PRELIMINARY FIELD REPORT No1: Vol 3-Mud Brick Conservation

April 2000

"Documentation and Conservation of King Khasekhemwy's Funerary Monument at Abydos"

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with

William C. S. Remsen, Anthony Crosby and William Kelly Simpson

Egyptian Antiquities Project

USAID Agreement No. 263-G-00-93-00089-00

Awarded to

THE AMERICAN RESERCH CENTER IN EGYPT (ARCE)

Address: 909 North Washington Street, Suite 320, Alexandria, VA22314

By the

USAID Program Office of Productive Sector Development / Office of the Environment / USAID / Egypt

In collaboration with the United States Agency for International development and the Egyptian Ministry of State for Antiquities.

DOCUMENTATION and CONSERVATION of the SHUNET el ZEBIB MONUMENT

(c. 2,700 BC) **Abydos, Egypt**

PRELIMINARY FIELD REPORT NO. 1
(IN THREE VOLUMES)

VOLUME 3 - MUD BRICK CONSERVATION FIELD REPORT No. 1

Submitted APRIL 2000 to the

Shunet el Zebib Archaeological Conservation Project
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This report was prepared for
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under USAID Grant N0. 263-G-00-93-00089-00 (formerly 263-0000G-00-3089-00)

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LIST OF ILLUSTRATIONS

Errata

p. 5 The final sentence should read "... the important site character that ..."

p. 18. In the third paragraph from the bottom, the second sentence should read " ...if the amount of water is decreased, the ... "

p. 33 Figure 34 caption should read "Partial east elevation of the west wall."

ABSTRACT

The intent of the initial fieldwork phase of the conservation project was to collect and analyze information in order to develop a draft conservation plan. The plan is to be completed after the archeological excavation component, which will take place later this year. The fieldwork began with a condition survey that was the structure for the development of cause and effect relationships that result in decay. The conservation issues were investigated, important information collected and conditions documented. During this process several critical safety and conservation issues were uncovered, investigated and recorded.

There are major components of the mud brick walls that are in danger of collapse. An estimate is that one half of one percent of the total volume of the walls could be lost if action is not taken. These same problems are critical safety issues as well, particularly with a full archeological season to get underway later this year. Recommendations in this draft report include emergency and immediate actions that address these issues.

INTRODUCTION

This Draft Conservation Report is the results of a mission to the Shunet el-Zebib at Abydos, Egypt on January 17 through January 25, 2000. This report is meant to be one part of a three-part report, the other parts address (1) structural issues and (2) overall site planning and future use, research and analysis, the construction methodology, and interpretation.

The purpose of the site visit and this report was to begin the development of a comprehensive understanding of the values of the structure, the condition, and the pathology of the building materials and systems. This is for the purpose of the eventual development of a comprehensive protection plan for the Shunet. The condition of the structure and the identification of the building pathology are primary, but other values, such as the research potential of the structure and the site, the future interpretive and educational values and the symbolic and visual values will also be important factors in the determination of the conservation protection plan.

In addition to the other conservation team members, the overall Shunet archeological expedition Associate Director Matthew Adams provided valuable assistance with his knowledge of the site and the site critical issues, actual assistance in the field, and his management of the travel and lodging requirements and other logistical issues that were associated with the site work.

The weather during the site work ranged from lows between 2 and 5 degrees C. and highs between approximately 20 and 25 degrees C. The working hours were calm with little wind except for Tuesday, January 18 when the wind blew all day.

CHAPTER I: GENERAL SITE DESCRIPTION

Description of the Site

The immediate site of the Shunet is located approximately 100 meters above sea level and approximately 10 kilometers west of the Nile River. The immediate grade is rolling mounds of fine sand, which are continually shifted from the predominant north winds. Scattered throughout are ground deposits of flint. The mounds in some cases consist of the redeposited sand and in other cases sand that has drifted over and cover or partially cover other cultural features (Figure 1).

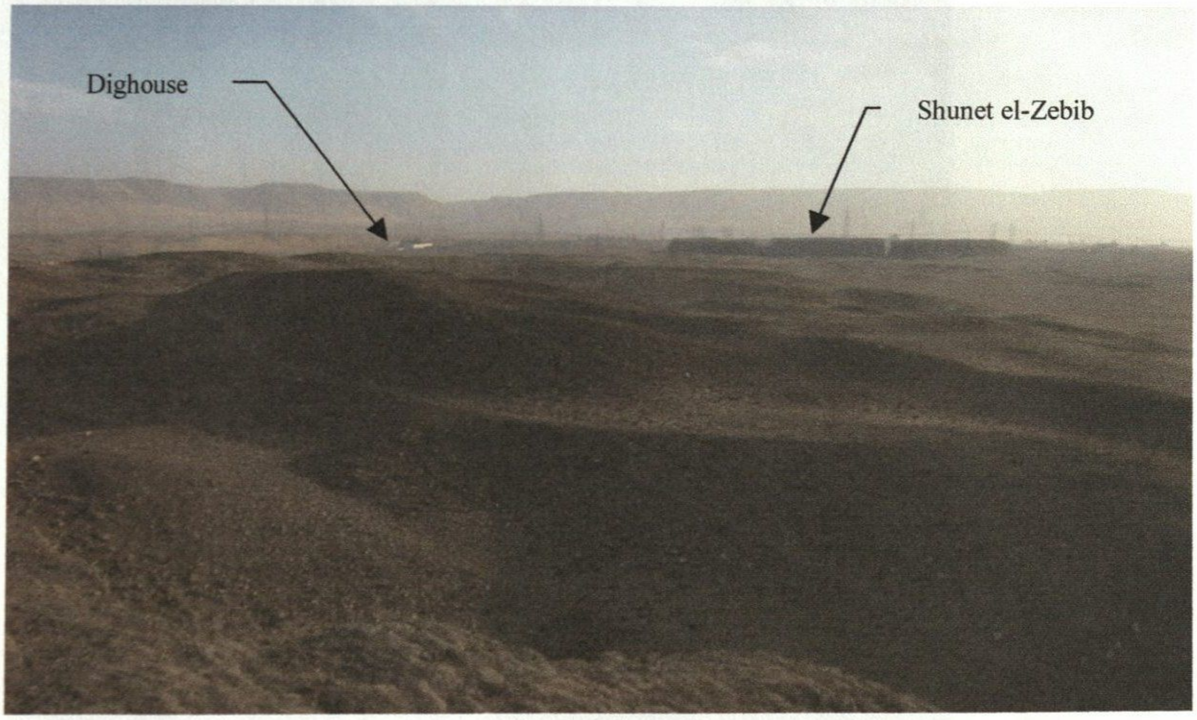

Figure 1: The immediate environments of the Shunet looking west from the approximately 400 meters from the west.

The cultural features in the area are extensive and mud brick walls and broken and displaced mud brick fragments can be seen in most all areas of the immediate site. Other cultural materials such as stone fragments and even fragments of organic materials abound.

Farther to the west are relatively recent irrigated agricultural fields and still farther are the cliffs that form the western edge of the Nile Valley. Located approximately 200 meters to the north of the Shunet is the village of Dier Sih Damiana and located to the east approximately 400 meters is the village of Beni Mansur (Figures 2 and 3). The area of the sand mounts to the west and north of the Shunet is used for the deposition of dead livestock.

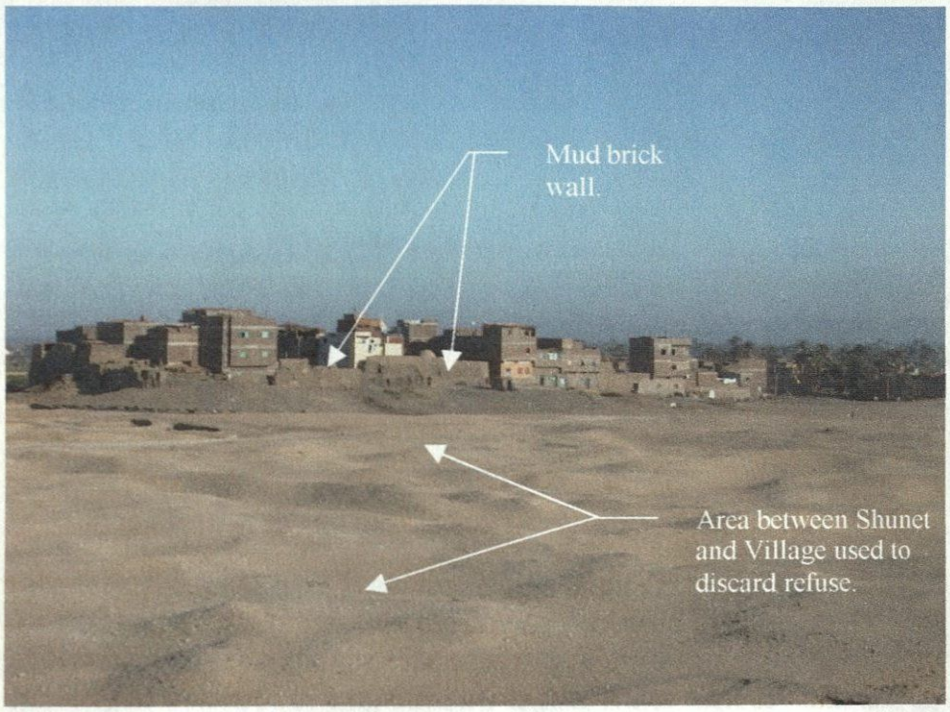

Figure 2: The village of Dier Sih Damiana is located approximately north of the Shunet. The mud brick wall that partially surrounds the village can be seen along the left half of the image.

Figure 3: The village of Beni Mansur is located east of an early period village site. Massive mud brick walls define the site on its west side.

General Climatic Conditions

The average annual precipitation is less than 25 mm. The average high daily temperatures during the summer months of May through August are approximately 42 degrees C., but extremes can be considerably higher.

Prevailing winds are from the north and west, and coming off the desert are also hot and dry. The wind speed during the second day of the site work was constant in the range of 350 – 500 meters per minute, or 15 – 25 miles per hour.

The relative humidity during at the site between January 17 and January 25 averaged approximately 25-35% as the daily lows and 60-65% for the daily highs. The relative humidity correspond to the daily temperature gradients, hence the absolute moisture content of the air probably varied little.

Presently, the water table is approximately 6 meters below the existing grade measured in the well at the Dig House. Without having access to hydrological information it is impossible to predict the corresponding current water table level at the Shunet. There is certainly no evidence of a significantly higher water table level at the site. However, the increase in irrigation could possible result in a raising of the water table, To actually affect the lower walls of the Shunet, the water table would have to be within a meter of the existing ground level and that is probably a remote possibility at most. However, the water table at the site should be continually monitored to insure that the Shunet will not be affected by ground water.

Area Land Use

The land that is under irrigation is increasing and in recent years has "leap frogged" over the immediate area of the Shunet and the arable land is only a few hundred meters to the west. Several of the area villages are encroaching on the cultural site as the demands of a growing population increases. The area immediately around the Shunet is used by some of the local people to discard dead livestock. In the dry climate, the remains dehydrate quickly; packs of dogs also feed on the remains and aid in the rapid disposal system. This is only an issue related to human safety, as the dogs often appear quite aggressive.

General Character of the Site – Character Defining Features

The purpose of establishing character-defining features is to evaluate the impacts of plans for future changes and alterations to the site. A character-defining feature is primarily thought to be visual, but other non-visual character may be important as well. The process of determining the significant character of a site may also identify non-significant, but extremely important elements in how a place is perceived. As an example, presently the power towers located to the west of the site are very strong visual elements in the landscape, although there will probably little argument that they distract form the Shunet itself. On a smaller scale, the existing voids on the west side of the west wall are certainly strong visual elements that affect the perception of the wall (Figure 4). To provide structural integrity to the wall repairs will have to be made. The impacts of the repairs will impact the character of the wall. The fact that the excavation of these voids was associated with a human activity that reflects another period is also an important consideration in the determination of the significant character that should be protected. The result would probably be a structural intervention that responds adequately to the structural problem while also respecting and leaving evidence of the void.

Figure 4: A detail of the west side of the west wall showing the visual impact of one of the Coptic cells cut into the wall.

The above are examples of specific actions, one having a negative impact, the other having a positive impact. Clearly defining the existing character defining features are important in assessing the loss of certain values when no action is taken. If conservation treatments, primarily structural interventions, are not undertaken, the character of the Shunet will continue to change as more material is lost. The change will probably be accumulative and no one specific loss will dramatically change the character. However, the smaller losses will have an accumulative effect and significant differences will result. The smaller continual losses may also increase the risk of a more traumatic loss.
The general character of the site and a very important character-defining feature is the general relationship of the natural landscape and landforms to the Shunet. Other important character-defining features are the actual texture of the individual courses of mud brick and the differentiation of the difference courses. The rhythm established by the pilasters is another important character that provides visual references to the original structure. Figures 5 through 10 are graphic representations of these primary features.

This brief section is not intended to be definitive at this point but begin the process of determining the important site charter that should be completed later.

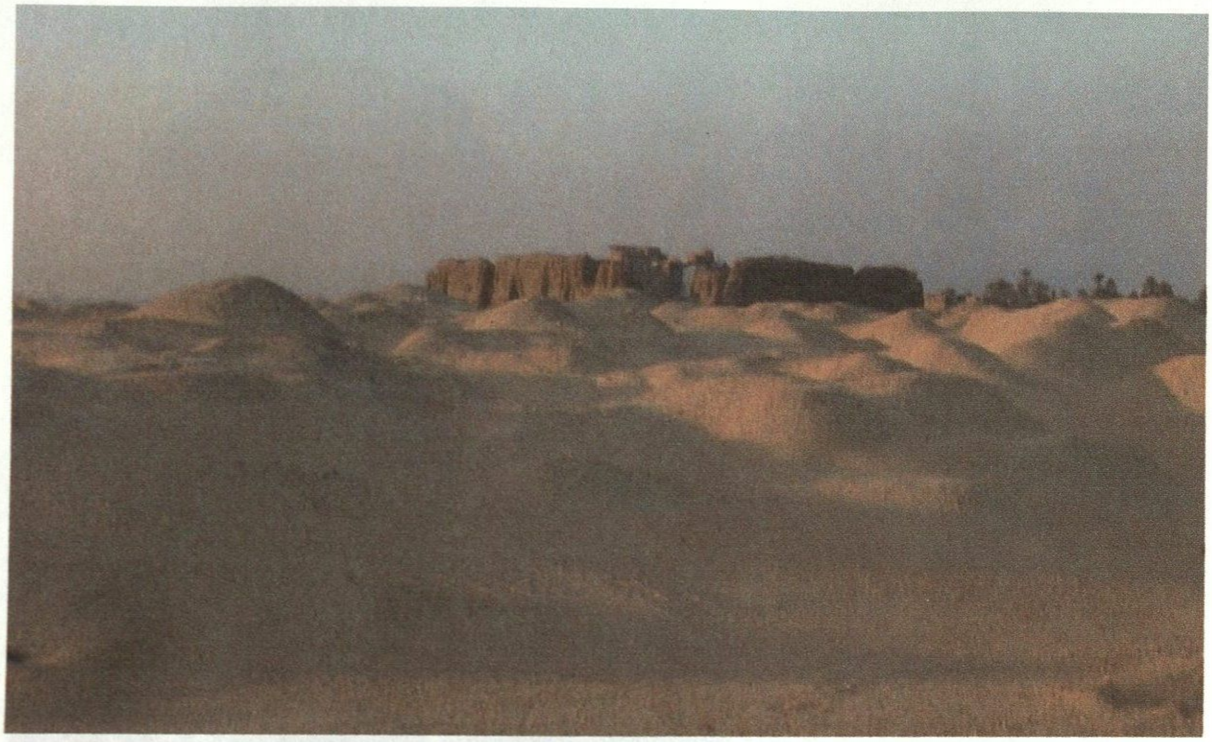

Figure 5: An overall view of the Shunet from the south.

Figure 6: A view of the west wall from the northeast late in the afternoon.

Figure 7: A closer view showing the wall texture and form that is typical. This view is of the south end of the north portion of the west wall at the west gateway.

Figure 8: A detail of the individual mud bricks.

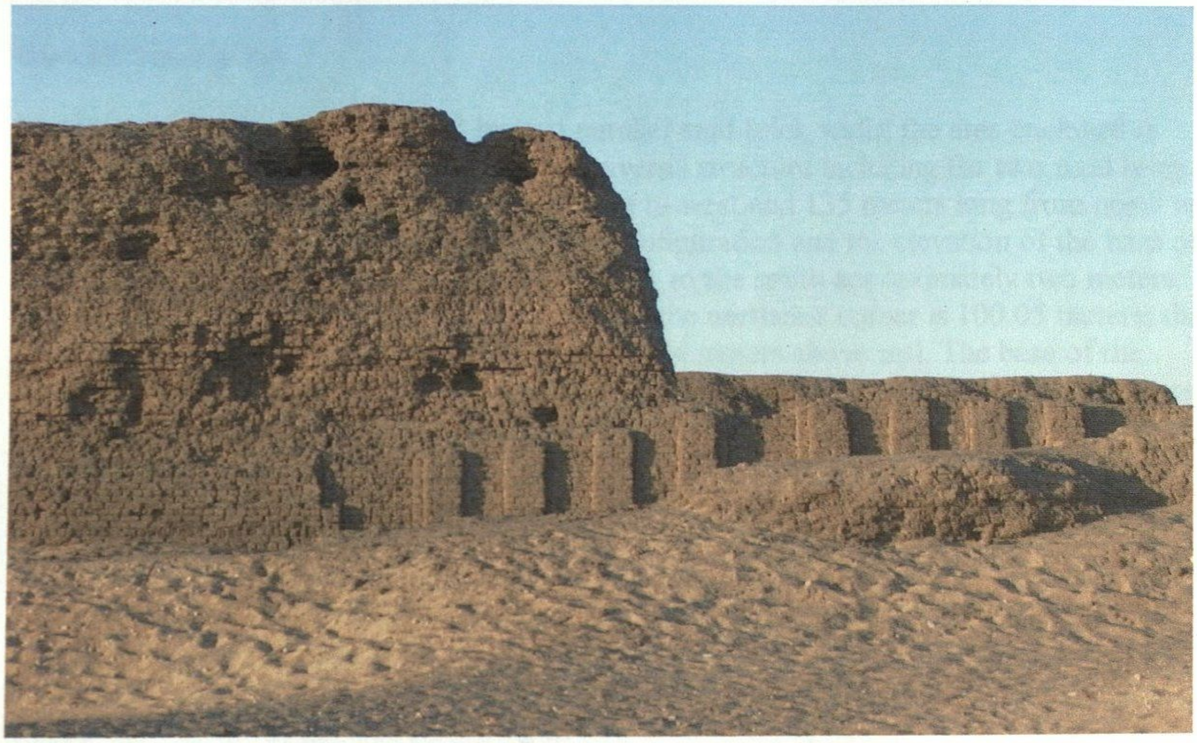

Figure 9: East wall showing important character of general wall texture and color and the rhythm of the pilasters.

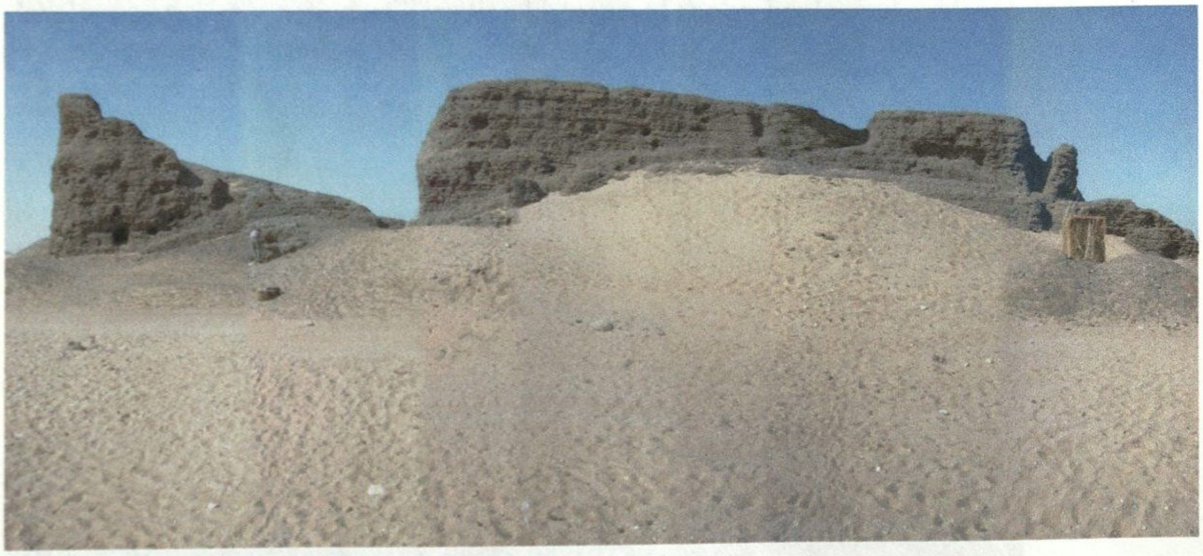

Figure 10: Composite image of the south wall of the Shunet showing its massing, colors and textures, and relationship to the landform.

CHAPTER II: DESCRIPTION OF THE SHUNET

Overall Description

The Shunet is a large area enclosed by two parallel mud brick walls; the area enclosed is approximately 57 meters by 113 meters. The overall structure including the two mud brick walls is approximately 75 meters wide from east to west and 135 meters long from north to south. Based on excavations to determine the configuration and the elevation of the base of the walls, the grade of the structure slopes slightly to the south approximately two meters. The elevation at the base of the wall above msl at the northeast corner is 100.05 meters; the present ground level in the southeast corner is 98.84 meters above msl. The base of the wall at the southwest gateway is 99.33 meters above msl, which is approximately .5 meters above the base in the southwest corner. It will be important to more clearly define the base of the structure and the cultural levels during the excavation expedition.

The present height of the interior walls from the base is between 10 and 11 meters. The height from the existing levels of fill varies from between approximately 2 meters to 10.5 meters (Figure 11). The interior walls are 5 meters thick and approximately 3 meters thick at the top. Both the interior and exterior surfaces are battered at an angle of approximately 5 degrees from vertical. The tops of the taller portions of the walls that could be determined are consistent and the average of the elevations taken is 110.253 meters with a low of 109.282 meters and a high of 110.92 meters. The original height of the walls is not known, but the consistency in the wall height of the higher portions implies that they were perhaps not significantly higher. However, the complete geometry can be best understood when the entire structure is more accurately documented. Perhaps an accurate graphic reconstruction can be produced that is consistent with the extant remains, the architectural development of this period of Egyptian history and the archeological evidence as to the possible use and purpose of the structure.

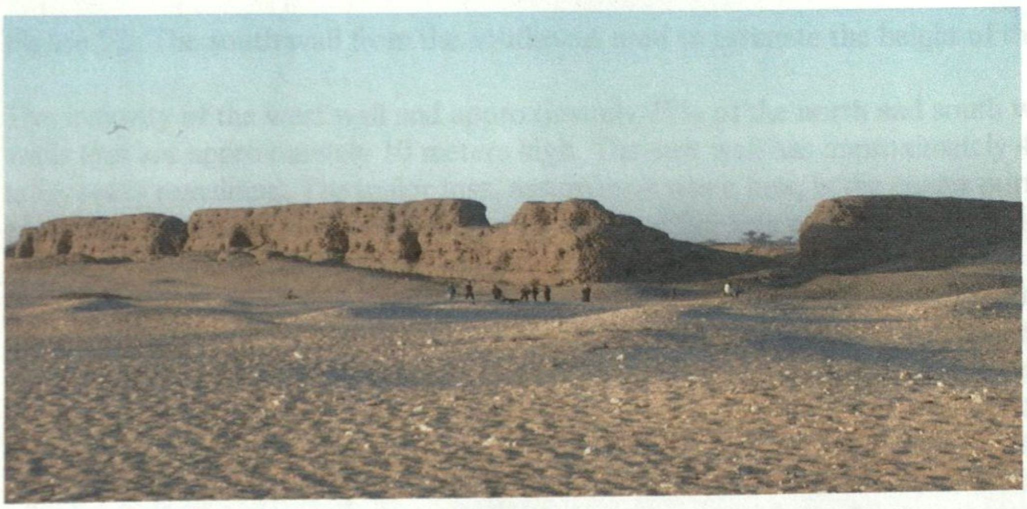

Figure 11: The Shunet from the southwest looking at the southwest corner. The southwest gateway is located immediately right of the corner.

The exterior walls are located approximately 3 meters from the interior walls and are approximately 3 meters thick near the base. The present height varies considerably as some of the walls were protected from erosion by massive amounts of fill sand. Based on an estimated height of approximately 4 meters above the base of the wall at the southwest corner, which appears to be the highest point, the exterior walls may have been approximately half the height of the interior walls. A horizontal projection line on the image of Figure 12 appears to be about one meter above the highest point of the south outer wall. That line also appears to be about the level of the "water table" or 6 meters above the base of the wall. The existing drawings appear to indicate approximately the same thing. Again, accurate graphic documentation of all the walls will provide more accurate projections.

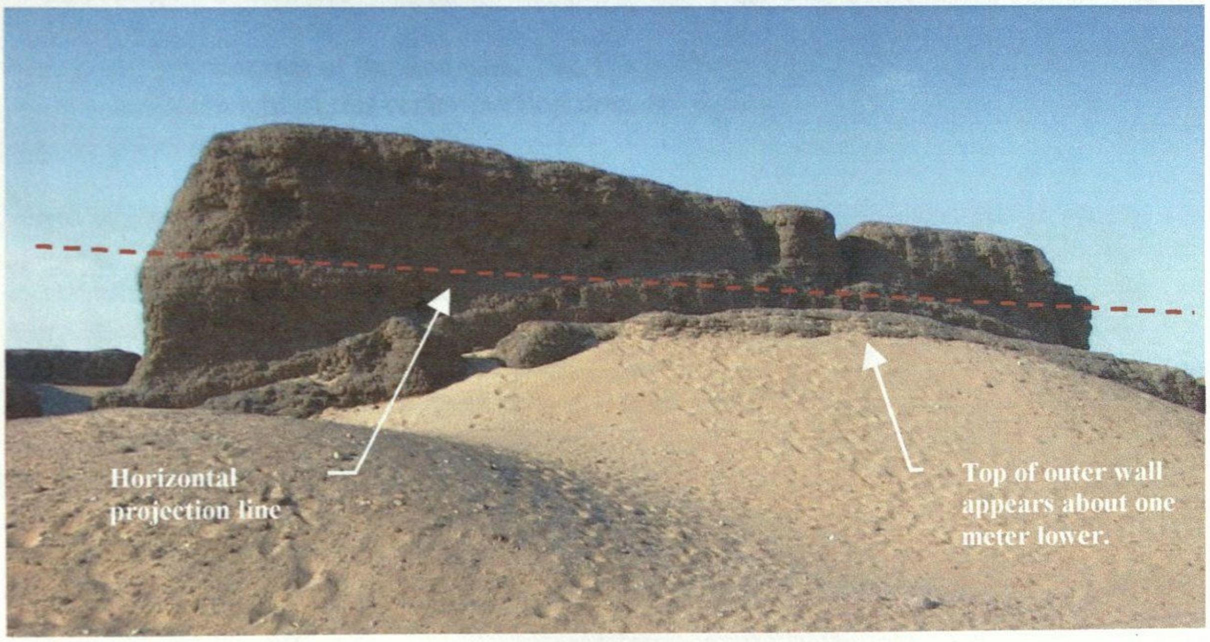

Figure 12: The south wall from the southwest used to estimate the height of the outer wall.

The majority of the west wall and approximately 75% of the north and south walls are walls that are approximately 10 meters high. The east wall has approximately 40% of the taller walls remaining. The major loss, assuming it was a loss, is the center portion of the east wall. There are no obvious large mounds on either side of the wall that might indicate the location of large amounts of wall fall. It is possible that the debris from the collapse was removed in an earlier undocumented excavation. Of course it is possible that remains of the wall may still be found. The construction of the wall is certainly consistent with the other walls and there is no reason to believe that it was constructed any differently. However, the consistency of the height of the remaining wall does not appear to be the result of a process of decay and collapse. Could the wall have been "mined" for other structures in the area, or systematically removed for some other reason. Whatever the answer, it does appear that the wall loss was not recent and may have occurred in ancient times (Figure 13)

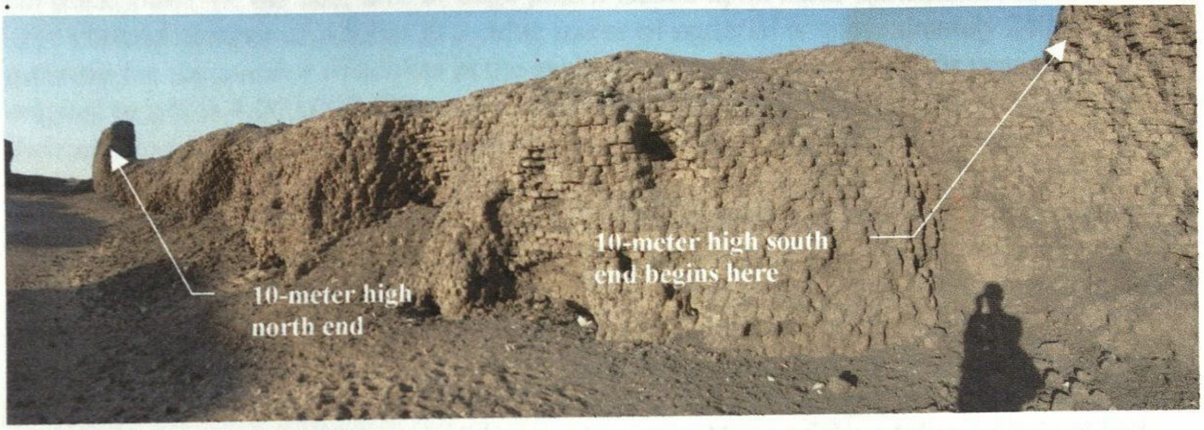

Figure 13: A panorama of the east wall. The image distorts the length of the wall but the relative similar height of this center portion does not appear to be the result of s normal natural decay process.

There is a large amount of fill on the interior of the structure as well as surrounding the exterior. The entire fill is probably the result of the natural deposition of wind blowing over a several thousand-year period. The age of the deposits can only be determined by associated cultural material, but some of the material is know to contain materials that are 2,000- 2500 years as related by Matt Adams on site. It is probable that the present fill around the Shunet was in place quite early and that minor alteration and re-deposition occurred when there were changes in the general wind patterns in the area and within the Shunet as portions of wall collapsed and a new relationship of solids and voids resulted in new micro-turbulence patterns. Presently, the greatest depth is in the northwest and southwest corners and south of the south wall. It is also quite possible that some of the fill has been removed and the results, of several thousand years of deposition has been altered.

During the survey of conditions both of the site and the structures that are related to conservation issues, flags and an anemometer were used to try to get an idea of the wind patterns within the interior as well as on portions of the exterior. As we only had one day of wind only some very general observation could be made. The subject will require additional study to better understand the past effects of wind, but more importantly to understand the effects of the removal of the existing fill and if new patterns of micro-turbulence develop.

Construction Methodology

Mud Brick Description

The mud bricks used in the construction of the Shunet are very consistent in size. They are 9 cm thick, 26-27 cm in length and 13 cm wide. The mortar joints are also consistent although there are some variations, probably when it was necessary to actually level a course of adobes. The thickest mortar joint observed was 5 cm thick, but the average and by far the majority were 1.5 cm thick. Mortar was also consistently applied in the same 1.5

cm thick joints for the bed, face or edge joints. Based upon these dimensions, the approximate number of Adobes in a cubic meter of material is approximately 240. An estimate for the number of adobes in the main inner walls, if they are at or near their original height is 4,000,000. The outer walls would have contained, if they were also at their approximately original height, another approximately one million adobes.

The adobes were certainly formed in a mold, but there were not sufficient evidence of mold marks to determine the manufacturing process. Some historic period molds known to exist are simple open wood boxes (Adams 2000). There was a small indention in the ends of some of the adobes that could be examined. The indention was approximately 2 cm wide by 10 cm deep, but varied to some extent, and some appeared to have been formed by two parallel and adjacent pieces of wood. There was also the negative impression of this same indention in some of the remaining mud mortar. None of the adobes examined had the same marks on both ends and some adobes had no marks at all. During future architectural and archeological investigations, perhaps the purpose of the indention will become clear.

Material Analysis

Several samples of mud bricks and mortar were selected, identified, and bagged for analysis. As it was not possible to actually remove samples from the site, the analysis will be conducted at a later time. Permission will first be requested from the Egyptian authorities to remove the samples and then an appropriate testing facility will be selected. The analysis of the selected materials is for the purpose of establishing general material characteristics. Based on the results of the first stage of testing and analysis, these and other material samples will undergo additional testing and analysis.

The primary purpose of the testing and analysis of the construction materials is to better understand the decay mechanisms and so that the most appropriate and most compatible materials are selected for the conservation treatments. Other side benefits of the testing may shed additional light on the construction sequences and the construction methodology.

Several simple field tests were performed on the samples while in the field at Abydos. They consisted of simple settlement tests, visual observation, color identification, basic shrinkage observations, and workability and wet tension tests.

The following are observations from these field tests:

(1) Settlement Test:

- It is estimated that the sand fraction composes approximately 65% of the total; the silt and clay fraction is approximately 35%.
- Further observations after several more hours of settlement it appears that the actual clay fraction is very small, probably no greater than 1-2%.
- Little to no organic material observed in mortar sample – nothing settled out and the water was just slightly yellowish.

- Nearly all the material had settled out after about 40 minutes.

(2) Visual, shrinkage, workability and wet tension tests:

- Material was very fine sand, not well gradated, probably all passing a .02 sieve.
- Very fine chopped straw was in the bricks.
- Materials used in both the mortar and the mud bricks appeared very similar.
- Material felt gritty and the finer fraction felt silky, but not greasy.
- Material would form only a 1/8-inch string ca. 8 cm long.

(3) Color (Munsell 1975)

- Color varies with quality of light, but in situ samples of both mortar and mud bricks on the Munsell Color Classification system were classified as 2.5 Y 6/3, light brownish gray; 10YR 6/2, light brownish gray; and 2.5 Y 7/2, light gray. These colors are very similar.
- The clay fraction, or what appears to be the clay fraction was darker than the sands and silts, but they were not individually classified.

It is important that the testing and analysis begin as soon as possible so that the information is available when fabric conservation treatments are specified.

Mud Brick Construction

The basic construction methodology was extremely consistent throughout the structure. The only variations were associated with minor corrections in the coursing to accommodate changing wall thickness of the battered walls and the periodic leveling of courses. The exterior coursing pattern was alternating rows of headers and stretchers, with at least two examples of a slightly different coursing pattern at the northeast and southeast gateways of a row of headers between two rows of stretchers. There may have been some specific reason for the modification of the normal pattern at these two similar areas to adjust for the wall thickness immediately adjacent to the opening (Figure 14).

The coursing pattern in the interior wall mass is through-wall headers. There are some minor variations, probably for the purposes previously mentioned. Because of the relative small size of the adobes and the scale of the structure, the overlapping of the vertical joints of the through-wall headers is often minimal or even stacked on top of one another (Figure 15). The consistency of the mortar tends to compensate for what is considered a basic flaw as it contributed to the mud brick mass acting as a monolithic mass rather that as individual building units. However, under a wide range of structural loading over its 4700-year life, crack patterns have developed that often follow the naturally weaker points of those stacked joints.

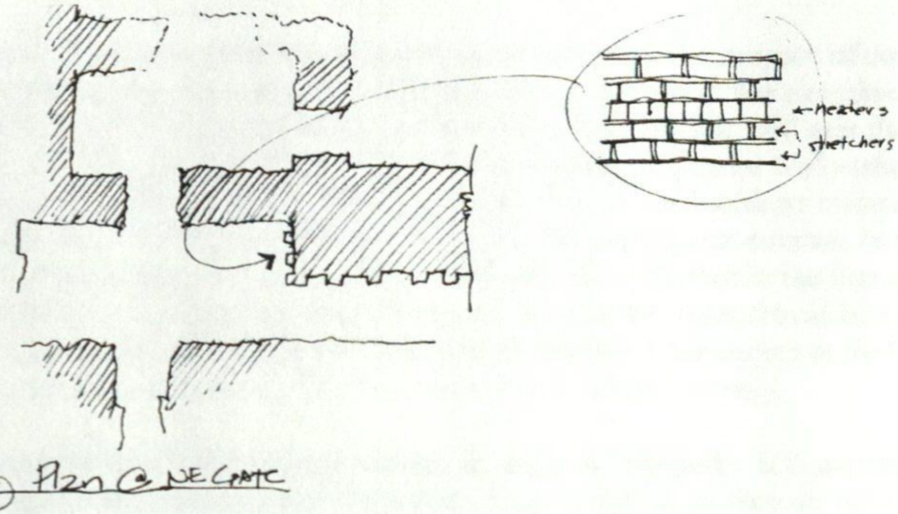

Figure 14: Sketch plan at northeast gate showing location of the 2:1 coursing pattern.

Figure 15: Detail of a typical wall showing through-wall headers and occurrence of stacked joints.

It appears that during construction, the construction surface was leveled every fifth of sixth course. In conjunction with this leveling course, there appears to be a consistent relationship to the existence of partial courses of headers turned on edge as well and more rarely headers turned slightly off axis and on a diagonal. There is also evidence that a mat, perhaps woven, was also placed at these leveling courses. They was no effort to specifically identify and map the locations of the mats, but during the investigation and collection of information related to conditions and material and building system pathology, they were located mapped when they were observed.

The base of the inner walls was exposed at two areas for the purpose of documenting the actual condition at the base of the walls and also to document the elevations of the base of the walls. The two locations were (1) the north end of the east wall near the northeast corner and (2) in the area of the southwest gate along an interior wall surface. The first mud brick course was laid directly on a leveled base of sand with no evidence of a footing or foundation. The first course was exactly like the subsequent courses. In the area of a pilaster at the northeast location, the pilaster was also reflected in the first course. During the excavations in subsequent expeditions the base of the walls should be examined and documented at several different locations to insure that what occurs at the locations that were excavated represent a consistent pattern and not an anomaly.

Pilasters exist on all of the exterior walls, or did exist originally. It is not known whether or not these pilasters extended the full height of the structure, as they do not exist on the upper portions of the walls; the ones that do remain are on the wall surfaces that were covered and protected by fill. Some of the better-preserved pilasters are along the center portion of the east wall (Figure 16). The pilasters were constructed integrally with the mud brick coursing. Every fifth course a header extends into the main wall providing a structural tie between the wall and the pilaster. The existence of the tie indicates that the pilasters were planned from the beginning and not added as a later change. However, the mud brick ties were not adequate and many have sheared off. Resulting in the collapse of an entire exposed pilaster, the displacement of smaller parts of the pilaster, or the structural vulnerability of other pilasters that are inadequately attached, but still in place.

Figure 16: Pilasters on the east side of the east wall.

