ELIZABETH RIGHTER

THE IMPORTANCE OF SOIL SAMPLING AND ANALYSIS TO INTERPRETATION OF ARCHAEOLOGICAL SITES

INTRODUCTION

Stratigraphy and the understanding of soils; their composition, nature and depositional history, are basic to the archaeological method. Systematic observation and collection of soils, can maximize our abilities to interpret given sites. During the summer of 1983, one two-week session of our Earthwatch Project at Zufriedenheit Plantation, Magens Bay, St. Thomas, was devoted to applying soils sampling techniques in the field and laboratory, and evaluating their usefulness in site interpretation.

The principal Colonial habitation site at Zufriedenheit, occupied between ca. A.D. 1683 and A.D. 1860, is located on a flat eight-acre alluvial plain at the base of steep slopes on the north side of St. Thomas. (Figure 1). The soils of this area of the Zufriedenheit Plantation reflect the effects of man's activities on the land since before occupation of the site by prehistoric cultural groups, and it was our belief that the area offered a unique opportunity to utilize soils data to interpret the sequences of events, cultural and natural, which occurred in an island coastal environment during a period of about 1300 years. This paper will present some of the field techniques findings of the soil sampling program.

Prior to conduct of the systematic soil sampling program at Zufriedenheit, several one-meter square tests had been excavated in and adjacent to buildings that had been identified on 1764, 1785 and 1791 inventories as farm outbuildings and residential buildings (Zufriedenheit B East, Figure 2). During 1988, additional tests were made in the western section of the site (Zufriedenheit B West, Figure 1), which contained no above-ground structures; but which, on the basis of Hornbeck's 185-39 map of St.Thomas, had been identified as the salve village for the eighteenth and nineteenth century occupations of the plantation. Soil changes in the stratigraphic profile had been observed and recorded.

During the Earthwatch program, Ms. Ellen Craft of the Cooperative Extension Service of the University of the Virgin Islands volunteered to assist by instructing myself and the volunteers in the field, supervising the collection of soil samples and providing the services and facilities of the Cooperative Extension Service lab for processing and analyzing the samples, and for computerizing the data. The soils information and field sampling techniques presented herein were provided by Ms. Craft, while the interpretations of results are a combined effort, utilizing both soils data and cultural information recovered from archaeological testing and historical research.

After completion of the project, Ms. Craft and the author determined that the most useful techniques were those applied in the field, while the interpretive value of the chemical analyses conducted was variable. For one thing, because it was a cooperative program, at no cost to the Zufriedenheit Project, the chemical tests were, by necessity, those utilized in agricultural studies; for example, samples were measured for available phosphorous and available carbon, which limited their effectiveness for archaeological interpretation. Nevertheless, once these limitations were understood, other factors could be identified which were helpful. Of the laboratory tests run, tests for micronutrients such as copper, zinc and manganese yielded the least interpretive information, while laboratory tests for nitrogen (unfortunately not conducted during this study), phosphorous, sulphur, organics, iron, calcium and salts were found to be the most useful.

FIELD TECHNIQUES

First of all, in the field, we selected the excavation pits walls which we wished to sample. Each selected soil face was cleaned to expose a fresh stratigraphic column. The first step in each case, was to record the stratigraphic soil differences which were readily observable (Figures 3,4). The depth from datum of each stratigraphic level was recorded, and a standard soil profile was sketched. With Ms.Craft's assistance, we learned how to detect subtle differences in soil strength, structure (per form and size), texture and color; and how to conduct limited tests for chemical composition including soil pH (Figure 5). These techniques enabled the identification of additional stratigraphic levels.

MEASURING SOIL STRENGTH

Many of these techniques are well known to archaeologists, but the application of a tool known as a "penetrometer" to measure soil strength was perhaps the most innovative. We noticed that, in the field, the demarkation between layers was not always obvious or agreed upon by two separate observers. The penetrometer was very useful in providing an objective method of distinguishing levels by soil strength. With this simple tool, consistent numerical values for soil resistance or compaction can be recorded and compared.

Measurements are taken at two-centimeter intervals up and down the stratigraphic column (Figures 6,7,8). With even pressure, the tool is inserted horizontally into the pit wall until it is fully inserted. A red band around the tool rod slides up the length of the rod until maximum strength is registered. The number on the implement adjacent to the sliding red band is then read and recorded on the profile drawing. Readings are grouped according to strength alone (Figures 6,7,8) and soil layers are distinguished by this criterion. In this way, the penetrometer enables detection of soil compaction variation which may otherwise not be visible.

Occasionally, soil strength may vary within a stratum, sometimes because of plant or tree roots. In general, however, the penetrometer is of great assistance in identifying stratigraphic levels which are visibly similar to those above and/or below but which may have been compared by human utilization for such things as house floors, dirt roads and pathways.

Two examples of the usefulness of this field technique are shown in Figures 3,6,4 and 7). In the first case, compaction tests were applied to a test square that had been excavated in an outbuilding identified on the 1764 plantation inventory as a storehouse and dovecote. Architecturally, the building type was one that could have been erected any time between the late seventeenth century and the early nineteenth century. The questions were, "Was this structure erected during the earliest Colonial occupation (ca. 1683) of the site, or after the plantation had been occupied for some time? Was the area utilized during the prehistoric occupation of

Magens Bay?"

