

THE INFLUENCE OF GEOLOGY AND OTHER
RELATED SOIL FORMING FACTORS ON
THE INHERENT FERTILITY OF
SOILS IN THE ASELA AREA

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THE INFLUENCE OF GEOLOGY
AND OTHER SOIL FORMING FACTORS
IN THE INHERENT FERTILITY OF
SOILS IN THE ASSELA AREA,
ARSSI, ETHIOPIA.

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ABSTRACT

The geology of the Asela area has been studied in detail and the fertility status of the soils in relation to the factors of soil formation (parent material, climate, topography, organisms and time) examined qualitatively and semi-quantitatively. The area is associated with Pliocene and younger volcanics (central and fissural) and is intensively affected by different episodes of faulting. Basalts, Trachybasalts, trachytes and acidic pyroclastics are the rocks occurring in the area. The major soils are the dark-dark brown and the reddish brown soils of the plateau and the dark-brown-dark yellowish brown soils of the rift. In general, the rift soils have higher plant nutrient status than the plateau soils. Removal of materials is important on the plateau and addition in the rift. Parts of the plateau and most of the rift floor are affected by poor drainage. The abundance of surface hindrances on the surface of the rift soils might be attributed to the young age of the rocks in the latter. In terms of physical limitations of the land, both the lowland and the plateau have their drawbacks. The cumulative influence of the topography and the climate is found to be dominantly responsible for the lateral and vertical variations of the inherent fertility of the soils.

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1. INTRODUCTION

Ethiopia is a country based dominantly on agricultural economy. The Chillalo District of Arrsi region (Central Ethiopia), which includes the area of the present survey is one of the well-known regions for its production of wheat and barley.

CADU (Chillalo Agricultural Development Unit), presently called ARDU(Arrsi Rural Development Unit), has conducted several studies in different fields: pedological, ecological, hydrogeological etc...

Since a great deal of work has been contributed to the Chillalo District by this group, those points which might add further information about soil fertility status in the area and its qualitative and quantitative relationships to the factors of soil formation, have been worked in this study in a semi-detailed manner.

1.1. Location and Communication

The study area, covering a surface of about 550km², lies within 39° 00' - 39° 15' E long. and 8° 62' - 8° 82' N lat. It is located about 175 km southeast of Addis Ababa and includes portions of the main Ethiopian Rift and of the Southeastern Plateau around the town of Asela.

It is accessible by the main highway, Addis Ababa - Nazreth - Asela - Goba. Another road also runs from Asela,

through Ogolcho, to Meki and Adami Tulu. Two roads branching from the main highway cover part of the area; one branch leads to Kersa and another crosses the ARDU project area south of Asela.

1.2. Objectives

In spite of the fact that mechanized and cultural farming are practiced extensively, the area lacks detailed scientific studies with respect to soil fertility. The present study is essentially geological and pedological, and attempts to show a general perspective of soil characterization in the area.

The main objectives of this paper are:-

- 1) To examine, in detail, the geology of the Asela area;
- 2) To establish qualitatively and whenever possible to quantify, the relationships that exist between the fertility status of the soils in the region with the soil-forming factors (parent material, climate, topography, organism and time); and
- 3) To come up with a possible conclusive remark on the existing relationships, which, by extrapolation, might apply to other regions with similar geological, physiographical, climatic and biologic features.

The results obtained could supplement the reconnaissance land use study in Ethiopia, which is being carried out by FAO

and Ethiopian experts of the Land Use Planning and Regulatory Department of the Ministry of Agriculture.

1.3. Previous Works

The surveyed area only sometimes falls partially within general studies; essentially geological, such as those carried out by Di Paola (1972; 1976), Juch (1975), Kazmin and Seife (1978), Mohr (1962; 1963; 1966; 1967; 1970); pedological, carried out by Trapp (1974), Hammer (1974), Kebede Tato (1970) and Murphy (1969).

1.4. Methods and Materials

Geological, drainage and soils map were produced from data collected in three field trips totalling 30 days. A topographic map of 1:50,000 scale was used as a base, with aerial photographs of the same scale as supplementary.

Traverses were taken along stream channels and also in profiles not uniformly spaced. Various rock exposures were examined and sections prepared. Rock samples representing the different pyroclastic and lava flows were collected for petrographic studies.

Soil sampling was mostly done by digging pits 1-3 cubic-meter, except for those samples taken from swampy areas, in which case a hand auger was used. Few samples were also collected from the sides of small gullies. In all cases, 1-4 samples were taken from each profile at different depths,

the number depending on the variability of the soil with depth and the thickness upto the bedrock. Soil sample sites were not uniformly distributed throughout the area. This was done, because uniform spacing of sample sites does not always fulfill that requirement of maintaining four of the five soil-forming factors constant, in order to examine the role of the variable. In the soils' aspect, emphasis was not given to the mountain area.

52 soil samples were analyzed in the soil section of the Land Use Planning and Regulatory Department of the Ministry of Agriculture. Analysis of some duplicate samples was also carried out in the ARDU Soil Laboratory at Asela.

