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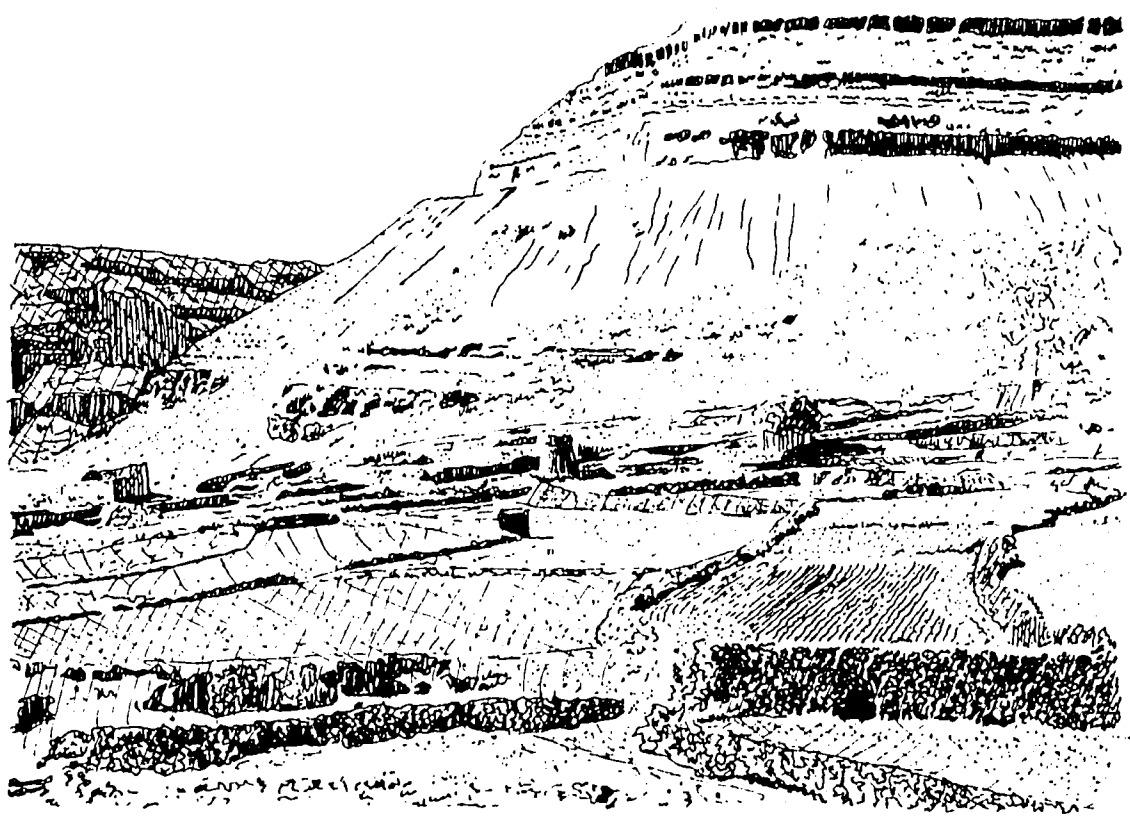
# SOIL SURVEY OF THE YEMEN ARAB REPUBLIC

## Progress Report II

## March, 1981-September, 1981




DEPARTMENT OF AGRONOMY

N.Y. STATE COLLEGE OF AGRICULTURE AND LIFE SCIENCES
A STATUTORY COLLEGE OF THE SUNY AT CORNELL



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New York State College of
Agriculture and Life Sciences
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Ithaca, New York 14853

# SOIL SURVEY OF THE YEMEN ARAB REPUBLIC

Project funded by USAID Contract NE-C-1665
Land Classification and Soil Survey of the Yemen Arab Republic
Project 279-0042

## PROGRESS REPORT

March 1981- September 1981
(Internal Working Document, not for Publication or Reference)

by

Cornell Yemen Soil Survey Staff

Ithaca, N.Y.
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## FOREWORD

This report is a cumulative report on all soil survey activities and results since the commencement of the project. It also serves as a six month progress report required by USAID, the funding agency. This report emphasizes the results obtained after the initiation of field work in Yemen. Dr. Jack King, as permanent field officer stationed at Taizz, and Dr. Terence Forbes, on TDY, started selection and surveying of pilot areas in April, 1981. Once a methodology was developed, field work progressed rapidly. In April and May, most of the survey effort was concentrated on topographic map sheets five and seven. Soil profiles were described and samples were collected for routine analyses at Taizz and for mineralogical, micromorphological and other special analyses at Cornell. By the end of August, 1981, Dr. King had visited every region of the country and contacted local officials for more intensive survey work in the near future.

Approximately 60 soil samples have been analyzed by the Taizz and Cornell laboratories. Analytical results can be found in the soil profile descriptions in Chapter 4 of this report.

Seven false-color infrared imagery scenes were processed digitally for use in extrapolating ground information observed in accessible areas to inaccessible areas. Two more scenes are currently being processed and the nine scenes will be used to construct a false-color infrared map at 1:500,000 for the whole country.

This report also presents a discussion of soil relationships in Yemen, map unit descriptions and a map of tentative associations of soil subgroups for topographic map sheet seven. The report is intended to be an example of the format of the final soil survey report. The map delineations will be refined along with the composition of soil associations and a section on recommendations for land use will be added. The report also deals with budget and administrative aspects of the project operations.

# INTRODUCTION

At present, only limited information is available on the soils of the Yemen Arab Republic. The few soil surveys that have been conducted are not sufficient or adequately correlated in a national or international system to serve development needs. They vary in degree of detail, and require complementary studies to respond to an increasing demand for soil resource information. This reduces their usefulness and restricts the transfer of technical knowledge from other areas with similar ecological conditions.

This project involves the mapping of soils and land resources of the Yemen Arab Republic. The study will be a part of the data base for planning the development of agriculture and urban infrastructures.

The objective of the soil survey is to produce a generalized 1:500,000 soil map based on field observations, which will be extrapolated by interpretations of satellite and air-photo imagery. The map will show associations of subgroups as recognized by USDA Soil Taxonomy.

During the report period, one soil surveyor with support equipment and personnel has been stationed in Yemen with operations based in Taizz. Field work has included soil profile examination and mapping. Soil analyses required to place the soils into Soil Taxonomy classification have been started in support of the field work. Representative soil profiles will be sampled, tested and described throughout Yemen as part of this effort. The surveyor is assisted by Yemeni personnel, both professional and non-professional. Soil samples will be analyzed by the FAO-assisted Agricultural Research Service in Ausseifere; some special and texture analysis have been performed at Ithaca.

The information provided upon completion of this project will be useful in the planning of development activities in Yemen. The survey will assist in locating areas of high potential where more detailed soil information would facilitate the introduction of new technology for agricultural production.

The present project will map those areas of Yemen west of longitude 45 degrees, 30 minutes. The survey area does not include islands in the Red Sea.

# Chapter 1
# GENERAL DESCRIPTION OF THE AREA

## CLIMATE

The Yemen Arab Republic has a climate characteristic of the arid and semi-arid tropical areas. Rainfall is seasonal and very variable, and is primarily controlled by the effects of the mountains. Weather and climate data are very scarce.

### RAINFALL

Rainfall varies from approximately 1000 mm/yr in the Ibb area to near 0 mm/yr along the coast and in the Rub Al Khali. A probable modal rainfall map is shown in Map 1.1. The largest amounts of rainfall are associated with the highlands as humid winds from the Indian Ocean and Red Sea are forced to rise and cool. Once past the highest mountains, the winds have dropped their moisture and rainfall decreases rapidly to the east.

### TEMPERATURE

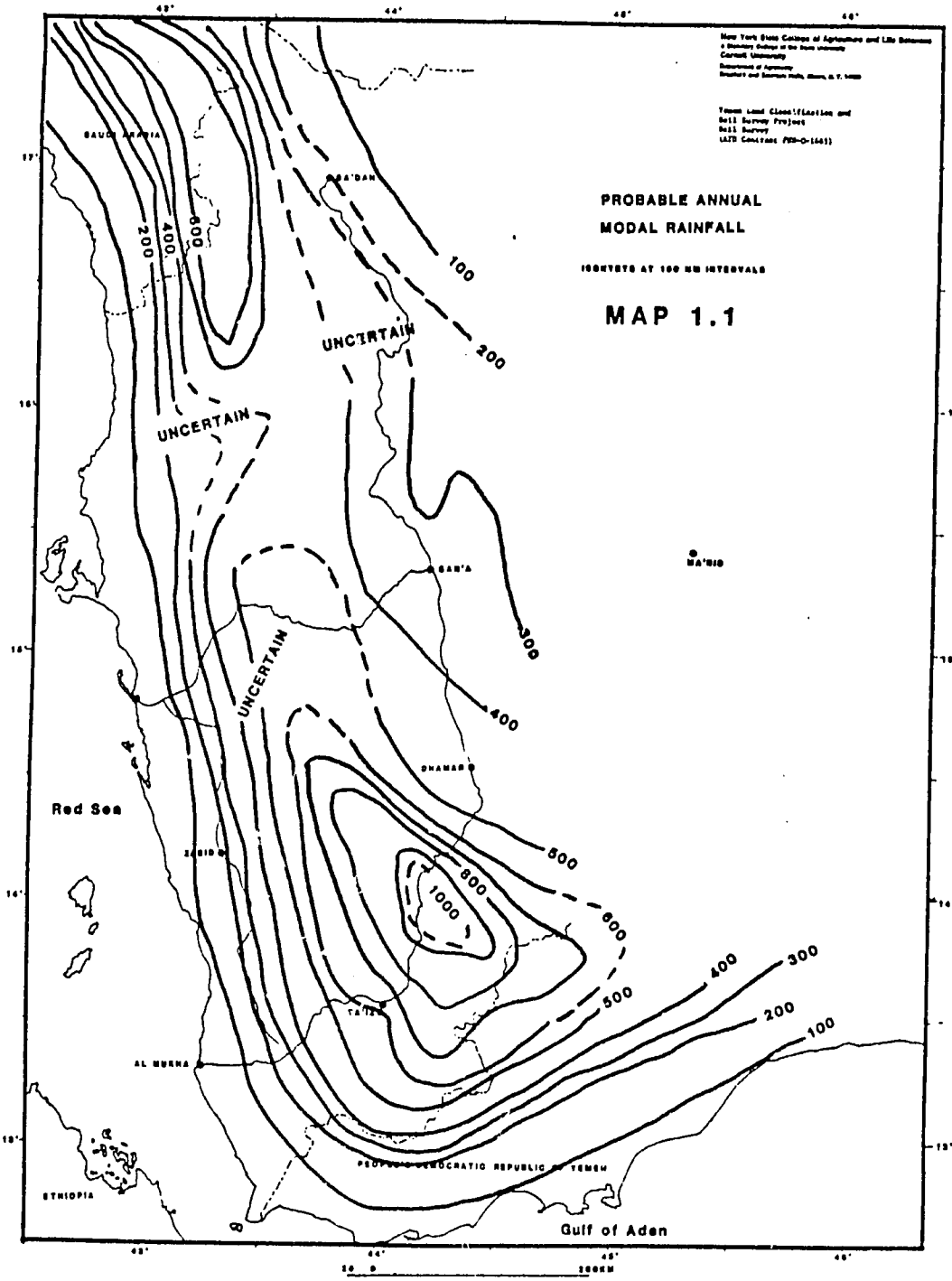
Temperature in Yemen is strongly influenced by elevation. The yearly average ranges from 15 degrees Celsius at Sana to 26 degrees at Hodeidah on the coast.

High potential evapotranspiration rates, resulting from high temperatures (Figure 1.1), are moderated on the Tihama somewhat by the comparatively high relative humidity. Extremely dry conditions with dessicating winds, as found in Sahelian Africa, are not common.

Freezing weather seldom occurs in the lowlands. However, nighttime freezing weather is common in some of the highland areas. For example, at the Kitab dairy on the Dhamar Plain 100 consecutive nights of below 0 degrees Centrigrade were recorded. The lowest recorded temperature was -9 degrees Centigrade at the same location.

November 1, 1981

YEMEN ARAB REPUBLIC



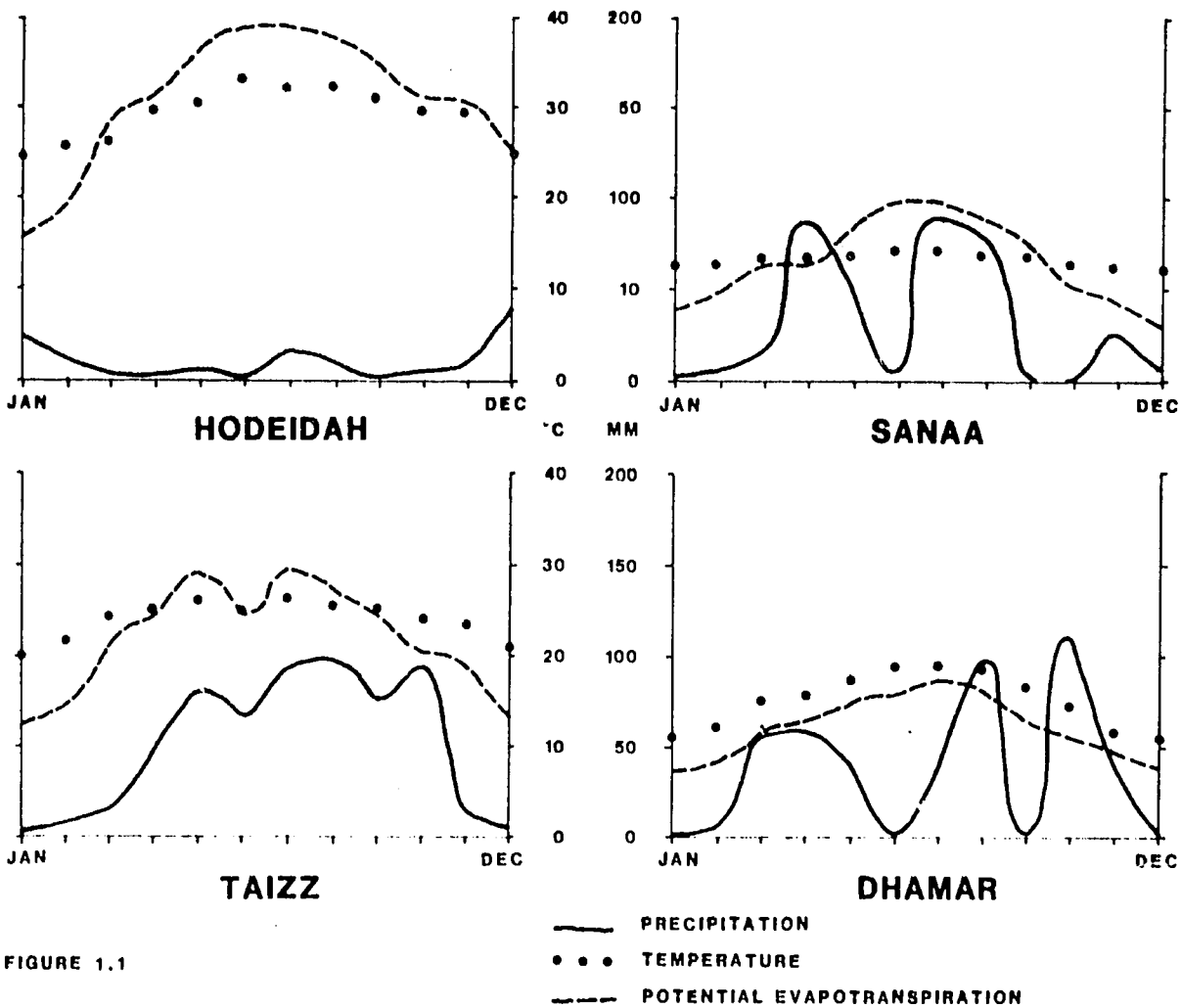



FIGURE 1.1

**Climatic Data for Yemen**

# GEOLOGY

This information is adapted from reports by Geukens (1966) and Grolier and Overstreet (1978).

The Yemen Arab Republic includes four major geologic provinces; (1) the pre-Cambrian shield areas; (2) sedimentary rocks of Paleozoic and Mesozoic ages; (3) Tertiary and Quarternary volcanics; and (4) Quarternary alluvial deposits. A generalized geologic map is given in Map 1.2.

## PRE-CAMBRIAN SHIELD

The pre-Cambrian shield is the basement of the Arabian peninsula. It is composed of igneous and metamorphic rocks. The igneous rocks include pink orthoclase granites, diorite, gabbro, and mafic volcanics. Metamorphic rocks include mica, chlorite and garnet schists, gneiss, quartzite, marble, slate, and amphibolite. The structure of the shield is very complex, because the rocks have been folded and faulted several times.

## SEDIMENTARY ROCKS

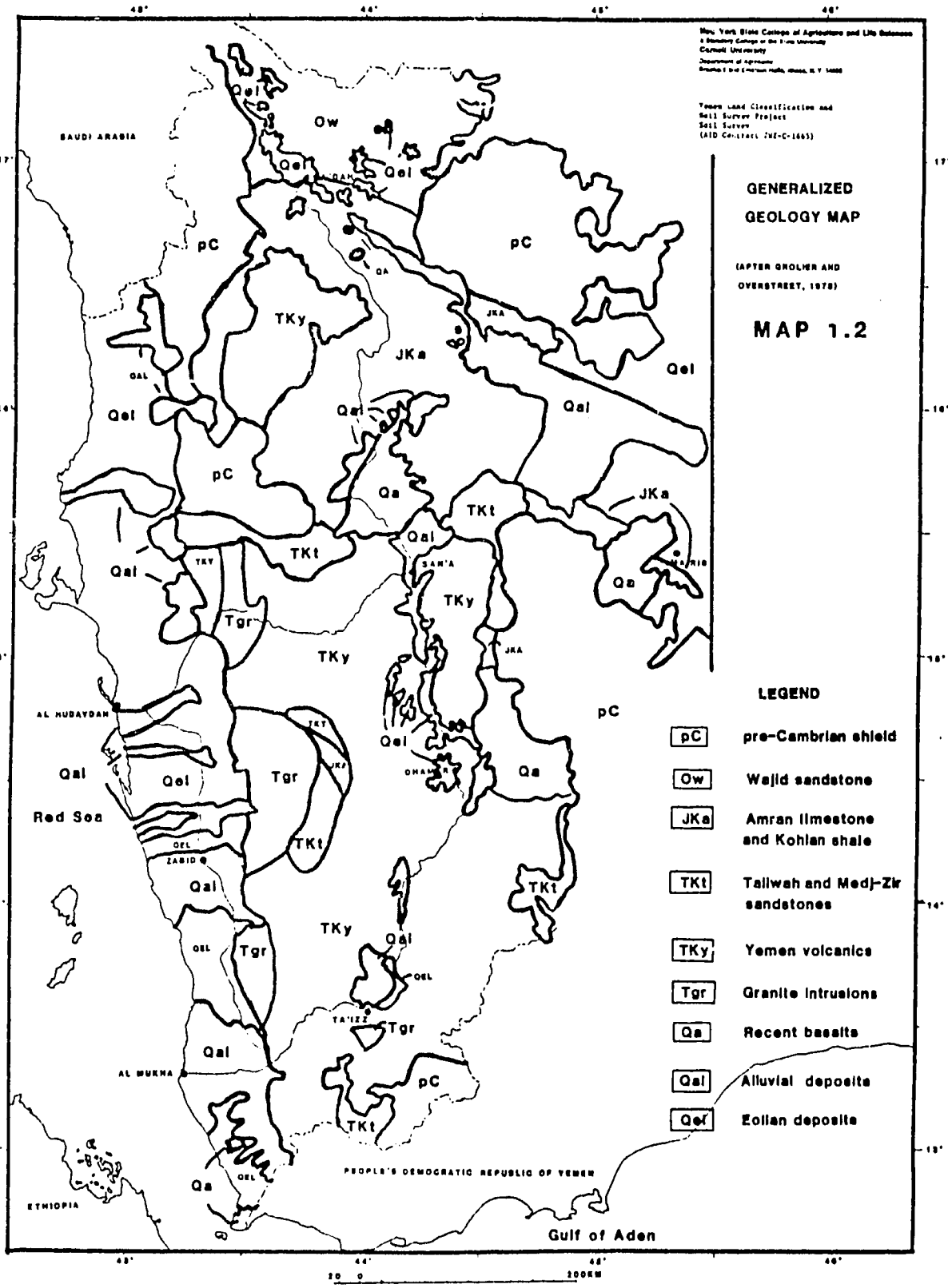
There are three sets of sedimentary rocks in Yemen, the Wajid sandstone, the Kohlan and Amran groups and the Taliwah and Medj-Zir groups, going from oldest to youngest.

All of the sedimentary rock groups are approximately horizontal. The Wajid sandstone rests directly on the pre-Cambrian shield. The Kohlan group is also in contact with basement rocks. The Kohlan and Amran groups and the Taliwah and Medj-Zir groups are conformable. The Amran and Taliwah groups are unconformable.

Wajid Sandstone : The Ordivician Wajid sandstone is a cross-bedded, coarse-grained, well-rounded, quartz sandstone. It includes frequent conglomeratic gravel lenses. The grain size decreases to the north. It contains no fossils.

Kohlan and Amran Groups : The Jurassic Kohlan group consists of green silty shale and arenaceous sandstone which includes conglomerate lenses. The sandstone is interbedded with and overlies the shale. The sandstone becomes purer in quartz to the north. The Kohlan Series is generally unfossiliferous.

YEMEN ARAB REPUBLIC



The Kohlan group grades into the overlying Jurassic Amran group. The Amran group contains fossiliferous blue and light gray limestone, marl and calcareous shale and sandstone. The Amran group varies in lithology from place to place, depending on environmental conditions in each area at the time of deposition.

Tawilah and Medj-Zir Groups : The third group of sedimentary rocks includes the Cretaceous Tawilah and Tertiary Medj-Zir Groups. They are cross-bedded, coarse-grained quartz sandstones. They generally contain hematite nodules where they are in contact with volcanic materials. The lower Tawilah group includes conglomerate layers interbedded with red and green shale layers. The Medj-Zir group contains locally fossiliferous layers of calcareous shales.

## TERTIARY AND QUARTERNARY VOLCANICS

Yemen Volcanics : The Yemen volcanics includes Tertiary volcanic rocks (the Trap Series) and contemporaneous granite laccoliths. The Trap Series (Geukens, 1966) is made up of alternating lava flows, basalts, porphyries and various tuffs. The original volcanic craters are rare. The Trap Series includes sedimentary deposits, which were laid down during volcanically quiet times. These deposits include fossils.

The granite laccoliths are exposed both within and adjacent to the Trap Series, and also in the sedimentary rocks north of Sana. They are heavily dissected.

Quarternary Volcanics : Granites which are younger than the Trap Series, and volcanoes whose cones are still intact are present throughout Yemen. These were emplaced in the Quarternary. The granites include tourmaline and amphibole crystals. The volcanoes are basaltic and are often enclosed in layers of tuff. The most recent volcanism is located in the Dhamar-Rada area.

## QUARTERNARY ALLUVIAL DEPOSITS

Quarternary alluvial deposits can be divided on the basis of their mode of transportation into wind-laid and water-laid material.

### Wind Deposits

Loess : Loess deposits are found in areas where mountains are high enough to be a barrier to the wind, causing it to drop its load. The loess of Yemen probably originated in the desert to the northeast, the direction of the prevailing winds. Many of the loess deposits, particularly in the inter-mountain plains, have been reworked by alluvial deposits.

Dunes : In the survey area, sand dunes are found primarily on the Tihama, where the ground is level. Barchans and some longitudinal dunes are found, indicating that sand supply is the limiting factor of dune formation. The source of the sand is probably the wadi beds and alluvial fans, which receive sand from wadis coming out of the mountains. The great sand seas of the Rub Al Khali are outside of the survey area.

### Fluvial Deposits

Alluvial fans and plains : Alluvial fans are deposited where a quick decrease in slope causes a wadi to slow down and drop its load. Plains are constructed in areas of little relief, where wadis spread out and lose most of their speed. Fans are found on the Tihama and along the Wadi Al Jawf, where mountains meet level areas. Alluvial plains are found in the same places, and also in mountainous areas, where inter-mountain basins act as traps of sediments carried by wadis. The fans are made up of coarse-grained material, since the dryness and lack of vegetation allow the wind to carry away finer particles. In the plains and along the wadi terraces, fine materials are common in most places, gravelly and stony materials occuring only in the active stream beds of the wadis. The source of the sediments carried by the wadis is the weathering of the mountains, which are made up of the rocks described above, and reworked alluvial loess.

## LANDFORM REGIONS

A map of the landform regions of the Yemen Arab Republic is given in Map 1.3. The legend of the map is given in Table 1.1. The map divides the country into areas in which similar soils are expected to occur as associations in a generally uniform pattern. The landform regions were recognized on the basis of topography, bedrock geology, and climate. The topographic relationships between the landform regions are shown in Figure 1.2.

The sources used for the preparation of this map were the USGS 1:500,000 geologic and geographic maps (Grolier and Overstreet, 1978), which used digital Landsat imagery as their base. Selected areas were also examined with airphotos at 1:60,000 scale, obtained from the Resource Information Laboratory at Cornell University. Because of the scale (1:500,000) of the geologic information used, only general landform regions were outlined. Soils expected to occur in each area were tentatively classified to the Soil Taxonomy subgroup level.

YEMEN ARAB REPUBLIC

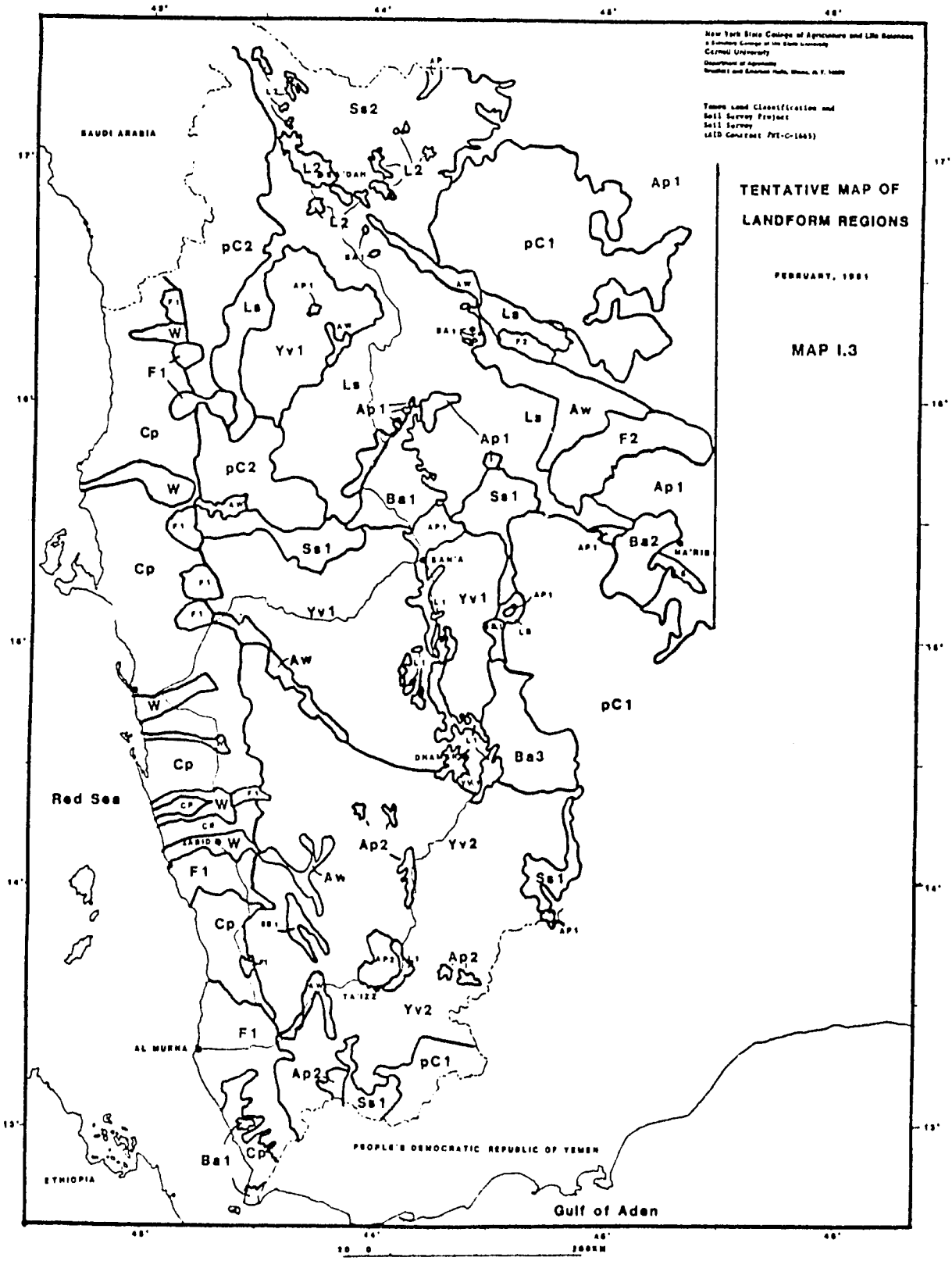
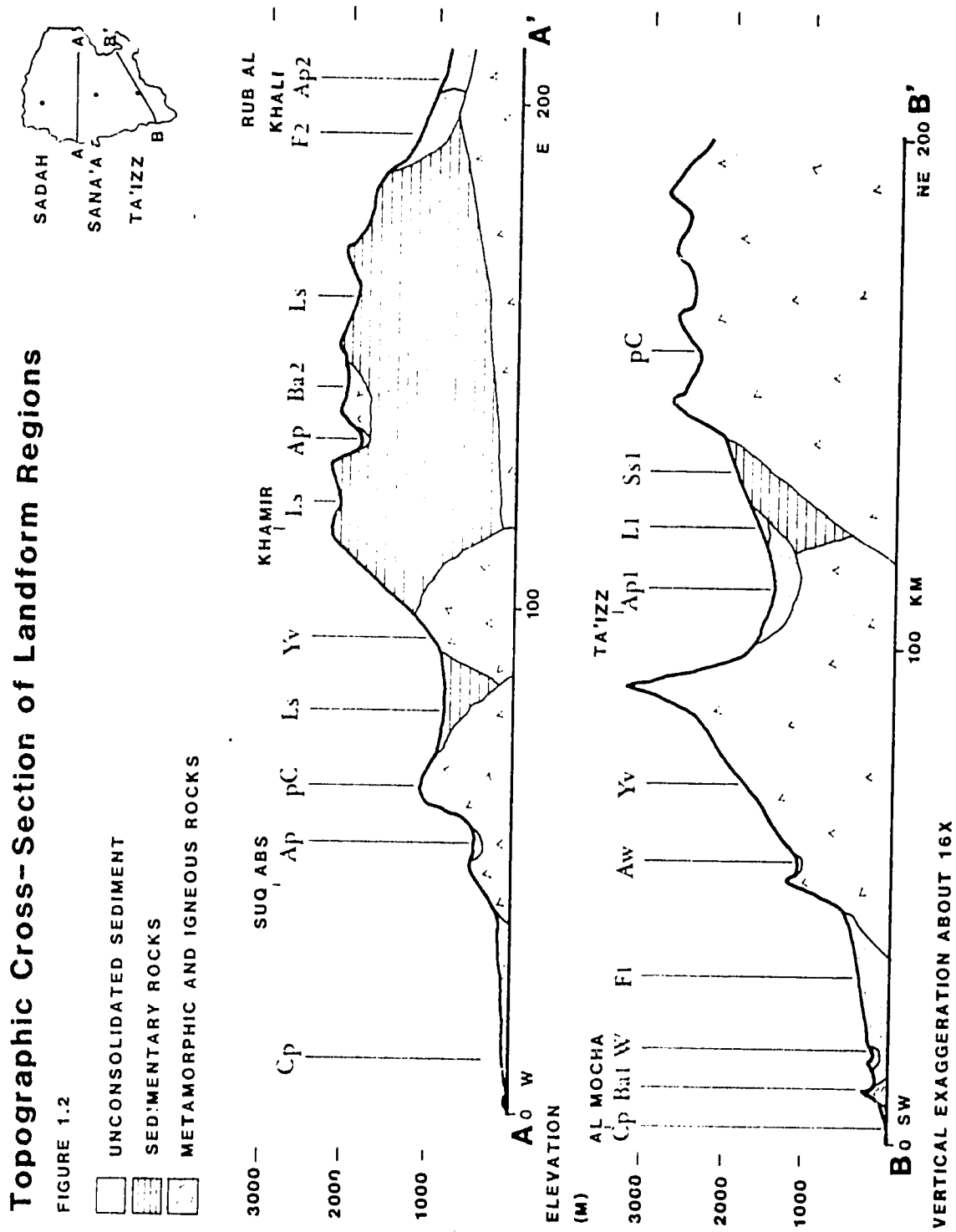


TABLE I.1 LANDFORM REGIONS OF YEMEN

| MAP SYMBOL | LANDFORM REGION | DESCRIPTION | ELEVATION (M) | RAINFALL (MM) | AMOUNT OF AGRICULTURE | ACCESSIBILITY | POSSIBLE SOIL SUBGROUPS |
|---|---|---|---|---|---|---|---|
| Ap1 | Alluvial plains | Broad plains with protruding volcanic cones | 2500 | 300 | Moderate | Good | Typic Torrifluvents<br>Aquollic Salorthids<br>Typic Torriorthents |
| Ap2 | Alluvial plains | same as above | 1500 | 900 | Extensive | Good | same as above<br>Typic Torrerts<br>Udic Pelusterts |
| Aw | Wadi alluvium | Wadis between steep valley walls | Variable | Variable | In wadi flood plains | Variable | Typic Torrifluvents<br>Typic Tropofluvents<br>Typic Calciustolls<br>Typic Torriorthents<br>Typic Calciorthids<br>Typic Camborthids |
| Ba1 | Basalt flows | Basalt cones and flows, colluvium grading into alluvial fans | 2000-2200 | 300 | Low | Good | Ustochreptic Calciorthids<br>Natric Camborthids<br>Lithic Camborthids |
| Ba2 | Basalt flows | same as above | 1200 | 200? | Low | Good | same as above |
| Ba3 | Basalt flows | Dissected basalt plateau | 2500 | 400 | Moderately extensive | Fair | same as above |
| Cp | Coastal plain | Flat to gently rolling alluvial plain; Barchans and some longitudinal dunes | 60 | <200 | None | Good | Typic Camborthids<br>Typic Torrifluvents<br>Typic Calciorthids<br>Typic Salorthids<br>Typic Tropofluvents |
| F1 | Alluvial fans | Alluvial fans cut with wadis | 0-300 | 200-300 | Extensive; bund farming in drier areas | Good | same as above |
| F2 | Alluvial fans | same as above | 1000 | 0-100 | None | Poor | same as above |
| L1 | Loess | Occurring in mountains | 2000 | 400 | Extensive, heavily terraced | Good | Aridic Haplustolls<br>Typic Natrustalfs<br>Typic Ustorthents<br>Typic Ustropepts |
| L2 | Loess | Flat, broad plains | 2600 | 400 | Low | Good | Typic Torriorthents<br>Aquollic Salorthids<br>Typic Ustorthents |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ls | Limestone | Dissected and jointed limestone plateau | 1800 | 200 | Extensive; but no terracing on valley walls | Good | Ustochreptic Calciorthids<br>Lithic Calciorthids |
| pC1 | pre-Cambrian shield | Jagged mountainous channels with braided stream channels | 1800 | 200 | None (some minor in valleys in north) | Poor | Typic Torriorthents<br>Complexes of rock outcrop<br>Typic Torrifluvents |
| pC2 | pre-Cambrian shield | same as above with with terracing for agriculture | 1000-2600 | 600 | Important in valleys and heavily terraced | Fair | Typic Torrifluvents<br>Ustochreptic Calciorthids<br>Lithic Calciorthids<br>Aridic Calciorthids<br>Typic Torriorthents<br>Aridic Argiustolls |
| Ss1 | Sandstone | Highly dissected sandstone plateau with entrenched streams | 2000 | 600 | None | Poor | Lithic Camborthids<br>Fluventic Camborthids |
| Ss2 | Sandstone | same as above | 1500 | 100 | Little | Poor | same as above |
| W | Coastal Wadis | Intermittent stream channels on coastal plain | <300 | <200 | Moderately extensive; threatened by blowing sand | Good | Typic Camborthids<br>Fluventic Haplustolls<br>Typic Torrifluvents<br>Typic Calciorthids<br>Typic Salorthids |
| Yv1 | Yemen Volcanics | Highly dissected volcanic plateau with alluvial plains between mountains | 2400 | <600 | Little- in river valley, few terraces | Good | Complexes of rock outcrop<br>Typic Camborthids<br>Typic Torriorthents<br>Typic Torrifluvents |
| Yv2 | Yemen Volcanics | Moderately dissected volcanic plateau | 2000 | >600 | Moderate; extensive terraces | Fair to Good | Aridic Haplustolls<br>Typic Calciustolls<br>Typic Ustropepts<br>Typic Ustrochrepts<br>Typic Ustorthents<br>Complexes of rock outcrop |


Topographic Cross-Section of Landform Regions
FIGURE 1.2
UNCONSOLIDATED SEDIMENT
SEDIMENTARY ROCKS
METAMORPHIC AND IGNEOUS ROCKS
SADAH
SANA'A
TA'IZZ
A
A'
B
B'
ELEVATION (M)
3000
2000
1000
SUQ ABS
Cp
Ap
pC
Ls
Yv
KHAMIR
Ls
Ap
Ba2
Ls
RUB AL KHALI
F2
Ap2
A 0 W
100
E 200
A'
AL MOCHA
Cp
Ba1
W
Fl
Aw
Yv
TA'IZZ
Ap1
L1
Ss1
pC
B 0 SW
100 KM
NE 200
B'
VERTICAL EXAGGERATION ABOUT 16X

The country was divided into seven general areas, with as many subdivisions as necessary. These are: pre-Cambrian shield areas, sedimentary rock areas, the Yemen volcanics area, recent basalt flows, loess deposits, the coastal area and inland alluvium.

