Environmental Assessment – Annex 2: Geological Investigations
(EA)
Part A
(January 2005)
REINFORCEMENT AND UPGRADING OF DSM, KILIMANJARO AND ARUSHA TRANSMISSION LINES AND DISTRIBUTION SYSTEM PROJECT:

Environmental Studies

ANNEX 2:

Geological Investigations

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ACRONYMS AND ABBREVIATIONS

CH Inorganic clays of high plasticity
kv Kilo Volt
MA Moshi-Arusha
ND Non-Dispersive
QDS Quarter Degree Sheet
pH Negative decimal logarithm of the hydrogen ion activity
Pi Plasticity Index
TANESCO Tanzania Electric Supply Company Limited
Km Kilometers
SM Silty sands and sand-clay mixtures
ToR Terms of Reference
TP Test Pit
ACKNOWLEDGEMENT

The author is highly indebted to the following people for the assistance in one-way or the other. Their logistical support and comments as well, have been helpful in carrying out this task:

**Dar es Salaam:**
- Mr. K.R. Abdulla - Tanesco, Director Corporate Planning & Research
- Mr. D.E.P. Ngula - Tanesco, Manager Research & Development
- Mr. M. Katyega - Tanesco, Chief Research & Investigation Engineer
- Mr. K. Kabaka - Tanesco, Senior Geologist
- Messrs Mansur, H & Lazimah, J - Tanesco Environmental Engineers

**Arusha:**
- Mr. C.J. Masasi - Tanesco Regional Manager
- Mrs. Dina Msuya - Tanesco Civil Engineer Technician, Transmission Lines
EXECUTIVE SUMMARY

- This document is an annex to the main report for Reinforcement & Upgrading of Dar es Salaam, Kilimanjaro And Arusha Transmission Lines ENVIRONMENTAL STUDIES. It deals with issues pertaining Geology and in particular soil conditions and its main objective is to obtain general overview of the geological/soil conditions of the project areas.
- The proposed corridors for the Moshi – Arusha 132 kV overhead transmission is approximately 70 km long and the Dar es Salaam transmission routes are approximately 43 km long.
- Regionally, the Moshi – Arusha area lies within the Great Eastern African Rift Valley and is dominated by volcanic formations. The transmission corridor traverses east west through southern lower flat lying foot of the mounts Kilimanjaro and Meru. The proposed transmission corridor was selected to run parallel with the existing 132 kV transmission line from Moshi Kiyungi substation to Arusha Njiro substation.
- The Moshi – Arusha transmission towers will be founded in volcanic sediments mainly consisting of Sandy Silty CLAY and few places have soils mainly composed of Sandy SILT/Silty SAND.
- Soil samples taken from Moshi – Arusha Transmission line corridor have pH values slightly varying, a bit on the acidic side and largely on the alkaline side. About 80% of the tested soil samples have PH values greater than 7.0 indicating that the soils are alkaline in nature. Only 20% of the tested soil samples show acidic nature. By these results, the ground conditions in the Moshi – Arusha Transmission line route are not acidic and therefore it may be inferred that the site pose a very less corrosive threat to the transmission towers. During the fieldwork, random visual inspection was conducted on the existing 132 kV transmission towers and corrosive effects were not observed on the towers.
- The Dar Transmissions corridors are located in the coastal plain environment dominated by superficial sands of the flat, low lying coastal plain represented by redistributed outwash material from the fault blocks. River alluviums consisting of sands varying from off-white to buff-brown are also found in the corridors. Test on soil pH for the samples collected from Dar corridors show that the soils specimen are acidic, but the number of soil samples is too small to make a definitive conclusion.
- Due to terrain nature of the transmission corridors and non-dispersive nature of the few samples taken from the sites, it is apparently inferred that soil erosion along the transmission is not severe. Control measures for soil erosion will have to be determined on a tower-to-tower case during the design/construction phase. At this stage of this report we may not have a suitable blanket solution.
- Due to the preliminary nature and time/budget constraints of the study, the Field Resistivity measurement for assessing electrical conductivity of the ground, was not conducted during this period and thus it is recommended to be done at later phase of the study/implementation.
1. INTRODUCTION

The field investigations for Reinforcement & Upgrading of Kilimanjaro-Arusha Transmission Lines and Dar es Salaam transmission lines took place between weeks no. 49 and 52 of 2004. This report gives an account of preliminary findings with respect to geological/soil conditions of the project area.

The project areas are situated in Northern and Eastern parts of Tanzania for Moshi-Arusha and Dar es Salaam Transmission routes respectively. The Moshi-Arusha Transmission Corridor lies between $3^\circ 22' S$ and $3^\circ 26' S$ Latitudes, $36^\circ 41'E$ and $37^\circ 19'E$ Longitudes. The Dar es Salaam transmission corridors lie between the following geographical coordinates: $6^\circ 43' S$ and $6^\circ 56'S$ latitudes and $39^\circ 10' E$ and $39^\circ 21'E$ longitudes. General locations of the project areas are shown in Figure 1.

![Figure 1: General location of the Project Area](image-url)
1.1 Scope of Work

The scope of the assignment was to obtain general overview of the soil and general geological condition of the area so as to highlight preliminary effects of soil erosion with respect to Environmental Impact Assessment. Specifically, the scope included:

- Scan and traverse along the proposed corridor documenting rock and soil types in general i.e. Overview Mapping.
- Zoning and documenting different geomorphologic conditions along the proposed corridor
- Spot soil investigations at few selected sites at locations to be determined at the site by the geologist.

1.2 Methods of Investigations

Senior Geologist, Mr. Leonard B. Kassana of Research and Development Department, TANESCO Head Office, executed all investigations in accordance to the ToR.

The field light investigations consisted of:
- Carrying out soil investigations within the selected transmission corridors by test pitting. Soil samples were collected for laboratory analysis as well
- Ground water measurements in the Investigation pits.
- Overview Geological Mapping
- Literature search relevant to the project.

An overview mapping was based on:
- Interpretation of topographic map at 1:50,000 and 1:100,000 scales
- Interpretation of Geological maps, Quarter Degree Sheet (QDS) at a scale 1:125,000
- Walkover survey along the proposed transmission corridors

Refer to Appendix 6.1 for maps locating investigation areas.

2. TOPOGRAPHY, REGIONAL GEOLOGY AND SITE GEOLOGICAL CONDITIONS

2.1 Kilimanjaro – Arusha Region

2.1.1 Topography

The project area is dominantly covered by volcanic mountain massifs rising abruptly from plateau country at about 900 m.a.s.l For Arusha areas, mount Meru raises from about 900 m.a.s.l to the summit of about 4600 m.a.s.l and Kilimanjaro rises from about 900 m.a.s.l to the highest peak of 5895 m.a.s.l.

In general, the proposed transmission line runs parallel to both existing 132 KV Moshi – Arusha Transmission line and the main Moshi – Arusha road. The line runs almost east west direction south of the high volcanic mountains in Africa, namely Kilimanjaro and Meru. The transmission lines are running parallel to the Moshi-Arusha road in the south of the mountains. North of this road, the terrain is of moulded topography formed by Meru lahars while in the south of the road and where our transmission proposal is running, outwashes from the lahars form a more even plain.

Wide spread topographical features are formed by the spread of ‘lahars’ or cold mudflow in the south and southwest of mount Kilimanjaro emanating from Kibo peak and mount Meru.