The various laboratory techniques employed in the soil analysis are briefly mentioned hereunder. (They are referred from Jackson 1973, second edition).

Texture was determined by the Hydrometer Method. Light and heavy mineral studies were carried out by separating the two in bromoform (sp. gr. 2.9) in the Geology Department of the A.A.U. The Munsell and the Standard Color Charts were used to determine dry and wet soil colors. Soil pH was measured electrochemically by means of glass electrode. Phosphorus was analyzed by Olsen's method. The Wakley-Black method was employed for soil organic matter determination and the Kjeldahl method for total nitrogen. Exchangeable calcium and magnesium were extracted by neutral normal NH_4OAc and determined by means of Versene titration. Available K^+ was determined colorimetrically and Na^+ by flame photometer. For CEC, determination with ammonium was used.

2. CLIMATE

Disregarding the microclimates caused by minor topographic features, the study area can generally be divided into two major climatic units, on the basis of precipitation and temperature conditions. These are:-

- 1) The warm, dry rift valley; and
- 2) The moist, cooler plateau.

According to the works of Kebede Tato (1970) and Alemayehu Mengistu (1975), (especially the latter), from which most of the climatic and vegetational data were drawn, the second climatic unit is further subdivided into two: the cooler area of the high altitudes and the frost area of the higher parts of Chillalo Mountain.

The authors pointed out that all the three areas get rainfall at about the same time, but in varying intensities.

In the Chillalo District to which belongs the investigated region, three seasons are known in a year: the dry season (Bega) which lasts from October - January; the small rainy season (Belg) extending from February - May and the big rainy season (Keremt) from June - September (Kebede Tato, 1970; Alemayehu Mengistu, 1975).

The general rise in elevation from north to south and from west to east is accompanied by corresponding increase and decrease, respectively, of precipitation and temperature in these directions. This relationship is evidenced by the meteorological data of four representative stations in the

area: Asela, Kulumsa, Dugda and Arata.

The town of Asela is situated on the North-central part of the study area, at an altitude of 2350 m. The mean annual precipitation recorded at the Asela station for the period 1966-73 was 1370 mm. The second station, Kulumsa, is at the northern edge of the mapped area at an altitude of 2200 m. The mean annual precipitation in the years 1966-73 amounted to 834 mm. Dugda, which is located in the rift valley (1800 m) received a mean annual precipitation of 619 mm between 1970-73. The mean monthly maximum temperature, however, showed increases from Asela, through Kulumsa to Dugda (fig.1). Temperature also increases from Asela to Arata which is located at 1760 m (Fig. 2).

Similarly, rainfall records for Asela (1975 - 79), Kulumsa (1975 - 79) and Arata (1975 - 78) showed decreases in the order of arrangement and mean annual precipitation values were 1315, 877 and 816, respectively (Fig.3).

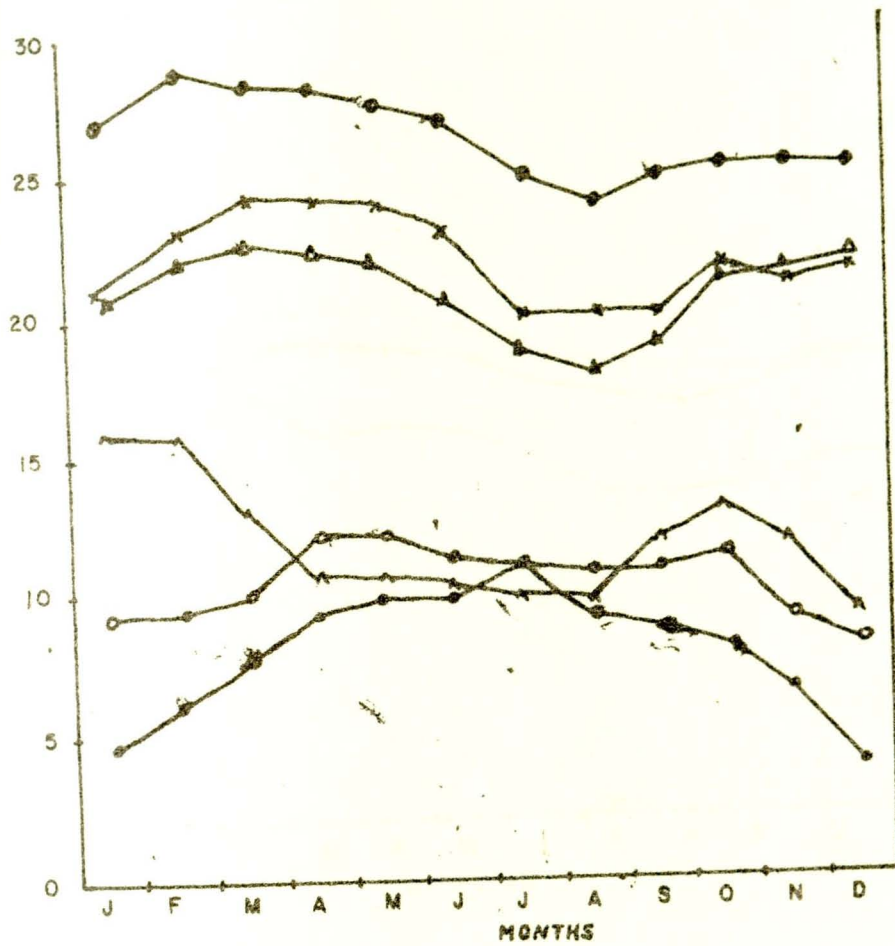


Fig.1 Temperature data.