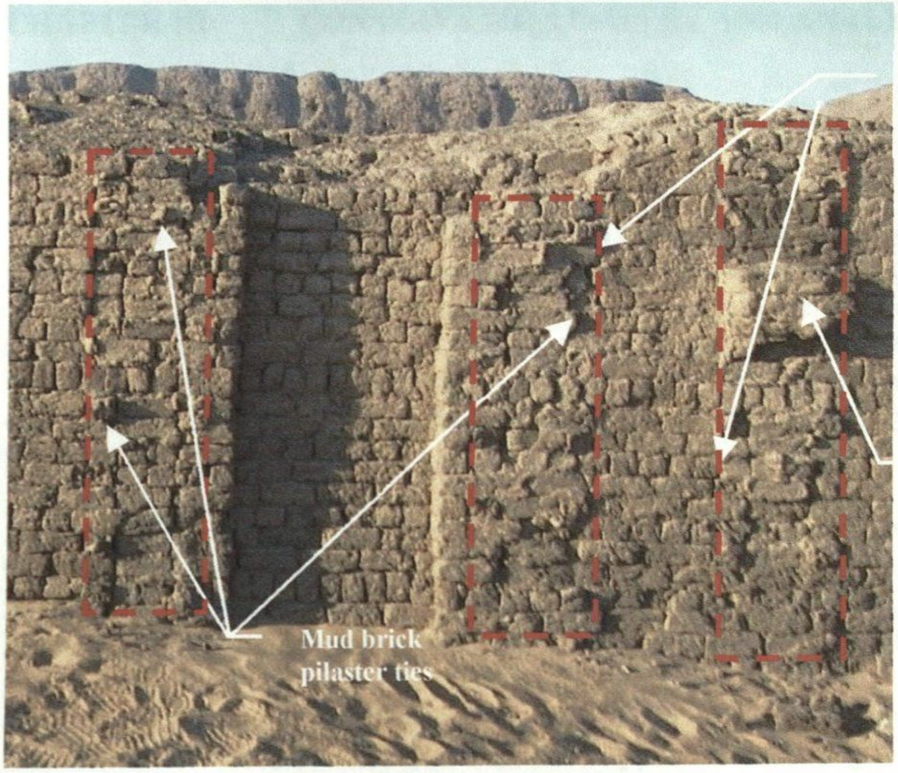

Figure 17: Detail of pilasters on east wall showing locations of missing pilasters and remains of the mud brick ties.

There do not appear to be any significant voids in the mud brick walls of the structure except in those areas where mud bricks have been removed or excavated by animals and humans, primarily at and near the bases of the walls. Vent holes, supposedly to aid in the drying of the walls during construction, were described in a previous publication (reference). However, no evidence for such a phenomenon was found. The effectiveness of such a feature for the stated purpose would be minimal at best, unless they occurred in great numbers, numbers that would have certainly severely compromised the structural integrity of the structure. Certainly our failure to locate and the illogical benefit of the vents do not preclude their use in portions of the structure that no longer exist. But id makes their existence unlikely at best.

Construction Overview

The construction of the Shunet was very consistent throughout. If the process could be described in contemporary terms one would say that the construction drawings and specifications for the Shunet were completed, reviewed and approved prior to the construction and that there were no change orders during the entire construction process. When the first mud brick was laid on the leveled sand base, the designers and owner knew exactly what the finished product would look like.

CHAPTER III: CONSERVATION SURVEY AND ANALYSIS

Methodology of Survey and Analysis

The analysis of the performance of the material fabric and the building systems is undertaken for the purpose of identifying threats so that appropriate conservations treatments can be planned and undertaken. The first step in the process is the identification of the specific conditions of the structure and the characteristics in the microenvironment that are known, or that are potential sources of decay. The development and understanding of the relationship of the conditions, part of which are effects of decay, and the causes is the essence of the analysis.

After a brief overview of the Shunet and its immediate area, the process of developing an understanding the conditions and the pathology of the materials and the systems began. Information was collected of the conditions of the structure and the microenvironment. Prior to even going to the site some basic information on climatic conditions and area geology was collected in the Library at ARCE. I began to systematically look at all of the exposed material and record those conditions and features on digitized images. The actual field sheets are included in this draft report as Appendix A. During the process of this condition survey, a more clear understanding of the conditions changed. This continuing process of understanding the structure and the materials also affected the information that was recorded. Often areas were resurveyed as conditions on another wall or feature helped clarify a question that existed previously. This survey was an overall survey looking specifically at conservation issues.

The other members of the conservation team were investigating more specific issues such as the methodology of constructions and the specific structural condition. These were the primary responsibilities of the team members, but the team members continually consulted and worked together on all aspects of the site work and the collection of information for a clearer understanding that will lead the overall project recommendations. At night issues were discussed so that the field work on the next day could be more efficient.

Several material samples were collected for analysis and some basic field tests were performed. These samples were identified and some specific tests suggested as the first step in a detail materials analysis. The basic field tests did produce some important information that helped in the analysis.

A summary of preliminary findings was produced prior to leaving the site in order to provide as much information as possible so that the plans for the subsequent archeological component of the project could proceed. This was important so that the conservation issues, health and safety concerns, and archeological research could be anticipated and planned for as soon as possible.

The information collected in the field was reviewed and further analyzed in the respective offices of the conservation team members to produce this draft report.

Mud Conservation Overview

Material Characteristics

Mud bricks, adobes, are composed of soil that is formed using a certain amount of water and under some pressure, whether applied by hand or some mechanical device. The range of the variables, material composition, water and pressure can and often does vary tremendously. The "optimum" distribution of sands, silts and clays are well documented in the laboratory; the optimum distribution of the basic materials can also be determined for any particular material sources in any general location. In this use "optimum" means the distribution of the materials, the appropriate amount of water and the appropriate amount of pressure to form the units that will provide the greatest strength. The result is basically a material formed by the interlocking of grains of sand by clay platelets. It is a physical, not a chemical change that results from the dehydration of water when the molded adobes are dried in the sun and provides the primary cohesion character (Houben 1994, pp 20-33).

There are other forces that also provide integrity, or cohesion, to the material and basically hold everything together. The electronic bonding resulting from shared electrons between the water molecule and the mineral fractions are relatively strong. These forces essentially lock some of the water molecules so tightly that they will remain even under extreme heat and other evaporative forces such as wind. The conditions that will break these bonds are not realized in a natural environment.

Cohesion is gained in the fabrication process by a workable, and not necessarily an optimum combination. Basically, if the amount of water is, the amount of pressure has to be increased to provide the same basic level of cohesion; the reverse is also true. A raw soil used for rammed earth construction damp but it is relatively dry and does not approach the plastic limit of the material. The same material used to form individual building units in a mold, because the pressures cannot be as great, the moisture content has to be higher. Mud bricks that are formed in hand molds normally contain water greater than the plastic limit of the material and often even or greater than the liquid limit.

As the material looses moisture, or dehydrates, in the drying process, the mud brick will gain cohesion. However, cohesion can also be lost by adding water back, or re-hydrating the mud brick, essentially reversing the results of the dehydration process. The process also happens unintentionally as the re-hydration process occurs when water gains access to the adobe material as a result of the rainfall or surface runoff. The results in both cases are that water molecules either accumulate between the clay platelets, or they attach themselves to the platelets. As this process continues, the mechanical properties of the adobe, the compressive and tensile strength, are reduced dramatically. This is the main deteriorating process of a mud brick and its extension, a mud brick building system.

Cohesion can also be lost, or at least severely compromised by excessive drying of the materials. As mentioned above, some of the forces that hold the material together are quite strong, but an adobe can begin to loose some cohesion under high temperatures and very dry conditions – conditions that are often experienced in hot and dry desert climates. The result is a surface powering and a more brittle character that is not as strong as would otherwise be the case.

Water Transportation and Effects

Another characteristic of typical adobe material is that the vehicle for the transport of water in the material, capillarity, is less strong than in other porous materials. Consequently, rainwater falling on the surface does not penetrate into the mass of the material, and it dries quickly. However, if the source of water is more constant, water can penetrate into the mass of the material and affect its performance. An adobe wall in a low area where water can accumulate will draw water into it through capillary action and lose compressive strength quickly. As the bearing capacity is reduced, depending on the loads on the wall, the material will begin to compress, and the wall will begin to settle. If the source of the water remains, the moisture content of the material will continue to increase until the lower part of the wall can no longer carry any load, and the wall, if it is thin, could overturn. Of course the adobes walls of the Shunet are certainly not thin and would never reach the stage where an entire wall overturns. However, just as we see the failure of portions of the walls because they have been undercut, the same localized failure pattern would be seen to a much greater extent, if the lower walls ever became wet.

Rainwater falling on a horizontal surface will penetrate into the adobe material more because the water remains in contact longer. Combined with the direct force of falling rain, horizontal surfaces, primarily the tops of unprotected walls, will erode at ten times the rate of vertical surfaces. If the material is wet prior to rainfall, the effects of the rain will be much greater on the vertical as well as the horizontal surfaces.

Effects of Soluble Salts

Soluble salts can migrate into and through the material as water gains access through capillarity suction. As water evaporates the solution becomes more concentrated and eventually salt crystals begin to form. In the formation of the salt crystals in the small spaces, voids, and capillaries of the adobe material great forces are exerted. The formation of the salt crystals occurs at or near the surface of porous materials, because during the normal evaporative process, the water moves to the surface. On relatively dense materials, the salt crystals may form only on the surface. On more friable surfaces and materials that are less dense, the salts will form not only on the surface but beneath the surface as well. Surface forming salts are known as efflorescence and salts that form beneath the surface are known as sub-florescence. Sub-florescence is much more destructive than efflorescence as sub-florescence salts form within the material matrix and break adhesion of the individual grains.

Salt crystals may also form deeper within the mass of an adobe wall in some cases. The process and the extent that this occurs are not fully understood, but when it does occur, the effects may be even more deleterious.

Soluble salts will also increase the hygroscopicity of the adobe material, depending on the types of salts presence. Some salts are highly hygroscopic while others are not. These salts will attract moisture from the atmosphere and increase the moisture content of the material. The phenomenon was clearly evident in the north wing.

Wetting - Drying Cycles

Another process that is not fully understood is that of wetting – drying cycles. Wetting – drying cycles may have little effect unless they occur when the material is subjected to external loading as when someone walks on top of an adobe wall. The effect of loading when the strength of the material has been substantially reduced can be seen in the deformation of the material. The same stress on the material may also occur at the macro scale and result in the increased friability and the loss of strength that can be observed once the material is dry again. The stress associated with the application of external loading may simply speed up the process that will occur regardless.

The hygroscopic nature of the soluble salts and the effects of the growth of destructive salt crystals through the hydration and dehydration process are another important factor in the wetting – drying process. The actual effects can be seen in the loss of surface integrity and the increase in surface friability.

Expansive Clays

The type of clays is also a factor in its performance. Non-expansive clays such as the kaolinite and the illite groups are non-expansive clays, or marginally expansive with water. Other clays such as the calcium or sodium rich smectite group and mixed layer illite-smectite group are more expansive (Smith 1982). In the context of adobe conservation, the expansion and shrinking characteristics will be a factor when the materials become wet, and particularly during the wetting – drying process.

Wind Erosion

Wind erosion is seldom a problem unless there are considerable abrasive material available and extremely strong winds occurring over a long period of time. The combination of strong winds and rain will cause much greater erosion than wind and abrasive materials alone and somewhat more than rain that is not wind driven. Hot and dry winds increase the actual amount of erosion as the surface looses some cohesion, although not as much as when the surface is wet. The combination of winds and long periods of exposure has resulted in the scouring effect that exists on much of the wall surfaces of the Shunet.

Humans, Insects and Animals

The effects of the extrinsic factors of humans, insects and animals are normally only mechanical, and that seems particularly the case at the Shunet. Excrement from animals can produce by-products that can be deleterious to some materials such as stone and brick masonry and wood, but that is not a factor with adobe. The excrement can also be an indirect factor in material decay as it can serve as a source of food for other animals and microorganisms. In the case of the Shunet, the burrowing of holes by animals, the removal of sections of walls for adaptive uses by humans and the nesting of insects appear to be the principle factors.

The understanding of some of these basic concepts is an important key in determining the conditions of the structure and being able to relate those conditions to the causes of deterioration. If a condition exists that is normally associated with wetting and drying cycles and the transport and deposition of soluble salts such as the desegregation and detachment of surface materials, one looks for the presence of moisture, or a previous or potential moisture source. If the "cause" of the decay does not exist, in this example the moisture, then another cause has to be determined. The process of looking at deterioration (effect) and looking for the cause of the deterioration is one part of the process. Identifying a cause that is normally associated with decay (effect) and then looking for the actual effect, that may not be obvious, is another part of the process.

Condition Survey; Identifying the Conservation Issues

General Site Overview

The first step in undertaking the condition survey was to development some basic concepts as to the issues. This was a rather quick overview of the site and notes were taken on the site plan. In addition to looking at the site and the ground adjacent to the standing walls, some of the basic characteristics of the conditions were noted for inclusion on the survey sheets of the wall surfaces. The plan is reproduced here as Figure 18.

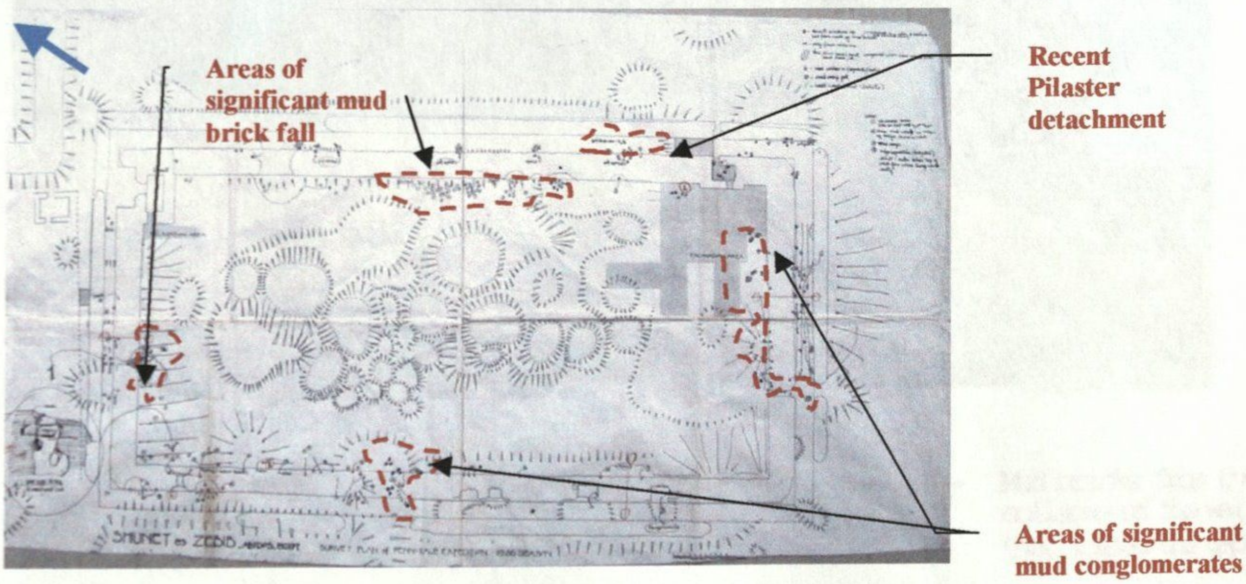

Figure 18: A digitized reproduction of the actual site survey sheet.

The specific areas identified above were the areas where larger amounts of wall material were identified. Scattered amounts of mud brick fragments and the mud conglomerates were located around other areas of the site. The mud conglomerates are the products of probably a long period of mud-daubing insects that attached the mud nests to the mud brick walls and continue to build up over the years until the mud brick areas could no longer support the weight. One of the largest was located at the base and near the center of the north side of the south wall. It was slightly less than one cubic meter in volume and weighed several pounds.

The larger concentration of mud bricks were located is areas where there was the more recent loss. The area on the west side of the east wall is in very poor condition in many locations and the larger accumulations of mud bricks reflect a continue loss of material. The same is true of the section of the north wall where the accumulated fall appears to be quite recent. Matt Adams thought that the wall did not have a gap at this location but spanned over an eroded opening when he was at the site one year before. The mud bricks near the lower part of the east portion of the fill may well have been accumulated over a long continuous period of erosion and detachment of the mud bricks rather than only associated with a more recent episode. Immediately under the surface of the sand in that areas are more broken pieces of mud bricks and also what appears to be vegetable matter. (Figures 19 and 20).

It would be important to know the actual amount of time it took for the wall fall to have accumulated to be able to better understand the approximate rates of decay. In addition, it will be important to document the wall material that is excavated during the archeological season.

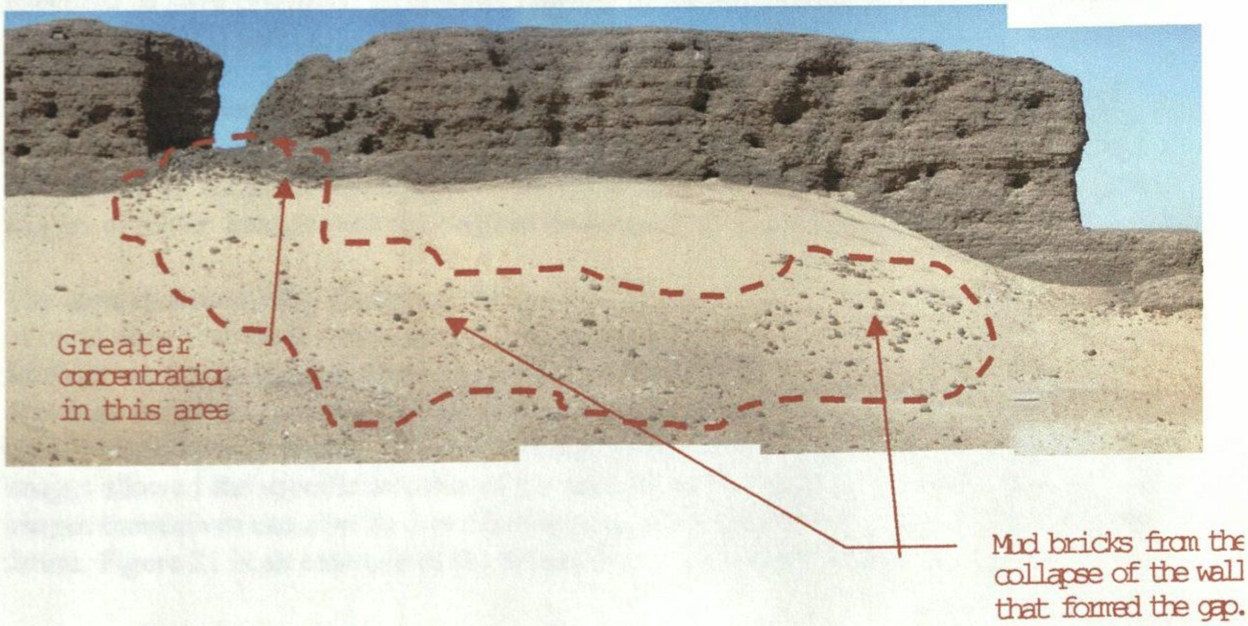

Figure 19: A digitized composite image of the south elevation of the north wall showing the gap and the accumulation of mud bricks, which probably came from the collapse.

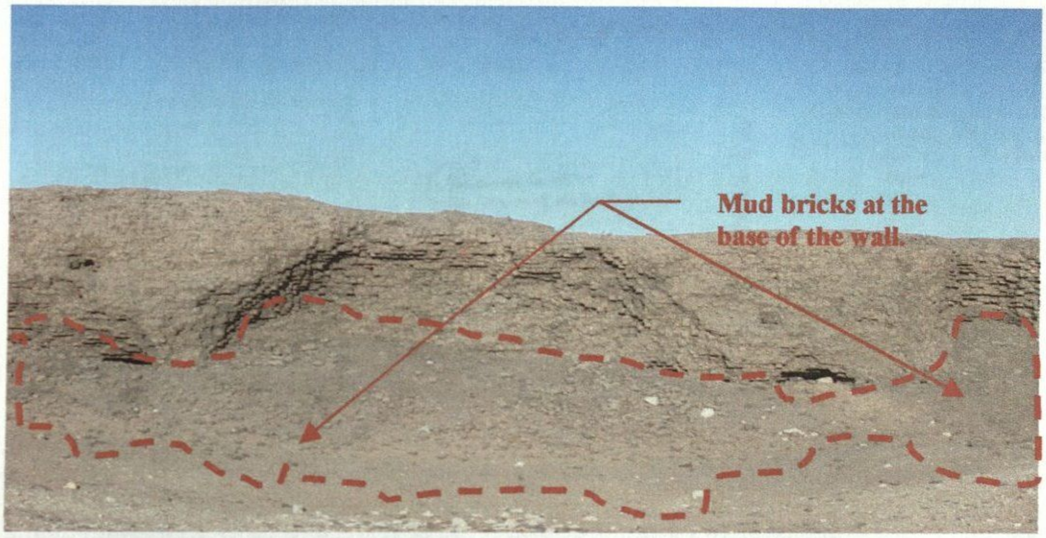

Figure 20: Center portion of the east elevation of the east wall showing a large accumulation of mud bricks on the surface of the ground.

Other conservation issues identified in general during this overall site survey were the large numbers of animal burrows, particularly on the west side of the east wall and the east side of the west wall and the wasp-like insects that were inhabiting many areas of the mud brick walls. Others issues that seemed potentially critical enough were the birds nesting in holes in the walls, the large wall voids in the west side of the west wall, vertical through wall cracks, and loose mud bricks. Still others were mud drips on the wall surfaces that appeared to have produced from water running down the wall surface, the detachment of sections of walls, wind erosion, and the condition of the actual mud bricks and mortar.

A brief glossary was then prepared for the actual survey of the walls that included the conservation related conditions. Digital images were then taken for all the wall surfaces and printed on standard white paper. The actual field notes were taken on these images. Copies of all the images with the original field notes are included as Appendix A.

The condition recording continued throughout the site visit. However, the actual recording of conditions was most importantly a systematic approach to insure that all walls and features were investigated. Since the results of the survey, the notes and sketches on the drawings are subjective; the specific results cannot be specifically quantified so they cannot be compared directly with future subjective surveys. However, the use of the actual images allowed the specific location of a condition to be accurately located again and the images themselves can also be directly compared with images of the same features in the future. Figure 21 is an example of the actual survey sheets and notes.

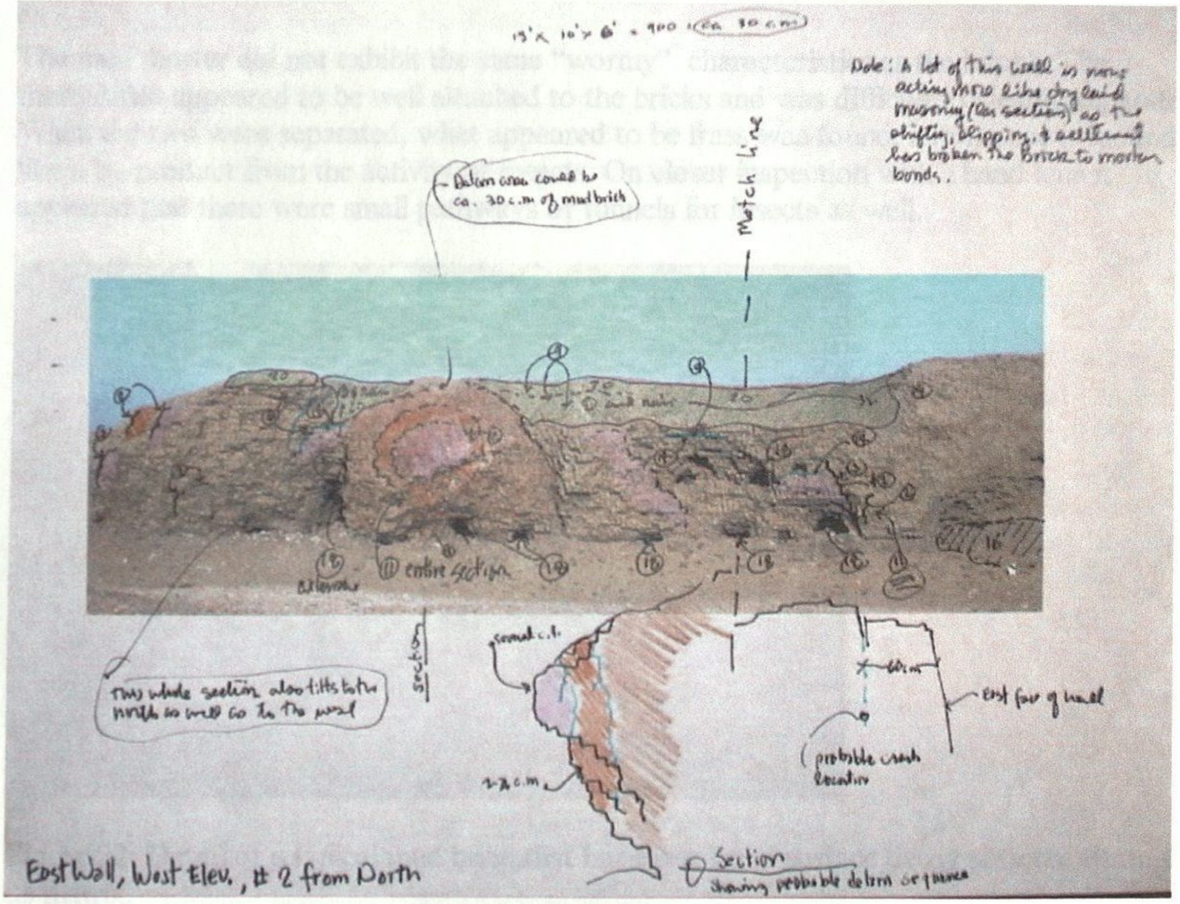

Figure 21: Sample of survey sheet; this one is of a section of the west side of the east wall.

The specific conditions that existed on all the low outer wall surfaces were not recorded systematically as were the inner walls. There was simply not the time available and it was felt that the overall performance of the low walls were not different except in conditions that were directed related to the different geometry of the two types of walls. Further evaluations may result in differences in the pathology of these two different walls that is not obvious now.

Specific Observations and Considerations Developed During the Site Survey

The mud bricks appeared to be relative porous as many had holes and voids throughout the mass of the entire brick (Figure 22). They can best be described as having a vermiculated or wormy appearing surface. There actually seemed to be a range of these conditions as on the other end of the extreme some of the bricks had very few holes. The surfaces of the more extreme cases have an estimated 50% of the actual surface missing. A thin knife blade could be pushed easily into these highly decayed bricks up to the depth of the entire blade, or approximately 7 cm. The solid compacted bricks were denser with few "worm" holes; in these the knife blade could be forced only about 3 cm into the brick. The bricks that seemed to be somewhere between the two extremes were slightly more dense than the worse ones.

The mud mortar did not exhibit the same "wormy" characteristics as the bricks. The mortar also appeared to be well attached to the bricks and was difficult to cleanly separate. When the two were separated, what appeared to be frass was found. In any case it looked like a by-product from the activity of insects. On closer inspection with a hand lens it appeared that there were small pathways or tunnels for insects as well.

Figure 22: Detail of a typical mud brick that has these same surface decay patterns through its matrix.

There are numerous cracks of various widths throughout the structure, and they appear to be the results of various types of deformation or movements of one portion of a wall from another, one course of mud bricks from another, or the separation or detachment of parts of a mud brick mass. No evidence was seen of cracks that can be associated with the loss of cohesion of the material.

There seemed to be a pattern of the distribution of the mud wasps on the surface but it was not clear during the initial phase of the condition survey. They seemed to prefer the west or northwest facing wall surfaces; the specific patterns were investigated further during the wall survey.

There was also a distinct surface texture difference between different areas of the wall surfaces. Some of these appeared to relate to the length of exposure of the surface to the desert wind. Other differences in the texture of the surface appeared to have the same exposure, but still were different. The overall effect of the wind and the specific differences in wall texture were also noted for further investigation.

Condition Survey; Mapping the Conditions

The conditions of each of the wall elevations will be summarized; following the summary of the wall conditions, comparisons and conclusions will be discussed and the most significant conditions, or what appear to be the greatest threats, will be discussed in even more detail.

East Elevation of the East Wall

The east wall has two high portions separated by a long low portion. There is another low portion at the south end in the area of the southeast doorway. Previous excavations have exposed approximately the lower two meters of most of this wall. There is a very distinctly different in the texture of the wall surface best defined by the remaining pilasters. Unfortunately the pilasters are deteriorating and will continue to deteriorate. If the approximate dates of the excavation were known, the rate of decay could be estimated. Figures 23 and 24 are elevations of the two high wall sections. Some of the more critical conditions are noted.

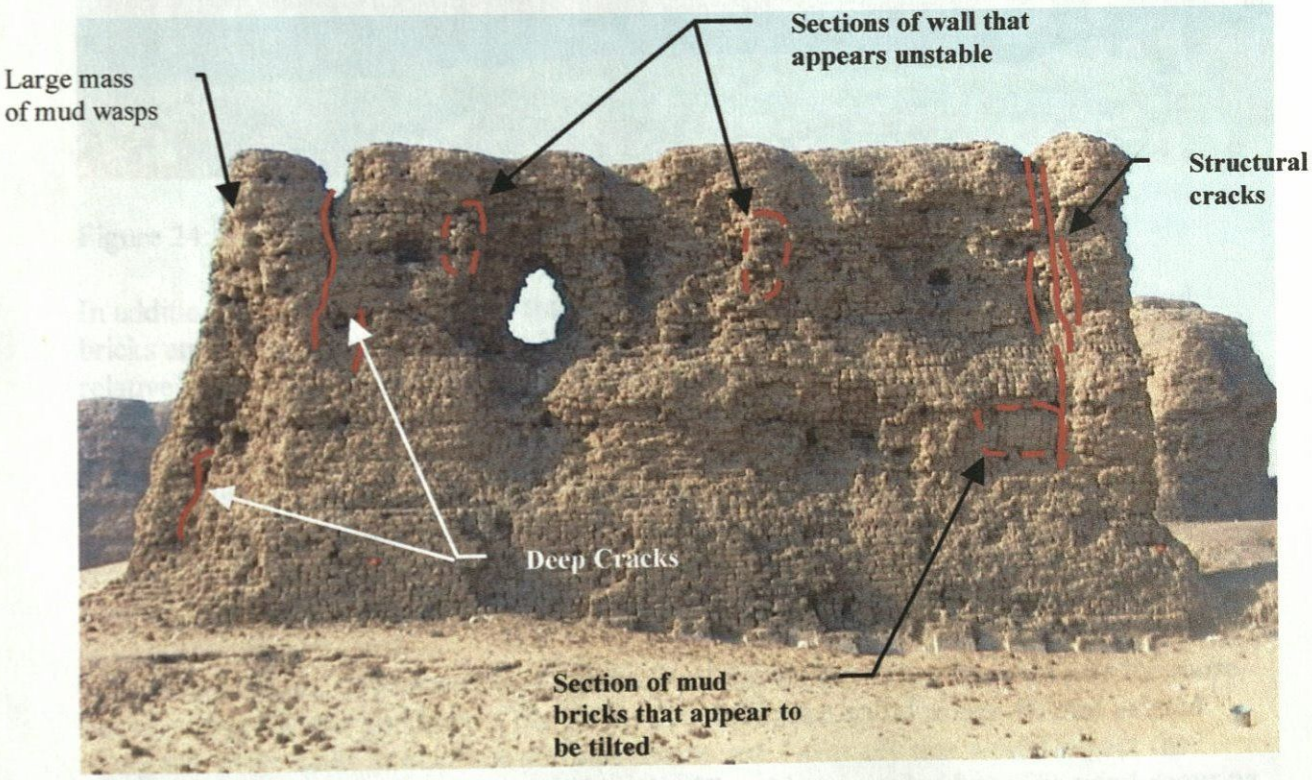

Figure 23: North end of the east elevation of the east wall.

The section of unstable wall right of the opening appears to be approximately 1.5 cubic meters; the section to the left appears to be less than .5 cubic meters. There are also voids behind and to the sides of these two sections. The "tilted" mud bricks near the east end appear to be associated with the structural cracks that extend down from the top of the wall. Structural cracks, which are represented by dotted red lines, also reflect the separation process of the west end of the wall from the main portion. The area of the wall within several meters of the hole should be further evaluated more thoroughly from ladders or scaffolding. There are also loose adobes on the mid to upper portions of the wall and minor evidence of birds on this wall.

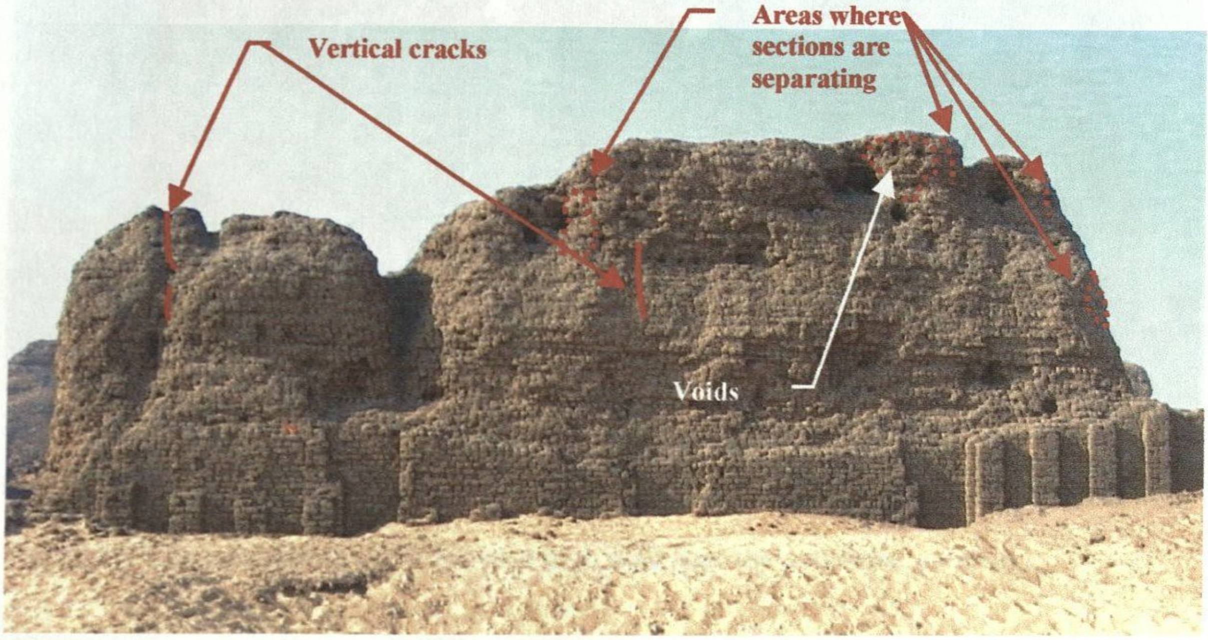

Figure 24: South high section of the east wall, the east elevation.

In addition to the several sections that appear to be delaminating, there are loose mud bricks and voids near the two large holes. There is some mud wasp activity, but it is relatively minor, as is the evidence of birds.

The conditions on the west sides of these same two wall sections were similar, but did have other conditions that seemed to be related to the west exposure and to more radiant energy. The major difference was the large mud wasp colony at the upper portion of the large recess near the center of the south high wall. There were also animal burrows that were not observed on the east side of these same walls.

Another significant difference in the condition of the walls on the west side was the more heavily eroded lower portions of the walls. The difference could reflect fill that existed along the lower walls at one time and since removed. Normally one would expect the lower areas would have been protected by the fill and have eroded less. The wind scouring on the upper portions of the walls implies that the surfaces that are currently exposed on the lower portions of the walls have had less exposure to the winds. Of course the specific wind patterns and the micro-turbulence that would occur could explain some of the difference, but it could hardly explain the level of differences that now exist (Figures 25 and 26).

West Elevation of the East Wall

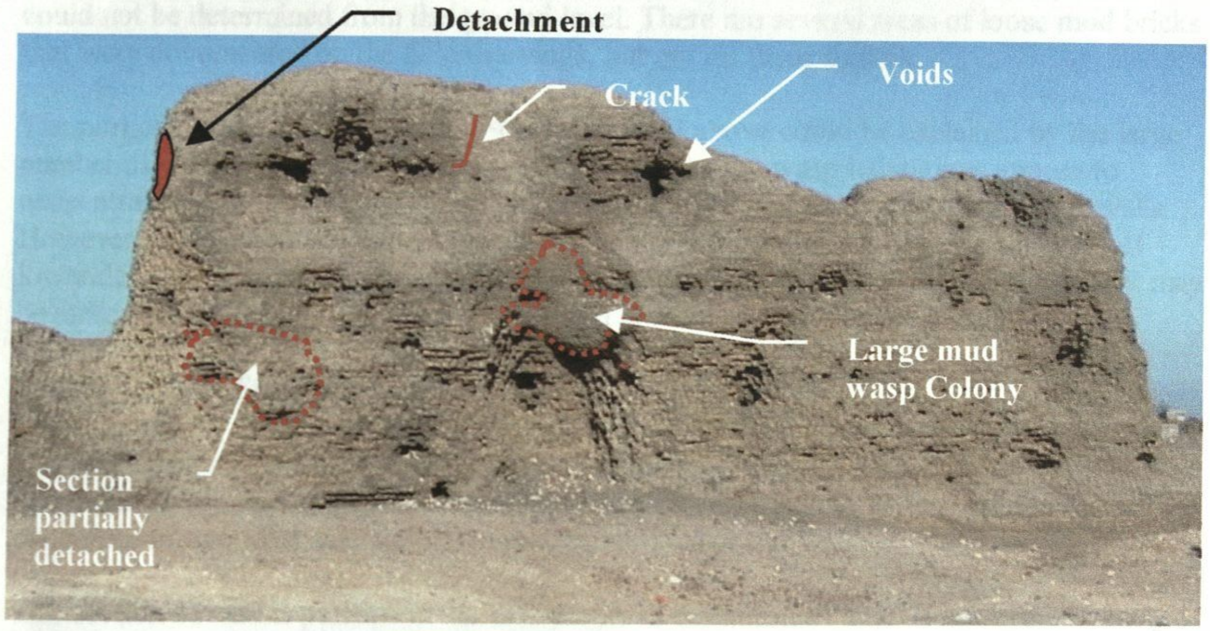

Figure 25: The west elevation of the east high wall near the southeast gateway.

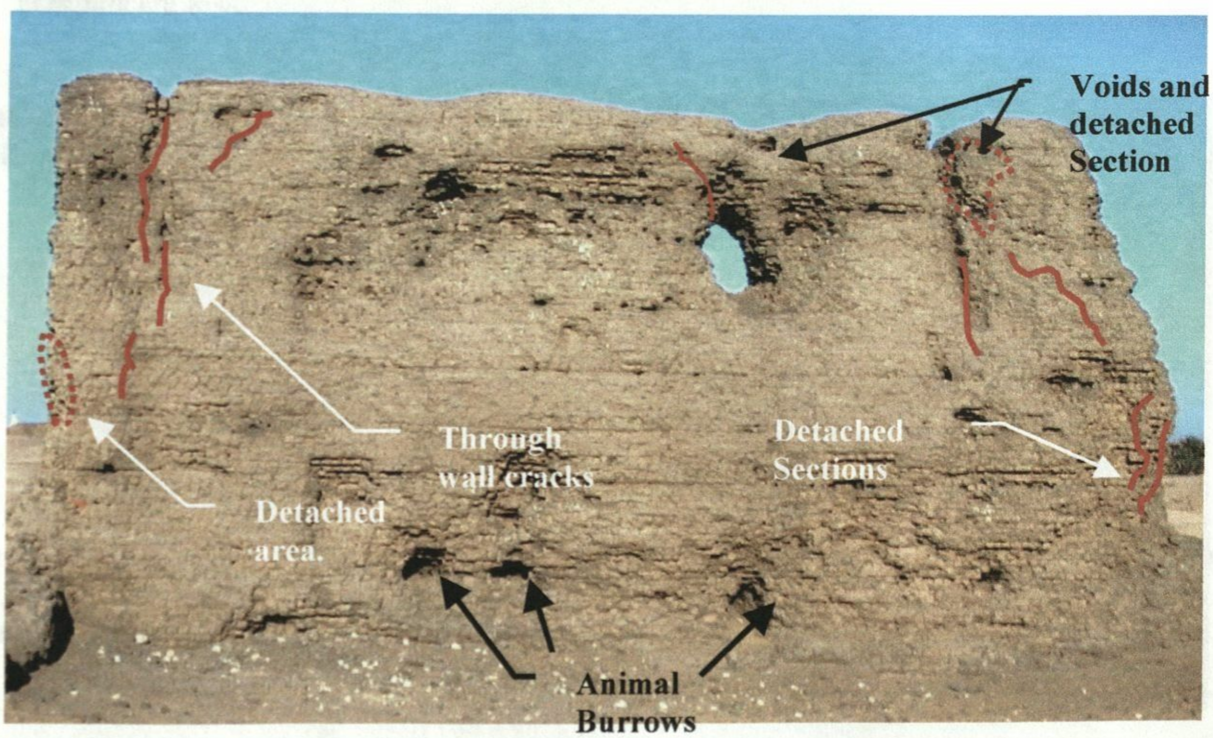

Figure 26: West elevation of the east high wall near the northeast corner.