Under floor bricks which were in place, but which were adjacent to disturbed floor bricks in very loose sandy soils, a single fragment of Creamware, generally dating between A.D. 1765 and A.D. 1810 was found. It was not certain whether the floor was original. During 1986, students from the University of the Virgin Islands had conducted limited testing of the structure. Without benefit of detailed soils sampling techniques, four strata had been identified between the top of the bricks and 51 cm below the bricks (Figure 3). In 1988, after application of the penetrometer to the exposed soil face, an additional compacted level was identified (Figure 6). This level, between 34 cm and 41 cm below the bricks, exhibited stronger structure and significantly more compaction than did the level between 28.50 and 34.00 below the bricks. This evidence provided by the penetrometer was useful to our interpretation, because it suggested that before the structure was built, (1) the area had been subjected to substantial human foot traffic and (2) soils from off-sites, most likely clay loam soils eroded from cultivated slopes above, had been deposited on the site. The presence of this previously unidentified layer tended to corroborate the archaeological evidence that the building had not been erected until after the Colonial plantation had been occupied for some time.

The second most dramatic result from the penetrometer tests occurred in a deep test excavated in 1986 (Figure 4). Conditions of this test, conducted adjacent to Unit 1, were unusual, in that nineteenth century artifacts were recovered at a depth of 110 cm below surface, directly adjacent to a structure whose foundations only extended about 45 cm below surface into sandy soils. It was hypothesized that this area might have been an outhouse mentioned in a 1791 inventory, a garbage pit, or a lowlying swampy area into which trash was tossed. It was hoped that the chemical analyses would shed some light on this feature, and more will be said about this later. The first finding, after application of the penetrometer, was that the originally recorded six strata were found to number eight (Figure 7).

IDENTIFICATION OF SOIL STRUCTURE

The second most useful technique in our field soil sampling at Zufriedenheit was observation and recording of soil structure. Observation of differences in soil structure can be useful in identifying the introduction of "exotic" soils, such as fill, or the rapid deposition of soils carried from elsewhere and deposited on a site by flooding or soil washing. In the Virgin Islands, most subsoils are "subangular blocky", indicating a substantial amount of soil development. When soils like these appear in the stratigraphic column above soils with less structure, it is indicative of the introduction of soils from off-site, rather than development of soils in place.

IDENTIFICATION OF SOIL TEXTURE

Soil texture, a descriptive aid for comparing strata and identifying their geological derivation, essentially refers to the relative amounts of clay, silt and sand that are present in a soil sample. The largest particles are sand; next in size are silt and the smallest are clay (Figure 8).

RECORDING SOIL COLOR

The observation of soil color in the field has been standardized utilizing a Munsell Soil Color Chart which consists of 277 standard color chips arranged by variables known as hue, value and chroma. For example, in a Munsell notation such as, "10YR 6/4", "10YR" refers to *hue,* the numerator, "6" refers to *value* and the demoninator, "4" refers to *chroma.*

To obtain realistic readings, it is advisable to have readings on the site made by the same individual, and it is important to have good sunlight in which to make the observations. Small samples of soil are collected from the stratigraphic column and compared against the color chart. For each sample, the darkest particles in the sample and the lightest particles should be separately compared with the chart and recorded. Readings should be made for the sample when it is dry and again when it is wet. Thus, four reading should be recorded for each sample. Finally, the relative proportion of dark to light particles in each sample should be observed and noted (Figures 6 and 8).

FIELD ESTIMATIONS OF SOME ASPECTS OF SOIL CHEMISTRY

Outside of the lab, some aspects of soil chemistry may be estimated in the field. The presence or absence of calcium carbonated may be detected by adding a few drops of 1N hydrochloric acid to a small amount of soil. If the acid fizzes, calcium carbonates are present. This is common in soils containing sand that was created from coral reefs (not quartz or *halemites)* or which is limestone-based. Fizzing may also indicate the presence of shells or decomposed shells.

Soil pH, which indicates the degree of acidity or basicity of the soil, also may be estimated in the field. In some soils, pH testing predominantly measures the amount of calcium carbonate in the soil. In the Virgin Islands, alluvial soils tend to register 6.5 to 7.5 on the pH scale: while caliche, which is uplifted limestone which has been dissolved and recemented, measures 8. Again, such information is useful in determining whether or not non-conforming soil types, such as coral sand or limestones, have been introduced to the stratigraphic column, and may assist in detecting the presence of decomposing shells. Since soil pH affects the types of vegetation that the soil can support, soil pH testing can provide clues to possible vegetation types present on the site at a given point in the stratigraphic sequence (Figures 6,7,8).

PREPARING FOR LABORATORY ANALYSES

After completion of the tests that could be applied in the field, soil samples of about 0.50 liter each were collected from each stratum and taken to the lab for chemical analyses. Samples for flotation and for pollen and phytolithic analyses were also collected at this time.

LABORATORY ANALYSES: INTRODUCTION

In the lab the samples were dried for 24 hours at 195^{0} F, screened, and then ground into 10-mesh size using a Dynacrush grinder. The samples were analyzed for pH; soluble salts, organic matter and sodium content and texture; as well as for ten elements which included five macronutrients (potassium, phosphorous, calcium carbonate, magnesium, and sulfur), four micronutrients (zinc,l iron, copper and manganese) and sodium, Nitrogen could not be analyzed due to lack of the proper equipment at the time that the samples were being processed.