(Modified after Alemayehu Mengestu, 1975)

Dugda 1970-73 (Alt. 1800m)

●-● Mean monthly max. temp.

▲-▲ Mean monthly min. temp.

Mean annual prec. 615 mm

Kulumsa 1966-73 (Alt. 2200m)

X-X Mean monthly max. temp.

O-O Mean monthly min. temp.

Mean annual prec. 834 mm

Asela 1966-73 (Alt. 2350m)

△-△ Mean monthly max. temp.

●-● Mean monthly min. temp.

Mean annual prec. 137 mm

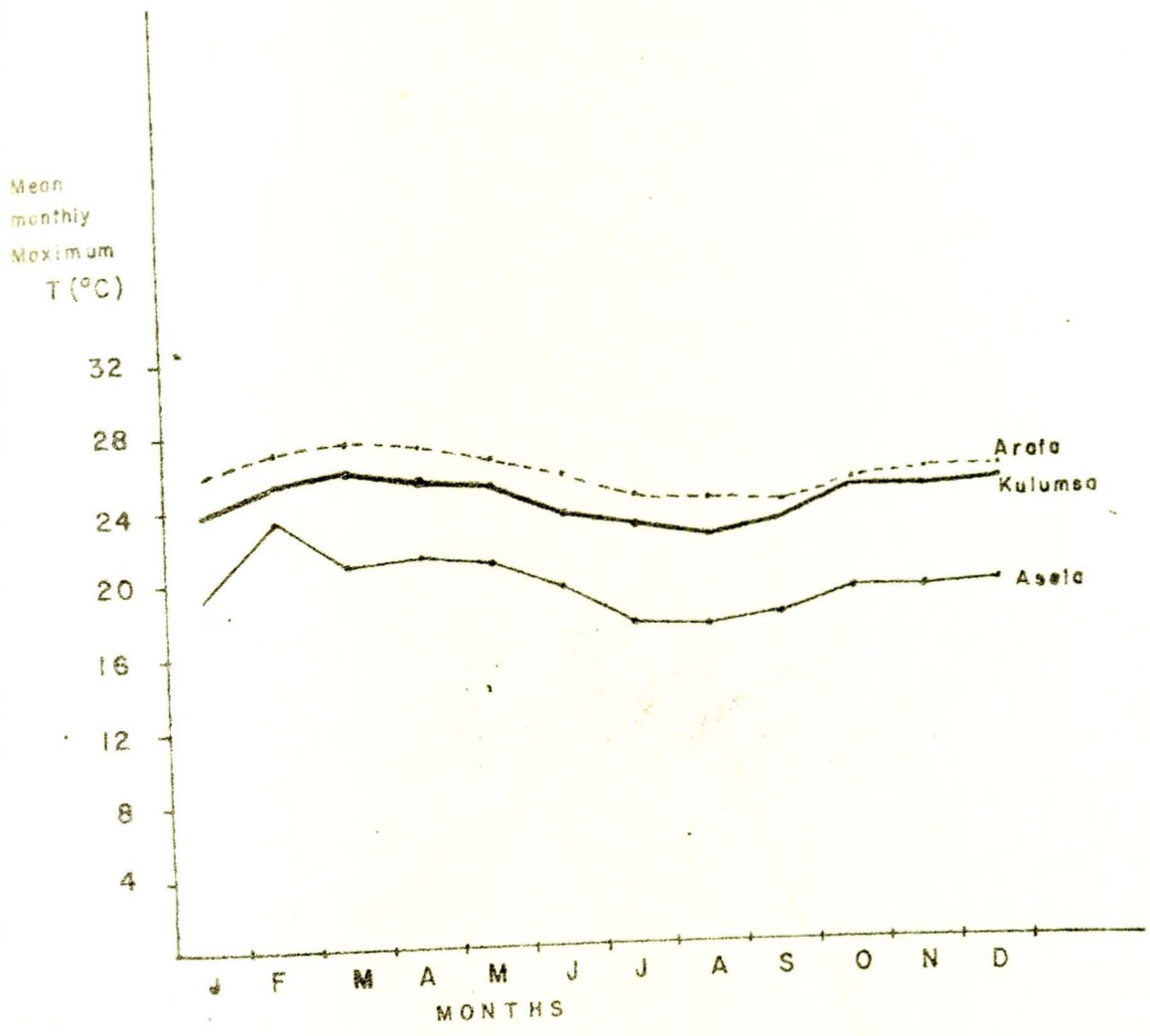


Fig. 2

Temperature data (Obtained from ARDÜ)

- Arata (1975-78)
- Kulumsa (1975-79)
- Asela (1975-79)



Fig. 3

Rainfall data (Obtained from ARDU)

- ASELA (1975-79)
- KULUMSA (1975-79)
- ARATA (1975-78)

3. VEGETATION AND LAND USE

The vegetation within the area markedly changes with elevation. A west-east traverse within the study area shows the variation in the distribution of plant species and communities. Nevertheless, certain species of trees, grasses and shrubs cross the boundaries of the zones to which they belong and appear, relatively sparsely in adjacent vegetational zones.

