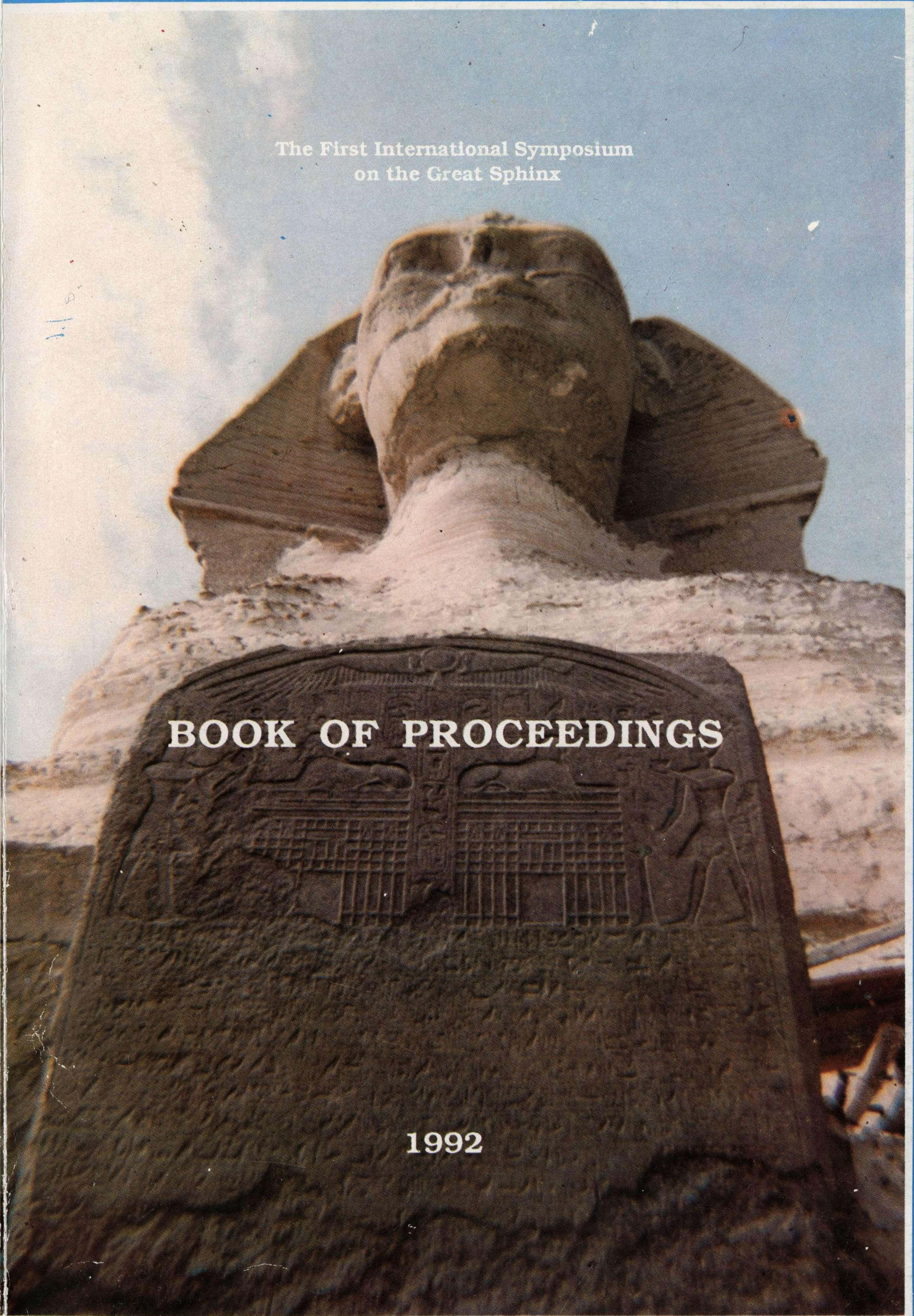
The First International Symposium
on the Great Sphinx

BOOK OF PROCEEDINGS

1992



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Printing Supervision & Execution
Amal Safwat el-Alfy
Egyptian Antiquities Organization Press.

Deposit No 9756-1992
I.S.B.N. 977-235-077-7

THE FIRST INTERNATIONAL SYMPOSIUM
ON THE GREAT SPHINX :

TOWARDS A GLOBAL TREATMENT OF THE SPHINX

CAIRO, 29 FEBRUARY - 3 MARCH 1992

- **PATRON** : MR. FAROUK HOSNI, MINISTER OF CULTURE

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Ministry of Culture
Egyptian Antiquities Organization

PROCEEDINGS OF THE FIRST INTERNATIONAL SYMPOSIUM ON THE GREAT SPHINX
CAIRO, 29 FEBRUARY - 3 MARCH, 1992

- Publication of the BOOK OF PROCEEDINGS has been co-sponsored by the International Coordinating Unit of the Egyptian Environment Affairs Agency - Cabinet of Ministers.

- **Editor** : Feisal A. Esmael

- **Cover Photographs** :

  Front; The Sphinx holding on to a Distant Dream.

  Back; The Making of a sphinx, Environmental Evolution at work. Articles on the subject, and photography, by Farouk El-Baz.

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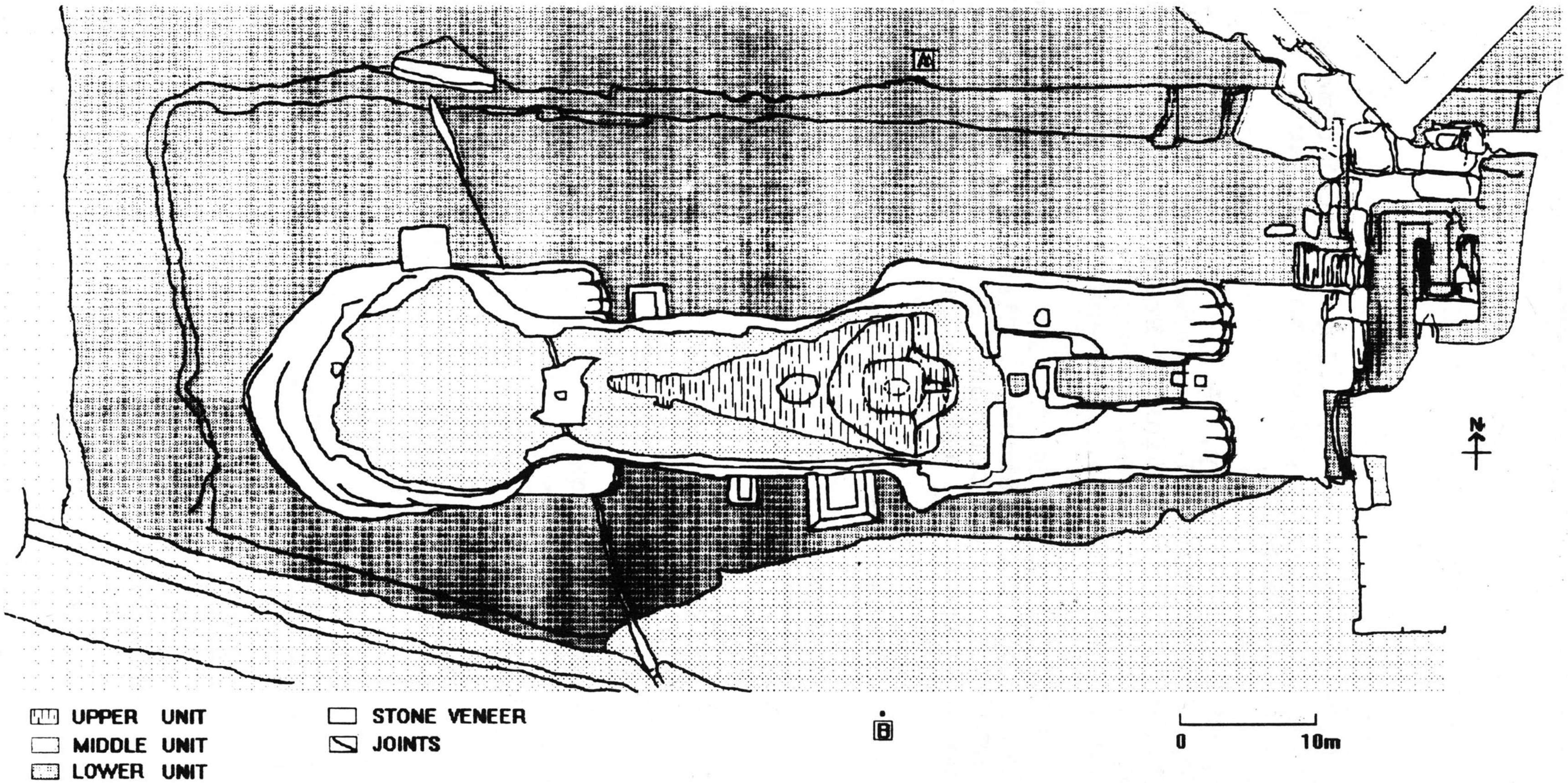
A
UPPER UNIT
MIDDLE UNIT
LOWER UNIT
STONE VENEER
JOINTS
B
0
10m
N

FIGURE 1

DOCUMENTATION OF THE SPHINX

Mark Lehner

DOCUMENTATION OF THE SPHINX

Mark Lehner

I INTRODUCTION

The Great Sphinx of Giza may be the most popular statue in the world. The Sphinx, in fact, symbolizes the questions posed by antiquity for today's civilization. Increasingly over the last two decades, the foremost question of the Sphinx is how it might be preserved for future generations. In spite of the Sphinx's popularity - or perhaps because of it, captured in thousands of tourist photographs and postcards - until recently there was a surprising lack of mapping and architectural recording of the Sphinx[1]. The purpose of this article is to introduce the documentation of the Sphinx and its site by the ARCE Sphinx Project and the Giza Plateau Mapping Project (GPMP). This documentation may be useful in future conservation studies.

The Sphinx Project began in 1979 under the auspices of the American Research Center in Egypt, James, P. Allen, was Project Director and I served as the Field Director (Lehner, Gauri, and Allen 1980). The Giza Plateau Mapping Project began in 1984 sponsored by the American Research Center in Egypt, Yale University, and since 1990, the Oriental Institute of the University of Chicago (Lehner 1985, 1986).

II SPHINX SURVEY

2.1 LOCAL SPHINX GRID

The importance of the local Sphinx grid established by the work of Zahi Hawass in 1978, and used by the ARCE Sphinx Project, is that the numerical values on the graphic records of the Sphinx, including the master plans and elevations, are based upon this coordinate system (Fig. 1).

We chose an arbitrary point 3.5 m in front of the Sphinx's south forepaw on a line that approximates the east-west center axis of the Sphinx Temple. We defined this point as the intersection of east-west line N3000 and north-south line E500. Using an old transit with a built-in surveyor's compass and Vernier scale, the grid was oriented to magnetic North on February 20, 1978. We assigned grid coordinate values that decrease to the north and east and increase to the south and west in order to accommodate an expansion of the grid into the archaeological zone.

During the excavations of Zahi Hawass across the modern road, a cement marker to the east of the Sphinx near Nazlet e-Samman was chosen as an arbitrary datum for elevations. This was defined as + 10 m. This vertical control was transferred by differential leveling to grid points monumented with small masonry nails in the floor around the Sphinx. Cole's (1925) values with respect to sea level were transferred from the survey pins at the corners of the Khufu Pyramid. The vertical values in all the ARCE Sphinx Project drawings are according to the local Sphinx arbitrary datum. However,the addition of 9.331 to any of the Sphinx values gives the height above mean sea level in meters according to our tie-in with the survey pins at the corners of the Great Pyramid.

2.2 PHOTOGRAMMETRIC SURVEY

The ARCE Sphinx Project began in June 1979. In September 1979 the German Archaeological Institute in Cairo donated the use of their photogrammetric system to the documentation of the Sphinx. The survey grid was adjusted and checked with several theodolites. The orientation remained magnetic North as read on February 20, 1978.

Kapp used the Jena-Optic stereo-metric camera SMK 120 with a base of 120 cm, and the Topcard B plotting system, to produce front, north and south elevations of the Sphinx (Figs. 1 - 4), and master profiles through the statue every 5 m (Fig. 4). The original drawings were plotted at scale 1:50.

The total length of the Sphinx from the tip of the masonry-covered forepaw (which extends 0.26 m further east than the north forepaw) to the masonry-covered tail at the rump is 72.55 m.[2] The total height of the statue, from its bedrock floor to the tip of the cobra on the forehead (as now preserved), is about 20.22 m, with some slight variation due to irregularities in the floor. The top of the back, at its highest point, is 12.38 m above the level of the floor. The original side elevations and top plan, at 1:50, are about a meter and a half in length. This scale allowed the total Sphinx image to be included in one sheet and the rendering of even the smallest brick-sized stones. However, graphic reduction to the size of most journal pages is difficult !

At the time of the photogrammetric survey layers of masonry covered the core body up to about two-thirds of its height on the south side and to one-third its height on the north side. Kapp contoured the exposed bedrock part of the statue, including the head, at 25 cm intervals. The numerical values for the contour lines of the front elevation are those of the N-S grid lines, where they cut through the Sphinx, likewise, the contour values on the side elevations are those of the E-W grid lines. In the side elevations of the Sphinx the head is a little shy of a true profile, more so on the north. From the sides of the Sphinx ditch the top of the head was slightly beyond the range of correction for the photogrammetric system. Kapp rendered the individual stones of the masonry on the lower parts of the Sphinx.

In June 1980, I took the side elevations to the site and color-coded the various phases of masonry on the basis of stratification (one layer of repairs over another), or, where the patchwork of various additions was contiguous, on the basis of mortar, tool marks and stone sizes. In figures 3 and 4 the exposed ancient phases of masonry are shaded. The unshaded masonry was put up from 1926 to 1979.

Figure 5 shows the vertical sections that Kapp rendered approximately every 5 m laid down onto the base outline of the Sphinx. In Figure 6 two of these profiles are rendered in their proper horizontal spacing. This profile cuts through the front the Sphinx's face and neck and continues north and south to take in the sides of the Sphinx ditch. Gauri (1984) used the differential weathering pattern on Member II of the Sphinx body to give designations to individual limestone beds.

2.3 SPHINX MAPPING

The first priority for mapping the Sphinx was a 1:50 master plan that would accompany the photogrammetric elevations. The master plan was accomplished over two years, from 1979 through 1980, as a series of separate drawings that were locked together on the basis of 'planning points'. The base outline was plotted by hand offset measures from grid lines. The top of the forepaws and top of the back were separate drawings also done by hand planning with offsets from grid lines that were projected up to these surfaces. This was facilitated by the ARCE Kern 1 - second theodolite and electronic distance measurer.

The greatest difficulty was mapping the surface of the ledge formed by the masonry additions to the natural-rock lion body. Since the ledge follows the curves of the body at various heights, level lines segments were selected to advantage, so that a datum tape could be set up, and the corresponding segments of the masonry ledge were planned as separate drawings. The end points of these datum lines were located by triangulation from the grid points on the Sphinx floor. This allowed the separate drawings to be locked together on the drafting table.

To map the head, 63 points were triangulated from grid points on the floor. The resulting plot was checked against "cuts" through the head and face from the photogrammetric elevations. A similar procedure was used to plot over-hanging bedrock ledges down the sides of the Sphinx body.

Figure 7 is the reduced master plan that resulted from this mapping. This is a form-line map without any vertical information. To accompany the contoured side views, a more schematic plan to the top of the Sphinx back (Fig. 8) was produced with contour intervals every 10 cm in order to pick up the slight relief.

Other maps of the Sphinx area produced during the ARCE Sphinx Project include :

- 1:100 detailed map of the Khafre Valley Temple, the Sphinx Temple, and the Amenhotep II Temple in front of the Sphinx (fig. 9);

- 1:200 contoured map of Sphinx, the temples in front, and the greater Sphinx "amphitheater" or quarry (Fig. 10).

- Geological map of the three principle layers of natural rock in the Sphinx and its amphitheater, termed Members I, II and III (Fig. 11)[3].

- Map of the dip plane of Member II through the Sphinx amphitheater (Fig. 12). This, like Fig. 11, was produced under the direction of Lal Gauri. A series of points in the same horizon (Bed 3i) were surveyed and the contours were generated through interpolation.

- 1:1,000 map of the Sphinx and modern installations to the East (Fig. 13).

- Profile of the Sphinx area with water table measurements taken during 1981-82 (Fig. 14; add 9.331 for values with respect to sea level).[4]

2.4 DETAILED STUDIES OF SPHINX MASONRY

A series of detailed plans and profiles were drawn at scale 1:20 of various parts of the masonry around the sphinx. These profiles give information about the condition of the bedrock core of the Sphinx before the most ancient restorations. For example, Fig. 15, a profile of masonry on the south side of the upper rump of the Sphinx shows that the softer Member II layer 3i was already weathered into a pronounced recess before the earliest restoration blocks (Phase I) were added. This is one of several places where large boulders from the Sphinx core body were about to separate before the masonry was added. Figure 16, on the other hand, illustrates how the lowest part of the Sphinx body, carved from the hard Member I stone, exhibits no deterioration before the earliest layer of masonry was added. [5] This opportunity to see the original bedrock profile of the Sphinx is in the passage forced below floor level, and up into the body of the Sphinx, at the rump, just north of the tail.