## DESCRIPTIONS OF LANDFORM REGIONS

### Basalt Flows

Recent basalt flows occur throughout the country. The area covered by these flows varies widely from region to region. Three major flows are distinguished. Smaller isolated flows and cones are grouped within one of the three major divisions.

The first flow observed (labelled Ba1) is located about 100 km north of Sana in an area which receives about 300 mm of rainfall per year. It is relatively unweathered. It does not appear to support agriculture, although nearby alluvial areas receiving irrigation are heavily cultivated. Isolated basalt cones were mapped with the Ba1 category because their alluvium could support agriculture, given enough moisture. At present however, there are generally no crops around these features, due to lack of rainfall and irrigation.

The second flow (Ba2) is located just west of Marib. It receives less than 200 mm of rain per year and is unweathered. Sparse irrigation agriculture exists in alluvial areas.

These two basalt landscapes consist of basalt cones and flows surrounded by colluvium grading into alluvial fans. The Ba2 flow is much less weathered than Ba1.

The third basalt flow (Ba3) region occurs about 80 km east of Dhamar and receives more rainfall than the other two. This region is a dissected basalt plateau. Airphotos were unavailable for this area, but the satellite imagery seems to indicate that the basaltic rocks are more weathered than in the other areas. Again, the surrounding basalt alluvium is densely cultivated.

### Coastal Area

This area is usually referred to as the Tihama. Three types of landforms were distinguished: wadis, alluvial fans and coastal plain.

Alluvial fans (F): Alluvial fans are low, relatively flat masses of loose rock material, shaped like a segment of a cone and deposited by a wadi where it issues from a narrow mountain valley.

The coastal alluvial fans were grouped as F1. The material making up the fans comes from the highlands; the Yemen volcanics in the south

and the pre-Cambrian shield in the north. Alluvial fans receive very little rainfall (200-300 mm/year), but are used for agriculture when wadi water is available. Some, at the mouths of the wadis coming out of the mountains, are cultivated, often using bund farming.

Coastal wadis (W): Wadis are stream channels that are dry except during the rainy season. In Arabic, wadi can refer to any stream channel whether it becomes dry or not. Wadis on the coastal plain receive water from the mountains to the east. There is little or no rainfall on the Tihama to supply wadis directly. Most of the water in wadis seeps into the underlying sediments before reaching the Red Sea. Wadi alluvium, which is brought from the mountains and adjacent fans, forms flat plains. Blowing sand often threatens cultivated fields on coastal wadis. There is little relief associated with wadi beds.

Coastal plain (Cp): The coastal plain is the area on the Tihama outside the wadi and alluvial fan areas. It is extremely dry, and wind is the primary landform-shaping force. Longitudinal dunes and barchans are prevalent. There is little relief besides the dunes on the coastal plains.

## Inland Alluvium

The areas of inland alluvium were divided into three categories: alluvial plains, wadi alluvium and inland alluvial fans. Alluvial plains and inland alluvial fans were probably formed during a previous pluvial period.

Alluvial plains (Ap): Alluvial plains are broad plains of alluvium covering bedrock between mountains. Some plains show protruding volcanic cones. The alluvium is a mixture of products of the weathering of the surrounding rock outcrops (volcanic and sandstone formations) and materials deposited by the wind. Two major classes of alluvial plains were separated on the basis of rainfall. Six hundred mm/yr was chosen as an arbitrary break point because it is near the boundary between the ustic and aridic soil moisture regimes. Those with higher rainfall (close to 1000 mm/year of rain) supported extensive agriculture (Ap2). Those in drier areas (rainfall around 300 mm/year) supported less agriculture.

Wadi alluvium (Aw): In the mountains, wadis are entrenched in steep valleys between mountain ridges. The areas along the major wadis in the mountains generally have a reliable supply of water and can support agriculture in the flood-plain. The moisture conditions of any individual wadi vary depending on the amount of rainfall and the type of alluvial material deposited.

Inland alluvial fans (F2): This unit includes two fans along the Wadi Al Jawf. These inland alluvial fans receive almost no rainfall (0-100 mm/year)

## Loess

Areas of loess deposits were divided into two groups, based on the amount of rainfall. Loess deposits are heavily eroded, on steep hillsides. The loess in the wetter areas (L1) generally is more dissected than that in the drier areas of the north, and is used more extensively for agriculture. Both loess areas are intensively terraced for agricultural purposes.

## Pre-Cambrian Shield Areas

The pre-Cambrian shield is made up of erosion-resistant igneous and metamorphic bedrock. Consequently, the terrain is very jagged and mountainous. Mountain ridges are separated by wadis or linear areas of alluvium. There appears to be little deposition of alluvial material in wadi beds, which are braided stream channels.

The pre-Cambrian shield areas are divided on the basis of rainfall. The pC1 unit is located in very dry areas (rainfall <100 mm/year), and is unable to support agriculture, except in isolated areas along major wadis. The wetter areas (rainfall of around 600 mm/year) make up the pC2 area. Agriculture is found both in the stream flood plains and on terraces up the sides of the ridges in these areas.

## Sedimentary Rock Areas

Limestone and sandstone are the two major kinds of sedimentary rocks deposited in Yemen. There are several different formations of each kind, but they appear to form similar landscapes.

Limestone areas (Ls): These are found in the drier areas of Yemen and are consequently very resistant to erosion. The area is dissected, generally along structural features, particularly joints. Agriculture is extensive where the water supply permits, but where rainfall is limited, little or no agriculture takes place. In the drier areas, there is little soil formation, due to lack of weathering of the rocks.

Sandstone areas (Ss): There are two major sandstone formations: the Taliwah group (Ss1) and the Wajid sandstone (Ss2). The Taliwah group is located in areas of relatively high rainfall and is highly dissected, with entrenched wadis between high mountain ridges. There appears to be little soil formation on the mountain sides or in the stream channels. There is little agriculture in these areas.

The Wajid sandstone outcrops in the dry northern area. They are less rugged than the Taliwah areas, with broader plains between mountains. Some agriculture is found on these plains, where rainfall or groundwater supplies permit.

## Yemen Volcanics

The Yemen Volcanics formation occurs extensively over southwestern Yemen. The area is generally a rugged igneous plateau, which has been strongly dissected. Mountainsides are rocky, with some soil formation in protected areas. Agriculture is concentrated in valley bottoms, with some terracing on less steep slopes.

The Yemen Volcanics area was divided into two areas on the basis of rainfall. The area with less than 600 mm of rain per year (Yv1) is more dissected and rugged. Farming in these areas is limited to wadi valleys, with a few terraces. The area receiving more than 600 mm/year is designated Yv2. In these areas, agriculture is more extensive, with a large amount of terracing.

# Chapter 2
# SURVEY METHODS

The soil survey methods are adapted to the 1:500,000 scale of the final map. This scale only permits the delineation of associations of subgroups (USDA-SCS, 1975) of soils which occur in a repeated pattern in the landscape. The map units are recognized on the basis of climate, geology, relief, vegetation, soil morphology, and by analyzing imagery obtained by satellite and aerial photography.

The survey work includes identifying the soils, classified to the subgroup level, which form the major soil associations and delineating these associations on 1:250,000 topographic maps. The field maps will be reduced to the final scale of 1:500,000 for publication.

Progress will be made by individual sheets, the locations of which are shown in Map 2.1, starting from the south and going north. All field operations should be completed in 18 months.

## OFFICE METHODS (BEFORE FIELD OBSERVATIONS)

A published geological map at 1:500,000 (Grolier and Overstreet, 1978) and selected airphotos at 1:60,000 were used to define landform regions (see Map 1.3). These regions are uniform in lithology, climate and relief.

Some information is currently available for specific areas of the Yemen Arab Republic. A major part of office operational tasks before field operations is compiling and reviewing all the available soils, geological and climatic data and reports.

Preliminary studies before field operations in Yemen included a search and review of existing soil studies (published and unpublished government consultant's reports) and soil surveys. The Yemen Ministry of Agriculture has commissioned soil reports and surveys of selected areas for possible intensive agricultural development. These reports and surveys are as follows:

## PREVIOUS REPORTS ON YEMEN SOILS

### REPORTS INDEXED IN MAP 2.1

1) Acres, B.D. 1978. Landforms and soil of the Dhamar Agricultural Improvement Centre. Yemen Arab Republic. Montane Plains and Wadi Rima Project: a land and water resources survey. Ministry of Overseas Development. Land Resources Division, Surbiton, Surrey, England.

2) Acres, B.D. 1980. Soils and land suitability of the Montane Plains and Wadi Rima. Montane Plains and Wadi Rima Project: a land and water resources survey. Overseas Development Administration. Land Resources Development Centre, Surbiton, Surrey, England.

3) Agrar- und Hydroteknik GmbH. 1980. Development of Wadi Jawf and its Tributaries, Technical Report: Soils. Yemen Arab Republic, Ministry of Agriculture.

4) Boros, I.J., Szabolcs, I. and Varallyay, G. 1970. Soil survey in the Tihama lowland (Yemen Arab Republic) I. Factors of Soil Formation ; II. Soils and land capability classes . Agrokemia es Talajtan 19:405-464.

4) Boros, I.J., and Lesztak, J. 1971. Soil survey in the Tihama lowland (Yemen Arab Republic) III. Water management properties of soils. Agrokemia es Talajtan 20:217-230.

5) Egli, E. 1978. "Landnutzung und Landnutzungsveraenderung in der region Wadi Mawr Arabische Republik Jemen." Geographischen Institut der Universtat Zurich.

6) Electrowatt Engineering Services, Ltd. 1978. Marib Dam and Irrigation Project, Yemen Arab Republic: Annexes I. Soil and Land Classification; III. Agriculture; V. Geology and Geotechniques; VII. Hydrology. Government of Abu Dhabi, Presidential Court.

7) Halcrow, W. and Partners. 1978. Wadi Surdad: Development on the Tihama. Volume 4-Soils and Land Capability Annex C Yemen Arab Republic, Ministry of Agriculture.

8) Pacheco, R.A. 1978. "The Application of Landsat Imagery to Soil and Land-use Mapping in the Central Region of the Yemen Arab Republic." FAO Seris AGLT, FAO, Rome.

9) Tesco-Viziterv-Vituki. 1971. Survey of the Agricultural Potential of the Wadi Zabid . Yemen Arab Republic. Soils and Land Capability. AGL: SF/YEM 1. Technical Report 8. Budapest.

10) Western, S. 1972. The classification of arid zone soils. 2. The classification of sedasols in Saudi Arabia. Journal of Soil Science 23:279-297.

## REPORTS ON YEMEN IN GENERAL

Asmaev, I.R. 1969. Data on soils of the southwestern part of the Arabian penisula. in Kovda, V.A. and Iabova, E.V. (ed.) Geography and Classification of Soils of Asia. Israel Program for Scientific Translations, p.249-257.

Grolier, M.J., Tibbitts, G.C., and Ibrahim, M.M. 1981. A qualitiative appraisal of the hydrology of the Yemen Arab Republic from Landsat images. USGS. Open-file Report 80-565.

Kopp, H. 1975. Die Raumliche Differenzierung der Agrarlandschaft in der Arabischen Republik Jemen (Nordjemen). Erdkunde 29:59-68.

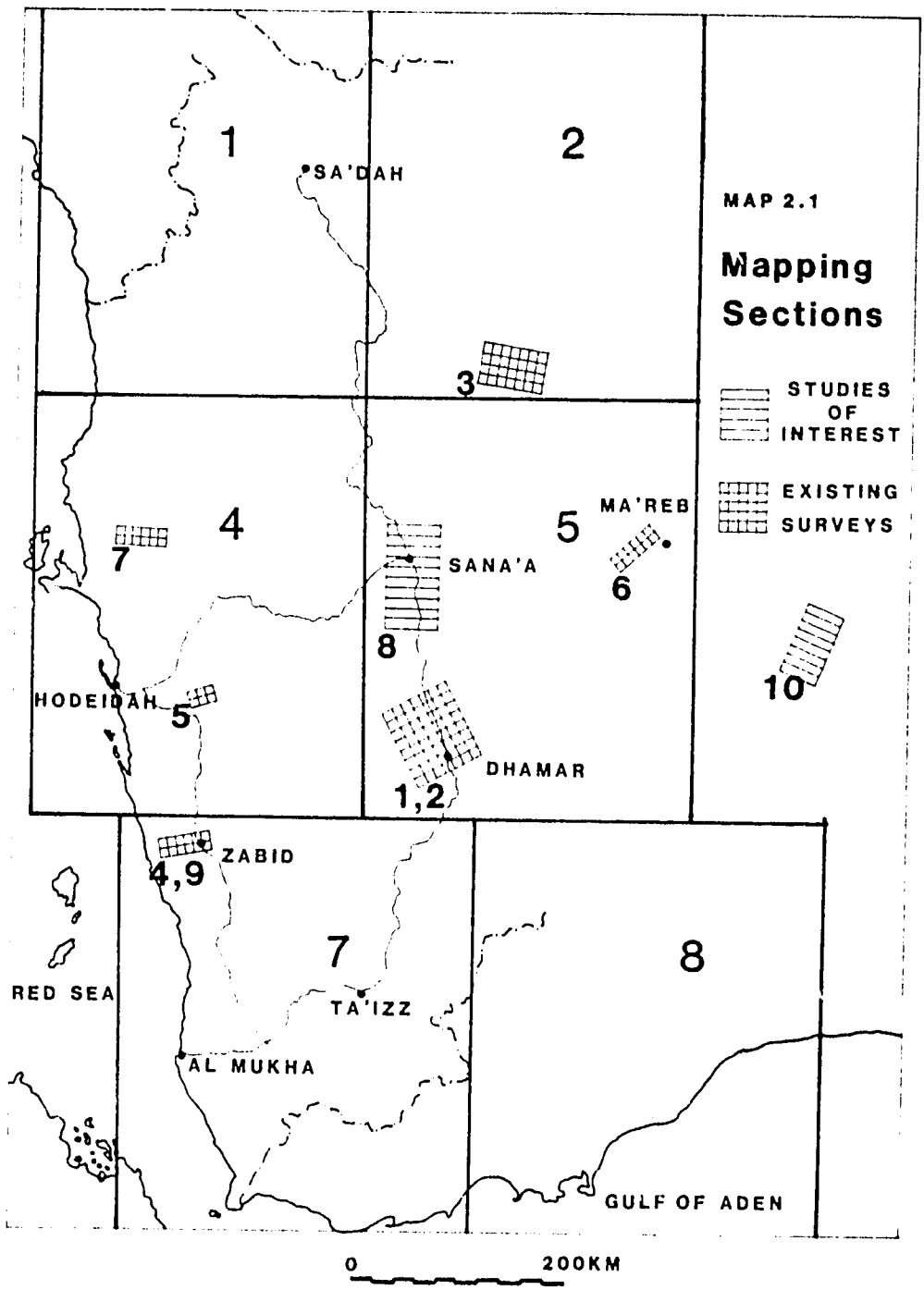
Schoch, R. 1977. Regionale Gliederung der Jemenitischen Arabischen Republik mit Hilfe von Landsat-Satellitenbildern. Thesis, Geographischen Institut der Universitat Zurich.

These reports will supplement field studies for the production of the 1:500,000 soils map. This survey will correlate country-wide the soils described in these separate, more detailed studies. No attempt will be made to duplicate the detailed work done in these areas.

Computer-processed digital Landsat satellite imagery is being used. Three Landsat bands, 4, 5, and 7 are digitally processed into a false-color infrared composite, which is then enlarged to 1:250,000 and 1:100,000. Homogeneous areas on the false-color infrared imagery are checked to see if they correspond with the landform regions previously defined. If necessary, adjustments will be made. A general idea of the relief, intensity of vegetation, drainage systems and lithology is derived from the false-color imagery.

Black and white airphotos (1:60,000) of selected sites were examined for pilot areas to be visited in the field. Relief, drainage, vegetation, soil parent materials and present agricultural land use are brought out in greater detail in these photos. The pilot sites estimate the soil pattern in each landscape and are used to select the location of characteristic pits for description and sampling.

## YEMEN ARAB REPUBLIC



## FIELD METHODS

The purpose of mapping the major components of the soil associations at large scales (about 1:25,000) in the pilot areas is to estimate the percentage each individual soil (as classified at the subgroup level) occupies in the association. The methodology will follow the guidelines of the USDA Soil Survey Manual (1975, draft version). During these field observations, an effort is made to study the correlation between field characteristics, airphotos and satellite imagery, in order to elaborate an identification key for the interpolation and extrapolation of soils data to inaccessible areas. Another objective of the field studies is to relate crop production and potential with soil and land characteristics, and to make interpretations for land-use. During reconnaisance trips to selected pilot areas, the dominant lithologies and their position in the landscape are noted as well as the presence and position of transported materials: colluvium, alluvium and aeolian deposits. The distribution of these formations is important for understanding the genesis of the soils, and allowing a more efficient mapping of them (see Chapter 3).

The predominant landscape units such as colluvial slopes, alluvial terraces, man-made terraces, wadis, coastal plains, lake beds, barchan dunes, etc., form the basis for description and selection of characteristic soil profiles for the pilot area. Traverses are made and soils are augered and examined at different sites along the landscape. Typical surface horizons are noted and checked for uniformity and average depth. The traverses give an idea of the extent of the various soils in the mapping unit.

Sites for characteristic profiles are selected away from slope-breaks and excessive human disturbances (except for man-made terraces). The profiles are described according to Guidelines for Soil Profile Description (FAO, 1977). Bulk samples are collected by horizon, as well as other samples for mineralogical, micromorpological and sedimentalogical studies.

## LABORATORY METHODS

According to the present agreements, the samples collected during the soil survey will be analysed by the soils laboratory in Aussefeire, Yemen. The analyses are necessary to define the soil characteristics important for classification. Specialized analyses, such as mineralogy and micromorphology, will be conducted as needed at the Agronomy Department at Cornell.

The soil analyses are a complement to the field observations, to confirm and verify the accuracy of the classification. The level of detail will probably not be adequate for purposes beyond the objectives of the general survey, such as feasibilty studies of irrigation or other development projects.

Routine analyses of horizon samples may include the following:

1) particle-size by the pipette method (Day, 1965, pp.545-562),
2) soil structure stability by measurement of hydraulic conductivity on fragmented samples (optional),
3) soil structure stability by measurement of wet settled floccules (optional),
4) shrink-swell on wetting and drying (COLE factor) (optional),
5) moisture retentivity at 15-bar and 1/3-bar pressures,
6) soil pH in saturated paste and 1:5 soil water ratio suspension,
7) soil salinity in terms of water soluble salts by measuring electrical conductivity (Ca, Mg, K, and Na) (carbonate, bicarbonate, sulfate, chloride, and boron-optional),
8) cation exchange capacity at pH 8.2 by NaOAc,
9) exchangeable Na and K,
10) determination of gypsum (gypsum requirement-optional),
11) carbonate by acid-neutralization using hydrochloric acid,
12) organic carbon,
13) total nitrogen,
14) available phosphorus.

Some profiles will be selected for specialized mineralogical, micromorphological and sedimentological analyses. These analyses will be used to define more clearly the genetic relationships of soils in Yemen. These analyses include:

1) clay mineralogy by X-ray diffraction (Whittig, 1965, pp.671-698) and thermal analysis (Barshad, 1965, pp. 699-742),
2) micromorphological features by petrographic microscope techniques (Cady, 1965, pp.604-631),
3) mineralogy of the sand fraction,

4) sedimentological analyses to determine transport and sorting relationships in soil particles (Forbes, 1981).

## OFFICE METHODS (AFTER FIELD OBSERVATIONS)

Soil descriptions are combined to define a legend of typical soil associations. Profiles are classified to the subgroup level according to Soil Taxonomy (USDA-SCS, 1975). The extent of benchmark soils are estimated for the pilot area.

Areas of similar soil associations are delineated on the satellite imagery. These areas are checked in the field to be sure they conform to the description of the pilot area. The selection of typical profiles and the extent of association-delineations is revised as further observation and new field information deems necessary.

# Chapter 3
# GENERAL PROPERTIES OF THE SOILS: THEIR GENESIS AND CLASSIFICATION

## GENETIC PROCESSES AFFECTING COUNTRY-WIDE SOIL RELATIONSHIPS IN YEMEN

The genesis of the soils of Yemen appears to be affected primarily by six natural processes and two man-induced processes. These processes result in the accumulation of soil parent material and in the formation of the soil itself. The natural processes which result in the accumulation of soil parent material are: aeolian deposition, desert sedimentation, colluvial deposition, and combinations of these three processes. The natural soil-forming processes which affect soil formation in Yemen are the intermittent, low level of soil leaching and the low level of organic matter accumulation. The man-induced process affecting parent material formation is the accumulation of sediment through terracing and irrigation. The man-induced soil-forming processes are the leaching of soil parent material by irrigation and the accumulation of organic material by cropping.

### NATURAL (ENVIRONMENTALLY CONTROLLED) PROCESSES

#### Parent material formation

Aeolian deposition of soil parent materials. Large and wide-spread deposits of calcareous loess are observed throughout the mountains and on the Tihama. Recent and ancient dunes are a predominant feature of the Tihama coastal area also. Aeolian transport and deposition of soil parent materials is still an important factor of soil genesis in Yemen.

In the mountains, most of the wind-transported material is silt and clay-size calcareous loess. This loess may originate locally, or possibly from the great Arabian (Rub Al'Khali) and Sahara deserts.

Field and airphoto observations show that deep loess deposits have accumulated in broad areas of low relief. In steep mountain areas, loess is deposited in valleys at least 2 km wide. Larger loess deposits such as the Al Ganed plain (40 km northwest of Taizz) appear

to be graben areas filled with thick windblown sediments (Figure 3.1). On steep slopes and in wadi flats, the loess is reworked and transported by water. Aeolian-deposited loess layers are not observed in these landscape positions.

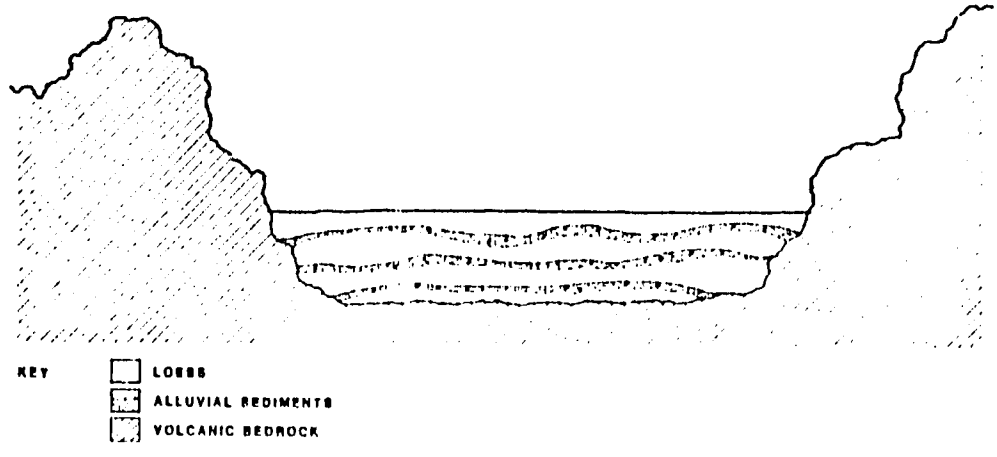



FIGURE 3.1

**Deposition of Loess in Broad Valleys Between Steeper Topography in the Yemen Volcanics**

On the Tihama, sand, as well as finer materials, is transported by the wind. Dunes grow inland, driven by prevailing winds from the Red Sea. Barchan and longitudinal dunes are frequently observed in the dry areas between wadis. Soil profile development is slow in these areas of shifting sand and loess. Textures of soils near the border of dune fields and wadis are coarse. Textures become finer towards the interior of the wadi (Figure 3.2).

Sand and silt dunes are presently encroaching on many cultivated areas in the wadis on the Tihama (Figure 3.2). This sediment encroachment has no doubt been important in the past also. Much arable land is lost each year by this encroachment, which forces local farmers to create more farmland in stabilized areas.

<u>Desert (alluvial) sedimentation</u>. Sedimentation by water is important both along wadis and on intermountain plains.

Sedimentary processes are particularly active along wadis. Sedimentation accounts for the layering and thin-bedding of many wadi soils. This is observed at the wadis on the Tihama and in large inland basins (such as Qa'Jahran, north of Dahmar). Large areas of soils in the inland plains also appear to have deep caps of more

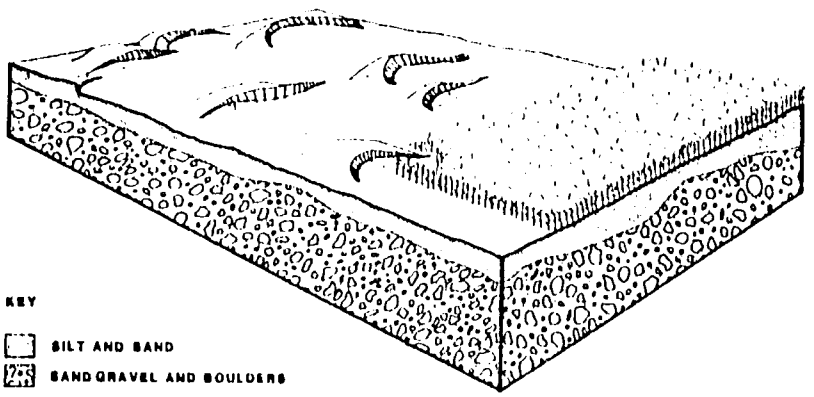



FIGURE 3.3

**The Encroachment of Dune Fields on Cultivated Wadi Soils**

recent water-laid material. In all of these areas, the most striking differentiation of the soil profiles is produced by sedimentation.

In a transect across Wadi Zabid (Figure 3.3) several levels of natural alluvial terraces, each with distinct textural compositions, are observed. The older, more extensive terraces contain less sorted, coarser materials (gravel and small boulders) while younger, less extensive terraces are typically better sorted and finer in texture.

In an east-west transect along the Wadi Zabid from the volcanic mountains to the Red Sea, another sequence of sediments is observed (Figure 3.4). This sequence of soil parent materials appears typical for the Tihama as a whole. In general, materials become finer eastward from the mountains until a zone of recent sedimentary marine deposits is reached near the Red Sea.

Deposition in wadis or on marine beaches is not the only kind of water-controlled sedimentation of soil parent materials in Yemen. In Qa'Jahran (the Dhamar Plain) extensive lacustrine deposits (Acres, 1980) are observed in the north. These deposits suggest a slightly moister period in the past or alternatively, restricted drainage in an horst and graben landscape. These lacustrine sediments are typically covered with a thin, more recently deposited loess cap (Figure 3.5).

Colluvial deposition. The extensive colluvial deposits in the Yemen volcanic zone are distinct from aeolian and alluvial deposits. Characteristically, they occur as moderately sloping pediments at the base of steep volcanic walls or mountain sides (Figure 3.6). The volcanic stones, gravel and boulders in the colluvium are usually sharp and rough-edged. Colluvial pediments in the higher rainfall areas near Ibb are deeper (reach closer to volcanic outcrop summits) and less steep than those in lower rainfall areas, e.g. near Sana'a.

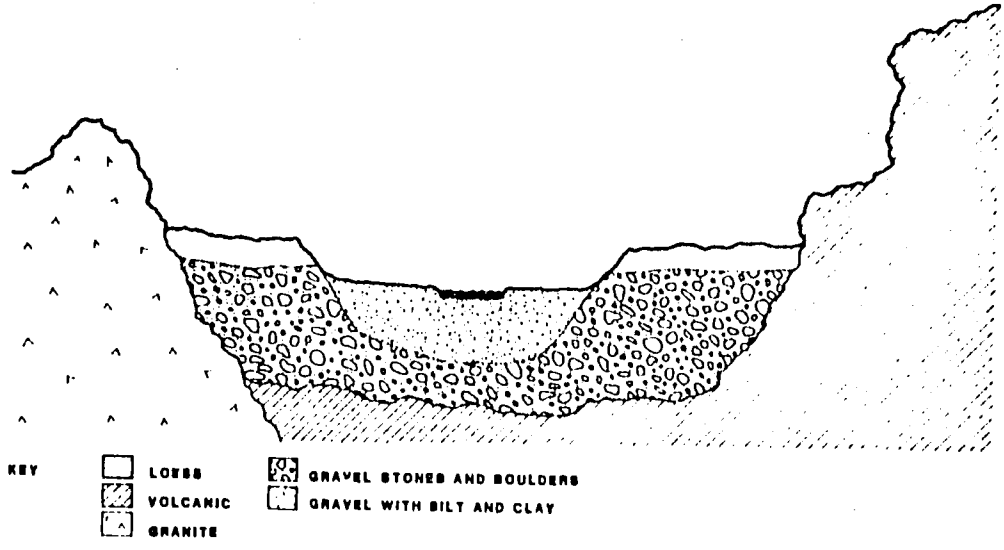



FIGURE 3.3

**A N-S Transect Showing the Location of Major Alluvial Terraces Across Wadi Zabid Near the Volcanic Foothills**

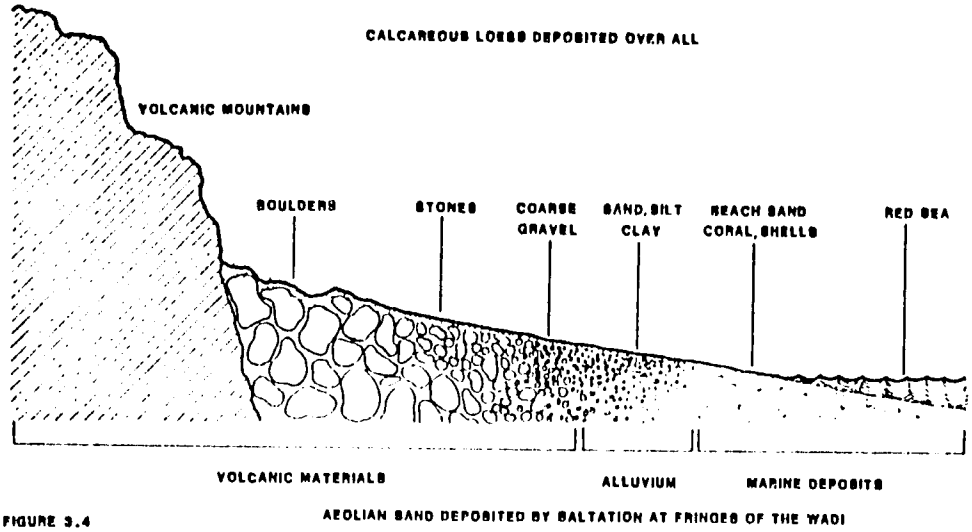



FIGURE 3.4 AEOLIAN SAND DEPOSITED BY SALTATION AT FRINGES OF THE WADI

**Parent Materials on an E-W Transect Along Wadi Zabid**

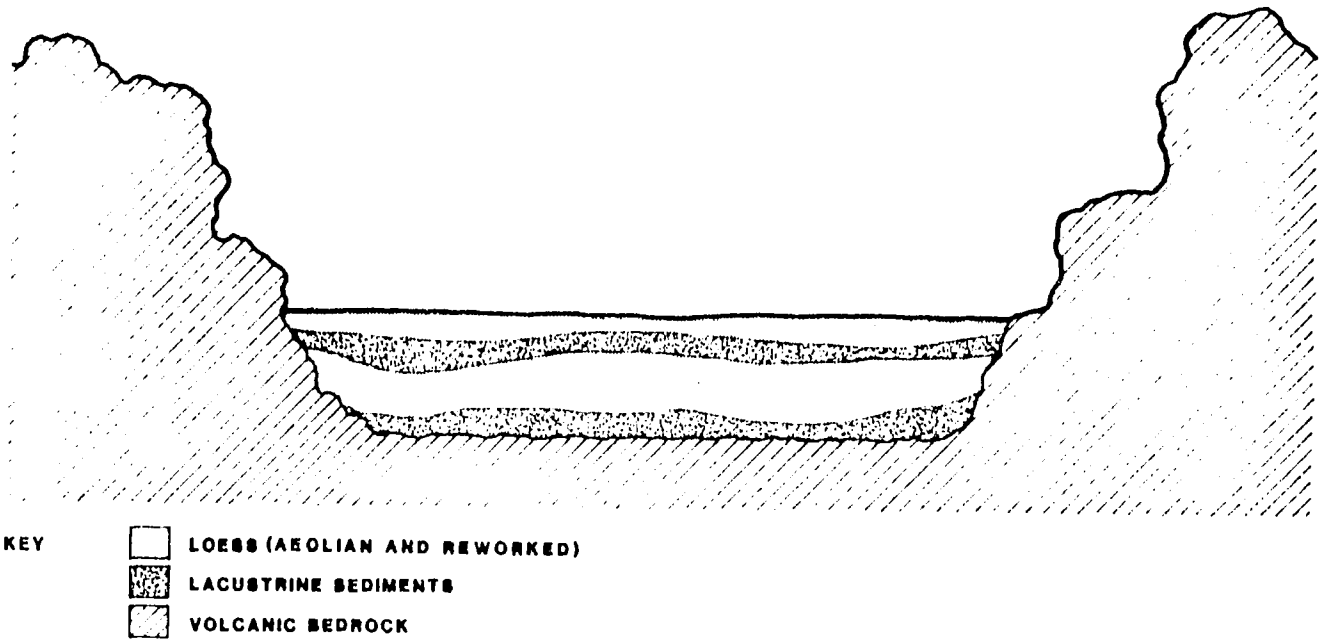



FIGURE 3.6

**Lacustrine Sediments Overlain by Aeolian Loess at Qa'Jahran**

Combinations of alluvial, colluvial and aeolian deposits. Most soil parent material in Yemen accumulates from all three processes of soil parent material formation. One often observes alternating layers of colluvium, alluvium or loess in any sequence or combination. Colluvium mixed with loess is characteristic of many soils of the volcanic highlands.

This accumulation of parent material often results in a buried soil horizon. On flat to gently rolling broad landscapes, one often observes buried soils characterized by dark A1 horizons covered by more recently deposited materials (Figure 3.5). These buried soils can be covered by aeolian, colluvial or alluvial materials. For example at Ibb, roadcuts often show alluvial sediments overlain by loess. In these cases, a very abrupt boundary is observed. Buried dark A1 horizons capped with more recently deposited colluvium mixed with loess are not uncommon (Figure 3.7).