The classification of the area into vegetational units as given in the following section, is based on the works of Alemayehu Mengistu (1975) and of Lill and Lundgren (1969). According to these authors (with some modifications), the area of interest can, in a generalized manner, be classified into four vegetational zones. These are :-

1) Alpine area

The alpine area covers the higher parts of Chillalo Mountain (more than 3000 m. a.s.l.) which receives high precipitation and low temperature.

In terms of areal extent, the shrubs Erica arborea and Hypericum revolutum are dominant in this zone. several species of grasses and herbs also constitute part of this floral community.

2) Highland area (2500 - 3000 m)

This ecological zone occupies the mountain slopes, valley bottoms, open and rolling plains. It is

constituted by three major, distinct plant communities: Hagenia and Juniperus forest, Podocarpus forest and open grassland.

3) Medium altitude area (2000 - 2500 m)

The lower limit of this zone coincides, approximately with the plateau - rift boundary. The vegetation in this area can be generalized as Podocarpus forest, scattered tree grassland with Acacia trees, and open grassland. Eucalyptus forest is dominant around the town of Asela.

4) Lowland area

The lowland area is mainly the rift floor and includes part of the main escarpment. In the study area, this zone falls within the range of altitude of 1700 - 2000 m. It consists of swamp grassland and scattered tree grassland with Acacia as the dominant tree.

The vegetation on Chillalo Mountain and its slopes, in the valley bottoms and on the escarpment slopes, is in its natural state. The need for agricultural land, together with the need for firewood and charcoal, has resulted in deforestation which is still encroaching upslope. Most of the area probably once was under natural forest cover before human interference started to be operative.

Inspite of all these anthropic influences which might bring serious ecological disturbances, a greater part of the study area is still under forest cover- natural or otherwise.

Both on the plateau and the rift, a large area is used for grazing and large and small scale farming. Part of the area within the rift has turned out to be swamps and small lakes. A portion of the area is nothing but bare rock surface; settlement areas cover a small proportion of the whole area.

4. GEOMORPHOLOGY

Its geological history being short (Upper Pliocene and younger, based on Mohr, 1967 and other works), all the geomorphic features in the area are very young.

In the eastern part stands the huge volcanic edifice of Chillalo Mountain, associated with numerous parasitic cones of basalt. A gradual descent leads to the high, flat and gently westward sloping plain.

The abrupt drop at the main escarpment, the rim of which is marked approximately by the 2020 m contour, interrupts these topographic units on the plateau.

The morphology of any region highly influences the physical and chemical conditions (fertility in the present case) of the soils by controlling the drainage. The next few paragraphs attempt to give a glimpse of the various geomorphic features in the Asela area, together with the drainage conditions as related to soil characters.

Fig.4 shows a rough subdivision of the area on the bases of the pattern and density of drainage. In general, somewhat parallel belts of decreasing intensity of drainage (increased water permanence in soils) from the mountain to the floor is noticeable.

The high altitudes of Chillalo (approximately above 3000 m) show radial drainage and high density of streams with commonly narrow, sharp-crested divides. The interior

of the caldera at the top (drained by the head waters of the Kulumsa River) does not belong here.

The slope which commonly exceeds 30 percent does not favour proper soil development. Moreover, it enhances the removal of already developed soil by erosion as is evidenced by some truncated profiles. The thick vegetation cover has its own role in the nature of soil development. On the one hand, it furnishes organic matter which forms humic acids that aid in chemical weathering; on the other, it prevents rain drop erosion and also other erosive processes.

Despite the thick vegetation cover, the soils are patchy in occurrence, with shallow profiles.

The foothills and the base of the mountain are characterized by the same radial pattern of drainage. The small streams that emanate from the higher parts, flowing to the gentler slopes, join to form a smaller number of larger rivers and streams. For this reason, the density of drainage is reduced. The divides between river channels are wide and mostly flat-topped.

The soils here enjoy perfect aeration and they develop deep profiles.

The third unit is the gently inclined high land area bounded from the lowland by the main escarpment of the rift. It is flat to gently sloping. The stream and river channels are spaced very wide apart. A certain degree of structural (fault) control of drainage begins to manifest itself here.

This is evidenced by the trend some streams follow, which is normal to the general east-west trend of flow on the plateau.

Run-off is not well concentrated and the gently sloping portion of this land segment is affected by sheet erosion. However, lateral cutting of fields by rivers is also operating.