The detailed profiles also illustrate the stratification of the various repairs to the Sphinx. Figure 17 is an example at the northwest rear haunch of the Sphinx where, again, a large boulder was ready to separate from the core before the earliest repair masonry shored it up (the cross hatching in the drawing represents modern cement - mostly from Baraize's 1926 work). Phase II is the next ancient restoration composed of smaller blocks that were added over the recut surface of Phase I on the rear haunches. Phase III, composed of small, soft, brick-sized stones, covers the north hind paw as shown in the bottom of Figure 17. The modern stones are probably Phase III replaced by Baraize in 1926.

The Phase III stones in Figure 17 are exactly those that fell in October 1981, a collapse that motivated the increased concern and restoration work of the 1980's. This work covered most of the features that are illustrated in these detailed studies. From October 1981 until April 1982, I drew the cuts that were made through the Sphinx masonry during the veneer replacement restoration work. Fig. 18, for example, is the east side of the break in the stonework after the October 1981 collapse on the north hind paw. The lower part of the fallen masonry was mostly Phase III (Graeco-Roman) and behind the small brick-sized stones there were 10 to 20 cm of loose sand and limestone chip fill that covered harder mortar packing of an earlier phase and hard Member I bedrock.

A particularly detailed study was done of the masonry in the chapel of the Sphinx, located at the base of the chest between the forepaws (Fig. 19). Each structural element was given a number and profiles were drawn to illustrate the structural relations between major parts of the masonry (Fig. 20 - 21). A series of relationships between the Thutmose IV granite stela (ca 1400 BC), the south forepaw, and the Phase I masonry against the chest of the Sphinx indicate that Phase I is probably 18th Dynasty (Lehner 1990). Fig. 21 shows the lower part of the Sphinx chest, an area of some concern in the latest restoration efforts. The chest is composed almost entirely of the Member II series of limestone layers, although Member I is found at the very base. The granite Thutmose IV stela rests against a platform composed of large stone blocks with a narrow empty space in the middle of the platform, creating a kind of room. In 1926 Baraize covered the opening with iron beams and grey cement (cross-hatched in Fig. 21).

2.5 SPHINX COMPUTER MODELLING

The Sphinx Computer Modelling Project (SCMP) was begun in January 1990 in connection with the preparation of the proposal of the Getty Conservation Institute to the Egyptian Antiquities Organization for conservation studies of the Sphinx. Jon Jerde, President of the Jerde Partnership Inc., an architectural firm in Venice, California, donated equipment, time and expertise, to produce the project. Tom Jaggers, CAD Director of the Jerde Partnership, carried out the computer work.

The goal is to produce a computer-generated three-dimensional model of the Sphinx that will allow the Sphinx to be viewed from any angle or perspective. The computer model can only be as accurate as the drawings of the Sphinx (produced during the ARCE Sphinx Project) on which it is based. In these drawings the Sphinx is contoured at 10 cm and 25 cm intervals.

The first stage was to digitize the contours of the Sphinx and its site. Digitizing is putting the graphic (vector) data into points (pixels) with three coordinate values. Jaggers used an ALR (Advanced Research Logic) Personal Computer and the Auto Cad (Release 10) program to digitize the 1:50 front and side elevations, the top plan, and the 1:200 map of the surrounding ditch.

The next step was to connect the contours by adding a wirework frame in order to establish a plane, a process called meshing. This allows the computer to hide lines that should not be seen from a given point of view. After meshing, the Sphinx model was comprised of 250,000 <u>faces</u>, a face being one surface unit (the equivalent for a surface to a pixel for a line; a flat side of a box is one face), and took up 9 megabytes of memory. Fig. 22 is the first computer plot of the digitized and meshed Sphinx contours.

Once the meshing was complete, pure processing time was required in order to hide lines for a given point of view. See Jaggers (1991) for a more technical description of the Sphinx computer modelling.

I used the Sphinx model to experiment with reconstructions of the Sphinx's original appearance (for example with beard and nose intact), and its appearance after its actual reconstruction in the New Kingdom when it was entirely clad in the Phase I restoration masonry. At this period there may have been a royal statue set up at the base of the chest upon the limestone foundation behind the Thutmose IV Stela (Fig. 19), although this is only a hypothesis. The images of the reconstructed Sphinx has to be contoured and digitized in order to be modelled, and this Sphinx computer model received a fair amount of attention (Lehner 1991a, 1992).

But the model of the Sphinx as it is has more significance for conservation studies. This computer modelling has shown the complexity of the geometry of a ruined monument. It is not as easy to capture with high resolution the morphology of the actual weathered Sphinx as it is the simpler geometry of a reconstructed Sphinx. Although it is less elegant, the model of the Sphinx as-is may prove useful for studies of wind and particulate flow, accelerated weathering studies, planning tourist and traffic patterns, etc.

III GIZA PLATEAU MAPPING PROJECT

The first goals of the Giza Plateau Mapping Project were to provide a survey network and a detailed 1:500 topographical and archaeological map of the Giza Plateau (Lehner 1985; 1986). The topographical map awaits the completion of aerial photography and post-flight photography ground control, but the survey network was completed in 1986. The survey network has provided excellent control for the excavations now undertaken by the GPMP. We are able to locate our work anywhere on the plateau to an accuracy of millimeters with respect to the GPMP GRID and to sea level. The GPMP GRID is useful for any future mapping and conservation studies.

David Goodman of the California Department of Transportation (CALTRANS), Office of Geometronics, designed the GPMP survey. The principle control was an eleven-course traverse that encircles the three pyramid complexes and their associated ancient cemeteries (Fig. 23). The traverse runs along the ridge of the Maadi Formation south of the pyramids, and around the bowl-shaped depression of the Maadi Formation above the Southern Field (Porter, Moss and Malek 1974, 294-298, pl. III). There is a series of points around the area of the Sphinx. The GPMP GRID is oriented to true North on the basis of sightings on Polaris. Coordinate values are based on the center of the Khufu Pyramid, an arbitrary, calculated center that was designated North 100,000 meters and East 500,000 meters (Fig. 24).

During the 1988-89 season of the GPMP we were informed that the Egyptian Remote Sensing Center intended to do controlled aerial photography of the Giza Plateau. This was intended to complement the photogrammetric survey that produced 1:500 maps of the valley near the plateau for the AMBRIC consortium and the Cairo Waste Water Project. Goodman furnished the Remote Sensing Center with maps of flight lines for the plateau, and over the next two days we marked our main and auxiliary points with lime so that they would show on the aerial photographs. What remains is to carry out the post photographic ground control and to plot the maps, if the photographs meet plotting requirements.

Goodman's report on the specifications of the GPMP survey control are reproduced below.[6]

IV GIZA PLATEAU COMPUTER MODELLING

In 1991 we began a program to computer model the Gize Plateau at the Computer Laboratory of the Oriental Institute at the University of Chicago. John Sanders, Director of the Computer Laboratory, and Peggy Sanders digitized the 1:5,000 map of the Giza Plateau that was compiled from aerial photogrammetry flown in 1978 as part of the map series for the Egyptian Ministry of Housing and Reconstruction. We also used GPMP survey data. For this we had to merge the data from two grid coordinate systems - that of the 1:5,000 maps and the GPMP GRID.

Peggy Sanders used Autocad (Release 10) to digitize the contours that are plotted at 1 meter intervals in the 1:5,000 maps. John Sanders wrote a program in Auto Lisp to extract the X, Y and Z coordinates of each contour line that was digitized. He created a data file in the SUN SPARC Station (1+) and used the program, Aricad Topographer, to create an Arris data base of the Giza Plateau surface. Sanders used other Arris modules to render the surfaces. Figure 25 is one point of view of the raw digitized contours before the topographical surfaces were rendered. The bases of all buildings were extended deeper than they really are, so that when the surface was rendered it engulfed the extended base of each pyramid, temple, and mastaba to create the true baseline of these structures.

In recent months, Sanders created a DXF file of the Giza Plateau topography and architecture and sent this to the Jerde Partnership where Jaggers merged the Giza Plateau and the Sphinx data bases. For this we had to find the correspondence between the Sphinx local grid, the GPMP grid, and the grid of the 1:5,000 maps. The combined model of the Sphinx and Giza Plateau is comprised of about 2.3 million faces.

Our computer modeling continues. We are trying to achieve more detail in the model of the Sphinx statue, and we are digitizing the Sphinx Temple and Khafre Valley Temple in front of the Sphinx. We are also working toward more detailed renderings of the pyramids and other architecture on the plateau. We hope that such three-dimensional documentation will be an act of conservation in its own right, and that it will be useful for other studies of the Sphinx conservation.

NOTES

1. A number of these studies addressed the texts and stone architecture associated with the Sphinx. Three studies exist on the topic "sphinx". One covers generic sphinxes from ancient Egypt, the Near East, Greece, Rome, and Islamic Period, the Renaissance, and modern times (Demish 1977). Another deals with the ichnography of the sphinx in the Near East through the Second Millenmium (Dessenne 1957). Schweitzer (1948) studied the sphinx and lion in all major periods of ancient Egypt. There is also a lengthy treatment of the role and meaning of the lion in ancient Egypt, in which the generic sphinx is discussed (de Wit 1951).

   From two years of excavation at the Sphinx, Selim Hassan published one large tome (Hassan 1953) and shorter versions(1949, 1951) of his results and interpretations, but these did not include a physical description or study of the Sphinx itself. Ricke (1970) carried out an exhaustive survey, mapping and detailed interpretation of the 4th Dynasty Temple in front of the Sphinx. His study involved some documentation and study of the Sphinx and the Khafre Valley Temple, but it focused mainly on the Sphinx Temple. Petrie (1883) mapped the interior of the Khafre Valley Temple, as did Hölscher (1912) who also excavated and mapped the terrace in front of the Valley Temple. Zivie (1976, 1980, 1984) catalogued, analyzed and interpreted New Kingdom texts from Giza, which focus mainly on the Sphinx, with some commentary on proceeding periods and a follow-up study of later periods (Id. 1980).

2. Assuming that the small, brick-sized masonry at the tip of the forepaws is no more than 0.15 m thick and that the masonry covering the t ail is about 0.50 m thick (as in the section through the masonry at the rump, the length of the bedrock core is approximately 71.90 m. This would make the length of the bedrock reserved for the core body of the Sphinx about 137 Royal Cubits. The Sphinx measures 19.10 m across the haunches its widest part. It is thinnest across the waist, measuring 10.00 m at its masonry-covered base and only 3.6 m across at the top. From front elbow to elbow the Sphinx is 18.50 m wide. It measures 12.70 m across the chest.

3. There is a general correspondence between the principal parts of the statue and the principal geological layers, or members, from which it was formed. The base is cut into Member I, a very hard layer; the body is shaped mostly in member II, a series of softer beds; and the head is formed from Member III, a layer of intermediate hardness.

The floor all around the Sphinx was cut down into the hard Member I rock. Thus, some of this rock was left in the lower part of the core that the builders reserved for carving the Sphinx. Due to the dip in the geological formation - from the NW to the SE of less than 6 degrees - Member I rock rises to a height of about 3.70 m in the rear of the statue, but to a height of only 1.09 to 0.65 m in the forepaws and in the area of the chapel.

Aigner (1983a) did not distinguish layers of the Sphinx head from those of the body; in fact the former are somewhat ambiguous in his depositional model of how the Giza limestones were formed. However, he agrees that the Egyptians reserved a harder layer for the head. They seem to have actually spaced the forehead,eyes, nose and mouth according to these upper layers, and according to the thin separation lines between them. (Id. 1983b, 383-4, Fig. 8).

Said (1962, 98) distinguished the Sphinx head and neck layers as a bed distinct from the body. The upper layers are characterized by the abundance of the fossil <u>Operculina pyramidum.</u> These fossils help make the head layers hard but not britle - qualities of good building stone. The head is formed from the top of the Upper Eocene geological layer at Giza (Said and Martin 1964,112, 115).

Gauri (1984, 33) gave these upper layers member status, calling the uppoer unit the "Akhnet Member", after the ancient Egyptian word for "horizon." He describes Member III as nearly nine meters thick, "the lower one-third of which, forming mainly the neck of the Sphinx, is a relatively softer limestone being richer in the clastic (clay) fraction. The upper portion is a massive limestone interlayered with four distinct partings, each nearly 10 cm thick, of somewhat softer limestone similarin composition to the limestone of the neck" (Ibid). The Member II sequence is one of softer, more yellowish beds with greater clay content, interspersed with harder and whiter beds. The clastic (clay) fraction becomes less in each bed (eg. from 2i to 2ii) as well as from bottom upward throughout the entire sequence. Gauri attributes this layering to periods of sea turbulence that brought in more land-derived sediments interspersed with periods of sea tranquility (Ibid., 27).

The head is of much darker color than the neck and body because of a protective patina that formes naturally in the upper Member III stone. According to Gauri's analysis, this is due to higher amounts of gypsum (calcium sulphate) in the stone. "This gypsum presently forms the duricrust which gives the brownish appearance to the head region and has contributed to its durability" (Ibid., 33).

4. The following are the measurements of the water table in 1981-82 :

Point	Location
W2	Shaft in the vestibule of the Khafre Valley Temple
W3	Drill hole in pillar socked of the Sphinx Temple west colonnade
W4	SRI 1978 drill hole in Sphinx Temple court
W5	Forced passage under the rear of the Sphinx
W6	Shaft in the Khafre Causeway midway between the Sphinx and the Second Pyramid.
W7	"Well" at the location of the Men-kau-re Valley Temple, below the modern cemetery.

Measurements (in meters) re: sea level :

DATE*	W2	W3	W4	W5	W6	W7
10/11/81	15.38	15.42	15.50[1]			
26/11/81					15.39	
01/12/81	15.38	15.41	15.49[1]	15.38		15.3
10/12/81	15.38	15.37	15.38	15.37		
26/12/81	15.38	15.37	15.38	15.38	15.39	
04/01/82	15.376	15.386	15.381	15.391		15.38
11/01/82	15.366	15.40	15.361	15.361	15.356	
18/01/82	15.361	15.396[2]	15.356	14.346		15.36
25/01/82	15.386	15.406	15.381	15.381	15.402	
01/02/82	15.376	15.40	15.381	15.381		
08/02/82	15.361	15.49[3]	15.356	15.351	15.356	
15/02/82	15.376	15.386	15.381	15.371		15.39
22/02/82	15.391	15.386	15.381	15.386		
02/03/82	15.376	15.386	15.379	15.391	15.396	
08/03/82	15.371	15.386	15.376	15.376		
15/03/82	15.361	15.386	15.366	15.351	15.366	
29/03/82	15.346	15.381	15.346	15.341	15.346	

(*) DAY/MONTH/YEAR

1. Higher measures in this drill hole were due to displacement when the level was taken with a pipe placed into the hole; later measures were done with a thin tape measure ruled with millimeters.

2. This is a shallow hole that ends just at the water table. Slightly higher levels here are probably due to slurry at the bottom of hole.

3. Bottom of the hole had filled due to recent rain.

The water table seems to have lowered considerably since these measurements were taken.

5. It may bet hat some of the lower Phase I blocks are Old Kingdom and that the 4th Dynasty builders finished the rough core of the lion body with casing, similar to the core and casing building style of the pyramids, mastabas, and nearby temples. Zahi Hawass (forthcoming) has suggested that when the 18th Dynasty Egyptians excavated

the Sphinx, under Amenhotep II and Thutmose IV, they found that Old Kingdom casing blocks has fallen off the higher parts of the Sphinx body, and they replaced them against the Member II bedrock that has weathered drastically since the 4th Dynasty. Baraize found a very similar situation in which many casing blocks has fallen off the Sphinx when he excavated it in 1926. I have suggested that the 18th Dynasty restorers took blocks from the Khafre causeway walls to repair the Sphinx (Lehner 1991b). The granite stela of Thutmose IV between the forepaws is actually a reused lintel. According to the maps of Hölscher (1912) and Ricke (1970) the pivot sockets on the backside of the stela fits only a few doorways in the Sphinx Temple and in Khafre's Pyramid Temples. These doorways are in the Upper Temple, one of which is the entrance to the temple from the causeway.

6. GPMP CONTROL SURVEY

David Goodman

In the 1984/85 inaugural season of the GPMP, basic horizontal survey control was established in an eleven-course traverse skirted the major ancient features of the plateau. Where this was not possible, auxiliary stations were established outside the basic control traverse. In addition, supplemental stations were set at or near every major aspect or feature of the necropolis.