## Soil-forming processes

Intermittent and low levels of soil leaching. Large regions of Yemen are in the aridic soil moisture regime. Leaching of carbonates and other salts is not advanced. The highest rainfall in the country (near Ibb) may be marginally udic. As a result of the low level of

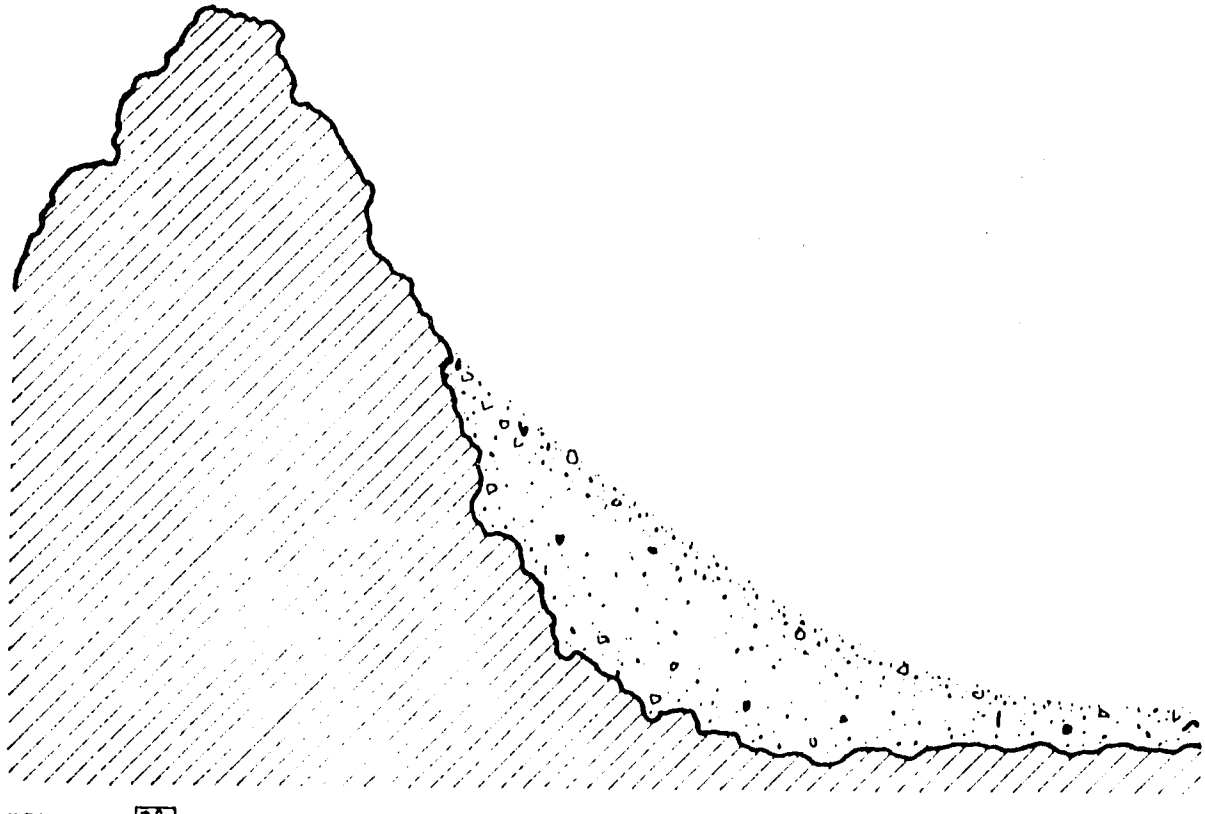



FIGURE 3.6

**Colluvial Pediment Near The Base of a Volcanic Rock Outcrop Near Al Ganed**

leaching, soil mineralogy is characterized by a young weathering stage.

Intermittent and low levels of leaching control the location of carbonates and carbonate morphology in the profile. All profiles examined in the field were at least slightly calcareous. Typically, some leaching of carbonates has occurred, so calcareous concretions were formed in B-horizons of some soils. In some areas where significant water may episodically collect, for example, at the bases of steep volcanic mountains, distinct zones of petrocalcic horizons are present (Figure 4.5).

Low levels of organic matter accumulation. In Yemen, as in most arid regions, there is little accumulation of organic matter in soil horizons. Only in areas of higher rainfall (as in the Ibb area), or at water collecting positions in the landscape (lower-slope concave positions) does organic matter accumulate to any great extent in surface horizons. Mollic epipedons are generally found in such situations.

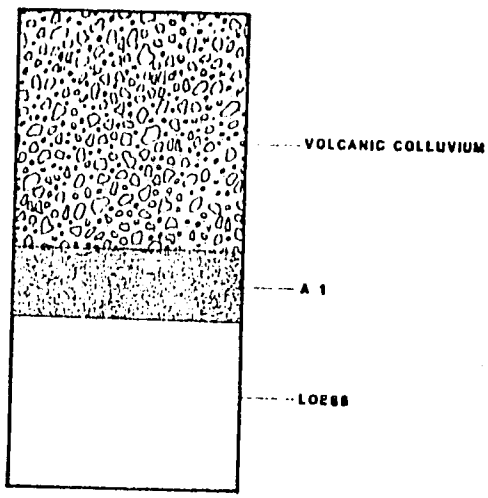



FIGURE 3.7

**A Typical Buried Soil Profile Near Ibb**

## MAN-INDUCED PROCESSES

### Parent material formation

Accumulation of sediment by terracing and irrigation. It has been suggested that men have been constructing terraces in Yemen for at least 2000 years. In the mountainous areas, soil horizonation has been slowed or altered significantly by this human activity. Similarly, sedimentary processes have been controlled and modified by farmers building bunds, terraces and other barriers along wadis on the Tihama and inland.

Terracing retains and collects soil parent material along the mountain slope. The natural processes of erosion and movement of soil materials downslope to accumulate in valley bottoms or to be carried away by wadis has been greatly slowed.

Two kinds of terraces were recognized in the Yemen volcanic zone. These are: 1) loess terraces and 2) colluvial terraces. All the terraces observed could be classified into one of these two groups.

Loess terraces have no constructed retaining wall. Originally, these loess terraces may have been constructed without stones because there were no stones in the immediate vicinity. Loess material is heaped up and a vertical free-standing wall is constructed. Loess erodes less easily than colluvial soil parent materials.

Colluvial terraces consist of colluvium from volcanic rocks mixed with some loess. These terraces were probably originally built with stones because farmers had to get rid of stones in their fields and heaped them up as walls. The walls are usually large. The soil material in colluvial terraces is quite erodable as seen in terraces with broken-down walls. The colluvium itself is usually gravelly and/or stony and has a lower water-holding capacity than the loess material.

Long periods of irrigation and water control have also modified the depostion of soil parent materials. Spate irrigation on the Tihama has increased the sedimentation on the lower, flatter areas. This sedimentation results in the formation of terraces often having differences in height of several meters.

Soil-forming processes

Leaching of soil parent materials by irrigation. Irrigation of some form has been going on perhaps as long as the construction of terraces. In the highlands, rainwater collection on fields by bunds and ridges is perhaps the most important form of irrigation. Terracing makes the small amount of precipitation more effective by reducing runoff. Leaching of soil parent materials is increased to some degree and moisture is retained for cropping.

Along the Tihama spate (overland flow) and well irrigation have been practiced. Leaching and reprecipitation of salts is involved here. However, this was not immediately apparent in any of the areas visited, and will need to be confirmed by analytical lab results.

Increased accumulation of organic matter. Soils which have been intensively irrigated for cropping for long periods of time have higher amounts of organic matter in their surface horizons. However, organic matter does not generally accumulate sufficently to form mollic epipedons.

## TAXONOMIC SOIL CLASSIFICATION, CORRELATION AND THE MAPPING LEGEND

The mapping units are associations of subgroups (USDA-SCS, 1975). In the tentative legend given (Table 3.1), associations are named by landform and soil climate. A map symbol for the association is also given. The composition of associations (subgroups) also includes any designated associations (usually composed of series) from previous detailed soil survey reports or the pedon numbers from the current field descriptions. The subgroup classifications (USDA-SCS, 1975) for each previously published association and their profiles are also given.

Table 3.1: Soil associations, mapping symbols, series composition and subgroup classification for soils in the Yemen volcanics and part of the Tihama coastal plain.

| ASSOCIATION | SYMBOL | SERIES AND PEDON NUMBERS | SUBGROUP CLASSIFICATIONS (SOIL TAXONOMY, 1975) AND PREDOMINANT MISCELLANEOUS UNITS |
|---|---|---|---|
| Semi-aridic loessal plains | SLP | FI<br>FIII | Typic Torriorthent<br>Aquollic Salorthid |
| Semi-aridic to ustic volcanics | SUV | FII<br>KXIV<br>FIV<br>FV,KXIII | Typic Camborthid<br>Aridic Haplustoll<br>Typic Calciustoll<br>Typic Ustropept |
| Tihama coastal soils | TC | | Typic Torrifluvent<a<br>Beach sand<a |
| Tihama wadi soils | TW | FVI<br><br>Calcareous alluvial soils (no. 102)<b<br>Wind erosion affected soils (no. 49) <b<br>Tropical arid brown soil (no. 147)<b<br>Salt affected soils (no. 17) <b | Typic Torrifluvent (salty phase)<br>Typic Torrifluvent<br>Typic Torriorthent<br>Typic Camborthid<br>Typic Calciorthid |
| Tihama plain and terrace soils | TPT | - | Typic Camborthid<a |

Table 3.1 continued...

| | | | |
|---|---|---|---|
| Intermontaine plain | IMP | FVII | Typic Torrert |
| | | FVIII | Udic Pellustert |
| | | Shirah <c | Typic Torrert, Typic Camborthid |
| | | Thamar <c | Typic Camborthid, Typic Salorthid, Aquollic Salorthid |
| | | Amid <c | Typic Camborthid |
| | | Baradum <c | Typic Camborthid, Typic Calciorthid |
| | | Sumarah <c | Typic Camborthid, Typic Calciortid |
| | | Yizlah <c | Typic Camborthid, Typic Calciorthid |
| Semi-aridic volcanics | SV | FIX | Typic Ustorthent |
| | | FX | Typic Natrustalf |
| | | FXI | Typic Tropofluvent |
| Inland alluvial plains | IAP | KXXIV,KXXV | Typic Calciorthid<a |
| | | - | Typic Torrifluvent<a |
| Aridic volcanic soils | AV | KXIX | Typic Calciorthid<a |
| | | - | Volcanic rock outcrop<a |
| Pre-Cambrian wadis | PCW | KXII | Typic Torriorthent |
| | | - | Typic Tropofluvent |

Key: a- tentative subgroups for incomplete map units
b- from the soils report by Tesco-Viziterv-Vituki (1971)
c- from the soils report by B.D. Acres, 1980

# Chapter 4
# THE SOIL MAPPING UNITS

## SEMI-ARIDIC LOESSAL PLAINS (SLP)

This association consists of deep, eroded and uneroded, well-drained, yellowish brown and brown silty soils containing alternating gravel layers and shallow, poorly drained, dark brown silty soils occuring in depressions. Miscellaneous land units include small areas of volcanic rock outcrops.

### LOCATION AND EXTENT

This association of soils and rock outcrops typically occurs in all loessal plains of Yemen. They are found at Al Ganed, Yerim, and probably other areas to be studied. Their total extent is roughly estimated at 5%<a of the entire country.

In the association as represented by the Al Ganed plain only, the well-drained Typic Torriorthents occupy most of the area, approximately 85%<a. Aquollic Salorthids occupied approximately 5% and miscellaneous rock outcrops approximately 10% of the total area.

### GEOMORPHOLOGY

The landforms are typically broad, gently undulating plains with convex slopes (Figure 4.1). Slopes appear to radiate from isolated volcanic rock outcrops. These upland, undulating plains grade gradually into broad-based, flat or almost flat lowlands with a seasonal water table not far from the surface.

---

a- The percentages given are tentative and will be revised upon further investigation.

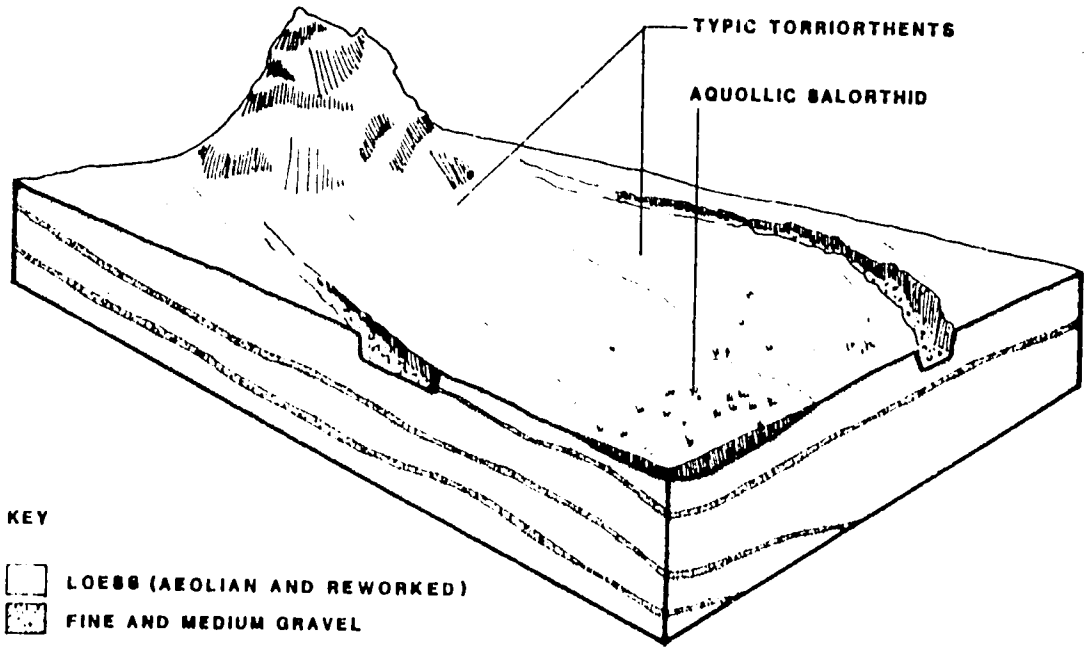



FIGURE 4.1

**Landscape Relationships of Semi-Aridic Loessal Plain (SLP) Mapping Unit**

GENESIS AND IMPORTANT ENVIRONMENTAL INFLUENCES

The predominant parent material for the association is calcareous loess. After aeolian deposition, the loess has been reworked by alluvial and colluvial processes and mixed and redeposited with layers of volcanic gravels, and snail shells (ostracods) at some places.

Evapotranspiration is high in the typically aridic soil moisture regime. As a result, carbonates are not leached.

Lack of a protective vegetation cover and intensive farming has encouraged erosion of most of the upland Typic Torriorthents. Distinct A1 horizons with organic matter accumulation were not observed. Gullies are a common feature of the loessal plains (Figure 4.1).

The depressions, or areas of Aquollic Salorthids, showed evidence of a permanent high water table. Surface and subsurface drainage away from these depressions is slow. As a result, these areas accumulate salts and are not generally cropped.

Vegetation at well-drained sites is usually sparse tussocks of *Acacia arabica*. The low, wet sites have a tight cover of Bermuda grass and sedges.

Fields of some well-drained soils are demarcated with ridges and are used to grow sorghum, corn and wheat. Other large upland areas do not appear to be cropped at all. Wet sites are not cultivated but are used for extensive grazing by cattle, sheep and goats.

## PEDON DESCRIPTIONS

### PEDON FI

SITE INFORMATION

Profile number: FI
Series name: Unknown
Classification: TYPIC TORRIORTHENT, COARSE LOAMY, MIXED, _____ FAMILY
Date and time described: April 13, 1981, 2 PM
Authors: T. Forbes and J. King
Location: 5 km southwest of Al Ganed, east of airport
Elevation: 1420 m
Landform: Convex slope, plain
Slope class: Undulating
Microtopography: Gullies, tussacks
Slope: 4%
Land use: *Acacia arabica* present, surrounding areas used for sorghum, corn and wheat
Climate: Unknown (rainfall about 200 mm/yr)

SOIL INFORMATION

Parent Material: Alluvium and colluvium from volcanic rocks of hillcrest. Large addition of loess.
Drainage class: Well-drained
Moisture conditions: Dry down to one meter, then slightly moist.
Depth to groundwater: Unknown
Surface stones or outcrops: Fine gravel partially covering surface; hillcrest very rocky.
Evidence of erosion: Severe sheet and gully erosion, possible wind erosion.
Salt content: No apparent salt or alkali
Human influence: Heavy grazing

Profile Description

| | |
|---|---|
| C1<br>0-20 cm<br>F1 | Light yellowish brown, 10YR 6/4 (dry); silt loam; weak coarse to fine subangular blocky structure; non-sticky, non-plastic, very friable (moist); soft (dry); common, very fine discontinous, horizontal, inped, tubular, closed pores; calcareous; common fine roots; clear, broken boundary. |

| | |
|---|---|
| IIC2<br>20-31 cm<br>F2 | Brown, 10YR 5/3 (moist); slightly gravelly silt loam; weak coarse to fine subangular blocky structure; non-sticky, non-plastic, very friable (moist); few, very fine, discontinous, random, inped, tubular, closed pores; calcareous; frequent mineral fragments- basalt rock; few small roots; clear, broken boundary. |
| IIIC3<br>31-41 cm<br>F3 | Yellowish brown, 10YR 5/4 (moist); silt loam; weak to moderate, coarse to fine subangular blocky structure; slightly sticky (wet); slightly plastic, very friable (moist); few, micro, discontinous, random, inped, tubular, closed pores; calcareous; few fine to very fine roots; clear, wavy boundary. |
| IVC4<br>41-69 cm<br>F4 | Yellowish brown, 10YR 5/4 (moist); gravelly silt loam; moderate coarse to fine subangular, blocky structure; slightly sticky (wet); slightly plastic, very friable (moist); few very fine, discontinous, random, inped, tubular, closed pores; calcareous; few gravels, angular to sub-angular fresh basalt rock fragments; few ostracod shells; very few fine roots; clear wavy boundary. |
| VC5<br>69+ cm<br>F5 | Yellowish brown, 10YR 5/4 (moist); silt loam; weak to moderate, coarse to fine, subangular blocky structure; slightly plastic and slightly sticky (wet); very friable (moist); few, very fine, discontinous, random, inped, tubular, closed pores; calcareous; very few coarse and fine roots. |

Note: Gravel layer thickness and depth is quite variable for polypedon.

## ANALYTICAL DATA FOR SITE FI

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-20 | C1 | vf | g | 13.1 | 77.5 | 9.4 | sil |
| 2 | 20-31 | IIC2 | fr | g | 27.3 | 63.2 | 9.5 | sil |
| 3 | 31-41 | IIIC3 | vf | - | 11.6 | 77.1 | 11.3 | sil |
| 4 | 41-69 | IVC4 | f | g | 31.2 | 59.6 | 9.2 | sil |
| 5 | 69+ | VC5 | vf | - | 27.4 | 61.7 | 10.8 | sil |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.1 | 0.4 | 0.3 | 1.2 | 9.1 | 60.9 | 12.8 | 3.7 |
| 2 | 11.2 | 3.2 | 1.5 | 3.6 | 7.8 | 50.6 | 9.2 | 3.4 |
| 3 | 1.1 | 0.8 | 0.5 | 1.8 | 7.4 | 59.2 | 13.1 | 4.8 |
| 4 | 13.5 | 3.4 | 4.2 | 2.5 | 7.6 | 50.0 | 6.2 | 3.3 |
| 5 | 6.9 | 1.8 | 0.8 | 2.7 | 15.3 | 44.5 | 12.5 | 4.7 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Avail. P ppm | CaCO3 % | Organic Matter% | Total N% | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 9.0 | 7.8 | 0.22 | 8.74 | 18.4 | 0.60 | 0.062 | 19.9 |
| 2 | 8.8 | 7.75 | 0.87 | 8.51 | 20.6 | 0.38 | 0.056 | 17.2 |
| 3 | 8.7 | 7.9 | 0.56 | 7.82 | 21.2 | 0.63 | 0.042 | 21.3 |
| 4 | 9.0 | 7.9 | 0.9 | 7.82 | 17.8 | 0.21 | 0.021 | 16.6 |
| 5 | 9.0 | 7.9 | 0.8 | 3.7 | 17.6 | 0.30 | 0.018 | 18.3 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay l-loam s-sand si-silt

# PEDON FIII

## SITE INFORMATION

Profile number: FIII
Series name: Unknown
Classification: AQUOLLIC SALORTHID, FINE CLAYEY, MIXED, _____ FAMILY
Date and time described: April 14, 1981, 3:20 PM
Authors: T. Forbes and J. King
Location: 3 km south of Al Ganed airport, off main road
Elevation: Unknown
Landform: Broad-based lowland
Slope class: Flat or almost flat
Microtopography: Slightly eroded bare spots between tight cover of Bermuda grass
Slope: 2%
Land use: Grazing
Climate: Unknown

## SOIL INFORMATION

Parent Material: Alluvium from surrounding terraced areas
Drainage class: Imperfectly drained
Moisture conditions: Moist throughout, wet at water table
Depth to groundwater: Unknown
Surface stones or outcrops: No surface stones or outcrops
Evidence of erosion: Patches of bare eroded soil
Salt content: Class 2- salt crystals apparent on surface
Human influence: Grazing by ruminants

## Profile Description

| | |
|---|---|
| A1sa<br>0-36 cm<br>F9 | Dark brown, 10YR 4/3 (moist); common small white spots of salt crystals; silty clay loam; moderate very coarse to fine subangular blocky structure; slightly sticky, plastic (wet); firm (moist); common fine, discontinous, vertical inped, tubular, open pores; strongly calcareous due to presence of crystalline salt spots; common fine roots; clear, smooth boundary. |
| Bg<br>36+ cm<br>F10 | Matrix- gray, 5YR 6/1 (wet); many, fine, distinct, clear, dark brown (7.5 YR 4/4) mottles; silty clay; weak, coarse to fine subangular blocky structure; sticky and plastic (wet); friable (moist); common, fine, discontinous, vertical, inped, tubular, open pores; strongly calcareous; a few fine roots. |

Note: Water table at 67 cm.

ANALYTICAL DATA FOR SITE FIII

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-36 | A1sa | vf | - | 0.6 | 59.6 | 39.8 | sicl |
| 2 | 36+ | Bg | vf | - | 1.2 | 48.3 | 50.4 | sic |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0.3 | 0.3 | 10.2 | 28.5 | 20.9 |
| 2 | 0 | 0.1 | 0.1 | 0.4 | 0.6 | 14.1 | 18.4 | 15.9 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Avail. P PPM | CaCO3 % | Organic Matter% | Total N% | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.9 | 8.2 | 7.7 | 3.0 | 25.2 | 1.91 | 0.119 | 39.1 |
| 2 | 8.8 | 8.1 | 7.3 | 3.7 | 36.6 | 0.88 | 0.064 | 35.2 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand
l-loam si-silt

## SEMI-ARIDIC TO USTIC VOLCANICS (SUV)

This mapping unit consists of brown, stony, colluvial, uncropped Typic Camborthids in the lowest rainfalls areas to the south and Aridic Haplustolls in the higher rainfall areas around Ibb; brown, deep, well-drained Typic Calciustolls formed on natural alluvial terraces; deep, well-drained yellowish-brown to brown silty, terraced Typic Ustropepts and large areas of volcanic rock outcrops.

### LOCATION AND EXTENT

This mapping unit occurs in the extensive areas of Yemen Volcanics in the Ibb region, of south central Yemen. This area has the highest average annual rainfall (approximately 1000 mm) in Yemen. Roughly 15%<a of the total land area of Yemen is characterized by this mapping unit. Within the mapping unit itself, about 30% of the area is rock outcrop, 30% is colluvial Typic Camborthids or terraced Aridic Haplustolls, 30% is loess, terraced Typic Ustropepts and 10% alluvium, terraced Typic Calciustolls.

### GEOMORPHOLOGY

The area is characterized by steep, rugged, volcanic peaks bordering deep, wide valleys, drained by wadis (Figure 4.2). Some walls of the volcanic peaks are very steep and have little or no deposits of colluvium. Less steep slopes are covered with a layer of colluvium mixed with loess to varying depths. Many of these colluvial slopes have been terraced. Terracing involves the construction of loose stone walls to retain colluvial material. The least steep slopes descending from the volcanic peaks have collected a deep deposit of calcareous loess. Most of these areas have also been terraced by farmers. Retaining walls are not constructed since no stones were available to make the walls. Silty material does not erode as easily as the colluvium. At the base of the colluvial and loessal terraced slopes are a series of natural alluvial terraces formed by wadis. The width and extent of these terraces vary.

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a- The percentages given are tentative and will be revised upon further investigation.

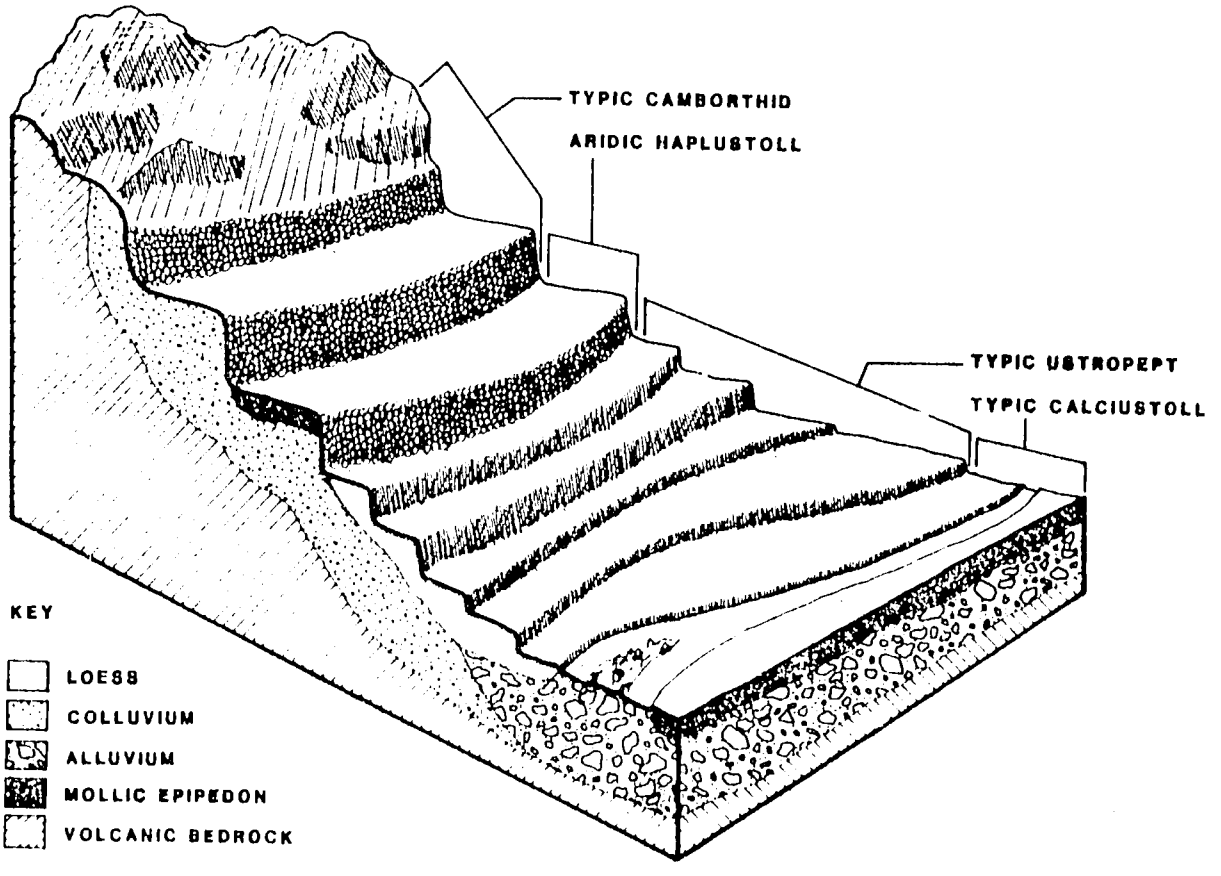


FIGURE 4.2

**Landscape Relationships for the Semi-Aridic to Ustic Volcanics (SUV) Mapping Unit**

GENESIS AND IMPORTANT ENVIRONMENTAL INFLUENCES

The genesis of these soils is controlled by the relative proportion of colluvium, calcareous loess, and alluvium that comprise the soil parent materials and the level of rainfall. In most profiles one of these parent materials predominates and controls the morphology to a great extent.

This area has the highest rainfall in Yemen (approximately 1000 mm annually). This is not adequate to completely leach the carbonates from the soil profile. Typically, carbonates have accumulated in a horizon of calcareous concretions (as indicated by the ca subscript in the pedon descriptions). In the least disturbed alluvial terrace sites, organic matter accumulates sufficiently to form mollic epipedons. The area, depending on the amount of precipitation which collects and is retained, is transitional between aridic and ustic soil moisture regimes. Ustic regimes occur near valley bottoms and on the gentler slopes where precipitation and runoff collects. All sites, even wadi bottoms, are well-drained.

Natural vegetation except for *Acacia arabica* is not present in most of the terraced areas. Terraces are usually planted with corn, sorghum, lentils and other grain legumes.

The soils of this region have been intensively cultivated for a long period of time. Terraces have been constructed at every site where sufficent soil material accumulates.

## PEDON DESCRIPTIONS

### PEDON FII

SITE INFORMATION

Profile number: FII
Series name: Unknown
Classification: TYPIC CAMBORTHID, LOAMY-SKELETAL, MIXED, _____ FAMILY
Date and time described: April 14, 1981, 11AM
Authors: T. Forbes and J. King
Location: Al Ihhran- 5 miles southeast of Al Ganed
Elevation: 1350 m
Landform: Colluvial footslope, convex slope
Slope class: Steep, dissected slope
Microtopography: Layer of cobbles on slope surface
Slope: 43-44%
Land use: Not used for cultivation
Climate: Unknown

SOIL INFORMATION

Parent Material: Colluvium from basalt and limestone
Drainage class: Well-drained
Moisture conditions: Surface moisture
Depth to groundwater: Unknown
Surface stones or outcrops: Stones, gravels and some boulders
Evidence of erosion: Some sheet erosion
Salt content: No alkali or calcium salts on rocks
Human influence: None

Profile Description

A1
0-13 cm
F6

Dark reddish brown, 5YR 3/4 (moist); stony, slightly gravelly, loam; weak, coarse to fine subangular blocky structure; slightly sticky and slightly plastic (wet); loose to very friable (moist); many micro to medium, discontinuous, random, inped, interstitial open and closed pores; very frequent volcanic and limestone stones; strongly calcareous; many coarse medium and fine roots; clear, wavy boundary.

B
13-70 cm
F7

Reddish brown, 5YR 4/4 (moist); stony and gravelly loam; very weak, medium to fine subangular blocky and crumb structure; very slightly sticky, slightly plastic (wet); loose to very friable (moist); many micro to some coarse discontinuous, random, interstitial, inped,

open and closed pores; calcareous; many fine and some coarse roots; very frequent volcanic and limestone gravel; gradual, irregular boundary.

Cca
70+ cm
F8

Brown, 7.5 YR 4/4 (dry); stony and gravelly loam; very weak, medium fine, subangular blocky and granular structure; slightly sticky and slightly plastic (wet); loose (dry); many micro to coarse, discontinuous, random, inped, interstitial, open and closed pores; very frequent volcanic and limestone stones and gravel; very few fine roots; strongly calcareous.

## ANALYTICAL DATA FOR SITE FII

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-13 | A1 | vfr | s | 36.7 | 44.6 | 18.7 | l |
| 2 | 14-70 | B | vfr | g | 46.7 | 36.2 | 17.1 | l |
| 3 | 70+ | Cca | vfr | s,g | 44.5 | 37.7 | 17.8 | l |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 9.5 | 7.7 | 5.4 | 8.2 | 5.9 | 24.8 | 16.9 | 2.9 |
| 2 | 13.1 | 10.3 | 7.5 | 10.9 | 4.8 | 19.3 | 14.2 | 2.7 |
| 3 | 14.7 | 11.0 | 6.8 | 8.5 | 3.6 | 15.0 | 14.6 | 8.1 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Avail. P ppm | CaCO3 % | Organic Matter% | Total N% | CEC meg/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.6 | 7.85 | 0.36 | 5.3 | 8.4 | 1.54 | 0.068 | 34.9 |
| 2 | 8.5 | 7.6 | 2.3 | 5.8 | 10.8 | 1.18 | 0.058 | 29.6 |
| 3 | 8.4 | 7.6 | 4.1 | 6.7 | 16.0 | 0.91 | 0.049 | 29.1 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand
l-loam si-silt

# PEDON KXIV

## SITE INFORMATION

Profile number: XIV
Series name: Unknown
Classification: ARIDIC HAPLUSTOLL, LOAMY-SKELATAL, MIXED, _____, FAMILY
Date and time described: May 17, 1981, 1 PM
Authors: J. King
Location: About 1 km south of Ibb on gravel road parallel with main paved road
Elevation: 1860 m
Landform: Terraced (formerly convex) colluvial footslope
Slope class: Steep to rolling topography, bottom of high volcanic mountain
Microtopography: Land has benn terraced
Slope: 15% between terraces, 0.5% on terrace
Land use: Mostly sorghum and maize
Climate: Unknown

## SOIL INFORMATION

Parent material: Volcanic angular and some rounded gravels and stones, probably mixed with some loess
Drainage class: Well-drained
Moisture conditions: Moist throughout
Depth to groundwater: Unknown
Surface stones or outcrops: Some loose stones on surface- resembles desert pavement
Evidence of erosion: No significant erosion
Salt content: No alkali; some calcareous material with depth
Human influence: Terraced

General Description of the Profile: Deep, dark colluvial profile with calcareous material at depth.

### Profile Description

| | |
|---|---|
| Ap<br>0-27 cm<br>K11 | Dark brown, 10YR 3/2 (moist); slightly stony and gravelly silt loam; slightly sticky and slightly plastic (wet); friable (moist); weak medium to fine subangular blocky and crumb structure; many micro and very fine discontinuous, random, inped, tubular, open pores; a few fresh volcanic stones and gravel |

(resembling desert pavement on surface); slightly calcareous; common fine and medium roots; clear, wavy boundary.

IIBca
27-54 cm
K12

Very dark greyish brown, 10YR 3/2 (moist); many fine, distinct, clear, white calcareous mycelia; very stony clay loam; slightly sticky and slightly plastic (wet); friable (moist); moderate medium subangular blocky to crumb structure; many fine and micro discontinuous, random, inped, tubular and interstitial, open pores; very frequent fresh volcanic stones and gravel; strongly calcareous; common fine and a few medium roots; clear, wavy boundary.

IIIBca
54-84 cm
K13

Very dark greyish brown, 10YR 3/2 (moist); many fine, distinct, clear, white, calcareous mycelia; gravelly loam; slightly sticky and slightly plastic (wet); friable (moist); moderate medium subangular blocky to crumb structure; many micro and very fine, discontinuous, random, inped, tubular, open pores; very frequent fresh volcanic gravel and a few fresh volcanic stones; a few fine and medium roots; strongly calcareous; clear, wavy boundary.

Cca
84-224cm
K14

Dark brown, 7.5 YR 3/2; gravelly, stony silty clay loam; slightly sticky and slightly plastic (wet); friable (moist); many micro and common fine, discontinuous, random, inped, interstitial and tubular pores; very frequent fresh volcanic gravel and stones; many fine, distinct, clear, white, calcareous mycelia; strongly calcareous; a few fine roots; clear, wavy boundary.