INTERPRETATION OF CHEMICAL ANALYSES

Three applications of the findings of the chemical analyses will be discussed here.

In the stratigraphic column sampled in 106W/73N (Figure 9), there was a distinct change in chemistry between the second and third stratigraphic layers. Soil pH changed from 7.75 to 8.01, while salt content jumped from 100 to 850. Potassium changed from 45.70 to 86.50 and calcium decreased from 1241 to 605. These dramatic differences suggested a sudden change in soil type, which correlated well with the archaeological findings of disturbed soil originating at 28 cm below datum along with the origin of Feature 3, a pit which contained a barrel hoop and other artifacts surrounded by ashy soil and charcoal (Figure 9). The chemical tests also indicated, however, that organic material decreased from 3.90 to 0.50, while phosphorous increased from 60 to 113 and sulfur jumped from 5 to 87. This was puzzling, considering the presence of charcoal in the pit, but the low reading for the organic material was explained by the nature of the tests: tests measured *available* carbon and other organics. Carbon tied up in charcoal is not available, however, burning releases both phosphorous and sulfur into the soils. The sharp increase in these two elements provided alternative evidence of burning. The high readings for phosphorous and sulfur continued through the stratigraphic column to Layer 6, suggesting that the barrel and its contents were burned *in situ* or discarded, probably as refuse, in an area where burning took place. Increased slats in these layers may indicate salt water intrusion, but a concomitant reduction in calcium probably indicates that fill soil was thrown into the pit also.

In test 90N/3W, the deep test discussed previously, it had been hypothesized that the depth of disturbed soils and the presence of artifacts to a depth of 110 cm might indicate an outhouse of refuse pit. The chemical analyses, however, indicated a low amount of organic matter which did not substantiate either of these hypotheses. Instead salts increased from 100 in the top layer to 1200 in the eighth layer and pH increased from 7.71 in Level 1 to 9.05 in Level 8. Thus, the indications at present are that the pit was excavated at the edge of a natural depression, perhaps a former salt pond. The clear stratification of soils also indicates that deposition was gradual over time.

Finally, samples were analyzed from a series of short trenches excavated between 69N/89W and 69N/100W (Figures 10,11,12). In 69N/89-90W, Levels B and C consisted of a tan hard pan of sandy clay loam of varying thicknesses (Figure 12). Visually, this layer was distinct from those above and below, and the compaction reading of 5+ indicated soil with strength markedly greater than other levels. In trench 69N/89-90W, Level F or Feature 4 (Figure 11), although the same color as the hard pan,had much less strength and extended to the bottom of the pit. There also appeared to be a difference in the strata on either side of Feature 4. Visually, Feature 4 appeared to be a robbed wall, post trench, or long narrow pit of some other nature. The feature contained a few rocks with a hoe blade adhering to one of the rocks.

The excavated trences at 69N (Figure 9) were situated close to a small gut or gully,l and there was a high probability that the gully formerly had been a road bed or was created by run of from a nearby road bed. Explanations for Levels B and C, which overlay markedly contrasting sandy soil, included: (1) fill emplaced for house floors (2) soils deposited by flooding or sedimentation and (3) eroded soil deposits that were compacted by use as a roadway. The hypothesis for the latter two explanations included the probability that early in the eighteenth century, after the introduction of sugar cane cultivation on the slopes above the habitation area and clearing of the slopes for erection of the sugar processing works, animal mill and bagasse sheds, soil erosion was accelerated. The B and C level soils, therefore, were tentatively identified as sediments eroded from the upper slopes during the early to mid-Colonial period and carried by flood waters to the alluvial plain where they settled out. If the soils were carried in the flooding gully, the thicker deposits would tend to be closer to the gut, as was the case.

Nevertheless, there were problems with these scenarios. If the area was subject to flooding, it was not likely that house floors would be present or that an area in the flood zone would be utilized as a road of any importance. Thus, one question was the time period for deposition of Levels B and C soils.

The results of the soil chemistry analyses did not present an easily decipherable picture, or one that, at first, corresponded well with the interpretations which were presented by the visual evidence (Figure 12). Ultimately, however, the soil chemistry provided data which strengthened some of the archaeological evidence and suggested a plausible time frame for deposition of the stratigraphic soil layers.

The soil profile of the south wall of 69N/89-90W indicated that Level F was an intrusive feature, either a robbed wall or a trench in which wood posts were set. The low organic content of Feature 4, indicated by the soil chemistry, suggested that Feature 4 was a robbed wall rather than a post trench.

Analysis of the variation in soil chemistry between layers permitted identification of the soil level which was ground surface at the time that the wall was constructed. Chemically, Levels K and E were more similar than were E and G, while Levels K and H were similar in most elements and identical in calcium. Level D contrasted chemically with F and also with Levels J and E. Level D was low in sulfur,in contrast to Levels E,F,G and K. Based on comparison of the chemistry of the layers, therefore, it appeared that Feature 4 separated Levels D,E,H and J,K,G; and was probably erected when Levels K and H were contiguous ground surfaces. Level E, which was high in organic matter, phosphorous and sulfur, appeared to have been an activity floor east of Feature 4 while Levels K and J were accumulating to the west. Level D soils appeared to have been deposited after this phase of use, and when Feature 4 was deteriorating (or robbed) and soils were infiltrating. Level C appeared to be the result of a separate and district episode, perhaps soil washed onto the site after a hurricane or severe flood.