There is very little mud wasp activity on the north high wall in contrast to a very large colony that is active on the south high wall. Wind has scoured these surfaces more than on the east side of the west walls. There is more bird activity on this side than on the east side of this same wall. The birds have created several holes, but the extend of the bird nests could not be determined from the ground level. There are several areas of loose mud bricks that were documented on the field drawings, but not on these figures.

The portions of the lower walls that were discussed above could be explained by the large number of mud wasps nests on the south high wall, as the wasp habitations appear to concentrate along some of the upper lines of the more heavily textured parts of the walls. However, there are noticeably less nests on the north high wall. Comparing the level of lower decay, it is also much lower than on the south wall. There are other patterns that may be more meaningful once additional fabric and archeological evidence is collected.

Central Section of the East Wall

The east elevation of the low central portion of the wall was not recorded comprehensively. Several specific areas were evaluated, primarily as they related to the conditions on the west side and the overall conditions of the wall.

This section of wall is perhaps in the worse overall condition of any. It has been severely undercut by animal burrowing and perhaps by the adaptive reuse of some of the walls by human interventions in historic times. Large sections of wall are essentially free standing and could collapse anytime with minimal additional changes. Any seismic event will result in significant loss.

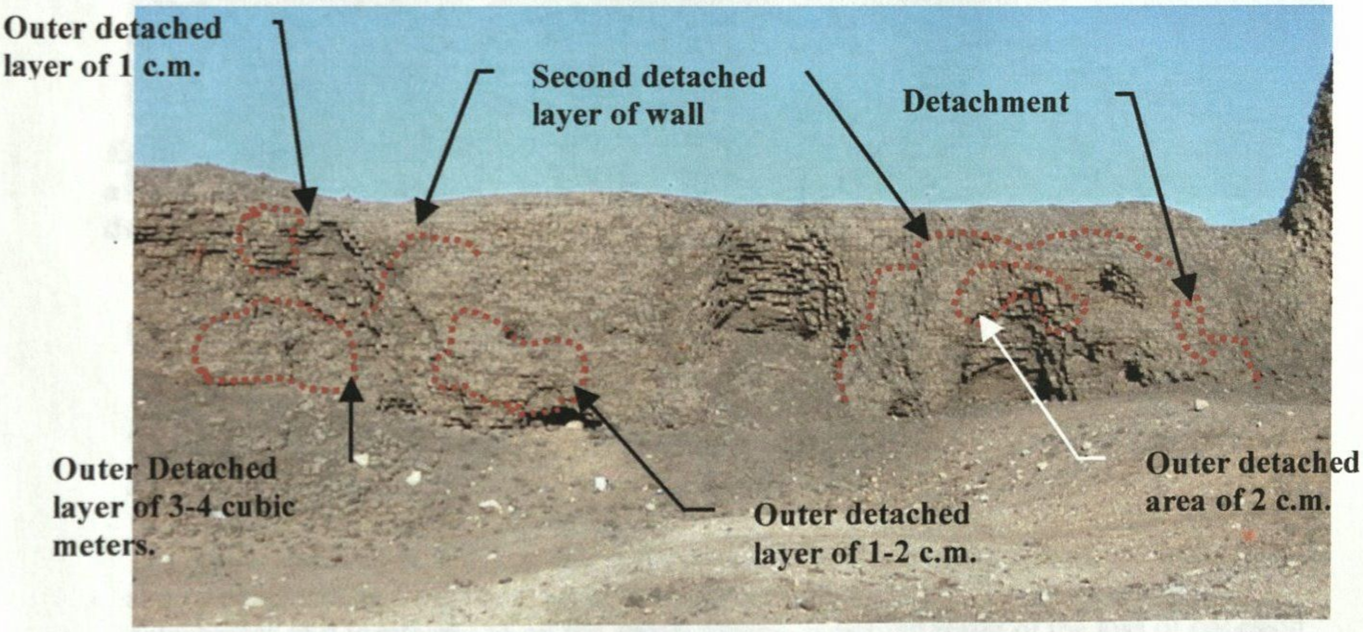

Figure 27: South part of the center section of the east wall.

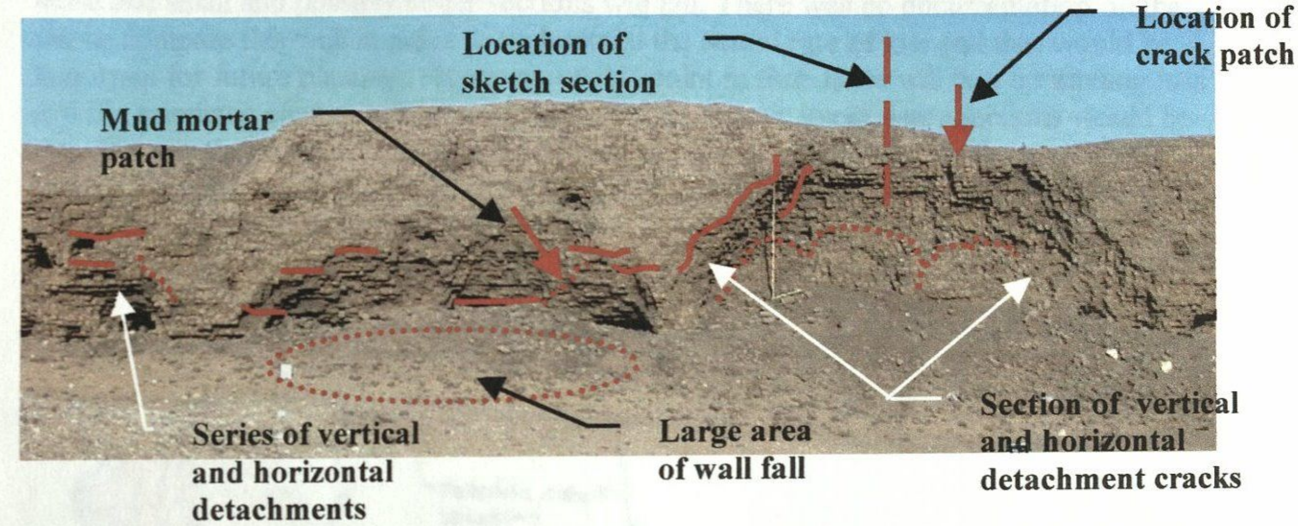

Figure 28: Central part of the low center section of the east wall.

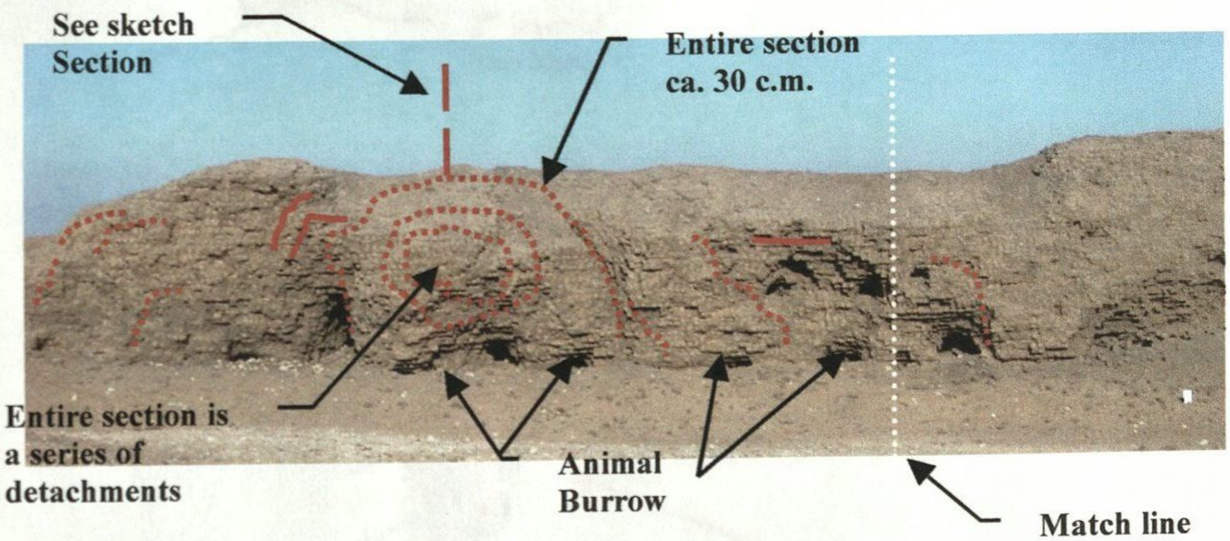

Figure 29: North part of the center section of the east wall.

The figures are just a summary of the condition of this wall. See the copies of the original sheets on which the more detailed notes were recorded.

The entire wall section is failing in a very regular pattern as a series of wall sections are simply delaminating from the mass of the wall immediate behind. The delamination, or detachment as it is referred to on the above figures, is not the result of the loss of cohesion of the material but because the undercutting has eliminated the support for the sections. The process will not stop now even if there are no additional excavations into the base of this wall section. The wall sections will continue to fail as individual mud bricks become loose and small and possibly larger sections will fall. There was no documentation on the site to compare this wall in order to understand the actual rate of loss and that would be important for future planning. However, at this point in time there will be a continuing loss and if a traumatic change occurred such as a minor seismic event, large sections would be lost. But whether the losses are accumulations of relative small losses or from on single event, the result will be the same. See Figures 30 and 31, sketch sections through the wall at two locations that demonstrate the process.

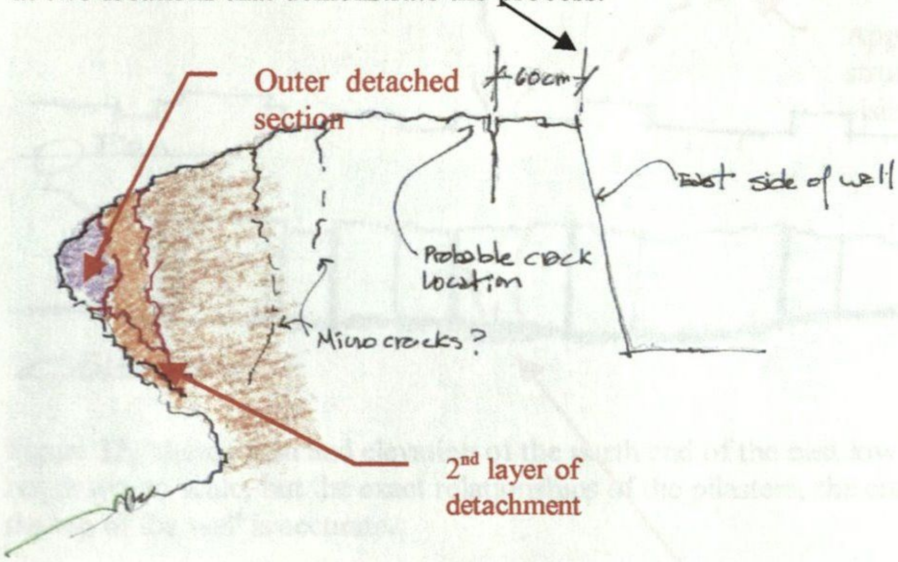

Figure 30: Sketch Section showing the typical detachment sequence on the west side of the east wall looking south.

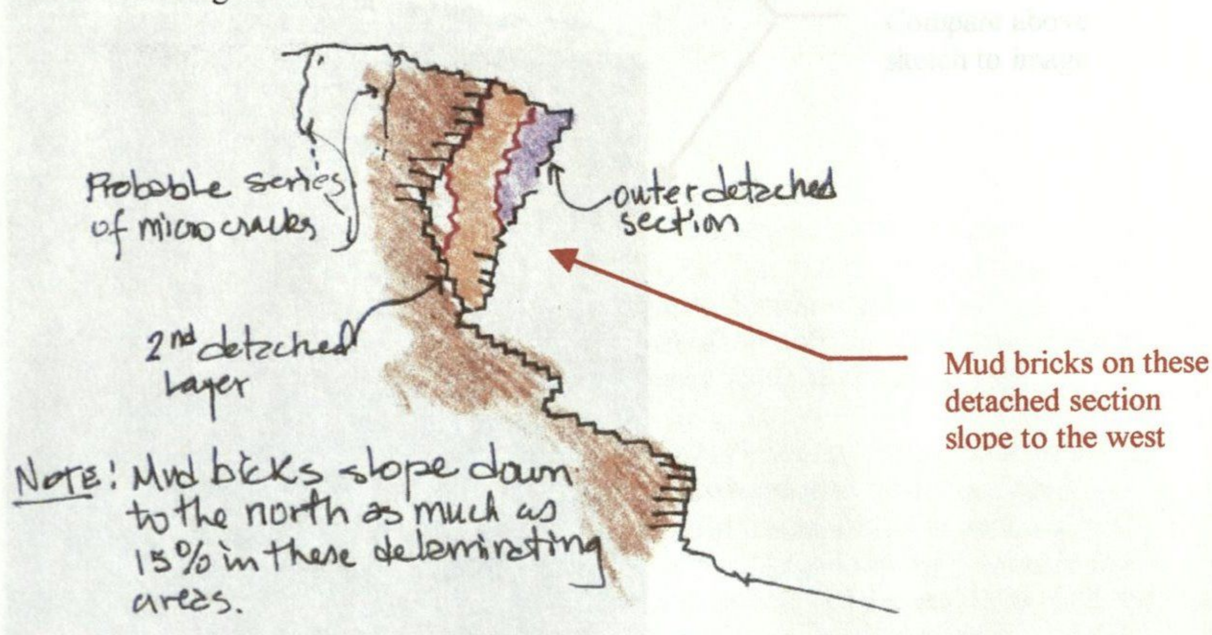

Figure 31: Sketch of detachment of the east wall near the south end of the low center section looking south.

Structural crack extend completely through the wall as well, and may be related to the overall stresses placed on the structure by the undercutting of the wall. Figures 32, and 33_, show one area where this is occurring.

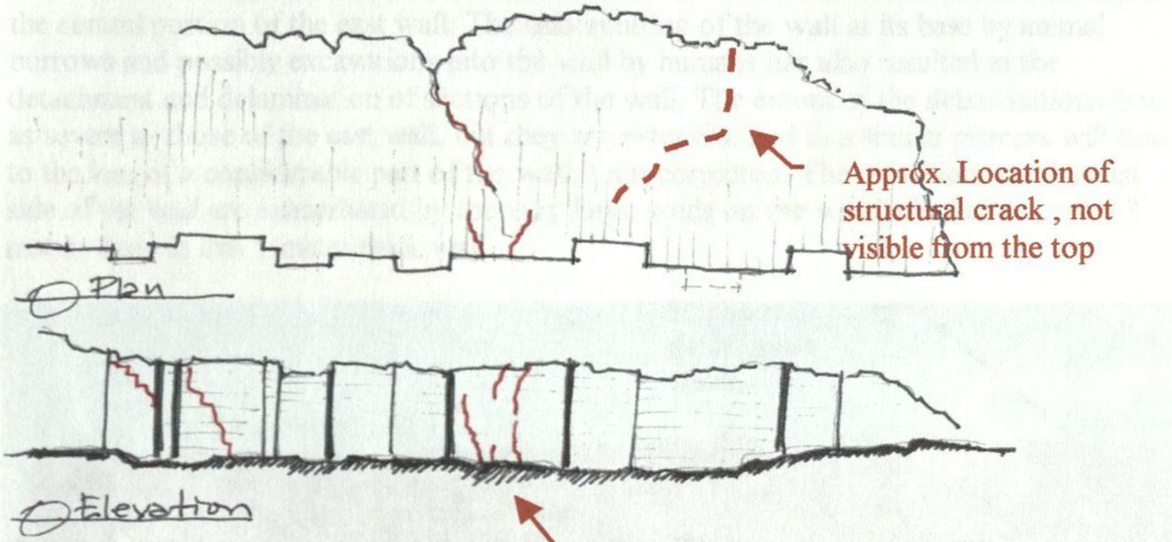

Figure 32: Sketch plan and elevation of the north end of the east low wall. The sketch is not drawn to scale, but the exact relationships of the pilasters, the cracks and the crack on the top of the wall is accurate.

Compare above sketch to image

Figure 33: Detail of the east side of the east wall that is shown in the sketch elevation above.

West Wall of the Shunet

The south section of the east side of this wall exhibits some of the same conditions that do the central portion of the east wall. The undercutting of the wall at its base by animal burrows and possibly excavations into the wall by humans has also resulted in the detachment and delamination of sections of the wall. The extent of the delaminations is not as severe as those of the east wall, but they are extensive and in a similar process will lead to the loss of a considerable part of the wall if not corrected. The conditions on the east side of the wall are exacerbated by the very large voids on the west side that are up to 3 meters deep in this 5-meter thick wall.

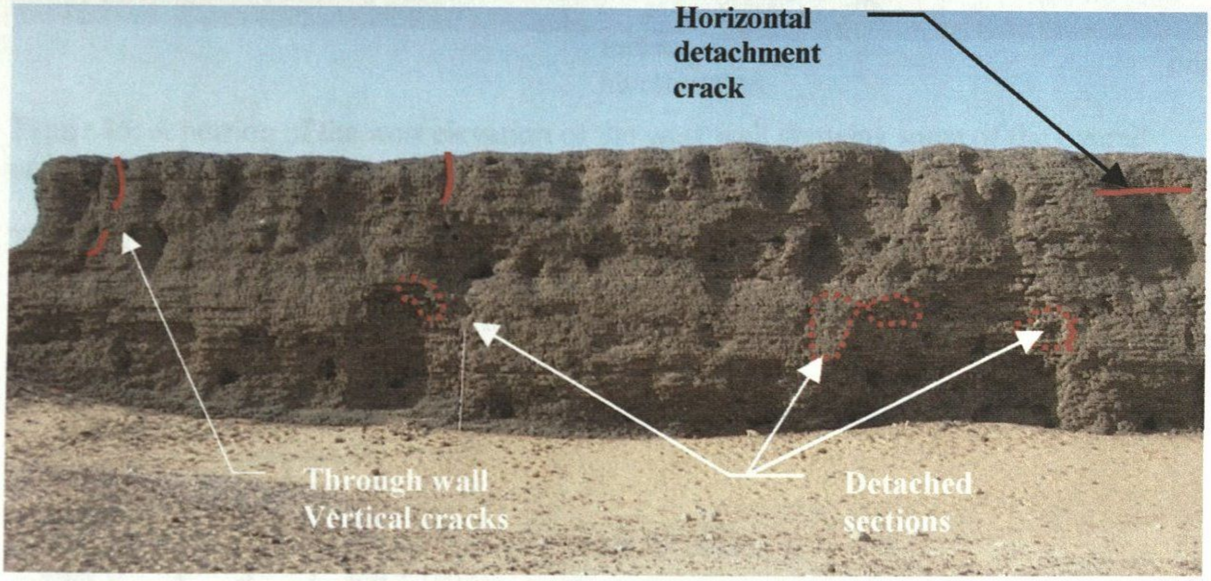

Figure 34: Partial west elevation of the west wall.

The conditions indicated on the above image are a summary of the most significant issues. In addition to the two issues pointed out above the wall has numerous mud wasp nests, bird nests, loose mud bricks and other smaller detachments. Similar condition exist on other wall sections but the most critical areas are the ends of the walls on either side of the west gateway and the north end of the wall near the intersection with the north wall.

Conditions on the west side of the wall are primarily characterized by the large voids that exist along its length. Where these voids exist there are numerous other conditions that reflect the lack of lower wall support such as loose mud bricks, detached sections, both horizontal and vertical cracks. There are also several very large mud wasp colonies that have built large mud nests that will eventually fall and sections of the mud brick wall will be dislodged and will fall as well. The figure of a typical section of the west side of the west wall will be followed by a series of figures will show some of the details of greatest concern.

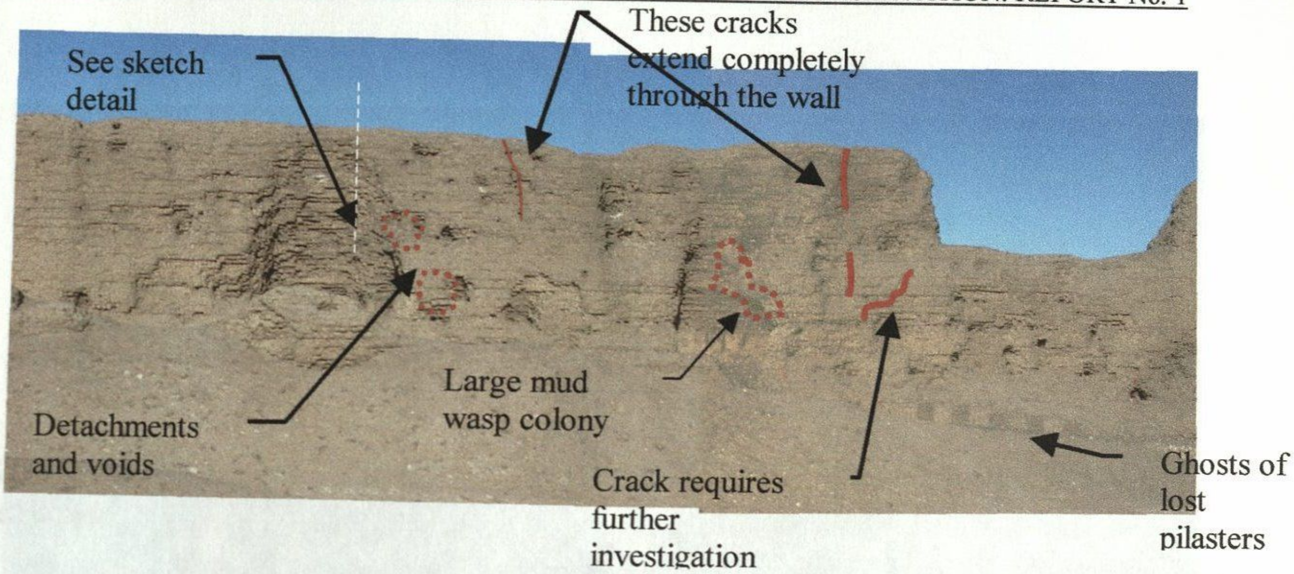

Figure 35: A portion of the west elevation of the west wall showing some of the overall and typical conditions.

The vertical cracks on the upper portions of the wall section are through wall cracks. The crack patterns continue lower in the walls near the ends of the wall section. In the case of the west wall, the most critical areas are the wall ends near the west gateway.

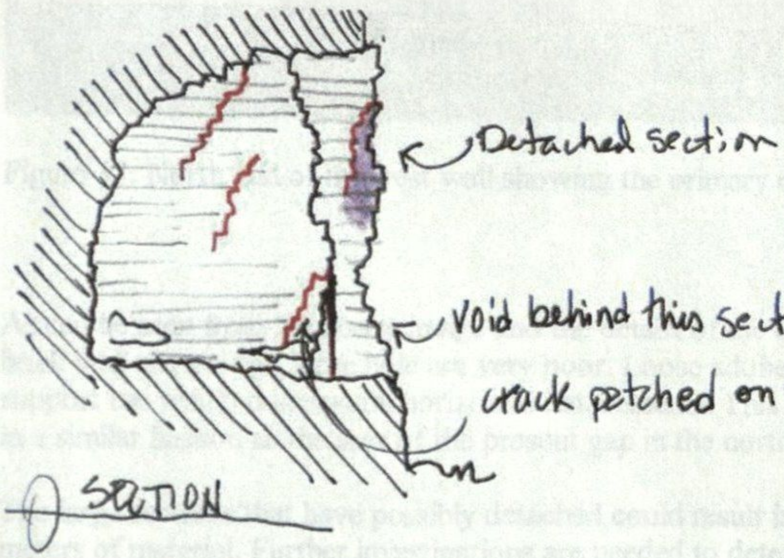

Figure 36: Partial section looking south through "cell" showing void, detachments and area of "tell tale" mud patch.

The above sketch is not drawn to scale, but the scale drawing through this same void is in the report of the structural engineer, Conor Power. It does show more or less typical conditions of voids, detachments, or delaminations, and associated structural cracks.

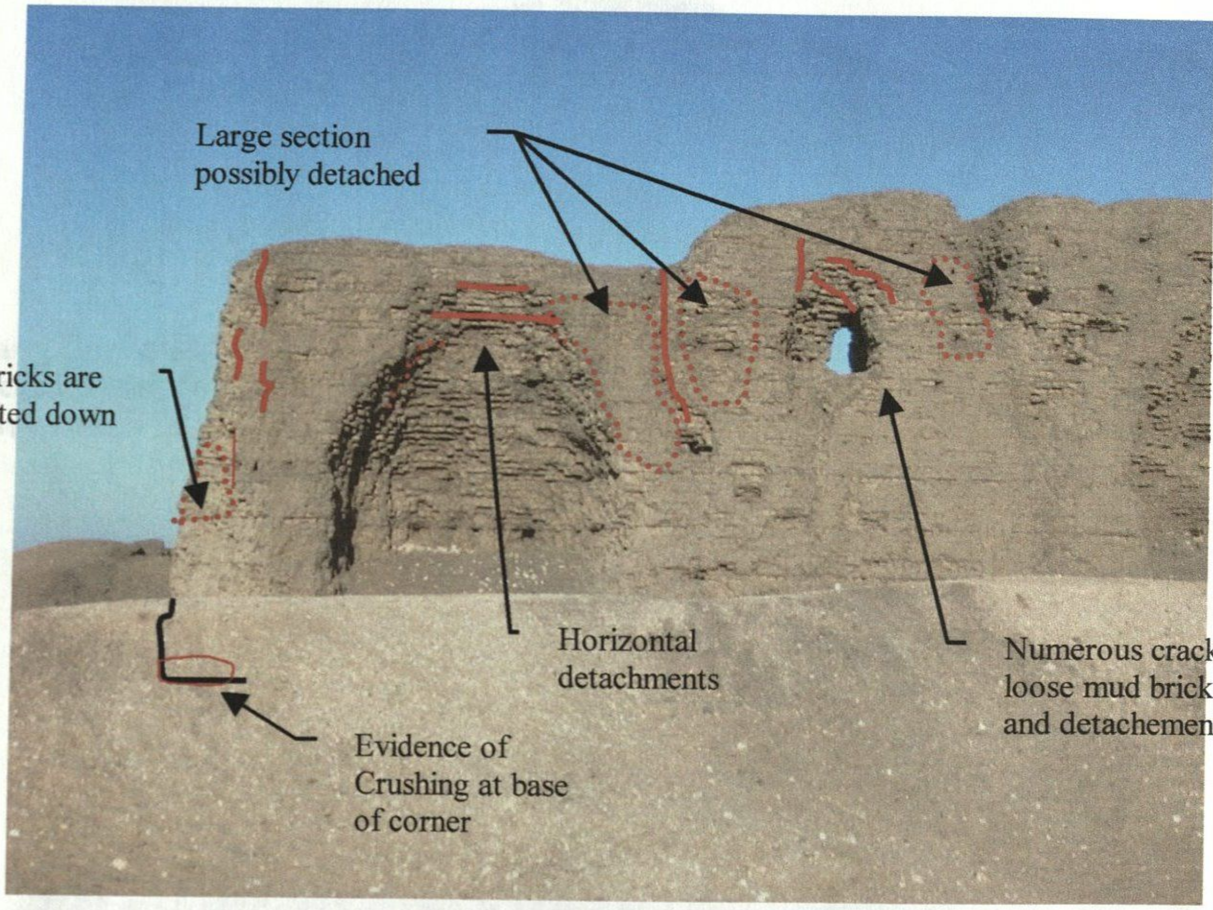

Figure 37: North end of the west wall showing the primary concerns at this location.

As can be seen from the above image and the details of the condition field sheets, the mud brick wall around this large hole are very poor. Loose adobes are numerous; the lack of support has resulted in several horizontal detachments. This area could collapse completely in a similar fashion as the area of the present gap in the north wall.

The large sections that have possibly detached could result in the loss of several cubic meters of material. Further investigations are needed to determine the specific critical areas so that conservation treatments can be initiated as soon as possible. Mud wasps are particularly numerous in the area of the large concave portion of the wall near the north end. As in the case of other walls where the wasps are numerous, there is the same pattern of decay, as the broken and missing sections seem to “move” higher and higher up the wall surfaces.

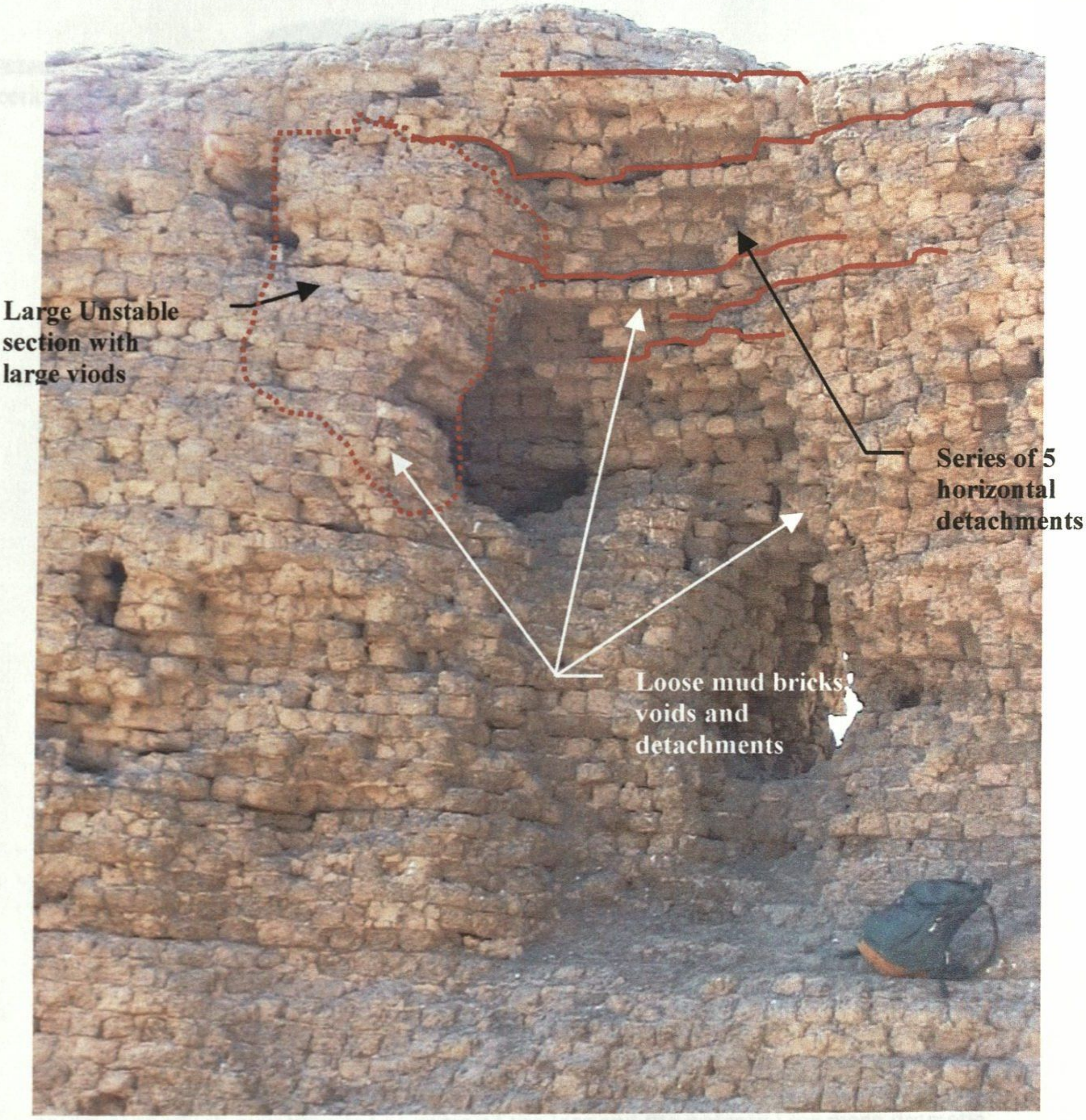

Figure 38: Detail of the north end of the west wall from the east.

The entire section of the wall in the image above is very unstable. Immediate conservation interventions are necessary to prevent additional traumatic loss. Loose mud bricks, and some of the delaminated portions could be lost at any time. It may be that the normal process will continue with the loss of small portion of the wall will continue until the entire section collapses in a manner similar to what must have happened to produce the gap in the north wall.

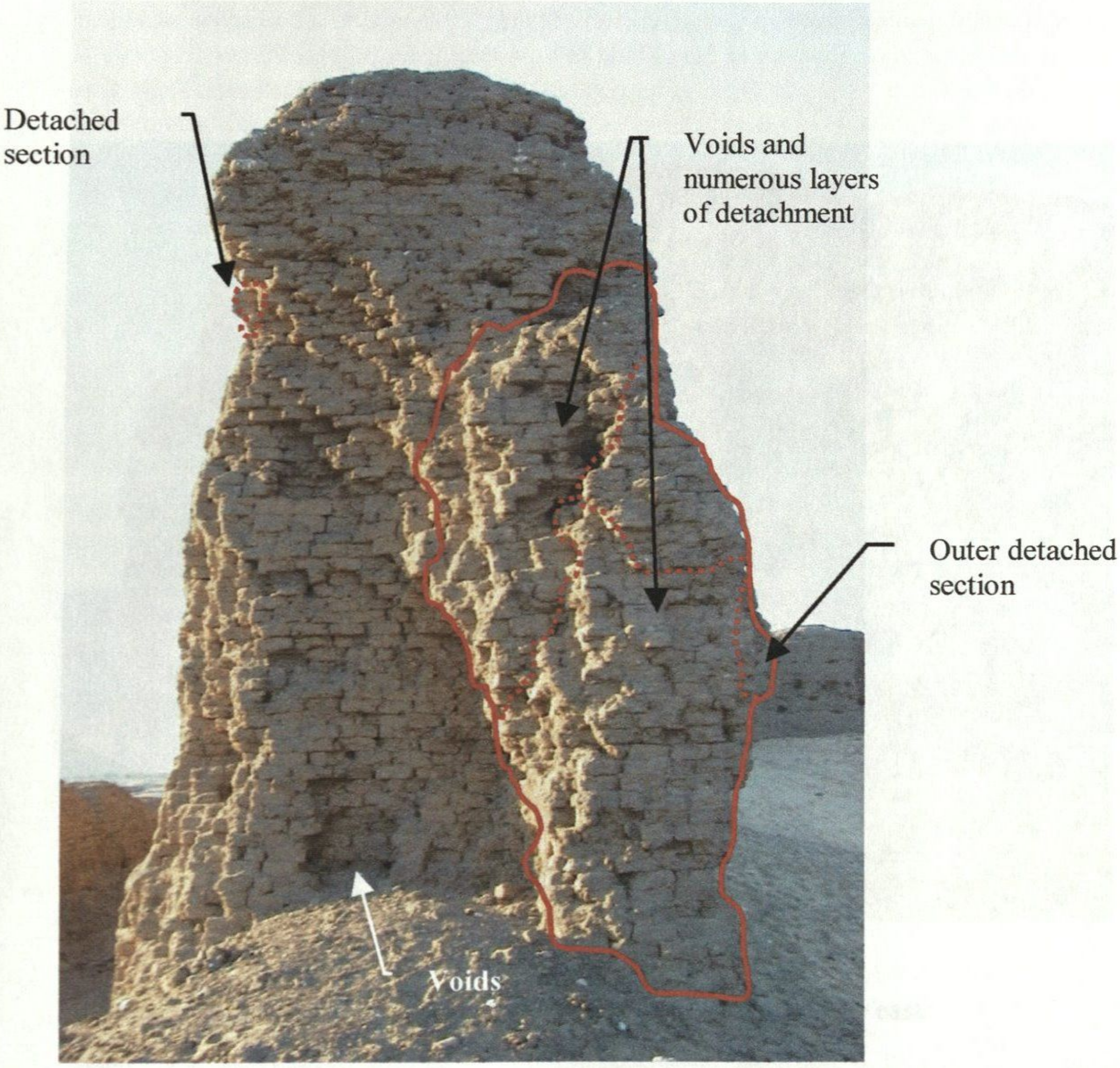

Figure 39: The south end of the north section of the west wall at the west gateway.

The entire right section of the wall could collapse with the loss of a minimal of approximately 10 cubic meters. The section has voids, cracks, loose mud bricks, detached sections and both vertical and horizontal delamination cracks. The are also some active mud wasps which may have led to some of the loss and the potential for more dramatic future loss, but again the poor structural condition seems primarily to be the result of the removal of a large part of the wall material to create a "cell". The estimated loss of ca. 10 cubic meters will only be the first or the next step. With its loss, when it happens whether all at once or by a series of lesser losses, the wall to the north, which is presently reasonably stable, will also be affected and its integrity will be compromised. A long vertical through wall crack located several meters from this corner may then be the next "line of retreat" for the stability of the wall. Figure 40 shows the area of this crack from the east side; it was patched with a mud patch so that future movement could be more easily detected.

Figure 40: South end of the north section of the west wall from the east.

South Wall of the Shunet

The south wall does not have the massive human or animal impacts that the east and the west walls have. However, the mud wasps seem to particularly find favor in the north side of this wall and the pattern of decay on that north side seems to be directly attributable to them. There are also more birds nesting in the south wall, but they do not seem to have any more of an impact there than in the other walls.

The long central portion of the high wall has several through wall cracks, somewhat like the long north wall and the longer section of the west wall. The structural cracks were mapped on both elevations, but no detail as to the width, the actual extent or other characteristics.

There are some typical detachments on the southwest corner, the west end of the main section of the wall at the southwest gateway and at the southeast corner. There are also extensive voids in the south side, normally occurring immediately above, within a meter, of the previous fill line. Several exist on the north side as well but less in number and not as large. These voids, which appear to be burrowing holes may also provide a clue about the extent of fill at various times and the approximately time or span of time when the damage occurred, particularly in the areas where wall surface are currently covered. From this evidence one might not expect major voids below the extent of the present fill, assuming that there has not been a significant amount of fill added over the past few hundred years. In the figure below, there are several holes that appear to be animal burrows below the line of previous fill.

In contrast to the effects and presence of the mud wasps on the north side of this wall, there are relatively few nests on the south side. There is one nest area over the void near the west end of the wall, but the remainders are small nests.

The following Figures summarize the conditions on one section of the north side of the wall, the section east of the southwest gateway, and a detail of the southeast corner.