Most stations were physically established by drilling 3/4" holes in stable bedrock and epoxying mushroom-shaped 3½ "a minimum survey disks with 5/8" corrugated stem into the holes and onto the rock (Lehner 1985, Fig.2). The disks were manufactured especially for the Project, and each bears the project name in intaglio relief. Into each disk a discrete station point was center-punched and the date of the setting and the station name were inscribed with punch dyes. Where the bedrock was too hard for drilling, cross-marks were scribed with punch dyes. Where the bedrock was too hard for drilling, cross-marks were scribed into the rock with a tungsten-carbide scriber. At all stations - basic, auxiliary, and supplemental - two or more "witness" or "reference" marks were scribed into the rock as locators and to insure the permanence of the stations.

Through the courtesy of Lietz/Sokkisha Co. of Overland Park, Kansas, second-order survey equipment was loaned, without any cost to the project, for the first season. The new equipment loaned by Lietz included a one-second theodolite, a RED 2A infrared electronic distance measurer (EDM) with liquid crystal display, and a B2C engineer's precise pendulum level.

The TM1A theodolite has these specifications :

1. Plate sensitivity - 20"/2mm.

2. Horizontal and Vertical Circles Readings - micrometer reading direct to one-second of arc, and

3. Telescope - magnification of 30 power and resolving power of 2.5 second of arc.

The RED2A is "spec'd" at a linear measurement accuracy of ±(5mm ±5ppm) mean square error. The B2C precise level has a standard deviation of ±1.0mm for a double-run line that is one kilometer long.

Each of the eleven stations of the basic control traverse was "occupied" by the theodolite and the EDM for measurements of slope distances between contiguous stations and of direction lines between the stations. The distance of each course (one station to another) was measured forward and back. Each slope measurement was a temperature- and pressure-corrected mean often independent measuring observations by the RED2A. The corrected slope distances were trigonometrically resolved into horizontal values. This was done through the use of the zenith angles that were observed at each station,

Second order, modified, observing procedures were used for the measurement of directions and zenith angles with the TM1A. These procedures included :

1. The shielding of the theodolite from the sun's rays by the use of a large umbrella;

2. The observing of four sets of directions with the circle set at a different initial value for each set (one set is comprised of a reading with the telescope in the direct mode and another reading with the telescope inverted) for each direction determined;

3. The rejection (and reobserving)of each set of direct and inverted observations whose average differed more than five seconds from the mean of all four sets; and

4. The use of the "forced centering" technique, whereby the accuracy of the theodolite/EDM setups were exactly the same as those of the target/reflectors. In addition, the tribrachs, which support the theodolite and the targets on the tripods, were checked weekly and their optical plummets were adjusted to ±1mm accuracy.

Azimuth control for the GPMP was established by observing the north circumpolar star "Polaris". Eight sets of direct and reverse sightings were observed on Polaris on the evening of December 31, 1984. The theodolite occupied the traverse station GP10 (Fig. 23) and the angle from Polaris to traverse station GP9 was measured. The azimuth thus determined of course GP9-10 is calculated to within ± five seconds of a true value.

The 6,000 meter + GPMP traverse began and ended in a closed loop at traverse station GP1. Azimuth closure error was nil! Thus, adjustment of "raw" azimuths was not required. Using these raw azimuths with corresponding measured course distances, a closure accuracy of one part in 315,000 was realized. This closure was considerably better than the accuracy that was sought, and it assures a precise horizontal control matrix for all subsequent GPMP surveying and mapping objectives.

The established horizontal control matrix, to be termed the"GPMP GRID" (Fig. 24), is astronomically oriented (from the Polaris observations). Coordinate values of the GPMP GRID are based on a calculated horizontal center of the base of the Great Pyramid of Khufu. This calculated center was assigned coordinates of North 100,000 meters and East 500,000 meters. The center of the Pyramid was calculated from a closed loop traverse, during the 1984-85 season, through the brass survey pins that were recovered in the "sockets" at the Pyramid's corners.

Two record survey monuments are documented as existing atop the Great Pyramid. One monument bears first-order and the other second-order geographic positions (expressed in latitude and longitude). The first order monument is a copper geodetic marker fixed with mortar in the SW corner of the square top of the Pyramid (the geographic coordinates of the first-order monument are : latitude 29°58'44.38"; longitude 31°07'57.02"; elevation 197.24). The second-order monument, 2.3 m northeast of the copper marker, is the prominent wooden pole at the center of the top. During the 1986 season of the GPMP, the first-order monument was "tied" into the basic control traverse with azimuth and slope distance measurements from basic traverse stations GP1 and GP8 (Fig. 23).

During the traversing of the first season, differences in elevations, delta E's, of stations on each and all of the courses were trigonometrically calculated from corrected slope distance and zenith angle measurements. Because each course was measured twice,from its opposite ends, dual calculations of all delta E's were possible. On most courses the dual delta E's agreed within ± one centimeter. At the time of the traversing a bench mark (of unknown elevation) of the Survey of Egypt was found in the N face of the First Pyramid, within a few meters of the NE corner. This was the only bench mark that was uncovered in the Giza Plateau and its environs. The elevation of this bench mark was found in the "Descriptions of Elevations of Survey Bench Marks : The Provinces of al'jisah and Beni Suef", Survey Department of Egypt (Cairo: Ministry of Finance 1936), p.18 as 61.724 above sea level. Values for elevation above sea level were given to our survey stations on the basis of the Pyramid bench mark.

The GPMP control matrix of X, Y, and Z values has been established. This matrix has been and will be the foundation for all subsequent and following field surveying and mapping and for photogrammetric mapping, studies, and quantity calculations.

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FIGURE CAPTIONS

FIGURE 1 : The local Sphinx grid of the ARCE Sphinx Project.

FIGURE 2 : Photogrammetric front elevation and profile of the Sphinx; contour interval is 25 cm. Original drawing is scale 1:50.

FIGURE 3 : Photograpmmetric south elevation of the Sphinx. Ancient masonry that showed as of September 1979 is shaded. Original drawing is scale 1:50.

FIGURE 4 : Photogrammetric north elevation of the Sphinx. Ancient masonry that showed as of September 1979 is shaded. Original drawing is scale 1:50.

FIGURE 5 : Photogrammetric profiles of the Sphinx, approximately ever 5m, laid onto the base outline of the Sphinx. Original drawing is scale 1:50.

FIGURE 6 : Profile of the front of the Sphinx face, chest, and sides of the Sphinx ditch with geological units indicated. Original drawing is scale 1:50.

FIGURE 7 : Contour map of the Sphinx natural rock core body; contour interval is 10cm. Original drawing is scale 1:50.

FIGURE 8 : Detailed map of the temples in front of the Sphinx; Khafre Valley Temple, left; Sphinx Temple, Right; Amenhotep II Temple, upper right. Original scale 1:100.

FIGURE 9 : Form-line master plan of the Sphinx. Original drawing is scale 1:50.

FIGURE 10 : Map of Sphinx "amphitheater"; contour interval is 50 cm. Original drawing is scale 1:200.

FIGURE 11 : Map of bedrock units : Member I (base), Member II (Sphinx body), and Member III (Sphinx head).

FIGURE 12 : Map of dip plane of Member II through Sphinx "amphitheater"; contour interval is 50 cm.

FIGURE 13 : Map of modern installations in front of the Sphinx. Original drawing is scale 1:1,000. Circled numbers : 1. Modern road; 2. Parking; 3. Sound and Light equipment building; 4. Sound and Light equipment; 5. Limestone and cement stage; 6. Seating area for Sound and Light; 7. Sound and Light main building; 8. Sound and Light garden; 9. Sound and Light buildings; 10. Sound and Light parking; 11. Private homes of Nazlet es-Samaan.

FIGURE 14 : Schematic profile of Sphinx area with water table as measured in 1978 (excavation of Zahi Hawass) and 1981-82.

FIGURE 15 : Profile of masonry at the upper SW part of the Sphinx rump (now covered by 1980's restoration). original drawing is scale 1:20.

FIGURE 16 : Profile of masonry at passage in NW part of Sphinx rump. Original drawing is scale 1:20.

FIGURE 17 : Profile of masonry at NW rear haunch of Sphinx, showing ancient masonry of Phase I, Phase II, and Phase III. Cross-hatching indicates modern (1926) cement. The upper part of the profile was covered by 1980's restorations. Original drawing is scale 1:20.

FIGURE 18 : East profile of the October 1981 break in the masonry on the side of the north hind paw of the Sphinx. Original drawing is scale 1:20.

FIGURE 19 : Plan of chapel and masonry at the base of the Sphinx chest with different groups of ancient masonry designated D through H. Positions of 1:20 profiles indicated by dashed lines. Original drawing is scale 1:50.

FIGURE 20 : Profile across inner sides of the Sphinx forepaws, with elevation of Thutmose IV granite stela and the masonry that frames the stela; individual features are numbered for structural analysis. Original drawing is scale 1:20.

FIGURE 21 : Profile of base of Sphinx chest and Thutmose IV granite stela with elevation of masonry behind the stela; cross-hatching indicates modern (1926) cement. original drawing is scale 1:20.

FIGURE 22 : Selected point of view of Sphinx computer model. Contours have been digitized and meshed. There is no line-hide, shading, or rendering, and gaps remain, in this view.

FIGURE 23 : Main traverse, auxiliary, and supplemental points established over the Giza Plateau by the Giza Plateau Mapping Project (GPMP).

FIGURE 24 : The GPMP GRID centered on the calculated center of the Khufu Pyramid given coordinate vales E500,000 and N100,000.

FIGURE 25 : Selected point of view of the digitized contours of the Giza Plateau. Contour interval is 1 m. The Sphinx data base has yet to be merged with that of the Giza Plateau in this view.

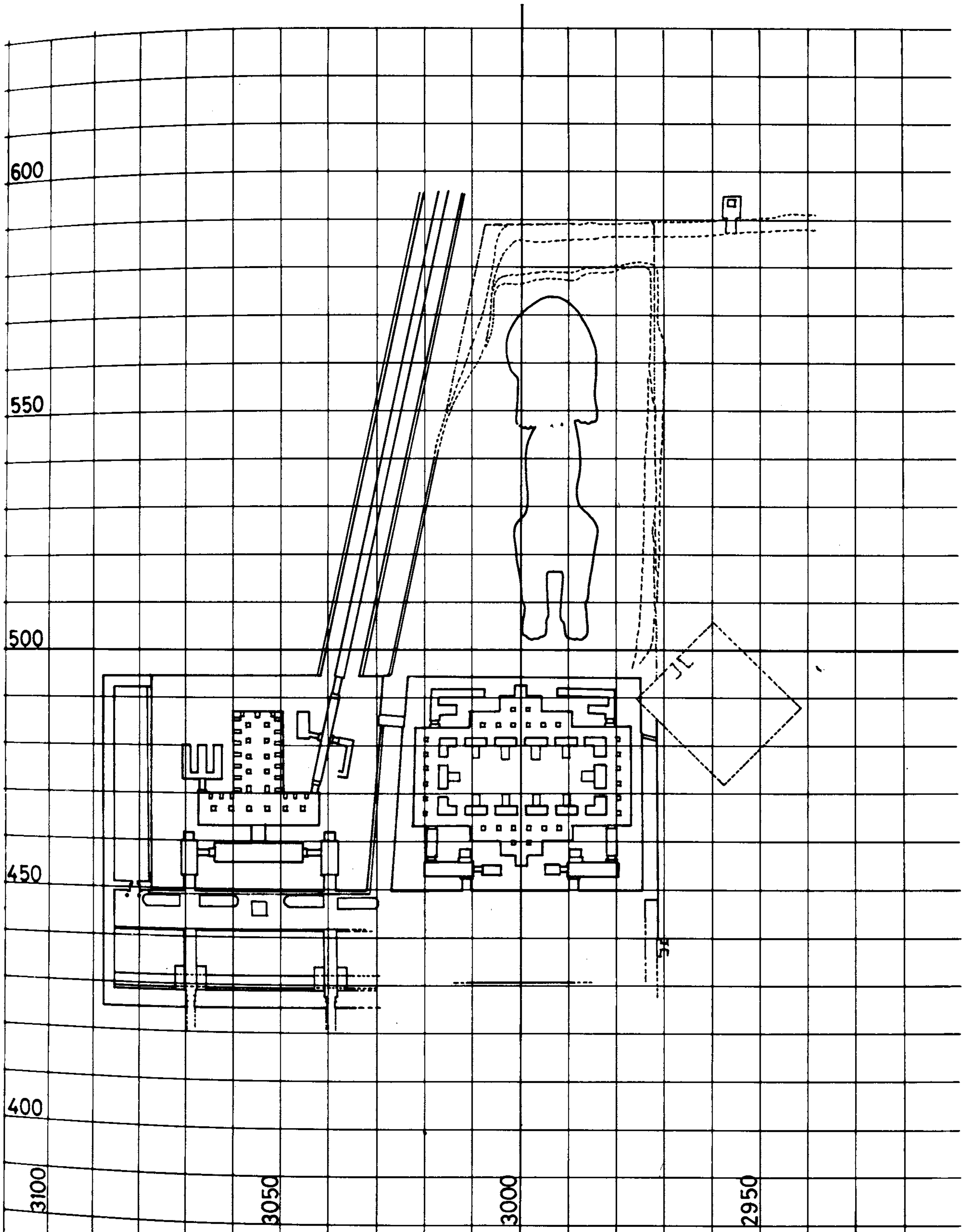


FIGURE 1

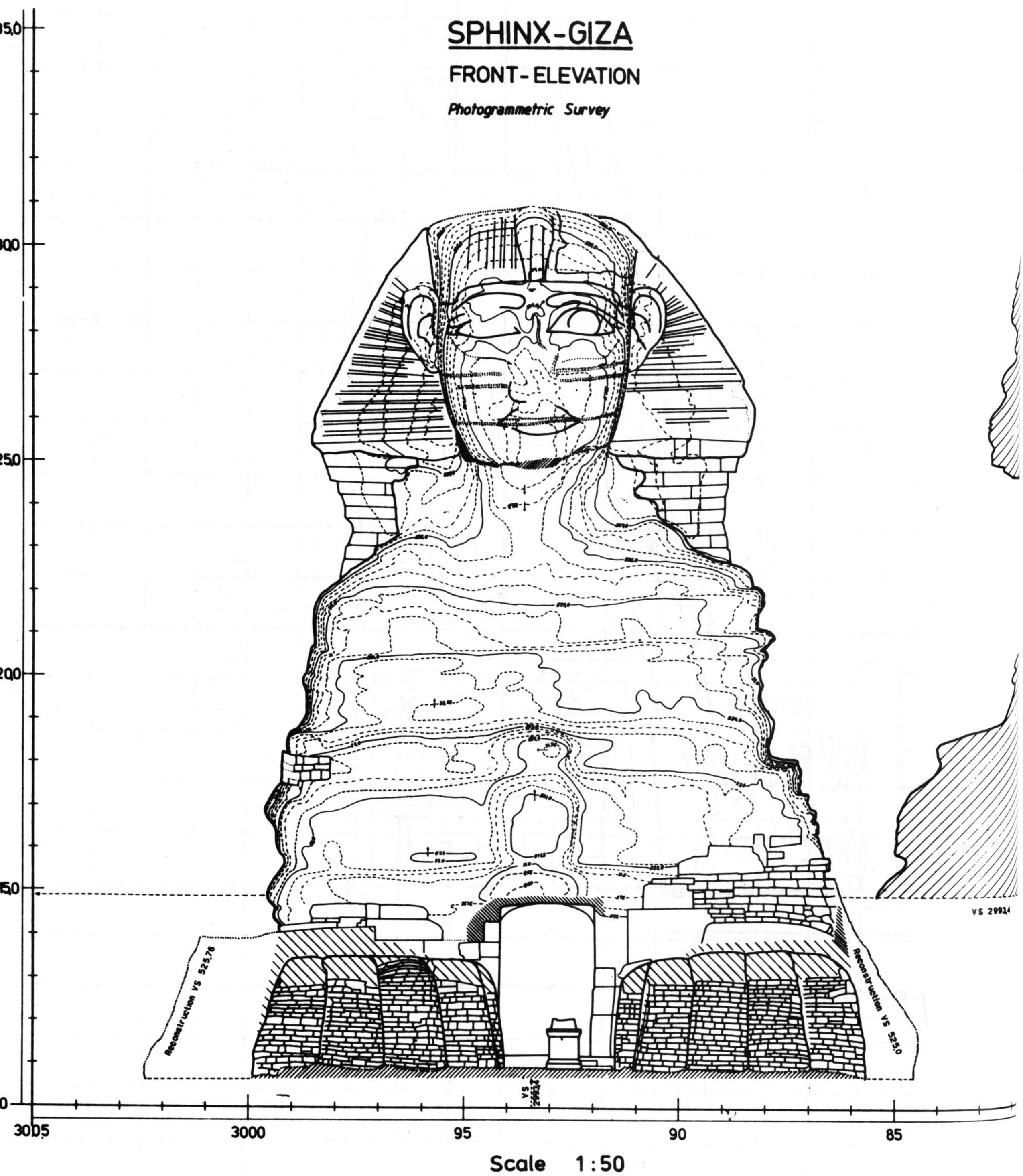

SPHINX-GIZA
FRONT-ELEVATION
Photogrammetric Survey
35,0
30,0
25,0
20,0
15,0
10,0
3005
3000
95
90
85
Reconstruction VS 525,76
Reconstruction VS 525,0
VS 2993,4
Scale 1:50

