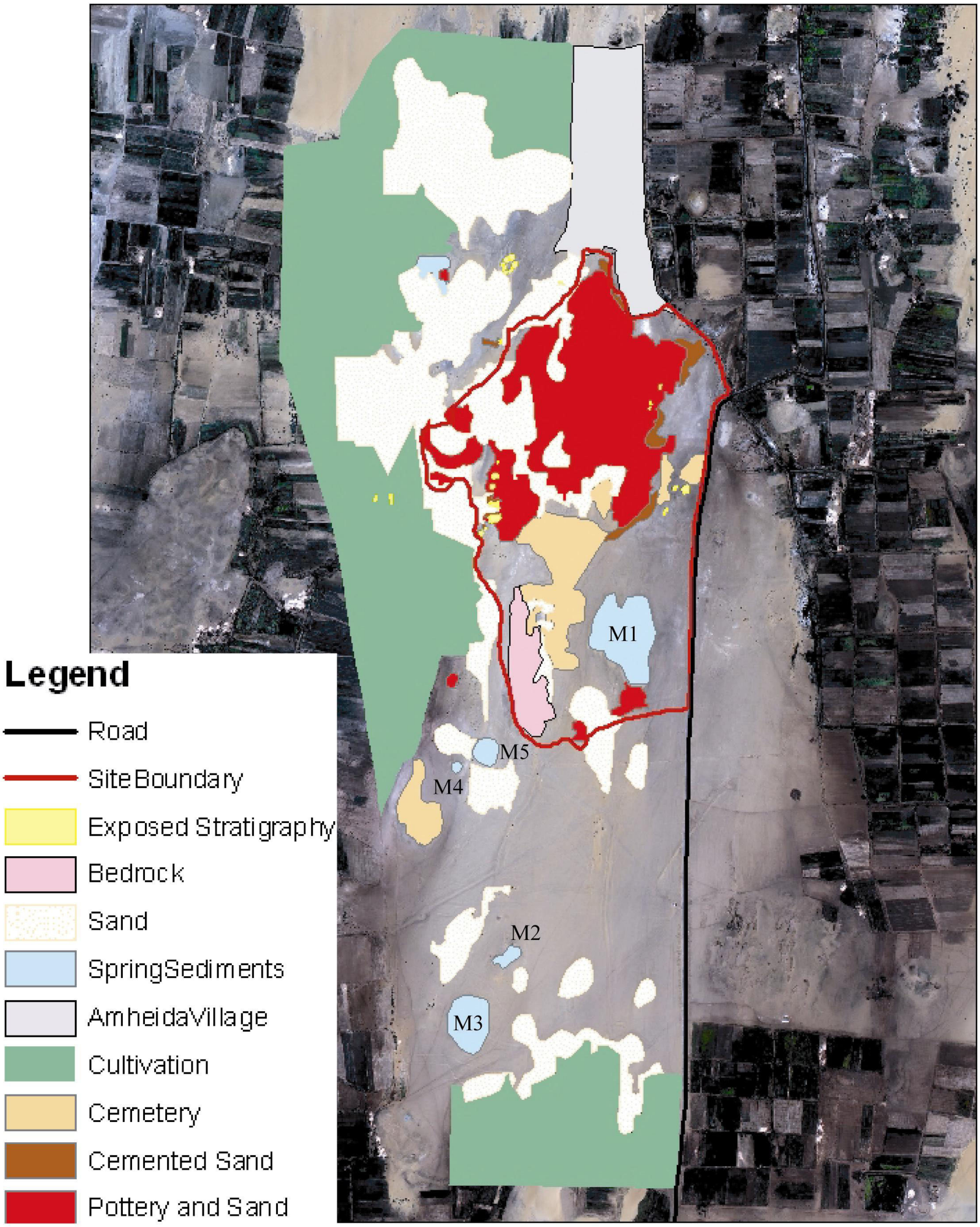

Figure 1. General map of the Amheida area, with exposed bedrock units displayed over aerial photography. Mapped units based upon work by site topographers, updated to represent 2010 geological investigations. Spring mounds are labeled by identifying numbers (M1, etc).