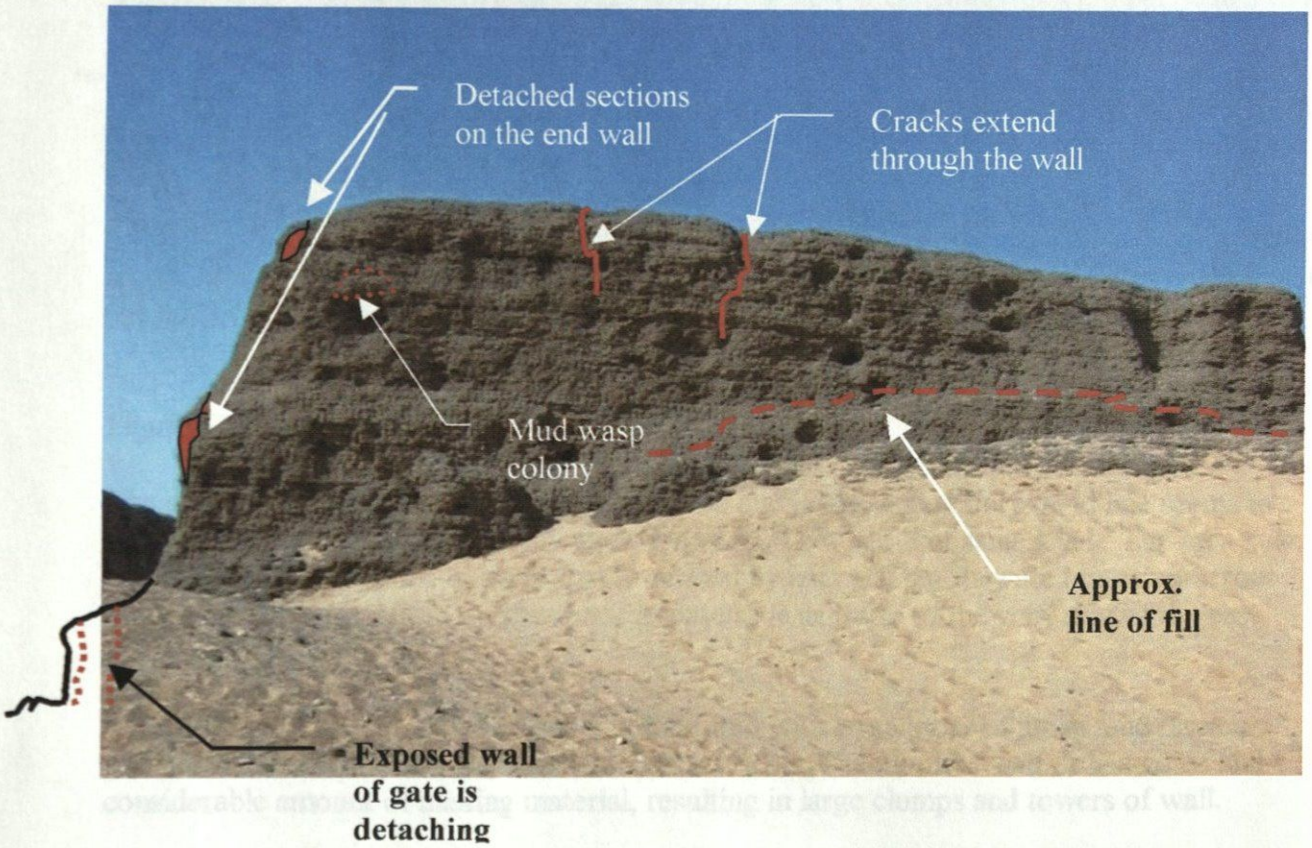

Figure 41: South elevation of a section of the south wall at the southwest gate.

The overall texture of the north side of this south wall is quite different than the south side. There appears to be more wind scouring on the south than on the north. This is not particularly surprising as the wind patterns in and around the Shunet would not be the same and there will be major and minor differences. Areas of micro-turbulence will also exist. There is also a greater contrast between the upper and the lower parts of the walls. The general wind patterns in the Shunet were documented during the one-day that the wind blew during the site visit. A sketch plan with the results of that documentation is included in the analysis summary of this report.

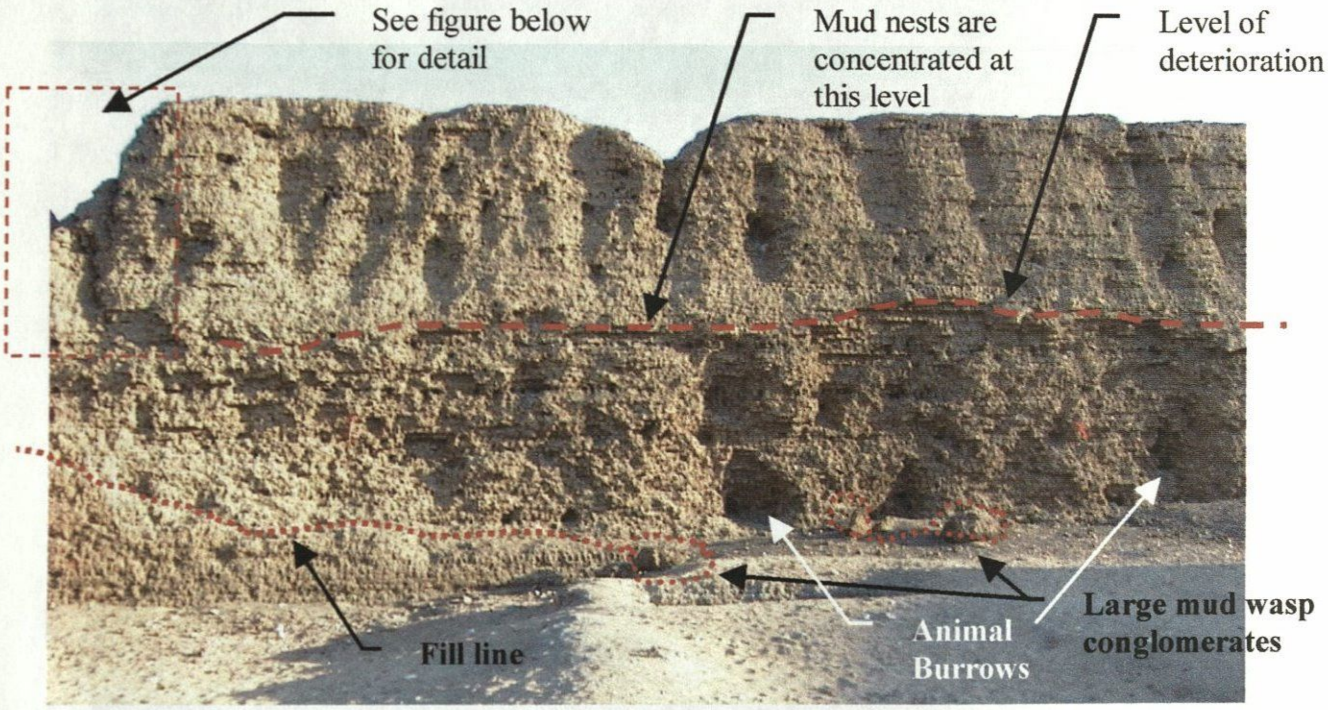

Figure 42: East end of he north side of the south wall.

The distinct difference in the wall texture above and below a near horizontal line seems to be directly associated with the concentration of mud nests at that same level. The area near the ground also has some holes probably created by animals, but they are not as numerous as on the south side of the wall, and not as extensive as those of the west side of the east wall.

The east end of this south wall is heavily fractured with large areas of loose mud bricks, vertical and horizontal cracks, and detachments of large sections of wall. It has voids and a considerable amount of missing material, resulting in large clumps and towers of wall.

The base of the upper portion of the wall from approximately 2-4 meters above the present grade is severely eroded. The level is at least partially associated with the level of fill that existed in this area. Wind certainly had an effect as it scoured the wall immediately above the fill, but presently the highly eroded area presently provides a convenient shelf to walk on. It may have also been a convenient place to walk even when the fill was up to this height.

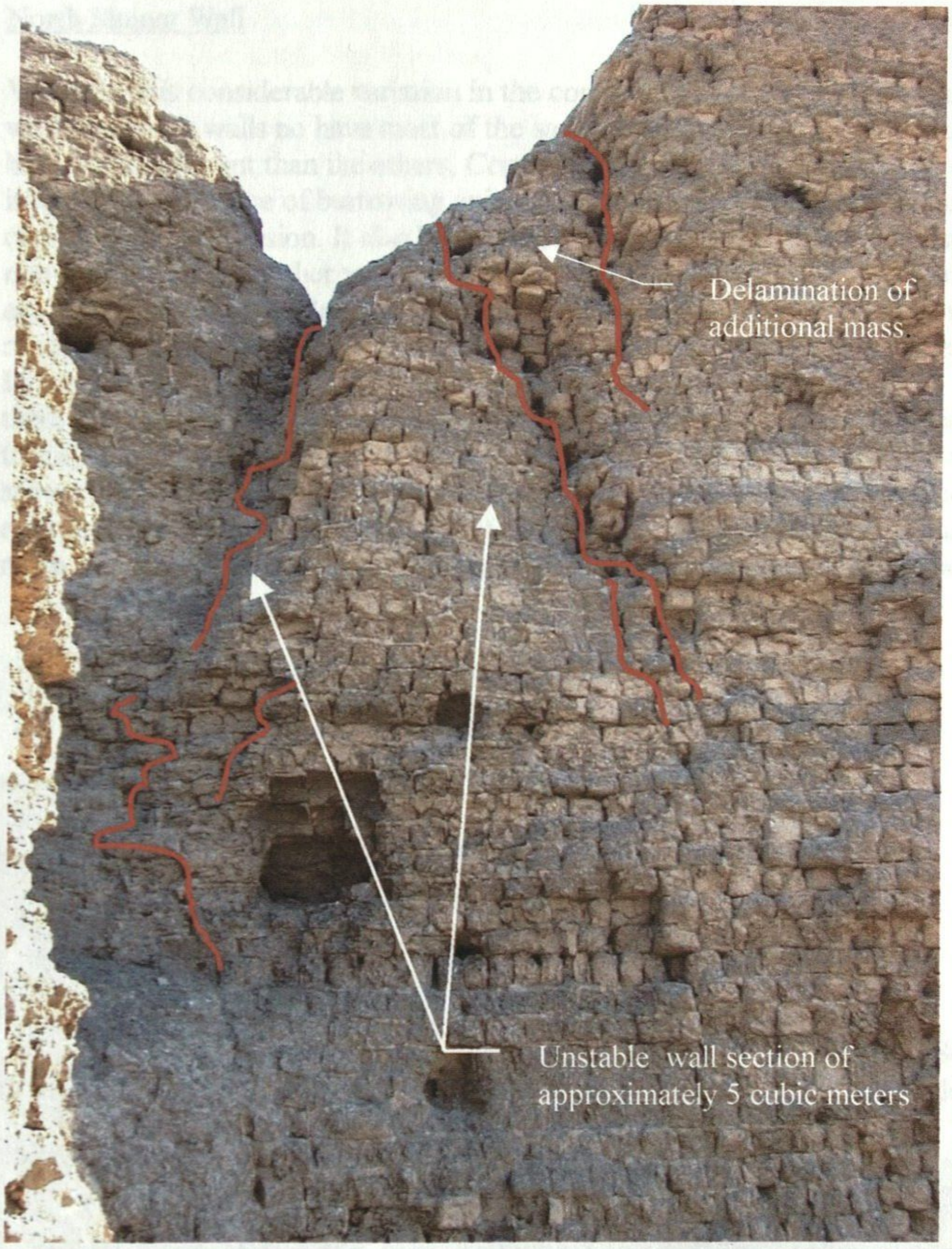

Figure 43: A detail of the east end of the south wall.

The detail above is just a part of this area of the wall that is in poor condition. Additional specific information is detailed in the field notes that are included in the Appendices. The conditions for the remainder of this corner are similar.

Generally, the south wall appears to be more stable than either the south wall or the east wall. There remains a considerable amount of fill on the central portion of the south side, but we can only anticipate that the condition of the wall that is presently covered by fill is in even better condition. Of course there are portions of the wall that are in extremely poor condition.

North Shunet Wall

While there is considerable variation in the condition of the walls of the Shunet, the east, west and south walls no have most of the same condition types in common. The north wall however is different than the others. Certainly it also has many of the same conditions of insect nests, evidence of burrowing animals, detachment of layers, loose mud bricks, birds, cracks, and wind erosion. It also has considerable damage from water, presumably by rainwater, which the other walls do not have. The most obvious evidence of this is the amount of vertical mud drips and small rills that appear on the entire north side of this north wall. The condition is greater on the west end but it can be found everywhere. Interesting enough, there are no more drips or rills on the south side of the north wall than there is on any other wall. In addition to the drips and rills the most significant condition that appears to be associated with the water is the erosion at the top of the wall. Mortar appears to be washed out and many mud bricks are loose. The upper wall condition does exist on a few areas of the south side of the wall, but it is pervasive on the upper part of the north side. Figure 44 is a part of the north side, the west end showing the conditions.

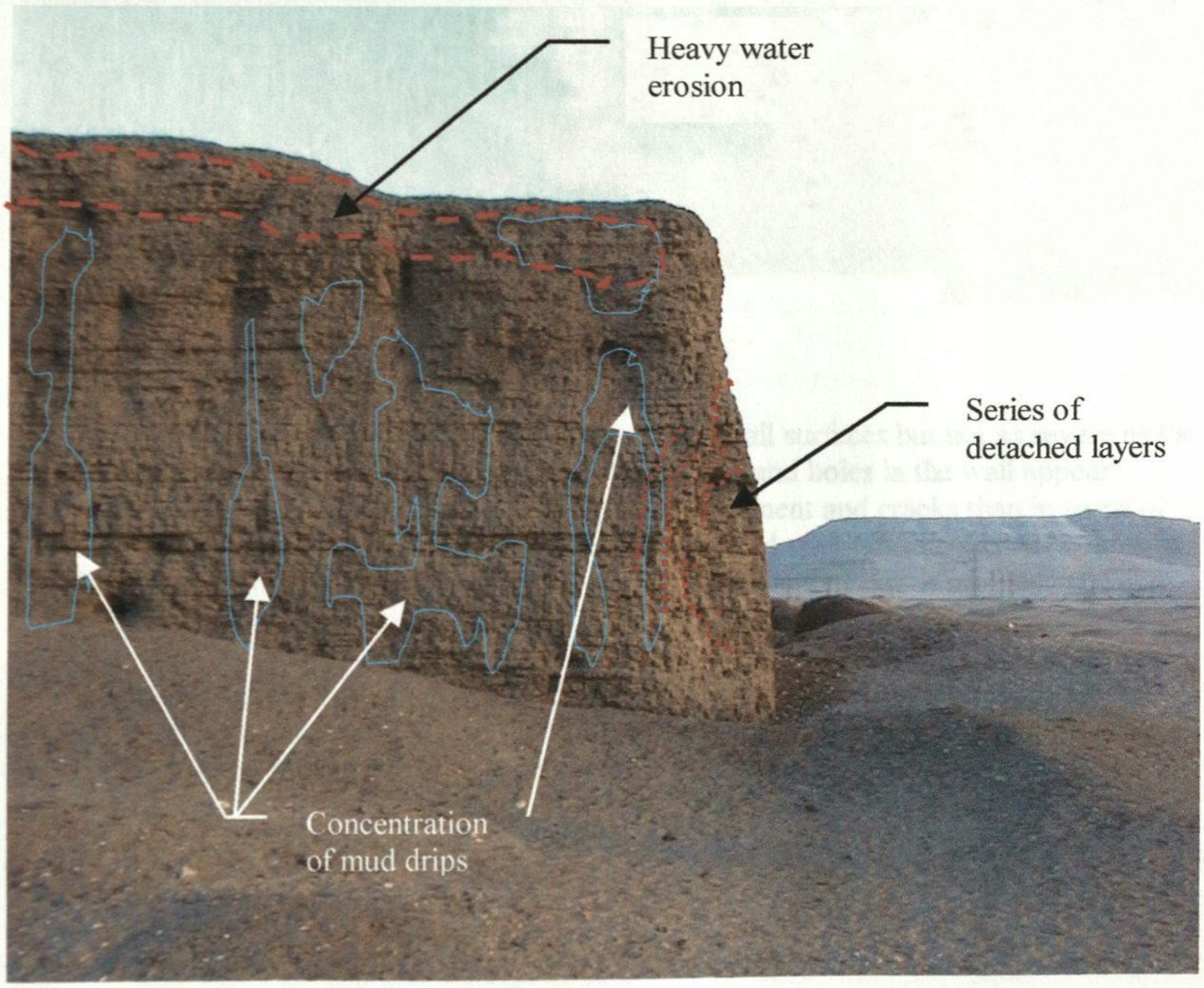

Figure 44: The west end of the north wall.

The typical conditions on the south side are shown in Figure 45, which is a section of the wall from the east end of the high wall.

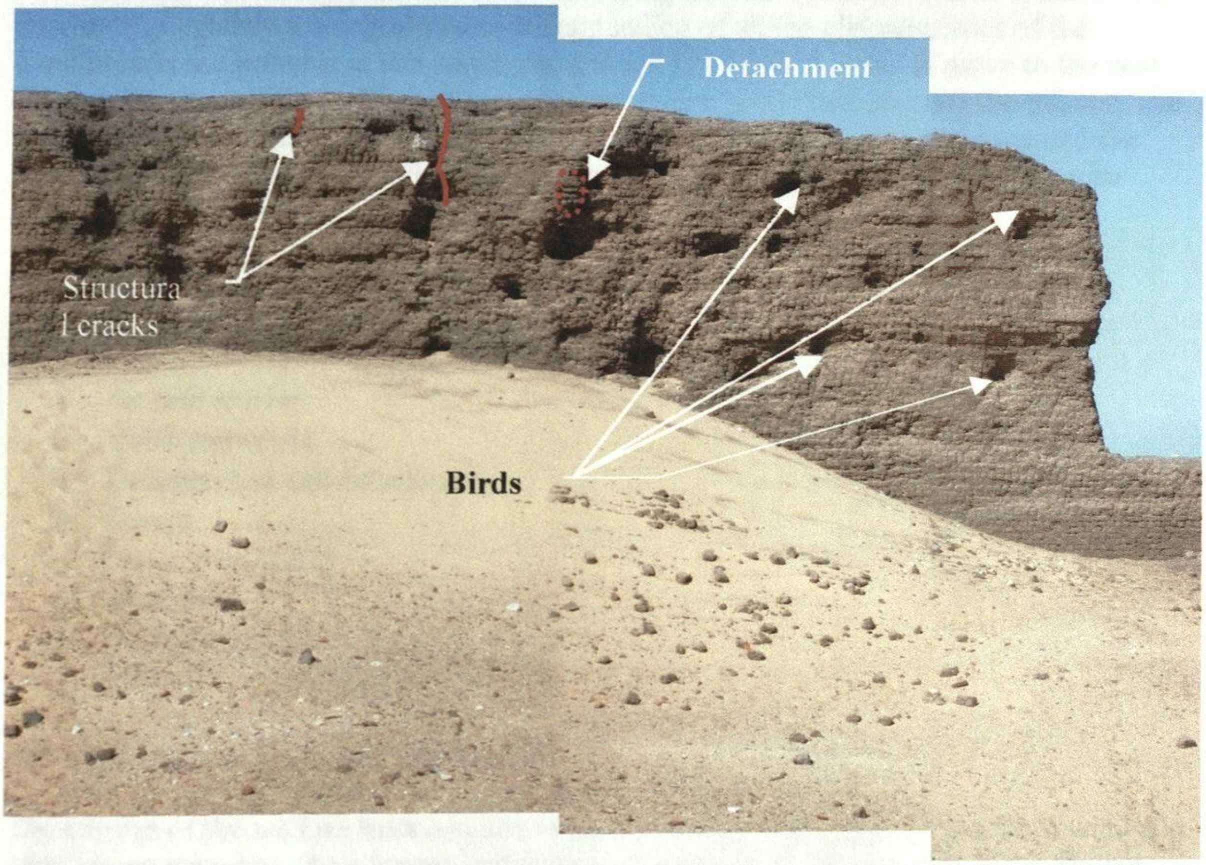

Figure 45: South side of the north wall.

The general wind erosion patterns are similar to other wall surfaces but not as severe as the south and the higher sections of the east wall. The voids and holes in the wall appear similar to other walls. There is less fracturing and detachment and cracks than in some of the walls but then those conditions are normally associated with larger voids. Of course the small voids in the north wall may well grow into larger ones, but that is probably nothing that will occur rapidly.

There is a large colony of mud wasps at the west side of the gap and the size would indicate that it was there long before the top portion of the wall collapsed. There may well have been more nests that fell along with the wall and may have contributed to its collapse.

Summary of Condition Recording and Analysis

There are basic condition patterns identified during the site work that can be summarized succinctly. Certainly a comprehensive understanding of all the characteristics of the conditions is not possible at this stage, but enough is known in order to move to the next stage in the process that will result in a comprehensive protection plan for the Shunet. The path to the next stage consists of both immediate interventions on the structure and the development of a more comprehensive understanding of the interventions that may be appropriate in the future.

The major conditions are listed below. Following the list are examples of each and a summary. The conditions are:

- Surface erosion
- Holes and voids
- Delamination and detachment
- Cracks
- Loose mud bricks
- Mud drips
- Wall fall
- Insects

Surface Erosion

The erosion of the wall surfaces appears to be the result mechanical erosion from wind and mind blown abrasives, from human activities such as walking on the walls of the Shunet, and animals. It does not appear to be the result of other processes such as wetting/drying cycles or the shrinkage of the surface material. A thin film was observed on some of the surfaces, which could be evidence of some surface phenomenon, but it did not appear to be pervasive and was not considered important enough to evaluate further during the site work.

The wind did not affect all wall surfaces equally. The north side of the south wall and the west side of the high sections of the east walls appeared to be more eroded than other wall surface (Figure 46). There were also some isolated portions of walls that were eroded differentially. An example of this can also be found on various walls and probably reflects micro-turbulence in those areas. Micro-turbulence can be subtle and a new pattern can begin when one brick is dislodged from a wall, or an animal begins making a hole for a nest. The lower walls, most of which have suffered more wall loss than the upper walls are not as eroded and that is understandable. It might be possible to estimate the rate of erosion if the approximate time can be documented that a surface was exposed and a quantifiable system to measure the erosion is developed.

An important next step is to quantify the specifics wind patterns in the monument in general and in specific areas as well. The use of a hand-held anemometer, a smoke gun, or just simple strips of plastic can collect a great deal of information.

Figure 46: The upper portion of the south section of high east wall is more eroded than some other wall surfaces

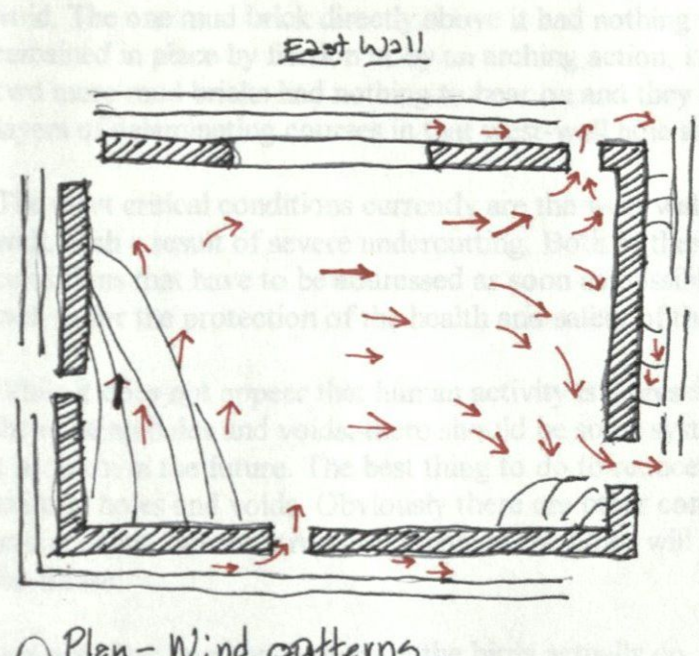

Figure 47: Sketch plan of Shunet showing general wind pattern at ground level on January 17th.

The wind patterns that occurred and were mapped do not represent anything but that one single occurrence. However, the general pattern did seem to have some relationship to the general deposition of sand. Since the measurements were not at the level of the more severe wind erosion, no specific conclusions could be reached. A manual anemometer measured the actual wind speeds.

Holes and Voids

This is a general category that includes the large wall voids on the west wall as well as the small holes that now serve as nesting or gathering places for birds. The larger voids are the one single condition that has resulted in the greatest amount of loss of material. The systematic removal of the material was in itself the cause of significant loss, particularly the results of the human activity that produced the cells, primarily in the west wall. But the subsequent loss of material gradually and probably in large sections at times has been even greater. The present conditions that relate to the greatest actual or potential loss are based on the lost of bearing support and the forcing of the material and the wall system to act in tension rather than in compression. A mud brick may have compressive strength in the range of 250-300 pounds per square inch (psi), but only a modulus of rupture of one tenth as much.

The detachment and the delamination of small and large sections of wall occur because of the lack of support for compressive loads. The large hole in the west wall is an example of the accumulative loss, perhaps over hundreds of years that probably began with a small void. The one mud brick directly above it had nothing to bear directly and while it perhaps remained in place by friction or by an arching action, it eventually fell. He results was that two more mud bricks had nothing to bear on and they eventually collapsed as well. The layers of delaminating courses in that west-wall hole show the process clearly.

The most critical conditions currently are the west wall and the central portion of the east wall, each a result of severe undercutting. Both of these walls constitute emergency conditions that have to be addressed as soon as possible for the protection of the Shunet as well as for the protection of the health and safety of those who may be close to the walls.

While it does not appear that human activity is a present problem in creating or expanding the existing holes and voids, there should be some system to insure that it does not become a problem in the future. The best thing to do to reduce the impacts of animals is to fill the existing holes and voids. Obviously there are other considerations that have to be taken into account, but the structural repair of the holes will help reduce the threats by animals in the future.

It is not clear how much damage the birds actually do, although there is no doubt that they cause some damage. The development of a better understanding of their effect should be a goal of further field investigations. Nesting and activity holes could be filled, as the majority probably should. If that action does not eliminate the birds, it would reduce their activity.

Delamination and Detachment

Delamination and detachment are used interchangeably in this report. Horizontal detachment occurs at a mortar joint above a void or large opening. There are some locations where numerous layers have become detached above a single opening. Various figures in the condition survey part of this report point out that phenomenon.

Vertical delamination is caused by the same lack of bearing support. The most critical example occurs at the ends of walls and at severely undercut walls. Refer to the description of the east wall for the example of this and the explanation. A rough calculation of the volume of loss from the west side of the center section of the east wall that seems the most critical is more than 75 cubic meters of material. That translates to approximately 18,000 mud bricks. That is less than ½% of the total number of bricks, but that is only that one wall. If all similar areas were added together, that is those areas that will fail without intervention the loss would be over 1% of the total mass of the Shunet. The loss from the process is accumulative and this 1% over the next few years will translate into even greater losses in the next few years after that.

Cracks

There are numerous cracks associated with the detachment of layers or sections of walls and there are through wall cracks that are not related to the to the process of delamination. These through wall cracks are vertical and they normally occur near the ends of walls or in long expanses of walls. Examples of the former are on the north and south ends of the north section of the east wall (Figure 48).

Figure 48: East side of the north section of the east wall showing the pattern of cracks at the ends of high walls.

The ends of the east wall are particularly severe and are probably the most critical, but the pattern is typical. These particular walls should be further evaluated and emergency action taken if it necessary.

Figure 49 is a sketch drawing, an orthographic projection of the Shunet showing the location of all vertical through-wall cracks that were observed. The basic pattern seems consistent. The locations are based on the visual survey and the relative severity was not evaluated by probing or by determining the actual separation and extent in any other way.

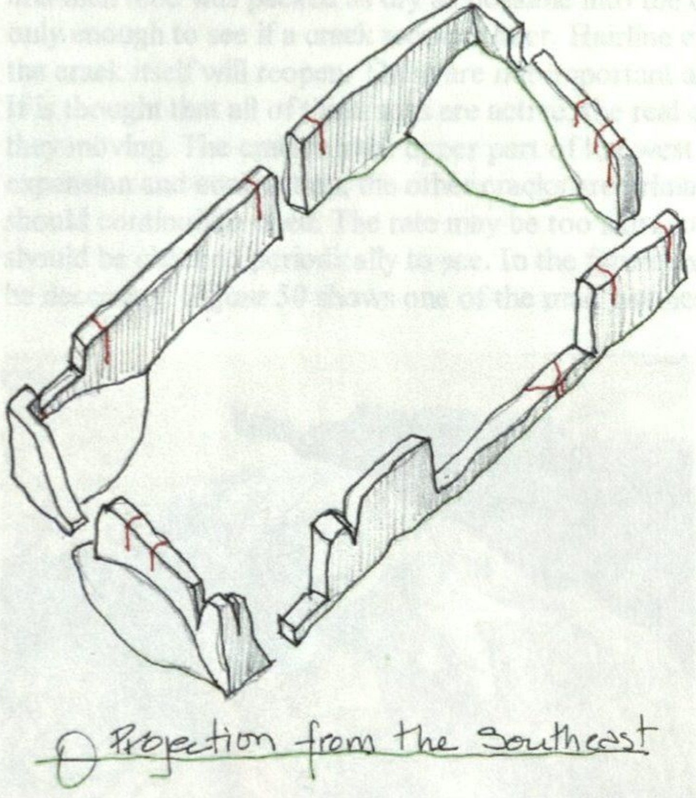

Figure 49: Sketch of the Shunet showing the general locations of the vertical through-wall cracks.

The one exception to the pattern is the lack of cracks in the south section of the east wall. Again this is based on visual observations and it would be important to look again to confirm the condition of that wall.

The mid wall cracks on the north and the south walls do not appear to be of concern. It is interesting that the same pattern does not exist, or at least was not observed on the west wall. Because of the severe undercutting of the walls, if a similar cause affected the west walls, the stresses could have been relieved through a series of micro cracks. Or the cracks may be there and were simply not noticed. Such cracks could be caused by thermal expansion or an out-of plane ground motion.

The cracks near the ends of the walls are probably the result of decay of the bases at those locations. The cracks could also be influenced by thermal expansion. In any case, providing additional support to the base of the walls should relieve the problem if it is continuing. If, on the other hand the mud brick material has loss its cohesion, the problem will probably just continue without having a reasonable treatment alternative.

Seven cracks were patched with mud as a method to monitor whether or the cracks were active. Four cracks were patched on the center low section of the east wall, one on the west side of the west wall, and two on the east side of the west wall. Cracks were first cleaned and then mud was packed as dry as possible into the crack ; the entire crack was not filled only enough to see if a crack reopens later. Hairline crack and at least one crack that echos the crack itself will reopen. These are not important and not indicative of active movement. It is thought that all of the cracks are active, the real question is how fast and how much are they moving. The crack on the upper part of the west wall may only be affected by thermal expansion and contraction; the other cracks are primarily on detachment cracks and they should continue to open. The rate may be too slow to see anything immediately, but they should be checked periodically to see. In the future more quantifiable crack monitors may be necessary. Figure 50 shows one of the mud patches being installed.

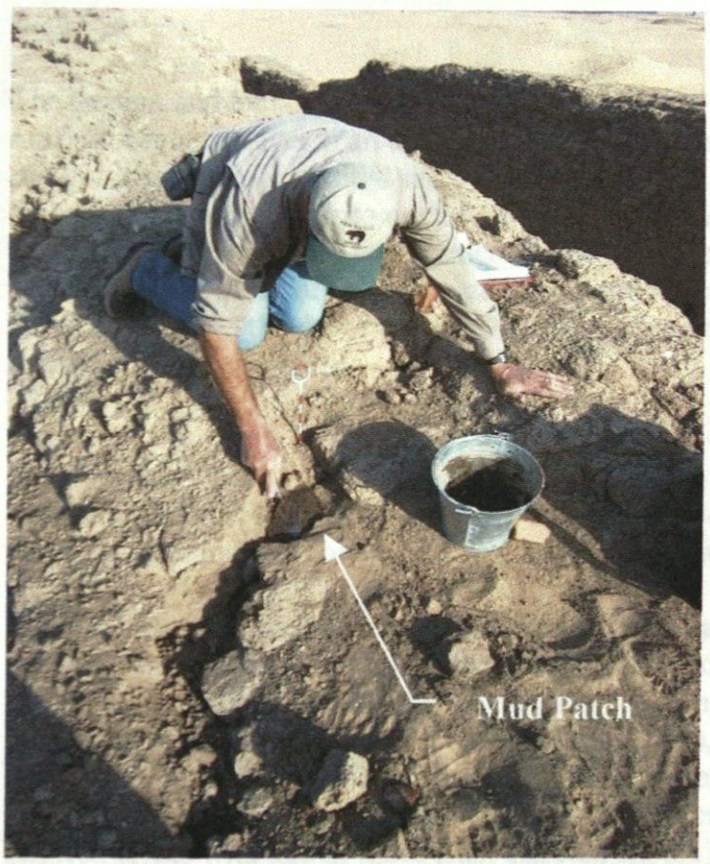

Figure 50: Patching large on the top of the east wall t monitor movement.

Loose Mud Bricks

There are literally thousands of loose mud bricks in the walls of the Shunet. Most will remain for a considerable time, some will fall individually, and some will fall in groups as some supporting element collapses. They occur along and in groups. They appear in the areas of greater fracturing such as the area near the hole in the west wall near its north corner and the center section of the east wall. They also occur on the top of the north wall where water appears to have eroded the mortar that bonded the individual bricks together. They are a safety issue and one brick that fell 10 meters could cause serious injury.

Mud Drips

The mud drips that occur primarily on the north side of the north are a mystery at this point. The concentration and the erosion caused by the water cannot be explained by a predominant weather direction. There is some evidence of rainwater on other walls but they are minor in comparison. At this point in the process it will just have to remain a mystery. The only logical explanation is the predominant weather direction although the evidence does not support it.

Wall Fall

The amount and location of wall fall was documented during the first site overview in order to begin to develop an understanding of the more critical areas. The wall fall was seldom noted after that initial site overview. It will be important during future archeological excavations to document the amount and the location of any construction materials. There may well be evidence that will help in developing an understanding of the actual time that some of the failures and the rate of decay. An understanding of the rate of decay is critical in the development of an understanding of the consequences of delayed conservation interventions.

Insects

Insects in the past have affected the Shunet and have cause damage. Insects presently cause damage and will continue to cause significant damage in the future.

It appears that insects ate the organic material from the mud bricks, probably a fine chopped straw, causing the characteristic vermiculated effect. This needs to be confirmed by material analysis, although there is nothing that can be done to change that now. The effect was pervasive and it appears that all mud bricks, regardless of whether they were located on the surface or in the center of the walls, were affected. There are some mud bricks that appear to have been affected less than others. A comparison of one of the most affected bricks with one of those least affected should provide important information in answering the question. The mortar, however, which appears to have been made with the same soil, but without vegetable matter, is not affected. Another part of developing an understanding of the issue is to consult with an entomologist familiar with the local area. Even more importantly, an entomologist could provide important information on the present insects that are affecting the structure.

The mud wasps or hornets are a direct cause of a substantial amount of decay. They prefer to attach their nests to the underside of an overhang, normally a projecting mud brick and the process of building more and more nests continues until the mud brick or wall section can no longer support the weight of the nest. The more obvious effects are the north side of the south wall. There is a very distinct horizontal line at which the nests are concentrated, above which is smooth wind eroded wall surface and below which is a concave and rough textured wall surface. The other obvious effect are the extremely large nest colonies that occupy some of the larger concave areas of the walls such as those on the west side of the west wall and the west side south section of the east wall. An entomologist is also need to provide information about these insects so that a treatment can be implemented.

Analysis of the Threats

The conditions that affect the performance of a material, a building or system component, a structure or a site are basically grouped in two main categories. These categories are intrinsic and extrinsic. Both normally consist of conditions that are detrimental to the structure's performance and those that are beneficial. An obvious beneficial condition in the extrinsic category at the site of the Shunet is the lack of rain; a detrimental extrinsic condition is the wind.

An example of an intrinsic condition is the construction system. It appears that the use of through wall headers nearly exclusively in the walls of the Shunet is detrimental; alternating courses of headers and stretchers throughout the mass of the walls would have performed better. The high quality of workmanship is a beneficial intrinsic condition and to some degree reduces the effect of the bonding pattern.

Intrinsic conditions are those that normally cannot be changed in a heritage monument. They are the characteristics of the building materials and the building systems and to change them would affect some of the values associated with the monument. Under the conservation principle of minimum intervention the intrinsic conditions can be considered simply the rules under which we play the game of heritage protection. The "rule" of through-wall headers cannot be changed. The object of the game is to restrict the movement of the structure so that the inherent weakness of the construction system does not come into play.

Extrinsic conditions are those that might be changed or altered to prolong the life of the monument. They are what are most often considered the causes of deterioration. Humans that use a heritage monument as a source of building materials for their own use is an extrinsic condition; their activities can be stopped. The ponding of water at the base of a wall allowing water to wick up into the wall is an extrinsic condition that can be eliminated, perhaps by simply redirecting the water to another location.

Some extrinsic conditions cannot be changed without an effort that would be heroic. The wind at the Shunet cannot be changed without such a heroic effort. While it may not be feasible to change the direction and the rate of the wind, there may well be some efforts that would change the micro-patterns of the wind and reduce the effect of the wind in some areas. Perhaps subtle changes could re-direct the wind of the micro-patterns to a less sensitive area. It might also be possible to protect the surface eroded by the wind with a sacrificial render, if the covering of the original surface did not negatively impact another value of the structure.

The obvious key is knowledge and understanding. To make the best decisions for the protection of the monument, it is important to know as much about the intrinsic and extrinsic conditions as possible. It is not sufficient to only know, for example, all the characteristics of extrinsic conditions. The only way it is possible to know whether or not they are detrimental is to know how the intrinsic conditions of the materials, systems, structure and site are affected by them. An intrinsic condition of mud brick is that the material has no ductility. Is that detrimental to the performance of the structure? It is detrimental only if there are conditions that stress the material. Is the lack of clay in the material used to make the Shunet mud bricks a detrimental intrinsic condition? It is detrimental only if the material is subjected to water.

Following is a table that lists threats and potential threats to the monument and the site. Associated with the threats are the effects of the threat, and a brief list of potential alternative actions. In some cases a threat may be only potential at this point because there may not be enough information about its affect. In that case, there are suggestions on what is necessary to determine whether or not the condition is in fact a threat, or to determine the severity of the threat. In another case the effect may be known but not the associated threat, or cause. In that case the effect will be listed without a threat. In still other cases there may be several potential threats or several potential; all are listed to be further evaluated and acted on. The immediate actions or emergency actions are highlighted.

Obviously the table is a work in progress. As more information is available some threats will be added and possible some will be eliminated or their severity may change. The table will also evolve as treatment alternatives are evaluated.

TABLE OF THREATS

THREATS	EFFECTS	ACTIONS
1. Wind 2. Humans and Animals	1. Surface erosion	2. Determine the rate and severity of the effect of the wind 3. Monitor the actual micro patterns oft the wind within the Shunet 4. Monitor human activity 5. Control human access to fabric 6. Determine the habits of the critters
1. Birds 2. Animals 3. Insects 4. Wind erosion	1. Nest building 2. Increase voids and holes	1. Evaluate the effects on wild life by filling the holes. 2. Determine the habits of the critters 3.
1. Insects?	1. Decay of mud bricks (vermiculated)	1. Determine the characteristics of the material 2. Identify insects or microorganisms. 3.
1. Ground motion movement 2. Undermining the walls 3. Inaction 4. Cracks 5.	1. Delamination/detachment of wall sections 2. Wall Collapse 3.	1. Emergency actions to stabilize walls. 2. Develop Safety plan 3. Take safety measures 4. Establish priorities 5. Determine characteristics of material
1. Undermining 2. Ground motion 3. Inaction	1. Cracks	2. Prioritize cracks 3. Test repair methodology
1. Rainfall 2. Wetting walls 3.	1. Mud drips 2. Surface erosion 3. Surface crusts 4. Formation of corrosive salts 5. Micro detachment of	1. Monitor effects and causes 2.

	surface 6. Washing away mortar	
1. Repeated high temperatures for several thousand years. 2.	1. ??????	1. Determine characteristics of materials. 2.
Loose adobes	1. Displacement and loss of fabric. 2. Injury	

Recommendations

Long-term recommendations are dependent on the answers to a vast away of questions and the development of additional information; consequently specific recommendations for long-term interventions are not responsible. Recommendations to undertake studies to begin to answer some of the questions that will lead to long-term interventions are certainly appropriate at this time. There are also priorities for those additional studies and the collection of information that are necessary to respond to immediate needs. There are also emergency needs that need to be addressed that can respond to the present state of conservation of the monument. The emergency actions are for the purpose of the protection of the resource; they will have to be expanded to accommodate the activities of the archeological field season.