FIGURE 2

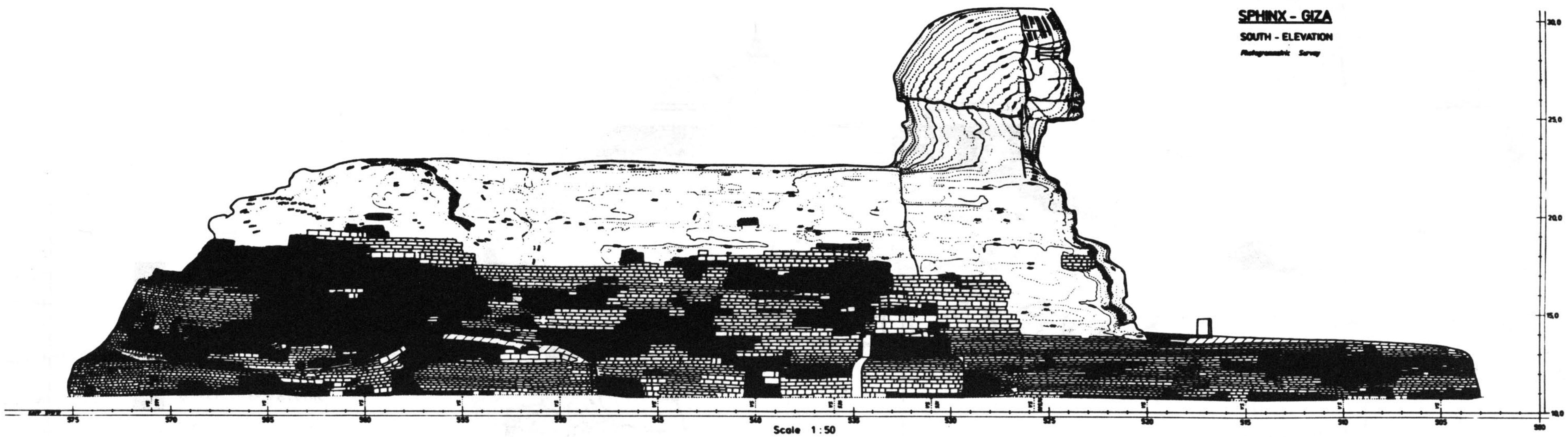


FIGURE 3

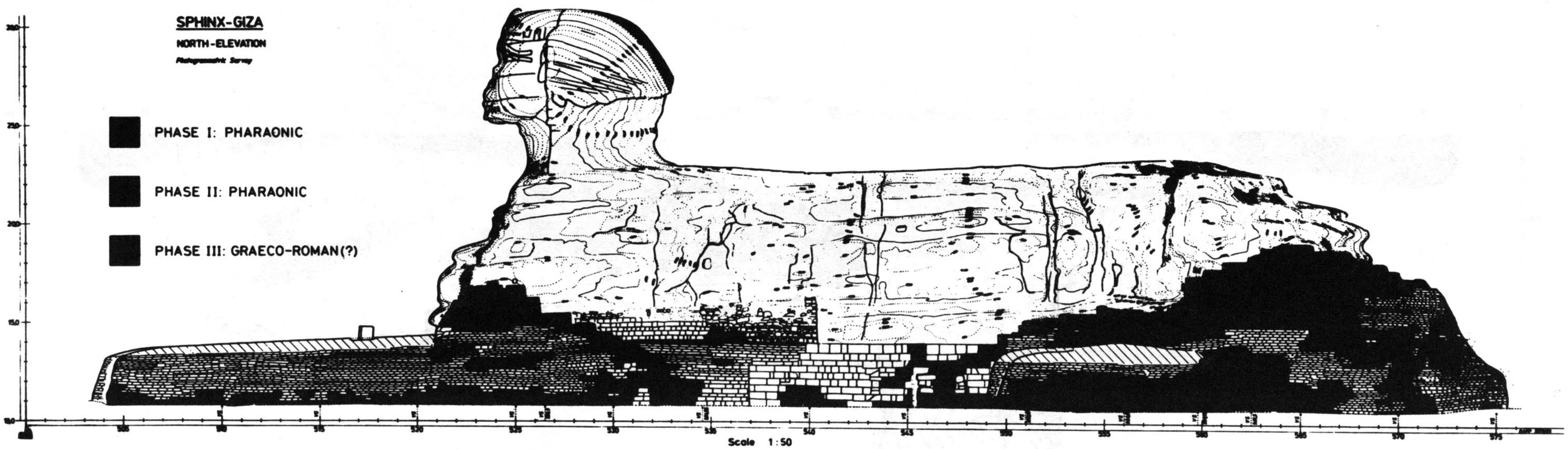

SPHINX-GIZA
NORTH-ELEVATION
PHASE I: PHARAONIC
PHASE II: PHARAONIC
PHASE III: GRAECO-ROMAN(?)
Scale 1:50

FIGURE 4

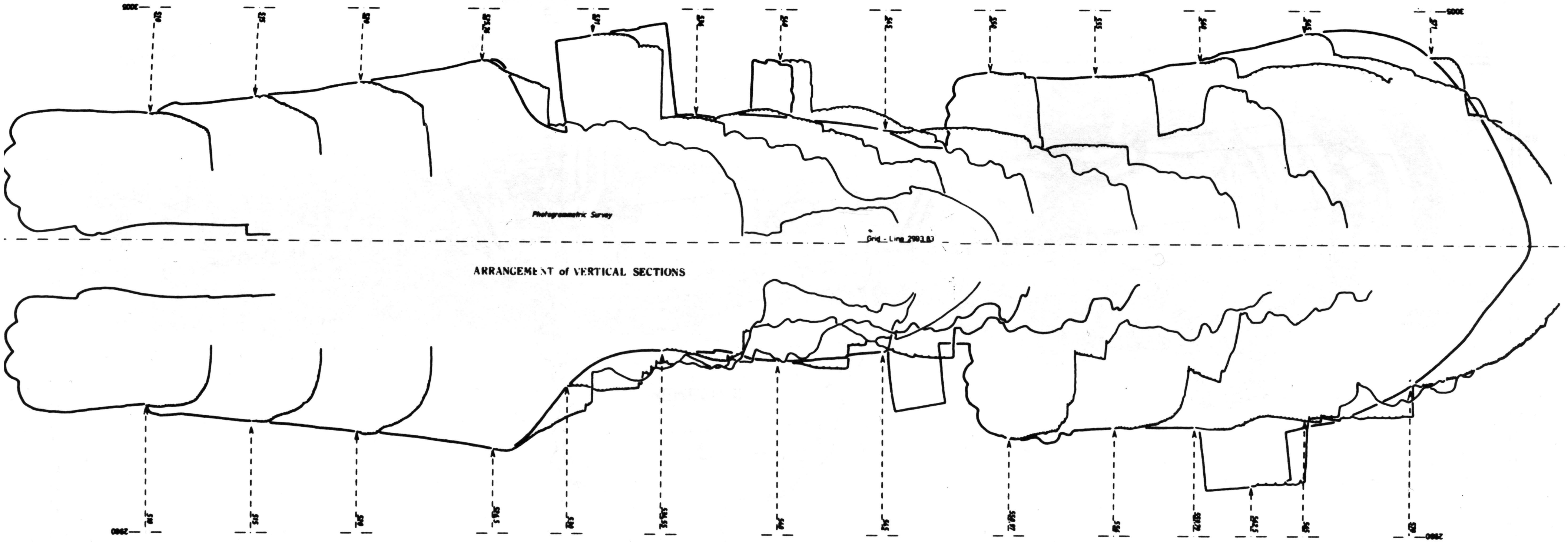

Photogrammetric Survey
Grid - Line 2993.83
ARRANGEMENT of VERTICAL SECTIONS

FIGURE 5

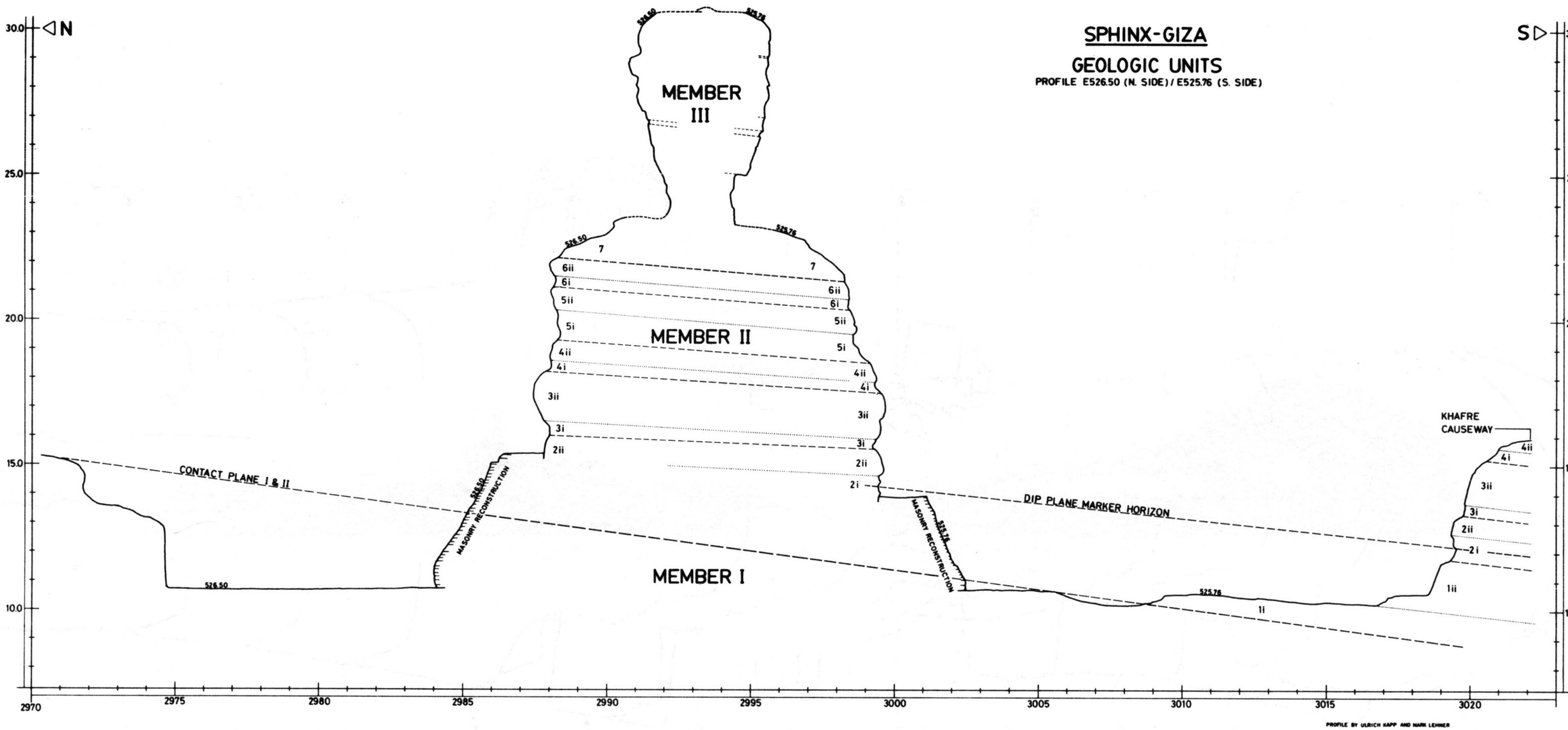

SPHINX-GIZA
GEOLOGIC UNITS
PROFILE E526.50 (N. SIDE) / E525.76 (S. SIDE)
N
S
MEMBER III
MEMBER II
MEMBER I
CONTACT PLANE I & II
DIP PLANE MARKER HORIZON
MASONRY RECONSTRUCTION
MASONRY RECONSTRUCTION
KHAFRE CAUSEWAY
526.50
525.76
7
6ii
6i
5ii
5i
4ii
4i
3ii
3i
2ii
2i
1ii
1i
30.0
25.0
20.0
15.0
10.0
2970
2975
2980
2985
2990
2995
3000
3005
3010
3015
3020
PROFILE BY ULRICH KAPP AND MARK LEHNER