For the further details of the topography the reader is kindly referred to the special QDS covering #42, 56 & 57 and QDS #55.
2.1.2 Regional Geology

Mt. Meru and Kilimanjaro are younger volcano products of Pleistocene to Recent. According to Quarter Degree Sheets (QDS) # 55 and the Kilimanjaro Special QDS, essentially the geology of the area is consisting of a pile of Neogene volcanic products and some interbedded sediments accumulated on eroded surface Precambrian metamorphic rocks.

The two volcanoes together with other formations are located on transverse branch of southern Gregory Rift, part Great Eastern Branch of the Great Eastern African Rift System as shown in figure 2.1.2.

For comprehensive reading on the project geology, the reader is referred to Geological Maps, Quarter Degree Sheets # 55, 42, 56 and 57.

2.1.3 Soils in the Project Area

The proposed transmission corridor traverses along lower, flat slopes of the Kilimanjaro and Meru mountains in the south. The south side of Mount Meru exhibits some black soils with distinctive
carbonate concretions. Elsewhere, soils on volcanic rocks show substantial colour variation from red to brown and even grey. In some areas calcareous duricrust zones are found within the project area.

Seven test pits were dug along the corridor to assess the lithological conditions. Field lithological descriptions of these superficial deposits show dominantly that the sediments are Clayey SILT/Silty CLAY with occasional sand pockets. For field details please refer to Appendix 6.2.

Large section where the transmission traverses is flat and only in few areas there are gentle slopes and examination of the existing 132 KV transmission towers which were built in early 1980s showed no sign of erosion effects. Thus due to low gradient nature of the corridor, the corridor is naturally facing no severe erosion.

Due to the preliminary nature of the investigation could not be well assessed but all test pits dug in corridor were dry and showed no sign of groundwater. Volcanic rocks that may be porous and vesicular in nature immediately underlie the superficial deposits. The former is full of pore spaces and the latter is full of many cracks and vesicles, so water is easier to get through the ground. So a high percentage of rainfall is absorbed into the ground. But since our excavation is shallow, we don’t expect to encounter ground water during excavation except where a stream depression is crossed.

2.2  Dar es Salaam Region

2.2.1 Topography

In general, Dar es Salaam is a coastal region whose widest topography lies between 0 m.a.s.l and 120 m.a.s.l. However Pugu hills who constitutes a small percent of the region rises to about 300 m.a.s.l forming the highest land in the region. The proposed transmission corridor traverses in a terrain whose altitude ranges between 15 and 60 m.a.s.l.

Major rivers within the project area are Kizinga, Mzinga, Msimbazi, Ubungo, Sinza and Mlalakuwa all draining towards Indian Ocean in the north easterly direction. Dar es Salaam Harbor is a Northerly part of River Mzinga mouth at the Indian coastline. The Dar es Salaam harbor is thought to have been formed by erosion effects of Mzinga and Kizinga rivers further deepened by tidal scour.

Further details for the topography may be found in the QDS 186.

2.2.2 Regional Geology and Soils

The main geological formations of Dar es Salaam region, in brief summary, are composed of:
- Pugu Kaolinitic Sandstones, which are fine to medium grained and off-white in colour. These are found in the south west of Dar es Salaam with an SW-NE trend line.
- Clay bound sands is another geological formation overlying the sandstones. The sandstones are reported to be of, probably, Mio-Pliocene age and they are semi-consolidated.
- Reef limestones occur at several localities in the region. The age of this formation is assumed to be Mio-Pliocene.
- Superficial sands of the flat, low lying coastal plain represented redistributed outwash material form the fault blocks. East of Pugu, the sands are clean and off-white but elsewhere they are buff to brown.
- River alluvium consisting of sands varying from off-white to buff-brown. The fine grades tend to be dark due to presence of admixed organic matter.

According to QDS 186, two types of faults dominate the region. The most dominant set is the one whose trend line varies between NE to N. This seems to control the major rivers in the region. Second set is the one apparently controlling the coastline in the region trending in the SE-NW direction. These faults are considered to be of recent age geologically. The reader is kindly referred to QDS 186 for further details of the regional geology.
3 LABORATORY SOIL INVESTIGATION

Soil samples were collected from both Moshi - Arusha and Dar es Salaam Transmission Lines corridors for the purposes of carrying out laboratory analysis. Investigation areas where soil samples were collected are shown on maps enclosed in this report in Appendix 6.1. The following test categories were ordered:

- Grain size distribution for soil classification
- PH levels for assessing acidic condition of the soils
- Pinhole tests

The laboratory investigations were carried out at the Soil Laboratory of the University of Dar es Salaam.

3.1 Methods

All soil investigations for the above mentioned tests were carried out in accordance to the known international standards. The following British Standards were employed during the testing:

- BS 1377 for Pinhole tests
- BS 1377: Part II: 1990 for Grain size distribution
- BS 1377: Part III: 1990 Test #9 for PH levels determination

3.2 Results & Discussions

Sieve Analysis results indicate that the soils in Moshi - Arusha Transmission Line corridor are composed largely of Sandy Silty CLAY and few places have soils mainly composed of Sandy SILT/Silty SAND. This means that the behaviors of soils in the project area are of varying nature corresponding to the behaviour of the composite soils. Generally, earthwork during the project execution should be well taken care of, otherwise piles of earth could easily be washed away and therefore increase turbidity/sediment loads within the water courses within the vicinity of the sites of the project activities. Refer to Table 1 and Appendix 6.3 for details on Sieve Analysis.

Laboratory soil analysis (Table 2 and Appendix 6.3) shows that soil samples taken from Moshi - Arusha Transmission line corridor have PH values slightly varying, a bit on the acidic side and largely on the alkaline side. About 80% of the tested soil samples have PH values greater than 7.0 indicating that the soils are alkaline in nature. Only 20 % of the tested soil samples show acidic nature. By these results, the ground conditions in the Moshi - Arusha Transmission line route are not acidic and therefore it may be inferred that the site pose a very less corrosive threat to the transmission towers. During the fieldwork, random visual inspection was conducted on the existing 132 kV transmission towers and corrosive effects were not observed on the towers.

Only two samples were collected from Dar es Salaam Transmission Line routes and tested for pH levels. The results indicate that the soils are acidic but with only two samples it is difficult to make a definitive conclusion on acidic conditions coverage on the ground in the area.