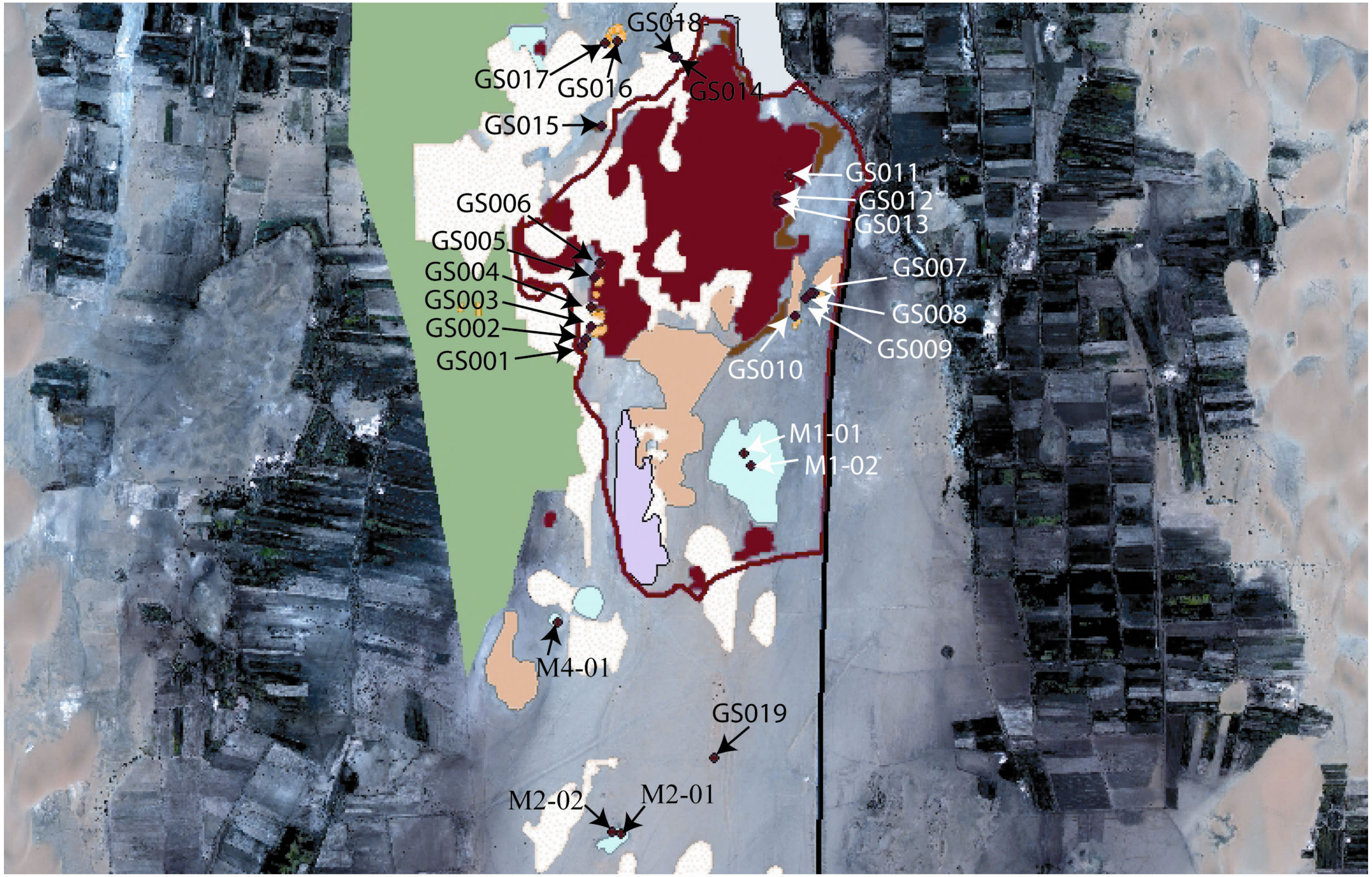

Figure 2. The locations and numbers assigned to geologic secitons (GS) described during the 2010 field season and sections described at spring mounds (M).