Emergency Actions

The following are listed in priority order. The order could shift somewhat once the actual work of the emergency actions begin. Some of these can be accomplished much more easily than others, and some of the actions may allow work to proceed in the vicinity.

1. Install shoring and bracing at the bases of the east side of the low center portion of the east wall.

- Fill holes, voids and undercuts at ground level with soil bags and other materials as appropriate (permanent repair will come later)
- Construct buttresses for the walls to resist additional movement.
- Cordon off and restrict activities near east side of walls

2. Install shoring and bracing at the north end of the west wall in the area of the through-wall hole (Figure 38)

- Erect scaffolding and shoring and bracing to support wall and suspect wall portions
- Pack voids with mud bricks and soil bags to provide support to the delaminating upper portions of the walls
- Cordon off and restrict activities on both sides of wall

3.Install shoring and bracing at the south end of the north portion of the west wall (Figure 39)

- Fill voids with soil bags and support upper portions with shoring.
- Cordon off area and restrict access

4. Install shoring and bracing in the cells along the west side of the west wall.

- Fill voids with soil bags and support upper portions with shoring.
- Cordon off area and restrict access

5. Install shoring and bracing at the southeast corner (Figure 43).

- Fill voids with soil bags and support upper portions with shoring.
- Cordon off area and restrict access

6. Install soil bags and use to buttress the lower wall base at the north end of the west wall at the gap of the west gateway.

- Fill voids with soil bags.
- Cordon off area and restrict access

7. Install shoring and bracing at the bases of the east side of the low center portion of the east wall.

- Fill holes, voids and undercuts at ground level with soil bags and other materials as appropriate (permanent repair will come later)
- Cordon off and restrict activities near east side of walls

Immediate Actions

Immediate actions are things that should be done within the year and sooner if conditions change that may affect the structure. The research aspects of the immediate actions should begin as soon as possible so as not to delay future actions that are dependent on the research and studies.

1. Undertake a more thorough site investigation of the ends of the walls in the area of major cracks and detachments
2. Identify additional fabric protection issues.
3. Investigate and initiate field tests of appropriate repair methodology.
4. Undertake a comprehensive material analysis of the mud bricks and mortar
5. Determine the extent, the species of the insects that have affected the material in the past or are currently active.
6. Begin a monitoring program
7. In conjunction with the preceding activities complete the conservation plan for the Shunet

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APPENDICES

APPENDIX A Copies of Condition Survey Field Sheets

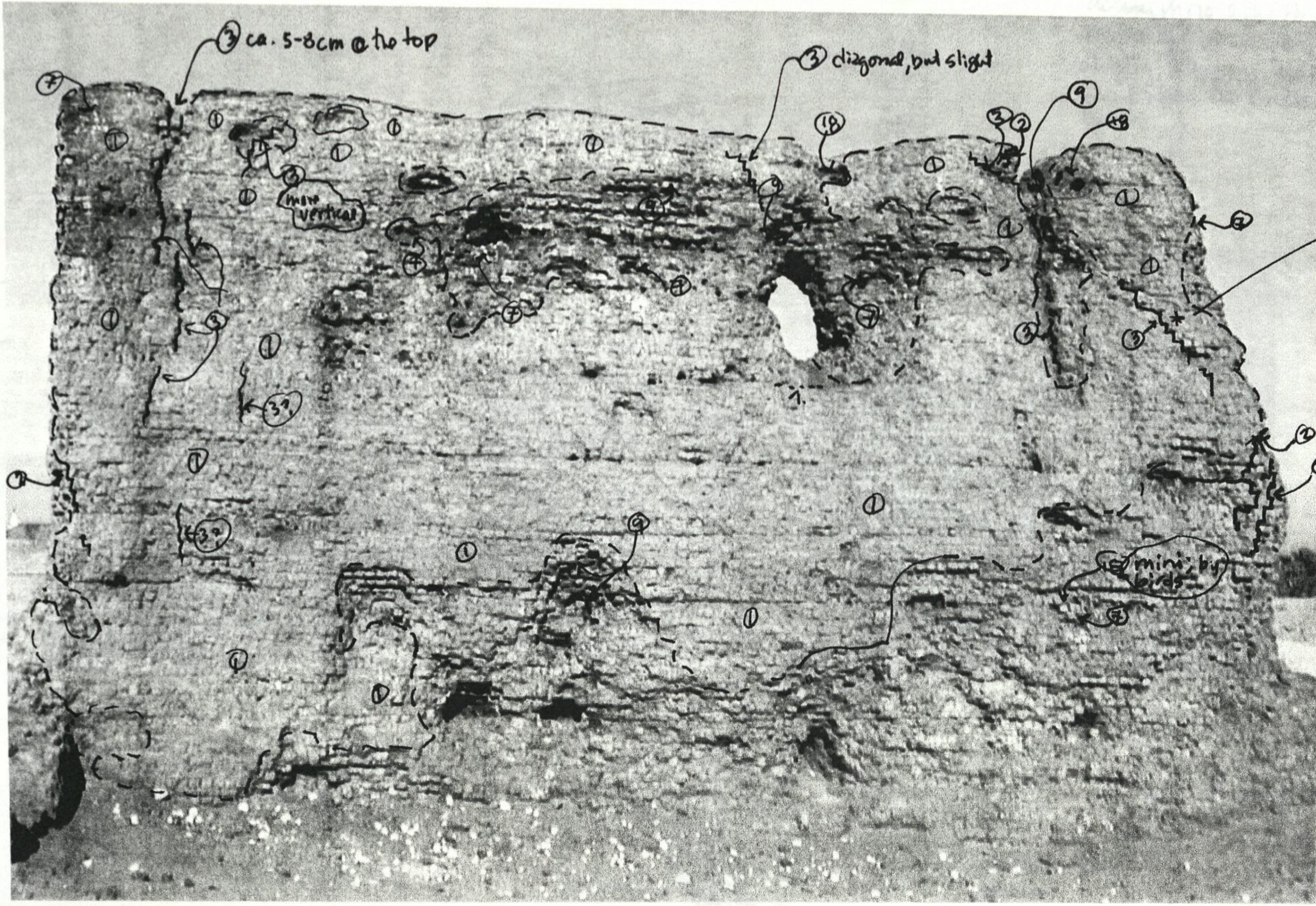
DECAY MAPPING – KEY TO INTERPRET FIELD NOTES

1. Wind erosion
2. Vertical delamination
3. Cracks
4. Vermiculated mud brick surface
5. Gray mud bricks (fresh fall)
6. Hornets / mud wasps
7. Birds
8. Insect digested mud
9. Loose mud bricks
10. Plaster
11. Wall section tilt – large wall sections that are rotating out away from main wall mass
12. Rain drip
13. Loose mud bricks
14. Horizontal delaminations
15. Brick mold marks
16. Wall fall
17. Diagonal bricks
18. Wall voids
19. Course mats – between courses of mud bricks
20. Human erosion
21. Wind scouring

East Wall Condition Mapping

1. [illegible] to [illegible] dow[illegible] bou[illegible] -4 [illegible] tu[illegible] table [illegible] flat [illegible] face

General comments: ① Very little hornet activity in areas of overhangs; wind has scoured these surfaces more than west wall. Hornets are all around on the east side on the SE corner of this wall section

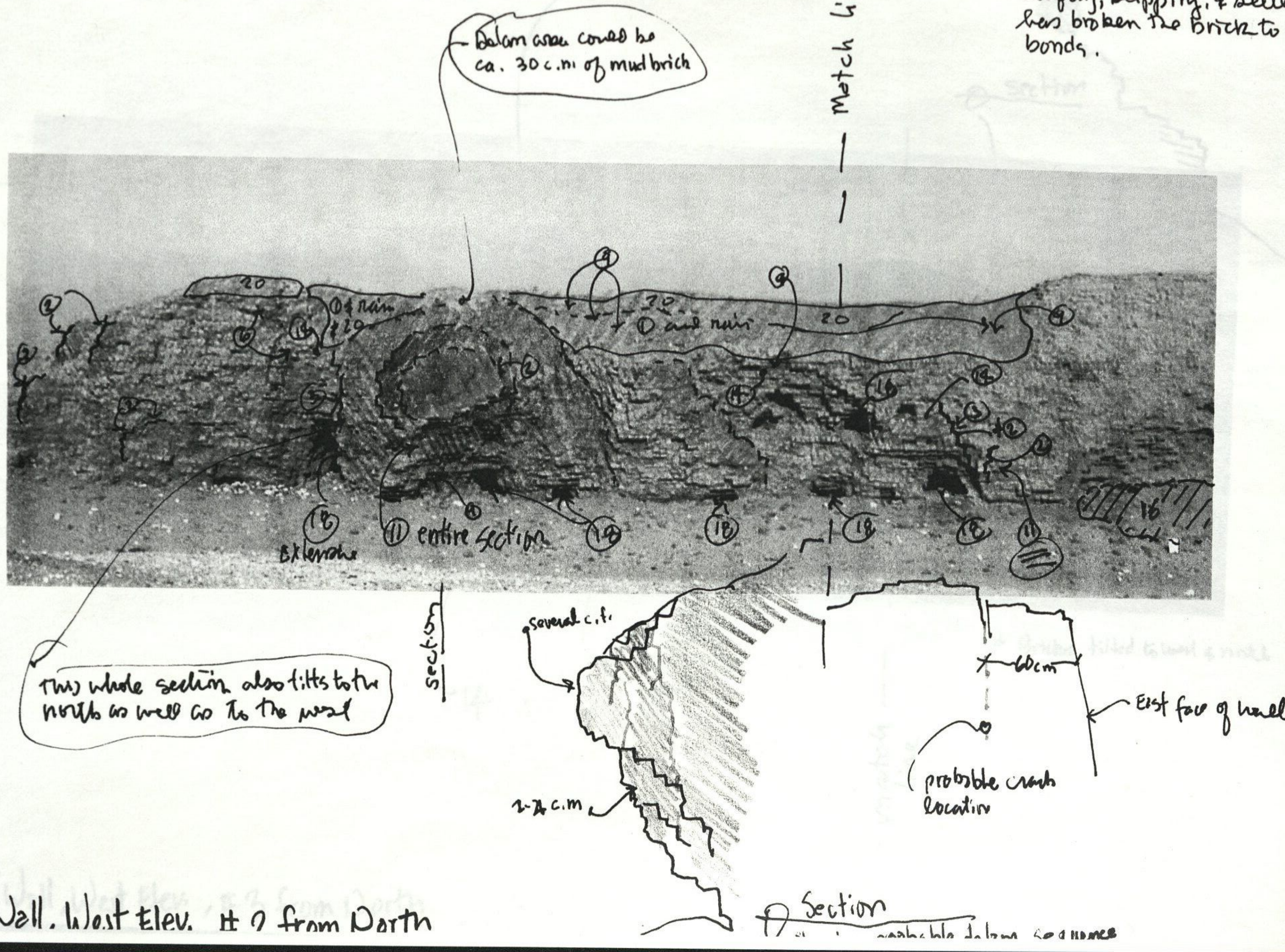


East Wall West-N end

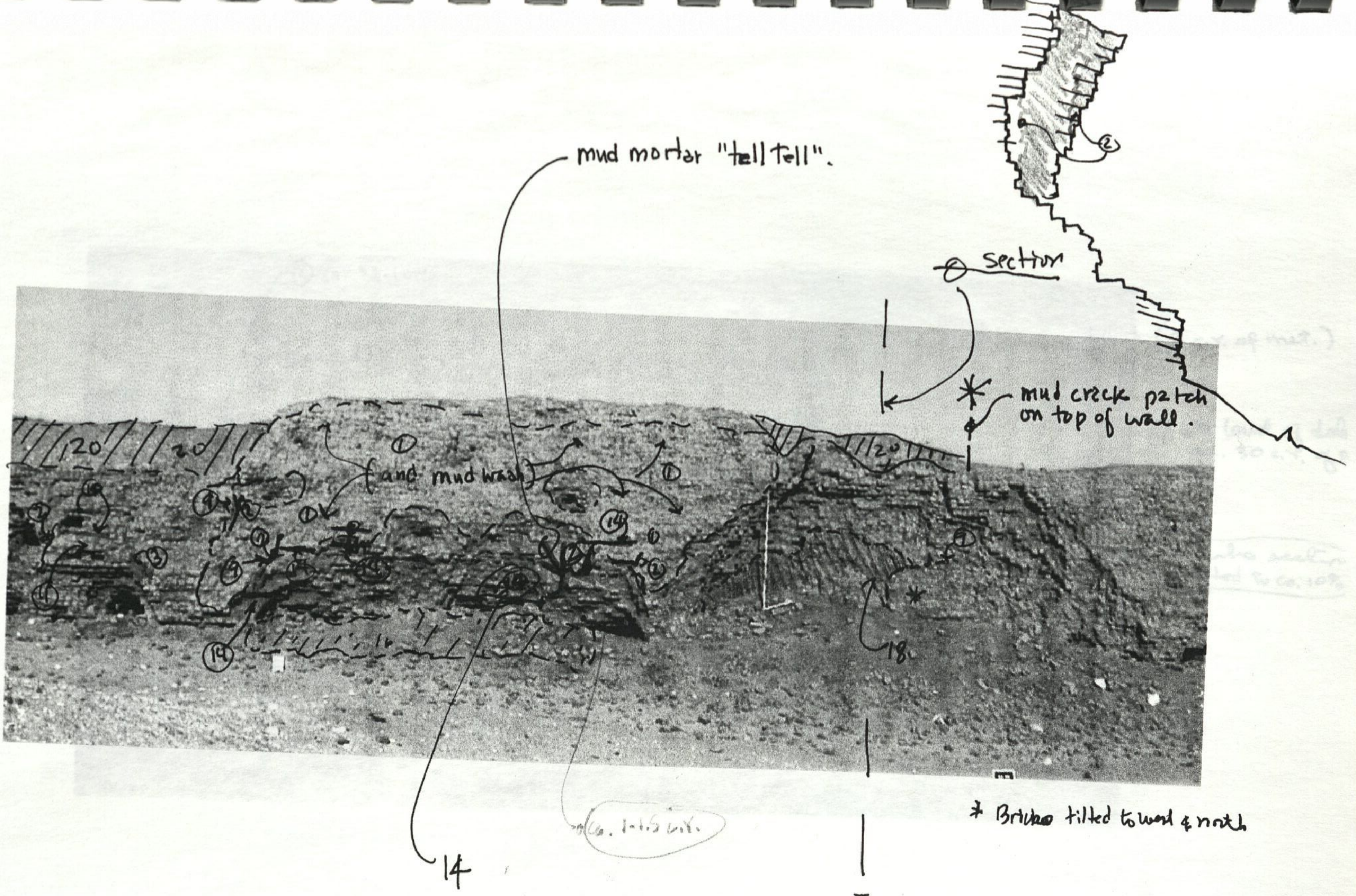
East Wall West Elev. #1 from North

15' x 10' x 6' = 900 = ca 30 c.m

Note: A lot of this wall is now acting more like dry laid masonry (ca section) as the shifting, slipping, & settlement has broken the brick to mortar bonds.

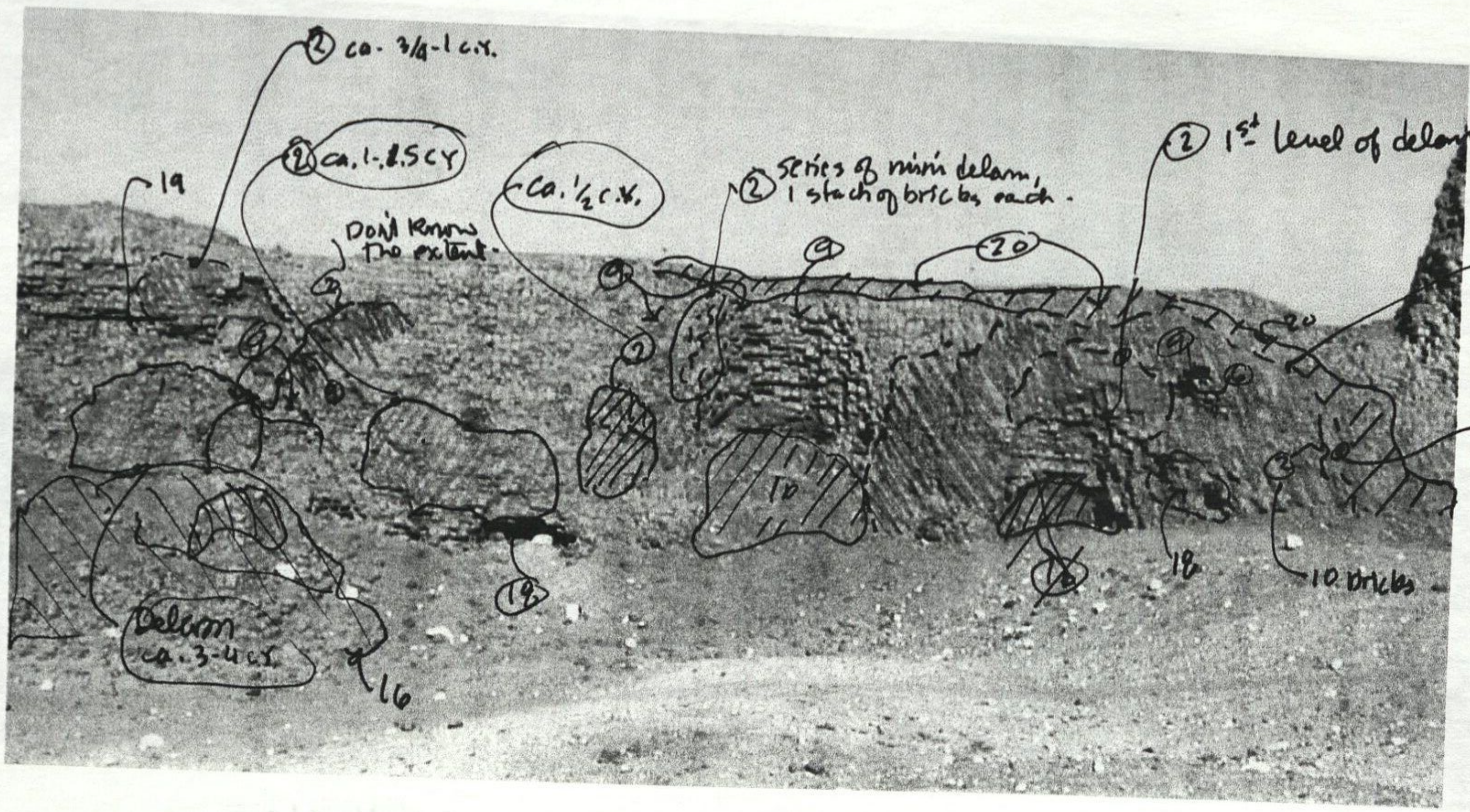


East Wall. West Elev. # 2 from North



East Wall, West Elev., # 3 from North

20x8x6 #1960
81
50



East Wall, West Elev., #4 from North

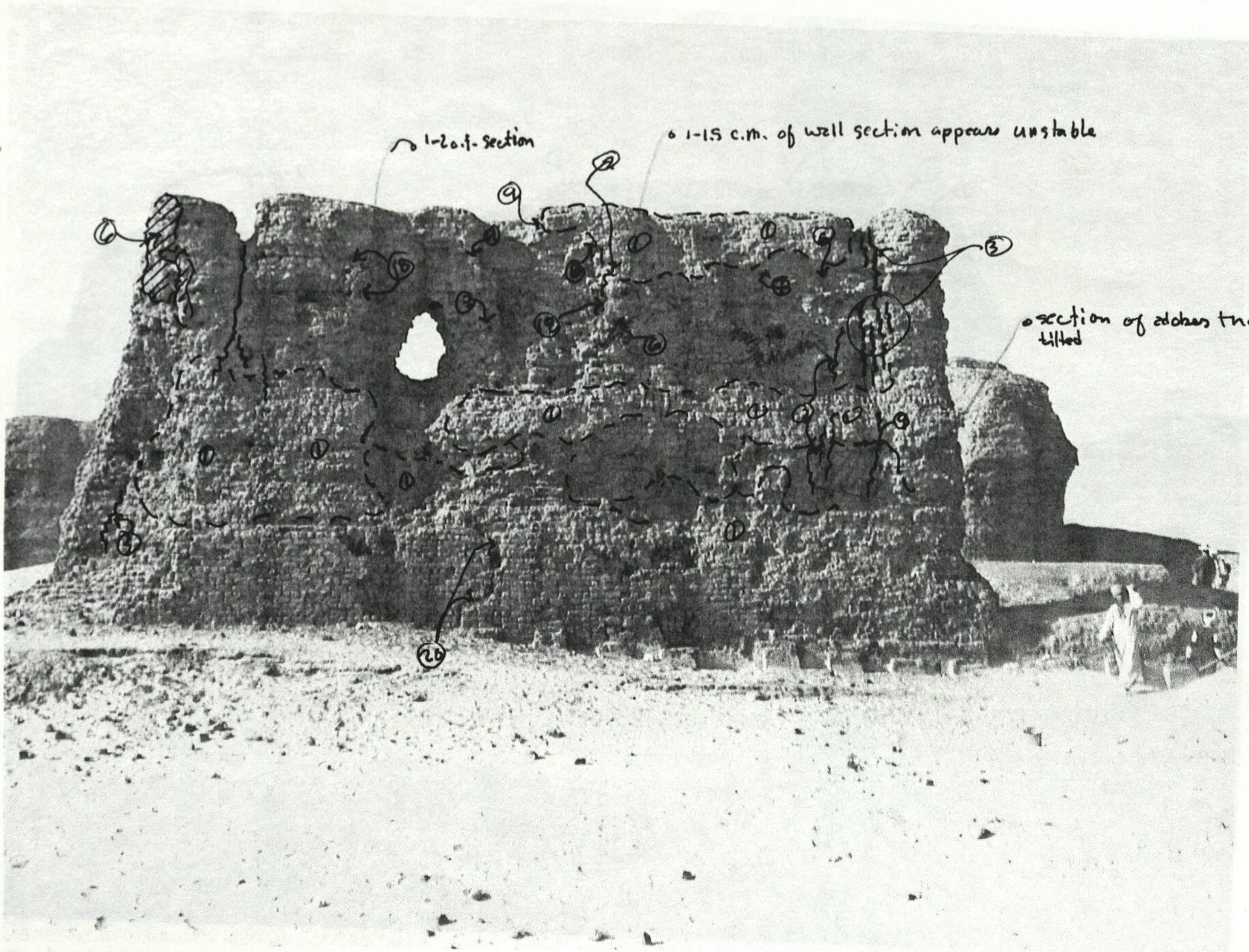
General comment: ① upper portion is heavily scoured similar to the north end of this overall wall ① less bird activity on this wall now and certainly less bird shit than on other walls

• 1 mud brick to 2 max. cracks (vertical delam)

East West 5 high Part Map -32n0021

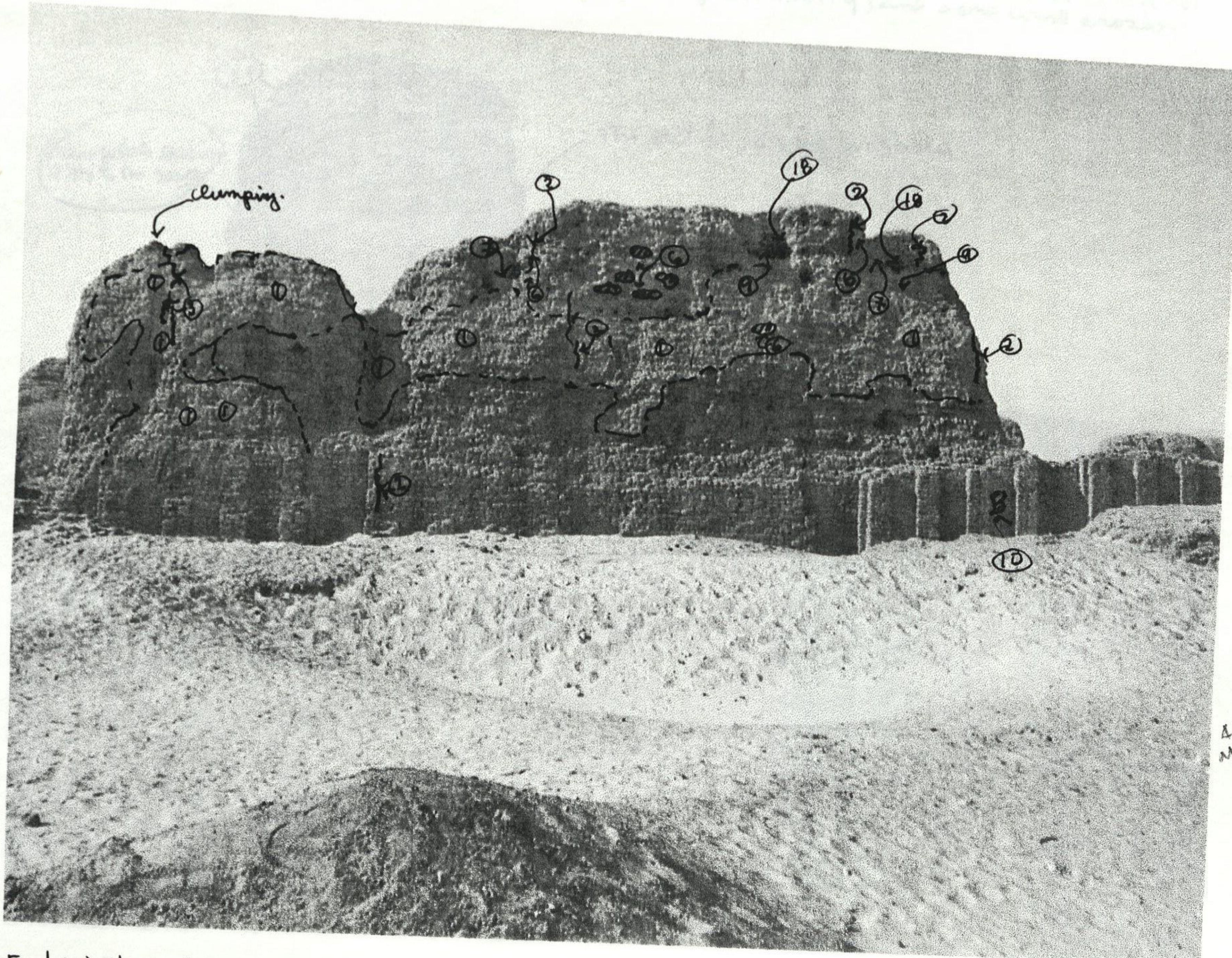
East Wall, West Elev., #5 from North

General comment: Wall is much less wind scoured than west side; some of that is because of more fall, but also from less wind.



Abydos East Wall
Map #3

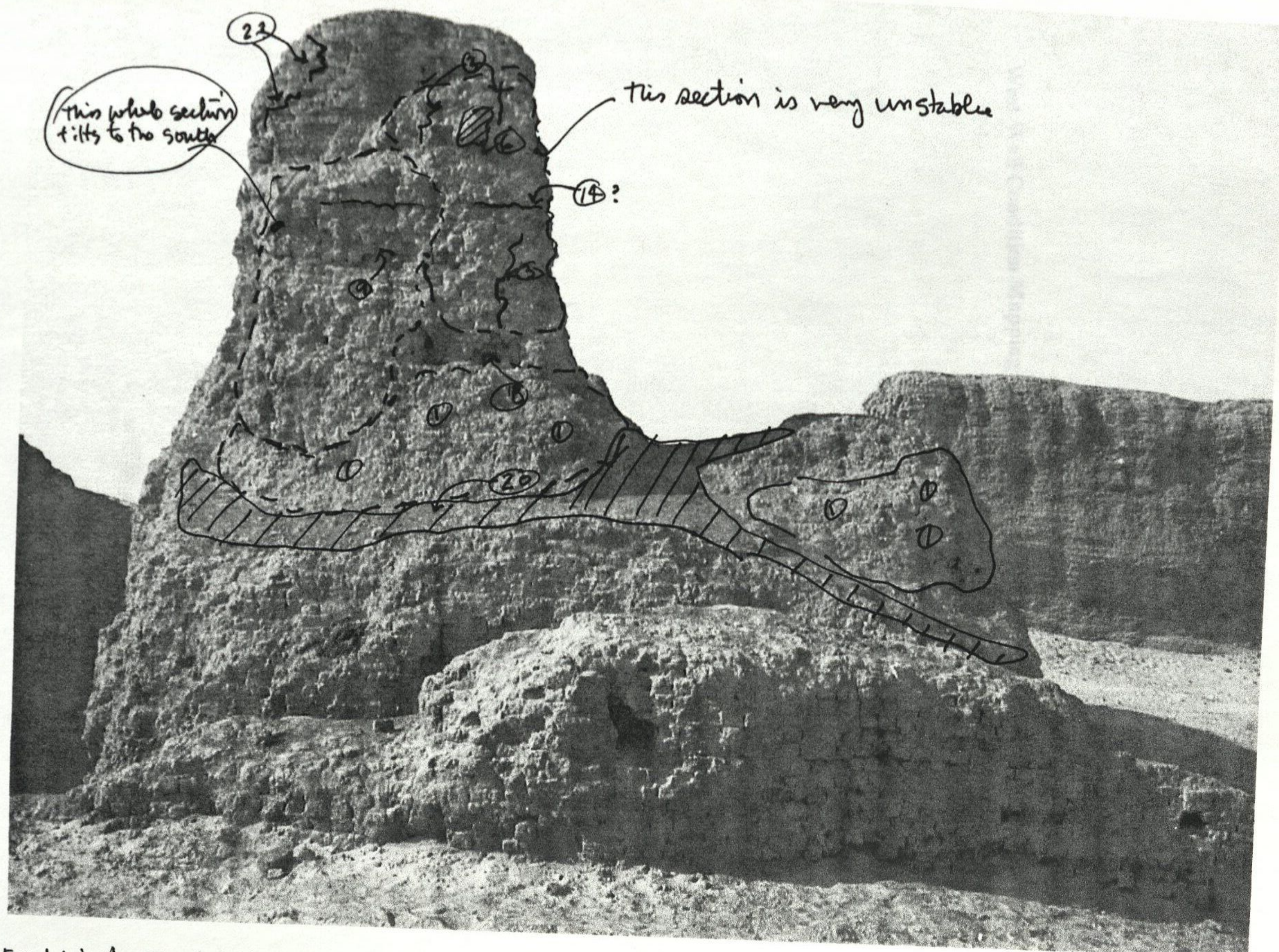
East Wall, East Elev. # 1 from North



East Wall, East Elev. #2 from North

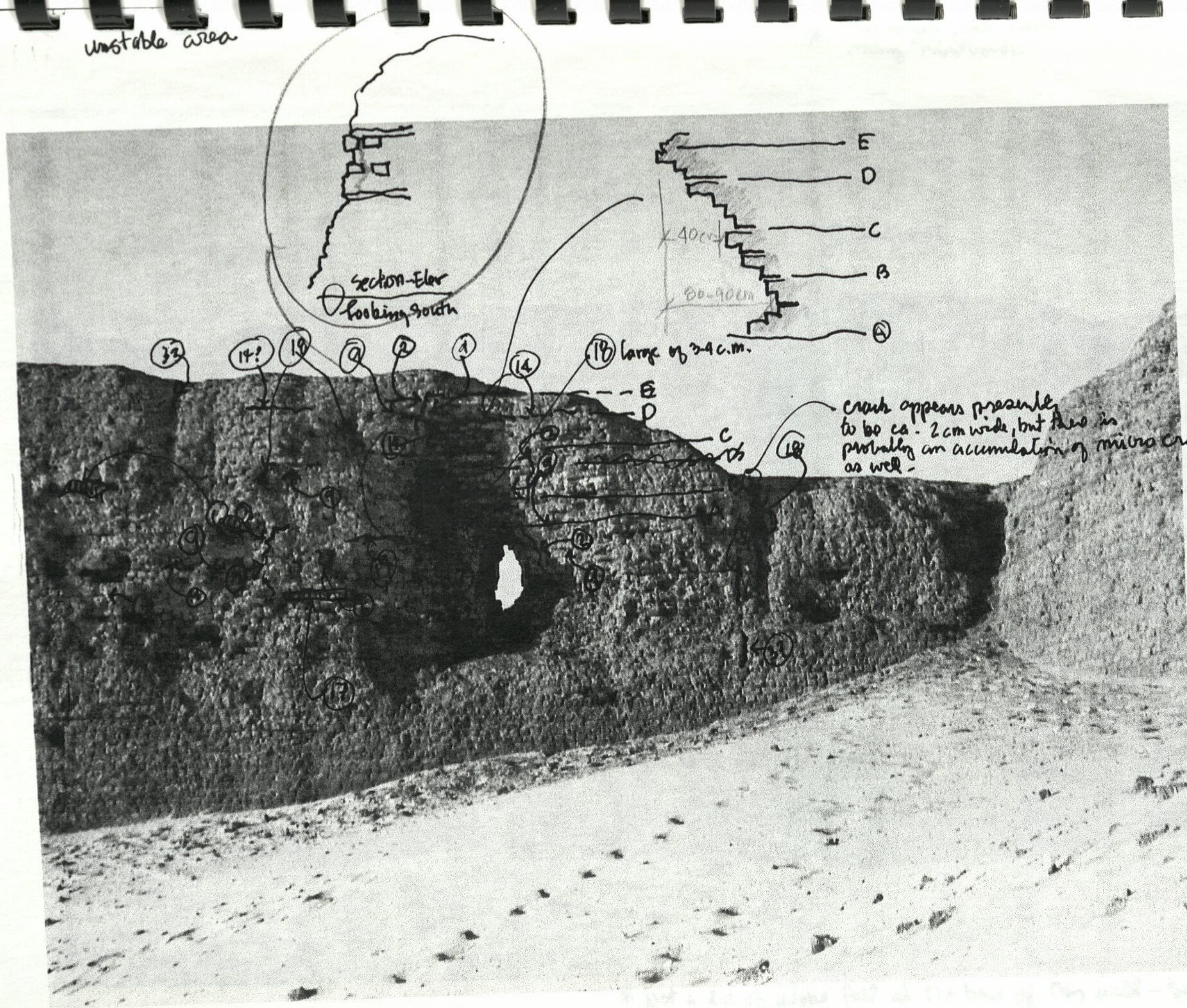
Abydos East
Map #2

... and erosion, but I ... hollow area was from severe
now believe that it is a combination
of wall fall (primarily) and some wind erosion.



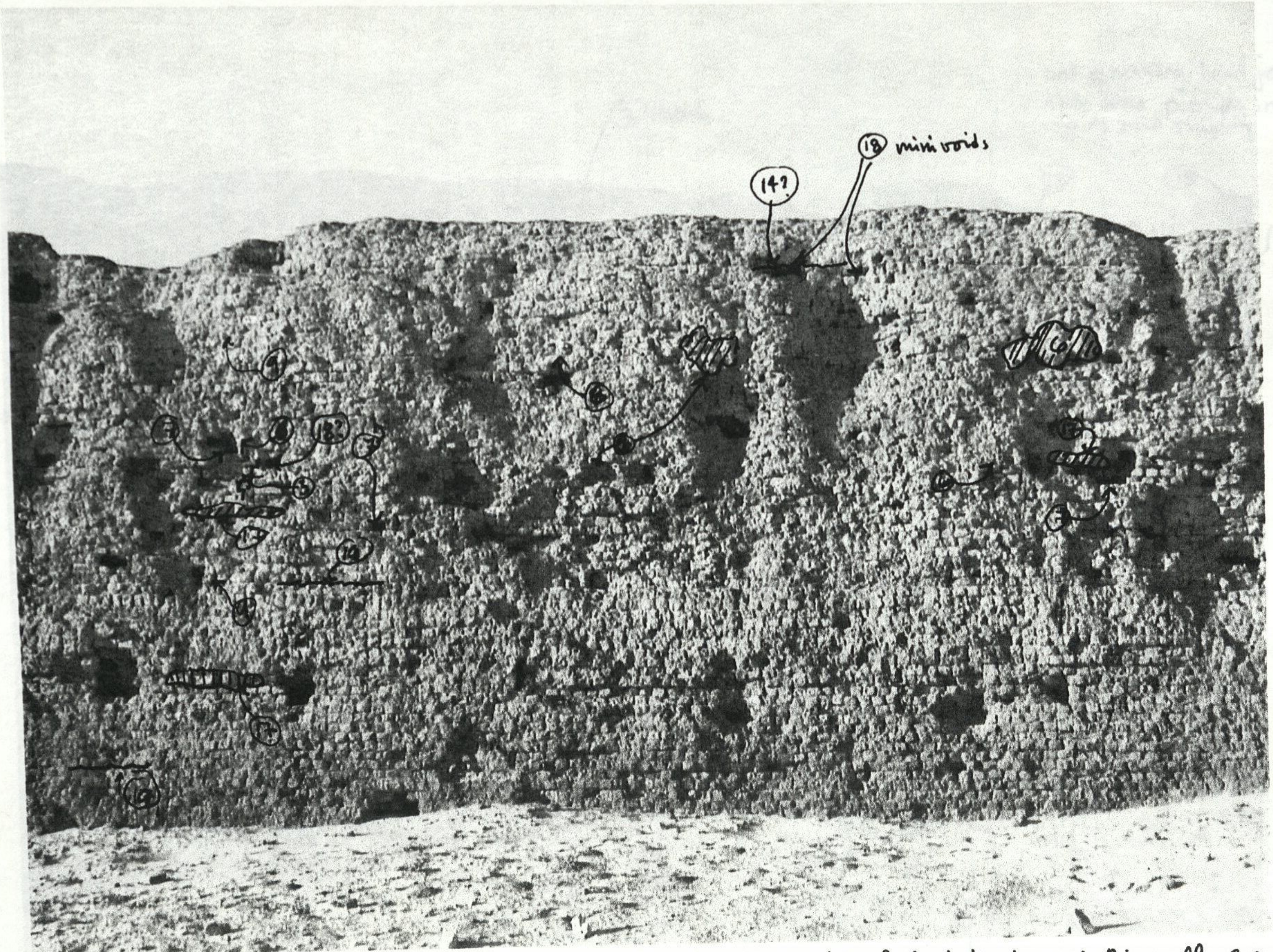
East Wall, East Elev. #3 from ~~South~~ North

West Wall Condition Mapping



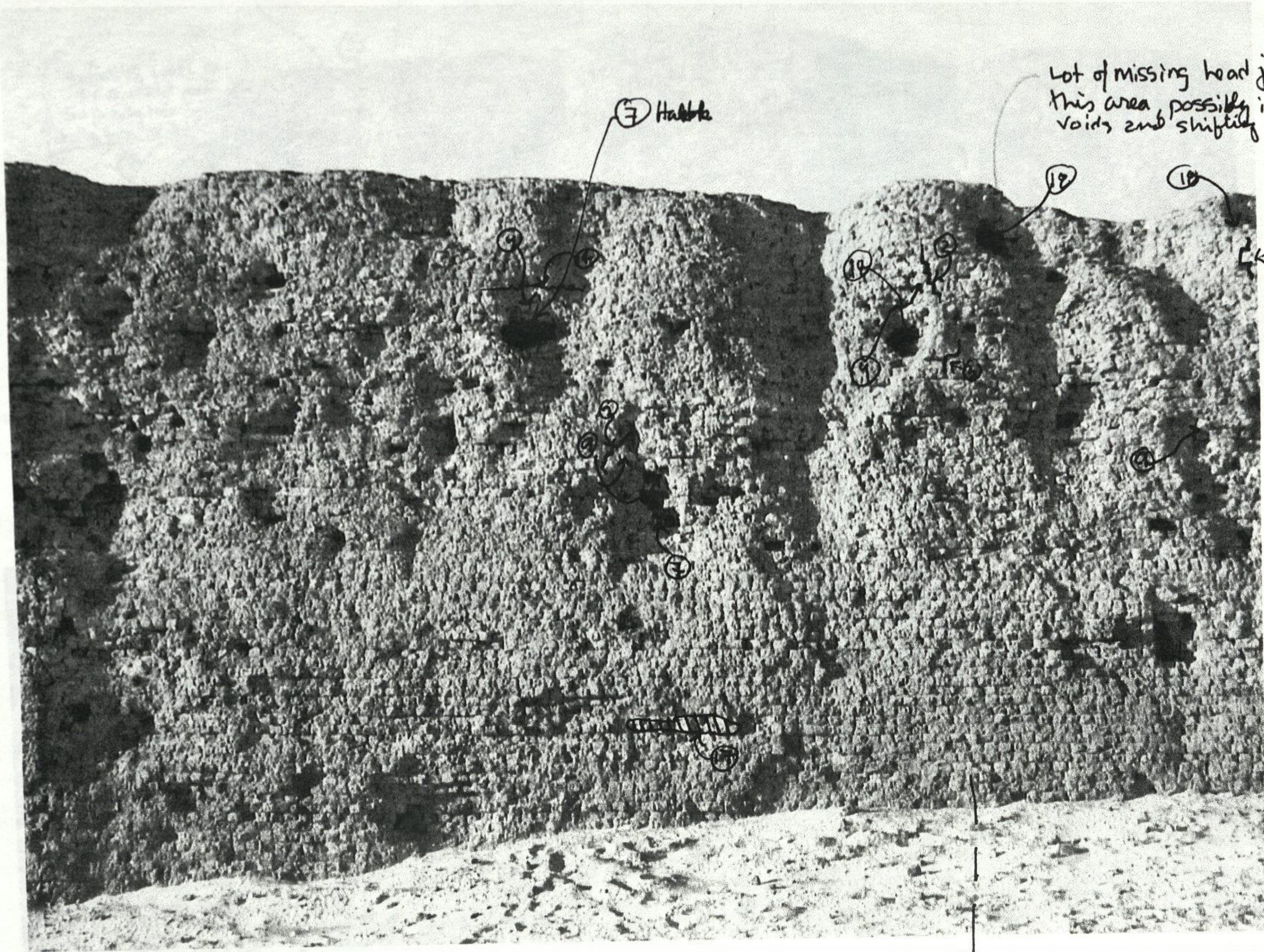
Westwall, East Elev., #1 from North

* This whole wall seems to have a great many "mini" voids.