However, due to laboratory apparatus malfunctioning, Pinhole tests were not completed as per our order that was submitted to the Soil Laboratory vide letter with ref. DCPR/MRD/CR/E/9 dated December 14, 2004. Only two Pinhole tests were successfully done and showed that the soil samples were non-dispersive soil (ND). See the results in Table 3 and Appendix 6.3.
Table 1: Grain Size Distribution for both Moshi – Arusha and Dar es Salaam Transmission Lines

<table>
<thead>
<tr>
<th>#</th>
<th>Location</th>
<th>Depth of Sampling in m</th>
<th>USCS Symbol</th>
<th>Soil Description</th>
<th>% Clay</th>
<th>% Silt</th>
<th>% Sand</th>
<th>% Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TP1 - MA</td>
<td>0.6 - 1.7</td>
<td>CH</td>
<td>Sandy Silty CLAY</td>
<td>52</td>
<td>43</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>TP2 - MA</td>
<td>0.0 - 0.8</td>
<td>CH</td>
<td>Sandy Silty CLAY</td>
<td>47</td>
<td>36</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>TP4 - MA</td>
<td>0.3 - 0.6</td>
<td>SM</td>
<td>Clayey gravelly Silty SAND</td>
<td>2</td>
<td>21</td>
<td>58</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>TP6 - MA</td>
<td>2.0 - 2.5</td>
<td>SM</td>
<td>Clayey Sandy SILT</td>
<td>7</td>
<td>50</td>
<td>43</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>TP7 - MA</td>
<td>0.6 - 1.7</td>
<td>CH</td>
<td>Gravelly Sandy Silty CLAY</td>
<td>57</td>
<td>31</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>MLIMANI CITY PROJECT, DAR</td>
<td>0.0 - 0.5</td>
<td>CH</td>
<td>Gravelly clayey Silty SAND</td>
<td>15</td>
<td>15</td>
<td>77</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Buza Kipera S/S - Mbagala, DAR</td>
<td>0.0 - 0.5</td>
<td>CH</td>
<td>Clayey Silty SAND</td>
<td>8</td>
<td>11</td>
<td>81</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2: PH Levels

<table>
<thead>
<tr>
<th>#</th>
<th>Location</th>
<th>Depth of Sampling in m</th>
<th>USCS Symbol</th>
<th>Soil Description</th>
<th>Average PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TP1 - MA</td>
<td>0.6 - 1.7</td>
<td>CH</td>
<td>Sandy Silty CLAY</td>
<td>6.36</td>
</tr>
<tr>
<td>2</td>
<td>TP2 - MA</td>
<td>0.0 - 0.8</td>
<td>CH</td>
<td>Sandy Silty CLAY</td>
<td>8.54</td>
</tr>
<tr>
<td>3</td>
<td>TP4 - MA</td>
<td>0.3 - 0.6</td>
<td>SM</td>
<td>Clayey gravelly Silty SAND</td>
<td>7.15</td>
</tr>
<tr>
<td>4</td>
<td>TP6 - MA</td>
<td>2.0 - 2.5</td>
<td>SM</td>
<td>Clayey Sandy SILT</td>
<td>9.56</td>
</tr>
<tr>
<td>5</td>
<td>TP7 - MA</td>
<td>0.6 - 1.7</td>
<td>CH</td>
<td>Gravelly Sandy Silty CLAY</td>
<td>7.63</td>
</tr>
<tr>
<td>6</td>
<td>MLIMANI CITY PROJECT, DAR</td>
<td>0.0 - 0.5</td>
<td>CH</td>
<td>Gravelly clayey Silty SAND</td>
<td>6.15</td>
</tr>
<tr>
<td>7</td>
<td>Buza Kipera S/S - Mbagala, DAR</td>
<td>0.0 - 0.5</td>
<td>CH</td>
<td>Clayey Silty SAND</td>
<td>7.07</td>
</tr>
</tbody>
</table>

Graphical representation and other details are found in the Appendix 6.3.

Table 3: Pinhole test

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Depth of Sampling</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP2</td>
<td>0.0 – 0.60</td>
<td>ND 4</td>
</tr>
<tr>
<td>TP7</td>
<td>0.0 – 1.30</td>
<td>ND 4</td>
</tr>
</tbody>
</table>
4 CONCLUSIONS AND RECOMMENDATIONS

- The proposed corridors for the Moshi – Arusha 132 kV overhead transmission is approximately 70 km long and the Dar es Salaam transmission routes are approximately 43 km long.
- Regionally, the Moshi – Arusha area lies within the Great Eastern African Rift Valley and is dominated by volcanic formations. The transmission corridor traverses east west through southern lower flat lying foot of the mounts Kilimanjaro and Meru. The proposed transmission corridor was selected to run parallel with the existing 132 kV transmission line from Moshi Kiyungi substation to Arusha Njiro substation.
- The Moshi – Arusha transmission towers will be founded in volcanic sediments mainly consisting of Sandy Silty CLAY and few places have soils mainly composed of Sandy SILT/Silty SAND.
- Soil samples taken from Moshi – Arusha Transmission line corridor have pH values slightly varying, a bit on the acidic side and largely on the alkaline side. About 80% of the tested soil samples have PH values greater than 7.0 indicating that the soils are alkaline in nature. Only 20 % of the tested soil samples show acidic nature. By these results, the ground conditions in the Moshi – Arusha Transmission line route are not acidic and therefore it may be inferred that the site pose a very less corrosive threat to the transmission towers. During the fieldwork, random visual inspection was conducted on the existing 132 kV transmission towers and corrosive effects were not observed on the towers.
- The Dar Transmissions corridors are located in the coastal plain environment dominated by superficial sands of the flat, low lying coastal plain represented by redistributed outwash material from the fault blocks. River alluviums consisting of sands varying from off-white to buff-brown are also found in the corridors. Test on soil pH for the samples collected from Dar corridors show that the soils specimen are acidic, but the number of soil samples is too small to make a definitive conclusion.
- Due to terrain nature of the transmission corridors and non-dispersive nature of the few samples taken from the sites, it is apparently inferred that soil erosion along the transmission is not severe. Control measures for soil erosion will have to be determined on a tower-to-tower case during the design/construction phase. At this stage of this report we may not have a suitable blanket solution.
- The test results at this stage are only indicative as they are not very elaborate and details are not adequate due to the preliminary nature of the study. Further and detailed sampling should be done to have more standard classification tests in the next stage of the project. Such tests may give additional qualifying data for the soils from the site.
- Due to the preliminary nature and time/budget constraints of the study, the Field Resistivity measurement for assessing electrical conductivity of the ground, was not conducted during this period and thus it is recommended to be done at later phase of the study/implementation.
6. REFERENCE

- Geological Survey Division of Tanzania, 1983: Quarter Degree Sheet (1:125,000) # 55, Arusha, 1st Edition.
- Geological Survey Division of Tanganyika, 1965: Special Sheet (1:125,000), Kilimanjaro - Moshi, covering QDS #42, 56 & 57.
- Survey and Mapping Division of Tanzania, 1965: Topographic Map 1:50,000 Sheet #52/2, Series, Edition 2-TSD/OSD.
APPENDIX 6.1: MAPS
New 132 kV Transmission Line Moshi to Arusha
(line route parallel to existing 132 kV line)

Figure 2

Reinforcement and Upgrade of Dar es Salaam, Kilimanjaro and Arusha Transmission and Distribution System

Environmental Study: Annex 2 Geo - Investigation
TANZANIA ELECTRIC SUPPLY COMPANY LIMITED

Reinforcement & Upgrading of Dar es Salaam, Kisanjolo and Arusha
Transmission Lines

ENVIRONMENTAL STUDIES

ANNEX 2: GEOLOGICAL/SOIL INVESTIGATIONS

Figure 3: Geological Map for Dar es Salaam

map from 1:50,000 sheets by Directorate of Overseas Surveys 1961; III & IV

d by Geological Survey Division

de the Survey Division of the Ministry of Lands, Parks and Wildlife

Scale 1:125,000 or 1 Inch = 1 973 Miles

Compiled, d
TANESCO Grid Reinforcement Project
New 132 kV Transmission Line (parallel to existing 132 kV line)