Waterlogging is a problem in the soils of this area.

In the proximity of the marginal escarpment, a small number of basaltic cones spot this section of the investigated area.

The rift valley area, including the marginal Eastern Escarpment, is dominated by structural landforms. Fault scarps and less commonly fault line scarps and composite scarps constitute important geomorphic elements.

On the main escarpment, a few cases of fault - controlled, minor rotational landslides have been observed. Very small scale talus fans could also be seen at the foot of this escarpment. Both features are not mappable at the scale given.

Faulting, having been the major tectonic phenomenon that operated in the area, it produced a series of small grabens and horsts. Few of the former have changed to small lakes and marshes.

The rift floor is a receptacle of debris derived from mass wasting and river loads. In addition to these, the rift floor is marked by small volcanic cones.

Drainage channels are strongly guided by faults. Rivers cascading the escarpment gradually, but most of the time abruptly change their east-west trend to that of the rift. In general, the area lacks good drainage. The soils have good texture, but they are rocky and stony.

The Asela area is drained by streams which rise from the mountain area and join the Ketar River. This river in turn flows into Lake Zway.

5. GEOLOGY

5.1. General

The volcanic and tectonic events which took place in the Asela area, essentially make a chapter in the volcano-tectonic history of the Main Ethiopian Rift. It would thus be appropriate to present a summary of the most important features of the latter before discussing the study area.

The Main Ethiopian Rift being a segment of the East African Rift System, is laterally bound by the Ethiopian Plateau to the west and the South-Eastern Plateau to the east (Fig.5).

It is a huge graben which is occupied by volcano-tectonic lakes. It is characterized by normal, step faults arranged in an en echelon style and trending mainly NNE - SSW, with rare NE - SW, N - S and NW - SE striking faults (Mohr 1967; Di Paola 1972; Geze 1975 and others).

Except on the Amaro (Mohr 1962, 1966; Baker et al. 1972) and the Kella (Di Paola & Seife 1979) Horsts where Pre-Tertiary rocks outcrop, the Ethiopian Rift is associated, essentially with Pliocene to present volcanism and volcano-sedimentary products (Abbate & Saggri 1979 in: Merla et al. 1979).

The two plateaus on its either side are characterized by a number of large and small shield volcanoes and by relatively less intense tectonism.