## ANALYTICAL DATA FOR SITE KXIV

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-27 | Ap | f | s,g | 27.7 | 51.9 | 20.4 | sil |
| 2 | 27-54 | IIBca | vfr | s,g | 29.7 | 39.5 | 30.8 | cl |
| 3 | 54-84 | IIIBca | vfr | g,s | 41.5 | 36.5 | 21.2 | l |
| 4 | 84-224 | Cca | vfr | g,s | 54.0 | 23.9 | 22.1 | scl |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 6.9 | 4.4 | 3.0 | 5.6 | 7.8 | 33.1 | 13.5 | 5.3 |
| 2 | 12.0 | 4.9 | 3.5 | 5.2 | 4.1 | 22.4 | 10.6 | 6.5 |
| 3 | 14.3 | 9.1 | 5.1 | 6.9 | 6.1 | 19.4 | 12.8 | 4.4 |
| 4 | 18.1 | 13.2 | 7.7 | 9.6 | 5.5 | 16.2 | 6.3 | 1.5 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Total N% | Organic Matter% | CaCO3 % | Avail P ppm | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.7 | 7.7 | 0.21 | 0.28 | 1.66 | 8.8 | 6.44 | 32.9 |
| 2 | 8.7 | 7.8 | 0.23 | 0.24 | 1.02 | 8.8 | 2.76 | 42.6 |
| 3 | 8.6 | 7.8 | 0.23 | 0.14 | 0.95 | 9.2 | 3.22 | 38.0 |
| 4 | 8.6 | 7.6 | 0.28 | 0.12 | 0.26 | 9.4 | 4.6 | 34.8 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand
l-loam si-silt

## PEDON FIV

### SITE INFORMATION

Profile number: FIV
Series name: Salaba
Classification: TYPIC CALCIUSTOLL, FINE SILTY, MIXED, _____, FAMILY
Date and time described: April 16, 1981, 10:30 AM
Authors: T. Forbes
Location: Near residences of Ibb Agricultural School
Elevation: 1860 m
Landform: Broad, flat upper terrace adjacent to wadi deposit
Slope class: Nearly flat plateau
Microtopography: Some low disintegrating terrace walls
Slope: 1-3%
Land use: Grass pasture- left in pasture for at least three generations
Climate: Unknown

### SOIL INFORMATION

Parent Material: Silty clay alluvium over loess over deep gravel deposits (from wadi)
Drainage class: Well-drained
Moisture conditions: Slightly moist surface to moist underneath
Depth to groundwater: Unknown
Surface stones or outcrops: No surface stones or outcrops
Evidence of erosion: No evidence of significant erosion
Salt content: Calcareous salts in deep horizons
Human influence: Some influence from disintegrating terraces nearby

General Description of the Profile: Soil has a deep dark profile with deep very dark A1. The profile becomes more calcareous with depth.

### Profile Description

| | |
|---|---|
| A1<br>0-49 cm<br>F11 | Very dusky red, 2.5 YR 2.5/2 (moist); silty clay loam; strong coarse to fine subangular blocky and crumb structure; slightly sticky, slightly plastic (wet); firm (moist); hard (dry); common, micro to fine, discontinuous, random, inped, vesicular, closed pores; very few round to subangular stones; very slightly calcareous; abundant fine and medium roots; clear, wavy boundary. |

Bca
49-77 cm
F12

Dark reddish gray, 5 YR 4/2 (dry); common, fine, distinct, clear, white calcareous salt crystals (calcite); silty clay loam; moderate, coarse to fine, subangular blocky structure; slightly and very slightly plastic (wet); friable (moist); hard (dry); a few very fine and common fine discontinuous, random, inped, tubular and vesicular closed pores; very few rounded stones (noncalcareous); calcareous; common fine and a few medium roots; gradual, wavy boundary.

Cca
77+ cm
F13

Dark brown, 7.5 YR 4/2 (moist); silt loam; moderate coarse to fine subangular blocky structure; non-sticky and very slightly plastic (wet); friable (moist); hard (dry); a few micro and very fine, discontinuous, random and vertical, inped tubular closed pores; common fine and medium, distinct, clear, white, carbonate mycelia; a few fine roots.

## ANALYTICAL DATA FOR SITE FIV

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-49 | A1 | vf | s | 6.8 | 62.7 | 30.4 | sicl |
| 2 | 49-77 | Bca | vf | s | 7.3 | 63.5 | 29.8 | sicl |
| 3 | 77+ | Cca | vf | - | 18.3 | 59.1 | 22.6 | sil |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1.1 | 0.9 | 2.6 | 2.1 | 25.0 | 23.4 | 14.4 |
| 2 | 0 | 0.1 | 0.2 | 2.5 | 4.5 | 28.2 | 26.6 | 8.8 |
| 3 | 0 | 0.1 | 0.5 | 7.7 | 10.0 | 29.9 | 23.5 | 5.7 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Avail. P ppm | CaCO3 % | Organic Matter% | Total N% | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 7.9 | 7.6 | 0.36 | 4.14 | 6.0 | 1.42 | 0.114 | 57.3 |
| 2 | 8.4 | 7.8 | 0.29 | 4.7 | 7.2 | 1.08 | 0.088 | 51.5 |
| 3 | 8.6 | 7.95 | 0.24 | 5.8 | 9.4 | 0.64 | 0.041 | 44.9 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand
l-loam si-silt

# FEDON FV

## SITE INFORMATION

Profile number: FV
Series name: Unknown
Classification: TYPIC USTROPEPT, FINE SILTY, MIXED, _____, FAMILY
Date and time described: April 16, 1981, 12:50 PM
Authors: T. Forbes
Location: Agricultural Institute- Salaba Seda, Ibb, loess terraces behind the school
Elevation: 1860 m
Landform: Side of flat-bedded terrace
Slope class: Rolling hill (terraced)
Microtopography: Microtopography evened out by terracing
Slope: 15%
Land use: Farmed for maize, sorghum, some beans
Climate: Probably ustic moisture regime

## SOIL INFORMATION

Parent material: Loess over colluvial, alluvial clay/loess mixture
Drainage class: Well-drained
Moisture conditions: Moist to dry
Depth to groundwater: Unknown
Surface stones or outcrops: Occasional stone on surface, no rock outcrop
Evidence of erosion: Some slumping along terrace edge, no significant erosion
Salt content: Calcareous salt accumulation at depth
Human influence: Top material especially disturbed by terracing

General Description of the Profile: Deep silty to silt loam profile with calcareous accumulation (nodules) at depth.

### Profile Description

| | |
|---|---|
| Ap<br>0-59 cm<br>F14 | Yellowish-brown, 10 YR 5/4 (slightly moist); slightly gravelly silt loam; moderate, medium to fine subangular, blocky structure; non-sticky and non-plastic (wet); very friable (slightly moist); hard (dry); a few fine and common very fine and micro, discontinuous, oblique and random, inped, tubular, closed pores; very few gravels and stones (noncalcareous); calcareous; abundant fine and medium |

roots; very few small, soft, carbonate nodules; gradual, wavy boundary.

C1ca
59-115 cm
F15

Dark-yellowish brown, 10YR 4/4 (moist); slightly gravelly silt loam; strong coarse to fine subangular blocky structure; non-sticky and non-plastic (wet); firm (slightly moist); hard (dry); a few medium and common very fine, discontinuous, vertical and oblique, inped, interstitial and tubular, closed pores; very few calcareous gravels; many medium, prominent, clear, white calcareous mycelia; very few small, hard, irregular, grayish white nodules; strongly calcareous; a few fine roots; gradual wavy boundary.

C2ca
115+ cm
F16

Dark brown, 10 YR 4/3 (moist); many fine and medium, prominent, clear white, calcareous mycelia; silty clay loam (slightly gravelly); strong coarse to fine subangular blocky structure; slightly sticky and slightly plastic (wet); very firm (slightly moist); hard (dry); common micro and very fine, a few fine and medium, discontinuous, random, inped, tubular, closed pores; very few gravel fragments; very few small, hard calcareous nodules; strongly calcareous; a very few fine roots.

## ANALYTICAL DATA FOR SITE FV

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-59 | Ap | vf | g,s | 12.5 | 72.7 | 14.8 | sil |
| 2 | 59-115 | C1ca | vf | g | 7.4 | 63.6 | 29.0 | sil |
| 3 | 115+ | C2ca | vf | g | 5.5 | 64.4 | 30.1 | sicl |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 3.2 | 1.6 | 0.8 | 1.4 | 5.5 | 60.2 | 8.6 | 3.9 |
| 2 | 0.6 | 0.2 | 0.1 | 0.5 | 5.9 | 48.4 | 10.7 | 4.4 |
| 3 | 0.9 | 0.5 | 0.2 | 0.2 | 3.5 | 44.0 | 16.4 | 4.0 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Avail. P ppm | CaCO3 % | Organic Matter% | Total N% | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.6 | 7.8 | 0.42 | 6.44 | 15.4 | 1.34 | 0.082 | 21.9 |
| 2 | 8.6 | 7.95 | 0.23 | 5.8 | 15.2 | 0.73 | 0.075 | 25.2 |
| 3 | 8.6 | 7.95 | 0.55 | 5.0 | 14.0 | 0.79 | 0.058 | 30.7 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand
l-loam si-silt

## PEDON KXIII

### SITE INFORMATION

Profile number: XIII
Series name: Unknown
Classification: TYPIC USTROPEPT, FINE SILTY, MIXED, _____, FAMILY
Date and time described: May 17, 1981, 10 AM
Authors: J. King
Location: One km from Salaba site at Ibb Agricultural School
Elevation: 1840 m
Landform: Rolling loess hill-colluvial
Slope class: Terraced, midslope
Microtopography: Terraced, flat with walls- about 1 meter
Slope: 25% between terraces; 1% on terraces
Land use: Sorghum and maize on terraces
Climate: Unknown

### SOIL INFORMATION

Parent material: Loess deposit with reworked surface modified by farmers to build terrace
Drainage class: Well-drained
Moisture conditions: Slightly moist upper part- down to original loess deposit
Depth to groundwater: Unknown
Surface stones or outcrops: none
Evidence of erosion: No significant erosion
Salt content: No alkali; calcareous salt accumulating
Human influence: Terraced farming has significantly modified upper 30 to 150 cm

General Description of the Profile: Deep dark calcareous silty profile with prismatic structure over light brown loess deposit.

### Profile Description

| | |
|---|---|
| Ap<br>0-20 cm<br>K6 | Dark brown, 10YR 4/3 (moist); silty clay loam; moderate medium to fine subangular blocky and crumb structure; non-sticky and slightly plastic (wet); firm (moist); a few fine and many micro, discontinuous, random, inped, tubular and interstitial open pores; slightly calcareous; many fine and medium roots; clear, wavy boundary. |

B
20-60 cm
K7

Dark brown, 10YR 4/3 (dry); silty clay loam; slightly sticky and slightly plastic (wet); very hard (dry); very strong coarse columnar to strong medium subangular blocky structure; a few fine and common micro, inped, discontinuous, random, tubular and interstitial open pores; calcareous; common fine and medium roots; gradual and wavy boundary.

C1ca
60-140 cm
K8

Dark brown, 7.5 YR 3/2 (moist); many, fine, distinct, diffuse, white calcareous mycelia on peds; silty clay loam; sticky and plastic (wet); very firm (moist); very strong coarse columnar to coarse subangular blocky structure; common fine and very fine discontinuous, random, inped, tubular, and vesicular, open and closed pores; a few small, soft, irregular calcareous nodules; strongly calcareous; very few pieces of pottery; a few fine roots; a few fresh, volcanic gravels; diffuse, irregular boundary.

C2ca
140-170 cm
K9

Light yellowish brown, 10YR 6/4 matrix with dark brown 10YR 4/3 material in cracks and former pores; silt loam; firm (moist); slightly sticky and slightly plastic (wet); common fine and many micro, discontinuous, random, inped, tubular open pores; many fine, distinct, diffuse calcareous mycelia; very few small, hard, angular, yellowish calcareous nodules; very strongly calcareous; a few fine roots; clear, wavy boundary.

C3ca
170+
K10

Very pale brown, 10YR 7/4 (dry); common, medium, distinct, clear, brownish material in tubular pores; few, fine faint, clear, white calcareous mycelia; very slightly gravelly silty clay loam; slightly plastic and non-sticky (wet); slightly hard (dry); common fine and many micro, discontinuous, random, inped, tubular, open pores; very few small hard, greyish, angular, calcareous nodules; strongly calcareous; a few fine roots;

## ANALYTICAL DATA FOR SITE KXIII

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-20 | Ap | vf | - | 5.2 | 63.1 | 31.7 | sicl |
| 2 | 20-60 | B | vf | - | 3.9 | 64.2 | 31.9 | sicl |
| 3 | 60-140 | C1ca | f | g | 4.8 | 59.0 | 36.2 | sicl |
| 4 | 140-170 | C2ca | vf | - | 3.7 | 66.8 | 29.5 | sil |
| 5 | 170+ | C3ca | vf | - | 4.4 | 65.5 | 30.0 | sicl |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.6 | 0.5 | 0.3 | 1.0 | 2.9 | 41.0 | 15.4 | 6.8 |
| 2 | 0.2 | 0.3 | 0.3 | 0.9 | 2.2 | 35.5 | 15.4 | 13.3 |
| 3 | 0.2 | 0.2 | 0.2 | 0.6 | 3.6 | 36.2 | 11.8 | 11.1 |
| 4 | 0.1 | 0.2 | 0.2 | 0.4 | 2.9 | 47.3 | 14.7 | 4.9 |
| 5 | 0.5 | 0.3 | 0.1 | 0.2 | 3.4 | 42.0 | 3.7 | 19.9 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Total N% | Organic Matter% | CaCO3 % | Avail P ppm | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.2 | 7.7 | 0.21 | 0.38 | 2.79 | 6.8 | 0.92 | 39.2 |
| 2 | 8.4 | 7.7 | 0.21 | 0.32 | 3.05 | 8.4 | 0.46 | 41.9 |
| 3 | 8.3 | 7.7 | 0.22 | 0.20 | 2.23 | 10.8 | 0.46 | 42.9 |
| 4 | 8.6 | 7.9 | 0.27 | 0.12 | 0.77 | 15.6 | 0.92 | 28.8 |
| 5 | 9.0 | 7.7 | 0.27 | 0.18 | 0.56 | 23.0 | 0.92 | 28.9 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand l-loam si-silt

## TIHAMA WADI SOILS (TW)

The mapping unit consists of arid, brown soils or Typic Camborthids formed from loess deposits, salt-affected Typic Torrifluvents and Typic Calciorthids located principally in the western area near the Red Sea coast; brown calcareous alluvial soils or Typic Torrifluvents with alternating silty and coarser layers; and brown soils (Typic Camborthids) affected by wind erosion with reworked aeolian surface layers. Most of the preliminary data for these soils was taken from a soil survey report by the Hungarian firm of Tesco-Viziterv-Vituki in 1971 (see Appendix 2).

### LOCATION AND EXTENT

These soils are located typically at all the major wadis and intermediate coastal plains of the Tihama. The association accounts for approximately 20%<a of the entire land area of Yemen, but undoubtedly includes a higher proportion of the total arable land because of the dominance of rock outcrops in mountainous Yemen.

Within the association itself, based on the field work undertaken by Tesco-Viziterv-Vituki (1971) in the Wadi Zabid area, approximately 30%<a are Typic Torrifluvents or calcareous alluvial soils, 69% are Typic Camborthids or wind-erosion affected soils and tropical arid brown soils, and 1% Typic Calciorthids.

### GEOMORPHOLOGY

The area is underlain by a detrital cone of volcanic materials (Tesco-Viziterv-Vituki, 1971) derived from the adjoining mountains to the east. Volcanic basement rock underlies the Tihama plain. It was downthrown by faults to the west parallel with the deep tectonic graben of the Red Sea (Tesco-Viziterv-Vituki, 1971). This depression contains sediments approximately 200 to 1000m thick composed mainly of gravel boulders and sand. At the surface, coarse sediments are interbedded with loess and desert sand.

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a- The percentages given are tentative and will be revised upon further investigation.

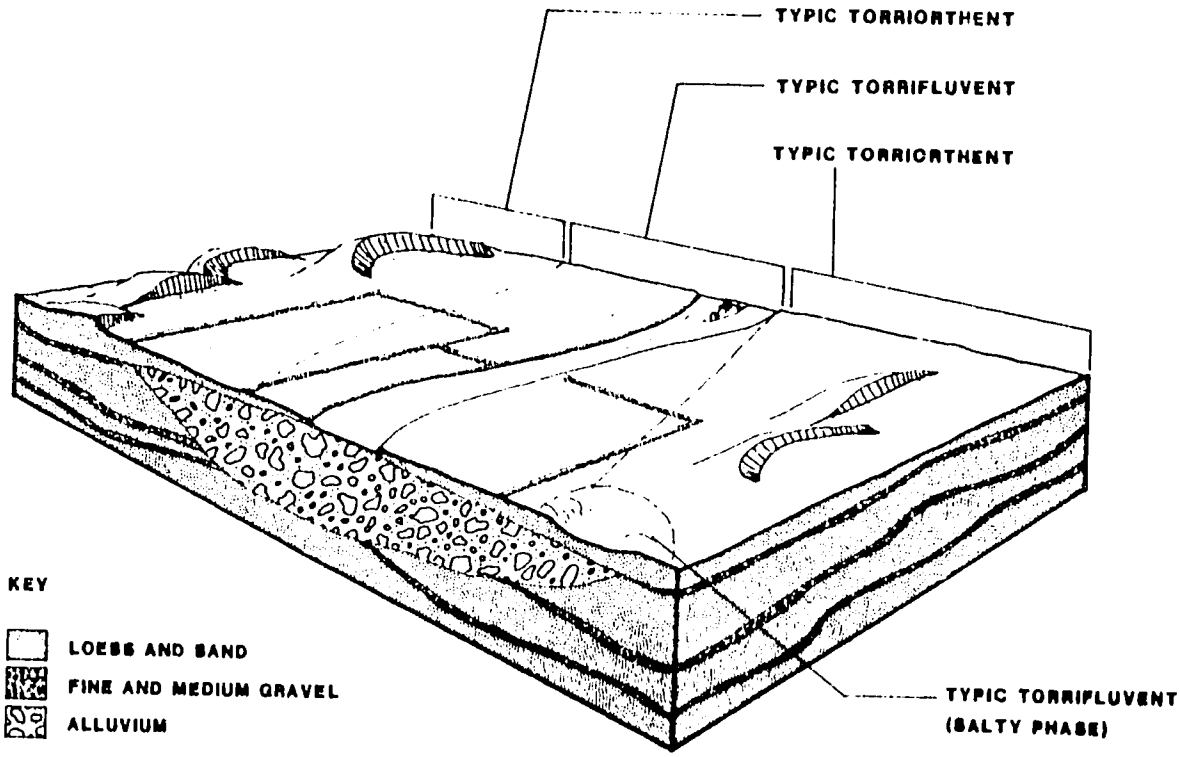


FIGURE 4.3

**Landscape Relationships for the Tihama Wadi (TW) Mapping Unit**

The area is characterized by a smooth, flat plain, sloping gently towards the Red Sea (Figures 3.3 and 4.3). Microrelief is more variable and areas of barchan and longitudinal dunes occur. Also, the microrelief of large areas of wadis has been altered by human activities. Farmers have used spate irrigation for centuries and constructed elaborate, mosaic patterns of bunds, some as high as 6 to 7 meters (Iesco-Viziterv-Vituki, 1971).

GENESIS AND IMPORTANT ENVIRONMENTAL INFLUENCES

The climate of the Tihama is arid. At Zabid, the mean annual rainfall is approximately 70 to 100 mm. 60 to 80% of this precipitation falls in July and August. Dust storms occur frequently throughout the year, especially in August (Iesco-Viziterv-Vituki, 1971).

All well-drained soils have an aridic soil moisture regime. Subsequently, little or no leaching occurs naturally. However, centuries of irrigation by farmers in areas adjacent to the major wadis have produced some shallow leaching of carbonates.

The long periods of spate irrigation have added a silty sedimentary layer to the profiles of many soils found near the large wadis. This silt material is most likely reworked loess transported as wadi

bedload. This silt layer has an important influence on the morphology and agricultural use of the soils.

## CLIMATE

In the Yemen climatic environment, the existing soil moisture regime is an important limiting factor to any agricultural use of the soils. Direct determination of the soil moisture regime of a map unit is difficult. Soil moisture regimes have been estimated with the scant climatic data available using the Franklin Newhall computer algorithm (Tavernier and Van Wambeke, 1976).

The soil moisture regime of four stations in the coastal plain/wadi map unit have been estimated. These stations are: Zabid, Zabid Camp, Hodeidah and Kamaran (Table 4.1). The data avaiable for Hodeidah and Kamaran are averaged over several years, and thus results for individual years are not available. Soil moisture calendars were computed for these stations from the averaged data (see Appendix 1). The temperature regime at Hodeidah is estimated to be isohyperthermic. Temperature data for these estimations were taken from Hodeidah since it was not available for most of the others. It was assumed that the temperatures were similar at all sites.

Table 4.1. Estimated soil moisture regimes for selected stations in the TW map unit.

| STATION | YEARS OF DATA | ESTIMATED SOIL MOISTURE REGIME |
|---|---|---|
| Zabid Camp | 7 | Aridic |
| Zabid | 6 | Aridic |
| Hodeidah | <a | Aridic |
| Kamaran | <a | Aridic |

<a- Mean values as given in World Wide Airfield Summaries, Naval Weather Service Command, Washington, D.C., May, 1974.

## VEGETATION

Natural herbaceous xerophytic vegetation includes: *Chrysopogon aucherii*, *Paspaladium desertorum*, *Coelachyrum praeflorum*, *Maerua grassifolis* and *Euphorbia sp*. Shrubs include: *Helitropium bicolor*, *Croton cliffordii*, *Olea chysophylla*, *Tarchonantus camphoratus*, *Juniperus procera*, *Calystegia sepium*, *Calystegia soldanella*, and *Lactarius volemus*. Arborescent plants include: *Acacia asak*, *A. mellifera*, *A. spirocarpoides*, *A. trotlis*, *Cammifora opobalsamum*, *Pistacia sp.*, *Tamariscus sp.*, *Rhodendrum sp.* and palms. Most of the

present vegetation, however, consists of cultivated crops, including: sorghum, pennisetum, maize, cowpeas, sesame, vegetables, and fruits (Tesco-Viziterv-Vituki, 1971). Significant quantities of organic material do not accumulate in soils because of the hot, dry climate.

## PEDON DESCRIPTIONS

### PEDON FVI

SITE INFORMATION

Profile number: FVI
Series name: Unknown
Classification: TYPIC TORRIFLUVENT, COARSE LOAMY, MIXED, ISOHYPERTHERMIC FAMILY, STRONGLY SALINE PHASE
Date and time described: April 22, 1981, 12:15 PM
Authors: T. Forbes
Location: Wadi Zabid area, Bani Fathal, 5 km from the Red Sea
Elevation: 50 m
Landform: Center of flat alluvial (aeolian) plain
Slope class: Flat alluvial wadi, much disturbed in areas by building bunds
Microtopography: Many sand blow out areas and remanants of stabilized sand dunes
Slope: 0-1%
Land use: Not cultivated, some shrubs adapted to salty conditions
Climate: Unknown

SOIL INFORMATION

Parent Material: Alluvial (wadi) and aeolian deposits
Drainage class: Well-drained
Moisture conditions: Soil moist below 10-20 cm
Depth to groundwater: Unknown
Surface stones or outcrops: No surface stones or rock outcrops
Evidence of erosion: Some sheet and aeolian erosion
Salt content: Salt (Ca or Na?) very apparent on soil surface; surface feels "spongy" when walking
Human influence: Appears undisturbed recently by humans, but may have been used intensively in the past

General Description of the Profile: Deep light to dark brown profile. Six sedimentary layers discerned. Sedimentation due to human, alluvial and aeolian processes.

Profile Description

| | |
|---|---|
| A1ca<br>0-18 cm<br>F17 | Brown, 7.5 YR 4/4 (moist); common, fine distinct, clear, white salt crystals; sandy loam (with fine sand); moderate to weak, medium to fine, subangular |

blocky structure; non-sticky and very slightly plastic (moist); very friable (moist); common micro and very fine, a few medium, discontinuous, horizontal and random, inped, tubular and vesicular, open and closed pores; very few gravel; very few small soft calcareous nodules, and few very small white salt crystals; strongly calcareous; no artifacts; very few, very fine roots; clear, wavy boundary.

IC1
18-78 cm
F18

Brown, 10YR 5/3 (slightly moist); very few, very fine distinct white salt crystals; silt loam (with very fine sand); moderate to weak, coarse to fine , subangular blocky structure; very slighly sticky and very slightly plastic, friable to very friable; common micro to very fine, few medium, discontinuous, random, inped, tubular, and vesicular, closed pores; very few basalt gravels; very few, very small, soft spherical, white salt crystals; strongly calcareous; frequent small to large (about 8 cm) orange pottery chips; a few small and very fine roots; gradual, wavy boundary.

IIC2
78-93 cm
F19

Yellowish brown, 10 YR 5/4 (moist); silt loam; moderate to weak coarse to fine subangular blocky structure; slightly sticky and slightly plastic (wet); very friable to friable (moist); segregation of light and dark material, some large pores contain what appear to be dried cutans, lighter material deposited by human influence illuviates into horizon beneath; common micro and very fine, a few fine and medium, discontinuous, random, inped tubular and vesicular, closed pores; very few basalt gravels; very few, very small, soft, spherical white salt nodules; very few, fine roots; strongly calcareous; no artifacts; gradual, wavy boundary.

IIIC3
93-118 cm
F20

Dark grayish brown, 10YR 4/2 (moist); very few fine, distinct, white salt crystals (nodules); very fine sandy loam; weak coarse to fine subangular blocky structure; non-sticky, non-plastic (wet); very friable (moist); very few fine and a few micro, discontinuous, random, inped, tubular, closed pores; very few small, soft, spherical salt nodules; strongly calcareous; a very few fine roots; clear, wavy boundary.

IVC4
118-135 cm
F21

Brown, 10YR 4/3 (moist); common, fine, distinct, gray salt nodules; loam; moderate, very coarse to fine subangular blocky structure; sticky and plastic (wet); friable (moist); lighter clay material segregated from coarser material (speckeled appearance)- resembles

inactive old cutans; a few fine and medium, common micro, very fine, discontinuous, random, inped, tubular, closed poes; very few basalt gravel; frequent, small to large, soft, spherical (and mycelia), white salt nodules and material; strongly calcareous; no artifacts; very few fine roots; clear, wavy boundary.

VC5
135+ cm
F22

Brown, 10 YR 4/3 (moist); loamy fine sand; weak coarse to fine subangular blocky structure; non-sticky and non-plastic (wet); very friable to loose (moist); common, micro, random, discontinuous, inped, interstital, closed pores; very rare basalt gravel; strongly calcareous; no roots; no artifacts.

## ANALYTICAL DATA FOR SITE FVI

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-18 | A1ca | vf | g | 59.9 | 30.4 | 9.7 | sl |
| 2 | 18-78 | IC1 | vf | g | 44.2 | 50.6 | 5.3 | sil |
| 3 | 78-93 | IIC2 | vf | g | 9.6 | 76.6 | 13.9 | sil |
| 4 | 93-118 | IIIC3 | vf | - | 60.9 | 36.3 | 2.7 | sl |
| 5 | 118-135 | IVC4 | vf | g | 33.9 | 47.2 | 18.9 | l |
| 6 | 135+ | VC5 | vf | g | 78.1 | 20.8 | 4.3 | ls |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.1 | 1.0 | 5.2 | 28.7 | 24.9 | 17.0 | 10.8 | 2.5 |
| 2 | 0.3 | 1.0 | 3.3 | 20.1 | 19.5 | 31.7 | 14.9 | 3.9 |
| 3 | 0.1 | 0.4 | 1.2 | 4.6 | 3.3 | 28.3 | 38.1 | 10.2 |
| 4 | 0.1 | 1.1 | 5.4 | 30.0 | 24.2 | 22.3 | 9.1 | 4.9 |
| 5 | 0.1 | 0.5 | 2.9 | 16.4 | 13.9 | 21.9 | 19.6 | 6.1 |
| 6 | 0.0 | 2.1 | 10.3 | 42.8 | 22.9 | 16.2 | 0.0 | 4.6 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Avail. P ppm | $CaCO_3$ % | Organic Matter% | Total N% | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 9.4 | 8.4 | 6.1 | 8.6 | 11.2 | 0.45 | 0.044 | 18.3 |
| 2 | 9.9 | 8.55 | 3.6 | 6.44 | 9.6 | 0.30 | 0.044 | 22.5 |
| 3 | 8.6 | 8.05 | 3.15 | 6.0 | 9.6 | 0.30 | 0.037 | 27.8 |
| 4 | 9.2 | 9.1 | 1.15 | 5.8 | 9.6 | 0.28 | 0.034 | 22.2 |
| 5 | 10.2 | 9.1 | 1.15 | 5.21 | 13.8 | 0.27 | 0.021 | 32.1 |
| 6 | 10.5 | 9.6 | 0.9 | 5.14 | 8.2 | 0.10 | 0.014 | 19.1 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

## INTERMONTANE PLAIN (IMP)

These soils occur in areas of inland alluvium, including ancient lacustrine sediments, volcanic colluvial and pyroclastic deposits and calcareous loess. Typic Torrerts and Udic Pellusterts forming on lacustrine sediments have dark clayey horizons with a more recent loess cap. Typic Camborthids and Calciorthids are brown silty soils formed on loess and volcanic colluvium and ash. Small depressions have salt-affected and seasonally wet Typic Salorthids and Aquollic Salorthids.

### LOCATION AND EXTENT

The total extent of the alluvial plain/lacustrine mapping unit is approximately 5%[a] of Yemen (based on consideration of the contiguous Ma'bar, Dhamar, Yerim areas as reported by Acres, 1980). Within this area, it is estimated that Typic Torrerts and Udic Pellusterts occupy approximately 10% of the area. Typic Camborthids occupy approximately 45%. Typic Calciorthids 20% and Typic Salorthids and Aquollic Salorthids approximately 5% of the mapping unit. 20% is represented by rock outcrops.

### GEOMORPHOLOGY

The landscape relationships of the area are complex. Dissected, volcanic highlands and lava flows grade into alluvial plains, underlain in some cases by ancient lacustrine sediments, all capped with a silt layer (Figure 4.4).

Highlands have steep sides with colluvial bases. Lava flows are extensions of the volcanic highlands in some areas. Both of these features consist mainly of rock outcrops. Valleys of inland alluvium are quite uniform and gently sloping except for occasional areas of volcanic rock outcrops, including ancient volcanic cones.

Some areas of inland alluvium are underlain by ancient lacustrine sediments capped with calcareous loess. These lacustrine sediments occur in large areas and are not related to specific small depressions

---

a- The percentages given are tentative and will be revised upon further investigation.

or other microrelief features. Predominant soils here include Typic Torrerts and Udic Pellusterts, silty cap phase.

The rest of the nearly flat valley of inland alluvium shows practically no dissection. Areas of accumulation of carbonates have Typic Calciorthids. Other areas with less carbonates have Typic Camborthids. Small depressions which tend to accumulate runoff form Typic Salorthids and Aquollic Salorthids.

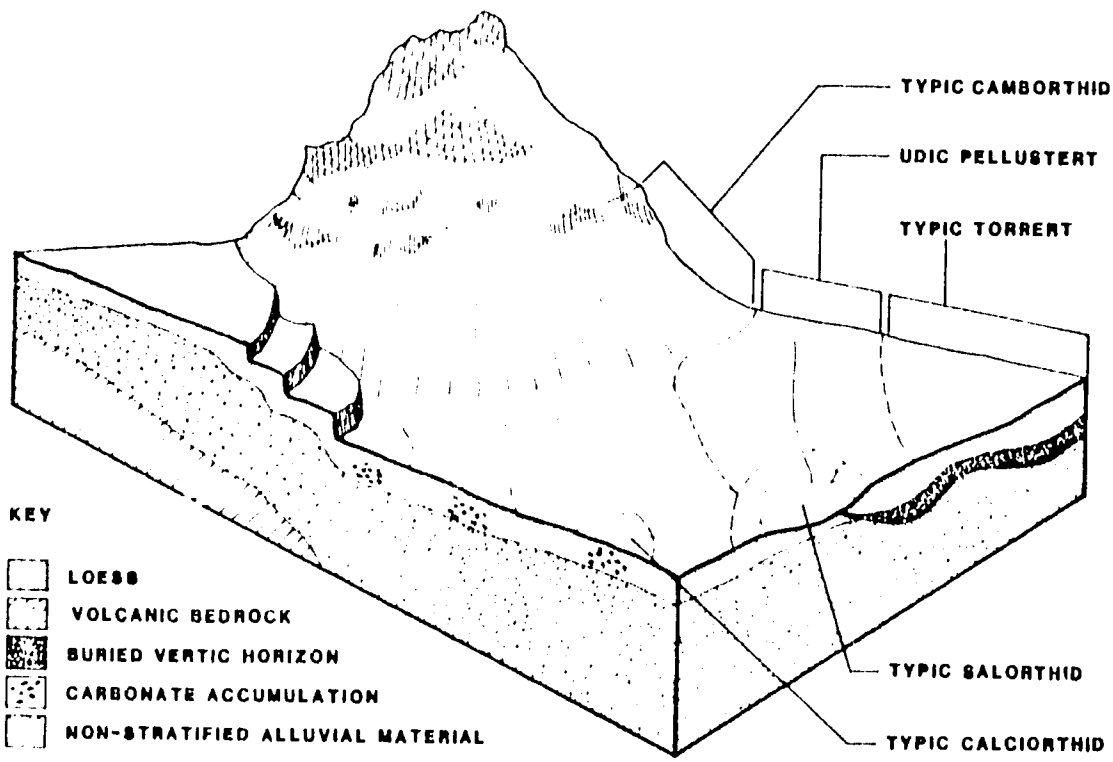


FIGURE 4.4

**Landscape Relationships for the Inter-Montaine Plain (IMP) Mapping Unit**

## CLIMATE

In the Yemen climatic environment, the existing soil moisture regime is an important limiting factor to any agriultural use of the soils. Direct determination of the soil moisture regime of a map unit is difficult. Soil moisture regimes have been estimated with the scant existing climatic data available using the Franklin Newhall computer algoritham (Tavernier and Van Wambeke, 1976).

The soil moisture regime of several stations in the alluvial lacustrine map units have been estimated. These stations include: Dawran, Rabat, Rhizwa, Dhaf, Ma'bar, DAFRD, Ad-Darb, Dhamar, Samah-Al-Oya, Ash-Shagrab, Maram and Sanaban (Tables 4.2). Temperature data for

these estimations was taken from Dhamar since it was not available for most of the others. The temperature regime at Dhamar is estimated to be isothermic. It was assumed that the temperatures were similar at all sites. Soil moisture calendars were also produced by the computer program cited above for Ma'bar and Rabat. They are included in Appendix 1.

Table 4.2 Estimated soil moisture temperature regimes for selected stations in the IMP map unit <a

| STATION | YEARS OF DATA | ESTIMATED SOIL MOISTURE REGIMES |
|---|---|---|
| Dawran | 2 | Ustic |
| Ma'bar | 5 | Aridic |
| Rabat | 3 | Udic |
| Rhizwa | 5 | Aridic |
| Dhaf | 3 | Aridic |
| DAFRD | 2 | Aridic |
| Ad-Darb | 4 | Aridic |
| Dhamar | 5 | Ustic |
| Samah-Al-Uya | 5 | Aridic |
| Ash-Shagrab | 5 | Aridic |
| Maram | 5 | Aridic |
| Sanaban | 5 | Aridic |

A- Raw data from Acres, 1980.

## GENESIS AND IMPORTANT ENVIRONMENTAL INFLUENCES

The presence of buried soils, relicts of soils formed in a previous wetter climate are the most striking and characteristic feature of this area. Lacustrine sediments deposited in a closed basin during wetter times have produced the Typic Torrerts and Udic Pellusterts. The present environment affects these old soils largely through loess deposition, which has formed a silty cap.

Alluvium mixed with the more recently deposited loess controls soil morphology over the rest of the great extent of the plain. Small depressions where water accumulates have Typic and Aquollic Salorthids. Some Typic Camborthids, nonarable and shallow soils, have formed in the areas of colluvium.

Rainfall in the area ranges from about 360 to 610 mm/yr (Acres, 1980). Evaporation is high, as estimated by Penman's formula, and ranges from approximately 1700 to 2400mm annually. Mean annual temperature ranges from 11 to 15 degrees Celsius, with killing frosts occuring in some elevated areas (Acres, 1980).

Areas of natural vegetation are rare. Most land is currently used for cultivation, grazing or water harvesting (Acres, 1980).

PEDON DESCRIPTIONS

PEDON PVII

SITE INFORMATION

Profile number: PVII
Series name: Unknown
Classification: TYPIC TORRERTS, FINE CLAYEY, MONTMORILLONITIC, _____, FAMILY, SILTY CAP PHASE
Date and time described: May 6, 1981, 9AM
Authors: T. Forbes
Location: Qa'Jahran, British experimental farm near Ma'bar, 70-75 km south of Sana'a
Elevation: 2230m
Landform: Wide, nearly flat plain; slightly convex middle footslope, 1 km from rock outcrop
Slope class: Nearly flat
Microtopography: Disturbance by human cultivation, formation of bunds
Slope: 1-2%
Land use: Not used, near garden area in front of housing of project
Climate: Unknown

SOIL INFORMATION

Parent Material: Lacustrine sediments (as reported previously) and alluvium-colluvium from rock outcrop and loess
Drainage class: Well-drained
Moisture conditions: Dry throughout
Depth to groundwater: Unknown
Surface stones or outcrops: No surface stones or rock outcrops
Evidence of erosion: No evidence of erosion at site.
Salt content: Calcareous concretions present in the profile; no obvious evidence of alkali (Na) salt
Human influence: Area has been cultivated for centuries with some form of irrigation- as evidenced by the top disturbed layer

General Description of the Profile: Deep, tri-color profile. Light brown loose surface, dark brown buried layer, followed by brown layer with very prominent calcareous, white concretions.