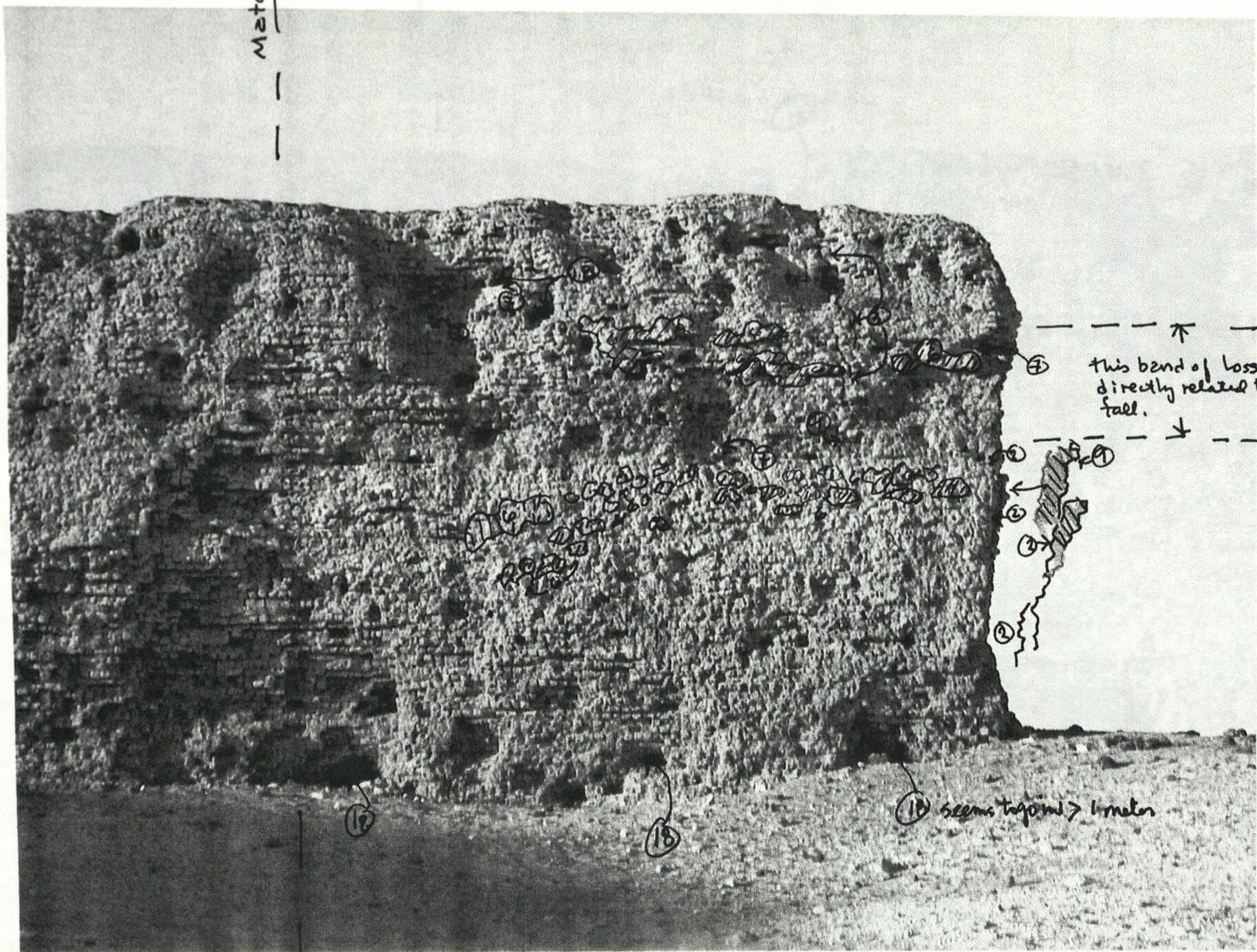
* Not a lot of adobe fall at the base of this wall – see plan. minimal, in fact.

WestWall. East Elev., #2 from North

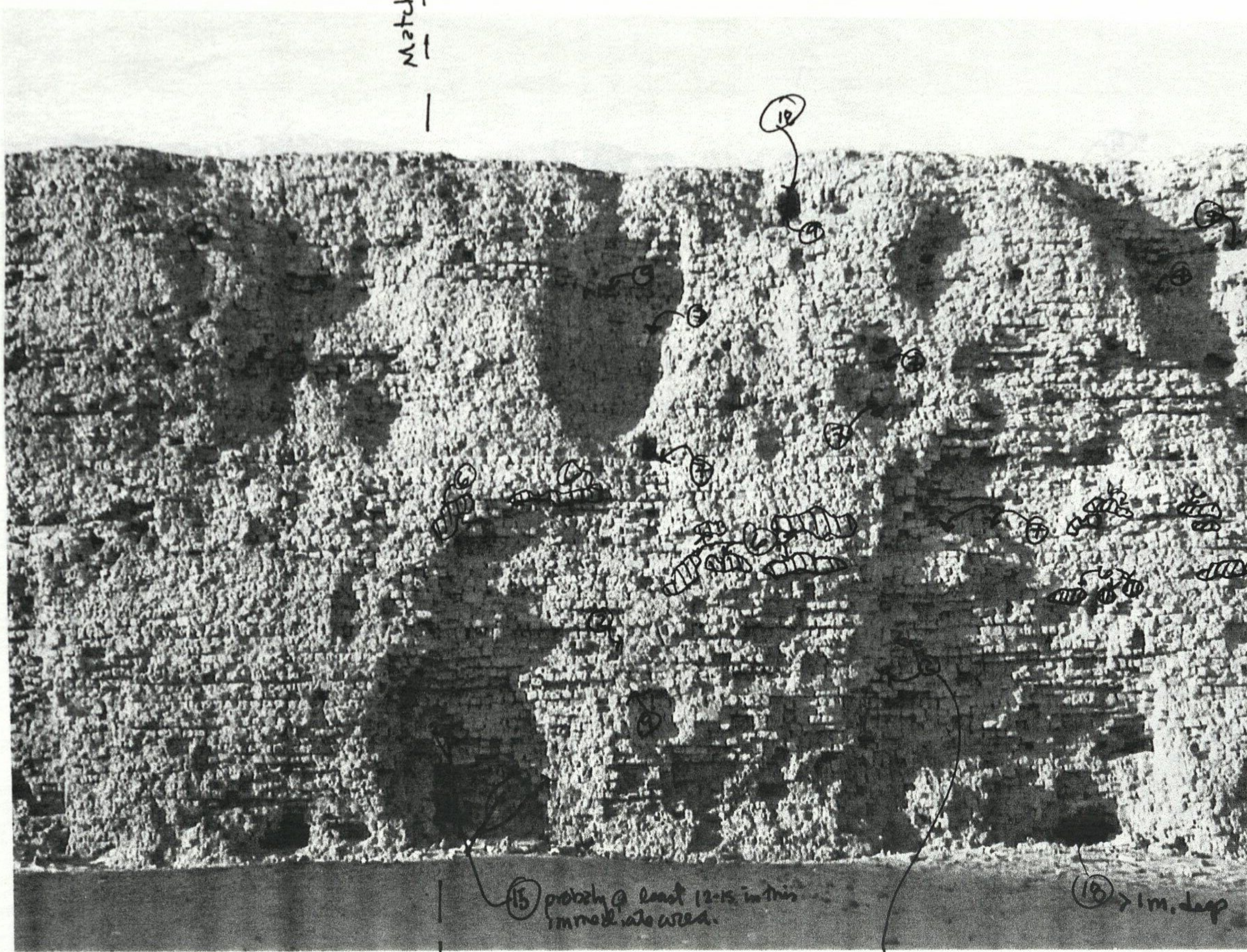


West Wall, East Elev., #3 from North.

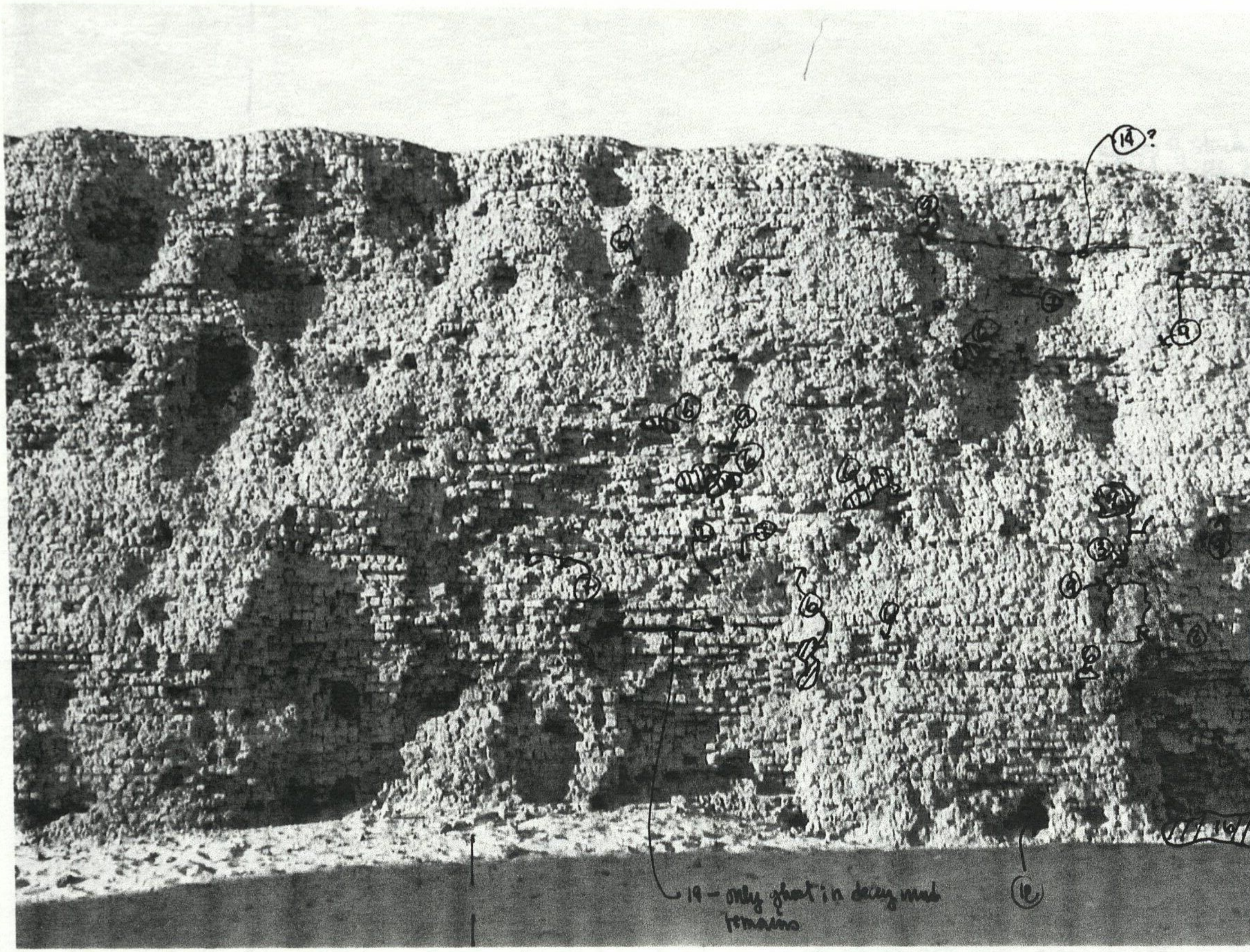
West Wall Ext. Elev. #4 from North



WEST Wall, East Elev. #5 from North



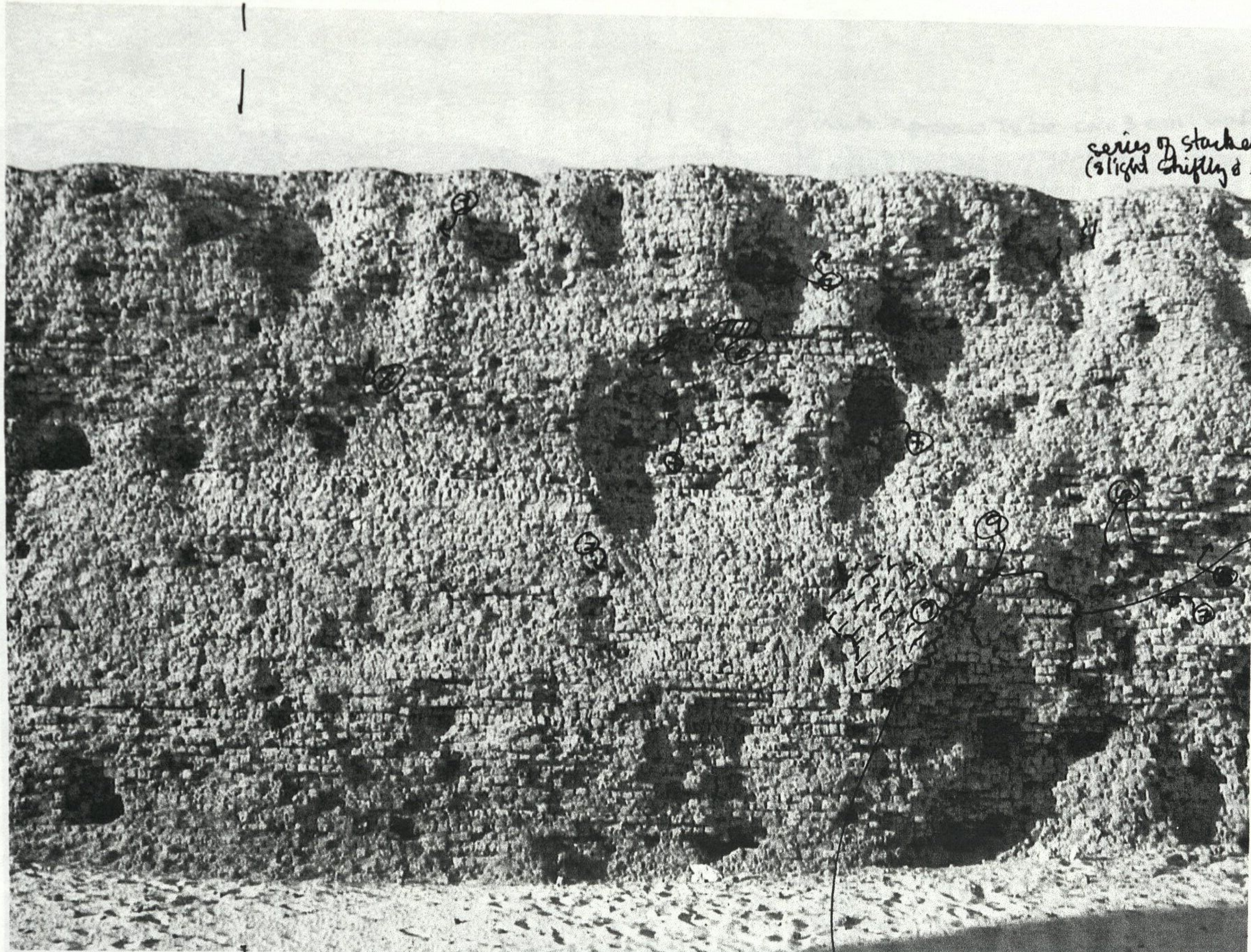
West Wall, East Elev., # 6 from North



West Wall, East Elev. # 7 north

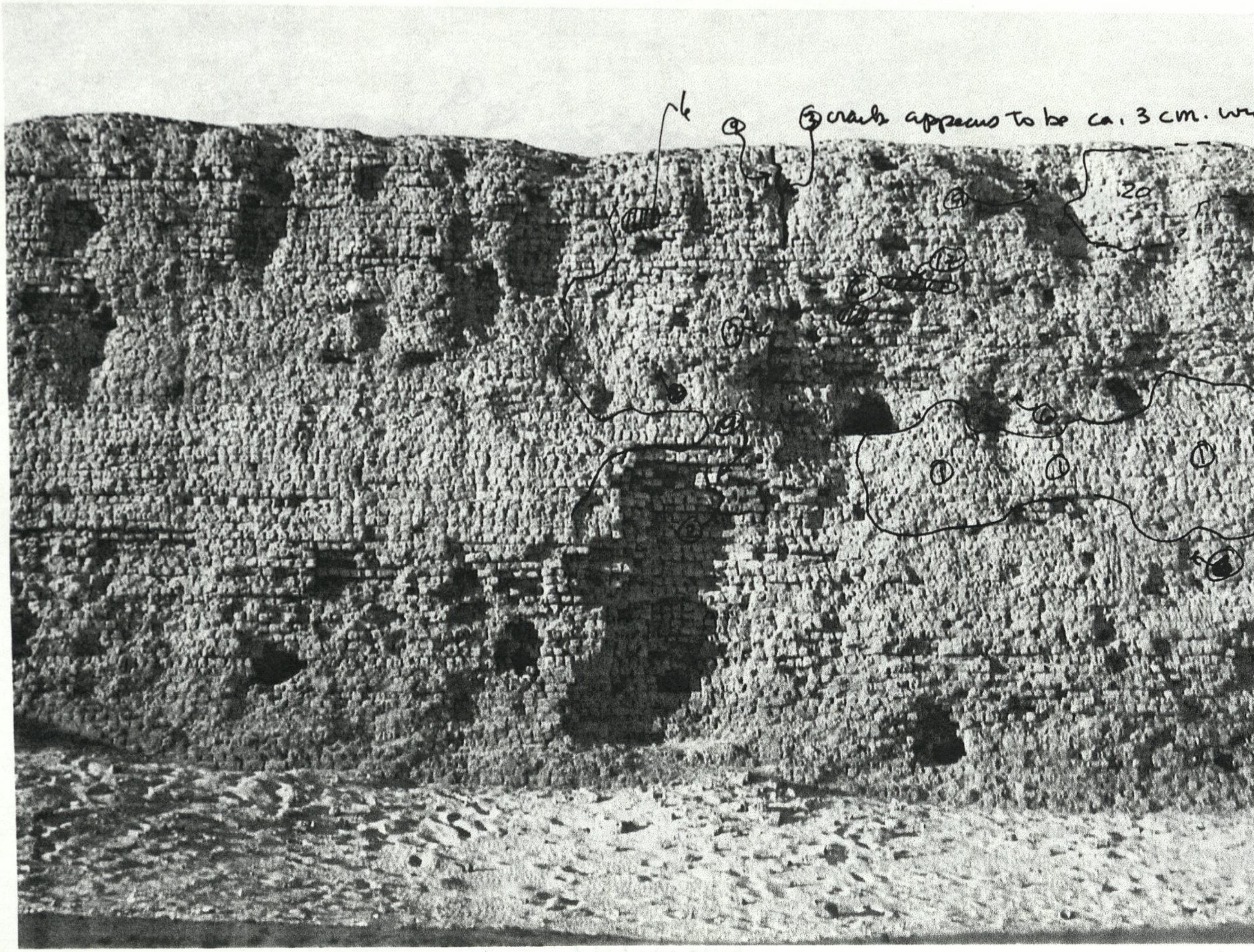
* [illegible] in "pl[illegible] [illegible] li[illegible] [illegible] of [illegible] long-term bird poop areas that looks like a lot of mud wash. Probably a combination of poop, mud, dust, etc.

match line



West Wall, East Elev. # 8 from North

* Birds become active in the morning and most active 8-10 am

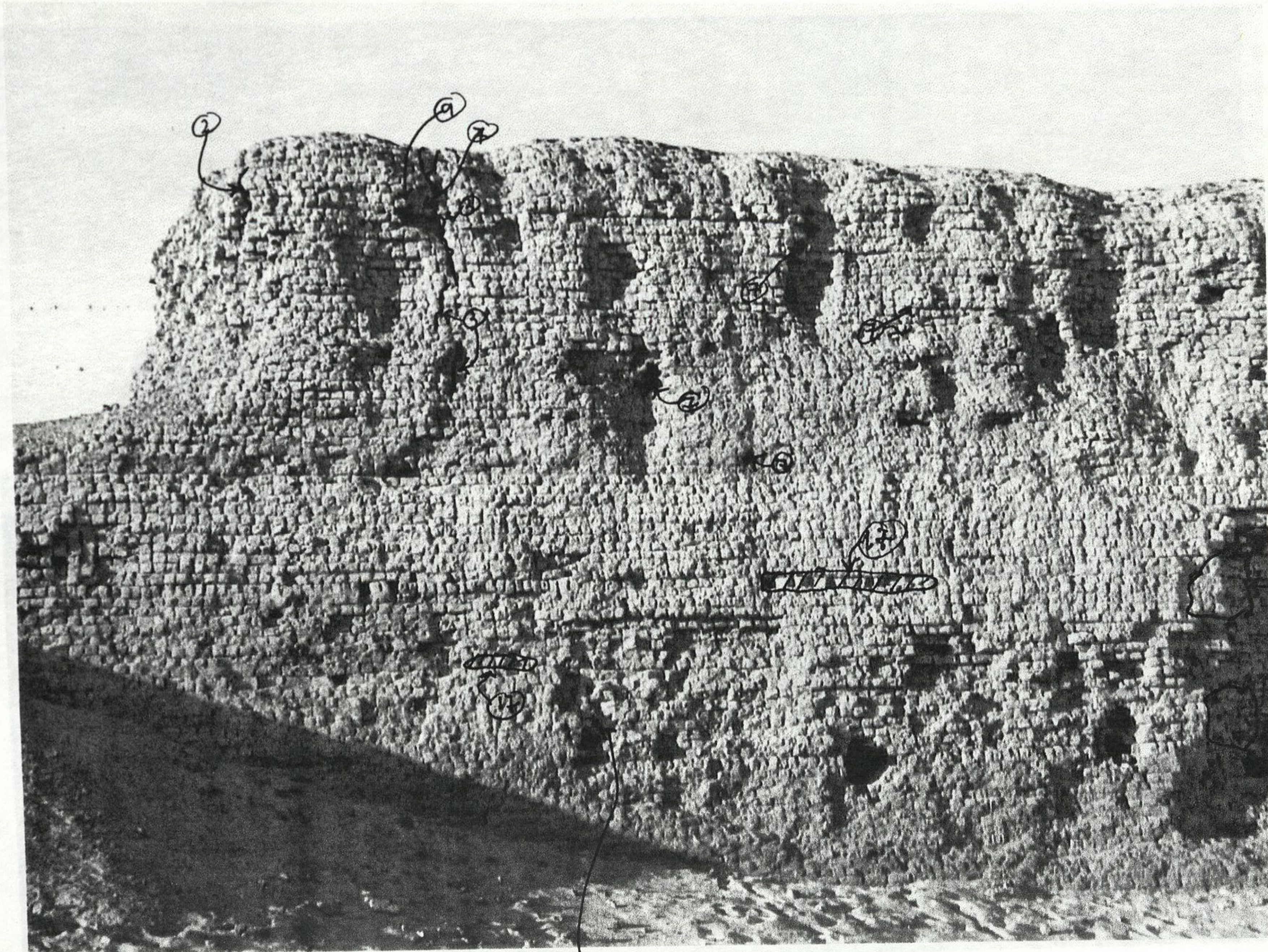


Wat Wall, East Elev. # 9 from north

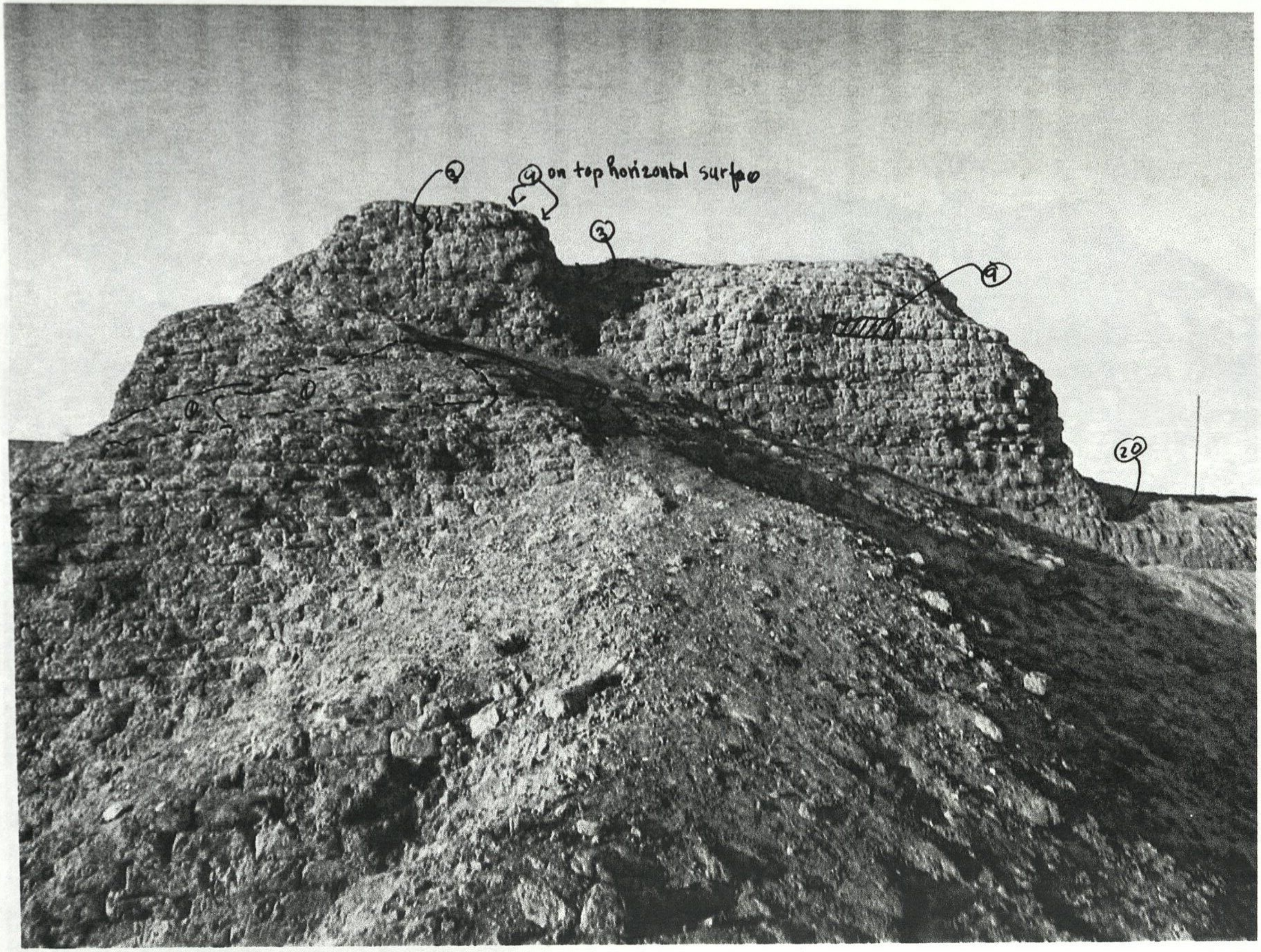
but nothing exists (decayed)

• No hornet nests

Little if any raindrip.



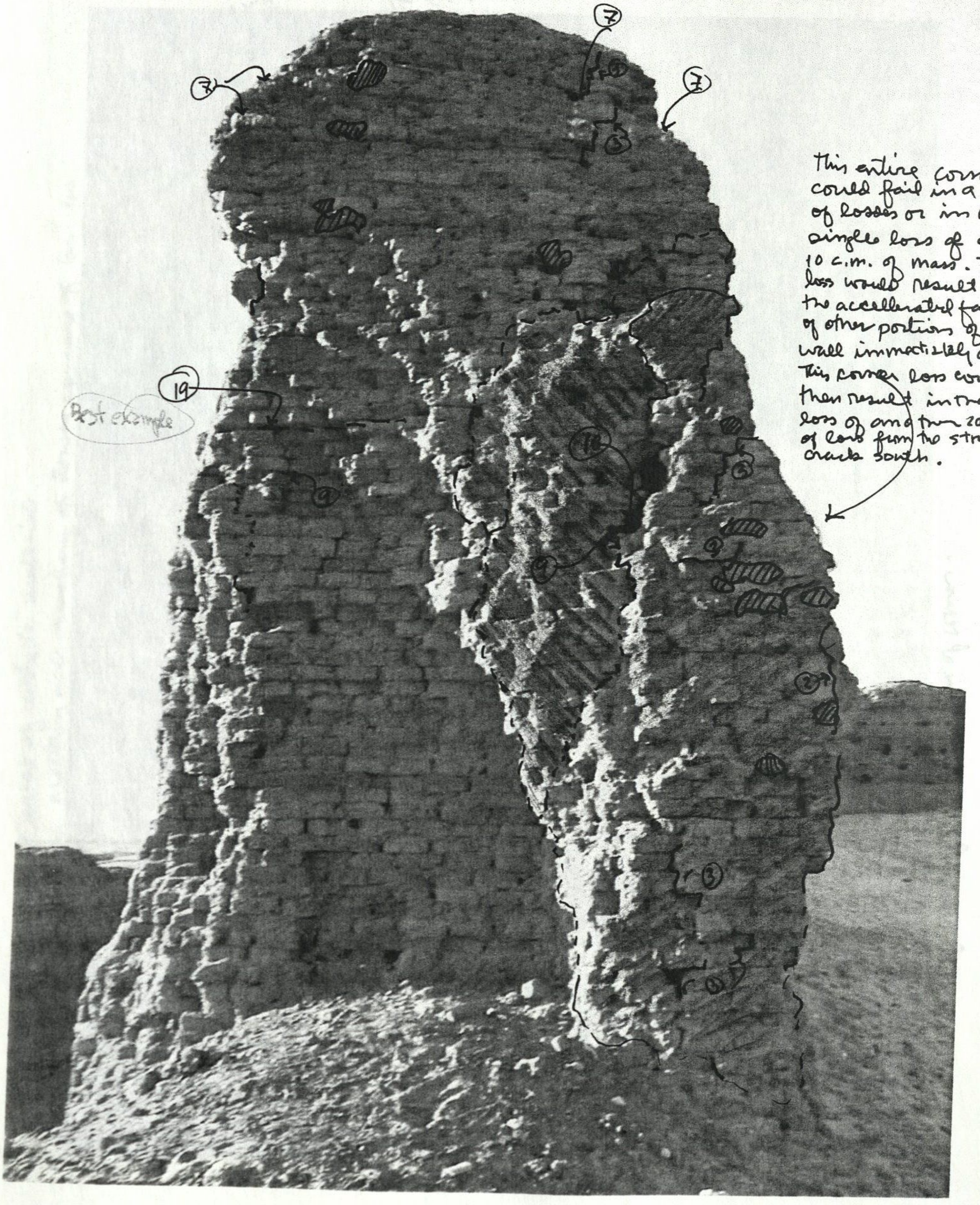
West Wall, East Elev. # 10 from North



West Wall, East Elev. # 11 from north

WEST WALL North end at Corn

11:30AM ; 24 Jan 2000



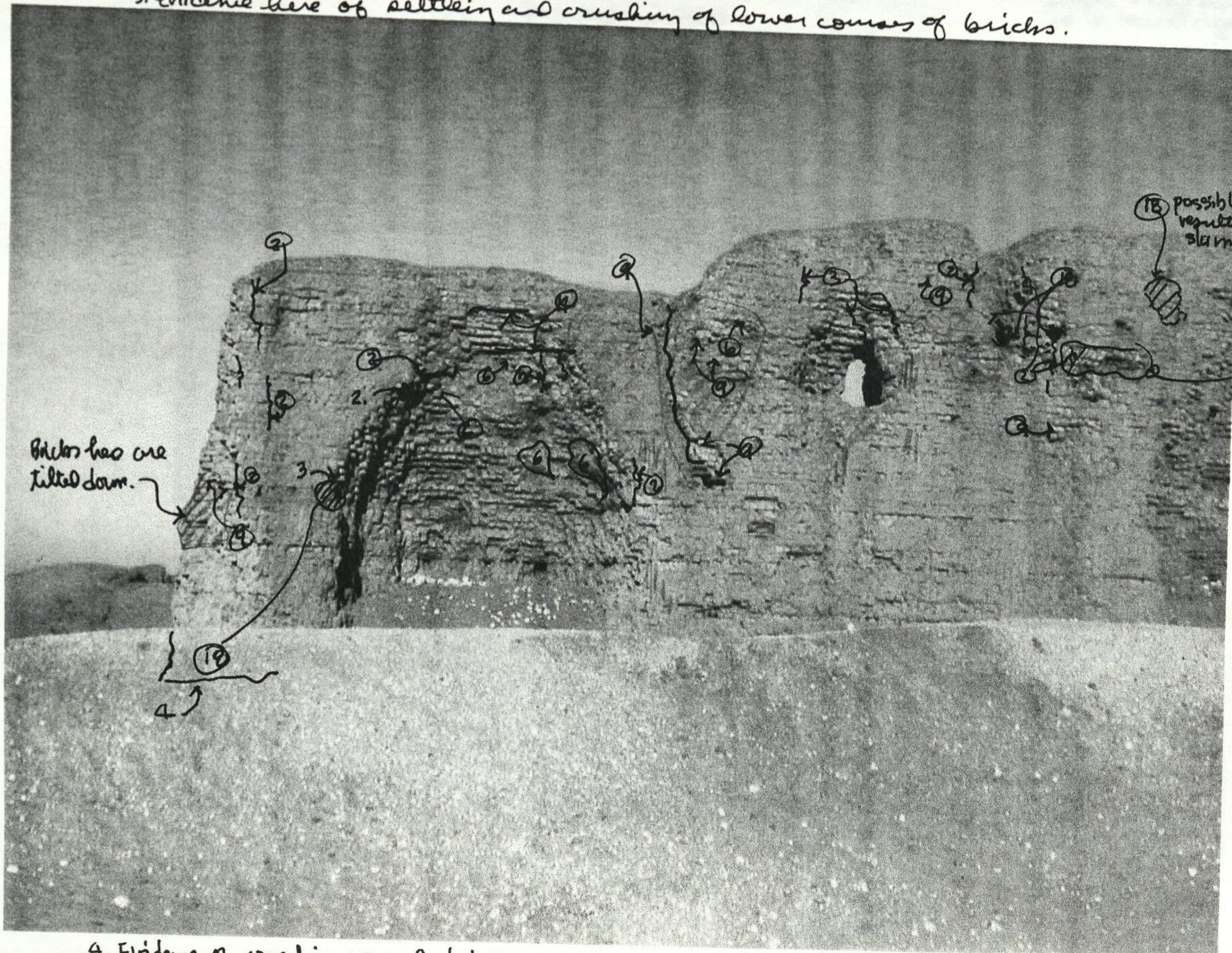
This entire corner could fail in a series of losses or in one single loss of ca 10 c.m. of mass. That loss would result in the accellerated failure of other portions of the wall immediately adjacent. This corner loss could then result in the loss of another 20 cm of loss from the structure cracks south.

West Wall South ~~North~~ end @ [illegible]

2. ... 20. ... of ... [illegible] ... assessed ... in ... pili... the ... of the ...

Large areas of unstable material.

3. Evidence here of settling and crushing of lower corners of bricks.



4. Evidence of crushing around at base of corner.

West Wall, West Elev. # 1 from North

1. [illegible] subject to [illegible] is probably a minimum of 1-2 c.m.

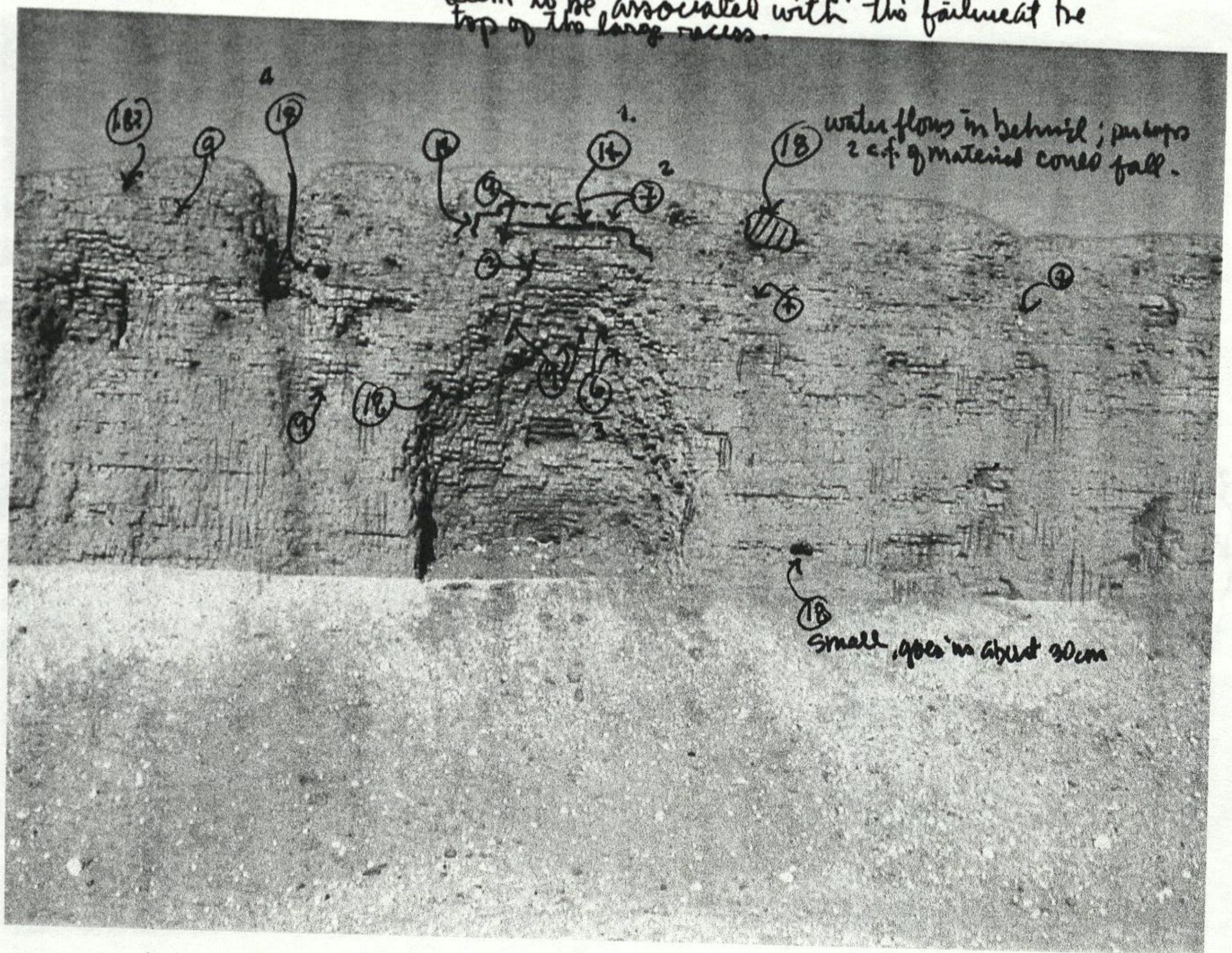
2. Birds, sparrows perching on shelf of delaminated material.