In the case of the B and C levels of 69N/89-90W, the soil chemistry did not readily support the hypotheses or time frames originally considered. Based on soil chemistry, Level E was interpreted to be a soil horizon upon which human or farm animal activity took place. Level D was perhaps a period of disuse or abandonment of the area and Level B and C soils were deposited after these period of occupation and abandonment.s Embedded in the hard pan soils of Levels B and C were sherds of tin-enamelled ware and Creamware. This evidence and the soil chemistry led the investigators to conclude that the Level B and C soils were deposited later than originally hypothesized. Levels B and C appeared to be eroded soils carried by the flooding gully which formed late in the Colonial occupation and after abandonment of the cartway for regular use. Thus, although erosion of the upper slopes may have been initiated with the introduction of sugar cane cultivation and the erection of sugar processing facilities at the base of the inland slope, the eroded soils of Levels B and C most probably resulted from accelerated and severe erosion of the upland slopes and surrounding areas after cattle grazing was introduced during the nineteenth century.

This scenario and time frame also fit well with the plantation history. An 1807 advertisement describes the Zufriedenheit property as excellent grazing ground and pasture land. Studies conducted by the Cooperative Extension Service (verbal communication Ms. Ellen Craft) have shown that; while properly grazed areas so not contribute significantly to erosion, clearcutting for grazing, and overgrazing of the Guinea grass, can increase erosion significantly. Abundant plots of Guinea grass on the upper slopes of the plantation today attest to that former use.

OTHER FINDINGS

In test pits excavated on the majority of the Colonial occupation site at Zufriedenheit, a white sand stratum was present at the base of culturally disturbed soils. This clean white sand evidenced little intermixed humus and apparently represented a period when the site bore little or no vegetation. This was confirmed by the chemical analyses which were very low in organics. Superimposed mixed sand and humus strata represented either (1) environmental changes that resulted in sparse vegetating of the portions of a former berm or beach; (2) periodic flooding from adjacent organically rich wet areas such as guts, ponds or marshy areas, or (3) human activity which introduced humus to the soil. In any case, it appears that prior to Colonial settlement of the area, a beach berm or beach was present where the main Colonial habitation site was located. The introduction of organics to the soil permitted changes in vegetation, and subsequently in faunal habitat. Surficial humic soils which overly the hard pan on the site apparently have developed in place as the site was revegetated, predominantly with sweet lime bush and genip trees, after erosion of the upper slopes abated. Only recently have construction activities in the upper slopes again contributed to deposition of eroded slope soils at the bases of guts on the plantation.

SUMMARY

In summary, the soils studies, including field observations, field recording and laboratory chemical analyses conducted at the Zufriedenheit Plantation site made a significant contribution to our interpretation and understanding of some of the cultural activities and natural processes that occurred in the principal habitation area. In some cases, additional information was collected which supported the other archaeological evidence, and in some cases our original hypotheses were negated or altered by the soil chemistry data. Systematic soil sampling procedures and pertinent soil chemistry analyses are essential to archaeological investigations, and we are indeed grateful for the opportunity provided by coordination with the Cooperative Extension Service.

I would like to thank Earthwatch for its support; the members of Earthwatch teams I en II who worked diligently and enthusiastically; the Cooperative Extension Service of the University of the Virgin Islands; the State Historic Preservation Office; Ms. Mary Lou Burnett of Channel 12; Mr. Fred Gjessing, Mr. Homer Wheaton, Mr. Paul Guerrard, Mr. and Mrs. Tom Lawrence; Ms. Joyce Craig; Mr. Jonathan Gjessing and my Field Supervisor, Isabelle Rubin.

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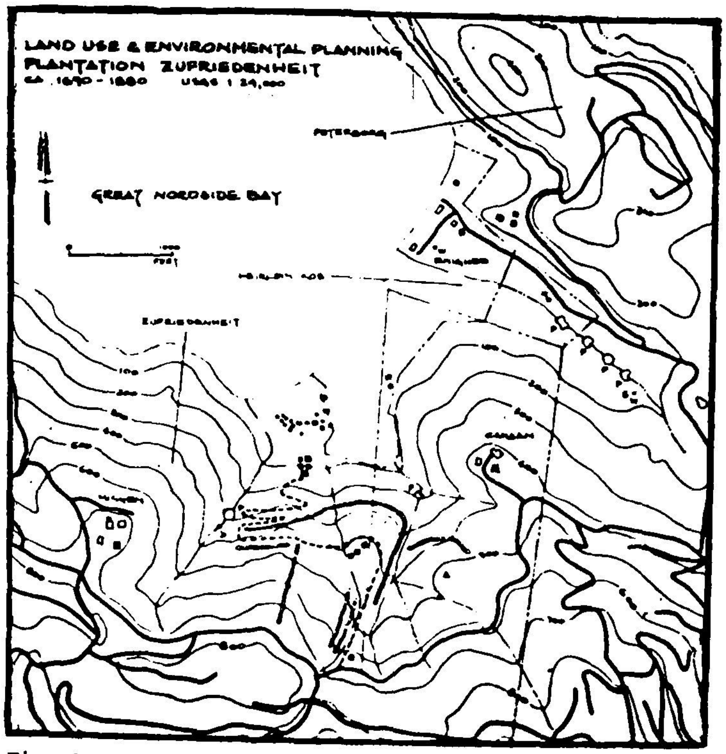


Fig. 1. Map of the Zufriedenheit Plantation: Zufriedenheit B is located at west end of the bay.