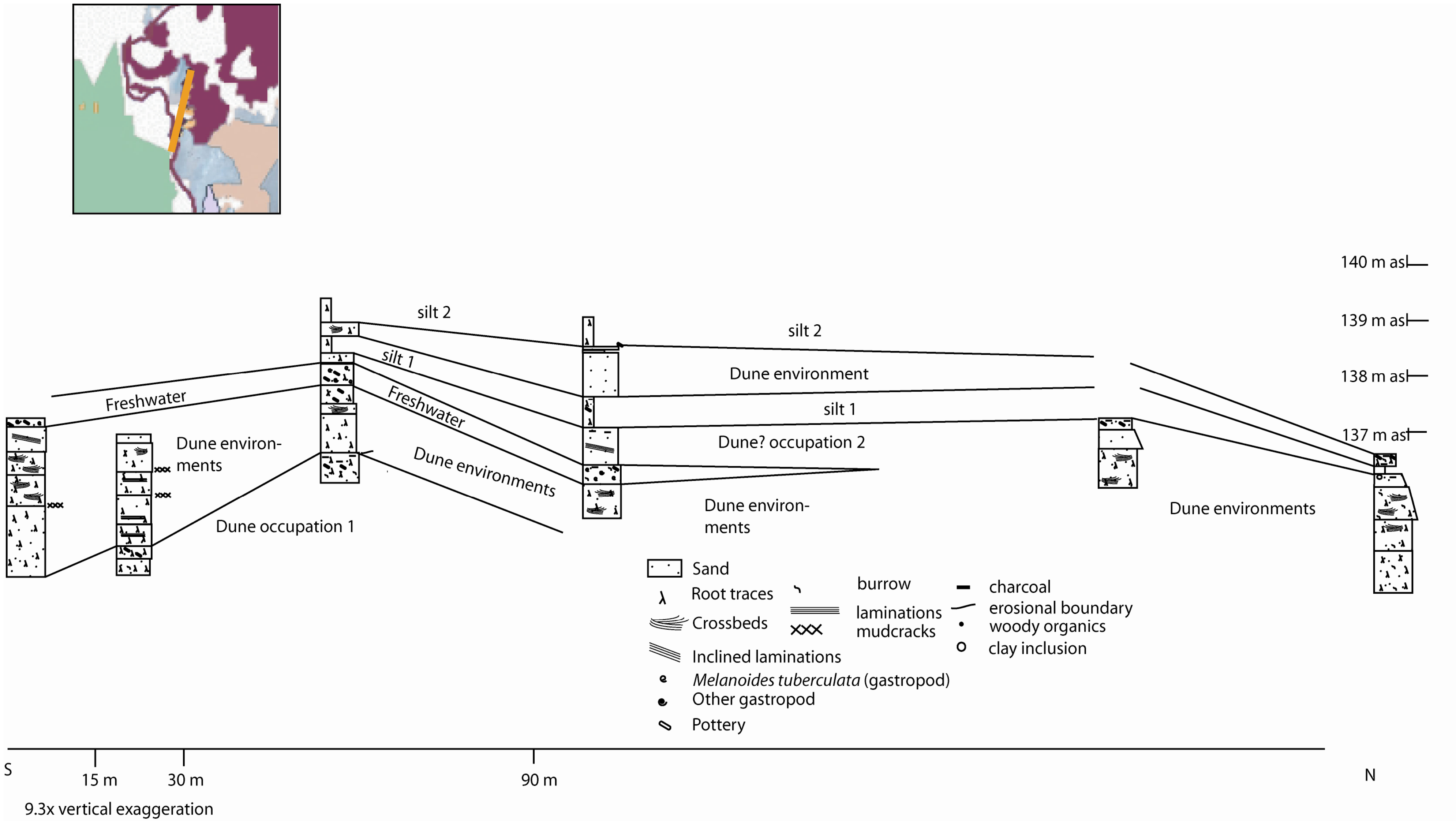

Figure 3. Fence diagram of geologic sections GS001-GS006. Inset shows the portion of Figure 1 in question, with a yellow line indicating the line of section. Sections hang from the upper left corner, which has been set using elevations obtained via total station in the field. Lateral thickness of units indicates grain size, with coarser sands as wider boxes. While details may not be visible, descriptions indicate current environmental interpretations for each unit or set of units.