## Profile Description

Ap
0-25 cm
F23

Yellowish brown, 10 YR 5/4 (dry); very slightly gravelly silt loam; moderate coarse to fine subangular blocky structure; very slightly sticky and very slightly plastic (wet); friable to loose (dry); common micro and few very fine, discontinuous, random, inped, interstitial and tubular open and closed pores; very few volcanic gravels and stones (fresh); common very fine to medium roots (and grass rhizomes); strongly calcareous; abrupt, wavy boundary.

A1b
25-58 cm
F24

Dark gray, 10YR 4/1 (dry); a few fine to medium, distinct, clear grey to white calcareous nodules; slightly gravelly silty clay loam; strong very coarse prismatic to very strong, medium blocky structure; sticky and plastic (wet); hard (dry); streak of brown, silty material seen in cracks; broken thick pressure faces (cutans or slickensides); a few micro and fine discontinuous, inped, interstitial and tubular, closed pores; very few small calcareous gravel (hard); very calcareous; a few fine and very fine roots; clear, irregular boundary.

Bbca
58-71 cm
F25

Yellowish brown, 10 YR 5/4 (dry); common, medium to fine, distinct, clear to diffuse, white to grayish calcareous nodules; slightly gravelly silty clay loam; weak coarse prismatic to medium and fine subangular blocky structure; sticky and plastic (wet); hard (dry); thin, broken clay pressure coatings or slickensides; very few micro, common fine and a few fine discontinuous, random, inped, interstitial and tubular, closed pores; a very few volcanic gravel; frequent small, hard calcareous white nodules; strongly calcareous; very few fine and very fine roots; gradual, broken boundary.

Cbca
71+ cm
F26

Brown, 10 YR 4/3 (dry); common, medium, prominent, sharp, white to grayish calcareous nodules; slightly gravelly clay; strong medium prismatic to strong fine subangular blocky structure; sticky and plastic (wet); slightly hard (dry); broken, moderately thick clay pressure coatings and slickensides; very few micro, a few very fine discontinuous, random, inped, interstitial and tubular closed pores; a very few fresh volcanic gravels; frequent to very frequent , small and large, soft and hard, irregular white and grayish, calcareous nodules; very strongly calcareous; rare fine and very fine roots.

## ANALYTICAL DATA FOR SITE FVII

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-25 | Ap | vf | g,s | 31.6 | 50.1 | 18.3 | sil |
| 2 | 25-58 | A1b | vf | g | 12.2 | 38.8 | 49.1 | sicl |
| 3 | 58-71 | Bbca | vf | g | 16.9 | 34.0 | 49.1 | sicl |
| 4 | 71+ | Cbca | vf | g | 11.2 | 39.2 | 49.7 | c |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.4 | 2.1 | 1.9 | 3.1 | 23.0 | 28.4 | 13.1 | 8.6 |
| 2 | 1.1 | 1.0 | 0.7 | 1.6 | 7.8 | 20.0 | 11.4 | 7.4 |
| 3 | 2.8 | 2.2 | 1.1 | 1.6 | 9.1 | 19.4 | 14.6 | 0.0 |
| 4 | 1.4 | 0.6 | 0.2 | 0.8 | 8.1 | 15.3 | 14.2 | 9.7 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Total N% | Organic Matter% | CaCO3 % | Avail P ppm | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.8 | 7.8 | 0.16 | 0.24 | 0.71 | 10.2 | 5.06 | 23.6 |
| 2 | 8.9 | 7.8 | 0.23 | 0.20 | 1.03 | 11.8 | 3.68 | 41.0 |
| 3 | 8.9 | 7.9 | 0.23 | 0.20 | 1.03 | 11.8 | 3.68 | 36.0 |
| 4 | 9.0 | 8.1 | 0.38 | 0.10 | 0.20 | 17.4 | 3.68 | 46.6 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand
l-loam si-silt

## PEDON FVIII

### SITE INFORMATION

Profile number: FVIII
Series name: Unknown
Classification: UDIC PELLUSTERT, FINE CLAYEY, MONTMORRILLONITIC, _____, FAMILY, SILTY CAP PHASE
Date and time described: May 6, 1981, 12:15 PM
Authors: T. Forbes
Location: Qa'Jahran, British experimental farm near Ma'bar, on the east side of highway, approximately 0.5 km from pit FVII
Elevation: 2230 m
Landform: Flat to concave slope
Slope class: Edge of colluvial/alluvial toeslope and plain (Qa'Jahran proper)
Microtopography: Ridging by farmers
Slope: 2%
Land use: Barley trial on one side and forage trial on the other
Climate: Unknown

### SOIL INFORMATION

Parent Material: Lacustrine sediment mixed with alluvium/colluvium of volcanic rock outcrop and loess cap
Drainage class: Well-drained with mottling starting at 108 cm
Moisture conditions: Profile slightly moist at surface and moist with depth
Depth to groundwater: Unknown, but estimate that it may be within 2.5 m
Surface stones or outcrops: A few surface stones; no rock outcrops
Evidence of erosion: No evidence of erosion
Salt content: No surface salt or alkali
Human influence: Very evident, have pulled up by plowing dark clayey layer into some parts of loess layer. Also have ridged and plowed for centuries

General Description of the Profile: Deep dark clayey profile with loess cap grading to gleyed clay at depth (about 140 cm)

### Profile Description

| | |
|---|---|
| Ap<br>0-34 cm<br>F27 | Dark yellowish brown, 10YR 4/4 (moist); clay loam; moderate to weak, coarse to fine, subangular blocky structure; non-sticky and very slighly plastic (moist); |

common micro and a few fine and very fine, random, inped, discontinuous, interstitial and tubular, closed and open pores; very few volcanic gravel; strongly calcareous; common fine and a few medium roots; abrupt wavy to irregular boundary.

A1b
34-87 cm
F28

Very dark gray, 10 YR 3/1 (moist); clay; weak prismatic to moderate medium to fine subangular blocky structure; non-sticky and slightly plastic (wet); friable (moist); patchy, thin, clay pressure coatings or slickensides; very few micro and a few fine, discontinuous, random, inped, interstitial and tubular, open and closed pores; very few volcanic gravel; calcareous; a few medium, fine and very fine roots; clear, wavy boundary.

IIC1ca
87-108 cm
F29

Brown, 10YR 4/3 (moist); common, fine to medium, distinct clear, white to grayish calcareous nodules; clay loam; very slightly sticky and very slightly plastic (wet); very weak medium prismatic to moderate medium to fine subangular blocky structure; patchy, thin, clay pressure coatings or slickensides; a few micro, fine and very fine, discontinuous, random, inped, interstitial and tubular, closed and open pores; a few volcanic gravel and a few small mica flakes; frequent small to large, hard and soft, irregular white to gray calcareous nodules; strongly calcareous; very few very fine roots; gradual wavy boundary.

IIC2ca
108-136 cm
F30

Very dark grayish brown, 10YR 3/2 matrix (moist) with light yellowish brown 10YR 5/6 and yellowish brown 10YR 5/4 limestone and decomposed limestone; clay loam; matrix with gravelly clay (decomposed rock); moderate coarse to fine subangular blocky structure; slightly sticky and slightly plastic matrix (wet) and sticky and plastic decomposed rock (wet); friable (moist) matrix) and firm (moist) decomposed rock); very thin and very patchy thin clay pressure coatings or slickensides in voids and pores; many micro and common fine discontinuous, random, inped, interstitial and tubular, closed and open pores; very frequent decomposed limestones and gravel and very few small mica flakes; very few small grayish calcareous nodules; strongly calcareous; a few fine roots; clear, wavy boundary.

IIICcag
136+ cm
F31

Gray, 5Y 5/1 (moist) with common, medium, prominent, clear , yellowish red 5YR 5/6 and 5YR 3/1 very dark gray mottles (stone remnants); clay; strong medium to fine subangular rock-like structure; sticky and plastic (wet); firm (moist); patchy thin clay pressure coatings

or slickensides; common fine and medium discontinuous, random, inped, interstitial, closed pores; very strongly calcareous; no visible roots.

Note: Vertical cracks approximately 20 cm deep and 2 m long occasionally observed within 10m of the profile.

## ANALYTICAL DATA FOR SITE FVIII

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-34 | Ap | vf | g | 29.8 | 43.8 | 26.4 | cl |
| 2 | 34-87 | A1b | vf | g | 8.7 | 38.9 | 52.4 | c |
| 3 | 87-108 | IIC1ca | f | g | 31.18 | 31.6 | 37.2 | cl |
| 4 | 108-136 | IIC2ca | vfr | s,g | 31.5 | 29.3 | 36.3 | cl |
| 5 | 136+ | IIICcag | vf | - | 5.1 | 36.8 | 58.1 | c |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 2.5 | 3.1 | 2.4 | 2.7 | 19.1 | 25.1 | 9.2 | 9.6 |
| 2 | .9 | 1.6 | 1.5 | 1.2 | 8.7 | 16.2 | 13.1 | 9.6 |
| 3 | 4.3 | 8.8 | 7.4 | 4.0 | 6.8 | 18.4 | 10.3 | 3.0 |
| 4 | 4.5 | 8.7 | 6.7 | 4.0 | 7.7 | 15.3 | 8.6 | 5.4 |
| 5 | 0.3 | 0.5 | 0.4 | 1.1 | 2.9 | 18.6 | 14.1 | 4.1 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Total N% | Organic Matter% | CaCO3 % | Avail P ppm | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 9.1 | 8.2 | 0.39 | 0.12 | 0.91 | 8.6 | 13.34 | 25.0 |
| 2 | 8.5 | 7.9 | 2.4 | 0.06 | 0.88 | 6.2 | 3.22 | 47.9 |
| 3 | 9.0 | 7.9 | 2.1 | 0.12 | 0.47 | 5.8 | 3.68 | 29.5 |
| 4 | 8.7 | 7.9 | 2.1 | 0.10 | 0.37 | 5.8 | 5.52 | 34.2 |
| 5 | 8.5 | 7.7 | 1.4 | 0.08 | 0.31 | 5.4 | 5.98 | 49.7 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand l-loam s-sand

## SEMI-ARIDIC VOLCANICS (SV)

This area is characteristic of large regions in Yemen which are comprised mostly of bare rock outcrops and bouldery, stony colluvium with little or no soil formation. The most extensive areas of soil occur along the edges and within narrow valleys formed on colluvium and loess and wadi alluvial deposits. Miscellaneous rock outcrops account for most of the area; yellowish brown, silty and colluvial Typic Ustorthents occur on colluvial and loess terraces; lower positions of the terraced areas have dark clayey Typic Natrustalfs with silty caps and natural terraces on the wadi have Typic Tropofluvents.

### LOCATION AND EXTENT

This mapping unit may cover 15 to 20%[a] of the surveyed area in Yemen. It is estimated that 80% of the association is volcanic rock outcrop. Terraced colluvium and loess or Typic Ustorthents comprise 10% of the association. Terraced clayey soils with silt caps or Typic Natrustalfs comprise a very low percentage of the area and approximately 8% of the area are natural alluvial terraces or Typic Tropofluvents.

### GEOMORPHOLOGY

The major part of the region is steep; some volcanic rock outcrops on escarpments show large characteristic basalt prisms. Steep-sided valleys are found occasionally (Figure 4.5). Within the valleys there are rolling to undulating topographies with deposits of rocky colluvium mixed with calcareous loess which accumulates at the bases of the valley sides. This colluvium and loess has been intensively terraced and cultivated by farmers for centuries. The steep deposits grade to gently sloping to flat wadi alluvial terraces which have also been changed by farmers building bunds to control flooding and sediment deposition during the rainy season or periods of high water in the wadi. The valley sediments form a distinct series of natural terraces with the youngest occuring near the wadi (Fig. 4.5).

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a- The percentages given are tentative and will be revised upon further investigation.

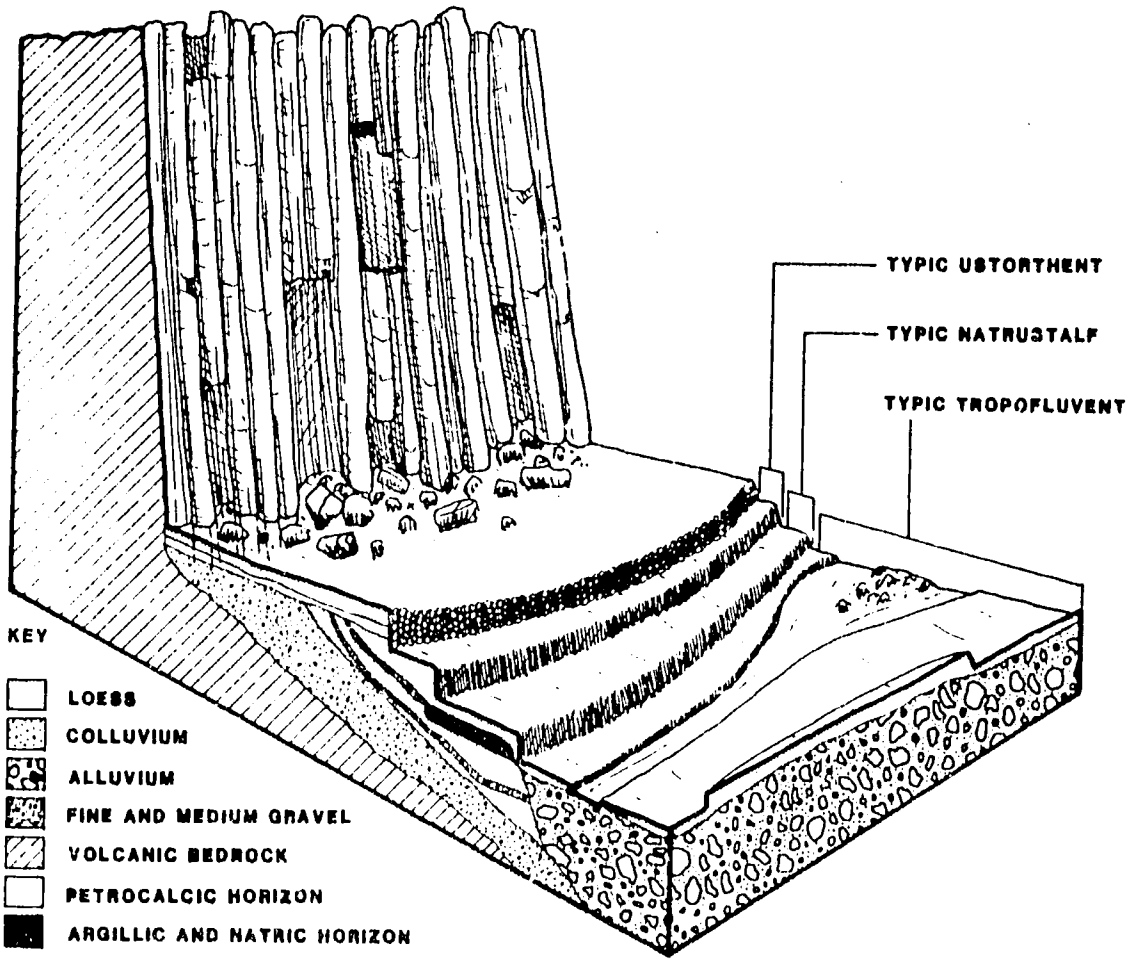


FIGURE 4.8

**Landscape Relationships for the Semi-Aridic Volcanics (SV) Mapping Unit**

GENESIS AND IMPORTANT ENVIRONMENTAL INFLUENCES

Although this mapping unit occurs in areas of very low precipitation the soils of the lower positions show evidence of leaching and translocation of suspended materials. Runoff from the steeper rocky areas accumulates in the narrow valleys and runs out through the wadis. The Natrustalfs at the intermediate positions above the alluvial terraces of the wadis indicate a wetter climate and consequently more runoff in the past. Upper colluvial pedons do not show significant leaching and therefore less profile development. Typic Ustorthents are predominant.

Th wadi and alluvial terraces adjacent to it have significantly more water as evidenced by the lush vegetation and crops. Also the wadis appear to flow continuously during the rainy season. As such it is assumed that an ustic soil moisture regime is likely for the band of alluvial soils (Typic Tropofluvents) adjacent to the wadi.

At the foot of cliff walls and escarpments some soils have petrocalcic horizons. This is probably caused by the water

percolation from the rocky higher areas which contain large amounts of carbonates.

VEGETATION

Woody vegetation for this association includes: *Ziziphus spina-christi*, *Acacia seval*, *Acacia tortilis*, *Tamarix orientalis*, *Ficus spp.*, *Cordia abyssinica*, *Eucalyptus spp.*, *Acacia flava*, *Tamarix articulata*, *Ficus salicifolia* vahl, and *Hyphaene thebaica*.

All arable land has been terraced and is currently cultivated. Crops demanding more moisture than that given by rainfall such as maize are grown near the wadi.

## PEDON DESCRIPTIONS

### PEDON FIX

SITE INFORMATION

Profile number: FIX
Series name: Unknown
Classification: TYPIC USTORTHENT, COARSE, LOAMY, MIXED, _____ FAMILY
Date and time described: May 11, 1981 7:30 AM
Authors: T. Forbes
Location: Al Jabjab near Al Naderah Town (Wadi Bana); 300 m from secondary school stadium
Elevation: 2100 m
Landform: Terraced footslope of volcanic mountain
Slope class: Sloping terraced land down to alluvial wadi bottom
Microtopography: Near washed-out gully; nearly level surface
Slope: Between terraces 29%; on terrace 10%
Land use: Previously cultivated for sorghum and lentil only, rainfed, never irrigated; now in fallow
Climate: Unknown

SOIL INFORMATION

Parent material: Colluvium from mountains and loess Some water-transported sediments also from mountain and loess.
Drainage class: Well-drained
Moisture conditions: Profile slightly moist to dry throughout
Depth to groundwater: Unknown
Surface stones or outcrops: A few surface stones, no rock outcrops
Evidence of erosion: Profile intially exposed by gully erosion
Salt content: Calcareous material increases with depth
Human influence: Terrace-building

General Description of the Profile: Deep, well-drained light brown silty then clay profile, calcareous mycelia increase with depth.

Profile Description

| | |
|---|---|
| Ap<br>0-22 cm<br>F32 | Dark yellowish brown, 10YR 4/4 (moist); gravelly and slightly stony loam; weak medium to fine subangular blocky and crumb structure; non-sticky and slightly plastic (wet); very friable to loose (moist); many micro and common, very fine and fine discontinuous, random, inped, interstitial and tubular closed and open |

pores; frequent volcanic gravel and a few volcanic stones (fresh); calcareous; many medium and fine roots; gradual wavy boundary.

C1
22-49 cm
F33

Dark yellowish brown, 10YR 4/4 (moist); with a few fine distinct, clear white calcareous mycelia; gravelly and stony loam; moderate coarse to fine subangular blocky and crumb structure; non-sticky and slightly plastic (wet); very friable (moist); common micro and a few very fine and fine, discontinuous, random, inped, interstitial and tubular, closed and open pores; frequent fresh volcanic gravel and a few fresh volcanic stones; calcareous; common medium and fine, and a few coarse roots; gradual, wavy boundary.

C2
49-115 cm
F34

Yellowish brown, 10YR 5/4 (moist); common, fine to medium, distinct clear, white, calcareous, mycelia; gravelly and stony, loam; moderate coarse to fine subangular blocky structure; non-sticky and non-plastic (wet); very friable (moist); soft (dry); many micro and common very fine and fine discontinuous, random, inped, interstitial and tubular, closed and open pores; frequent fresh volcanic gravel and stones; very few small and some large, soft and spherical and irregular white calcareous nodules; strongly calcareous; a few medium and fine and some coarse roots; gradual, wavy boundary.

C3ca
115+ cm
F35

Brown, 10YR 4/3 (moist); with many fine and medium distinct clear white calcareous mycelia; gravelly and stony clay loam; strong coarse to fine subangular blocky structure; slightly sticky and plastic (wet); friable (moist); slightly hard (dry); common very fine and fine discontinuous, random, inped, tubular, open and closed pores; frequent fresh volcanic gravel and stones; very few small and large soft, spherical and irregular, white calcareous nodules; strongly calcareous; very few medium and fine roots.

## ANALYTICAL DATA FOR SITE FIX

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-22 | Ap | fr | g,s | 48.9 | 44.9 | 6.3 | l |
| 2 | 22-49 | C1 | fr | g,s | 51.9 | 36.8 | 11.3 | l |
| 3 | 49-115 | C2 | fr | g,s | 42.8 | 42.9 | 14.3 | l |
| 4 | 115+ | C3ca | fr | g,s | 28.7 | 43.5 | 27.8 | cl |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.9 | 7.0 | 5.6 | 11.7 | 15.6 | 24.0 | 17.0 | 3.9 |
| 2 | 10.9 | 7.6 | 6.2 | 12.4 | 14.8 | 21.3 | 11.6 | 3.9 |
| 3 | 9.7 | 7.4 | 5.4 | 10.8 | 9.5 | 26.5 | 10.5 | 6.0 |
| 4 | 9.6 | 4.7 | 2.9 | 6.1 | 5.5 | 35.6 | 1.6 | 6.3 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Total N% | Organic Matter% | CaCO3 % | Avail P ppm ppm | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.4 | 7.8 | 0.19 | 0.12 | 1.34 | 10.0 | 2.3 | 50.8 |
| 2 | 8.8 | 7.8 | 0.27 | 0.12 | 0.67 | 10.2 | 3.22 | 50.5 |
| 3 | 8.7 | 7.9 | 0.95 | 0.10 | 0.47 | 10.2 | 3.22 | 50.0 |
| 4 | 8.7 | 8.0 | 0.18 | 0.08 | 0.32 | 10.2 | 7.36 | 54.8 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand
l-loam si-silt

## PEDON FX

### SITE INFORMATION

Profile number: FX
Series name: Unknown
Classification: TYPIC NATRUSTALF, FINE, CLAYEY, MIXED, _____ FAMILY
Date and time described: May 11, 1981, 7:30 AM
Authors: T. Forbes
Location: On secondary school sports field, Al Jabjab, Wadi Bana
Elevation: 2090 m
Landform: Terraced footslope of volcanic mountain
Slope class: Sloping terraced land down to alluvial wadi bottom
Microtopography: Near washed-out gulley; nearly level surface
Slope: 7% between terraces, 4% on terraces
Land use: Previously cultivated for sorghum and lentil only, rainfed, never irrigated, now in fallow
Climate: Unknown

### SOIL INFORMATION

Parent material: Mostly alluvium and volcanic colluvium from mountain with little loess cap on surface
Drainage class: Well-drained
Moisture conditions: Profile moist throughout
Depth to groundwater: Unknown (reported by locals to be about 3 m)
Surface stones or outcrops: No surface stones or outcrops
Evidence of erosion: No evidence of erosion
Salt content: No alkali, shallow to calcareous zone
Human influence: Terrace constructed

General Description of the Profile: Deep, dark, clayey profile with silty surface. Calcareous accumulation in second horizon.

### Profile Description

| | |
|---|---|
| Ap<br>0-15 cm<br>F36 | Brown, 10YR 4/3 (moist); very slightly gravelly silty clay (with some fine sand); moderate coarse to fine subangular blocky structure; non-sticky and slightly plastic (wet); friable (moist); some evidence of clay movement in large pores (very few cutans); many micro and very few, fine and very fine, discontinuous, random, inped, interstitial and tubular, closed and open pores; very few fresh volcanic gravels and stones; calcareous; very few finer roots; clear, wavy boundary. |

IIB21tca
15-91 cm
F37

Very dark greyish brown, 10YR 3/2 (moist); with common, medium, distinct, clear, white calcareous streaks; slightly stony and gravelly clay; very coarse to fine prismatic structure; sticky and plastic (wet); firm to friable (moist); continuous, moderately thick, clay cutans on peds and in large pores; a few fine and micro, discontinuous, random, inped, tubular and interstitial, open and closed pores; a few fresh volcanic gravels and rocks; strongly calcareous; very few very fine roots; abrupt, wavy boundary.

IIB22t
91+cm
F38

Black, 10YR 2.5/1 (moist); clay; very coarse to fine prismatic structure; sticky and plastic (wet); firm to friable (moist); continuous, thick, clay cutans on ped faces and in pores; very few micro and a few fine, discontinuous, random, inped, tubular and interstitial open and closed pores; very weakly calcareous.

Note: B2t appears to have become slowly calcareous by leaching of calcareous silty material above. Argillic horizon formed before the addition of calcareous loess material.

## ANALYTICAL DATA FOR SITE FX

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-15 | Ap | vf | g,s | 14.8 | 53.0 | 32.2 | sicl |
| 2 | 15-91 | IIB21tca | f | g,s | 16.2 | 45.2 | 38.7 | sicl |
| 3 | 91+ | IIB22t | vf | - | 4.4 | 49.7 | 45.9 | sic |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 3.5 | 2.3 | 1.5 | 3.3 | 4.3 | 30.6 | 13.9 | 8.5 |
| 2 | 3.5 | 2.7 | 2.0 | 4.4 | 3.7 | 20.5 | 19.5 | 5.1 |
| 3 | 0.3 | 0.5 | 0.4 | 1.1 | 2.2 | 22.9 | 19.0 | 7.8 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Total N% | Organic Matter% | CaCO3 % | Avail P ppm | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.6 | 7.9 | 0.28 | 0.12 | 0.79 | 12.4 | 7.82 | 44.3 |
| 2 | 8.7 | 7.9 | 0.27 | 0.14 | 0.70 | 12.0 | 8.28 | 57.2 |
| 3 | 8.8 | 7.9 | 0.21 | 0.22 | 0.70 | 11.0 | 6.9 | 61.9 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand
l-loam si-silt

# PEDON FXI

## SITE INFORMATION

Profile number: XI
Series name: Unknown
Classification: TYPIC TROPOFLUVENT, COARSE LOAMY, MIXED_____, FAMILY
Date and time described: May 11, 1981, 11:45 AM
Authors: T. Forbes
Location: Wadi Al Mahmarah; 4 km from Al Nadrah along Wadi Bana
Elevation: 2040m
Landform: Alluvial terrace next to braided gravel, flowing wadi
Slope class: Nearly flat alluvial terrace
Microtopography: Some ridging and construction of bunds made from boulders
Slope: 2-3%
Land use: cropped under maize
Climate: Unknown

## SOIL INFORMATION

Parent material: Alluvium mainly from volcanic rocks and calcareous loess in the drainage area
Drainage class: Well-drained
Moisture conditions: Moist
Depth to groundwater: About 2.5 m
Surface stones or outcrops: Some rounded boulders and stones
Evidence of erosion: Edge of terrace has been cut and eroded by flowing wadi
Salt content: No salt or alkali apparent
Human influence: Bund construction to trap wadi sediment and to prevent large-scale erosion

General Description of the Profile: Shallow silty/sandy, brown profile over rounded volcanic rock alluvium.

### Profile Description

| | |
|---|---|
| Ap<br>0-30 cm<br>F39 | Brown, 10YR 4/3 (moist); loam (with fine sand) with a few rocks and gravel; weak coarse to fine subangular blocky and crumb structure; non-sticky and very slightly plastic; very friable to loose; many micro, common fine and medium, discontinuous, random, inped, interstitial and tubular, closed and open pores; very few, fresh, rounded volcanic, rocks and gravel; very |

slightly calcareous; some small 2-3mm charcoal fragments; many fine, medium and coarse roots.

C1
30-60 cm
F40

Dark grayish brown, 10YR 4/2 (moist); fine sandy loam; weak coarse to fine subangular, blocky and crumb structure; non-sticky and non-plastic (wet); very friable (moist); many micro, common, fine and medium and a few coarse, discontinuous, random, inped, interstital and tubular, closed and open pores; a few fresh volcanic gravels; very slightly calcareous; common fine and medium roots; abrupt, wavy boundary.

C2
60+ cm
F41

Dark brown, 10 YR 3/3 (moist); gravelly, very stony sandy loam; very weak medium to fine subangular blocky structure; non-sticky and non-plastic (wet); very friable (moist); common micro and a few fine, discontinuous, random, inped and interstital, tubular, closed and open pores; many rounded fresh volcanic rocks and gravel; very slightly calcareous; one coarse and a few medium and fine roots.

## ANALYTICAL DATA FOR SITE FXI

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-30 | Ap | vf | s,g | 39.9 | 43.0 | 17.1 | l |
| 2 | 30-60 | C1 | f | g | 54.2 | 31.3 | 14.5 | sl |
| 3 | 60+ | C2 | fr | s,g | 59.5 | 26.6 | 14.0 | sl |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.1 | 3.7 | 6.7 | 16.1 | 12.3 | 32.4 | 9.1 | 1.5 |
| 2 | 1.3 | 7.2 | 12.3 | 22.7 | 10.7 | 22.7 | 7.6 | 1.1 |
| 3 | 9.5 | 12.7 | 11.2 | 17.5 | 8.6 | 20.4 | 5.8 | 0.4 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Total N% | Organic Matter% | CaCO3 % | Avail P ppm | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.6 | 7.6 | 0.35 | 0.32 | 1.86 | 10.0 | 8.74 | 32.3 |
| 2 | 8.9 | 7.6 | 0.30 | 0.28 | 1.14 | 9.2 | 9.2 | 27.7 |
| 3 | 8.6 | 7.8 | 0.30 | 0.28 | 1.07 | 8.6 | 11.5 | 25.5 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand
l-loam si-silt

## PRE-CAMBRIAN OUTCROPS AND WADIS (PCW)

This map unit is representative of areas of aridic pre-Cambrian rock outcrops and areas of wadis of minor extent with alluvial sediments. Rock outcrops occur throughout most of the area with terraced areas of Typic Torriorthents in small strips parallel to the wadis. Typic Tropofluvents are found on alluvial sediments in the wadis.

### LOCATION AND EXTENT

Areas of this mapping unit may comprise up to 10%<a of the surveyed area in Yemen. Within the mapping unit it is estimated that 80% of the association is pre-Cambrian rock outcrop. The pre-Cambrian rocks are predominantly acidic in character, consisting of quartzites, granites and others with high quartz content. Terraced colluvium mixed with calcareous loess form Typic Torriorthents or approximately 10% of the association. Bottom-land alluvial sediments or Typic Tropofluvents comprise another 10% of the association approximately.

### GEOMORPHOLOGY

The major part of this mapping unit is pre-Cambrian rock outcrop, which has been locally dissected by wadis. Wadis occur abruptly bordered on both sides by pre-Cambrian rock slopes and walls (Figure 4.6). Within these valleys there are some rolling to undulating areas of pre-Cambrian rock colluvium mixed with calcareous loess, all of which accumulates on the colluvial slopes of the valleysides. The colluvium and loess soils are terraced with rock retaining walls and are cultivated. These colluvial and loess deposits grade to gently sloping and flat wadi alluvial terraces. Areas of alluvium are eroded and reworked by the annual flooding of the wadis. The hydraulic flow in the wadi appears to be considerable.

---

a- The percentages given are tentative and will be revised upon further investigation.

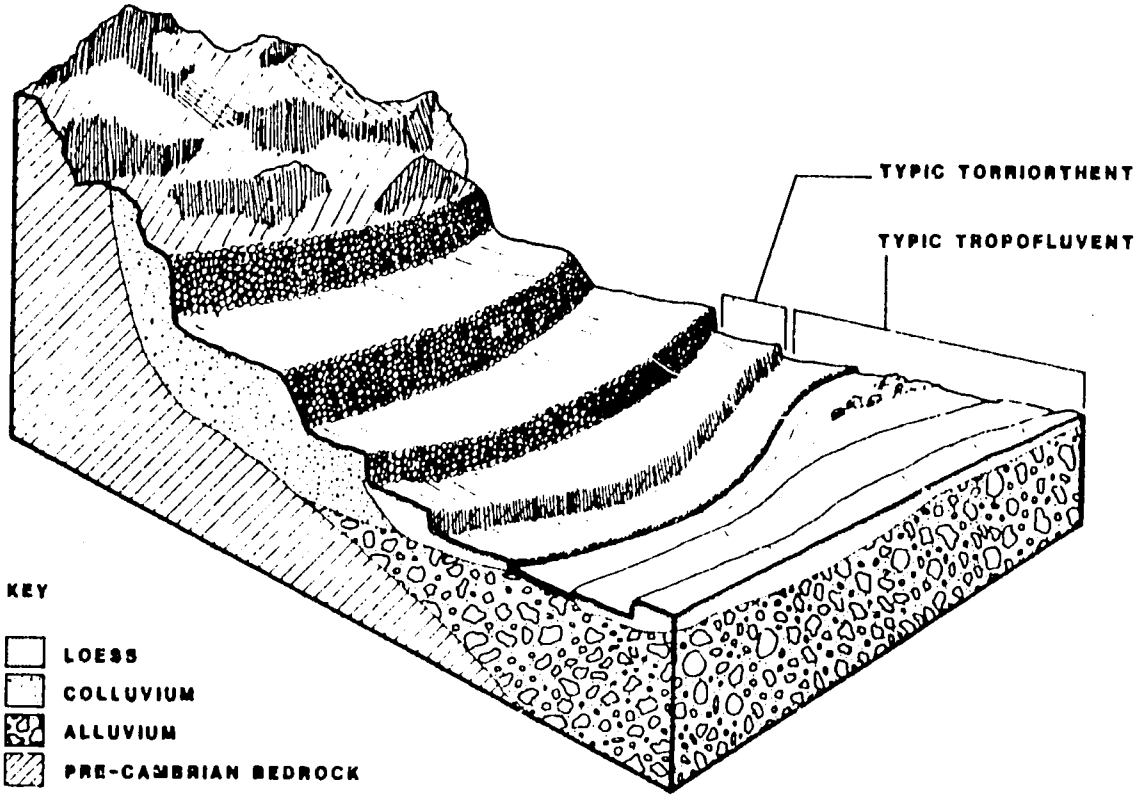


FIGURE 4.6

**Landscape Relationships for the Pre-Cambrian and Wadi (PCW) Mapping Unit**

GENESIS AND IMPORTANT ENVIRONMENTAL INFLUENCES

The soils of this mapping unit show similarities to colluvial and loessal soils and wadi soils of the volcanic areas. The influence of pre-Cambrian rocks, underlying and mixed in the soils as colluvium, on soil formation appears to be minor. The colluvial and loess terraced soils, Typic Torriorthents, are very similar to terraced soils in similar landscape positions in the volcanic areas. Calcareous loess appears to be the most important factor controlling soil genesis and morphology. Properties of the silt and clay fractions are determined by the loess material and the aridic climate in which they are deposited.

The Typic Tropofluvents or alluvial soils on the natural wadi terraces have wetter soil moisture regimes than the colluvial, loessal soils upslope. More water is available for leaching as evidenced by the lush vegetation and crops found along the wadi. The wadi appears to flow nearly continuously during the rainy season. It is assumed that an ustic soil moisture regime is likely for the alluvial soils at and adjacent to the wadi.

## PEDON DESCRIPTIONS

### PEDON XXII

SITE INFORMATION

Profile number: XII
Series name: Unknown
Classification: TYPIC TORRIORTHENT
Date and time described: May 16, 1981, 1:15 PM
Authors: J. King
Location: Just north of trail from Udayn to Hays (Tihama), 300m from Wadi Annah
Elevation: 1100m
Landform: Convex footslope of volcanic-metamorphic hill
Slope class: Rolling topography- gully erosion
Microtopography: Eroded area with many rock outcrops; areas similar to profile have been terraced; now falling into disuse
Slope: 15%
Land use: Some terracing, now mostly extensively grazed
Climate: Unknown

SOIL INFORMATION

Parent material: Loess (aeolian and alluvial/colluvial) and some volcanic and metamorphic rocks (granite and quartzite colluvium)
Drainage class: Well-drained
Moisture conditions: Slightly moist throughout
Depth to groundwater: Unknown
Surface stones or outcrops: Surface is similar to desert pavement
Evidence of erosion: Site is one wall of eroded gully
Salt content: No alkali- strongly calcareous with depth
Human influence: Terracing in some spots

General Description of the Profile: Deep brown silt to loam profile with distinct layering of sedimentary deposits.