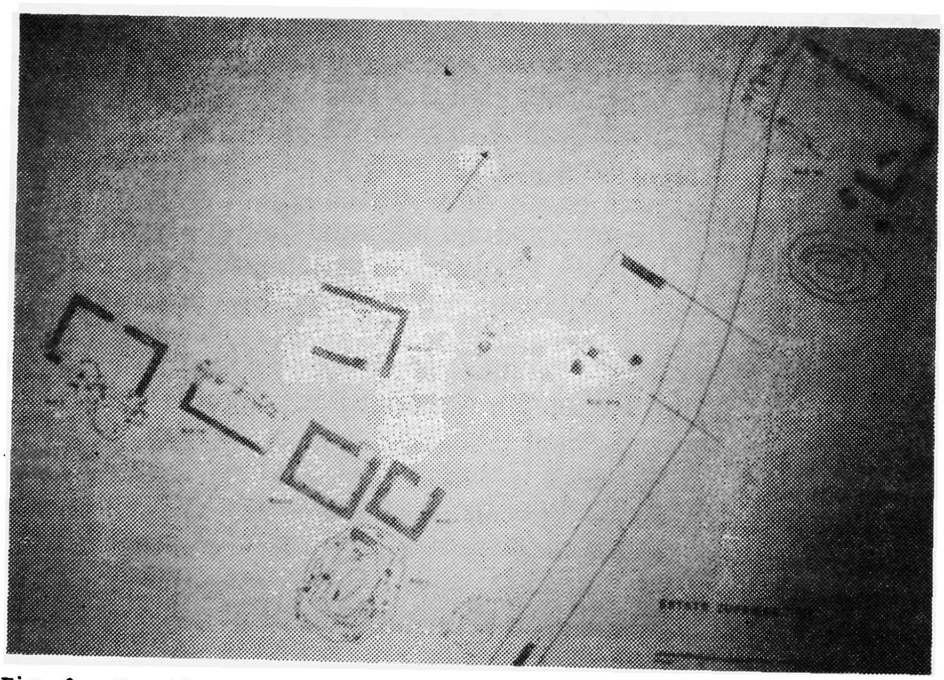


Fig. 2. Location of plantation buildings tested. Dovecote and storehouse is shown by the square foundation plan at top center.

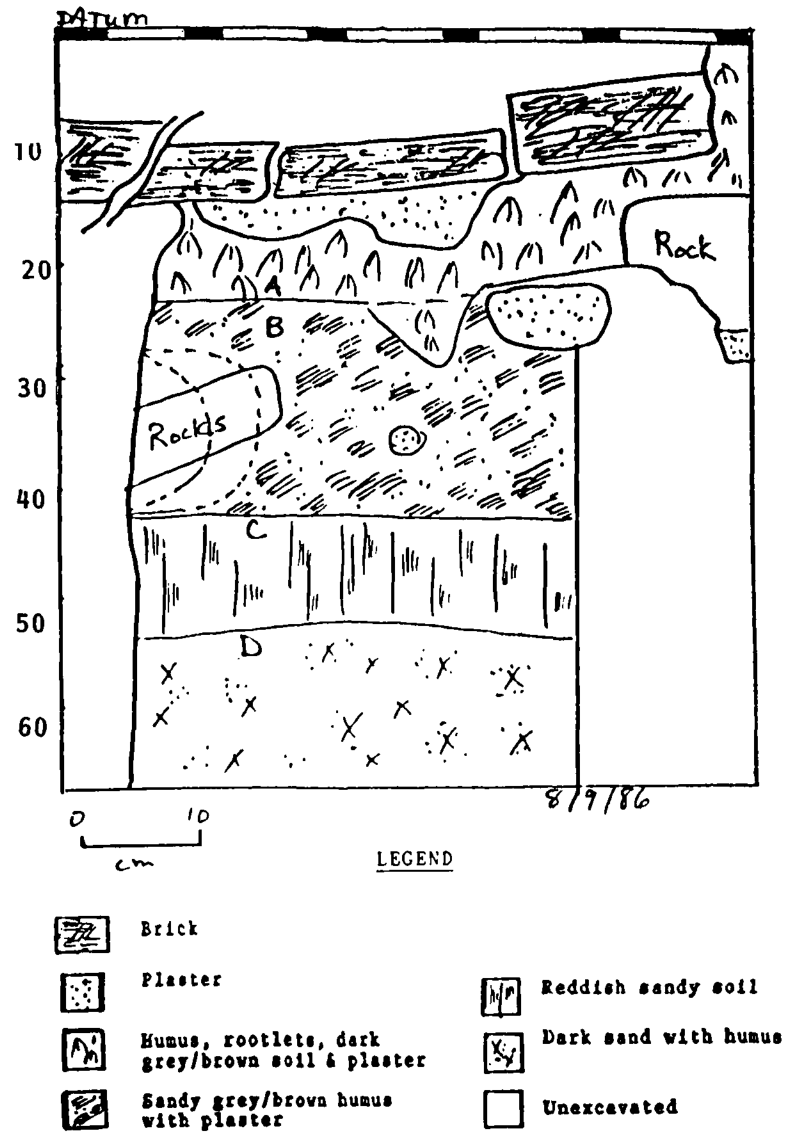


Fig. 3. 1986 stratigraphic profile of Unit 2, west wall, Zufriedenheit B East.