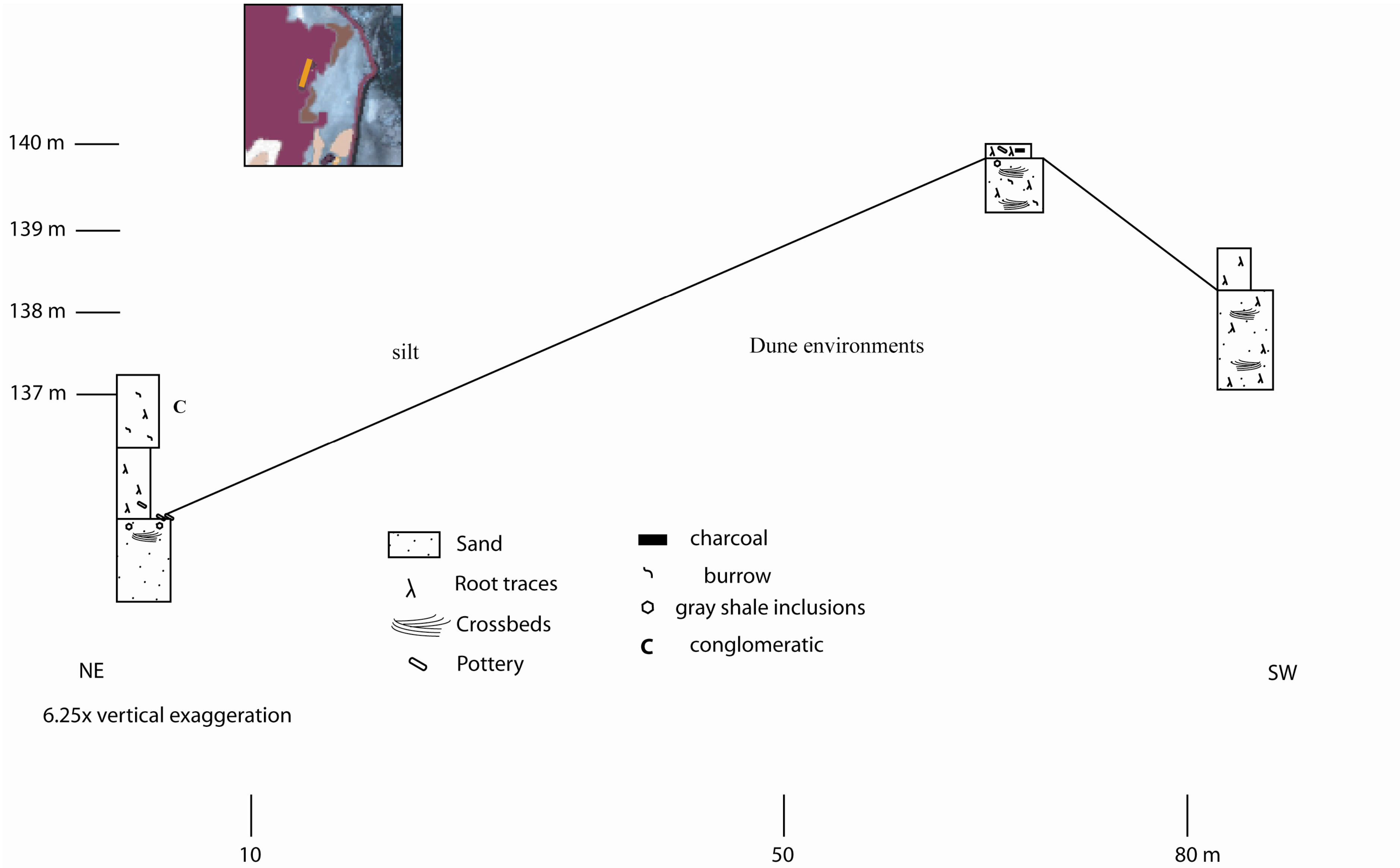

Figure 4. Fence diagram of stratigraphic sections GS011-GS013 from the eastern side of the site. Inset indicates the area of the map, taken from Figure 1, with the yellow line showing the area this section. Hanging points are upper left corners of sections, with elevations determined from the topographic model of the site. Lateral thickness of units represents grain size, with coarser sands represented as thicker boxes. While details may be difficult to discern, general environmental interpretations are included in text.