TANZANIA ELECTRIC SUPPLY COMPANY LIMITED
Reinforcement & Upgrading Of Dar es Salaam, Kihangiro And Arusha Transmission Lines
ENVIRONMENTAL STUDIES
ANNEX 2: GEOLOGICAL/SOIL INVESTIGATIONS
Figure 2: Investigation Map for Moshi Arusha 132 kV Transmission Line
TANZANIA ELECTRIC SUPPLY COMPANY LIMITED

ANNEX 2: GEOLOGICAL/SOIL INVESTIGATIONS

Figure 4: Dar es Salaam proposed 132 kV Transmission Lines
APPENDIX 6.2: TEST PIT LOGS
## APPENDIX 6.2: TEST PIT LOGS

### AA: MOSHI – ARUSHA 132 KV TRANSMISSION LINE

NB: All test pits were excavated within the existing Moshi – Arusha 132 KV Transmission way leave

#### TP 1

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.4</td>
<td>Dark Grey clayey SILT, with vegetation roots</td>
<td>0.60 - 1.70</td>
<td>GW = Dry</td>
</tr>
<tr>
<td>0.4 - 1.1</td>
<td>Brownish Grey clayey SILT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 - 1.7</td>
<td>Yellowish Brown SILT, hard clump</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### TP 5

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.3</td>
<td>Hard, Yellowish Grey clayey SILT</td>
<td>#1:0.21-0.51</td>
<td>GW = Dry</td>
</tr>
<tr>
<td>0.3 - 51</td>
<td>Consolidated soil – Yellowish grey hard crust with whitish spots</td>
<td>#2: 0.0-0.21</td>
<td></td>
</tr>
</tbody>
</table>

#### TP 6

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.6</td>
<td>Yellowish grey, loose, clayey SILT</td>
<td>2.0-2.5</td>
<td>River bank cut at Kiyungi S/S</td>
</tr>
<tr>
<td>0.6 - 1.20</td>
<td>Blackish grey, loose, fine SILT</td>
<td></td>
<td>All soils are ALLUVIAL sediments</td>
</tr>
<tr>
<td>1.20 - 2.5</td>
<td>Slightly yellowish grey, very loose, clayey SILT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### TP 2

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 0.6</td>
<td>Cobles, gravels in black cotton soil matrix</td>
<td>0.0-0.60</td>
<td>• Alluvial clay deposits with cracks seen on the surface.</td>
</tr>
<tr>
<td>0.4 - 1.0</td>
<td>Highly (grade IV) Weathered volcanic rock</td>
<td></td>
<td>• Cobbles are subangular</td>
</tr>
</tbody>
</table>
### TP 3: Located at 30 m north of angle tower # MA 111

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 – 0.50</td>
<td>Dark Brown, medium dense clayey SILT</td>
<td>0.0 – 50</td>
<td>Rock lump in filled with calcitic material</td>
</tr>
<tr>
<td>0.50 – 1.30</td>
<td>Highly weathered (grade IV) volcanic rock</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TP 4: Located 300 m west of River Sanya on the right hand side bank, flash flood area

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 – 0.8</td>
<td>Grey, loose, dusty sandy SILT</td>
<td>0.0-0.8</td>
<td>Gravels are sub angular</td>
</tr>
<tr>
<td>0.8 – 1.1</td>
<td>Gravel in Silty matrix</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TP 7: located 30 m north of tower # MA12, top of a ridge

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 – 1.30</td>
<td>Reddish Brown firm clayey SILT (Lateritic Soil)</td>
<td>0.0-1.30</td>
<td></td>
</tr>
</tbody>
</table>
BB: DAR ES SALAAM CITY 132 KV TRANSMISSION LINES

BB1: FZIII - MBAGALA s/s 132 KV TRANSMISSION LINE

TPD1: about 150 m west of the proposed angle tower TW14, logging done at the road cut of TAZAMA pipe access road.

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 – 1.80</td>
<td>Reddish Brown, sof to firm Silty CLAY</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TPD 2: located at the proposed Buza/Kipera (Yombo) 132/33 kv substation

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 – 0.30</td>
<td>Grey silty SAND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.30 – 1.00</td>
<td>Yellowish Grey silty SAND</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BB2: UBUNGO – MIKOCHENI 132 KV LINE

TPD3: located on the left bank of Ubungo River at the Sam Nujoma road bridge. All soils are alluvial deposits

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 – 0.25</td>
<td>Dark grey clayey SILT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.25 – 1.00+</td>
<td>Grey, medium SAND</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TPD4: Excavation pit of the Mlimani Holdings Project construction site

<table>
<thead>
<tr>
<th>Depth (m) from top</th>
<th>Lithological Description</th>
<th>Sample</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 – 1.40</td>
<td>Yellowish Grey, clayey coarse SAND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.40 – 2.00</td>
<td>Dark grey sandy clayey SILT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 6.3: LABORATORY TEST RESULTS
### SOIL pH TEST

COMMITTEE OF THE INTERNATIONAL SOCIETY OF SOIL SCIENCES

**PROJECT:** Tanesco Power Lines  
**Date:** 27 December, 2004

<table>
<thead>
<tr>
<th>SAMPLE No.</th>
<th>TP1 0.60 - 1.70</th>
<th>TP2 0.00 - 0.60</th>
<th>TP4 0.00 - 0.80</th>
<th>TP6 2.00 - 2.50</th>
<th>TP7 0.00 - 1.30</th>
<th>MLIMANI pH 0.00 - 0.50</th>
<th>MBAGALA KIBURUGWA PIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of soil used</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Volume of distilled water used ml</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Soil to Water RATIO</td>
<td>1:2.5</td>
<td>1:2.5</td>
<td>1:2.5</td>
<td>1:2.5</td>
<td>1:2.5</td>
<td>1:2.5</td>
<td>1:2.5</td>
</tr>
<tr>
<td>Average pH value</td>
<td>6.36</td>
<td>8.54</td>
<td>7.15</td>
<td>9.56</td>
<td>7.63</td>
<td>6.15</td>
<td>7.07</td>
</tr>
<tr>
<td>Temperature degrees centigrade</td>
<td>29.7</td>
<td>29.8</td>
<td>29.7</td>
<td>29.8</td>
<td>29.8</td>
<td>29.8</td>
<td>29.8</td>
</tr>
</tbody>
</table>

### PIN HOLE TEST

BS 1377: Part 5: 1990

<table>
<thead>
<tr>
<th>SAMPLE No.</th>
<th>SAMPLING DEPTH</th>
<th>CLASSIFICATION FROM PIN HOLE TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIT No. 2</td>
<td>0.00 - 0.60</td>
<td>ND4</td>
</tr>
<tr>
<td>PIT No. 7</td>
<td>0.00 - 1.30</td>
<td>ND4</td>
</tr>
</tbody>
</table>