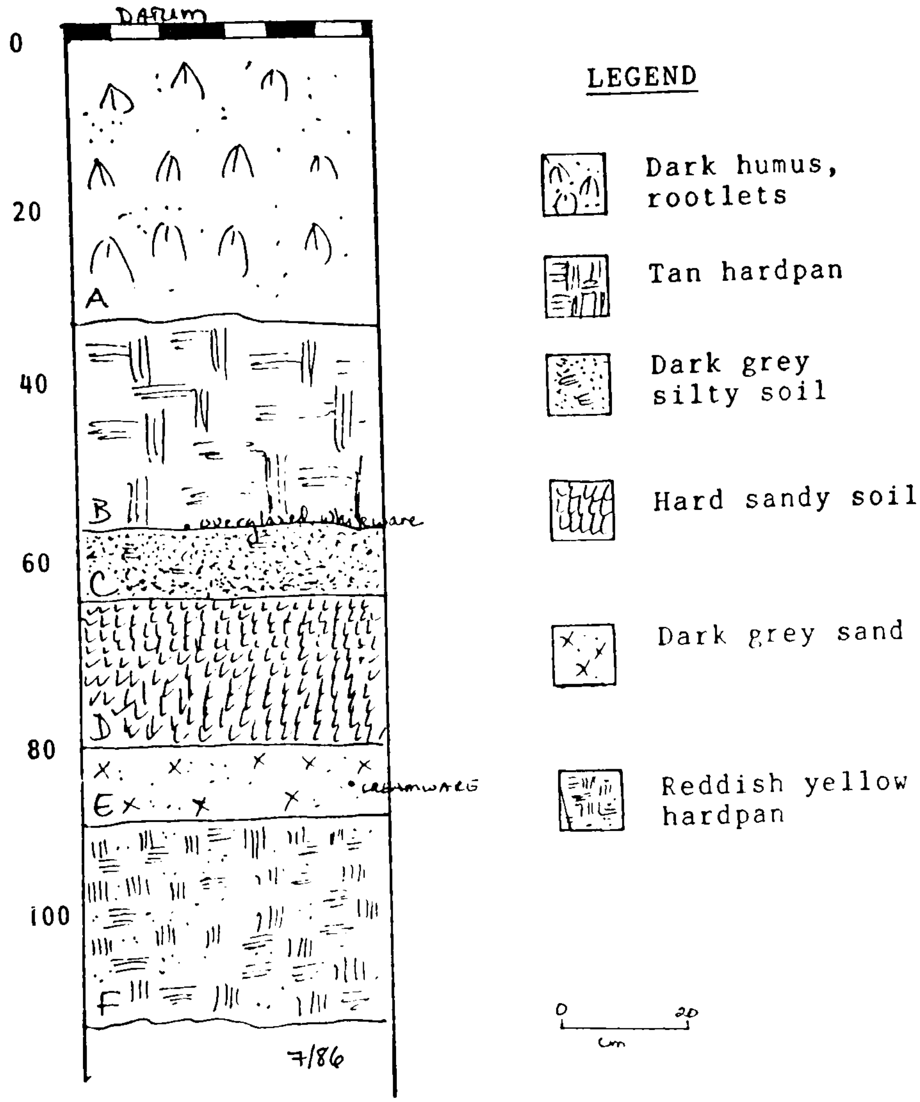
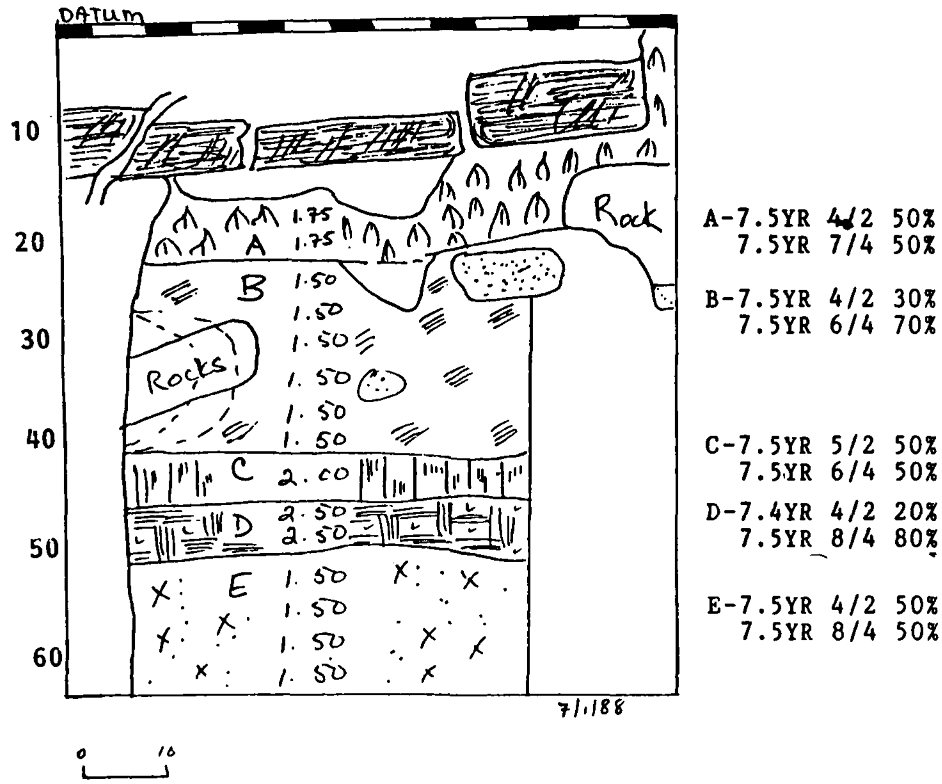


Fig. 4. 1986 stratigraphic profile of feature at 90N/3W, Zufriedenheit B East.