FIGURE 6

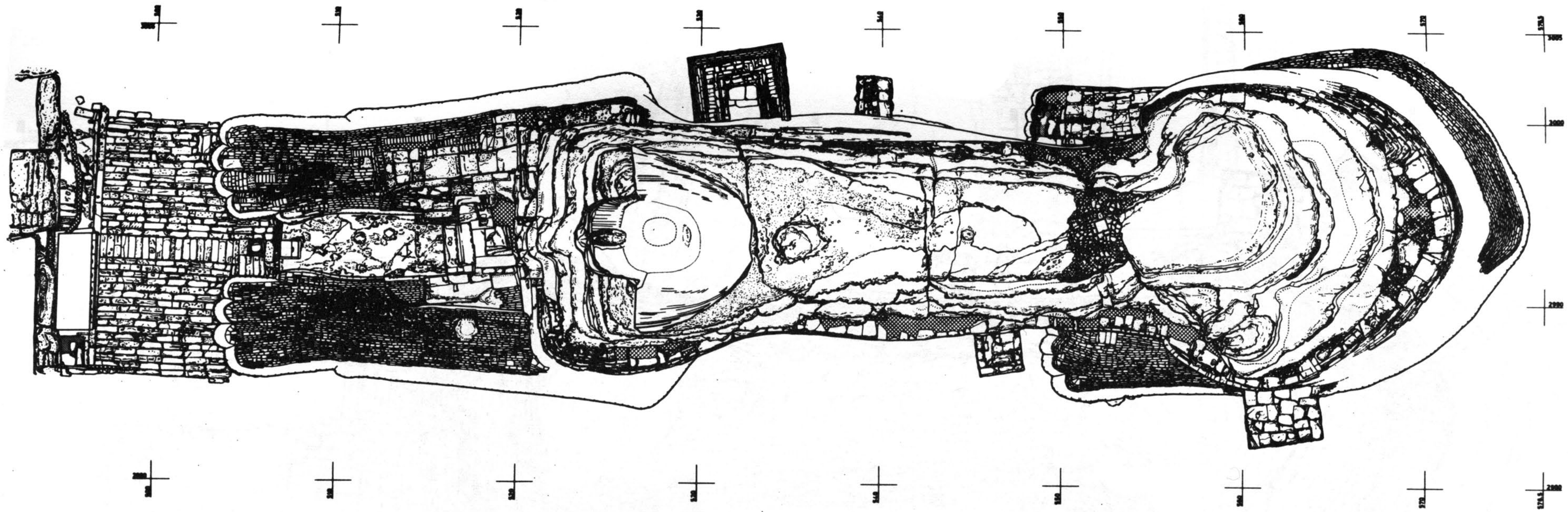


FIGURE 7

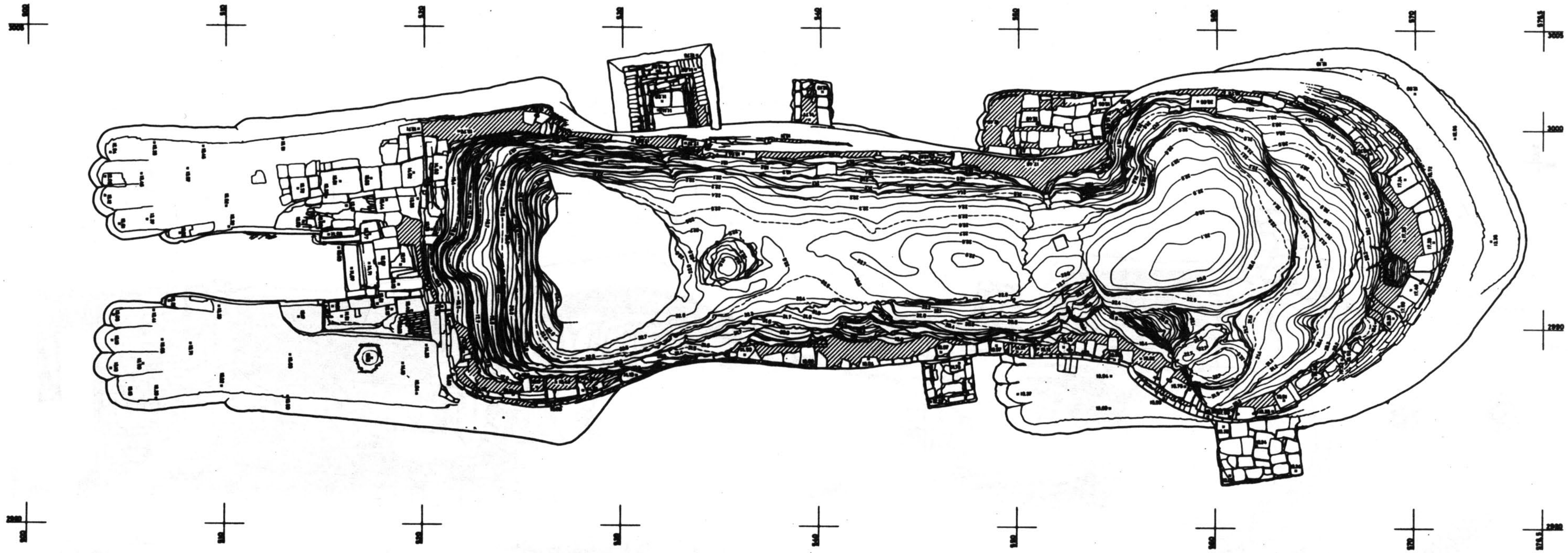


FIGURE 8

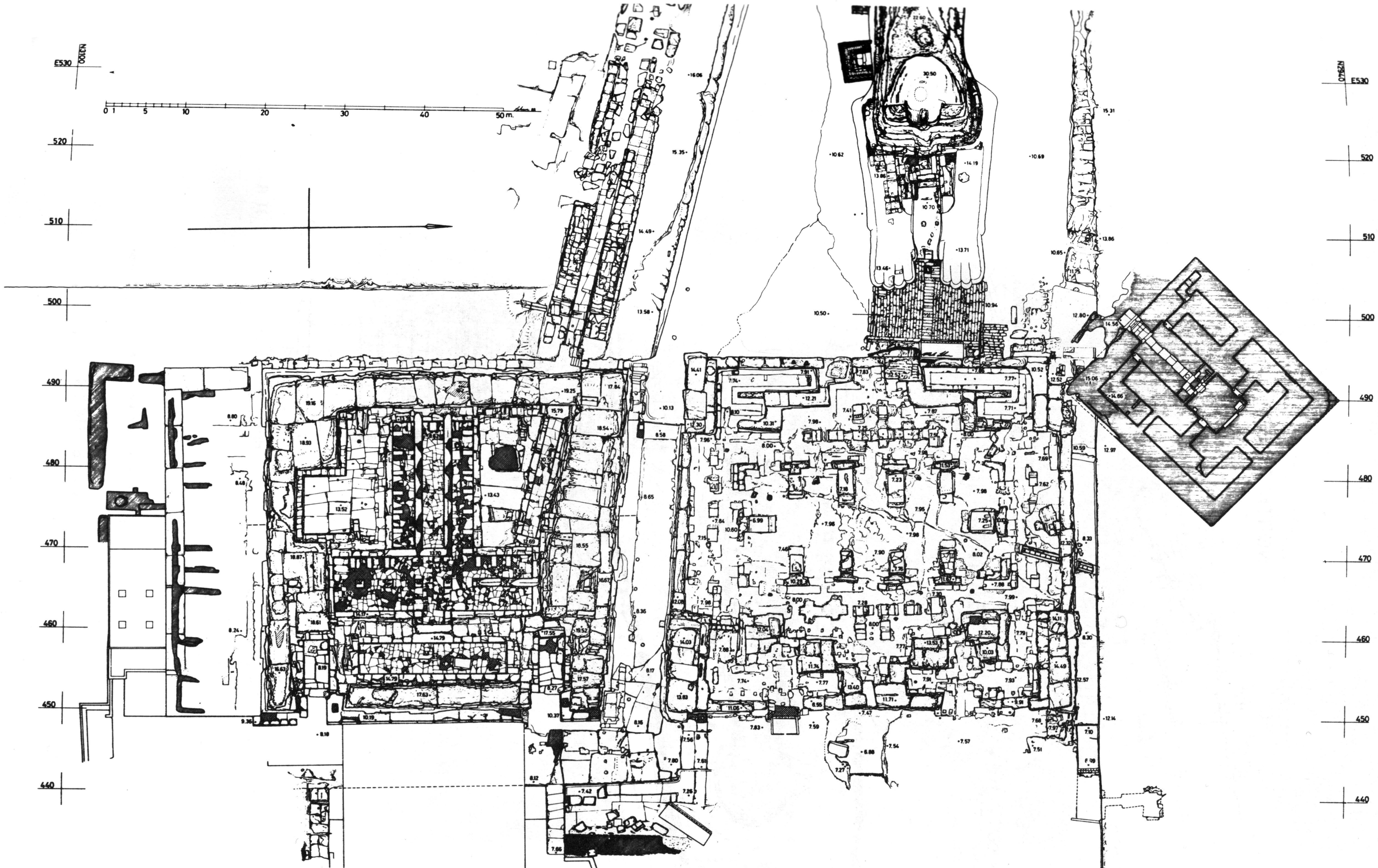

E530
N3100
0 1 5 10 20 30 40 50 m.
520
510
500
490
480
470
460
450
440
N2940
E530

FIGURE 9

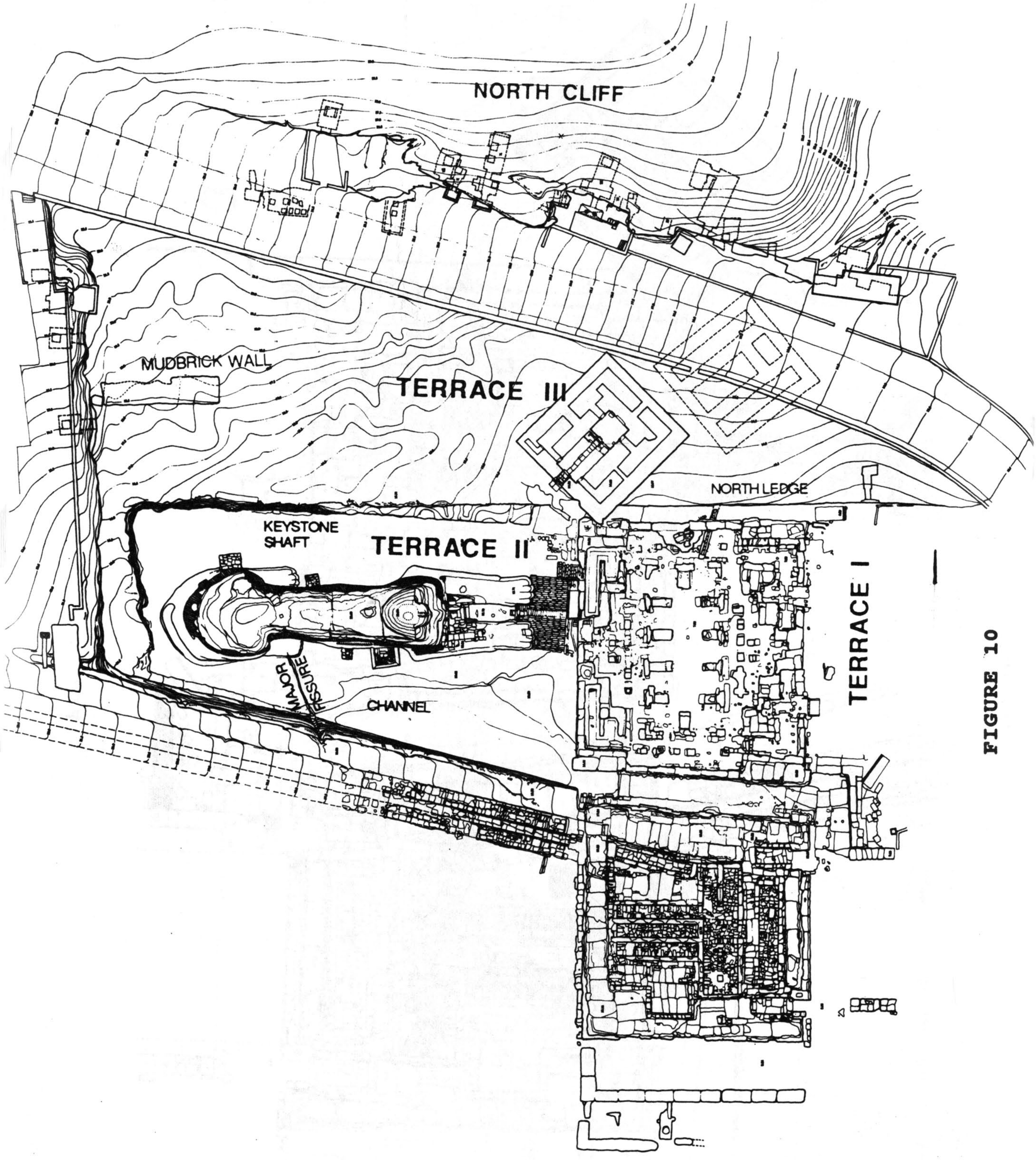

NORTH CLIFF
MUDBRICK WALL
TERRACE III
NORTH LEDGE
KEYSTONE
SHAFT
TERRACE II
MAJOR
FISSURE
CHANNEL
TERRACE I

FIGURE 10

SPHINX: GEOLOGIC MAP OF ROCK UNITS

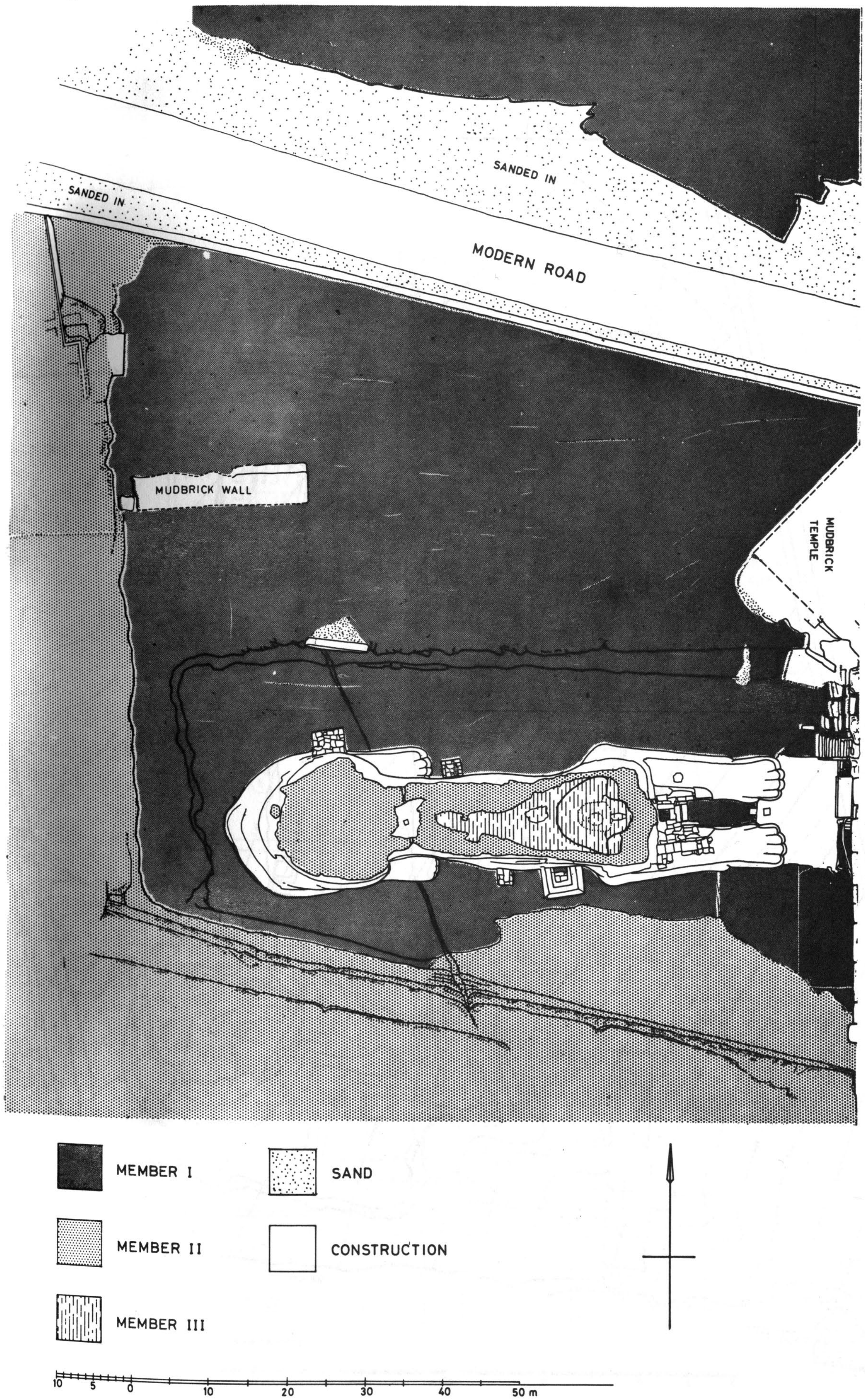
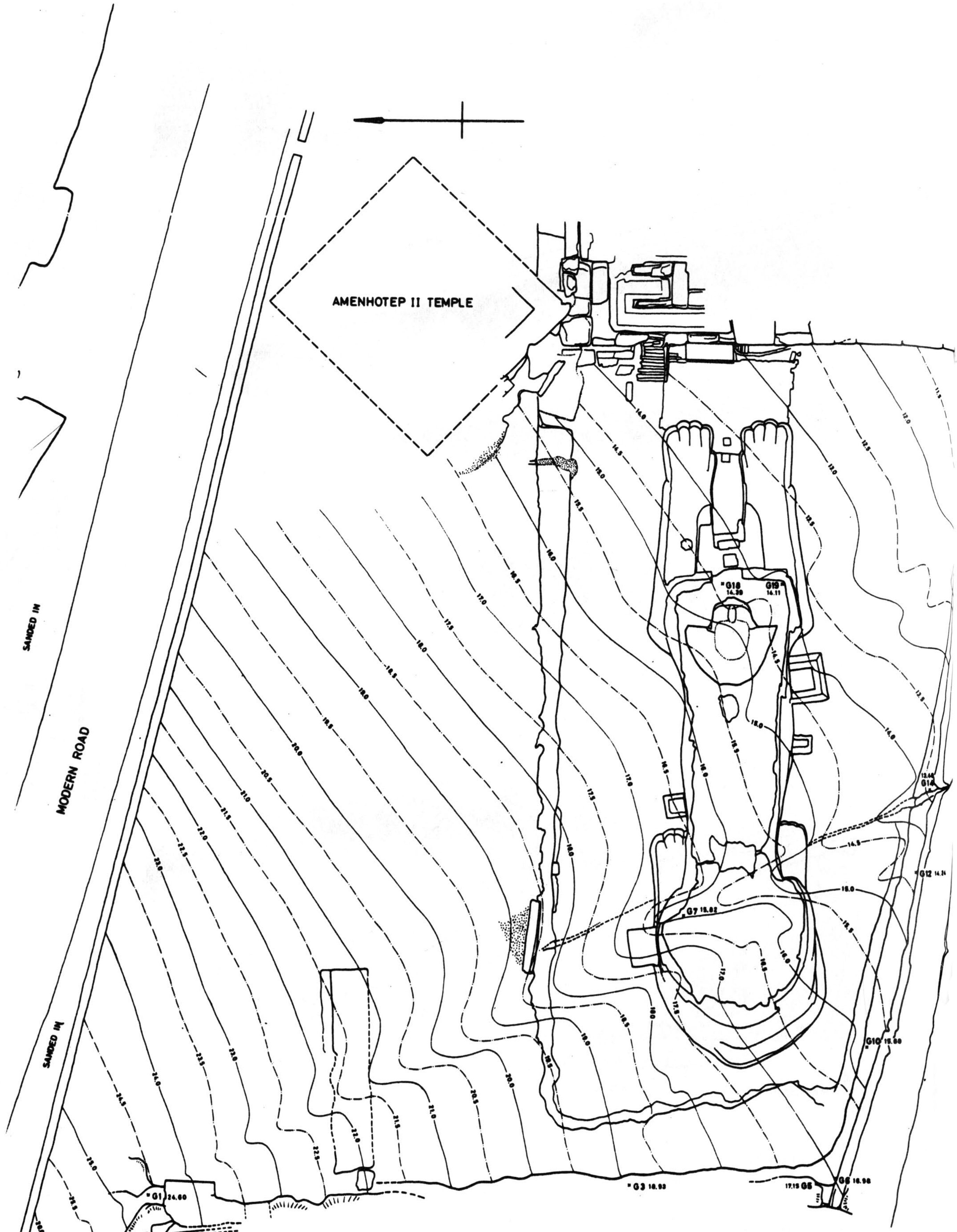


FIGURE 11



DIP PLANE MEMBER II (Bed 3i)