Profile Description

| | |
|---|---|
| Ap<br>0-15 cm<br>K1 | Grayish brown, 10YR 5/2 (moist); Gravelly sandy loam; moderate to weak, medium to fine subangular blocky and crumb structure; non-sticky and slightly plastic (wet); very friable (moist); many micro, discontinuous, random, inped, interstitial, open and closed pores; few sharp volcanic and metamorphic fresh gravel; calcareous; common fine roots; abrupt, wavy boundary. |

C1
15-35 cm
K2

Grayish brown, 10YR 5/2 (moist); stony gravelly sandy loam; moderate to weak, medium to fine subangular blocky and crumb structure; non-sticky and slightly plastic (wet); very friable (moist); many micro, discontinuous, random, inped, interstiatial, open and closed pores; few sharp volcanic and metamorphic fresh gravel; calcareous; common, fine roots; abrupt, wavy boundary.

C2
35-95 cm
K3

Brown, 10 YR 5/3 (moist); slightly stony, gravelly loam; moderate, medium to fine, subangular blocky and crumb structure; non-sticky and non-plastic (wet); friable (moist); common micro and very fine, discontinuous, inped, interstitial, open pores; fresh, frequent, rounded volcanic and metamorphic stones and sharp gravel; common, medium to coarse, distinct, clear white calcareous nodules; calcareous; a few fine roots; diffuse, wavy boundary.

C3
95-191 cm
K4

Light brownish gray, 10YR 6/2 (moist); a few streaks of darker material resembling material above; slightly stony silt loam; moderate medium to fine, subangular blocky structure; non-sticky and very slightly plastic (wet); firm (moist); many very fine discontinuous, random, inped, tubular closed pores; frequent, large and small, soft and hard, irregular, calcareous, white nodules; strongly calcareous; a very few large and fine roots; diffuse, wavy boundary.

C4
191+ cm
K5

Brownish yellow, 10YR 6/6 (dry); common, coarse, distinct, clear, dark brown, 7.5YR 3/2 mottles; very slightly stony silty clay loam; strong, very coarse prismatic to strong subangular blocky structure; slightly sticky and plastic (wet); hard (dry); common medium and many fine and very fine, discontinuous, vertical and random, inped, tubular, open and closed pores; frequent small to large, hard, irregular, white calcareous concretions; strongly calcareous; a few fine and medium roots.

Note: Soil appears to be similar to other loess soils at Al Ganed, and Wadi Bana. Effect of metamorphic rocks appears minor. loess dominates.

## ANALYTICAL DATA FOR SITE XXII

| No. | Depth (cm.) | Horizon | Coarse Frag. >2 mm * | Size Coarse Frag. ** | Total Sand 2-.05 mm | Total Silt .05-.002mm | Total Clay <.002 mm | Texture Class <2 mm *** |
|---|---|---|---|---|---|---|---|---|
| 1 | 0-15 | Ap | f | g | 56.2 | 32.5 | 11.3 | sl |
| 2 | 15-35 | C1 | f | g | 57.3 | 29.5 | 13.2 | sl |
| 3 | 35-95 | C2 | fr | s,g | 25.5 | 48.6 | 25.9 | l |
| 4 | 95-191 | C3 | f | s,g | 8.8 | 69.1 | 22.1 | sil |
| 5 | 191+ | C4 | vf | s | 3.8 | 62.2 | 34.0 | sicl |

| No. | Very Coarse Sand 2-1mm | Coarse Sand 1-.05 mm | Medium Sand .5-.25 mm | Fine Sand .25-.01mm | Very Fine Sand .01-.05mm | Coarse Silt .05-.02mm | Medium Silt .02-.005mm | Fine Silt .005-.002mm |
|---|---|---|---|---|---|---|---|---|
| 1 | 14.3 | 13.3 | 9.7 | 13.6 | 5.3 | 23.8 | 8.7 | 0.0 |
| 2 | 16.5 | 14.4 | 9.8 | 11.6 | 4.9 | 21.3 | 4.1 | 4.1 |
| 3 | 5.8 | 4.6 | 3.9 | 6.2 | 4.9 | 30.3 | 15.4 | 2.9 |
| 4 | 1.5 | 1.0 | 0.5 | 1.2 | 4.5 | 45.5 | 17.8 | 5.8 |
| 5 | 0.6 | 0.5 | 0.3 | 0.8 | 1.6 | 37.7 | 17.5 | 7.0 |

| No. | pH 1:5 | pH 1:1 | EC mmhos | Total N% | Organic Matter% | CaCO3 % | Avail P ppm | CEC meq/100g soil |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.7 | 7.9 | 0.19 | 0.40 | 0.96 | 13.4 | 12.88 | 15.3 |
| 2 | 8.9 | 7.9 | 0.18 | 0.22 | 0.55 | 10.5 | 8.28 | 15.6 |
| 3 | 9.0 | 7.9 | 0.81 | 0.16 | 0.31 | 8.6 | 6.44 | 28.2 |
| 4 | 9.3 | 8.0 | 0.85 | 0.16 | 0.18 | 7.2 | 5.52 | 34.0 |
| 5 | 9.0 | 8.0 | 1.1 | 0.14 | 0.28 | 6.2 | 10.12 | 43.0 |

*vf- very few (<5% by volume)
f-few (5-15% by volume)
fr-frequent (15-40% by volume)
vfr- very frequent (40-80% by volume)
(from Guidelines for Soil Profile Description, FAO, 1977)

** g-gravel (2-75 mm)
s-stones (75-250 mm)
b-boulders (>250 mm)

*** c-clay s-sand si-silt l-loam

## ADDITIONAL MAP UNITS

Several map units which appear in the tentative legend (Table 3.1) are too recent to incorporate into this report. Their composition in terms of soil subgroups and miscellaneous land units will be given in subsequent reports. Block diagrams of landscape relationships will also be given. These map units are: Tihama coastal soils (TC), Tihama plain and terrace soils (TPT), Aridic volcanic soils (AV), and Inland alluvial plain (IAP). Also some tentative subgroups will be added to existing map units (Table 3.1). These new soil subgroups will be incorporated into the block diagrams (landscape relations) for the next report.

The tentative legend (Table 3.1) and the tentative soil map of topographic map sheet seven included in the back pocket are working documents and will undoubtedly be revised several times before final publication of the report. All information given in the body of the report, the legend and map is tentative.

## PEDON DESCRIPTIONS FOR INLAND ALLUVIAL PLAINS

These pedon descriptions will be incorporated into the map unit Inland Alluvial Plains of subsequent reports.

### PEDON KXXIV

SITE INFORMATION

Profile number: K24
Series name: Unknown
Classification: TYPIC CALCIORTHID
Date and time described: July 27, 1981
Authors: J. King
Location: 10km west and slightly north of Taizz-Hodeidah road and 100m south of the west end of the old Taizz airport landing strip
Elevation: 1120m
Landform: Convex slope 20m from crest of alluvial terrace
Slope class: Hilly
Microtopography: None
Slope: 12 degrees, 22%
Land use: Scattered cactus, low grass, low intensity grazing
Climate: Information not available

SOIL INFORMATION

Parent material: Top five horizons are alluvium; the sixth a buried soil
Drainage class: Well-drained
Moisture conditions: Dry throughout
Depth to groundwater: Not known, no effect on profile
Surface stones or outcrops: Exceedingly stony and gravelly
Evidence of erosion: Gully erosion
Salt content: Calcareous except for sixth horizon
Human influence: Nil

General Description of the Profile: Four distinct horizons are very apparent in the profile. A light-colored, fine-textured surface horizon, a pale brown horizon which proved upon closer examination to be three horizons, a light-colored calcic horizon and under that a dark reddish brown buried soil. This last horizon is of particular interest because it is not calcareous and has large nodules of yellowish white crystalline material in it. Some similar nodules can also be found in the overlying calcic horizon.

Profile Description

| | |
|---|---|
| A2<br>0-10cm<br>K47 | White, 2.5YR 8/2 (dry) and light yellowish brown, 10YR 6/4 (moist); gravelly sandy loam; structureless; nonsticky and nonplastic (wet); very friable (moist); loose, noncoherent (dry); weathered gravel; strongly calcareous; very frequent, very fine and very few medium roots; clear wavy boundary. |
| B1<br>10-28cm<br>K48 | Brown, 10YR 4/3 (moist) and brown, 10YR 4/3 (dry); slightly gravelly silt loam; nonsticky and nonplastic (wet); very friable (moist) and soft (dry); few very fine tubular pores; weathered gravel; strongly calcareous; very frequent very fine and very few medium roots; gradual wavy boundary. |
| B2<br>28-43cm<br>K49 | Brown, 10YR 4/3 (moist) and dark yellowish brown, 10YR 4/4 (dry); slightly gravelly silt loam; weak medium prismatic structure; nonsticky and very slightly plastic (wet); very friable (moist); soft (dry); few very fine tubular pores; weathered gravel; strongly calcareous; frequent very fine and very few medium roots; clear wavy boundary. |
| B22ca<br>43-55cm<br>K50 | Dark yellowish brown, 10YR 4/4 (moist), light yellowish brown, 10YR6/4 (dry); slightly gravelly silt loam; moderate medium prismatic structure; sticky, slightly plastic (wet); very friable (moist); slightly hard (dry); weathered gravel; frequent large sphereical, white, soft, calcareous nodules; common very fine roots; abrupt, smooth boundary. |
| K2<br>55-93cm<br>K51 | Light yellowish brown, 10YR 6/4 (moist), white 10YR 8/2 (dry); slightly gravelly silt loam; weak medium and fine subangular blocky structure; nonsticky and nonplastic (wet); very friable (moist); soft (dry); weathered gravel; frequent, large, irregular, white, calcareous nodules; few, very fine roots; clear, wavy boundary. |
| B2tb<br>93-150+cm<br>K52 | Brown, 10YR 4/3 (moist), pale brown, 10YR 6/3 (dry); slightly gravelly silt loam; moderately strong subangular blocky structure; slightly sticky and very slightly plastic (wet); very friable (moist); soft (dry); frequent vertically elongated large white nodules; noncalcareous; very few fine roots. |

## PEDON KXXV

### SITE INFORMATION

Profile number: K25
Series name: Unknown
Classification: TYPIC CALCICRTHID
Date and time described: July 28, 1981
Authors: J. King and Abdul Elah Abu Ghanem
Location: 26m downslope from pit K24
Elevation: 1100m
Landform: Within 30m of base of alluvial terrace, slightly concave slope
Slope class: gentle
Microtopography: None
Slope: 13 degrees, 23%
Land use: Scattered cactus, low grass, and low intensity grazing
Climate: No available information

### SOIL INFORMATION

Parent material: Alluvium
Drainage class: Well-drained
Moisture conditions: Moist below 43cm
Depth to groundwater: Not known - no effect
Surface stones or outcrops: Exceedingly stony and gravelly
Evidence of erosion: Gully erosion
Salt content: Calcareous
Human influence: Nil

General Description of the Profile: The overall impression is of a pale brown soil with frequent gravel and a few stones. The exception to this is horizon three which is an obvious class two calcic horizon and horizon five which could be easily observed as being more yellowish in hue.

### Profile Description

| | |
|---|---|
| A<br>0-13cm<br>K53 | Dark brown, 10YR 4/3 (moist) and pale brown, 10YR 6/3 (dry); gravelly and slightly stony silt loam; weak medium subangular blocky structure; nonsticky and slightly plastic (wet); very friable (moist); soft (dry); few fine tubular pores; few stones, frequent gravel, weathered and somewhat rounded; strongly calcareous; very frequent very fine roots; clear, wavy boundary. |

| | |
|---|---|
| B11<br>13-30cm<br>K54 | Dark brown, 10YR 4/3 (moist), and pale brown, 10YR 6/3 (dry); slightly gravelly, slightly stony silt loam; weak medium prismatic and subangular blocky structure; slightly sticky and slightly plastic (wet); very friable (moist); slightly hard (dry); few fine tubular pores; few somewhat rounded, weathered stones and gravel; strongly calcareous; frequent very fine roots; clear, wavy boundary. |
| B12ca<br>30-122cm<br>K55 | Dark yellowish brown, 10YR 4/4 (moist) and pale brown, 10YR 6/3 (dry); gravelly and stony silt loam; weak, medium subangular blocky structure; nonsticky and slightly plastic (wet); very friable (moist); slightly hard (dry); few fine tubular pores; frequent somewhat rounded, weathered gravel and stones; common very fine roots; clear, wavy boundary. |
| C<br>122-184cm<br>K56 | Dark brown, 7.5YR 4/4 (wet) and pale brown, 10YR 6/3 (dry); gravelly silt loam; moderate medium subangular blocky structure; nonsticky and slightly plastic (wet); very friable (moist); somewhat hard (dry); few fine tubular pores; frequent somewhat rounded weathered gravel; strongly calcareous; few very fine roots; clear, wavy boundary. |
| IIC<br>184+cm<br>K57 | Dark yellowish brown 10YR 4/6 (moist) and light yellowish brown, 10YR 6/4 (dry); silt; moderate coarse subangular blocky structure; nonsticky and slightly plastic (wet); very friable (moist); somewhat hard (dry); few fine tubular pores; strongly calcareous; few very fine roots. |

## PEDON DESCRIPTIONS FOR ARIDIC VOLCANIC SOILS

This pedon description will be incorporated into the map unit Aridic Volcanic Soils of subsequent reports.

### PEDON KXIX

SITE INFORMATION

Profile number: K19
Series name: Unknown
Classification: TYPIC CALCIORTHID
Date and time described: July 13, 1981
Authors: J. King
Location: 6 km northeast of Souk al Uraysh 40 m east of Taizz Hodeidah Rd
Elevation: 495 m
Landform: Gently concave slope near foot of a low hill
Slope class: Alluvial plain with scattered low hills with volcanic outcrops
Microtopography: Bank of shallow erosion gully
Slope: Sloping 9%- 5 degrees
Land use: Low intensity grazing
Climate: No accurate data, but rainfall more similar to Tihama than to Taizz. Probably in the neighborhood of 400 mm coming in erratic storms during the summer months. With the use of bunds, poor crops of millet, mainly apparently for forage rather than grain, are grown in this region on the flat land.

SOIL INFORMATION

Parent material: Partially derived from the volcanic rock of the nearby outcrops, but primarily the loess which is encountered throughout Yemen
Drainage class: Class 4, well- drained
Moisture conditions: Slightly moist 15-40 cm depth, but dried within minutes of being exposed to the air.
Depth to groundwater: Unknown, but probably more than 50 m
Surface stones or outcrops: Desert pavement, volcanic outcrops on the hill directly above and within 75 m of the profile site
Evidence of erosion: Gully erosion
Salt content: Calcareous
Human influence: None

General Description of the Profile: Strongly calcareous throughout, but no visible carbonates 0-8 cm. Carbonates forming mycellia and plating out on rocks 8-38 cm; carbonate nodules very common at 38+ cm.

Profile Description

| | |
|---|---|
| C1<br>0-8 cm<br>K34 | Very dark grayish brown, 10 YR 3/2 (moist) and brown, 10YR 5/3 (dry); very gravelly silt; weak fine to very fine subangular blocky structure; slightly sticky, slightly plastic (wet); very friable (moist); soft (dry); strongly calcareous; few micro roots; clear, wavy boundary. |
| C2ca<br>8-38 cm<br>K35 | Brown, 10YR 4/3 (moist) and yellowish brown, 10YR 5/3 (dry); very gravelly, slightly stony silt; weak fine to very fine, subangular, blocky structure; slightly sticky and slightly plastic (wet); very friable (moist); soft (dry); very few very fine tubular pores; carbonate mycelia and pebble coatings; strongly calcareous; strongly calcareous; no roots; clear, wavy boundary. |
| C3ca<br>38+ cm<br>K36 | Dark yellowish brown, 10YR 4/4 (moist) and yellowish brown, 10YR 5/4 (dry); very gravelly , slightly stony silt; moderate, medium to very fine subangular blocky structure; slightly sticky, slightly plastic, very friable (moist); soft (dry); few, very fine tubular pores; very frequent small to large soft irregular, white, calcareous nodules; strongly calcareous; no roots. |

# PART II: OPERATIONS

## OUTLINE OF STAFFING AND ADMINISTRATION

Contract AID/NE-C-1665 was signed March 12, 1980 for a Land Classification and Soil Survey of the Yemen Arab Republic for a total estimated contract cost of $637,031.

A search plan for the Senior Research Associate position to be located in Yemen was implemented, with the intent of having a field soil survey officer in Yemen as soon as possible. A total of 16 candidates applied for this position. Most of them were third country nationals. A candidate was selected and clearance requested through the contract office. In October, notification was received that the candidate could not be approved. A second candidate, a U.S. citizen, was selected and clearance procedures requested. The position was offered to Dr. Jack King, contingent upon USAID clearance and approval.

In August, a second Senior Research Associate position was classified and was posted along with a technician position, and applications of qualified candidates were solicited.

In November, Dr. Terence Forbes was appointed to the second Senior Research Associate position. Ralph Stuart was hired for the technician position.

Jeff Lee, desk officer for Yemen in AID Near East Bureau, visited the Cornell campus in December, and discussed the project workplan and logistic support required in Yemen to carry out the soil survey.

At the end of December, clearance was obtained from AID Yemen Mission for Dr. King, and plans were begun for him to travel to Yemen for a short term visit to review facilities for soil analysis, and meet with Yemen government and USAID personnel regarding field operations for the project. Stopovers in Zurich and London were made to obtain any mapping information available for the soil survey project.

Dr. King went to Yemen on January 8, 1981 (see below). An operational bank account was to be opened for the project in a bank in Taizz or Sana, but was delayed due to currency exchange problems. Dr. King returned to Cornell University February 6, 1981, and equipment for field work in Yemen was ordered and assembled for shipment in March.

Final arrangements for Dr. King's departure for Sana were completed. He left to start the 18 month field operations in Yemen on March 9. Dr. Forbes joined him to assist in soil survey procedures on April 1.

An outline was prepared for the preparation of the final project publication and report for the soil survey, using computer storage and editing facilities.

## PRELIMINARY TRIPS TO YEMEN

### 1) Dr. A. Van Wambeke

Dr. Van Wambeke traveled to Yemen May 3-7, 1980 to be informed on the status of the logistic support to be provided by the Yemen government and the USAID mission in Sana. He met with C. Bell, acting USAID Mission Director, Harry Johnson, USAID program officer, Campbell S. McCluskey and Arthur Britton, USAID project officers, Mohammed Sharaf-Aldin, Acting Director, Ministry of Agriculture and Yaya Sharga, Sana Provincial Agricultural Officer.

According to Mr. Johnson vehicles for the survey would be provided by USAID rather than the Yemen government. One vehicle was available for field work from the inception of the contract and another was on loan to another project.

Dr. Van Wambeke visited the Soils Laboratory at Ausseifere (Taizz) and met with Dr. Salah Elgawhary, Director of the FAO project. He examined the soils laboratory with R.K. Sharma (U.N. volunteer) and A.R.S. Qassim. All equipment was in place for routine soil analyses, including texture, pH, cation exchange capacity, organic carbon, nitrogen, electrical conductivity, exchanageable bases and soluble salts. A problem may be obtaining priority for the Cornell soil samples. There will be a maximum of 1500 to be analyzed as soon as possible after arrival at the laboratory. According to Mr. Sharma there should be no problem.

It was decided that because most agricultural research in Yemen is carried out in Taizz, the resident soil surveyor is to be stationed at Taizz to allow better interaction with local soil scientists and increase cooperation between FAO, UN, Yemen and the project.

2) Dr. J. King

Dr. King visited Yemen in January, 1981 to investigate the preparations required for the soil survey. His trip included visits to Sana, Taizz, and Hodeida.

Taizz: In Taizz, Dr. King visited the Soils Laboratory of the Agricultural Research Service at Ausseifere. A brief but useful conversation on the relationship between the Cornell soil survey and the research station was held with Dr. Faud, director of the station, as well as with other members of the station staff. Dr. King met with Dr. Salah Elgawhary, Dr. Ismail Gewaifel, R.K. Sharma and Dhruba Shrestha. The soil tests performed are those reported by Dr. Van Wambeke. The methods used are those described in FAC Soils Bulletin 10: Physical and Chemical Methods of Soil and Water Analysis and Methods of Soil Analysis by the American Society of Agronomy. The laboratory equipment available includes an atomic absorption spectrometer, a flame photometer, a colorimeter and pH and conductivity meters.

In Sana, Dr. King met with USAID officers, primarily C. McCluskey and T. Bertotti, representatives of the Consortium for International Development and the Yemen Ministry of Agriculture.

In Hodeidah, Dr. King visited Mr. Tewari and Mr. Bamatraf and visited the Surdad farm project.

## SEARCH FOR EXISTING INFORMATION

### Off-Campus Search

Dr. Terence Forbes visited the U.S. Geological Survey and the Soil Conservation Service, U.S. Department of Agriculture in Washington, D.C. January 21-23, 1981 in order to gather unpublished or otherwise inaccessible geological, hydrological, meteorological and soils information on the Yemen Arab Republic. He met with Dr. David Davidson, Mr. Lopez, and Mr. J. Morgan (USGS) and Drs. R. Arnold, R. Gilbert, Mr. L. Miller and Mr. W. Reybold (SCS).

An hydrological study was compiled by the Geological Survey in final report form. A final copy and map (1:500,000) of "A Qualitative Appraisal of the Yemen Arab Republic from Landsat Images- Open-File Report 80-(565)" was sent to Cornell.

Dr. R. Gilbert (SCS) provided a copy of The Physical, Chemical and Mineralcgical Properties of Certain Soil Areas in the Kingdom of Saudi Arabia, August 15, 1980. The possible application of future results of the Agristar project was also discussed. Application of Agristar techniques is not presently feasible.

Mr. Reybold and Miller provided a copy of the SCS draft Soil Map of the World covering Yemen. Dr. F. Newhall's research records were examined for possible climatic data on Yemen. None were found.

On his return trip from Yemen in January, Dr. King visited several places in Europe to acquire information useful for the survey.

Rome, Italy: He visited Dr. Pacheco and Dr. Pecrct of FAO. Dr. Pecrot gave him access to the FAO library and maps. There was no new information fcund. Dr. Pacheco provided a copy of his reconnaissance soil study of North Yemen and two other related studies.

Tubingen, Germany: Dr. King met with Professor Kopp, who was wcrking on a 1:500,000 land use map of North Yemen, which was published in German, Arabic and English. It defines regions of land use and should prove useful for survey work.

Zurich, Switzerland: Dr. King met with Dr. Ing. Reimer Bohave and Mr. Miroslav Trinacity of Electrowatt Engineering Services, Ltd. and Rudolph Schoch, University of Zurich. Dr. Bohave and Mr. Trinacity provided information on the soils, geology, agriculture and hydrology of the Marib area, including a 1:50,000 scale soil map covering 5000 hectacres. Rudolph Schoch provided a copy of Erwin Egli's thesis on land use at Wadi Mawr.

England: Dr. King visited two engineering firms, Sir Alexander Gibb and Partners and Sir William Halcrow and Partners, and the Directorate cf Overseas Surveys. The engineering firms were unable tc provide copies of their reports immediately. The Directorate of Cverseas Surveys provided information about the availability of maps and air photos required for the survey work. A study of the soils of the Montane Plains was also provided.

## Cornell Campus Literature Search

The Cornell library was used to provide as much background information as possible on Yemen, with particular emphasis on the types of soils expected in arid tropical regions. Over two hundred articles were copied for use in Yemen. Most of these are given in the bibliography at the end of this report.

## TESTING OF LABORATORY METHODS

The Cornell staff has been testing the Differential Thermal Analyzer and the Thermogravimetric Analyzer located on campus in order to have it available for mineralogical analysis of clay samples sent back from Yemen.

Techniques of particle size analysis, separation and mounting of sand particles for microscopic examination, and clay separation have been established for soil samples to be sent to Cornell from Yemen. CEC has also been determined for some horizon samples at Cornell.

The Taizz (FAO, Ausseifere) soil chemical laboratory has established methodologies and produced results on some horizon samples for the following tests: 1) particle size by hydrometer, 2) pH (1:1), 3) electrical conductivity, 4) available phosphorus, 5) percentage calcium carbonate, 7) percentage organic matter, 7) percentage total nitrogen, and 7) some CEC determinations.

Computer programs for the analysis of climatic data have been developed and tested. A system has been established for entering and maintaining a running copy of laboratory data for the final report in the computer.

### PRELIMINARY RESULTS OF CATION EXCHANGE CAPACITY DETERMINATION ON YEMEN SAMPLES

Samples were extracted with NaOAc at pH 8.2 to exchange cations, then washed with isopropyl alcohol to remove excess NaOAc solution; then extracted with NH4OAc to displace sodium. Na was determined by atomic emission to calculate Cation Exchange Capacity (CEC).

Two methods of extraction were tried: first, samples were extracted by the centrifugation/decantation method in H.D. Chapman, 1965, Methods of Soil Analysis, Part II, p.899. Second, samples were extracted by use of a vacuum extractor which uses a continuous leaching technique. The vacuum extractor method was further tested by using increasingly large volumes of the NaOAc and NH4OAc extracting solutions to see if the extraction was complete, and by using a smaller sample size.

Table P.1. Comparision of CEC obtained by the two methods on 9 samples.

| Sample | Centrifuge method | Vacuum extraction* |
|---|---|---|
| 246 | 32.7, 20.2 | 49.5 |
| 247 | 38.3 | 39.1 |
| 248 | 19.9,17.6 | 15.4 |
| 249 | 17.2 | 13.6,13.0 |
| 250 | 21.3,23.9 | 16.5 |
| 251 | 16.6 | 11.0 |
| 252 | 18.3 | 13.9 |
| 253 | 34.9 | 34.7, 35.8 |
| 254 | 29.6,32.3 | 32.1 |

*Procedure used for vacuum extractor was 2.5g sample extracted with 50 ml NaOAc, followed by 30 ml of isopropyl alcohol and finally 50 ml of NH4OAc.

Samples with the higher CEC's had close agreement on results with the two methods (except 246). Samples with lower CEC's generally had a higher result with the centrifuge method than with the vacuum extractor. The CEC's fall into the same relative order by both methods with the exception of #246. The Spearman rank correlation coefficent (for a non-parametric test) was calculated for nine pairs of samples. The first CEC value given was used in the case of duplicates. The null hypothesis that the two sets of results are independent was rejected at the alpha=0.05 level. There is a direct relationship between the results of the centrifuge and vacuum extraction method.

It is possible that the excess NaOAc solution in the centrifuge method is not completely removed by the isopropyl alcohol wash and is then showing up in the NH4OAc wash. After centrifuging, the soil did not redisperse well upon shaking with the alcohol which could account for NaOAc retention. Sample 246's erratic results are probably due to its failure to redisperse well with any of the extracting solutions. (It was very gummy when wet.)

Using larger volumes of extractants seemed to have little effect on results. found to be slightly lower. Therefore it appears that complete extraction is taking place with lower extractants.

Based on these results (Tables 1-3) it is decided that the vacuum extractor method will be used because of the greater ease of the method. Also a 2.5g sample and 50ml of NaOAc and 50ml of NH4OAc will be used.

Table P.2. Effect of variation of sample size on CEC found by vacuum extraction method (using 50 ml NaOAc/ 50ml NH4OAc).

| Sample | CEC (2.5 g sample) | CEC (1.5 sample) |
|---|---|---|
| 249 | 13.0 | 15.7 |
| 253 | 35.8 | 36.4 |

Table P.3. Effect of variation of volume of leaching solution (2.5g sample).

| Sample | 50 ml NaOAc 50 ml NH4OAc | 50 ml NaOAc 95 ml NH4OAc | 100 ml NaOAc 50 ml NH4OAC | 100 ml NaOAc 95 ml NH4OAc |
|---|---|---|---|---|
| 249 | 13.0 | 13.6 | 11.5 | 13.4 |
| 253 | 35.8 | 35.7 | 32.7 | 33.6 |

## PREPARATION OF TENTATIVE MAPS

Tentative maps of landform regions and generalized geology of Yemen have been produced by the staff. Probable modal rainfall maps have been reproduced from other publications.

A tentative soils map of topographic sheet seven for the Taizz area is included in the back pocket. Tentative descriptions of most of the mapping units are given in Chapter 4 of the report.

## SATELLITE IMAGERY

Optically processed imagery from remote sensing data was obtained from the Resource Information Laboratory at the College of Agriculture at Cornell (Dr. E. Hardy and R. Senykoff). This imagery is being tested in the field.

The soil survey staff also contacted the Cornell Center for Remote Sensing about the possibility of using computer-processed Landsat data for making the soil survey. Cornell does not presently have the hardware necessary to produce the imagery for survey use. Dr. Warren Phillipson referred the staff to Dr. Gary Petersen of Penn State University.

Dr. Jack King, Dr. Terence Forbes and Ralph Stuart visited Pennsylvania State University in order to discuss the feasibility of using Landsat digital imagery to draw more precise delineations for the soil map of Yemen. They met with Dr. Gary Petersen, Dr. George McMurtry, Dr. Brian Turner, Dr. Gold, Mr. Dean Mimms and Mr. Rich Day (all of the Office of Remote Sensing of Earth Resources (ORSER)).

The results of ORSER's research on specific applications in semi-arid Utah were discussed. A copy of M. L. Imhoff's thesis on The Role of Landsat Data Products in Soil Surveys and documentation on ORSER's computer software were received. ORSER suggested that enhanced imagery transformed by principal components would be a significant contribution to survey remote sensing in Yemen. This imagery was produced by Earth Satellite Corporation (Washington, D.C.). False-color infrared imagery to be used in the field is now available for testing in the same areas as the optically processed images.

Computer tapes were purchased from USGS (EROS) in South Dakota. Earth Satellite Corporation produced false-color, infrared digital imagery from these tapes. This imagery is used to identify areas of soils similar to those of the pilot areas. This imagery was tested in the field during Dr. Forbes' TDY in Yemen.

## YEMEN FIELD AND LABORATORY ACTIVITIES

ack King began the 18-month soil survey operations in Yemen in 1981. Taizz is his initial base. Dr. Terence Forbes joined h 27th to assist in the field work.

g the seven week period of Dr. Forbes' TDY, pilot areas for rk were selected in the Al Ganed, Ibb, Zabid, Dhamar, Wadi Udayn areas. Soil descriptions were made and soil samples ken. Duplicate soil samples were taken so that routine could be performed in Ausseifere (Taizz) while mineralogical ations were made at Cornell University.

King's family joined him in Taizz in June for the remainder of ect. Household goods were shipped via sea freight.

irst soil samples were received from Yemen at Cornell for and mineralogical analyses upon the return of Dr. Forbes from in May. A second set of samples was received in September.

work in Yemen progressed rapidly. By the end of August, areas included Wadi Bana, Udayn, Ibb, Marib, Al Bahr, Hajdah, Wadi Soug Alarish, the Al Camp region, Ramadah, Wadi Rasyan, Wadi , Al Turbah, Wadi Warazan and Jaba of Al Masrak. In many of s, assistance was received from extension agents from the Uplands Rural Development project, courtesy of Mr. Ghazi Director. Good progress was made in mapping the soils covered eet 7 of the 1:250,000 topographic series and work is nearing on for this particular area.

Fort was made to expedite laboratory operations in Taizz (FAO, ce) and obtain necessary lab equipment and apparatus needed characterization and analyses for the soil survey project. s soil survey project purchased and shipped pipettes for -size analysis, a Barnstehl distillation unit, water softener , and glass bottles to be used in the laboratory.

izz (FAO, Ausseifere) laboratory has produced results for pH electrical conductivity, available phosphorus, percentage carbonate, percentage organic matter and percentage total for most of the pedons included in this report. CEC was d for some of these. The results are given in the al results" tables in Chapter 4.

## ADMINISTRATIVE TRAVEL

Dr. Terence Forbes met with World Bank and USAID officials concerning remote sensing materials and coordination of the Yemen project in Washington, D.C., March 1-3, 1981.

Dr. Forbes met with World Bank concerning airphotos for the soil survey and USAID regarding his forthcoming TDY, March 15-17, 1981.

Dr. Forbes was on TDY in Yemen March 27-May 21, 1981.

Dr. Forbes met with the USGS about hydrological reports for the project June 4-6, 1981 and reported to AID about his Yemen TDY.

Dr. Forbes went to Washington, D.C. July 22-24, 1981 to meet with AID personnel and assist Earthsat Corporation with fitting false-color infrared imagery with topographic base maps.

## LINKAGES AND CONTACTS DURING REPORTING PERIOD

The following people have been helpful arranging office space, equipment, etc. in Taizz: Dr. Jamal Fuad Director, Agricultural Research Station (FAO), Taizz, Dr. Ismael Gewaifel, Soil Survey and Land Classification Expert, Agricultural Research Station (FAO), Taizz, Dr. Salah Elgawhary, Soil Chemistry and Fertility Expert (FAO) and Dr. Ali Althor, head of the soils section at the Taizz Agricultural Research Station.

During work in the southern part of the country- except for the Tihama- help was received from extension agents and others working with SURDUP (Southern Uplands Rural Development Project) which is a major Ministry of Agriculture effort, funded by the World Bank. Help has been recieved from:

| | |
|---|---|
| Ghazi Nasser | Director General SURDUP |
| Mahamad Abdullah | Chief, Extension Section, SURDUP |
| Mahmoud Zaim | Extension Expert, SURDUP |
| Mahmoud Aljadah | Assistant Extension Expert, SURDUP |

| | |
|---|---|
| Mahamad Nabil | Assistant Extension Expert, SURDUP |
| Abdullah Atirk | Extension Supervisor in Kalaiba |
| Abdul Daim Sharaf | Chief of Horticultural Section |
| Abdul Samat Attiah | Horticultural Expert |

The TDA (Tihama Development Authority) is another organization similar to SURDUP under the Ministry of Agriculture, but which has responsibility for managing Ministry affairs in the Tihama. SURDUP receives funding from several sources in addition to the World Bank. The following individuals connected with the TDA have been helpful in work on the Tihama and in collecting reports and climatic data.

| | |
|---|---|
| Ahmad Ali Humad | Director General, TDA |
| Ibrahim Eldomi | Director, TDA |
| Mohammad Anwar | Senior Hydrologist, Hydrology section, TDA |

Ahmed El Darwish, Irrigation Adviser UNDP/IBRD helped obtain copies of the Wadi Bana, Rasyan, and Siham reports.

Ahamed H. Abu Ghanem and Saleh A. Alkuhali helped facilitate survey work in the Wadi Bana.

Dr. Helmet Egre and Rudolph Straub (Prof. Kopp's Atlas Project) and Jan Leunk, Hydrologist, DHV supplied a land use map and good leads on other information.

Other individuals contacted who were helpful to the commencement and administration of the soil survey in the Yemen Arab Republic during the reporting period include:

Mr. Mohamet Sharaf-Aldin, General Co-Manager of US Agricultural Development program, MOA, Sana'a.

Mugbil Ahmed Mugbil, Deputy Minister of Agriculture.

Mr. Pietrostefani Sanmprogetti, Infrastructure Division, San Donato, Milan, Italy.

Mr. Dwayne Hammer, Project Manager (042), USAID.

Mr. Abdul-Elah Abu-Ghanem, Project counterpart and facilitator.

Mr. Johann Stocker, Furlanis Road Construction Company.

Mr. George M. Lane, ambassador of the USA, Sana'a.

Mr. Francesco Polcini (His Excellency) Ambassador of Italy, Sana'a.

Mr. Campbell McCluskey, Project Manager, USAID.

Dr. Ali Noman, MOA, Sana'a.

Dr. A. Osman, Soil Science Division, The Arab Center for the Studies of the Arid Zones and Dry Land, (ACSAD) Damascus, Syria.

Mr. J.J. McNally, Flight Operations Director, BKS Surveys Ltd., Co. Londonderry, Northern Ireland.

Mssrs. John Keast, Collin Bardsley, Peter Mansell (BKS Surveys Ltd., Sana'a).

Mssrs. William Peters and Luvern Resler, the World Bank and Bureau of Reclamation, respectively.

## BUDGET SUMMARY

Major expenditures during the reporting period 4/1/81- 9/1/81, in addition to salaries and indirect costs, occurred in locating Dr. King and his family in Yemen and transporting their household goods to Taiz; the purchase and transport of laboratory and field equipment to Yemen; and the purchase of computer tapes and generation of false-color, infrared digital imagery to identify soil areas for the soil survey project.

In-country support costs for the soil survey operations have increased from the beginning of the reporting period as the field work progressed to full-scale operational status.

In-country support costs which included field transportation, administrative travel within Yemen, vehicle upkeep, in-field per diem costs for driver and facilitator, a second project vehicle, office equipment, and housing expenses were provided by USAID Sana.