Fig. 5. Earthwatch volunteers conducting chemical tests in the field.



LEGEND

Brick	Weak, structureless pH 7
Plaster	Strong structure, compact subangular blocky. pH 7
pH 7 Strong, granular with rootlets. Structureless.	Structureless, weak. Loamy sand, rootlets. pH 7
pH 7 Weak, not granular or blocky. Moderate rootlets.	Unexcavated

Fig. 6. Clustering of penetrometer readings to distinguish stratigraphic layers on west wall of Unit 2, Zufriedenheit B East.

LEGEND

Structureless, granular soil with rootlets, dry	pH 7.71
Structureless, angular blocky, dry soil	pH 7.90
Subangular, blocky soil with rootlets, dry	pH 7.61
Moderately developed Subangular, blocky	pH 8.15
Structureless with rootlets, granular	pH 8.27
Moist subangular, structureless, blocky	pH 8.92
Subangular, blocky with rootlets	pH 9.14
Weakly developed, subangular, blocky	pH 9.05

** Note: Color could not be done in the field because of inadequate sunlight.

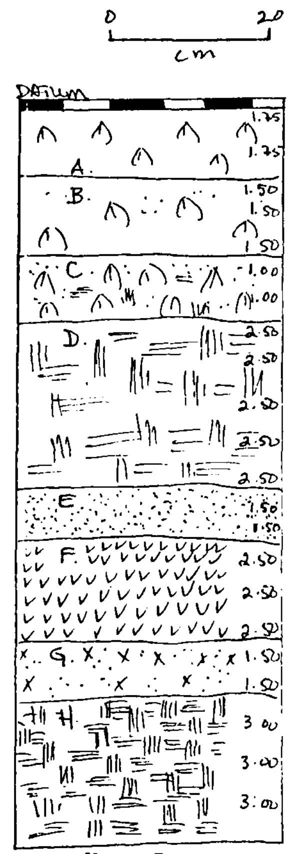


Fig. 7. Clustering of penetrometer readings to distinguish layers. Test 90N/3W, Zufriedenheid B East. 1988.

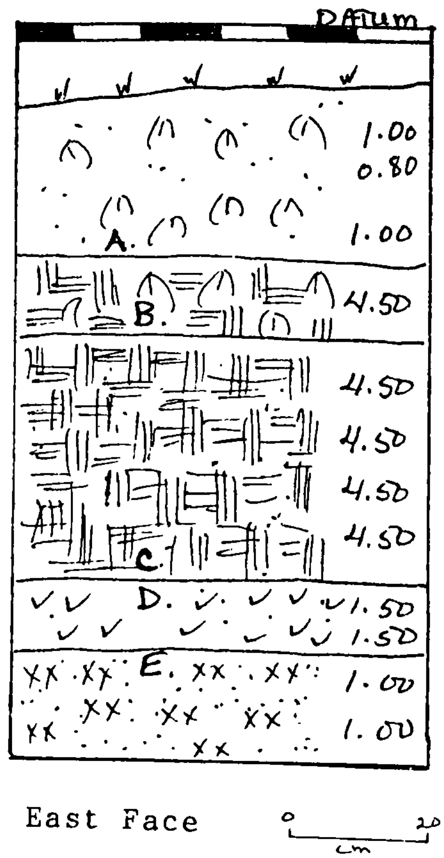

Granular, moderately developed, structureless. Rootlets. Sandy clay loam. pH 7.78
10YR 3/2, 90%
10YR 4/3, 10%


Subangular and angular peds that break into granular pieces Medium rootlets. Sandy clay loam. pH 7.63
10YR 4/4, 80%
10YR 3/1, 20%


Angular blocky, moderately developed. About 25% structureless. Rootlets.
pH 7.71
7.5YR 4/4 80%
7.5YR 7/6 20%


Structureless, weakly developed. Sandy loam.
pH 7.92
7.5YR 4/4 70%
7.5YR 7/6 30%


Structureless with a few granular peds. Very weakly developed. Sandy loam.
pH 8.40
10YR 5/4 50%
10YR 7/3 50%