FIGURE 12

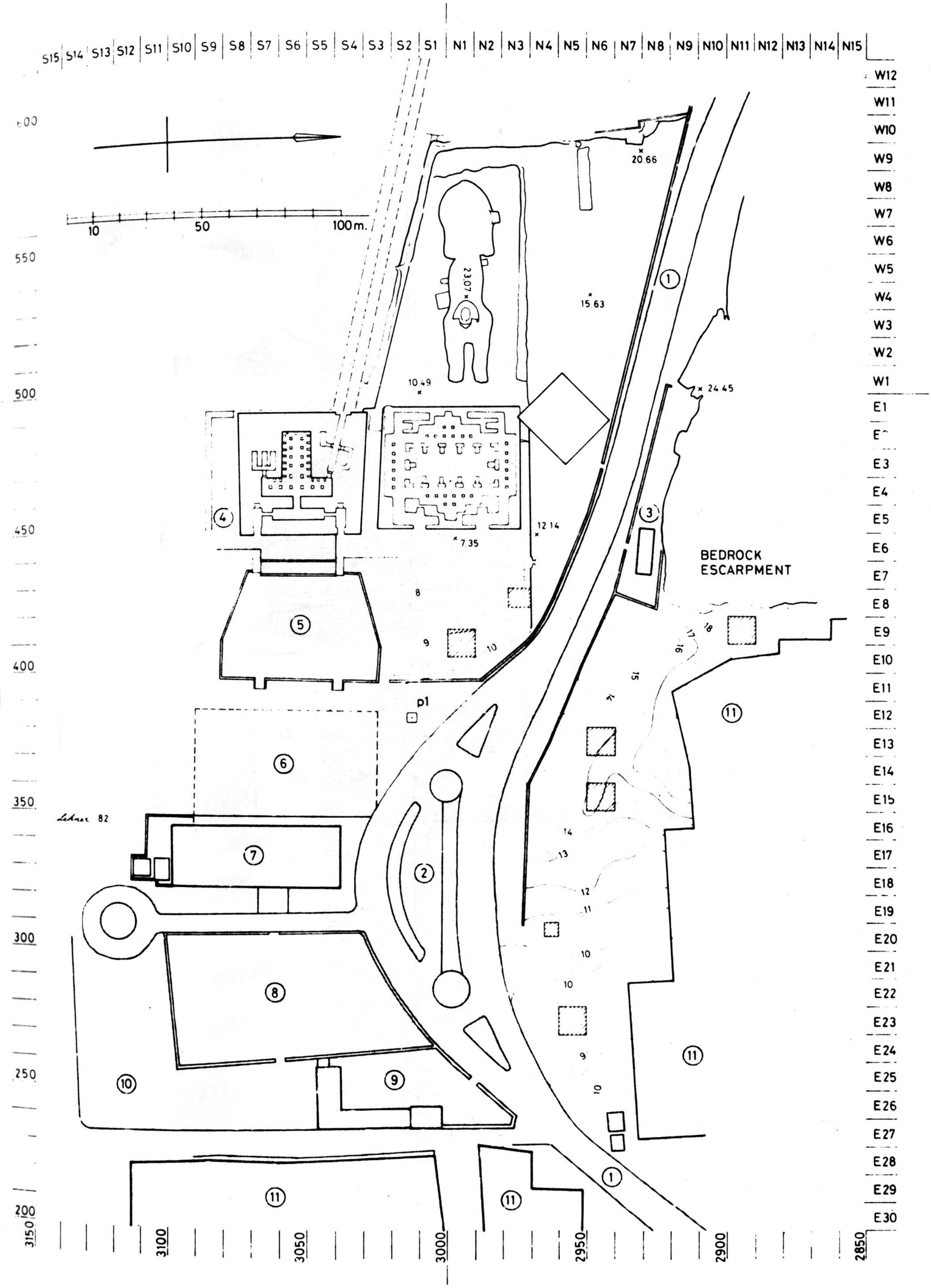

S15 S14 S13 S12 S11 S10 S9 S8 S7 S6 S5 S4 S3 S2 S1 N1 N2 N3 N4 N5 N6 N7 N8 N9 N10 N11 N12 N13 N14 N15
W12 W11 W10 W9 W8 W7 W6 W5 W4 W3 W2 W1
E1 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18 E19 E20 E21 E22 E23 E24 E25 E26 E27 E28 E29 E30
550
500
450
400
350
300
250
200
3150 3100 3050 3000 2950 2900 2850
10 50 100m.
20.66
23.07
15.63
10.49
24.45
12.14
7.35
BEDROCK
ESCARPMENT
p1
Lehner 82
1 2 3 4 5 6 7 8 9 10 11

FIGURE 13

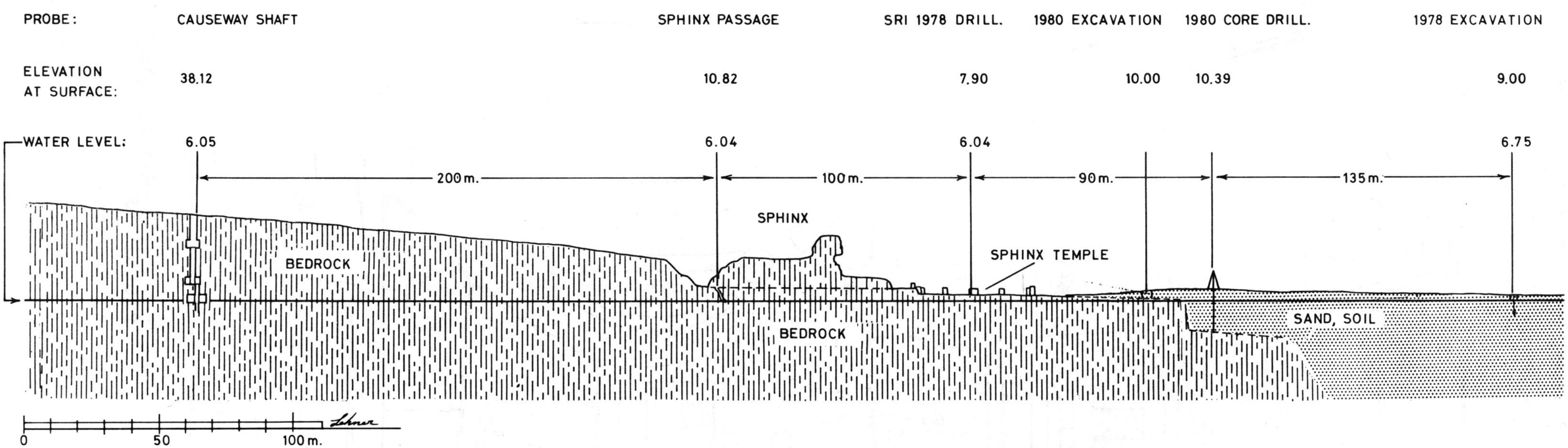

PROBE:
CAUSEWAY SHAFT
SPHINX PASSAGE
SRI 1978 DRILL.
1980 EXCAVATION
1980 CORE DRILL.
1978 EXCAVATION
ELEVATION AT SURFACE:
38.12
10.82
7.90
10.00
10.39
9.00
WATER LEVEL:
6.05
6.04
6.04
6.75
200 m.
100 m.
90 m.
135 m.
SPHINX
BEDROCK
SPHINX TEMPLE
BEDROCK
SAND, SOIL
0
50
100 m.
Lehner

FIGURE 14

SECTION-ELEVATION 14

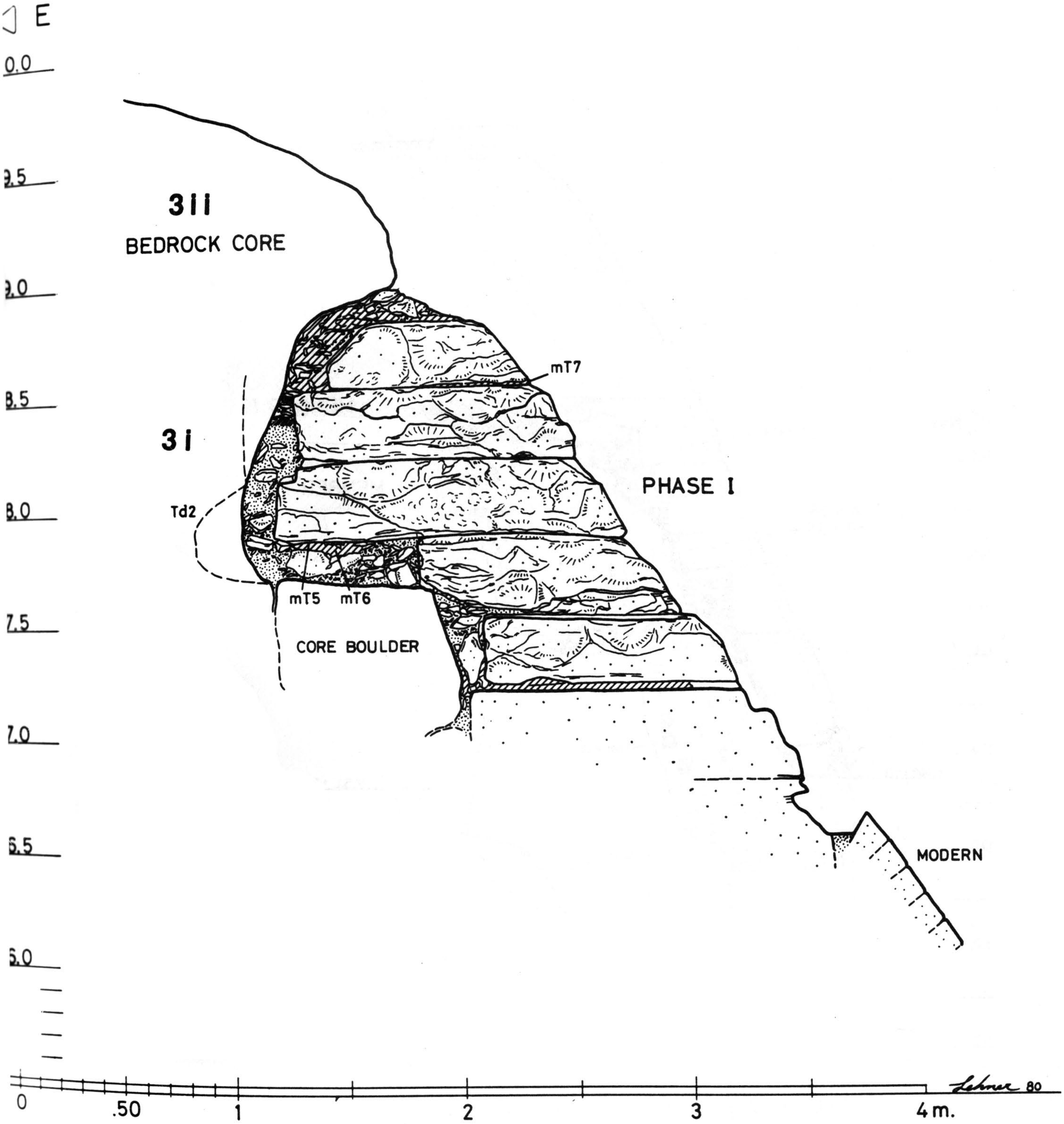


FIGURE 15

SECTION 37

WITH ELEVATION VIEW NE SIDE OF UPPER PASSAGE

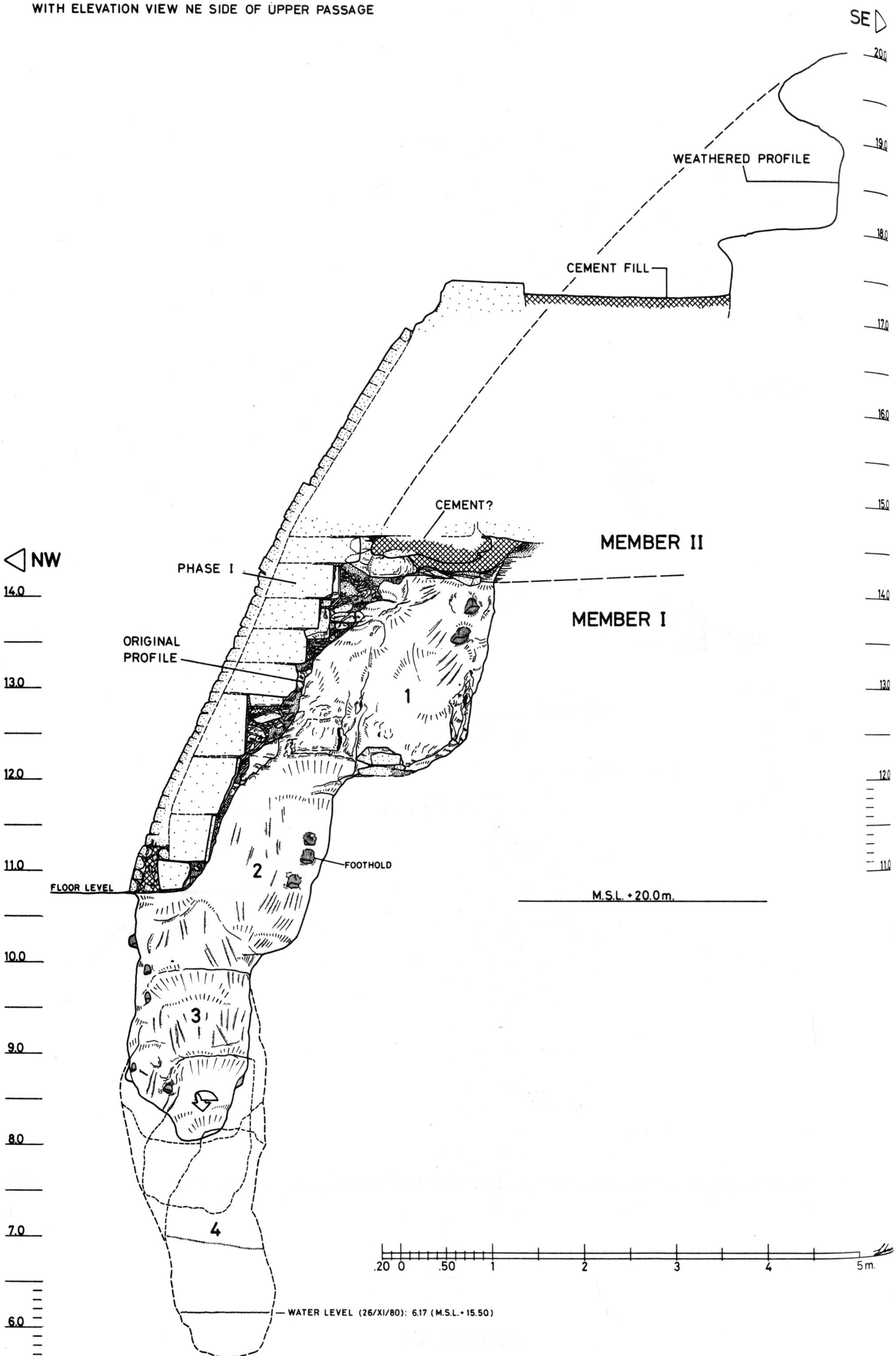
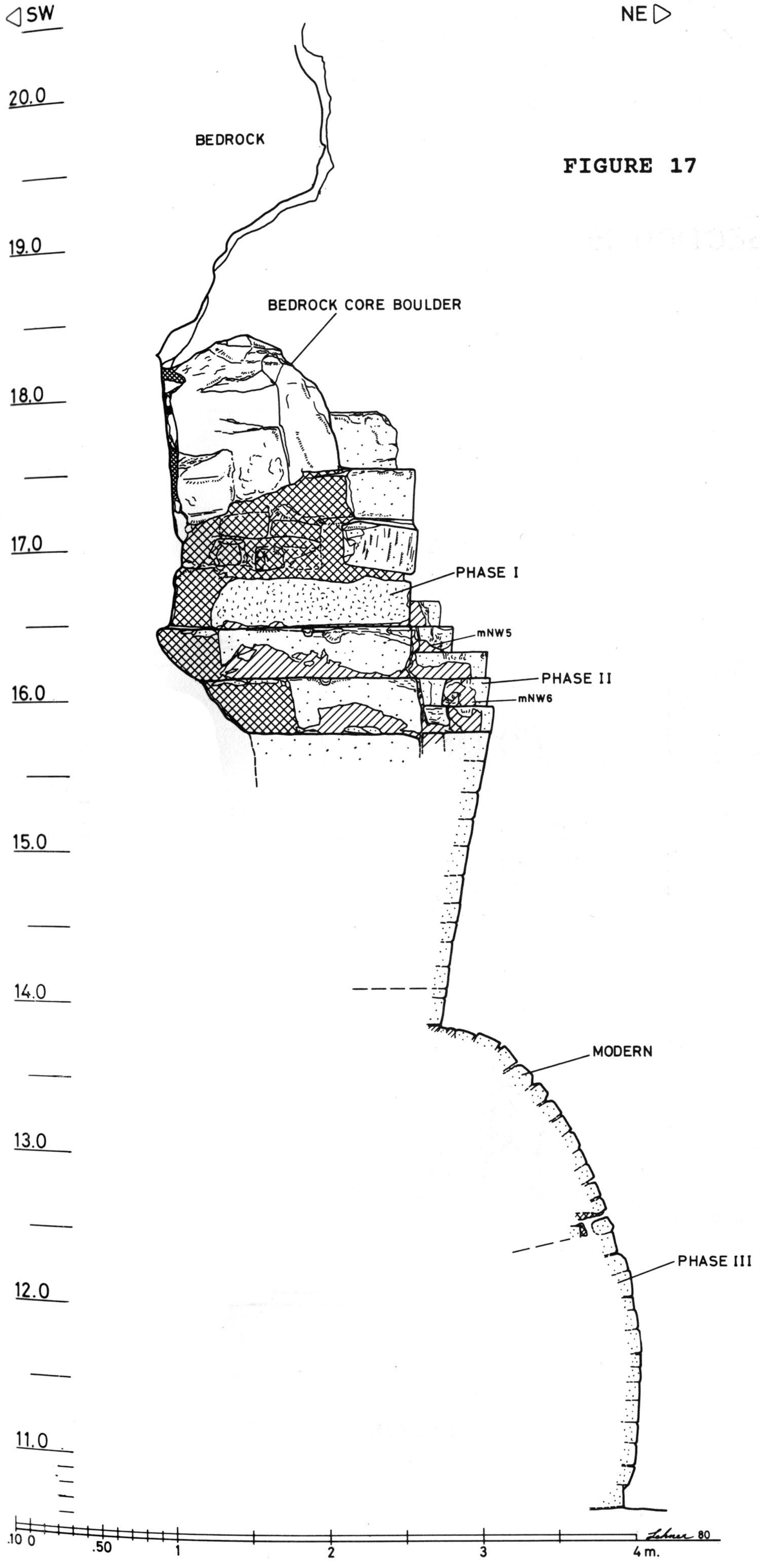