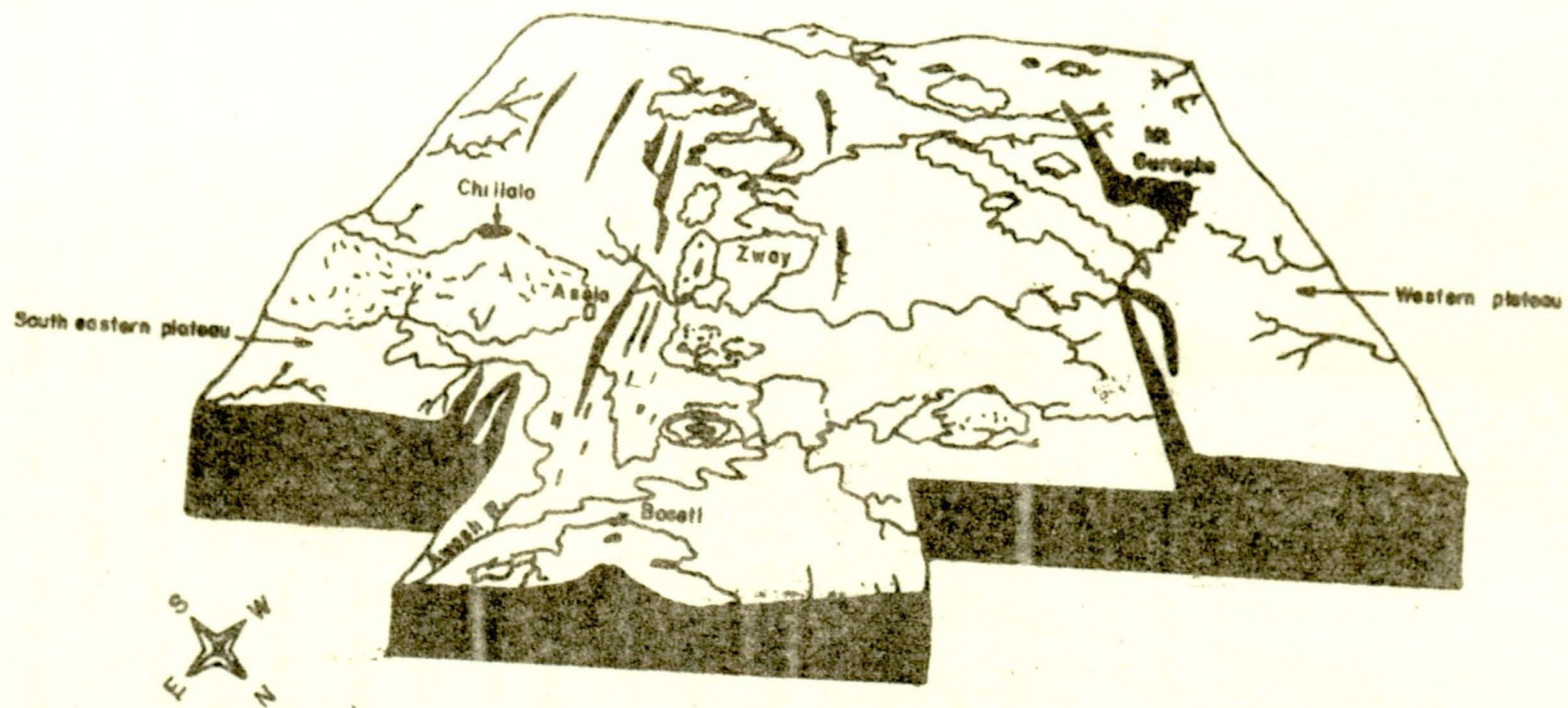


Fig.5 Block diagram showing the main structural features of the Ethiopian Rift Valley between $7^{\circ}00'$ & $6^{\circ}40'$ lat

(After Di Paola 1972)

Many authors (Burke & Dewey 1970 and others) relate its genesis to the Afro-Arabian Doming of the Lower Tertiary times. On the other hand, recent views (Bahat 1979; McConnel 1980 and others) maintain that the East African Rift as a whole, is an ancient feature.

According to Bahat's model of rift genesis (Fig.6), fracture initiation took place at lake Malawi (along C); by fracture propagation and repeated bifurcation, the Ethiopian Rift (E) came into being.

A portion of the investigated area falls within the central part of this complex structural system.

The Asela area comprises lava flows and pyroclastics belonging to the "Nazreth Series" and "Wonji Series" of Meyer et al. (1975). The rocks occurring in this area are ignimbrites, welded and unwelded tuffs, basalts, trachytes and trachybasalts. Their sources were both fissural and central type.

Different phases of faulting are evident in the area.

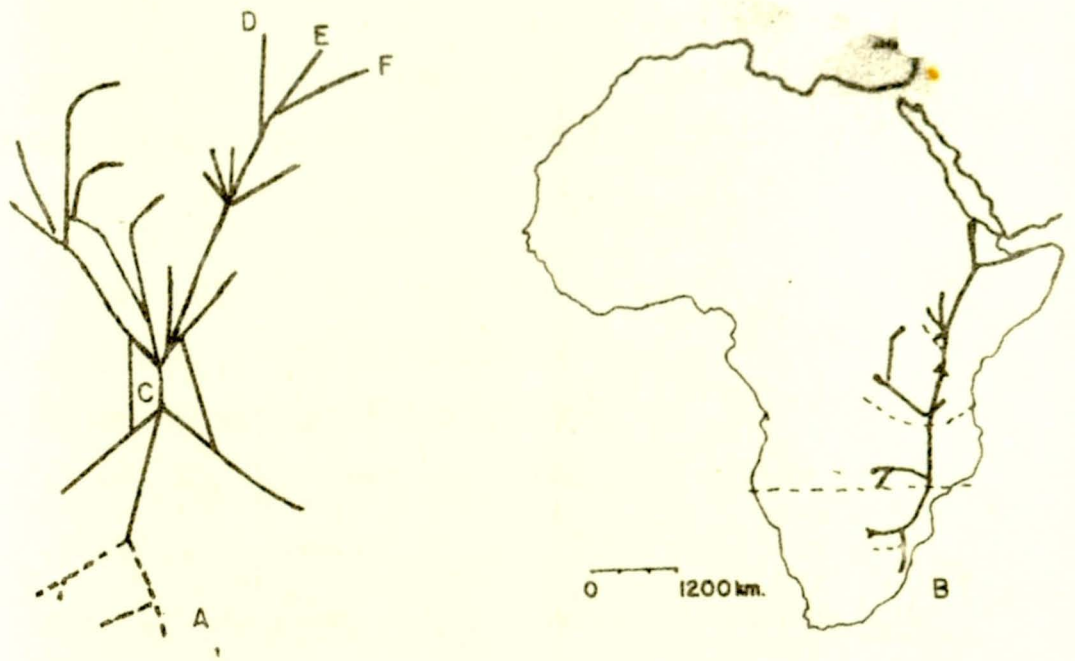


Fig. 6 A. Sketch Map Of Fracture Model Resembling Major Rifts In The African Continent (after Bahat, 1979)

B. The African Rift System (after Bailey, 1964)
Dotted Lines Indicate Position Of Initial Fracturation.

C. Centre of fracture inflation

D. Red Sea

E. Main Ethiopian Rift

F. Gulf of Aden

2. Geology of the study area

5.2.1. Stratigraphy

The succession of rocks in the area, from the youngest to the oldest, can be summed up as follows:

Rift floor basalts

Rift floor pyroclastics

Main escarpment basalts

Pyroclastics of the plateau

Trachybasalt and Trachytes of Chillalo

Chillalo Basalts

Chillalo is a NNE - SSW elongated volcanic mountain on the South-Eastern Plateau. It rises gently from the flat-lying highland to an elevation of 4000 m a.s.l. at its summit. It stands east of the town of Asela prominently overlooking the rift towards the west and it is topped by a caldera, which, according to Di Paola (1972), is about 6 km in diameter.