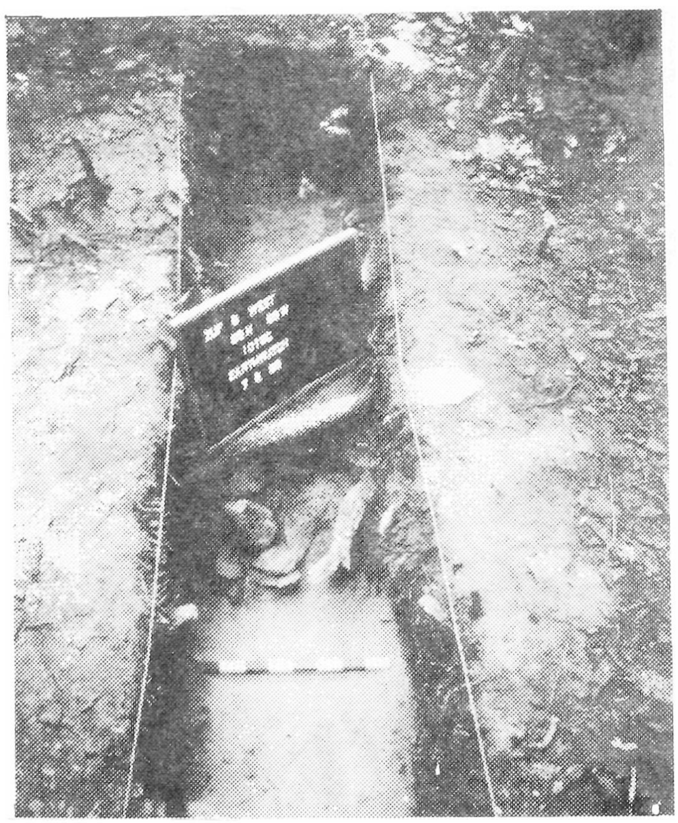
East Face

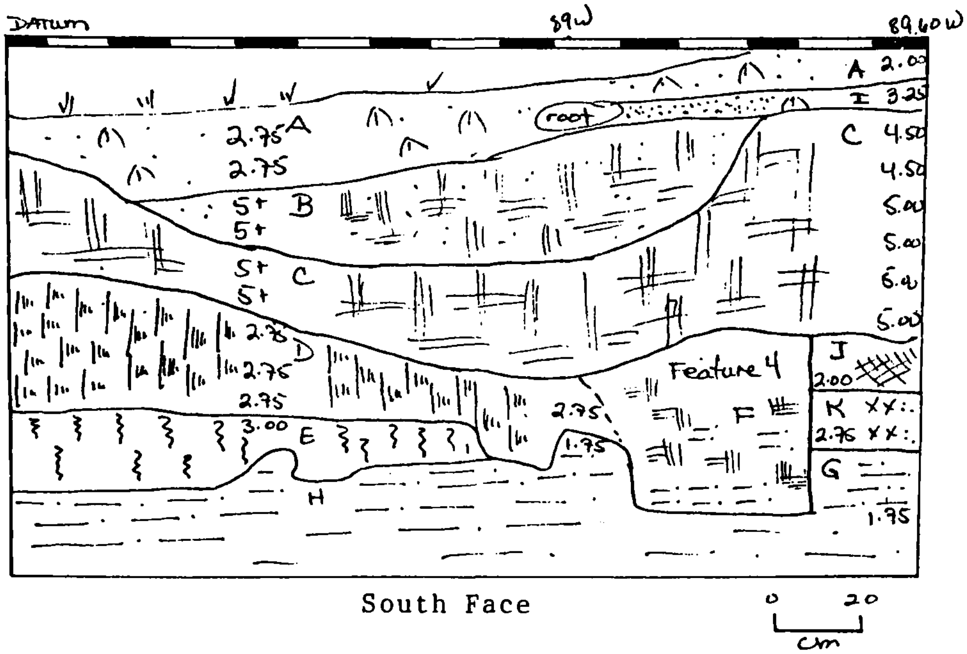
Fig. 8. Stratigraphic Profile of 69N/97W, Zufriedenheit B West, St. Thomas.

Fig. 9. Feature in 106W/73N, Zufriedenheit B West.

Fig. 10. Trenches at 69N, Zufriedenheit B West.

Fig. 11. Feature 4 in 69N/89-90W, Zufriedenheit B West.





Granular, moderately developed, structureless. Medium roots. Sandy loam.
10YR 4/3, 60% pH 8.01
10YR 4/2, 40%

Granular, moderately developed. Structureless. Clay loam with sand.
10YR 4/3, 50% pH 8.30
10YR 7/3, 50%

Angular, blocky, weakly developed. Sandy clay loam.
pH 8.49 10YR 5/8, 30%
10YR 6/6, 70%

Angular, blocky, moderately developed. Strong. 75% breaks into granular out of place and 25% is structureless. pH 8.08 (B)
pH 8.13 (C)
10YR 4/4, 75%, 10YR 7/6, 25% (B)
10YR 5/6, 30%, 7YR 6/6, 70% (C)

Structureless, weak sand.
pH 8.59 (G); pH 9.05 (H)
10YR 8/2, 70% (G)
10YR 7/3, 30%
10YR 8/2, 80% (H)
10YR 8/4, 20%

Structureless, some strength. Very sandy loam. pH 8.08
10YR 6/3, 50%
10YR 7/3, 50%

Structureless with some granular peds. Very sandy loam. pH 8.20
10YR 6/3, 80%
10YR 7/3, 20%

Very weakly developed. Structureless. Sandy loam.
pH 8.28 10YR 6/3, 30%
10YR 7/2, 70%

Very weakly developed, sand. structureless. 10YR 8/2, 50%
pH 8.03 10YR 7/3, 50%

Fig. 12. Stratigraphic profile of 69N/89-90W, Zufriedenheit B West, St. Thomas.