**TESTED AND REPORTED BY:**  
A. J. MBUYAH  
Dept. of Transportation & Geotechnical 
Faculty of Civil Eng. & The Built Environment  
College of Engineering & Technology  
University of Dar-es-Salaam  
P. O. Box 35131
<table>
<thead>
<tr>
<th>SAMPLE No.</th>
<th>LOCATION No.</th>
<th>DEPTH OF SAMPLING</th>
<th>USCS SYMBOL</th>
<th>SOIL DESCRIPTION</th>
<th>U&lt;sub&gt;c&lt;/sub&gt;</th>
<th>C&lt;sub&gt;c&lt;/sub&gt;</th>
<th>% CLAY</th>
<th>% SILT</th>
<th>% SAND</th>
<th>% GRAVEL</th>
<th>CONSISTENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TP 1</td>
<td>0.60 TO 1.70</td>
<td>CH</td>
<td>SANDY SILTY CLAY</td>
<td></td>
<td></td>
<td>52</td>
<td>43</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TP 2</td>
<td>0.00 TO 0.80</td>
<td>CH</td>
<td>SANDY SILTY CLAY</td>
<td></td>
<td></td>
<td>47</td>
<td>36</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>TP 4</td>
<td>0.30 TO 0.60</td>
<td>SM</td>
<td>CLAYEY GRAVELLY SILTY SAND</td>
<td></td>
<td></td>
<td>2</td>
<td>21</td>
<td>58</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>TP 8</td>
<td>2.00 TO 2.50</td>
<td>SM</td>
<td>CLAYEY SANDY SILT</td>
<td></td>
<td></td>
<td>7</td>
<td>50</td>
<td>43</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
### Soil Analysis Table

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Location No.</th>
<th>Depth of Sampling</th>
<th>USCS Symbol</th>
<th>Soil Description</th>
<th>% Clay</th>
<th>% Silt</th>
<th>% Sand</th>
<th>% Gravel</th>
<th>Consistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>TP7</td>
<td>0.60 TO 1.30</td>
<td>CH</td>
<td>GRAVELY SANDY SILTY CLAY</td>
<td>57</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>MILIMANI</td>
<td>0.00 TO 0.50</td>
<td>CH</td>
<td>GRAVELY CLAYEY SILTY SAND</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>MBAGALA</td>
<td>-</td>
<td>SM</td>
<td>CLAYEY SILTY SAND</td>
<td>8</td>
<td>11</td>
<td>81</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- TP7 DEPTH 0.00 - 1.30 metres
- MILIMANI DEPTH 0.00 - 0.50 metres
- MBAGALA - metres

**Note:**
- Particle size in mm
- Cumulative percent passing

---

**Department of Transportation and Geotechnical Engineering, USM Laboratory for Soil Mechanics and Foundation Engineering**

**Project:** IACEC POWER LINE

**Operator:** LSA

**Checked by:** MUSGRAVA J

**Date:** December 7, 2004

---

**Department of Transportation & Geotechnical Engineering**

**Faculty of Civil Eng. & The Built Environment**

**University of Dar-es-Salaam**

**P. O. Box 35131**

**Dar-es-Salaam - Tan**
APPENDIX 6.4: PROJECT PHOTO ALBUM
APPENDIX 6.4: PROJECT PHOTO ALBUM
AA: MOSHI – ARUSHA 132 KV

Km 00: View showing LHS bank of the Lukaranga River. In the background the Moshi-Arusha tower no. 1 can be seen

Km 3.0: View to the East

Km 3.3: View to the East
Km 6: View to the East

Km 6: View showing a local lady collecting 'Magadi' - Soda Bicarbonate

Km 14: View to the East
Km 24: View to the South

Km 24: View into TP 4

Km 24: View to the tower footing
Reinforcement & Upgrading Of Dar es Salaam, Kilimanjaro And Arusha Transmission Lines

ENVIRONMENTAL STUDIES – ANNEX 2: GEOLOGICAL/SOIL INVESTIGATIONS

Km 30: View to the West.

Km 34: View to the West.

Km 34: View to the East.
Km 34: View into the TP 3

Km 58: View to the West

Km 58: View showing the expansive ground
Reinforcement & Upgrading Of Dar es Salaam, Kilimanjaro And Arusha Transmission Lines
ENVIRONMENTAL STUDIES – ANNEX 2: GEOLOGICAL/SOIL INVESTIGATIONS

Km 58: View into TP 2

Km 72: View to the East

Km 72: View into TP 1
Reinforcement & Upgrading Of Dar es Salaam, Kilimanjaro And Arusha Transmission Lines
ENVIRONMENTAL STUDIES - ANNEX 2: GEOLOGICAL/SOIL INVESTIGATIONS

BB: DAR ES SALAAM TRANSMISSION LINE CORRIDORS
BB1: UBUNGO – MIKOCHENI LINE

Km 0.3: View showing the alluvial sand on the RHS of Sinza River

Plate BB1-1

Km 3.3: View at Mlimani City Project construction pit showing erosive effects on the soil strata

Plate BB1-2

Km 3.3: View as plate BB1.2 showing a wide view of the construction pit

Plate BB1-3
BB2: FZII SS-MBAGALA SS LINE

Km 0.0: View looking northerly direction showing the Factory Zone III 132/33 kV substation

Plate BB2-1

Km 0.0: View looking southerly direction showing the 132 kV Feeder outlet Factory Zone III 132/33 kV substation to

Plate BB2-2

Km 9.1: Looking southeast direction showing terrain and vegetation where the line traverses

Plate BB2-3
Km 9.1: Looking northwesterly direction showing terrain and vegetation where the line traverses.

View at km 10.0: Looking southeast showing the terrain condition of the line traverse.

Km 12.0: Looking west showing terrain condition of the line traverse.
View at Mbagala substation looking north showing the line traverse and terrain conditions

View at Mbagala existing substation looking east direction
APPENDIX 6.5: OTHER RELEVANT LITERATURE
Ministry of Industries, Mineral Resources and Power
(Geological Survey Division)

Explanatory Notes
on the
Geological Map of Kilimanjaro
The Sheffield University Kilimanjaro Expedition began the mapping of the mountain in 1953 with the assistance of the Geological Survey of Tanganyika. This project was under the leadership of Mr. W. H. Wilcockson and included Mr. P. Wilkinson, Dr. C. Downie and Dr. D. W. Humphries. Officers of the Geological Survey attached to the Expedition were N. J. Guest, G. P. Leedal and D. N. Sampson. During the first season a general reconnaissance was carried out making use of early German toponographical maps of the mountain.

The members of the Expedition continued work on the mountain in 1957 when the preliminary geological work had indicated the general distribution of lavas from the volcanic centres. Prof. L. R. Moore and Dr. R. Neves then joined the Expedition.

To complete the area of the quarter degree sheets 42, 56 and 57 rapid mapping on the plains and lower slopes in the neighbourhood of Moshi was completed in 1963 by E. W. Hartley and G. R. Orridge of the Geological Survey Division and in the extreme north-west by D. N. Sampson.

The geological map has been prepared by Dr. C. Downie and Mr. P. Wilkinson. The final completion of the map was held up until the 1:50,000 contoured map based on air photographs were available. The compilation from this scale and the draughting and checking has been carried out by H. E. Empson, Chief Draughtsman of the Geological Survey Division.

A full geological account is in the final stages of preparation by members of the Geological Department of Sheffield University. Meanwhile it is felt appropriate that the results of the mapping should be issued in the 1:125,000 geological series being published by the Tanganyika Government. The following account by Mr. P. Wilkinson, Dr. C. Downie and other members of the expedition provides a preliminary description and summary of the history and petrography of this famous mountain. Brief descriptions of the economic and water supply aspects of the geology have been added by officers of the Geological Survey.

A number of papers have already been written on Kilimanjaro by members of the Expedition and these are listed at the end of this account. They do not, however, constitute a full bibliography of geological work done in this area.