FIGURE 16

FIGURE 17



SECTION-ELEVATION 22

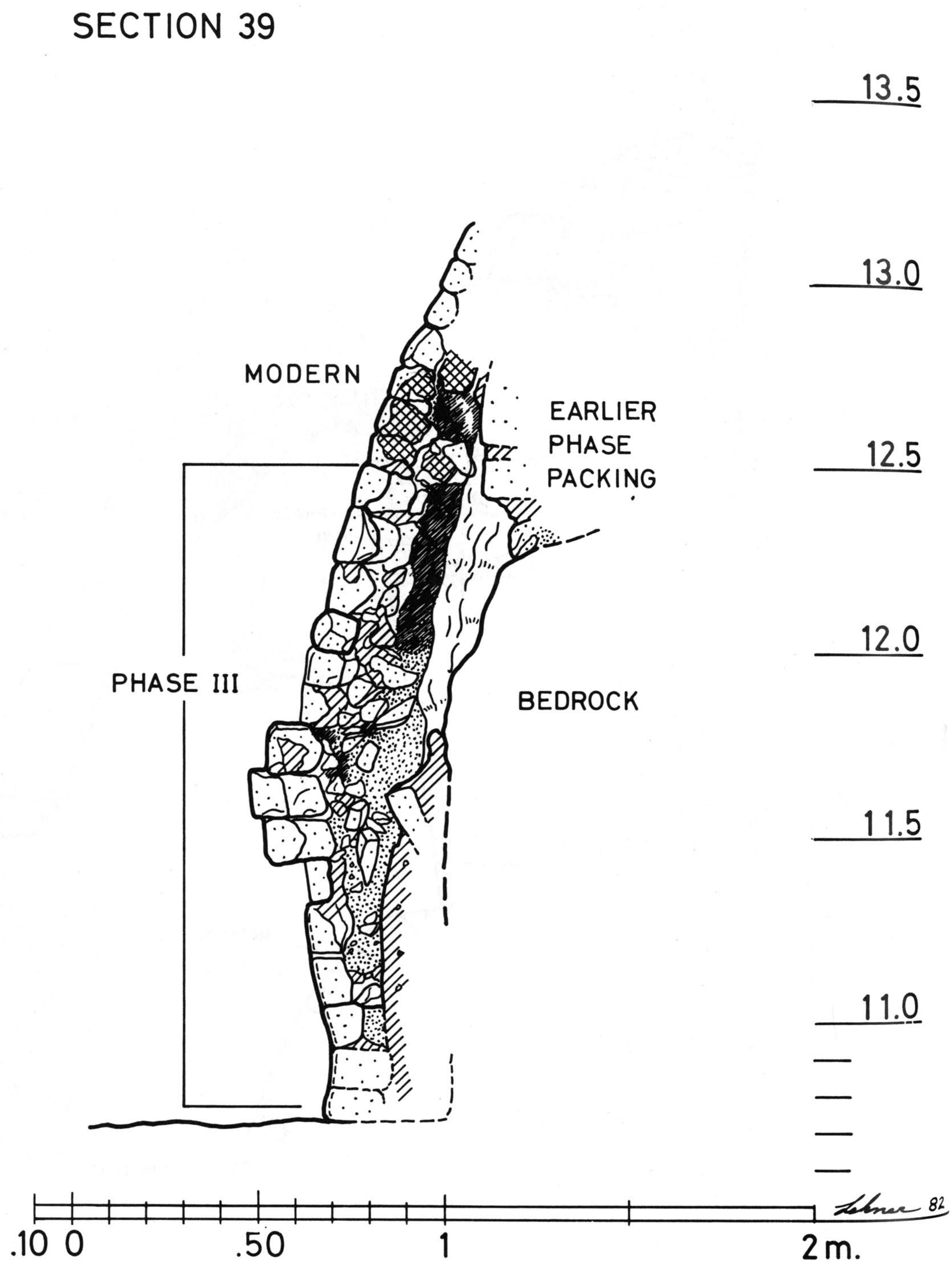

SECTION 39
13.5
13.0
MODERN
EARLIER
PHASE
PACKING
12.5
12.0
PHASE III
BEDROCK
11.5
11.0
.10 0
.50
1
2m.
Lehner 82

FIGURE 18

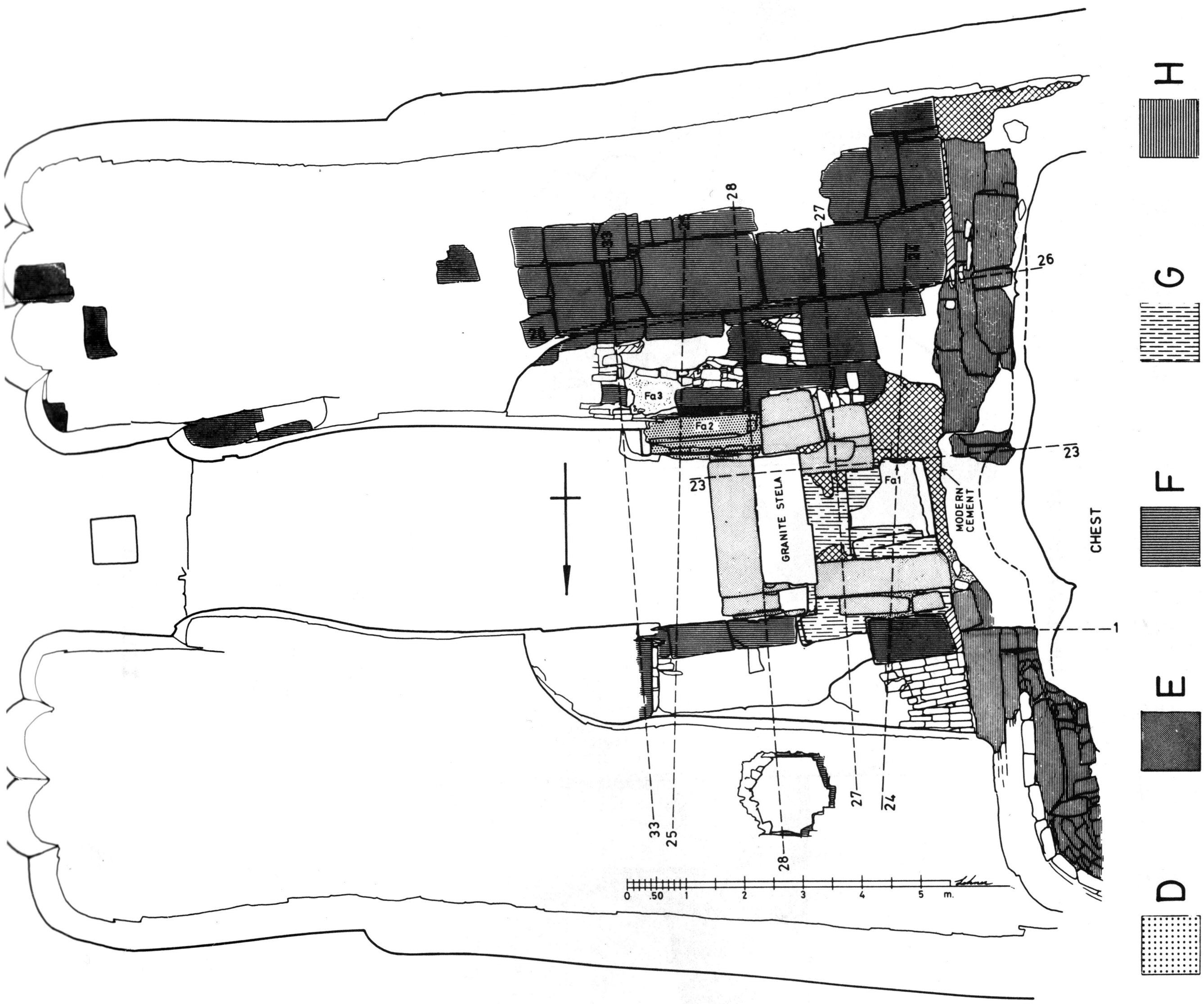

GRANITE STELA
MODERN CEMENT
CHEST
Fa1
Fa2
Fa3
0 .50 1 2 3 4 5 m.
D
E
F
G
H

FIGURE 19

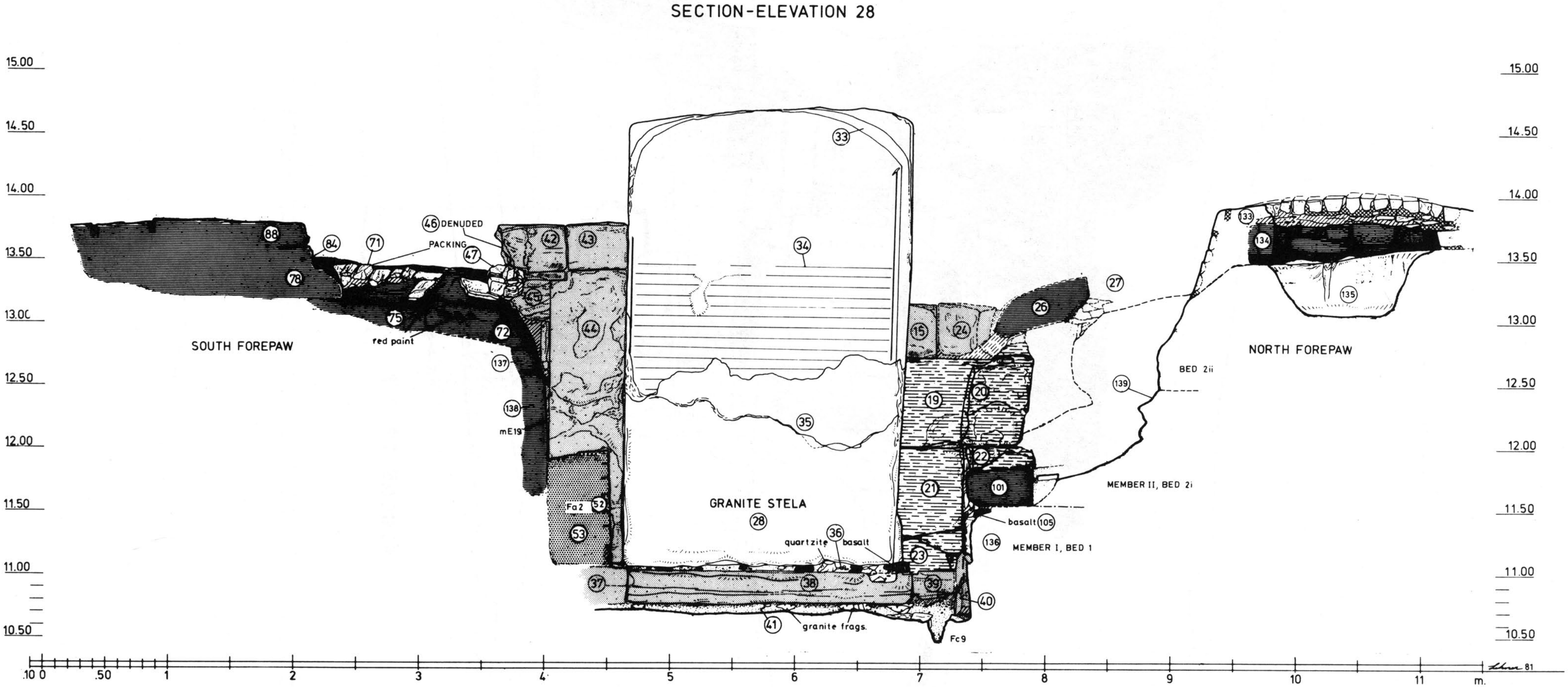

SECTION-ELEVATION 28
15.00
14.50
14.00
13.50
13.00
12.50
12.00
11.50
11.00
10.50
SOUTH FOREPAW
NORTH FOREPAW
DENUDED
PACKING
red paint
mE19
Fa2
GRANITE STELA
quartzite
basalt
granite frags.
Fc9
basalt
MEMBER I, BED 1
MEMBER II, BED 2i
BED 2ii
.10 0
.50
1
2
3
4
5
6
7
8
9
10
11
m.

FIGURE 20

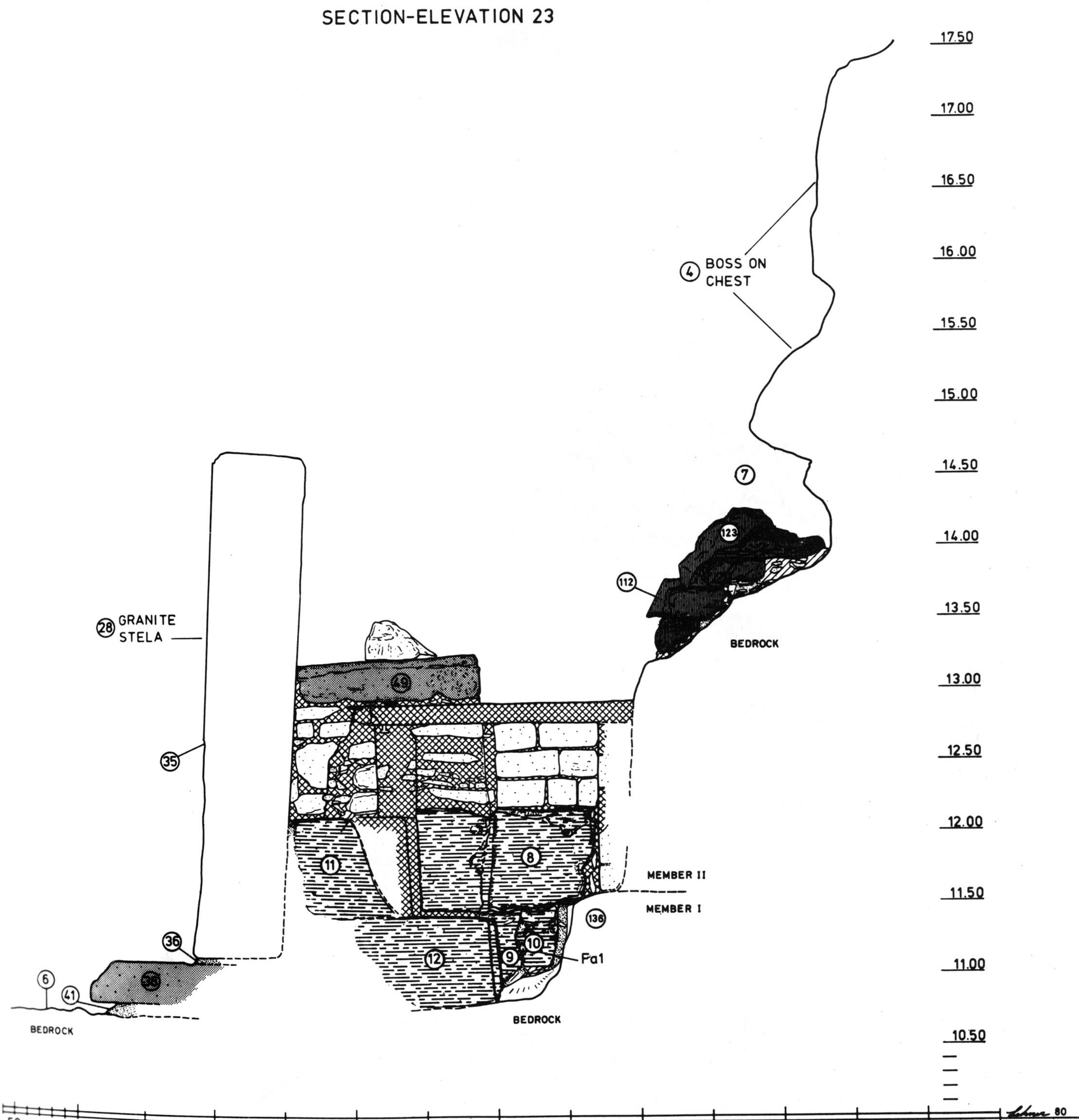

SECTION-ELEVATION 23
17.50
17.00
16.50
16.00
15.50
15.00
14.50
14.00
13.50
13.00
12.50
12.00
11.50
11.00
10.50
4 BOSS ON CHEST
7
123
112
BEDROCK
28 GRANITE STELA
49
35
11
8
MEMBER II
MEMBER I
136
10
12
9
Fa1
36
6
41
BEDROCK
BEDROCK
50
1
2
3
4
5
6
7
m.