Its products include basalts, trachytes and trachybasalts and are the oldest rocks in the area (Fig.7).

5.2.1.1. Chillalo Basalts

The marginal escarpment shows, at the Bolkesa River waterfall, a downthrow of about 220 m. The Chillalo Basalt, which is exposed at the base of the escarpment, attains a maximum

thickness of 15 m (Fig 8 column A). Several valley sides and floors on the western side of Chillalo mountain indicate the continuity of this lava flow to higher elevations, under the cover of the plateau pyroclastics and the other younger products of Chillalo itself. It has a large extension over the plateau to altitudes of about 3000 m, as observed on the south-western side of this mountain, at Borora.

At different places, different rocks are found directly overlying the Chillalo Basalt.

At the bottom of the main escarpment, it is locally floored by a 2 m thick agglomeratic material, and covered, conformably, by another, thick (approximately 40 m) agglomeratic unit. Along the course of the Kulumsa River (North-east of Asela), the basalt is overlapped by Ignimbrites. About 1 km upstream along the same river, it is overlain by trachybasalt, while at the Tiliku Dasha River (south-east of Asela), Chillalo Trachytes directly rest on it.

The rock is typically aphyric (with rare, small phenocrysts), dense and greyish-dark in color. Scoriaceous, strongly porphyritic and vesicular varieties are also not uncommon.

Despite their macroscopic differences, all varieties have a general petrographic similarity, with minor differences.

They are characterized by a groundmass of feldspar microlites with some interstitial glass (in some samples) and abundant iron oxide. A scoriaceous variety showed a high vitric groundmass. The dominant mineral occurring as phenocrysts, is plagioclase feldspar (labradorite) which rarely shows zoning. Also occur as phenocrysts, partly iddingsitized olivine, hypersthene and biotite. Olivine and pyroxene occur in the groundmass as well.

Their mineralogical differences (eventhough minor), together with the variation of the rocks directly overlying them, suggest that the Chillalo Basalts may not be the products of one-shot eruption only. These basalts belong to the "Pliocene Main Basalts" of Juch (1975).

5.2.1.2. Trachybasalt and Trachytes of Chillalo

The two rock types are discussed together, because of the lack of clear stratigraphic relationship between them; none of them was found overlying the other or vice versa. The opinion expressed in this paper that the trachybasalt is

older than the trachyte is briefly discussed at the end of this section.

The second oldest rock in the mapped area is the Chillalo Trachybasalt. In the succession exposed (about 200 m thick) at the main escarpment, along the Shorima River (Fig.8, column B), the base comprising a thickness of 10 - 15 m is represented by this trachybasaltic flow. It is interbedded with agglomerate for a thickness of about 60 m.

In a manner analogous to the basaltic unit, it extends over the plateau under the cover of younger volcanics. It is traced at the Kulumsa River Valley, overlying the basalt and covered by an ignimbrite flow.

It is slightly porphyritic, greyish dark in color and showing pronounced banding both macroscopically and microscopically. The orientation of the bands as observed in the field suggests an origin from Chillalo Mountain.

Petrographically, it is characterized by a microlitic groundmass with abundant iron oxide. The feldspar microlites occasionally show semi-parallel orientation. Plagioclase feldspar (Andesine - Oligoclase) which at times shows strong fracturing; with subordinate orthopyroxene

(hypersthene), clinopyroxene, biotite, iddingsitized olivine and alkali feldspar occur as phenocrysts.

The author is of the opinion that this flow (and also the underlying Chillalo Basalt) belong to early stages of volcanic activity of the Chillalo and that they were exposed on the plateau (along river channels) and at the marginal escarpment by erosion of the overlying rocks and by major faulting, respectively.

The absence of Chillalo Basalts at the base of the Shorima section while being exposed at the Bolkesa (south of Shorima), could be ascribed to the northward decline in the magnitude of the downthrow. The latter in turn is due to the scissor-type nature of the fault. Based on the observation at the Kulumsa River, where the basalt underlies the trachybasalt, it looks permissible to infer that the same situation exists at Shorima (i.e. the basalt is found buried under the trachybasalt).

The higher part of Chillalo Mountain comprises trachytic rocks which show abrupt, lateral variation in texture and color.

These rocks extend westward and they disappear before reaching the town of Asela. The absence of trachytic rocks in the successions of the main escarpment could only be due to inexten-

-sive nature of the lava flow.

At higher altitudes, plug-like trachyte dykes, radially disposed around the caldera, are very common. The trachyte flow radially dips towards the lower topography, which is indicative of an evident source from Chillalo Volcano.

Megascopically, the rock is typically grey in color and porphyritic, with abundant feldspar and very few biotite phenocrysts. Besides, vesicular and aphyric varieties are also present.