3. Several very small hornet nests.

All the cracks around the upper portion seem to be associated with the failure at the top of the large recess.

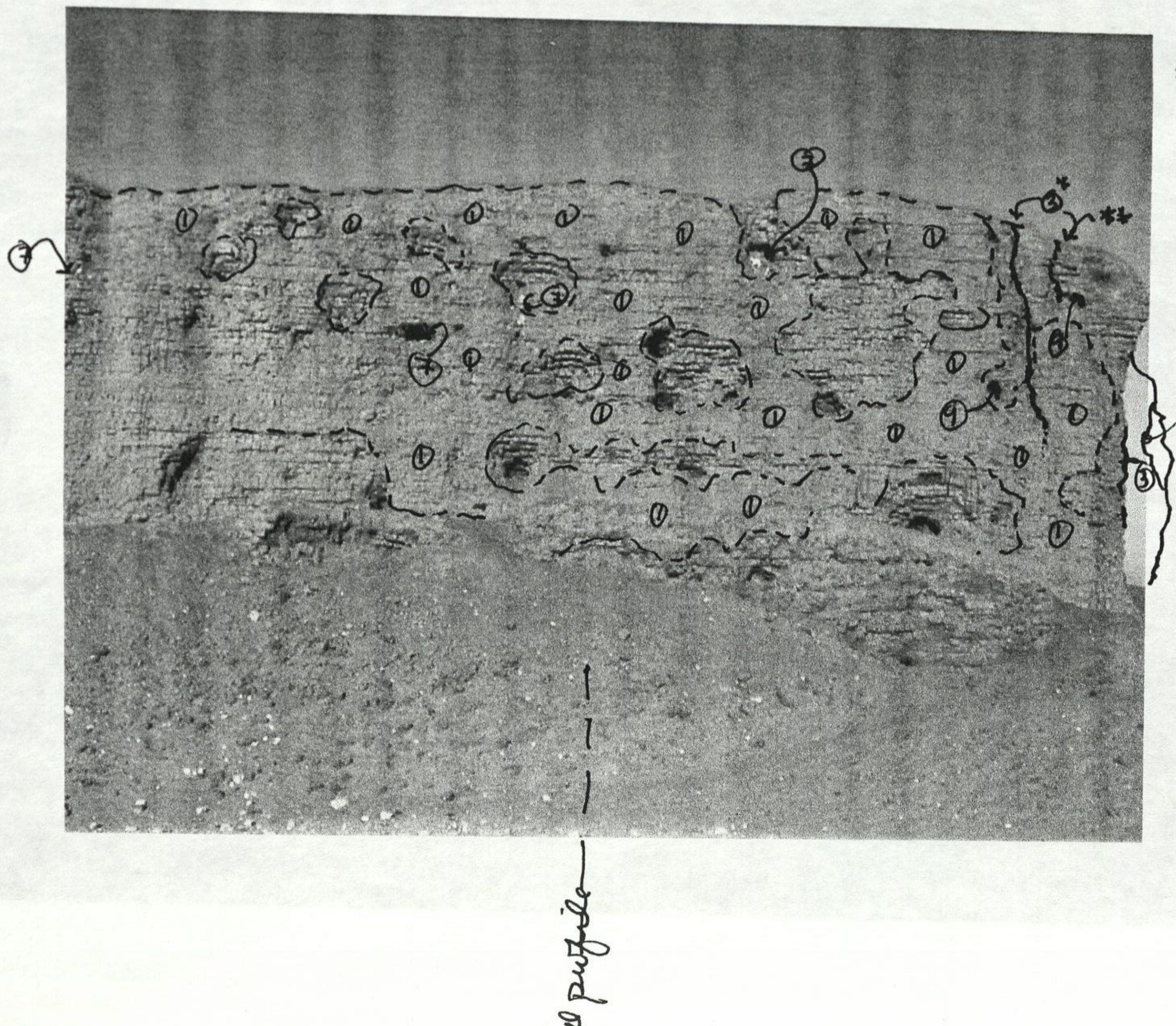
the larger amount of "old" chips [illegible] mean that this area is not as subject to wind erosion, although I see no overall differences.

* Surface looks "softer" - Is it the light?



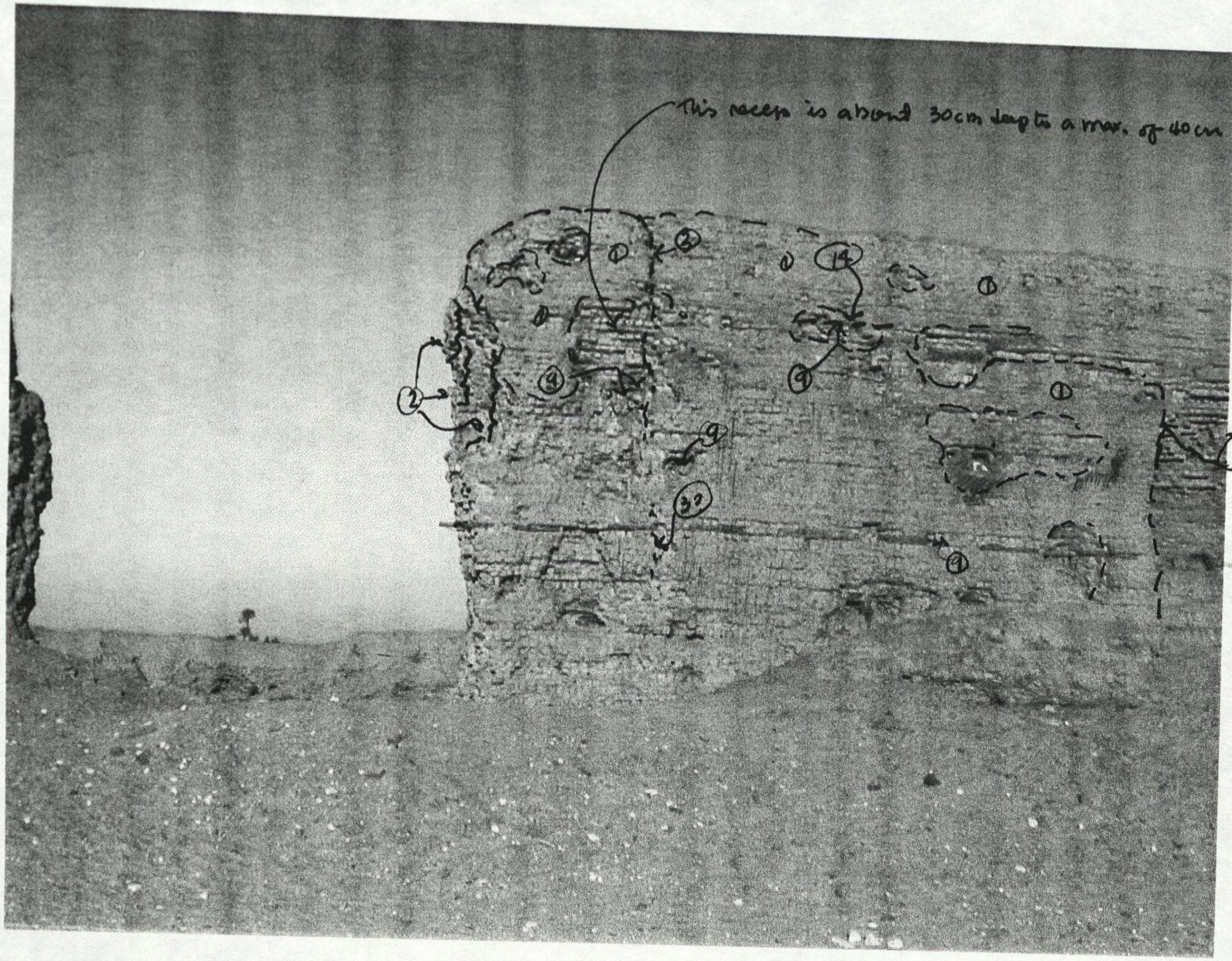
4. Appear to be a large void behind this area.

West Wall, West Elev. #2 from North

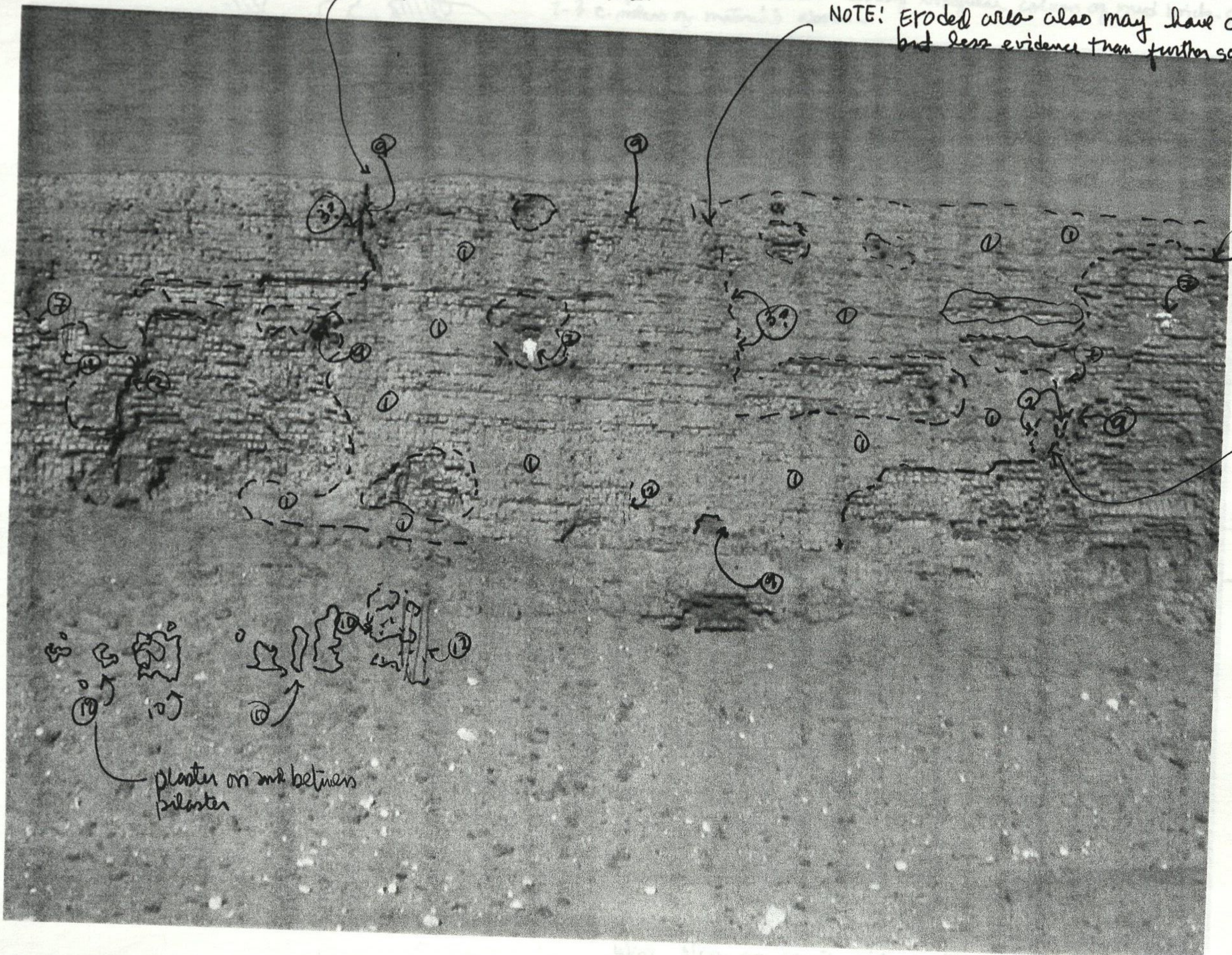


* ca. 3cm @ the top -
** ca. 1.5 cm wide
** 1.5 cm

West Wall, West Elev. # 3 from North

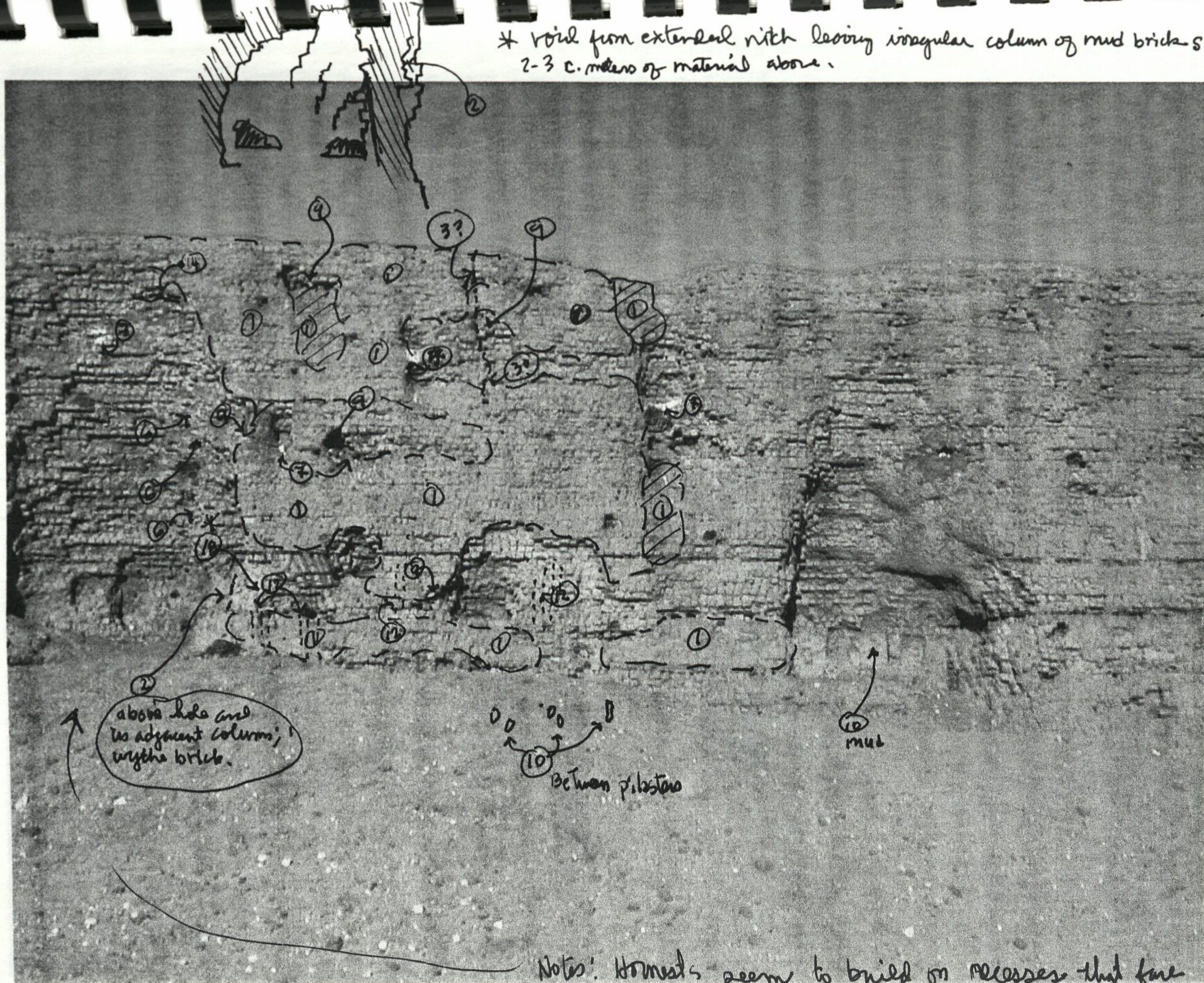


West Wall, West Elev. #4 from North



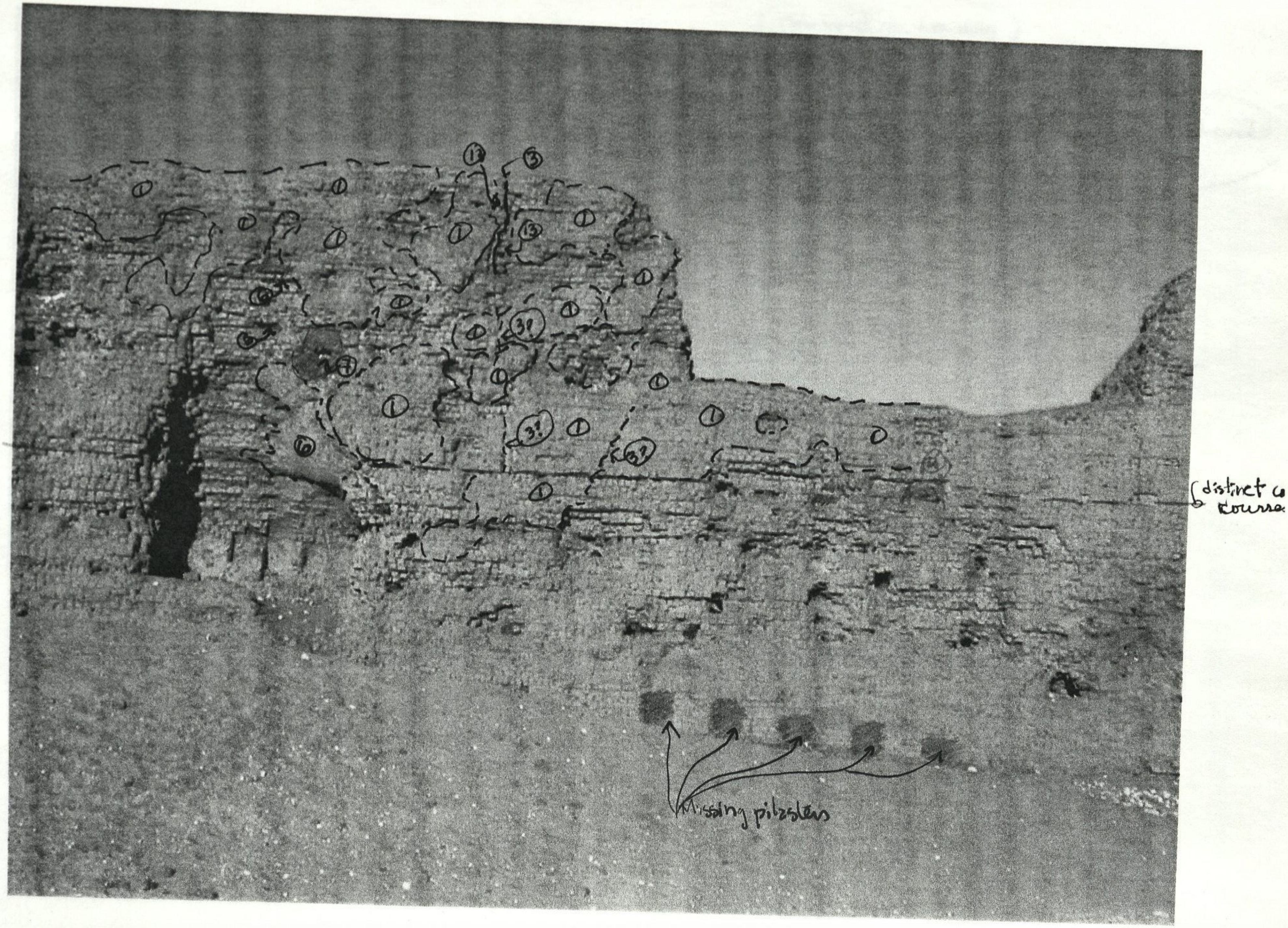
West Wall. ... #5 from North

* void from external niche leaving irregular column of mud brick supporting 2-3 c. meters of material above.

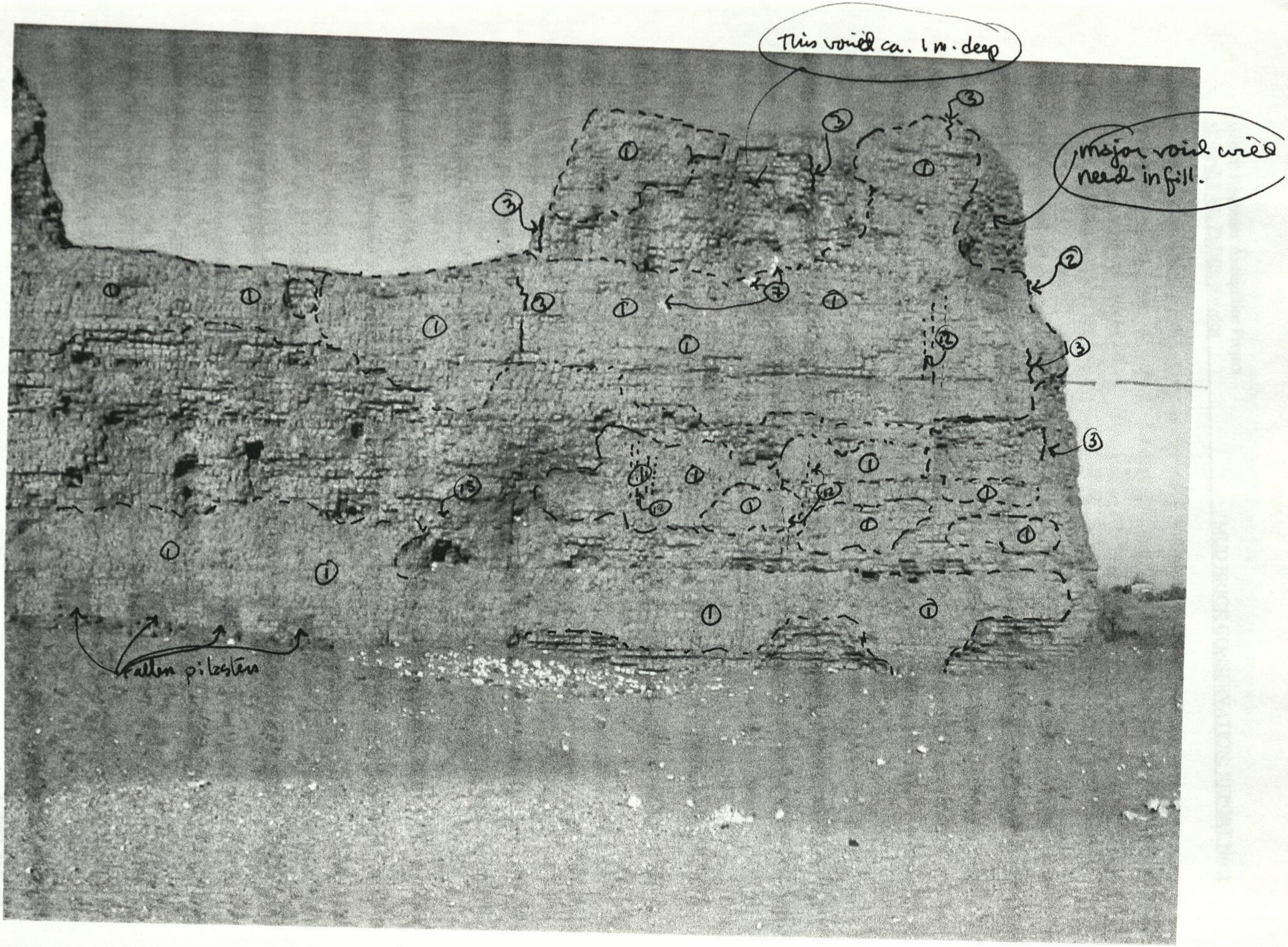


Notes: Hornets seem to build on recesses that face West. None on north side; extensive small on south side.

West Wall, West Elev. #6 from North



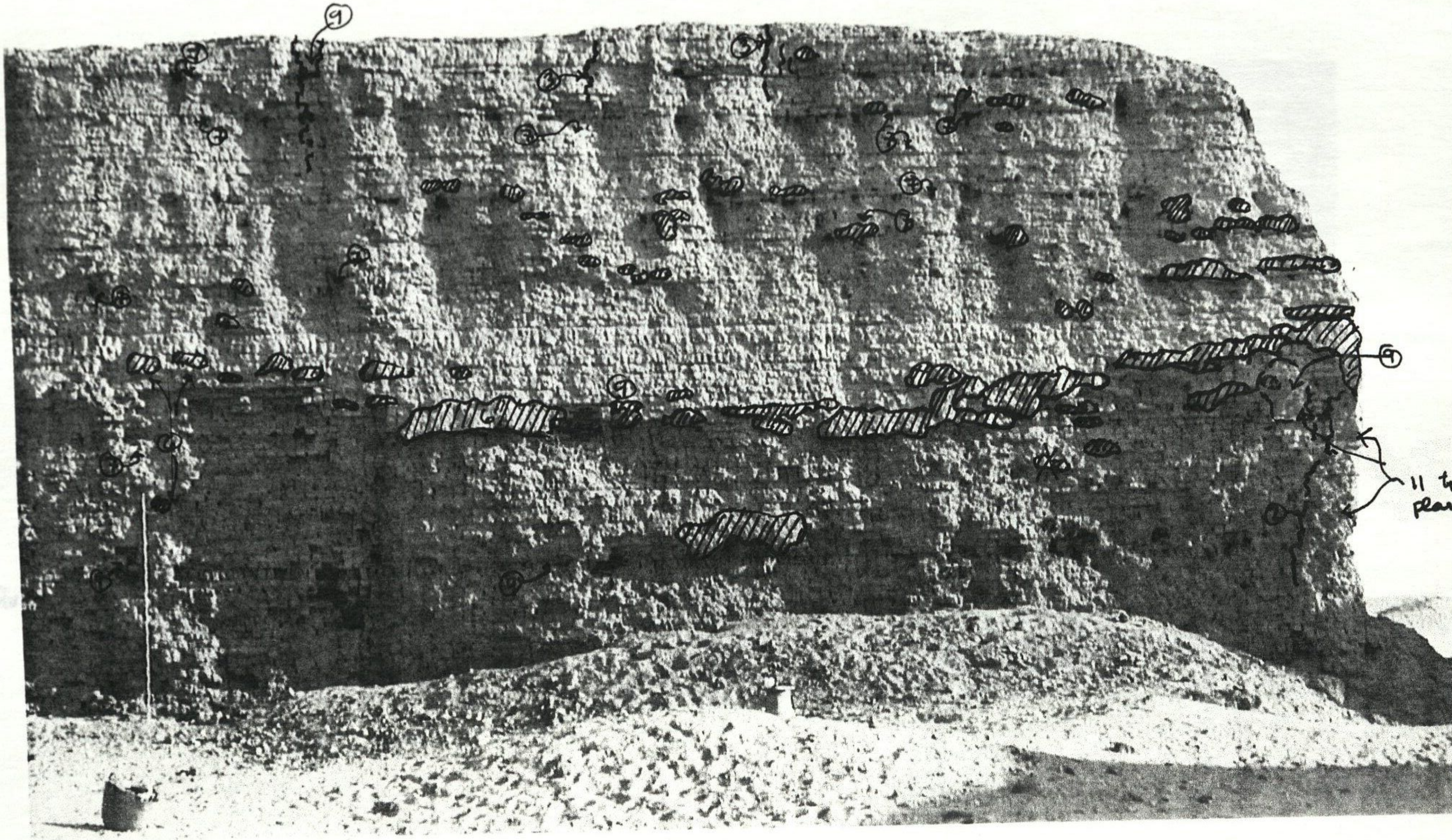
West Wall, West Elev., #7 from North



W[illegible] #8 from North

South Wall Condition Mapping

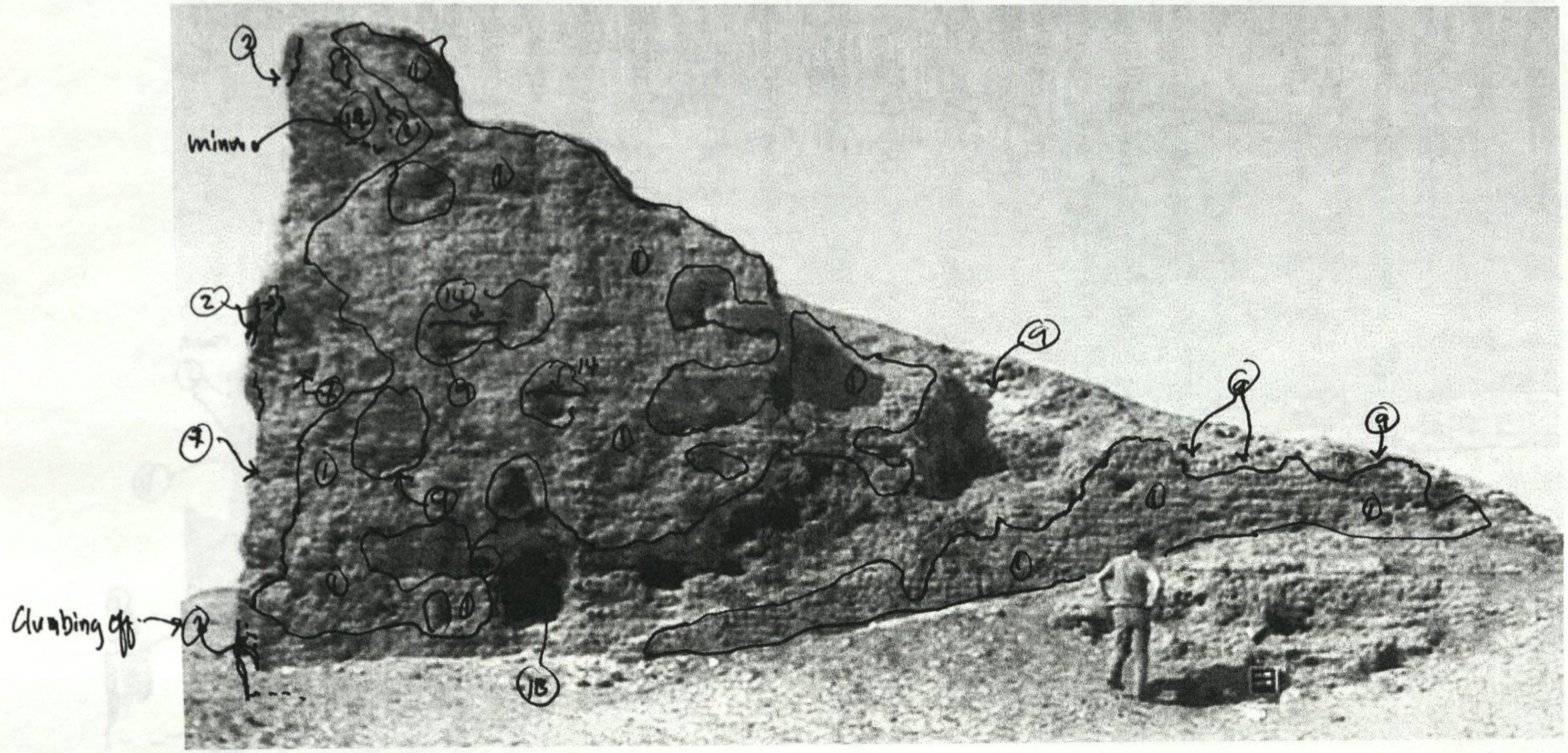
South Wall, North Elevation #1



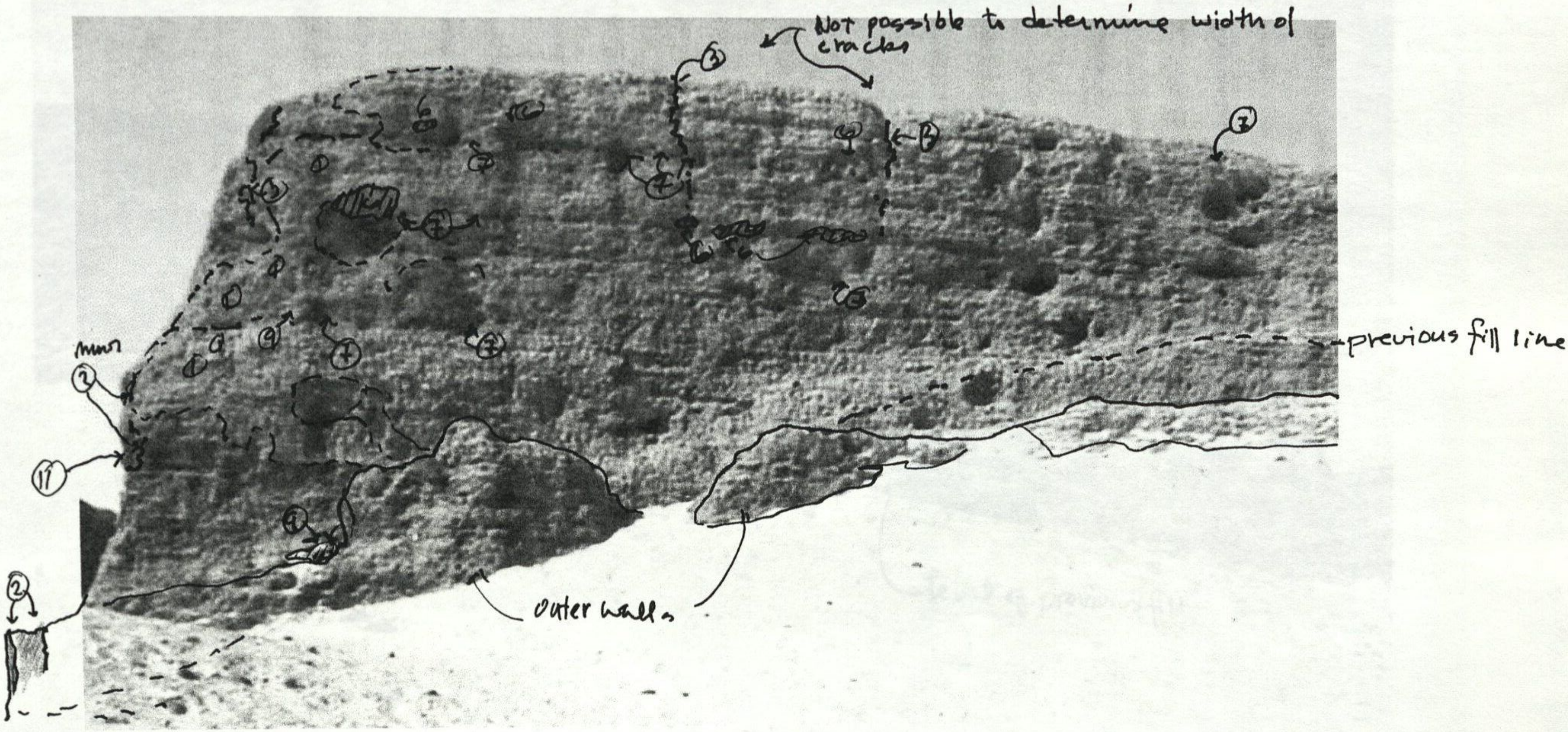
South Wall, North Elev. # 2

These spots represent recent fall
or abrasion erosion

No mud rills from water
No hornet nest (Aesh a Zinnén)
Very few birds on this wall face



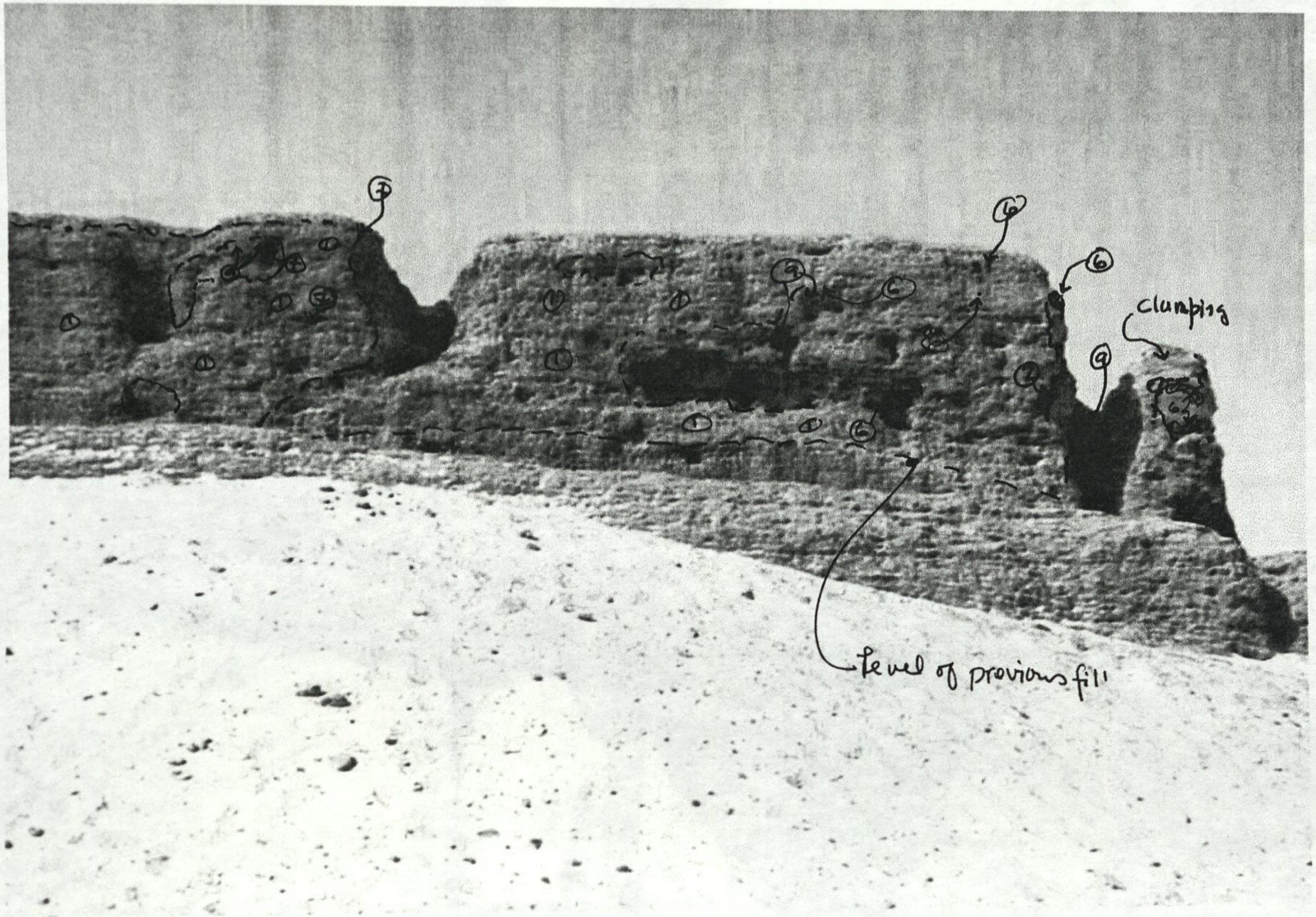
South Wall, South Elev. #1



South Wall, South Elev. #2

Bird, [illegible] be [illegible] on this side, but few what might appear as nesting holes.