FIGURE 21

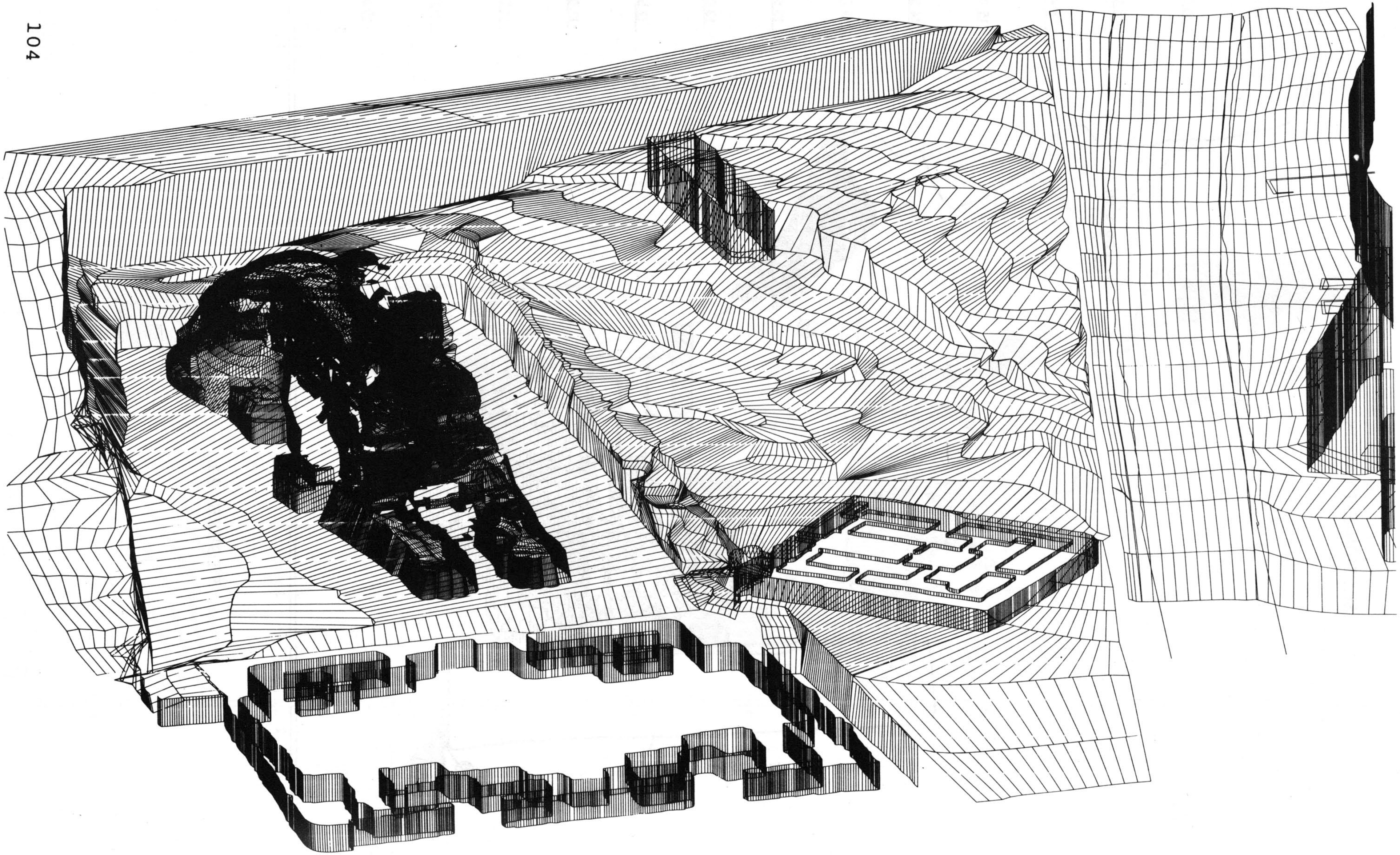
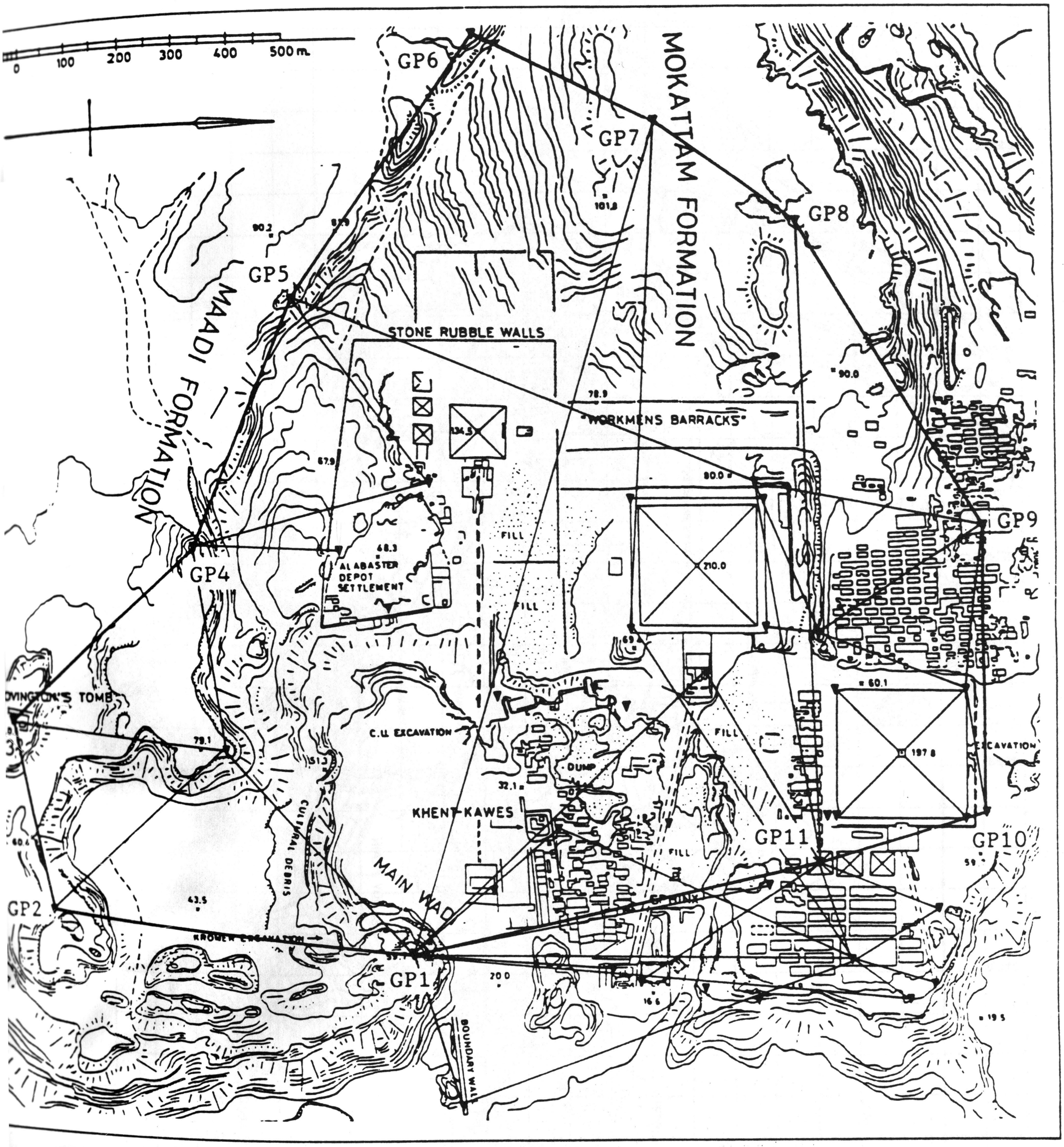
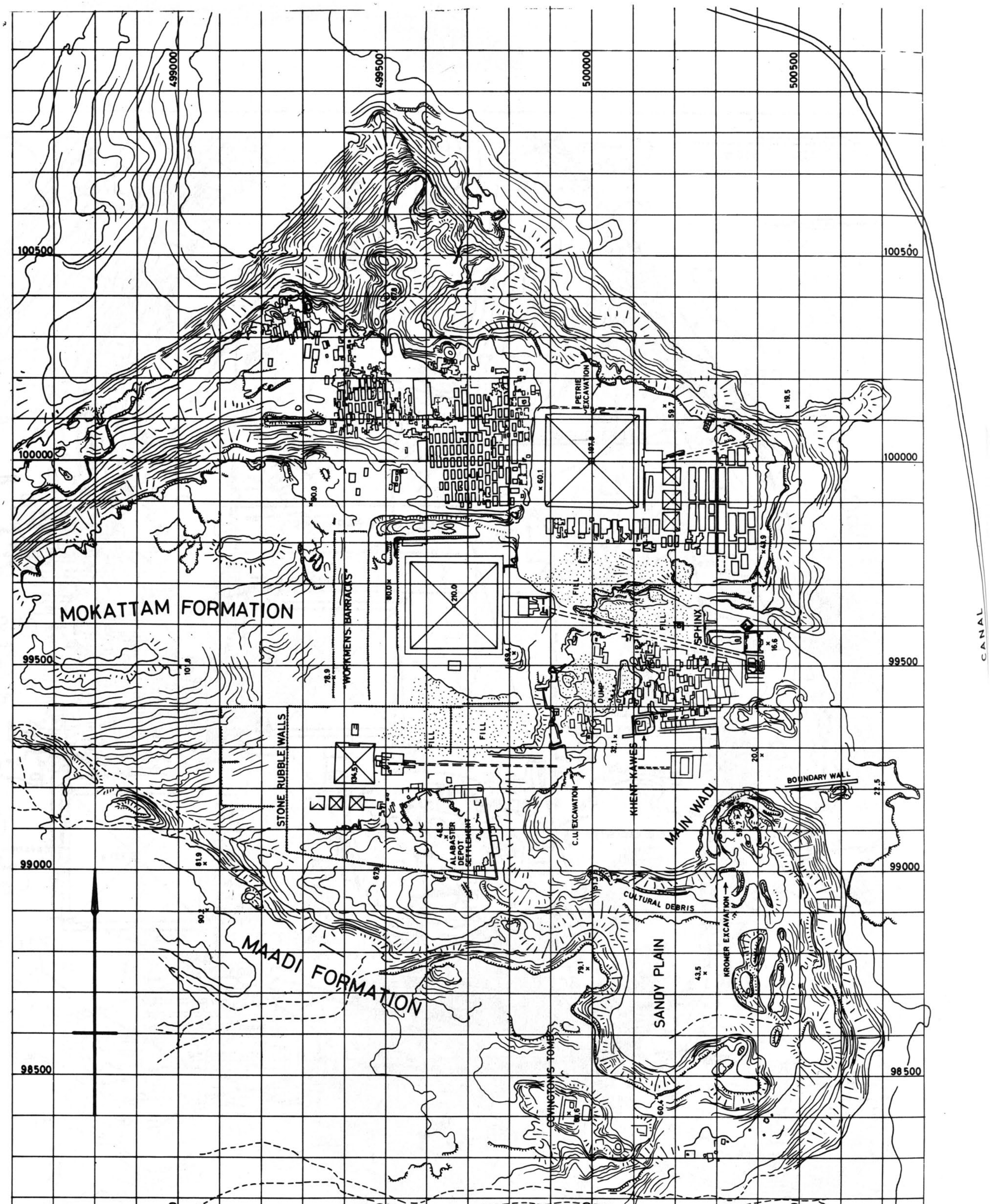


FIGURE 22



0
100
200
300
400
500 m.
GP6
GP7
MOKATTAM FORMATION
GP8
GP5
MAADI FORMATION
STONE RUBBLE WALLS
"WORKMENS BARRACKS"
GP9
GP4
ALABASTER DEPOT SETTLEMENT
FILL
EXCAVATION
C.U. EXCAVATION
DUMP
KHENT-KAWES
GP11
GP10
MAIN WADI
CULTURAL DEBRIS
GP2
SPHINX
GP1
BOUNDARY WALL

FIGURE 23



MOKATTAM FORMATION
MAADI FORMATION
WORKMEN'S BARRACKS
STONE RUBBLE WALLS
ALABASTER DEPOT SETTLEMENT
PETRIE EXCAVATION
FILL
DUMP
SPHINX
KHENT-KAWES
C.U. EXCAVATION
MAIN WADI
BOUNDARY WALL
CULTURAL DEBRIS
SANDY PLAIN
KROMER EXCAVATION
COVINGTON'S TOMB
CANAL
499000
499500
500000
500500
100500
100000
99500
99000
98500

FIGURE 24

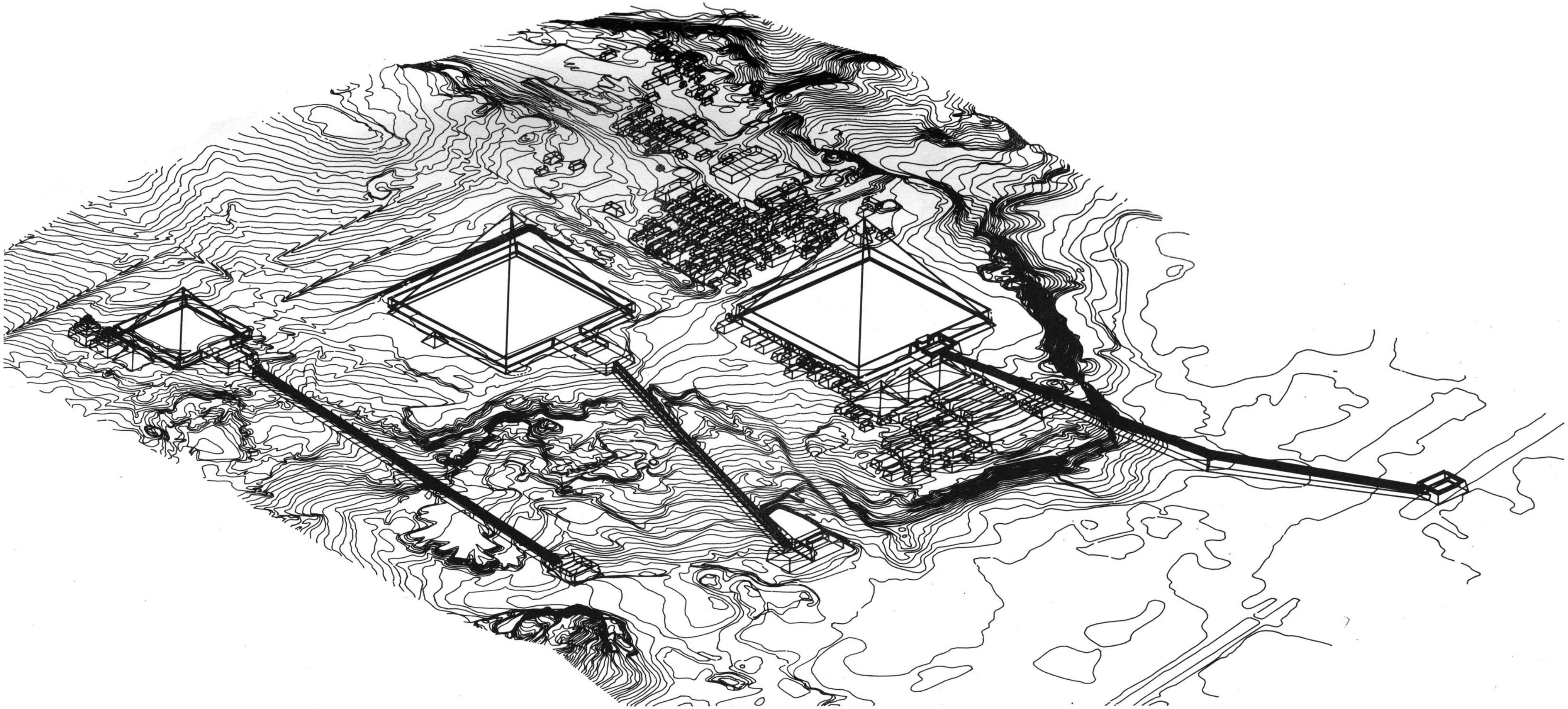


FIGURE 25