Dodoma, April, 1964

J. W. PAULISTER, Commissioner for Geological Survey
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PHYSIOGRA

Kilimanjaro, which occupies most of this sheet and spreads into adjoining ones, is a volcanic mountain massif rising abruptly from plateau country at about 3,000 to 4,000 feet above sea level to culminate on Kibo in Uhuru Peak, 19,340 feet, the highest point on the African continent. The plain on which the volcanic pile accumulated is a warped and faulted erosion surface the age of which is still uncertain.

Despite its near-equatorial position, the great height of the mountain has caused the glacierization of the Kibo peak above about 15,000 feet. Six glacial episodes have been recognized of which the third was the most extensive and included the glacierization of Mawenzi and to lesser extent of Shira as well as Kibo. The earlier of these glacial episodes took place during the activity of the volcanoes as shown by the presence of tillites underlying lava or pyroclastics, and have continued since the centres became extinct. Terminal moraines are found as low as 10,000 feet on Mawenzi and Kibo. Recent climatic change, however, has shifted the permanent snow-line above the summit level and the glaciers are now receding rapidly, leaving lateral and terminal moraines which form a distinctive feature of the topography. The great altitude also leads to striking contrasts in vegetation. A rough zoning of the mountain is as follows: (a) Ice and Alpine Desert, above 13,500 feet; (b) Heath or Moorland Zone from about 10,000 to 14,000 feet with giant senecios, lobelias and Erica spp.; (c) Mountain Rain Forest Zone, 6,500 to 9,500 feet; (d) Cultivated Temperate Zone, from plain level to about 6,500 feet with coffee, bananas, wheat, maize; (e) Plain at 2,500 to 4,000 feet, semi-arid steppe.

The drainage pattern, in a general way, radiates from the three major centres and rivers cut deep gorges into the flanks. Water-flow is seasonal in the north and east and passes, by way of the Taveta River, into the Athi (Galana) River system. In the extreme north-west the intermittent drainage flows into the dischargeless basin of Lake Amboseli. The rivers of the west and south drain into the headwaters of the Pangani River.

Widespread topographic features are formed by the spreads of “lahar” or cold mudflow in the south and south-west, emanating from Kibo and from Meru, a prominent extinct volcano which lies to the west.

In the south, at heights of about 2,500 feet, lie the extensive alluvial plains of the Upper Pangani and its tributaries, and in the north and southern parts of the Amboseli Basin appear as widespread alluvial and lacustrine deposits at heights of about 3,700 feet.

GLACIAL DEPOSITS

Above the forest level and at heights between 11,000 and 14,000 feet, terminal moraines belonging to the last glacialation are conspicuous on the flanks of Kibo and Mawenzi. Behind them the corresponding lateral moraines follow the ridges up to about 15,000 feet. The enclosed area is richly endowed with glacial phenomena including cirques, glaciated pavements, boulder-trains, crag and tail, roches moutonnées. Outwash gravels, almost entirely cover the Saddle area. Sets of retreat moraines are sometimes present and more recent moraines exist near the glacier snouts on Kibo.

Outwash sands and gravels cover wide areas of the flanks, notably north-west and south of Kibo and south of the Saddle. In places they extend down to below 9,000 feet.

GEOLOGY

Essentially the geology consists of a pile of Neogene volcanic products and some interbedded sediments accumulated on an eroded surface of Precambrian metamorphic rocks.

PRECAMBRIAN

Within the boundaries of the sheet there are only a few restricted outcrops of Precambrian rocks, all of which have been assigned to the Usagaran of the Mozambique orogenic belt. These outcrops represent the tops of inselbergs on the pre-volcanic surface and continue the topographic trends of the North Pare and Lelatema Mountains in the south.
north-west corner of the sheet biotite gneiss forms a small hill and, east of the north-western flanks of the Lelesma Escarpment. High-grade gneisses are here exposed and include garnet-quartz-feldspar granulite, quartzite, amphibolite-gneiss (Kondalith), dolomitic marble, calcite-dolomite marble and hornblende-biotite-quartz granulite. A small isolated outcrop of biotite gneiss occurs in the foothills.

On the south-east the outcrops around Kifumbu include quartz-feldspar-granulite, hornblende and/or biotite, biotite gneiss, and quartz-feldspar and hornblende pegmatite. The Lelesma Ridge consists of biotite and hornblende gneiss, biotite quartzose gneiss and semi-calcaceous gneiss. In the two hills north-west and north-east, retrograde hornblende-hypersthene gneisses, showing incipient migmatization are found. These occurrences in the south-east lie about a third of the way to the north of the North Pare Mountains. In general, the foliation of all these gneisses is NNW--SSE, with an inclination to the NE at 35°-45°.

NEOGEO

The commencement of volcanicity is uncertain. Further north in the south-east known Neogene volcanics have been dated by isotopic dating of a few samples. The earliest known volcanics can only be dated as Mio-Pliocene and activity has continued to the present time. The last eruptive event is dated at about 13 to 15 million years old, namely of Miocene age. The earliest volcanics are basaltic and basaltic andesitic lavas with andesitic dikes and sills, and charnockite and charnockitic gneisses.

The Shira structure consists of a single volcanic center, which has been divided into three main units:

1. The Shira, the oldest centre, is a relatively simple strato-volcanic cone with a single crater. Topographically, it forms a plateau 12,000 feet high, rimmed by a marginal series of hills and slopes. The central peak, Kibo Peak, is about 13,030 feet high. A shorter ridge bounds the south side of the plateau.

2. The eastern part of the Shira Plateau is dissected by more recent activity and is built mainly of lavas, although some pyroclastics are present. The rock associations include:

   * Mite < olivine basalt—trachybasalt—trachyandesite
   * Basanite—nephelinite

3. The southern part of the Shira Plateau rises the conical hill called Dzatskegol. Scattered remnants of a major vent-infilling occupy a roughly central position. The vent-infilling is mainly composed of basaltic lavas, with some basic lavas, and is penetrated by intrusions of doleritic and quartz-feldspar-granulite.

South of the Shira Plateau, in the upper parts of the Kikafu Valley, the Shira structure is highly dissected by glaciated valleys but on the flanks of the main Shira Ridge a small subsidiary centre of effusion became active at a late stage. A radial swarm of dykes, migmatite similar to the lavas, is conspicuous on the ridges, and concentric sheets of intrusive rocks, concordant with the lavas, are visible.

The central and largest of the Kilimanjaro centres is an elliptical volcanic dome of which has been obliquely truncated by collapse. The formation of a caldera one and a half miles in diameter. The highest point of the caldera rim is on the south and culminates in Uhuru Peak (formerly Kibo Peak, Spitz), 19,340 feet high. From the floor of the caldera rises an Inner Crater of 900 yards in diameter. Within the Inner Crater lies the "Ash Flute", the latter of which is 370 yards in diameter and 425 feet deep. The "Ash Flute" is the site of the last activity of the mountain. The southern slopes are dissected by glaciated valleys, but only near the Great Wet Side do erosion expose any considerable section into the strata. Further north, at about 13,000 feet, the dissection is deepest and the older rocks are to be found. The more recent lavas have tended to flow down the south side and east flanks and in this region nothing of the older structure is seen.
The lavas of Kibo show strong alkaline differentiation and range from andesite, through trachyte to nepheline-rich phonolite. A wide range of these lavas probably, and a detailed succession is well-established, especially in the west. Near the centre dips approach the horizontal; on the flanks they steepen. The lava flows of Kibo flooded westwards almost completely over Shira and the east they were strongly deflected to north and south by the peak of Mawenzi. Sections are available only on the south and west slopes and special deposits conceal the lavas over considerable tracts. The maximum thickness of the several lava groups, each of which may comprise scores of small flows, is given in the following account.