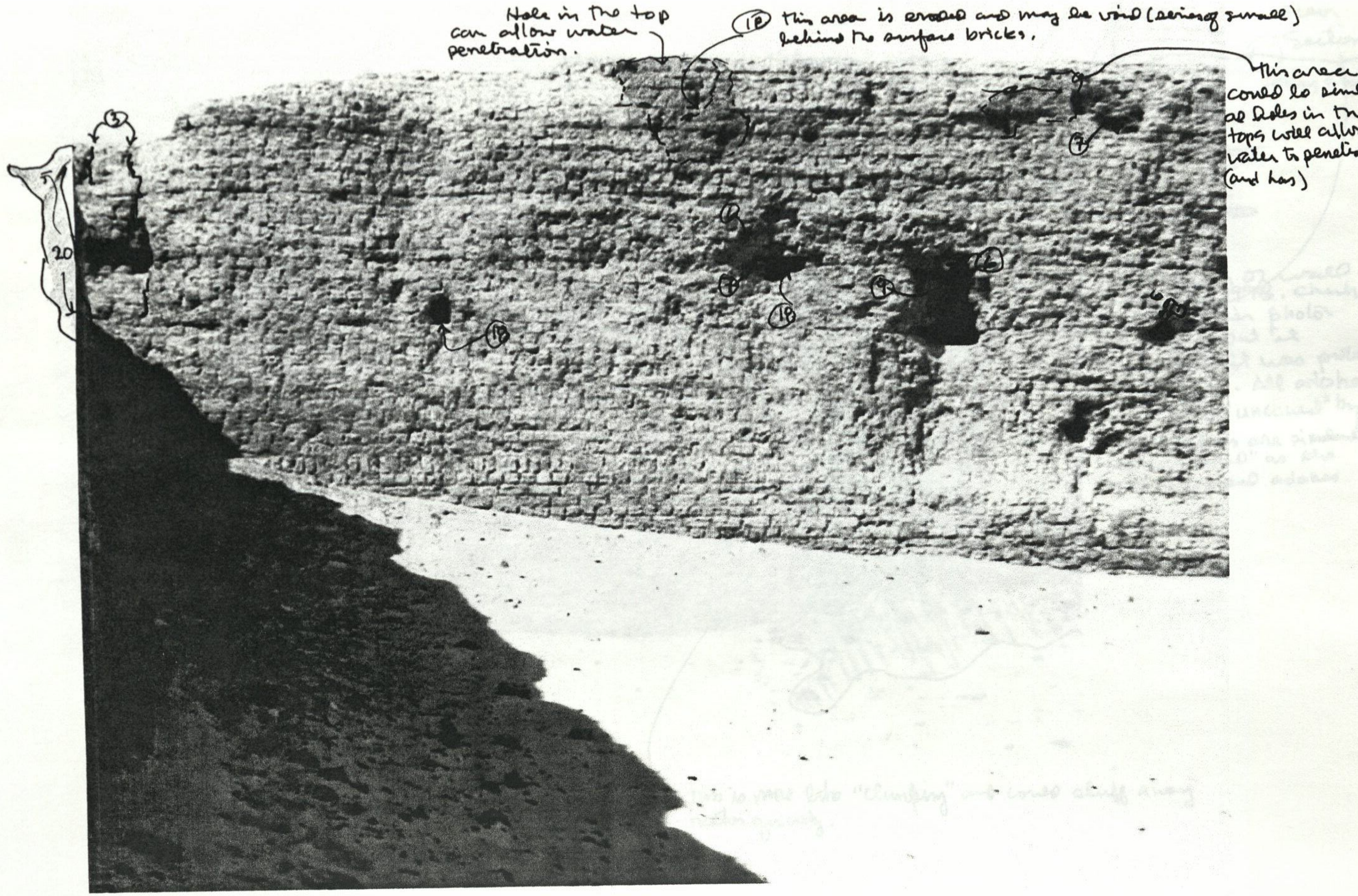
- certainly at the top of walls, more head joints are missing.



South Wall, South Elev. #3

South Wall West End at SW Gate

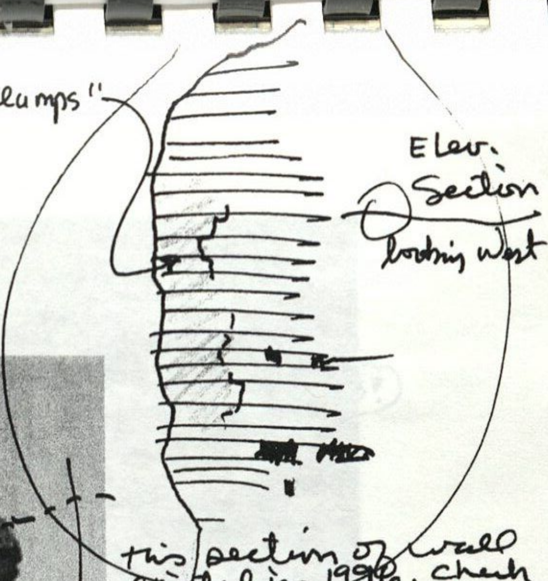
North Wall Condition Mapping



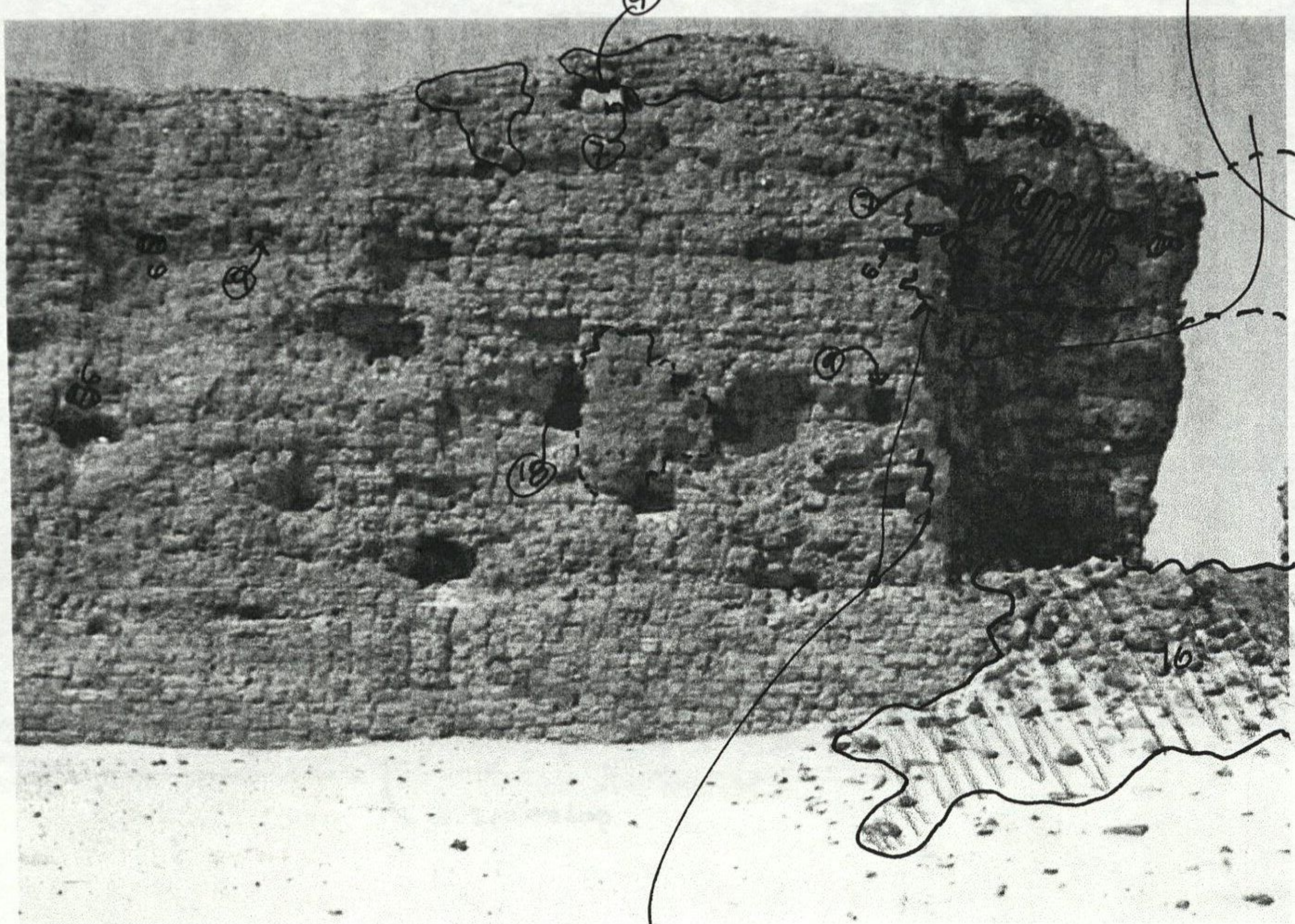
North Wall, South Elev. #1

"* surfaces w/ wind erosion, but not 'scoured'".

"clumps"



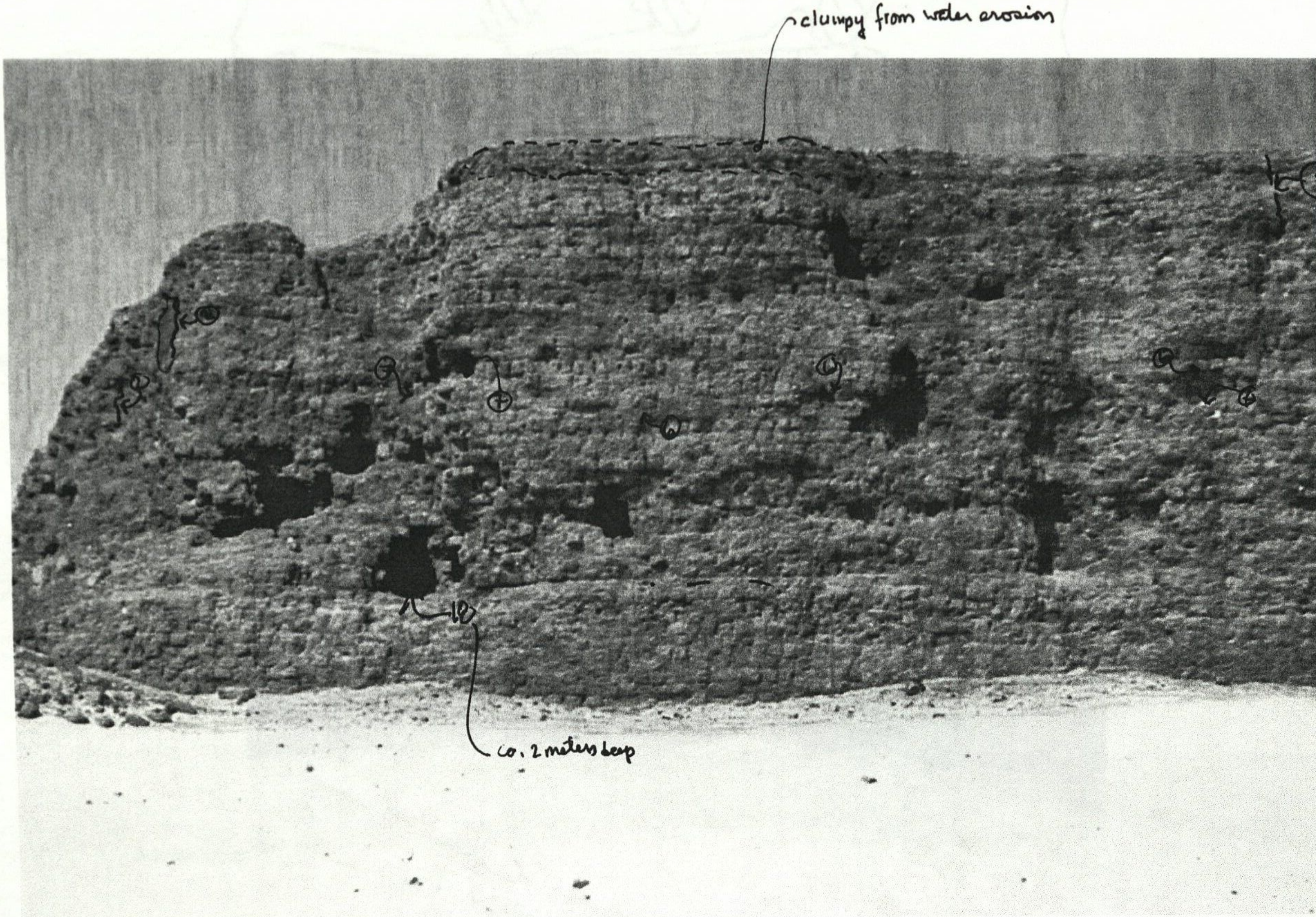
These areas look "clumpy" with a loss of eroded head joints, slight tilting.



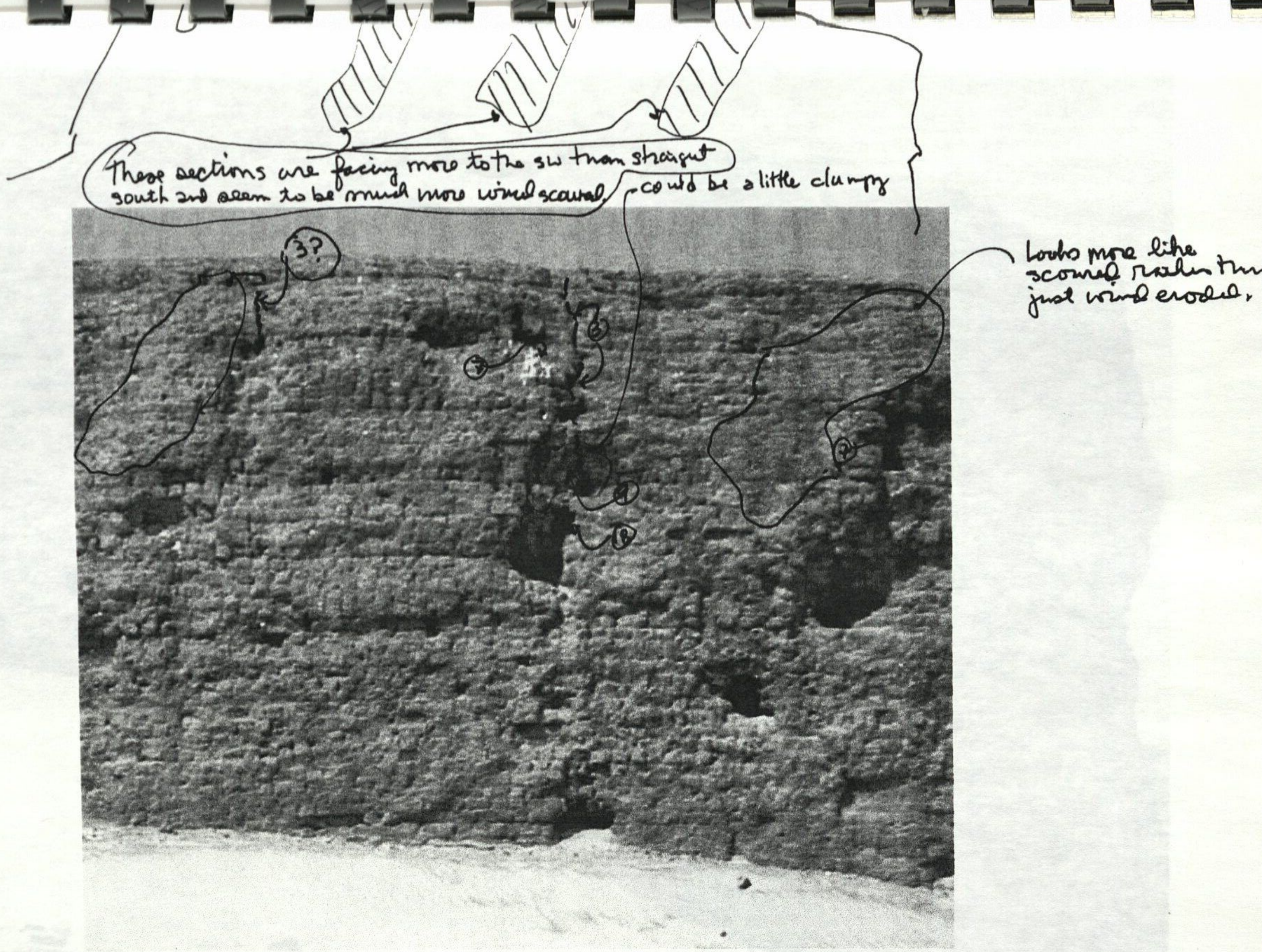
this section of wall existed in 1996. Check with earlier photos for extent, but it looks like it was probably pretty thin. All adobe faces now "uncovered" by the fall or loss are similarly "vermiculated" as the existing exposed adobes

This is more like "clumping" and could sluff away rather quickly.

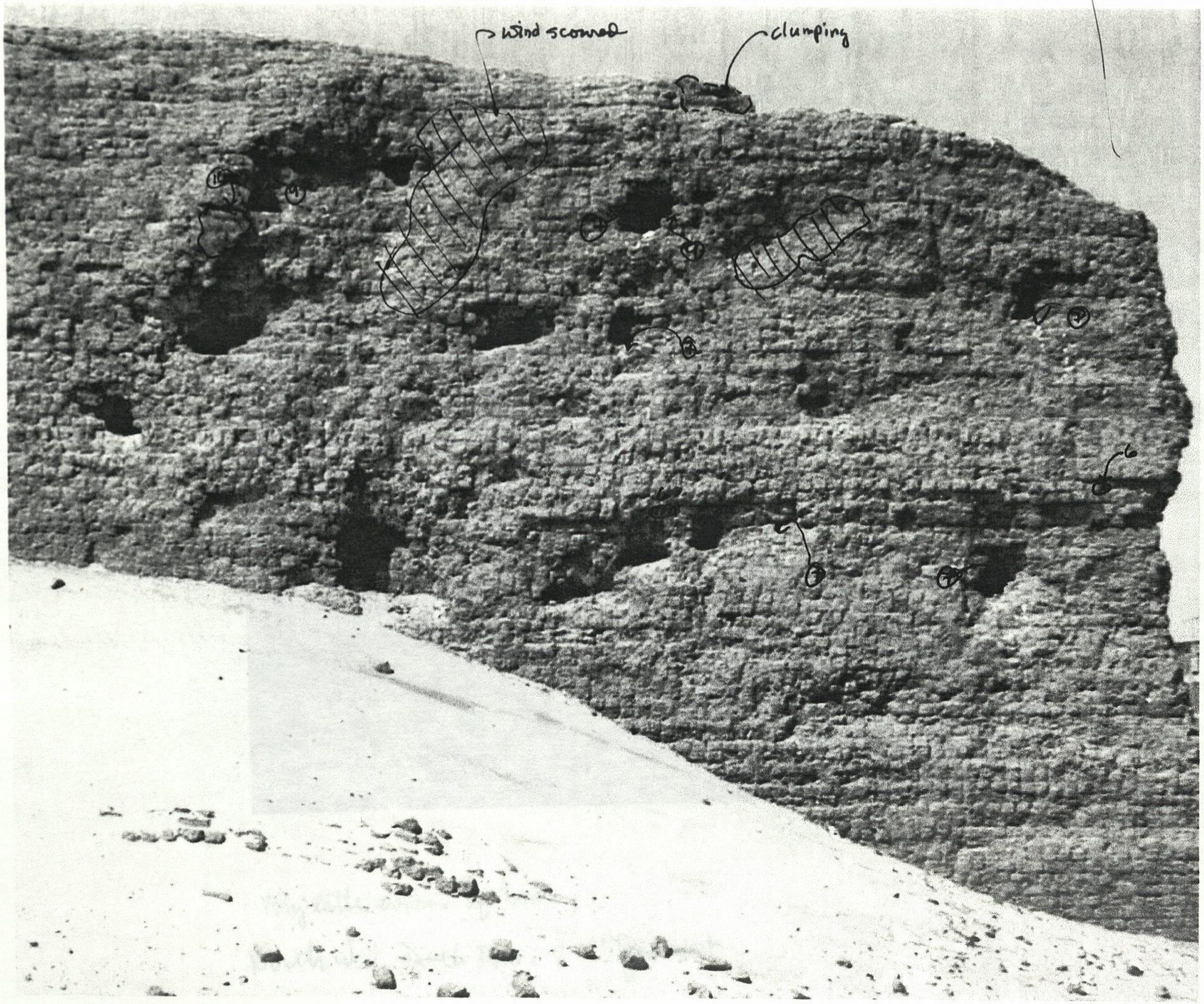
North Wall, South Elev. #2



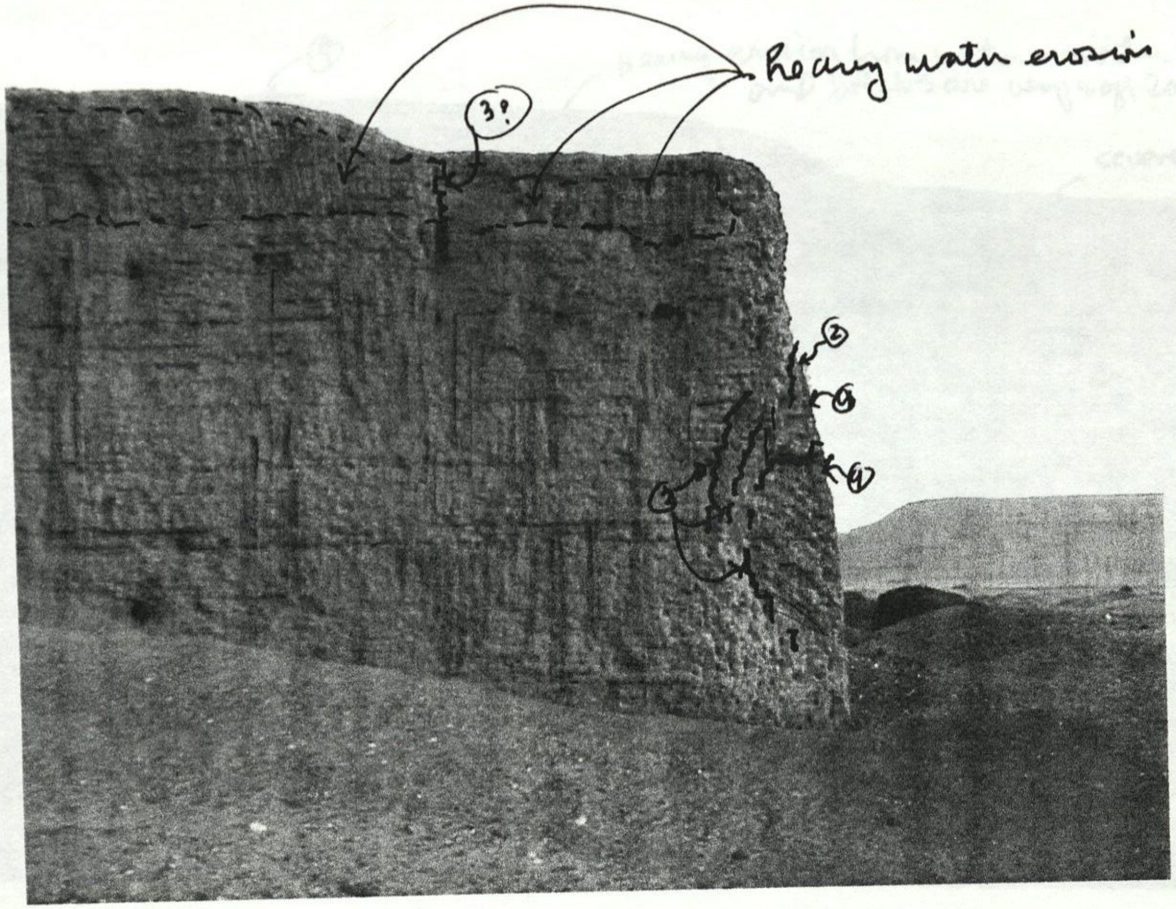
North Wall, South Elev. #3



North Wall, South Elev., #4



NORTH Wall, South Elev. #A5



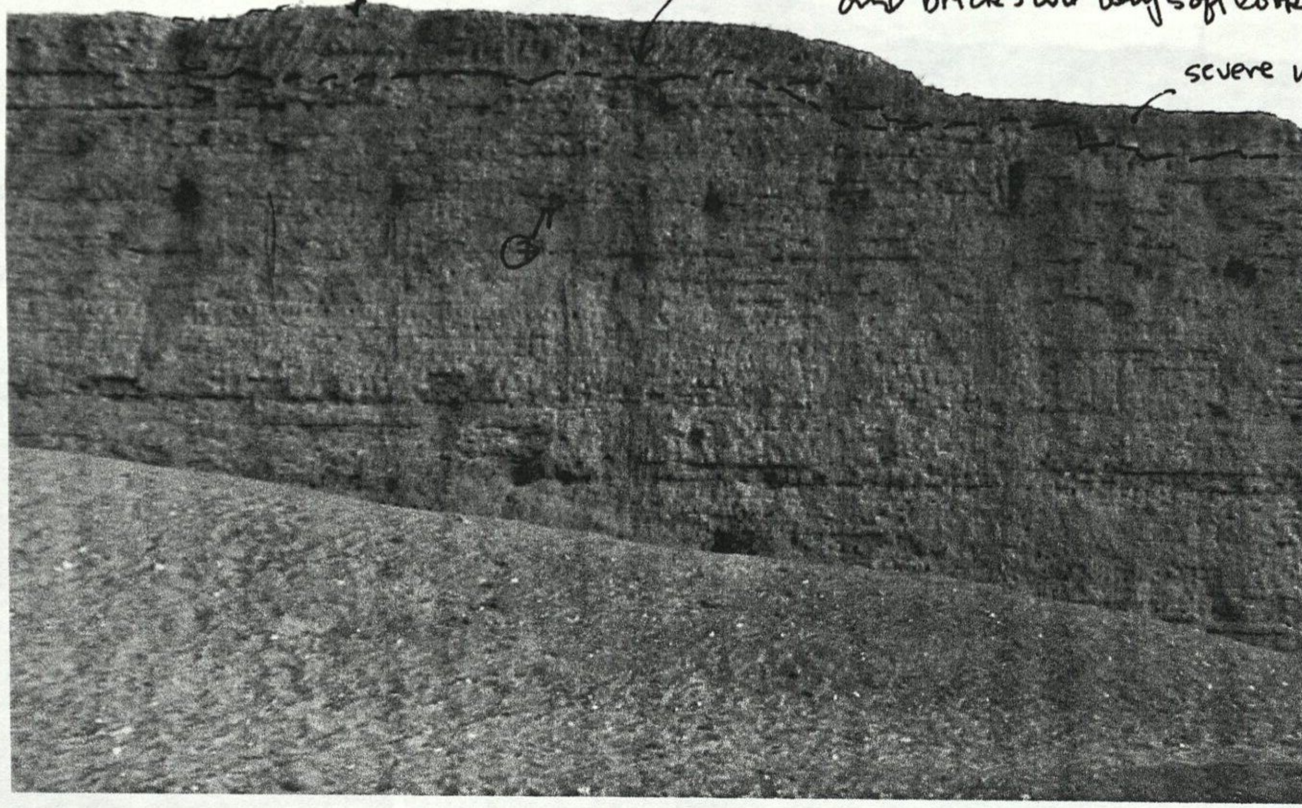
• Very little evidence of birds

North Wall, North Elev. # 1 from West

Heavy erosion from water - mortar is all washed out and bricks are very soft looking w/ rounded edges

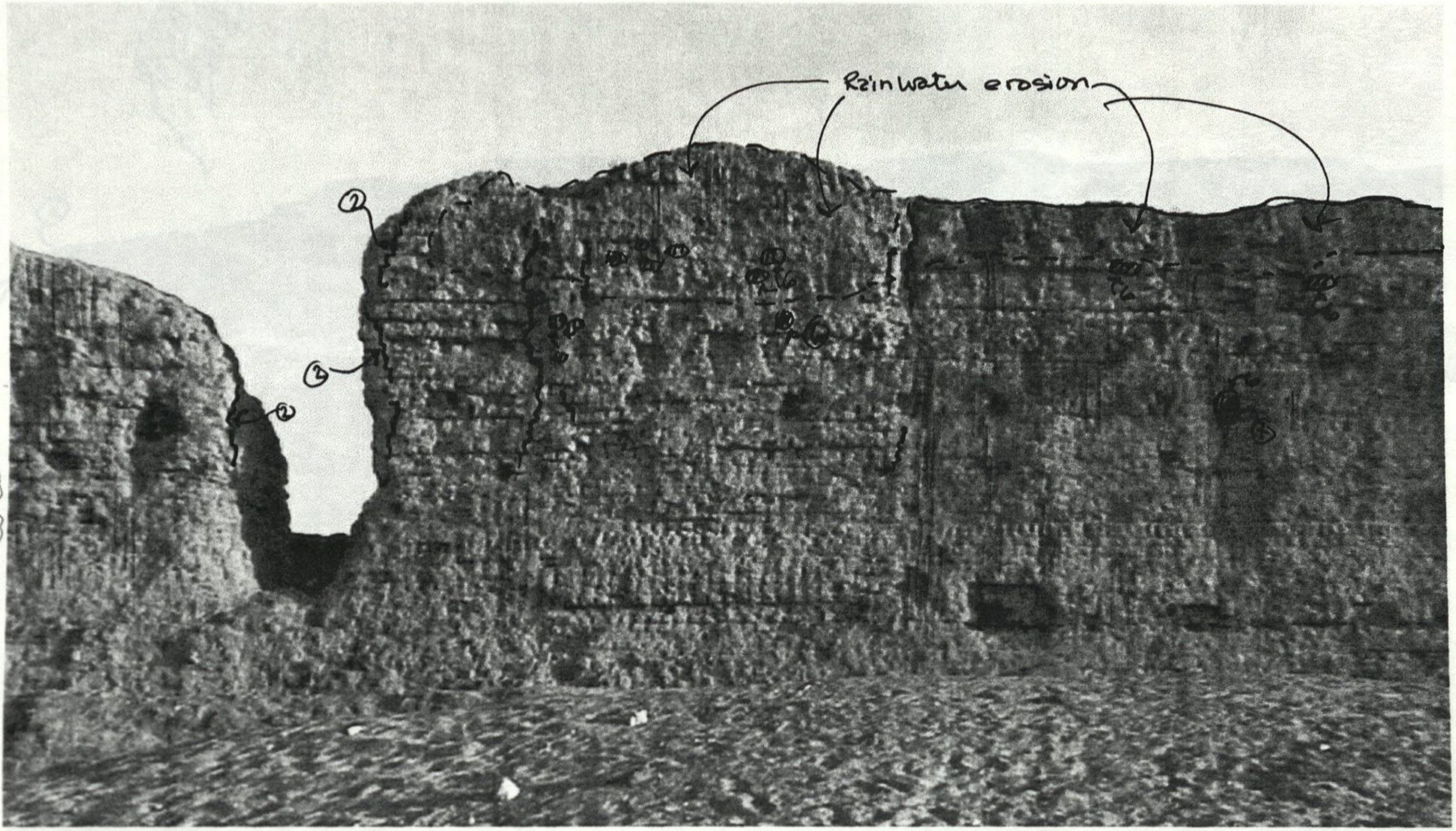
severe water erosion resulting in clumping, worn surfaces & washed away mortar joints.

(9)

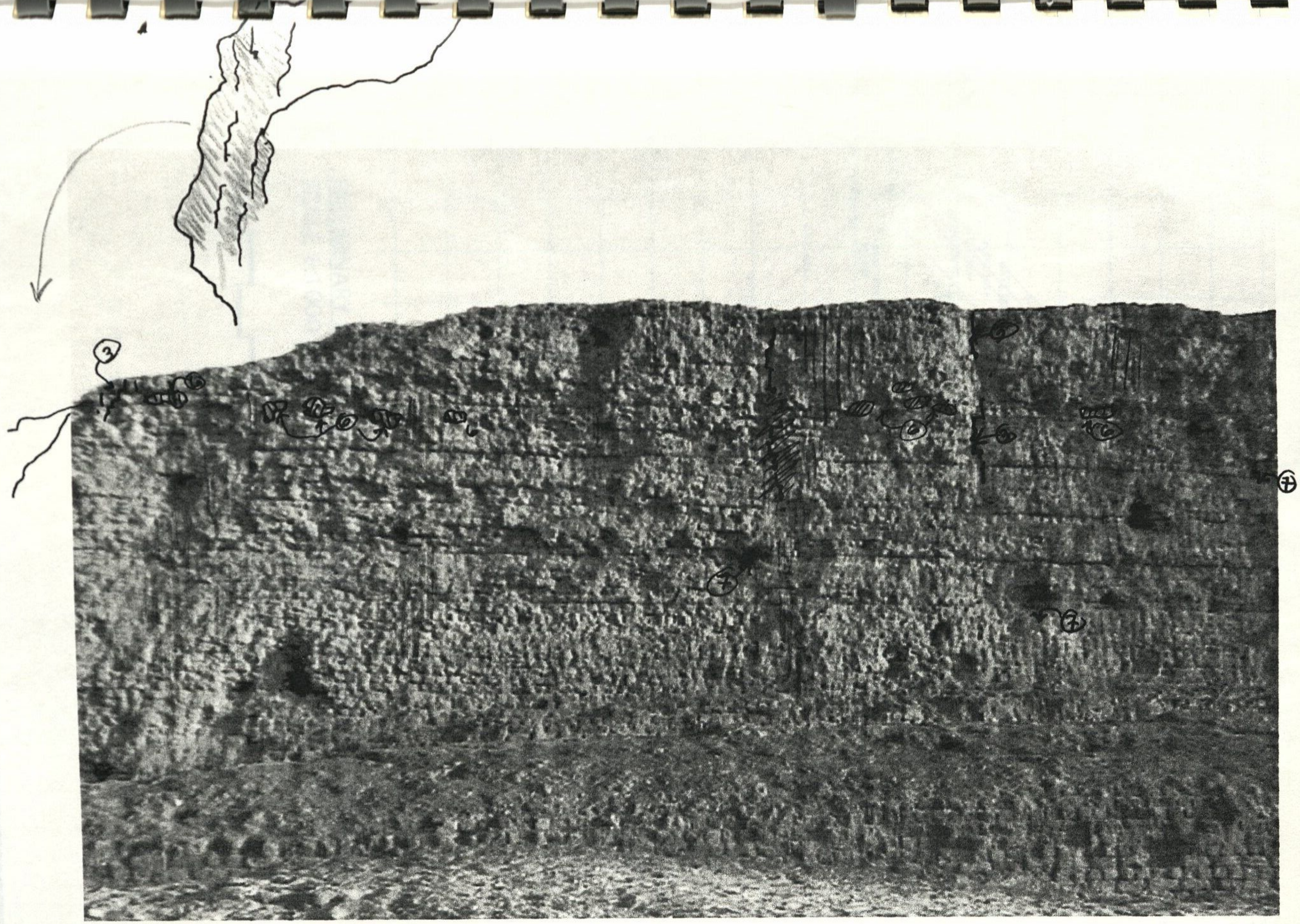


North Wall, North Elev. # 2 from W.

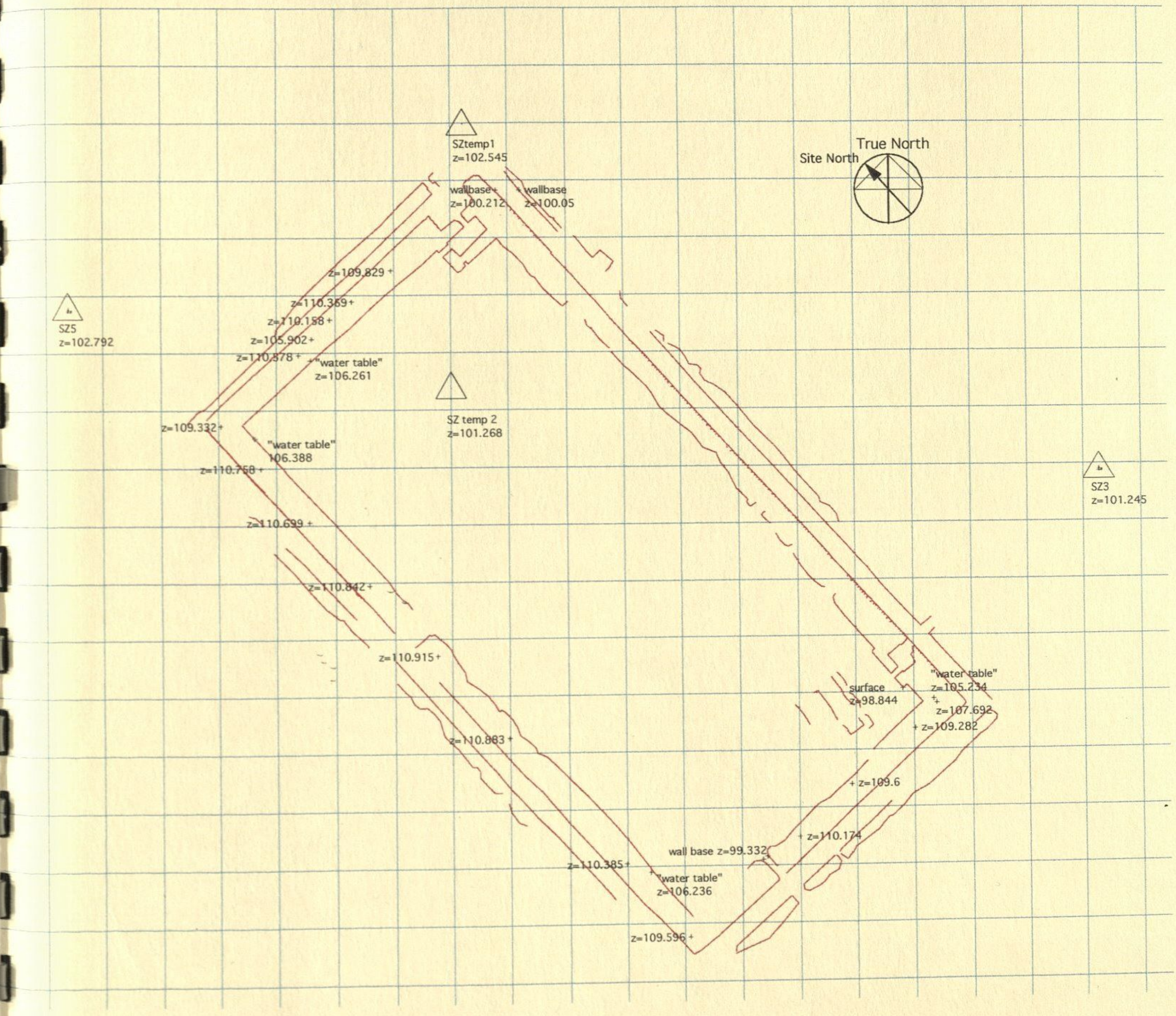
N[illegible] the [illegible] or at least obscured by water from rain.



NORTH WALL, N. ELEV. #3 from W.



NORTH WALL, North Elev. #4 from W.



PRELIMINARY PLAN OF SHUNET SHOWING LOCATIONS OF POINTS

SCALE 1:1000 Surveyed by Matt Adams with William Remsen, January 2000