An amendment to the contract was drafted to extend the contract period into late fall of 1982 in consideration of staffing delays in the beginning of the operation.

Table F.3: FINANCIAL REPORT
SOIL SURVEY OF THE YEMEN ARAB REPUBLIC
AID/NE-C-1665

| BUDGET CATEGORY | ORIGINAL BUDGET | EXPENSES 4/1/81-9/1/81 | ACCUMULATED EXPENSES TO DATE | BALANCE |
|---|---|---|---|---|
| A. Salaries and Wages | $114,625 | $18,877.40 | $42,391.41 | $72,233.59 |
| B. Fringe Benefits | 28,083 | 4,624.99 | 10,385.92 | 17,697.08 |
| C. Indirect Costs | 62,184 | 9,531.46 | 26,861.29 | 35,322.71 |
| D. Differential/ Allowances | 17,615 | 5608.67 | 7,145.81 | 10,469.19 |
| E. Travel & Transport | 36,543 | 27,872.36 | 39,930.52 | -3,387.52 |
| F. Equipment & Materials | 4,500 | 10,850.15 | 15,838.05 | -11,338.05 |
| G. Communications, Postage, Xerox, Office Supplies | 5,500 | 8629.80 | 11,161.97 | -5,661.97 |
| H. Yemen Costs | 111,000 | 11,494.27 | 14,042.05 | 96,957.95 |
| I. Defense Insurance | 5400 | 1282.00 | 1282.00 | 4118.00 |
| J. Miscellaneous Expenses: | | | | |
| a.) Services: | 0 | 35.75 | 424.03 | -424.03 |
| b.) Employment Expenses: | 0 | 297.19 | 1166.84 | -1166.84 |
| c.) Computer: | 0 | 857.54 | 1650.85 | -1650.85 |
| d.) Others | 0 | 52.44 | 52.44 | -52.44 |
| Totals: | $385,450 | $100,014.02 | $172,333.18 | $213,116.82 |

OPERATIONS SCHEDULE
YEMEN SOIL SURVEY
Department of Agronomy, Cornell University, Ithaca, N. Y.
USAID Contract No. AID/NE-C-1665
Project No. 279-0042

| TASKS | 1980 | | | | | | 1981 | | | | | | | | | | | | 1982 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N |
| Collect background and soil related data | -------* | * | * | * | * | | | | | | | | | | | | | | | | | | | | | | | | |
| Develop tentative landform region map | | | | | * | * | * | * | * | * | * | * | | | | | | | | | | | | | | | | | |
| First selection of soil pilot areas | | | | | | | | * | * | * | * | * | * | * | * | * | * | | | | | | | | | | | | |
| Analysis of soil samples (Ithaca) | | | | | | | | | | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Interpretation of imagery (Soils) | | | | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Field Investigations: Selection of pilot areas | | | | | | | | | | * | * | * | * | * | * | * | * | * | | | | | | | | | | | |
| Identification of major soil regions | | | | | | | * | * | * | | | | | | | | | | | | | | | | | | | | |
| Soil survey of pilot areas, Sampling | | | | | | | | | | * | * | * | * | * | * | * | * | * | * | * | * | * | | | | | | | |
| Analysis of soil samples (Taizz) | | | | | | | | | | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| Correlation of legend of final soil map | | | | | | | | | | | | | | | | | | * | * | * | * | * | * | * | * | * | * | * | * |
| Finalizing field soil survey | | | | | | | | | | | | | | | | | | | | * | * | * | * | * | * | * | * | * | * |
| Report Preparation: Profile description input | | | | | | | | | | * | * | * | * | * | * | * | * | * | * | * | * | * | | | | | | | |
| Analytical data input | | | | | | | | | | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| Legend preparation | | | | | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| Final soil report | | | | | | | | | | | | | | | | | | | | | | | * | * | * | * | * | * | * |

LEGEND: ***** ACTIVE PRODUCTION ----- ADMINISTRATIVE STAFF ONLY

November 1, 1981

## GLOSSARY

Alluvium: A general term for clay, silt, sand, gravel or other similar unconsolidated material deposited by a stream or other body of running water on the bed of the stream or its floodplain or deltas or as a cone or fan at the base of a mountain slope.

Argillic horizon: A mineral soil horizon that is characterized by the illuvial accumulation of layer-lattice silicate clays. The argillic horizon has a certain minimum thickness depending on the thickness of the solum, a minimum quantity of clay in comparision with an overlying eluvial horizon depending on the clay content of the eluvial horizon, and usually has coatings of oriented clay on the surface of pores or peds or bridging sand grains. (Soil Sci. Soc. of Am., 1978, p.24).

Aridic: A soil moisture regime that has no moisture available for plants for more than half the cumulative time that the soil temperature at 50 cm is above 5 degrees C and has no period as long as 90 consecutive days when there is moisture for plants while the soil temperature is continuously above 8 degrees C. (Soil Sci. Soc. of Am. 1978, p. 24).

Barchan: A moving, isolated, crescent-shaped sand dune which forms where sand supply is limited and wind is constant and moderate in speed.

Bunds: Any artificial embankment used to control the flow of water on a river or on irrigated land.

Calcic horizon: A mineral soil horizon of secondary carbonate enrichment that is more than 15 cm thick, has a calcium carbonate equivalent of more than 15% and has at least 5% more calcium carbonate equivalent than the underlying C horizon. (Soil Sci. Soc. of Am., 1978, p.24)

Colluvium: A general term applied to any loose, heterogeneous and incoherent mass of soil material or rock fragments deposited chiefly by mass-wasting, usually at the base of a steep slope or cliff.

Graben: An elongate, relatively depressed crustal block that is bounded by faults on its long sides.

Horst: An elongate, relatively uplifted crustal block that is bounded by faults on its long sides.

False-color infrared composite: Imagery produced from bands 4, 5 and 7 of digital multispectral scanner (MSS) data from the Landsat satellite.

Laccolith: A lens-shaped concordant igneous intrusion, less than 8 kilometers in diameter.

Lacustrine sediments: Sediments deposited at the bottom of a lake.

Longitudinal dune: A long, narrow, usually symmetrical (in profile) sand dune, oriented parallel with the direction of the prevailing wind responsible for its construction.

Loess: Widespread, unconsolidated, commonly nonstratified deposit of fine-grained, highly calcareous material. Loess is generally believed to be wind blown dust of Pleistocene age. Loess in Yemen may also be reworked by water sedimentation.

Marl: Unconsolidated deposits of a mixture of clay and calcium carbonate, formed under marine, or especially freshwater conditions.

Mollic epipedon: A surface horizon of mineral soil that is dark colored and relatively thick, contains at least 0.58% organic carbon, is not massive and hard or very hard when dry, has a base saturation of more than 50% when measured at pH 7, has less than 250 ppm P2O5 soluble in 1% citric acid and is dominantly saturated with bivalent cations. (Soil Sci. Soc. of Am., 1978, p. 27)

Petrocalcic horizon: A continuous, indurated calcic horizon that is cemented by calcium carbonate and, in some places, with magnesium carbonate. It cannot be penetrated with a spade or auger when dry, dry fragments do not slake in water and it is impenetrable to roots. (Soil Sci Soc. of Am., 1978, p. 27)

Sabkhah: Coastal and inland salt flats or playas, built up by deposition of silt, clay and muddy sand in shallow, sometimes extensive, depressions. The deposits are completely saturated with brine and are often salt encrusted.

Spate irrigation: Irrigation by diversion of water from a sudden flood on a river, caused by heavy rains higher up the valley.

Udic: The udic moisture regime implies that in most years the moisture control section is not dry in any part for as long as 90 days (cumulative). If the mean annual soil temperature is lower than 22 degrees Celsius and if the mean winter and the mean summer soil temperatures at a depth of 50 cm differ by 5 degrees Celsius or more, the soil moisture contro section is not dry in all parts for as long as 45 consecutive days in the four months that follow the

summer solstice in six or more years out of ten (Soil Taxonomy, p.55).

Ustic: A soil moisture regime that is intermediate between the aridic and udic regimes and common in temperate subhumid or subarid regions, or in tropical or subtropical regions with a monsoon climate. A limited amount of moisture is available for plants, but occurs at times when the soil temperature is optimum for plant growth. (Soil Sci. Soc. of America, 1978, p.28)

Wadi: A stream bed or channel, or a steep-sided and bouldery ravine, that is usually dry, except during the rainy season. Wadis often form oases. Also, the stream that runs in the bed.

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## Appendix 1
## SOIL MOISTURE REGIME ESTIMATES

Soil moisture regimes were estimated for various stations in Yemen, using a computer routine (Van Wambeke and Tavernier, 1976), which uses the Franklin Newhall Model of Computation. The routine takes data of two types as input and produces output based on the type of data provided. Both types of data use the latitude in order to estimate the potential evapotranspiration.

The first type of data is monthly precipitation and temperature data averaged over as many years as possible. This type of data is available for Hodeidah, Kamaran, Mabar, Rabat, Sanaa, and Taizz, with various numbers of years of data being represented in each. The output resulting from this type of data is an estimate of the soil moisture and temperature regimes and a soil moisture condition calendar for an "average" year.

The alternative type of data is monthly precipitation and temperature data for several years. At present, precipitation data is avaiable in this form for 14 stations. The averaged temperature data and latitude for Mabar were then used to estimate the temperature and potential evpotranspiration at these stations. This data produces yearly soil temperature and moisture regime estimates and an average estimate.

The output tables are listed in the rest of this appendix.

TABLE A.1: DETERMINATION OF CLIMATIC REGIME ACCORDING TO
SOIL TAXONOMY (USDA, 1974)
USING FRANKLIN NEWHALL SYSTEM OF COMPUTATION

STATION : HODEIDAH LATITUDE : 14 44 N

| INPUT DATA: | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION: | 5.0 | 5.0 | 2.5 | 2.5 | 2.5 | 1.3 | 12.7 | 2.5 | 2.5 | 2.5 | 10.1 | 22.9 |
| TEMPERATURE : | 25.5 | 25.8 | 27.5 | 28.9 | 31.3 | 32.5 | 33.0 | 32.7 | 32.5 | 30.8 | 28.1 | 26.1 |

OUTPUT : CALCULATED EVAPOTRANSPIRATION ACCORDING TO THORNTHWAITE

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 98.6 | 95.2 | 148.0 | 156.3 | 181.4 | 185.8 | 191.4 | 187.6 | 178.8 | 168.5 | 144.8 | 109.7 |

ANNUAL RAINFALL : 72.0 MM ANNUAL EVAPOTRANSPIRATION : 1846.2 MM

SOIL TEMPERATURE REGIME AT 50 CM DEPTH ESTIMATED FROM AIR TEMP.DATA
BY ADDING 2.5C TO ANNUAL MEAN AND REDUCING AMPLITUDE BY A FACTOR 0.66

| MEAN SOIL TEMPERATURES (DEGREES CENTIGRADES) | | | | SEASONS WHEN SOIL TEMPERATURE IS HIGHER THAN | | | |
|---|---|---|---|---|---|---|---|
| | | | | FIVE DEGREES | | EIGHT DEGREES | REGIME |
| ANNUAL | SUMMER | WINTER | DIFFERENCE | BEGIN | LENGTH (DAYS) | BEGIN | LENGTH (DAYS) | |
| 32.1 | 34.1 | 29.5 | 4.6 | | 360 | | 360 | ISOHYPERTH. |

MOISTURE CONDITION CALENDAR
(1 = DRY 2 = PARTLY DRY 3 = MOIST)

| MONTH | DAYS 1-------->11-------->21------->30 |
|---|---|
| JAN | 1111111111 1111111111 1111111111 |
| FEB | 1111111111 1111111111 1111111111 |
| MAR | 1111111111 1111111111 1111111111 |
| APR | 1111111111 1111111111 1111111111 |
| MAY | 1111111111 1111111111 1111111111 |
| JUN | 1111111111 1111111111 1111111111 |
| JUL | 1111111111 1111111111 1111111111 |
| AUG | 1111111111 1111111111 1111111111 |
| SEP | 1111111111 1111111111 1111111111 |
| OCT | 1111111111 1111111111 1111111111 |
| NOV | 1111111111 1111111111 1111111111 |
| DEC | 1111111111 1111111111 1111111111 |

| NUMBER OF CUMULATIVE DAYS THAT THE MOISTURE CONTROL SECTION IS | | | DURING ONE YEAR WHEN SOIL TEMP. ABOVE 5 DEG. | | | HIGHEST NUMBER OF CONSECUTIVE DAYS THAT MCS IS | | | | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|
| DRY OR DRY | MOIST | MOIST | DRY OR DRY | MOIST | MOIST | IN SOME PARTS OF ONE YEAR | WHEN TEMP > 8 | SUMMER SOLSTICE | WINTER SOLSTICE | |
| 360 | 0 | 0 | 360 | 0 | 0 | 0 | 0 | 120 | 0 | ABIDIC |

COMPUTED BY FORTRAN PROGRAM VW08 ,MARCH 1976 DATE :08/31/81

TABLE A.2: DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY(USDA,1974) USING FRANKLIN NEWHALL SYSTEM OF COMPUTATION

STATION : KAMARAN LATITUDE : 15 20 N

| INPUT DATA: | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION: | 5.0 | 5.0 | 2.5 | 2.5 | 2.5 | 1.3 | 12.7 | 17.8 | 2.5 | 2.5 | 10.1 | 22.9 |
| TEMPERATURE : | 25.5 | 25.8 | 27.5 | 28.9 | 31.3 | 32.5 | 33.0 | 32.7 | 32.5 | 30.8 | 28.4 | 26.1 |

OUTPUT : CALCULATED EVAPOTRANSPIRATION ACCORDING TO THORNTHWAITE

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 95.7 | 95.2 | 148.0 | 157.8 | 186.5 | 189.3 | 198.5 | 189.3 | 178.8 | 166.9 | 140.4 | 107.5 |

ANNUAL RAINFALL : 87.3 MM ANNUAL EVAPOTRANSPIRATION : 1853.8 MM

SOIL TEMPERATURE REGIME AT 50 CM DEPTH ESTIMATED FROM AIR TEMP.DATA BY ADDING 2.5C TO ANNUAL MEAN AND REDUCING AMPLITUDE BY A FACTOR 0.66

| MEAN SOIL TEMPERATURES (DEGREES CENTIGRADES) | | | | SEASONS WHEN SOIL TEMPERATURE IS HIGHER THAN | | | | REGIME |
|---|---|---|---|---|---|---|---|---|
| | | | DIF- | FIVE DEGREES | | EIGHT DEGREES | | |
| ANNUAL | SUMMER | WINTER | FEREN CE | BEGIN | LENGTH (DAYS) | BEGIN | LENGTH (DAYS) | |
| 32.1 | 34.1 | 29.5 | 4.6 | | 360 | | 360 | ISOHYPERTH. |

MOISTURE CONDITION CALENDAR

(1 = DRY 2 = PARTLY DRY 3 = MOIST)

| MONTH | DAYS 1-------->11--------->21------->30 |
|---|---|
| JAN | 1111111111 1111111111 1111111111 |
| FEB | 1111111111 1111111111 1111111111 |
| MAR | 1111111111 1111111111 1111111111 |
| APR | 1111111111 1111111111 1111111111 |
| MAY | 1111111111 1111111111 1111111111 |
| JUN | 1111111111 1111111111 1111111111 |
| JUL | 1111111111 1111111111 1111111111 |
| AUG | 1111111111 1111111111 1111111111 |
| SEP | 1111111111 1111111111 1111111111 |
| OCT | 1111111111 1111111111 1111111111 |
| NOV | 1111111111 1111111111 1111111111 |
| DEC | 1111111111 1111111111 1111111111 |

| NUMBER OF CUMULATIVE DAYS THAT THE MOISTURE CONTROL SECTION DURING ONE YEAR IS | | | WHEN SOIL TEMP. ABOVE 5 DEG. | MOIST IN SOME PARTS | DRY AFTER | MOIST AFTER | HIGHEST NUMBER OF CONSECUTIVE DAYS THAT MCS IS | | | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|
| DRY OR DRY | MOIST OR DRY | MOIST | DRY OR DRY | MOIST OR DRY | MOIST | IN ONE YEAR | WHEN TEMP > 8 | SUMMER SOLSTICE | WINTER SOLSTICE | |
| 360 | 0 | 0 | 360 | C | 0 | 0 | 0 | 120 | 0 | ARIDIC |

COMPUTED BY FORTRAN PROGRAM VW08 ,MARCH 1976 DATE :08/30/81

TABLE A.3: DETERMINATION OF CLIMATIC REGIME ACCORDING TO
SOIL TAXONOMY (USDA, 1974)
USING FRANKLIN NEWHALL SYSTEM OF COMPUTATION

STATION : MA'EAR LATITUDE : 14 47 N

| INPUT DATA: | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION: | 2.0 | 7.0 | 55.0 | 61.0 | 39.0 | 4.0 | 40.0 | 97.0 | 6.0 | 116.0 | 37.0 | 0.0 |
| TEMPERATURE : | 11.5 | 12.8 | 15.2 | 16.7 | 17.6 | 18.2 | 18.8 | 18.2 | 16.8 | 14.7 | 12.1 | 11.3 |

OUTPUT : CALCULATED EVAPOTRANSPIRATION ACCORDING TO THORNTHWAITE

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 37.4 | 40.1 | 59.1 | 68.3 | 77.6 | 80.2 | 85.9 | 81.0 | 68.3 | 55.6 | 39.6 | 36.0 |

ANNUAL RAINFALL : 464.0 MM ANNUAL EVAPOTRANSPIRATION : 729.2 MM

SOIL TEMPERATURE REGIME AT 50 CM DEPTH ESTIMATED FROM AIR TEMP.DATA
BY ADDING 2.5C TO ANNUAL MEAN AND REDUCING AMPLITUDE BY A FACTOR 0.66

| MEAN SOIL TEMPERATURES (DEGREES CENTIGRADES) | | | | SEASONS WHEN SOIL TEMPERATURE IS HIGHER THAN | | |
|---|---|---|---|---|---|---|
| ANNUAL | SUMMER | WINTER | DIFFERENCE | FIVE DEGREES BEGIN | FIVE DEGREES LENGTH (DAYS) | EIGHT DEGREES BEGIN | EIGHT DEGREES LENGTH (DAYS) | REGIME |
| 17.8 | 19.8 | 15.5 | 4.3 | | 360 | | 360 | ISOTHERMIC |

MOISTURE CONDITION CALENDAR
(1 = DRY 2 = PARTLY DRY 3 = MOIST)

```
                DAYS
                1--------->10-------->20------>30
        MONTH
         JAN    2222222222 2222222222 2222222222
         FEB    2222222222 2111111111 1111111111
         MAR    1111111111 1111122222 2222222222
         APR    2222222222 2222222222 2222222222
         MAY    2222222222 1111111111 1111111111
         JUN    1111111111 1111111111 1111111111
         JUL    1111111111 1111111111 1111111111
         AUG    1111111111 1111122222 2222222222
         SEP    2222222222 2222222222 2221111111
         OCT    1111111111 1111122222 2222222222
         NOV    2222222222 2222222222 2222222222
         DEC    2222222222 2222222222 2222222222
```

| NUMBER OF CUMULATIVE DAYS THAT THE MOISTURE CONTROL SECTION IS DURING ONE YEAR | | | WHEN SOIL TEMP. ABOVE 5 DEG. | | | HIGHEST NUMBER OF CONSECUTIVE DAYS THAT MCS IS SOME PARTS AFTER | | MOIST IN AFTER | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|
| DRY OR DRY | MOIST OR DRY | MOI ST | DRY OR DRY | MOIST OR DRY | MOI ST | IN ONE YEAR | WHEN TEMP > 8 | SUMMER SOL-STICE | WINTER SOL-STICE | |
| 151 | 209 | 0 | 151 | 209 | 0 | 116 | 116 | 45 | 0 | USTIC |

COMPUTED BY FORTRAN PROGRAM VW08 ,MARCH 1976 DATE :08/31/81

TABLE A.4: DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA, 1974) USING FRANKLIN NEWHALL SYSTEM OF COMPUTATION

STATION : RABAT LATITUDE : 14 47 N

| INPUT DATA: | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION: | 6.0 | 18.0 | 46.0 | 109.0 | 70.0 | 23.0 | 70.0 | 166.0 | 44.0 | 106.0 | 45.0 | 14.0 |
| TEMPERATURE : | 7.9 | 8.5 | 11.4 | 11.5 | 13.9 | 14.5 | 14.8 | 13.8 | 13.5 | 11.1 | 8.7 | 7.7 |

OUTPUT : CALCULATED EVAPOTRANSPIRATION ACCORDING TO THORNTHWAITE

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 32.8 | 32.5 | 51.9 | 52.4 | 68.6 | 70.8 | 73.8 | 67.4 | 62.6 | 49.8 | 35.9 | 31.5 |

ANNUAL RAINFALL : 717.0 MM ANNUAL EVAPOTRANSPIRATION : 629.9 MM

SOIL TEMPERATURE REGIME AT 50 CM DEPTH ESTIMATED FROM AIR TEMP.DATA BY ADDING 2.5C TO ANNUAL MEAN AND REDUCING AMPLITUDE BY A FACTOR 0.66

| MEAN SOIL TEMPERATURES (DEGREES CENTIGRADES) | | | | SEASONS WHEN SOIL TEMPERATURE IS HIGHER THAN | | | |
|---|---|---|---|---|---|---|---|
| ANNUAL | SUMMER | WINTER | DIF-FERENCE | FIVE DEGREES BEGIN | FIVE DEGREES LENGTH (DAYS) | EIGHT DEGREES BEGIN | EIGHT DEGREES LENGTH (DAYS) | REGIME |
| 13.9 | 15.8 | 11.6 | 4.2 | 360 | | 5 FEB | 316 | ISOMESIC |

SOIL TEMPERATURE CALENDAR (-: T<5 ; 5: 5<T<8 ; 8: T>8 )

| DAYS 1--------->11--------->21-------30 | | | MONTH |
|---|---|---|---|
| 5555555555 | 5555555555 | 5555555555 | JAN |
| 5555888888 | 8888888888 | 8888888888 | FEB |
| 8888888888 | 8888888888 | 8888888888 | MAR |
| 8888888888 | 8888888888 | 8888888888 | APR |
| 8888888888 | 8888888888 | 8888888888 | MAY |
| 8888888888 | 8888888888 | 8888888888 | JUN |
| 8888888888 | 8888888888 | 8888888888 | JUL |
| 8888888888 | 8888888888 | 8888888888 | AUG |
| 8888888888 | 8888888888 | 8888888888 | SEP |
| 8888888888 | 8888888888 | 8888888888 | OCT |
| 8888888888 | 8888888888 | 8888888888 | NOV |
| 8888888888 | 8888888888 | 5555555555 | DEC |

MOISTURE CONDITION CALENDAR (1=DRY 2=PARTLY DRY 3=MOIST)

| DAYS 1--------->11--------->21-------30 | | |
|---|---|---|
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |
| 3333333333 | 3333333333 | 3333333333 |

| NUMBER OF CUMULATIVE DAYS THAT THE MOISTURE CONTROL SECTION DURING ONE YEAR IS | | | | | | | | | | | | HIGHEST NUMBER OF CONSECUTIVE DAYS THAT MCS IS | | | | | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRY OR DRY | MOIST OR DRY | MOI ST | DRY OR DRY | MOIST OR DRY | MOI ST | IN ONE YEAR | WHEN TEMP > 8 | SOMEWHERE IN SOME PARTS ABOVE 5 DEG. | DRY AFTER WHEN SOIL TEMP. | MOIST AFTER WHEN SOIL TEMP. | | DRY | MOIST | MOI ST | | | |
| 0 | 0 | 360 | 0 | 0 | 360 | 360 | 316 | | 0 | 120 | | UDIC | | | | | |

COMPUTED BY FORTRAN PROGRAM VW08 ,MARCH 1976 DATE :08/31/81

TABLE A.5: DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA, 1974) USING FRANKLIN NEWHALL SYSTEM OF COMPUTATION

STATION : SANA LATITUDE : 15 24 N

| INPUT DATA: | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION: | 2.7 | 6.7 | 15.9 | 86.7 | 54.6 | 7.0 | 87.4 | 80.4 | 2.6 | 0.0 | 25.7 | 9.7 |
| TEMPERATURE : | 12.8 | 15.0 | 16.[illegible] | 16.9 | 18.8 | 20.5 | 20.5 | 19.8 | 18.8 | 15.5 | 14.0 | 11.6 |
| OUTPUT : CALCULATED EVAPOTRANSPIRATION ACCORDING TO THORNTHWAITE | 38.0 | 46.6 | 62.7 | 65.2 | 83.4 | 94.0 | 97.5 | 88.6 | 76.7 | 54.7 | 43.3 | 32.1 |

ANNUAL RAINFALL : 379.4 MM ANNUAL EVAPOTRANSPIRATION : 782.8 MM

SOIL TEMPERATURE REGIME AT 50 CM DEPTH ESTIMATED FROM AIR TEMP.DATA BY ADDING 2.5C TO ANNUAL MEAN AND REDUCING AMPLITUDE BY A FACTOR 0.66

| MEAN SOIL TEMPERATURES (DEGREES CENTIGRADES) | | | | SEASONS WHEN SOIL TEMPERATURE IS HIGHER THAN | | | | REGIME |
|---|---|---|---|---|---|---|---|---|
| | | | | FIVE DEGREES | | EIGHT DEGREES | | |
| ANNUAL | SUMMER | WINTER | DIFFERENCE | BEGIN | LENGTH (DAYS) | BEGIN | LENGTH (DAYS) | |
| 19.2 | 21.6 | 16.8 | 4.7 | | 360 | | 360 | ISOTHERMIC |

MOISTURE CONDITION CALENDAR
(1 = DRY 2 = PARTLY DRY 3 = MOIST)

| MONTH | DAYS 1-------->11 | 11-------->21 | 21------>30 |
|---|---|---|---|
| JAN | 1111111111 | 1111111111 | 1111111111 |
| FEB | 1111111111 | 1111111111 | 1111111111 |
| MAR | 1111111111 | 1111111111 | 1111111111 |
| APR | 1111111111 | 1111122222 | 2222222222 |
| MAY | 2222222222 | 2222222222 | 2222222222 |
| JUN | 2222221111 | 1111111111 | 1111111111 |
| JUL | 1111111111 | 1111122222 | 2222222222 |
| AUG | 2222222222 | 2222222222 | 2222222222 |
| SEP | 2222222222 | 2211111111 | 1111111111 |
| OCT | 1111111111 | 1111111111 | 1111111111 |
| NOV | 1111111111 | 1111111111 | 1111111111 |
| DEC | 1111111111 | 1111111111 | 1111111111 |

| NUMBER OF CUMULATIVE DAYS THAT THE MOISTURE CONTROL SECTION | | | | | | HIGHEST NUMBER OF CONSECUTIVE DAYS THAT MCS IS | | | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|
| DURING ONE YEAR IS | | | WHEN SOIL TEMP. ABOVE 5 DEG. | | | MOIST IN SOME PARTS | DRY AFTER | MOIST AFTER | |
| DRY | MOIST OR DRY | MOIST | DRY | MOIST OR DRY | MOIST | IN ONE YEAR WHEN TEMP > 8 | SUMMER SOLSTICE | WINTER SOLSTICE | |
| 252 | 108 | 0 | 252 | 108 | 0 | 57 | 57 | 48 | 0 |

ARIDIC

COMPUTED BY FORTRAN PROGRAM VW08 ,MARCH 1976 DATE : 10/26/81

TABLE A.6: DETERMINATION OF CLIMATIC REGIME ACCORDING TO SOIL TAXONOMY (USDA, 1974) USING FRANKLIN NEWHALL SYSTEM OF COMPUTATION

STATION : TAIZZ LATITUDE : 13 40 N

| INPUT DATA: | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRECIPITATION: | 3.0 | 9.3 | 14.2 | 45.6 | 82.9 | 67.0 | 92.0 | 97.2 | 76.6 | 90.7 | 16.1 | 7.6 |
| TEMPERATURE : | 20.5 | 22.3 | 24.4 | 25.1 | 26.4 | 25.3 | 26.6 | 25.9 | 25.2 | 23.9 | 23.5 | 21.0 |

OUTPUT : CALCULATED EVAPOTRANSPIRATION ACCORDING TO THORNTHWAITE

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 62.4 | 73.3 | 108.9 | 118.6 | 144.9 | 125.0 | 145.8 | 135.5 | 118.9 | 101.3 | 92.4 | 66.4 |

ANNUAL RAINFALL : 602.2 MM ANNUAL EVAPOTRANSPIRATION : 1293.3 MM

SOIL TEMPERATURE REGIME AT 50 CM DEPTH ESTIMATED FROM AIR TEMP.DATA BY ADDING 2.5C TO ANNUAL MEAN AND REDUCING AMPLITUDE BY A FACTOR 0.66

| MEAN SOIL TEMPERATURES (DEGREES CENTIGRADES) | | | | SEASONS WHEN SOIL TEMPERATURE IS HIGHER THAN | | | |
|---|---|---|---|---|---|---|---|
| | | | | FIVE DEGREES | | EIGHT DEGREES | REGIME |
| ANNUAL | SUMMER | WINTER | DIFFERENCE | BEGIN | LENGTH (DAYS) | BEGIN | LENGTH (DAYS) | |
| 26.7 | 27.6 | 24.6 | 3.1 | | 360 | | 360 | ISOHYPERTH. |

MOISTURE CONDITION CALENDAR
(1 = DRY 2 = PARTLY DRY 3 = MOIST)

| MONTH | DAYS 1--------->11--------->21------->30 |
|---|---|
| JAN | 1111111111 1111111111 1111111111 |
| FEB | 1111111111 1111111111 1111111111 |
| MAR | 1111111111 1111111111 1111111111 |
| APR | 1111111111 1111111111 1111111111 |
| MAY | 1111111111 1111122222 2222222222 |
| JUN | 1111111111 1111122222 2222222221 |
| JUL | 1111111111 1111122222 2222222222 |
| AUG | 2221111111 1111122222 2222222222 |
| SEP | 2222221111 1111122222 2222222222 |
| OCT | 2222211111 1111122222 2222222222 |
| NOV | 2222222222 1111111111 1111111111 |
| DEC | 1111111111 1111111111 1111111111 |

| NUMBER OF CUMULATIVE DAYS THAT THE MOISTURE CONTROL SECTION DURING ONE YEAR IS | | | WHEN SOIL TEMP. ABOVE 5 DEG. | MOIST IN SOME PARTS | | | HIGHEST NUMBER OF CONSECUTIVE DAYS THAT MCS IS | | | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|
| DRY OR DRY | MOIST OR DRY | MOIST | DRY OR DRY | MOIST OR DRY | MOIST | IN ONE YEAR | WHEN TEMP > 8 | SUMMER SOLSTICE | WINTER SOLSTICE | |
| 247 | 113 | 0 | 247 | 113 | 0 | 25 | 25 | 15 | 0 | ARIDIC |

COMPUTED BY FORTRAN PROGRAM VW08 ,MARCH 1976 DATE : 10/26/81

TABLE A.7: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION (CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:DAWRAN

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | CUMULATIVE DAYS MCS IN ONE YEAR IS M/D | CUMULATIVE DAYS MCS IN ONE YEAR IS MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 M/D | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 MOI | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS WHEN SOIL TEMP > 8 | MAX. CONSECUTIVE DAYS THAT MCS IS DRY AFTER SUMMER SOLST. | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 17.8 | 19.8 | ISOTHERMIC | 0 | 108 | 252 | 0 | 108 | 252 | 360 | 360 | 0 | 45 | USTIC |
| 1977 | 17.8 | 19.8 | ISOTHERMIC | 0 | 135 | 225 | 0 | 135 | 225 | 360 | 360 | 0 | 45 | USTIC |
| MEAN | 17.8 | 19.8 | | 0 | 121 | 238 | 0 | 121 | 238 | 360 | 360 | 0 | 45 | USTIC |
| STAND.DEV. | 0.0 | 0.0 | | 0 | 19 | 19 | 0 | 19 | 19 | 0 | 0 | 0 | 0 | |
| COEFF.VAR. | 0.0 | 0.0 | | 0 | 15 | 8 | 0 | 15 | 8 | 0 | 0 | 0 | 0 | |

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TABLE A.8: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION
(CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:BABAT

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | CUMULATIVE DAYS MCS IN ONE YEAR IS M/D | CUMULATIVE DAYS MCS IN ONE YEAR IS MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 M/D | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 MOI | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS WHEN SOIL TEMP > 8 | MAX. CONSECUTIVE DAYS THAT MCS IS DRY AFTER SUMMER SOLST. | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 13.9 | 15.8 | ISOMESIC | 0 | 102 | 258 | 0 | 102 | 258 | 360 | 316 | 0 | 46 | USTIC |
| 1976 | 13.9 | 15.8 | ISOMESIC | 0 | 22 | 338 | 0 | 22 | 338 | 360 | 316 | 0 | 53 | UDIC |
| 1977 | 13.9 | 15.8 | ISOMESIC | 0 | 35 | 325 | 0 | 35 | 325 | 360 | 316 | 0 | 70 | UDIC |
| MEAN | 13.9 | 15.8 | | 0 | 53 | 307 | 0 | 53 | 307 | 360 | 316 | 0 | 56 | UDIC |
| STAND.DEV. | 0.0 | 0.0 | | 0 | 42 | 42 | 0 | 42 | 42 | 0 | 0 | 0 | 12 | |
| COEFF.VAR. | 0.1 | 0.1 | | 36 | 81 | 13 | 36 | 81 | 13 | 0 | 0 | 78 | 21 | |

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TABLE A.9: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION
(CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:BHIZWA

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | M/D | MOI | WHEN SOIL TEMP >5 DRY | M/D | MOI | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | WHEN SOIL TEMP > 8 | DRY AFTER SUMMER SOLST. | MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 17.8 | 19.8 | ISOTHERMIC | 180 | 180 | 0 | 180 | 180 | 0 | 99 | 99 | 45 | 0 | USTIC |
| 1977 | 17.8 | 19.8 | ISOTHERMIC | 68 | 126 | 166 | 68 | 126 | 166 | 292 | 292 | 0 | 0 | USTIC |
| 1978 | 17.8 | 19.8 | ISOTHERMIC | 322 | 38 | 0 | 322 | 38 | 0 | 19 | 19 | 120 | 0 | ARIDIC |
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 289 | 71 | 0 | 289 | 71 | 0 | 44 | 44 | 45 | 0 | ARIDIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 247 | 113 | 0 | 247 | 113 | 0 | 70 | 70 | 45 | 0 | ARIDIC |
| MEAN | 17.8 | 19.8 | | 221 | 105 | 33 | 221 | 105 | 33 | 104 | 104 | 51 | 0 | ARIDIC |
| STAND.DEV. | 0.0 | 0.0 | | 100 | 54 | 74 | 100 | 54 | 74 | 108 | 108 | 43 | 0 | |
| COEFF.VAR. | 0.0 | 0.0 | | 45 | 51 | 223 | 45 | 51 | 223 | 103 | 103 | 84 | 0 | |

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TABLE A.10: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION (CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:DHAF

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | CUMULATIVE DAYS MCS IN ONE YEAR IS M/D | CUMULATIVE DAYS MCS IN ONE YEAR IS MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 M/D | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 MOI | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS WHEN SOIL TEMP > 8 | MAX. CONSECUTIVE DAYS THAT MCS IS DRY AFTER SUMMER SOLST. | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1978 | 17.8 | 19.8 | ISOTHERMIC | 313 | 47 | 0 | 313 | 47 | 0 | 47 | 47 | 120 | 0 | ABIDIC |
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 287 | 73 | 0 | 287 | 73 | 0 | 27 | 27 | 53 | 0 | ABIDIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 329 | 31 | 0 | 329 | 31 | 0 | 31 | 31 | 45 | 0 | ABIDIC |
| MEAN | 17.8 | 19.8 | | 309 | 50 | 0 | 309 | 50 | 0 | 35 | 35 | 72 | 0 | ABIDIC |
| STAND. DEV. | 0.0 | 0.0 | | 21 | 21 | 0 | 21 | 21 | 0 | 10 | 10 | 41 | 0 | |
| COEFF. VAR. | 0.0 | 0.0 | | 6 | 42 | 223 | 6 | 42 | 223 | 30 | 30 | 56 | 0 | |

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TABLE A.11: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION (CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION: MA'BAR