The succession of lavas has been determined as follows:

- Inner Crater group
  - Caldera Rim group
  - Lent group
  - Rhomb porphyry group
- Upper rectangular porphyry group
  - Lower rectangular porphyry group
  - Lava Tower trachyte group
  - Lower trachyandesite group
  - Upper trachyandesite group

A number of localities (and at certain well-defined stratigraphical horizons), fluvio-glacial and alluvial deposits occur among the lavas of Kibo and in many reach thickness of over 200 feet, e.g. in the Karanga Valley but their are small to be shown.

Out of the Kibo lavas seen belong to the earlier part of the Pleistocene but the most occur, and the Caldera Rim group erupted in the latter half of this period and the Inner Crater activity is Recent.

The lower rectangular porphyry group (200+ feet) is the oldest set of lavas exposed. It is a restricted outcrop near the Lava Tower and in the Umbwe Valley at 13,500 feet. Lithologically the lavas resemble the upper trachyandesites.

Lava Tower trachyte group (300 feet) is seen only in a few places high on the west flanks of Kibo. Lithologically the lavas are green, fluidal, fissile and are conspicuously xenolithic. Petrographically the lavas are aegirine-rich trachytes.

The lower rectangular porphyry group (2,000 feet) is also exposed in limited areas north-west flanks. Petrographically the lavas are trachyandesites, differing from and lower trachyandesites in the nature of the andesine megaphenocrysts. Lower rectangular porphyries the mega-phenocrysts are of andesine with a rhomb cross-section showing a length/thickness ratio in the range 1/1 to 4/1; in contrast, the feldspar is a labradorite with a more regular cross-section showing a length/thickness ratio in the range 1/1 to 1/1. This feature is more than a simple coincidence of crystal form, and it follows that the feldspar is a leucite and that the lava from this group is a leucite trachyandesite.

These lavas were intruded into the Kibarnese lavas and flowed along erosion surfaces, but it appears to grade upward into the upper rectangular porphyry group through lava-flows showing transitional phenocryst frequency and also in the presence or absence of nepheline megaphenocrysts. These features have proved stratigraphically significant.

The rhomb porphyry group (2,000 feet). The lavas of this group are characterized by abundant phenocrysts of alkali feldspar up to one and a half inch in length, sometimes comprising as much as half the volume of the whole matrix is usually dark grey and aphanitic to glassy, but locally they may reach thickness of over 200 feet. These lavas are known to be more than 25 miles from the probable point of origin. They were formed by characteristic tunnel-flow mechanism.

Locally in the region of the Penck and Nordner glacier Kibo porphyries are underlay by the distinctive Penck rhomb porphyry (400 feet) which is very sparse phenocrysts and in a very basic matrix. Elsewhere the Kibo porphyry succession commences with the Weru Weru agglomerate which is 300 feet thick in the Weru Weru Valley at 4,200 feet altitude. Neither of these has extensive outcrops and they have been included in the rhomb porphyry group on map.

The Lent group (1,000 feet). In many parts of Kibo the lavas of the porphyry group were succeeded, after a lengthy erosion interval, by the trachyandesites, trachytes and phonolites. These lavas, which are intermixed with the lava-flow sheets, are usually dark grey and aphanitic to glassy, and appear to have been present at the same time from fissures and centres. The most prominent centre, the Lent Peak region of Kibo, is an impressive collapsed dome.

The small rhomb porphyry group (700 feet). In the central region of the small rhomb porphyry group is succeeded by a group of lavas later in age than the Lent group which are characterized by abundant, euhedral rhomb-shaped phenocrysts of rocks of variable size, generally less than half an inch in length. Sparse, small megaphenocrysts of nepheline are also commonly present.

The lower rectangular group (1,000+ feet). Within the central portion of Kibo the Great West Notch show that the rhomb porphyry group is succeeded by a group of lavas in which the megaphenocrysts are of analcime-syenite, the bottom of which has not been reached, syenite contains small rhomb phenocrysts of alkaline feldspar, and in others they are small rhomb porphyry. It is, in fact, thought to be a pneumatic small rhomb porphyry magma which was extruded near the mouth of a cauldron subsidence preceded, and cooled slowly by virtue of its large mass, which may have been as much as 1,000 feet thick. Kibo; lahar. A small deposit covers a large area of the plains of Moshi at heights of below 3,000 feet. In places it shows the mound-like characteristic of "lahar". This deposit was formed by huge debris flows development of the Kibo Barranco which took place at some period subsurface formation of the small rhomb porphyry group and before the outpouring of crater lavas.

The Caldera Rim group (630 feet) is a group of rhomb porphyries with large, well-formed megaphenocrysts of alkaline feldspar accompanied by abundant mega-phenocrysts of nepheline which at approach one inch in length. These lavas formed a series of flat-lying flows filling a caldera which were small rhomb porphyry lavas. Later they spilled over the sides forming channel flows on the flanks of Kibo, especially on the north and north-west, where some extend to the edge of the map. The present summit ridge is a member of this group. Nepheline rhomb porphyries were also erupted from a parasitic centre on the Saddle.
Inner Crater group (425+ feet) comprises nepheline aegirine-phonolite small mega-phenocrysts of well-shaped nepheline and more irregular ones of aegirine-phonolite. These are the last groups of lavas to have been erupted and are the oldest in age. Their low cone fills the present caldera which formed at the Caldera Rim group. They spill over the rim of the caldera and form long, narrow flows on the north-east, and are also present on the west and south. A number of dykes are present on the slopes of Kibo above 13,000 feet on the south-west and west, but a few are recorded high on the north, from 1–8 feet wide. They comprise trachybasalts, rectangle porphyries, trachyte and phonolite.

Cones—Associated with the Kilimanjaro volcanism are small but adventitious cones. Two hundred and sixty-three of these minor volcanic events have been mapped on this sheet; generally they are situated on the lower slopes in zones down to the plains, but they also occur on the Saddle zone between 6,000 and 10,000 feet. The cones are usually only a few hundred feet in diameter and the same in height, but several reach a mile in diameter and over five feet in height. They consist mainly of scoria and ash, but a few have developed lava flows forming extensive fields as in the Upper Rombo and North rock-types identified are: aegirine-phonolite—olivine basalt—andesite—trachyte. However, these cones have not been studied in detail and there may be an even wider petrographic range. At least two periods of parasitic eruption are known. The later pre-dates the Caldera formation and is the youngest activity on the mountain except for the Inner Crater group. The older pre-dates the rhomb porphyry group but may post-date the single porphyry group. In addition, much older centres have been identified in the lavas of Mawenzi, and other periods of parasitic activity certainly occur. They are mostly arranged in well-defined belts corresponding in some cases clearly to regional tectonic or volcano-tectonic lines.