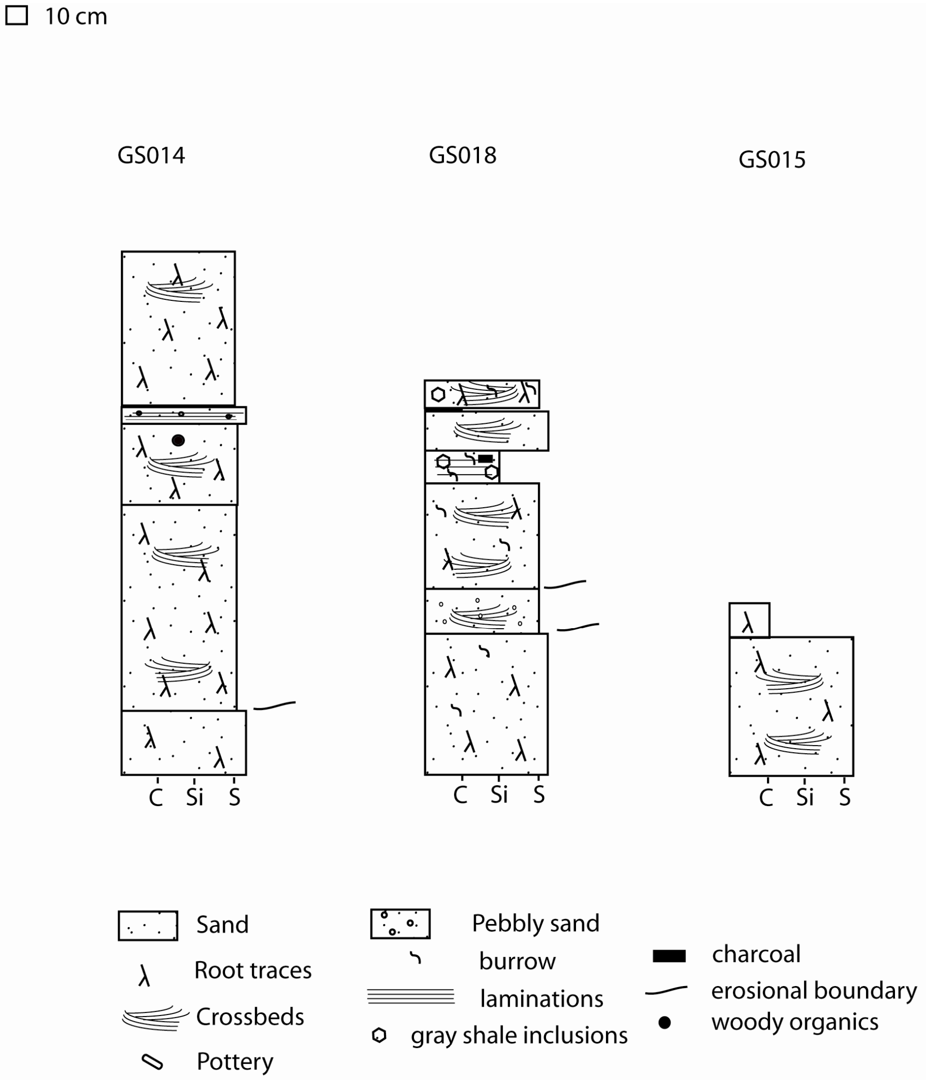

Figure 5. Sections from yardang outcrops to the north and northwest of the site. Unit thickness indicates grain size (Clay, SIlt, Sand) whereas vertical scale is indicated by the cm box. No hanging point elevations available; relative stratigraphy does not represent actual relative elevations. Instead, sections were drawn from the bottom up.