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | CUMULATIVE DAYS MCS IN ONE YEAR IS M/D | CUMULATIVE DAYS MCS IN ONE YEAR IS MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 M/D | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 MOI | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS WHEN SOIL TEMP > 8 | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS DRY AFTER SUMMER SOLST. | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 17.8 | 19.8 | ISOTHERMIC | 124 | 156 | 80 | 124 | 156 | 80 | 156 | 156 | 15 | 0 | USTIC |
| 1976 | 17.8 | 19.8 | ISOTHERMIC | 258 | 102 | 0 | 258 | 102 | 0 | 79 | 79 | 52 | 0 | ARIDIC |
| 1977 | 17.8 | 19.8 | ISOTHERMIC | 258 | 102 | 0 | 258 | 102 | 0 | 75 | 75 | 105 | 0 | ARIDIC |
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 264 | 96 | 0 | 264 | 96 | 0 | 40 | 40 | 51 | 0 | ARIDIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 314 | 46 | 0 | 314 | 46 | 0 | 46 | 46 | 45 | 0 | ARIDIC |
| MEAN | 17.8 | 19.8 | | 243 | 100 | 16 | 243 | 100 | 16 | 79 | 79 | 53 | 0 | ARIDIC |
| STAND.DEV. | 0.0 | 0.0 | | 70 | 38 | 35 | 70 | 38 | 35 | 46 | 46 | 32 | 0 | |
| COEFF.VAR. | 0.0 | 0.0 | | 29 | 38 | 223 | 29 | 38 | 223 | 58 | 58 | 60 | 0 | |

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TABLE A.12: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION (CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION: DAFED

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | M/D | MOI | WHEN SOIL TEMP >5 DRY | M/D | MOI | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | WHEN SOIL TEMP > 8 | DRY AFTER SUMMER SOIST. | MOIST AFTER WINTER SOIST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 322 | 38 | 0 | 322 | 38 | 0 | 22 | 22 | 59 | 0 | ARIDIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 277 | 83 | 0 | 277 | 83 | 0 | 48 | 48 | 45 | 0 | ARIDIC |
| MEAN | 17.8 | 19.8 | | 299 | 60 | 0 | 299 | 60 | 0 | 35 | 35 | 52 | 0 | ARIDIC |
| STAND. DEV. | 0.0 | 0.0 | | 31 | 31 | 0 | 31 | 31 | 0 | 18 | 18 | 9 | 0 | |
| COEFF. VAR. | 0.0 | 0.0 | | 10 | 52 | 223 | 10 | 52 | 223 | 52 | 52 | 19 | 0 | |

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TABLE A.13: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION
(CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:AD-DARE

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | M/D | MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | M/D | MOI | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | WHEN SOIL TEMP > 8 | DRY AFTER SUMMER SOLST. | MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 17.8 | 19.8 | ISOTHERMIC | 245 | 115 | 0 | 245 | 115 | 0 | 79 | 79 | 45 | 0 | ARIDIC |
| 1978 | 17.8 | 19.8 | ISOTHERMIC | 205 | 155 | 0 | 205 | 155 | 0 | 59 | 59 | 46 | 0 | ARIDIC |
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 183 | 177 | 0 | 183 | 177 | 0 | 52 | 52 | 23 | 0 | ARIDIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 272 | 88 | 0 | 272 | 88 | 0 | 46 | 46 | 51 | 0 | ARIDIC |
| MEAN | 17.8 | 19.8 | | 226 | 133 | 0 | 226 | 133 | 0 | 59 | 59 | 41 | 0 | ARIDIC |
| STAND.DEV. | 0.0 | 0.0 | | 39 | 39 | 0 | 39 | 39 | 0 | 14 | 14 | 12 | 0 | |
| COEFF.VAR. | 0.0 | 0.0 | | 17 | 29 | 223 | 17 | 29 | 223 | 24 | 24 | 30 | 0 | |

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TABLE A.14: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION (CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:DHAMAR

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | CUMULATIVE DAYS MCS IN ONE YEAR IS M/D | CUMULATIVE DAYS MCS IN ONE YEAR IS MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 M/D | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 MOI | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST WHEN SOIL TEMP > 8 | MAX. CONSECUTIVE DAYS THAT MCS IS DRY AFTER SUMMER SOLST. | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 17.8 | 19.8 | ISOTHERMIC | 165 | 125 | 70 | 165 | 125 | 70 | 119 | 119 | 35 | 15 | USTIC |
| 1977 | 17.8 | 19.8 | ISOTHERMIC | 135 | 36 | 189 | 135 | 36 | 189 | 225 | 225 | 0 | 0 | USTIC |
| 1978 | 17.8 | 19.8 | ISOTHERMIC | 169 | 126 | 65 | 169 | 126 | 65 | 149 | 149 | 15 | 4 | USTIC |
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 237 | 123 | 0 | 237 | 123 | 0 | 102 | 102 | 15 | 0 | USTIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 241 | 119 | 0 | 241 | 119 | 0 | 94 | 94 | 15 | 0 | USTIC |
| MEAN | 17.8 | 19.8 | | 189 | 105 | 64 | 189 | 105 | 64 | 137 | 137 | 16 | 3 | USTIC |
| STAND.DEV. | 0.0 | 0.0 | | 47 | 39 | 77 | 47 | 39 | 77 | 53 | 53 | 12 | 6 | |
| COEFF.VAR. | 0.0 | 0.0 | | 24 | 36 | 119 | 24 | 36 | 119 | 38 | 38 | 77 | 170 | |

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TABLE A.15: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION
(CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:SAMAR-AL-OYA

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | M/D | MOI | WHEN SOIL TEMP >5 DRY | M/D | MOI | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | WHEN SOIL TEMP > 8 | DRY AFTER SUMMER SOLST. | MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 17.8 | 19.8 | ISOTHERMIC | 321 | 39 | 0 | 321 | 39 | 0 | 20 | 20 | 85 | 0 | ARIDIC |
| 1977 | 17.8 | 19.8 | ISOTHERMIC | 196 | 164 | 0 | 196 | 164 | 0 | 135 | 135 | 45 | 0 | USTIC |
| 1978 | 17.8 | 19.8 | ISOTHERMIC | 317 | 43 | 0 | 317 | 43 | 0 | 29 | 29 | 76 | 0 | ARIDIC |
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 259 | 101 | 0 | 259 | 101 | 0 | 48 | 48 | 45 | 0 | ARIDIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 276 | 84 | 0 | 276 | 84 | 0 | 58 | 58 | 49 | 0 | ARIDIC |
| MEAN | 17.8 | 19.8 | | 273 | 86 | 0 | 273 | 86 | 0 | 58 | 58 | 60 | 0 | ARIDIC |
| STAND.DEV. | 0.0 | 0.0 | | 50 | 50 | 0 | 50 | 50 | 0 | 45 | 45 | 19 | 0 | |
| COEFF.VAR. | 0.0 | 0.0 | | 18 | 59 | 119 | 18 | 59 | 119 | 78 | 78 | 31 | 170 | |

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TABLE A.16: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION (CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION: ASH-SHAGRAB

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | CUMULATIVE DAYS MCS IN ONE YEAR IS M/D | CUMULATIVE DAYS MCS IN ONE YEAR IS MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 M/D | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 MOI | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST WHEN SOIL TEMP > 8 | MAX. CONSECUTIVE DAYS THAT MCS IS DRY AFTER SUMMER SOLST. | MAX. CONSECUTIVE DAYS THAT MCS IS MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 17.8 | 19.8 | ISOTHERMIC | 315 | 45 | 0 | 315 | 45 | 0 | 26 | 26 | 120 | 0 | ARIDIC |
| 1977 | 17.8 | 19.8 | ISOTHERMIC | 302 | 58 | 0 | 302 | 58 | 0 | 58 | 58 | 105 | 0 | ARIDIC |
| 1978 | 17.8 | 19.8 | ISOTHERMIC | 337 | 23 | 0 | 337 | 23 | 0 | 23 | 23 | 112 | 0 | ARIDIC |
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 332 | 28 | 0 | 332 | 28 | 0 | 28 | 28 | 47 | 0 | ARIDIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 340 | 20 | 0 | 340 | 20 | 0 | 20 | 20 | 85 | 0 | ARIDIC |
| MEAN | 17.8 | 19.8 | | 325 | 34 | 0 | 325 | 34 | 0 | 31 | 31 | 93 | 0 | ARIDIC |
| STAND.DEV. | 0.0 | 0.0 | | 16 | 16 | 0 | 16 | 16 | 0 | 15 | 15 | 29 | 0 | |
| COEFF.VAR. | 0.0 | 0.0 | | 4 | 46 | 119 | 4 | 46 | 119 | 49 | 49 | 31 | 170 | |

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TABLE A.17: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION
(CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:MARAM

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN YEAR IS DRY | M/D | MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | M/D | MOI | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | WHEN SOIL TEMP > 8 | DRY AFTER SUMMER SOLST. | MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 17.8 | 19.8 | ISOTHERMIC | 285 | 75 | 0 | 285 | 75 | 0 | 46 | 46 | 120 | 0 | ARIDIC |
| 1977 | 17.8 | 19.8 | ISOTHERMIC | 222 | 138 | 0 | 222 | 138 | 0 | 55 | 55 | 45 | 0 | ARIDIC |
| 1978 | 17.8 | 19.8 | ISOTHERMIC | 311 | 49 | 0 | 311 | 49 | 0 | 49 | 49 | 56 | 0 | ARIDIC |
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 339 | 21 | 0 | 339 | 21 | 0 | 21 | 21 | 120 | 0 | ARIDIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 314 | 46 | 0 | 314 | 46 | 0 | 46 | 46 | 59 | 0 | ARIDIC |
| MEAN | 17.8 | 19.8 | | 294 | 65 | 0 | 294 | 65 | 0 | 43 | 43 | 80 | 0 | ARIDIC |
| STAND.DEV. | 0.0 | 0.0 | | 44 | 44 | 0 | 44 | 44 | 0 | 13 | 13 | 36 | 0 | |
| COEFF.VAR. | 0.0 | 0.0 | | 15 | 67 | 119 | 15 | 67 | 119 | 30 | 30 | 46 | 170 | |

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TABLE A.18: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION
(CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:SANABAN

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | M/D | MOI | WHEN SOIL TEMP >5 DRY | M/D | MOI | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | WHEN SOIL TEMP > 8 | DRY AFTER SUMMER SOLST. | MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 17.8 | 19.8 | ISOTHERMIC | 313 | 47 | 0 | 313 | 47 | 0 | 47 | 47 | 120 | 0 | ARIDIC |
| 1977 | 17.8 | 19.8 | ISOTHERMIC | 215 | 87 | 58 | 215 | 87 | 58 | 75 | 75 | 45 | 0 | ARIDIC |
| 1978 | 17.8 | 19.8 | ISOTHERMIC | 300 | 51 | 9 | 300 | 51 | 9 | 38 | 38 | 67 | 9 | ARIDIC |
| 1979 | 17.8 | 19.8 | ISOTHERMIC | 360 | 0 | 0 | 360 | 0 | 0 | 0 | 0 | 120 | 0 | ARIDIC |
| 1980 | 17.8 | 19.8 | ISOTHERMIC | 305 | 55 | 0 | 305 | 55 | 0 | 33 | 33 | 53 | 0 | ARIDIC |
| MEAN | 17.8 | 19.8 | | 298 | 48 | 13 | 298 | 48 | 13 | 38 | 38 | 81 | 1 | ARIDIC |
| STAND.DEV. | 0.0 | 0.0 | | 52 | 31 | 25 | 52 | 31 | 25 | 27 | 27 | 36 | 4 | |
| COEFF.VAR. | 0.0 | 0.0 | | 17 | 64 | 188 | 17 | 64 | 188 | 69 | 69 | 45 | 223 | |

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TABLE A.19: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION
(CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:ZABID CAMP

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | M/D | MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | M/D | MOI | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | WHEN SOIL TEMP > 8 | DRY AFTER SUMMER SOLST. | MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1969 | 32.1 | 34.1 | ISOHYPERTH. | 349 | 11 | 0 | 349 | 11 | 0 | 11 | 11 | 75 | 0 | ARIDIC |
| 1970 | 32.1 | 34.1 | ISOHYPERTH. | 302 | 12 | 46 | 302 | 12 | 46 | 58 | 58 | 75 | 0 | ARIDIC |
| 1971 | 32.1 | 34.1 | ISOHYPERTH. | 346 | 14 | 0 | 346 | 14 | 0 | 14 | 14 | 75 | 0 | ARIDIC |
| 1972 | 32.1 | 34.1 | ISOHYPERTH. | 332 | 28 | 0 | 332 | 28 | 0 | 15 | 15 | 45 | 0 | ARIDIC |
| 1973 | 32.1 | 34.1 | ISOHYPERTH. | 332 | 28 | 0 | 332 | 28 | 0 | 13 | 13 | 45 | 0 | ARIDIC |
| 1974 | 32.1 | 34.1 | ISOHYPERTH. | 272 | 48 | 40 | 272 | 48 | 40 | 56 | 56 | 19 | 0 | ARIDIC |
| 1975 | 32.1 | 34.1 | ISOHYPERTH. | 301 | 22 | 37 | 301 | 22 | 37 | 46 | 46 | 45 | 0 | ARIDIC |
| MEAN | 32.1 | 34.1 | | 319 | 23 | 17 | 319 | 23 | 17 | 30 | 30 | 54 | 0 | ARIDIC |
| STAND.DEV. | 0.0 | 0.0 | | 28 | 13 | 22 | 28 | 13 | 22 | 21 | 21 | 21 | 0 | |
| COEFF.VAR. | 0.0 | 0.0 | | 8 | 56 | 125 | 8 | 56 | 125 | 71 | 71 | 39 | 223 | |

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DATE 10/14/81

TABLE A.20: DETERMINATION OF SOIL MOISTURE REGIME ACCORDING TO FRANKLIN NEWHALL SYSTEM OF COMPUTATION
(CORRECTION FOR TEMPERATURE IS 2.5; SEASONAL AMPLITUDE MODIFIED BY FACTOR 0.66)

STATION:ZABID

| YEAR | MEAN SOIL TEMPERATURE ANNUAL | MEAN SOIL TEMPERATURE SUMMER | TEMPERATURE REGIME | CUMULATIVE DAYS MCS IN ONE YEAR IS DRY | M/D | MOI | CUMULATIVE DAYS MCS WHEN SOIL TEMP >5 DRY | M/D | MOI | MAX.CONSECUTIVE DAYS THAT MCS IS MOIST IN SOME PARTS IN ONE YEAR | WHEN SOIL TEMP > 8 | DRY AFTER SUMMER SOLST. | MOIST AFTER WINTER SOLST. | MOISTURE REGIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1969 | 32.1 | 34.1 | ISOHYPERTH. | 360 | 0 | 0 | 360 | 0 | 0 | 0 | 0 | 120 | 0 | ARIDIC |
| 1970 | 32.1 | 34.1 | ISOHYPERTH. | 352 | 8 | 0 | 352 | 8 | 0 | 8 | 8 | 75 | 0 | ARIDIC |
| 1971 | 32.1 | 34.1 | ISOHYPERTH. | 360 | 0 | 0 | 360 | 0 | 0 | 0 | 0 | 120 | 0 | ARIDIC |
| 1972 | 32.1 | 34.1 | ISOHYPERTH. | 332 | 28 | 0 | 332 | 28 | 0 | 15 | 15 | 45 | 0 | ARIDIC |
| 1973 | 32.1 | 34.1 | ISOHYPERTH. | 353 | 7 | 0 | 353 | 7 | 0 | 7 | 7 | 75 | 0 | ARIDIC |
| 1975 | 32.1 | 34.1 | ISOHYPERTH. | 340 | 20 | 0 | 340 | 20 | 0 | 11 | 11 | 45 | 0 | ARIDIC |
| MEAN | 32.1 | 34.1 | | 349 | 10 | 0 | 349 | 10 | 0 | 6 | 6 | 80 | 0 | ARIDIC |
| STAND.DEV. | 0.0 | 0.0 | | 11 | 11 | 0 | 11 | 11 | 0 | 5 | 5 | 33 | 0 | |
| COEFF.VAR. | 0.0 | 0.0 | | 3 | 107 | 125 | 3 | 107 | 125 | 87 | 87 | 42 | 223 | |

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## Appendix 2
## SOIL DESCRIPTIONS FROM TESCO-VISITERV-VITUKI

### PEDON T102 (TESCO-VIZITERV-VITUKI, 1971)

SITE INFORMATION

Profile number: 102
Series name: Moderately coarse-textured, calcareous, deep, alluvial soil with two or more silt-accumulation layers.
Classification: Alluvial soils/ Calcaric Fluvisols/ Jc/ (Typic Torrifluvents)
Date and time described: November 12, 1969
Authors: I.J. Boros, soil surveyor for Tesco-Viziterv-Vituki
Location: Wadi Zabid Project, in the islet of the Wadi Bira on the southern part of the Project.
Elevation: Unknown
Landform: Relative low relief, deep depression to the southwest
Slope class: Plain, fields are surrounded by big earth banks
Microtopography: Surface of the land has ridges 4 cm high and furrows 4 cm deep, as a result of previous cultivation
Slope: Facing south
Land use: Recently sorghum sp. was grown, some weeds
Climate: Unknown

SOIL INFORMATION

Parent material: Irrigation deposit on loess-like materials.
Drainage class: Class 4-well-drained
Moisture conditions: 0-123 cm dry, 123-184 cm slightly wet
Depth to groundwater: Unknown
Surface stones or outcrops: None
Evidence of erosion: Slight
Salt content: None
Human influence: Very strong, construction of banks and irrigation canals for flood irrigation.

General Description of the Profile: Very much stratified soil profile. The silt accumulation layers improve the water management properties of the coarse soils.

Profile Description

| | |
|---|---|
| 0-14 cm | Brown, 10YR 5/3 dry, loamy sand, loose, dusty unstable structure, some silt particles are mixed to the loamy sand, many fragments of mica, plentiful fine dead roots, gradual boundary. |
| 14-25 cm | Brown, 10YR 5/3, dry, sandy loam, undisturbed, slightly compact, a few fine dead roots, many fragments of mica, unstable, angular blocky structure, some silt particles are mixed into the layer, a couple of white coatings, gradual boundary. |
| 25-35 cm | Brown, 10YR 5/3 dry sandy loam, but it is more sandy than the overlaying horizon, which is mixed with some silt paticles, slightly compact, unstable angular blocky structure, many fine dead roots, and fragments of mica, a few white coatings, distinct boundary. |
| 35-40 cm | Brown, 10YR 5/3, dry, silt accumulation horizon, in some parts, more sand has mixed, compact, platy, angular blocky structure, a few fine dead roots, many fragments of mica, a few white coatings, clear boundary. |
| 40-52 cm | Brown, 10YR 5/3, sandy loam, but the medium sand, which is located in the lower part of the horizon has greyish brown, 10YR 5/2 color, dry slightly cemented, unstable, blocky structure, some silt particles are mixed to the layer, many fine dead roots and fragments of mica, boundary clear, but waving. |
| 52-59 cm | Pale brown 10YR 6/3, dry loam, on the right side of this horizon, medium sand found, having color of grayish brown 10YR 5/2, in the layer silt is dominant, the latter is compact and has a platy rectangular structure. The sand is loose and has a dusty unstable structure. A few fine dead roots, many fragments of mica, boundary distinct. |
| 59-70 cm | Greyish brown 10YR 5/2 and brown 10YR 5/3, dry sandy loam, medium sand mixed with silty particles, slightly |

compact, dusty, unstable, angular, blocky structure, a few fine dead roots, many fragments of mica, boundary gradual.

70-155 cm Pale brown 10YR 6/3, dry, this horizon is a mixture of silt and fine sand In the middle of this horizon, the amount of silt decreases, while in the end, it is increasing, cemented, the pure silt has a platy rectangular structure, the sandy silt has an unstable angular blocky structure, there is a rusty coating (iron) on the surface of the silt particles, a certain part of the aggregates are porous, many root-prints, a few fine dead roots, many fragments of mica, a few fine and medium holes, boundary clear.

115-123 cm Greyish brown 10YR 5/2, loamy sand, dry, loose, structureless, many fragments of mica, a few fine dead roots, boundary clear.

123-149 cm Brown, 10YR 5/3 slightly wet, loam, porous, compact angular blocky structure, there is a thin layer of silt accumulation in the horizon, a few whie coatings, a few very fine deads roots, gradual boundary. ,cm

149-184 cm Brown, 10YR 5/3, slightly wet, loess-like material, porous, less compact than the over-lying horizon, angular blocky structure, a few fine dead roots, thin patchy white coatings.

# PEDON T147 (TESCO-VIZITERV-VITUKI, 1971)

## SITE INFORMATION

Profile number: 147
Series name: Medium-textured arid brown soil
Classification: Arid Brown Soils/(Haplic Xerosols), (Typic Camborthids)
Date and time described: Unknown
Authors: I.J. Boros
Location: Wadi Zabid Project, 1400m North of Wadi MAwr, right side of Wadi Zabid
Elevation: Unknown
Landform: Relatively high terraces of the area
Slope class: Plain to depressed, fields are surrounded by big earth banks
Microtopography: Surface of the land has 4 cm furrows and ridges from previous cultivation
Slope: Gently to the southwest
Land use: Recently sorghum and sesame sp. were grown, no crop-rotation
Climate: Unknown

## SOIL INFORMATION

Parent material: Loess-like material
Drainage class: Class 4 well-drained
Moisture conditions: Slightly wet throughtout except the external surface
Depth to groundwater: In the neighboring well, it is about 16 m
Surface stones or outcrops: None
Evidence of erosion: Very strong on the surface of the fields due to the high runoff speed of irrigation water
Salt content: None
Human influence: Very strong- expressed in the construction of banks, irrigation canals and other hydroloical structures with the aim of using flood irrigation water

General Description of the Profile: The profile is compounded of sandy silt, sandy loam, loam and clayey loam. The color varies from brown to greyish brown. According to the results of the particle size analysis, this soil can be called a medium-textured sandy loam. Its potential fertility is good, but agricultural use is limited by want of irrigation water supply.

## Profile Description

| | |
|---|---|
| 0-15 cm | Brown, 10YR 5/3 (dry), silty loam, loose from dusty to crumb structure, some sparkling fragments of mica, a few leaves of Sorghum ploughed into the soil, a few dead roots, gradual boundary. |
| 15-44 cm | Brown, 10YR 5/3 (slightly wet), loam, slightly compact, unstable, angular blocky structure, a few fine dead roots, gradual boundary. |
| 44-63 cm | Brown, 10YR 5/3 (slightly wet), loam, slightly compact, unstable angular blocky structure, in the middle of this horizon, there is a thin layer of silt, some sparkling fragments of mica, a few holes made by insects, clear boundary. |
| 63-75 cm | Brown, 10YR 4/7, (slightly wet), clayey loam but contains a notable amount of silt, compact angular, blocky structure, a few fine dead roots, some fragments of mica, distinct boundary. |
| 75-87 cm | Brown, 10YR 5/3 (slightly wet), loam, compact, angular blocky structure, porous, a few fine dead roots, some fragments of mica, thin patchy white coatings, many rootprints and root canals, gradual boundary. |
| 87-114 cm | Greyish brown 10YR 5/2 to brown 10YR 5/3, (slightly wet), medium to fine sandy loam, slightly compact, unstable angular blocky structure, thin patchy white coatings, a few fine gravels with a diameter of 2 cm, some holes of different size made by insects, clear boundary. |
| 114-180 cm | Brown, 10YR 5/3, slightly moist loess, compact, porous angular blocky structure, thin patchy white coatings, a few holes of different sizes, many termites mounds with wormcasts, a few fine dead roots. |

## PEDON T17 (TESCO-VIZITERV-VITUKI, 1971)

### SITE INFORMATION

Profile number: 17
Series name: Alkali soil with structural B horizon
Classification: Salt-affected soils (Typic Natragid)
Date and time described: August 24, 1969
Authors: I.J. Boros
Location: Wadi Zabid Project, near Tuheita village.
Elevation: Unknown
Landform: Sited in fields on 4-5 m loess-like deposit, located on the left bank of the ancient flow of Wadi Zabid.
Slope class: Nearly levelled fields surrounded by medium high banks.
Microtopography: Ridges and furrows on the soil surface as the result of previous cultivation.
Slope: Gentle slope towards the southwest.
Land use: Sorghum stubble on the eastern half of the field, second growth of the sorghum green.
Climate: Unknown

### SOIL INFORMATION

Parent material: Loess-like deposits.
Drainage class: Class 4-well-drained.
Moisture conditions: Top 50 cm dry, below slightly wet.
Depth to groundwater: Unknown
Surface stones or outcrops: None
Evidence of erosion: Very limited, mainly wind erosion.
Salt content: Moderate alkalinity.
Human influence: Very strong-construction of banks and irrigation activity.

General Description of the Profile: The profile belongs to the medium-textured soils. As it is moderately alkaline, the formation of the structural 'B' horizon is observable. The presence of silt shows that there was previous flood irrigation from the Wadi Zabid. Now the use of pumping irrigation has a certain danger, because the quality of the water is not satisfactory. But through the application of the necessary rate of irrigation water and modern agricultural management methods, all these problems can be solved.

## Profile Description

| | |
|---|---|
| Ap<br>0-11 cm | Brown, 10YR 5/3 (dry), loam, compact angular structure, the particles are very porous, plentiful alive and dead roots, boundary distinct. |
| B1<br>11-22 cm | Brown, 10YR 4/3 (dry), silty loam, more compact than the overlying horizon, subangular blocky structure, vertical cracks, the particles are very porous, small scateered patches of cutan on ped faces, plentiful roots. The compactness and columns formed by vertical cracks resemble the B1 horizon of alkaline soils (solonetz type). Boundary gradual. |
| B2<br>22-56 cm | Dark yellowish brown, 10YR 4/4 (slightly wet), loam, medium prismatic and columnar structure, very compact, very porous, plentiful fine dead roots, moderate patchy cutans, boundary clear. |
| B3<br>56-118 cm | Dark brown, 10YR 3/4 (slightly wet), loam, coarse prismatic structure, more compact than the overlying horizon, thick broken cutans, many holes, root canals and termite mounds, frequent dead and alive fine roots, boundary clear. |
| C<br>118-154 cm | Dark yellowish brown, 10YR 4/4, (slightly wet), silt loam, which looks like loess, fine prismatic and columnar structure, compact and very porous, thin patchy white coatings (less than in overlying horizons), a few fine roots. |

## PEDON T49 (TESCO-VIZITERV-VITUKI, 1971)

### SITE INFORMATION

Profile number: 49
Series name: Medium-textured soil, effected by wind erosion, recent wind deposit 10-25 cm in thickness
Classification: Soils, affected by wind erosion, Typic Torrifluvent
Date and time described: October 7, 1969
Authors: I.J. Boros
Location: Wadi Zabid Project, near the Wadi Al-Sharabi and the village Mahwa Al-Khelaif
Elevation: Unknown
Landform: Plain to depressed and the fields are surrounded by big earth banks
Slope class: Higher terrace of the area
Microtopography: Surface of the land has ridges and furrows of about 4 cm as a result of a previous bullocks cultivation
Slope: The slope of the field faces gently SW, The next terrace beyond this bank is about 2m lower
Land use: Recently, Indian cotton was grown, the plants were in very poor condition, nearly dried out, some were blossoming
Climate: Unknown

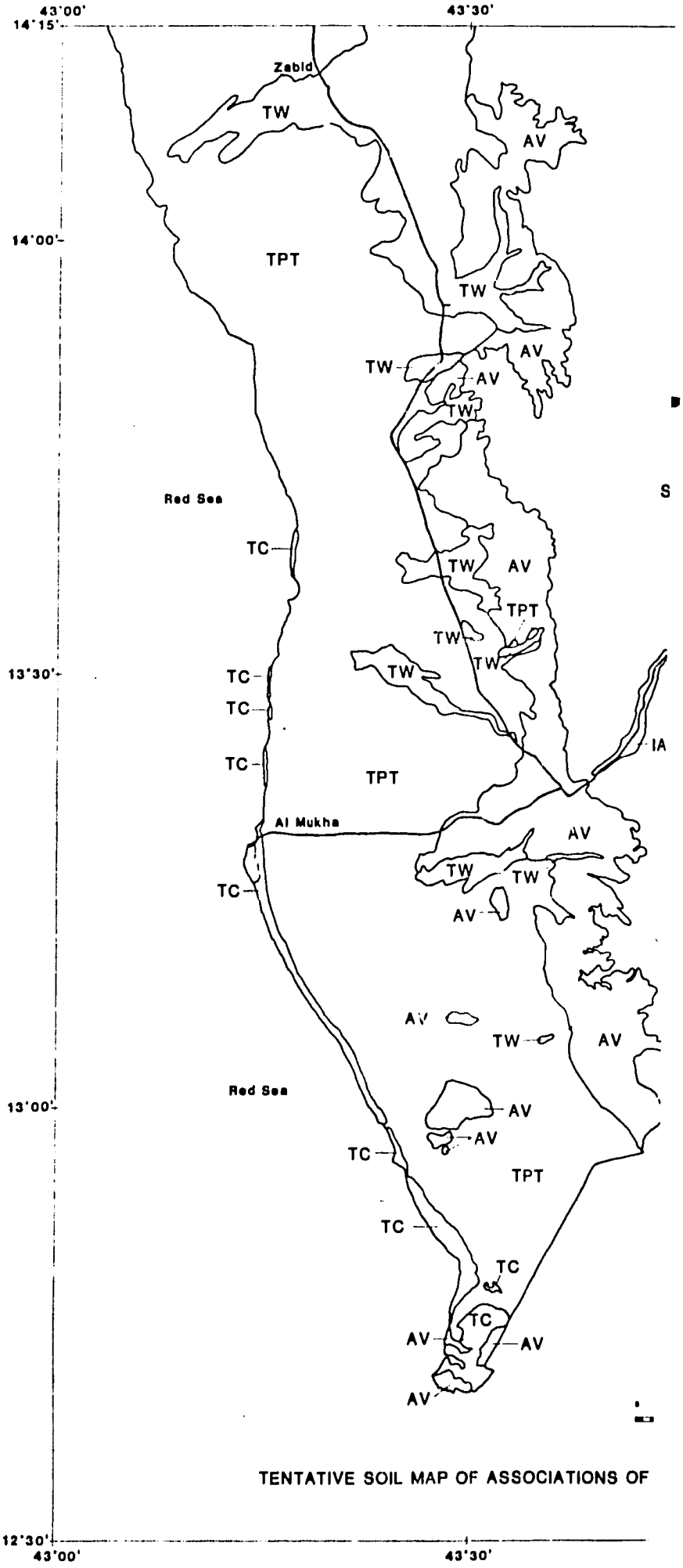
### SOIL INFORMATION

Parent material: Loess-like material
Drainage class: Class 4-well drained
Moisture conditions: Dry throughout
Depth to groundwater: None
Surface stones or outcrops: None
Evidence of erosion: Wind erosion considerable
Salt content: None
Human influence: Very strong, construction of banks, irrigation canals and other hydrological structures for flood irrigation.

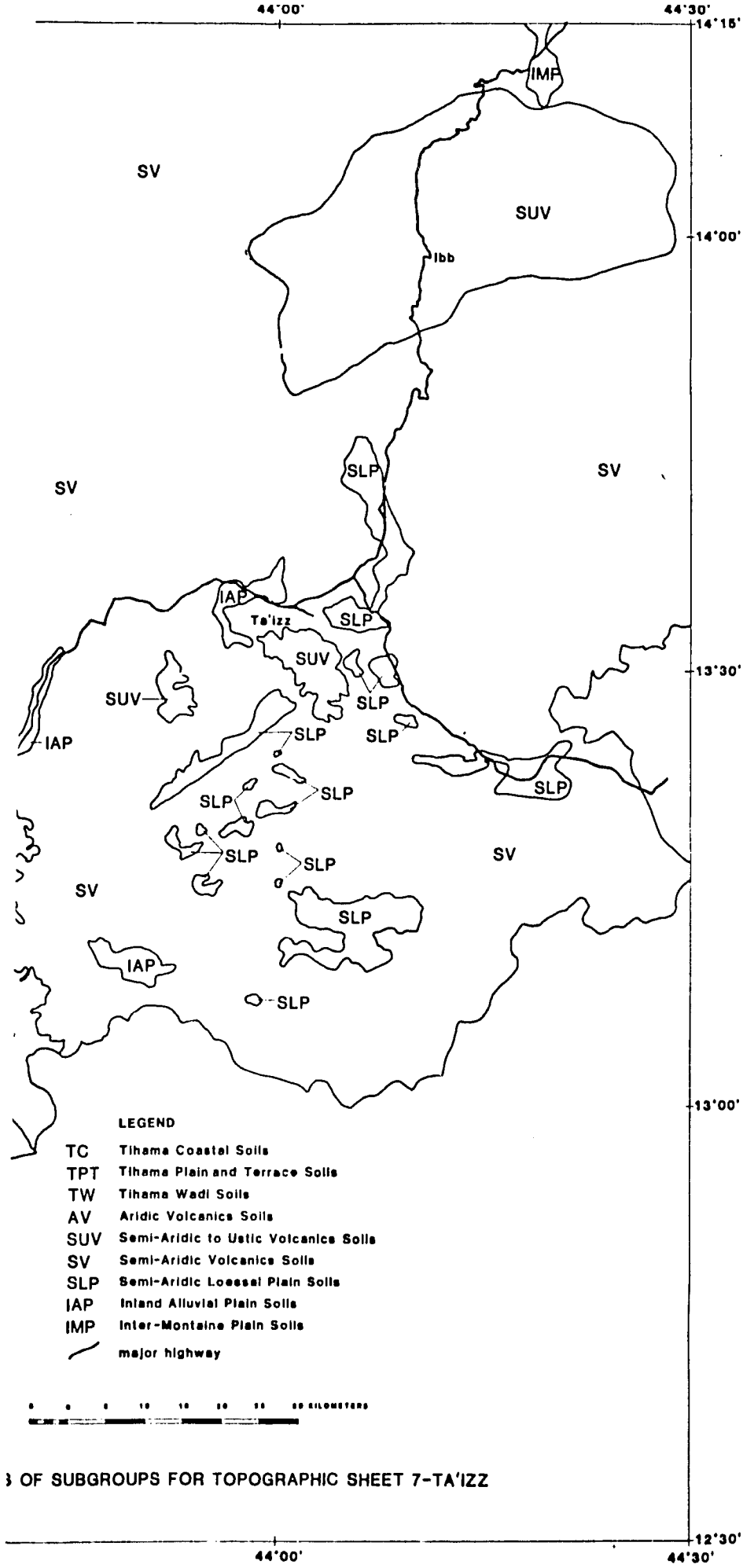
General Description of the Profile: Originally, this profile represented quite a good soil, but wind erosion has considerably lowered the fertility of the top horizons. Wind erosion control is indispensable. The latter combined with water supply and a reasonable irrigation practice gives the prospect of getting enough high yields of cash crops.

Profile Description

| | |
|---|---|
| 0-20 cm | Brown, 10YR 5/3 (dry), sandy loam with a great amount of dust, loose, fine angular blocky structure, many fine dead roots and decomposed residue of cotton, many fragments of mica, boundary gradual. |
| 20-48 cm | Dark brown, 10YR 3/4 (dry), loam, in the lower part of the horizon some leached in the tounges of sand, enough loose, fine angular blocky structure, many fine dead roots, in some parts there is an accumulation of silt, at the end of the horizon, thin patchy white coatings scattered, a few groundnuts of nusher, some holes made perhaps by termites, boundary gradual. |
| 48-88 cm | Brown, 10YR 5/3 (dry), silty loam, slightly compact, angular blocky structure, porous, many patchy white coatings, there are some sand tounges, many fine dead roots, a few termies holes, boundary clear. |
| 88-107 cm | Dark brown, 10YR 3/4 (dry), loam, porous, compact or slightly cemented, angular blocky structure, a few gravels, having the diameter of 1 cm, many fragments of mica throughout the horizons, a few fine dead roots, thin patchy coatings, boudary distinct. |
| 107-160 cm | Brown, 10YR 4/3 (dry), loam angular blocky structure, porous, a few very fine dead roots, thin patchy white coatings, some holes made by insects, a few gravels with the diameter of 1 cm , many fragments of mica. |




TENTATIVE SOIL MAP OF ASSOCIATIONS OF




3 OF SUBGROUPS FOR TOPOGRAPHIC SHEET 7-TA'IZZ

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