Saddle zone. This zone comprises eleven eruptive centres arranged in two NNW–ESE lines between the main centres of Kibo and Mawenzi. The southern line entirely pre-dates the Caldera Rim group in age and includes ankaramites, phonolites, and trachyandesites. The southern line entirely post-dates the Caldera Rim group and includes ankaramites and basalts. An isolated centre between the lines is the basalt and nepheline rhomb porphyry.

Rombo zone. This zone appears to continue the southern Saddle line to the north of Mawenzi. Comprising more than a hundred cones it is the densest concentration of parasitic cones on the mountain. The upper part consists of lava and scoria and is very ankaramitic in nature. The part within and below the forest, consists of ash cones with ankaramitic and olivine basaltic affinities. All this activity was concentrated in the lake Chala area. Lake Chala lies isolated at the south-eastern extremity of the Rombo zone. It is large, calm, clear, about 300 feet deep, and is surrounded by a rim of agglomerate and tuff. The walls expose Mawenzi-derived lavas. It is that the large spread of water-deposited calcareous tuffaceous grits in this area which is known as the Chala centre.

Sinya zone. This is a conspicuous raised area emanating from a point on the Saddle at 9,000 feet and running in the general direction of the Pare Range. There are twenty dissected basaltic scoriacones overlie and partly mask older series of basaltic to ultramafic lavas which apparently form the core of the raised area. These older rocks appear to be overlain by lavas of the group on their eastern margin, and may prove to correlate with the Neumann Tuff. In the absence of positive evidence, the whole of the series has been mapped as parasitic lavas, which do, in fact form much of the summit. The stratigraphic position and petrographic character are closely those of the Ol Motog group (q.v.) north of Shira.

Shira zone. Below 7,000 feet on the southern flanks of Shira is an area in number of very old and eroded cones occur, but their relationship to the unknown.

Shira and Lagunimera zones. From the west to the north of Shira there is a wide range of petrographic types known in the parasitic activity is four. Both pre-rhomb porphyry and post-rhomb porphyry activity is known. Shira zone forms a well-defined narrow linear zone extending from the Shira Plateau to the plains near Sinya. The lavas are chiefly andesitic and trachyandesitic. The later pre-dates the Sinya Beds and is the youngest activity on the mountain except for the Inner Crater rings from which the fumaroles are believed to indicate waning activity, but they may represent an earlier stage in the volcanics.

Present Volcanicity. Residual volcanicity is now confined to Kibo, the expression of fumarolic activity associated with the Inner Crater ring system. The fumaroles are believed to indicate waning activity, but they may represent an earlier stage in the volcanics.

Mera "lahar."—West of Shira the Kilimanjaro lavas pass under the lake a great "lahar" field extending westwards to Mera beyond the limits of the lake. The "lahar" was formed in recent times by the collapse of the east wall of the crater. In general, north of the Arusha-Moshi road the Mera "lahar" forms a broad tongue. The "lahar" deposit consists of 2 feet of material. The Sinya Beds are overlain unconformably by gravelly deposits. The Pangani deposits in the south consist mainly of gravelly deposits. The Pangani deposits in the south consist mainly of gravelly deposits.

Lagunimera lake beds. The lacustrine beds in the Lake Amboseli region are considered to be Neogene in age. The lower strata are the Sinya Beds which consist of dolomitic limestones with some silicified mudstones towards their upper parts. The limestones are the main host-rocks for the formation of the Sinya Beds which are overlain unconformably by the Ol Tukai Beds which form a great lake on the plains south of the Sinya Beds. These are green, silicified clays with marked thixotropic and swelling properties. The Ol Tukai Beds are composed of wind-blown material. The lake floor itself consists of fine sand dunes, and the lakes are filled with calcareous tuffaceous grits. Deposits of well-bedded calcareous sandstones and calcareous tuffaceous grits are common. The stratigraphic position and petrographic character are closely those of the Ol Motog group (q.v.).

Red soils. South of Kilimanjaro there are extensive alluvial deposits of sand and gravelly deposits. The soil consists of a number of layers. The topmost layer is a sandy layer with a thickness of 200 feet. Outcrops of Precambrian rocks are all surrounded by large spread of water-deposited calcareous tuffaceous grits. Deposits of well-bedded calcareous sandstones and calcareous tuffaceous grits are common. The stratigraphic position and petrographic character are closely those of the Ol Motog group (q.v.).

Wind-blown sands. Along the western edge of Lake Amboseli there are extensive deposits of wind-blown material. The lake floor itself consists of fine sand dunes, and the lakes are filled with calcareous tuffaceous grits.
VOLCANO-TECTONIC FEATURES

The water table and the map and these lines clearly have some form of structural control, whether this is of purely volcanic origin or has regional significance is not

ECONOMIC GEOLOGY

Meerschaum is mined at Sinya, north-west of Kilimanjaro. The deposits are associated with green septolic clays, which extend across the foot of the mountain near Moshi and the areas of Kilimanjaro. Building sand is quarried in the Pangani alluvium near the Chini.

Supplies. Kilimanjaro is situated in the centre of an extensive area of where the plains normally receive less than 20 inches of rain per annum. The highest rainfall (over 60 inches per annum) occurs on the southern slopes of the mountain centred on Machame and Marangu. The north-east side of the mountain, rainfall is lower, usually between 30 inches.

Permanent surface water is found mainly on the southern slopes of the mountain where the larger streams flow perennially. With the exception of the Karanga pools and the Rau, all these usually dry up before reaching the plains in the dry season. On the north and east sides of the mountain, permanent water is found on the lower slopes and only the Lumwe stream flows below the forest belt in the dry season. On the upper mountain slopes, surface water is found only at a few places (e.g. near Peters Hut) in the dry season.

Much of the rain falling on the mountain is dissipated in surface run-off, which is readily absorbed by the pervious volcanic formations and tends to the bottom of the forest belt, held up in some areas by impervious lava flows as small springs which occur frequently in the forest belt. Most of the water is utilised to feed pipe lines which serve the population on the lower slopes.

Springs occur at the foot of the mountain near Moshi and at Miwaleni on the south side. On the south-east, east and north sides of the mountain, all the large springs (Engare Nairobi) area, boreholes have been drilled for water in the Kilimanjaro-Moshi area. Boreholes drilled in volcanic formations around the foot of Kilimanjaro have been successful. Large quantities of ground water can be reached within 400 feet. Boreholes drilled near Moshi and Sanya Juu have frequently been dry with the exception of a few good ones which have given much higher yields. In the Karanga pools near Marangu, boreholes have been less successful. On the Kilimanjaro several successful boreholes have been drilled on the southern side near Marangu. Uru and Machame where surface water is abundant. In the Engare Nairobi area, boreholes have been less successful. In the Kilimanjaro area, only one borehole, at Keni, has been successful; five other boreholes drilled in Mt. Kenya and Mashati areas were dry.

The water table. Lake Chala has accumulated as a result of seepage of ground water into the large explosion crater which extends below the water table.

SELECTED BIBLIOGRAPHY


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<table>
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<th>NAMES</th>
<th>CRITERIA</th>
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**TABLE 4** - Based on the material passing the 3 in (75-mm) sieve.

**PLASTICITY CHART**
Table 4 Detail
For classification of fine-grained soils and fine fraction of course-grained soils.
Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols.
Equation of A-line:

\[ PI = 0.73 \times (LL - 20) \]

Notes:
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