The spectacular lateral variation in texture may be because all the lava did not flow out at one time, but accumulated in a series of small eruptions. An alternative explanation could be that it was a one-shot phenomenon, but the lava was not uniformly exposed to the atmosphere while it was cooling.

The variation in color could be explained in the above manner, or it might be attributed to differential weathering.

The possible explanations given for the color and textural changes of the trachyte do also apply to the basalts.

In spite of their surprisingly different appearances in hand specimens, the trachytes have

essentially similar mineralogical constitution, as petrographic studies evidenced.

Thin section studies show trachytic texture which is common to all varieties. The groundmass is trachytic with interstitial glass. Occasionally zoned plagioclase feldspar (within the oligoclase-andesine range) and alkali feldspar (sanidine) usually associated with subordinate biotite, hornblende, olivine and subhedral-euhedral cossyrite grains occur as phenocrysts. Iron oxide is a common accessory. In some samples, some of these oxides show a yellowish alteration rim of leucoxene - an alteration product from ilmenite.

It should be noticed that this mineral assemblages represents the Chillalo Trachytes, but it is also true that one or two minerals lack in some varieties or they may occur in different amounts if present.

Kazmin and Seife (1978) pointed out that the Chillalo Volcano evolved from rhyolites to trachytes. However, no rhyolitic rocks were identified in the present field work, at least in the surveyed portion of the mountain. Thin sections of rocks collected from the mountain area did not show any quartz phenocrysts.

In this paper, it is suggested that the evolutionary trend of Chillalo volcanicity was from basalts - through trachybasalts - to trachytes.

Field evidences clearly indicate that the basalt belongs to the earliest stage of volcanic activity. An ambiguity presents itself as to whether the trachybasalt or the trachyte is older. It has already been mentioned that the latter is younger.

The trachybasalt does not show up at elevations higher than where it was found at the Kulumsa River Valley suggesting that it is under the cover of the trachytes. Secondly, trachybasalt is an intermediate between basalt and trachyte. It is therefore true that the assumed trend of volcanic evolution is consistent with the theoretical trend followed by the differentiation of a basaltic magma to acidic ends, eventhough the latter stage has not been reached in the present case.

Several authors (Kazmin & Seife 1978, Mohr 1967 and others) believe that the activity of Chillalo began late in the Pliocene. The middle Pliocene - Middle Pleistocene age given by Di Paola (1976) for rocks from the western base of Chillalo, more or less agrees with the former.

5.2.1.3. Pyroclastics of the plateau

This large composite unit is extensive from the marginal escarpment to very high altitudes on the western side of Chillalo. In its entirety, it shows a very high degree of lateral and vertical (from one flow to another) variations which gave the bases for the identification of the different flows within it.

The distinction of the various flows was based mainly on their field appearances, such as color, texture, degree of welding, structure and the type, size and abundance of xenoliths whenever present.

Sections distributed throughout the area of investigation (and one outside the area), mainly on fault scarps and valley sides, have been studied and discussed individually, with attempts to correlate the rocks in one section with those in others.

Bolkesa (A)

It has already been mentioned that the Chillalo Basalt exposed at this place is sandwiched between a very thin layer of agglomerate at the bottom (locally) and a thick one at the

top, the thickness of the intercalation reaching upto 60 m.

The thick agglomerate consists of gravels and boulders belonging to the underlying basalt. It is separated from a thick sheet of greenish, compact ignimbrite (approximately 50 m thick) by a thin layer of ash flow.

The ignimbrite is fine grained and shows some feldspar phenocrysts, baked reddish lithic fragments and basaltic fragments. It has characteristically abundant, fairly welded, elongated perlitic fiamme of variable sizes, reaching a maximum length of 50 cm.

Petrographic study shows a groundmass of glass with flow banding. The flow bands sometimes form a wavy curve around feldspar grains. Phenocrysts of plagioclase (within the oligoclase-andesine range) and partially devitrified glassy fiamme are common.

Another layer of ash comes between this ignimbritic flow and the overlying, thin (3 - 6 m), subhorizontal layer of fine-grained basalt. Because of its stratigraphic position, this basaltic flow cannot be correlated with the Chillalo Basalts or with the escarpment basalts. The origin of this basalt is uncertain.

Shorima 1 (B)

The whole thickness of this exposure is about 200 m, out of which the bottom 60 - 65 m is an intercalation of agglomerate and trachybasalt, the latter forming the base. Upon this intercalation lies, conformably, a weathered tuffaceous material about 40 m thick, which is covered by a thin layer of ashflow. This in turn is overlapped by a fine grained basalt interbedded with agglomerate.

A dense, greenish-grey ignimbrite with insignificant amount of fiamme, blankets the basaltic flow. The former does not show a considerable mineralogical difference from those previously discussed.

Except for differences in thicknesses, the uppermost three pyroclastic flows in this section apparently correlate with their respective equivalents at the Bolkesa.

Shorima 2 (C)

A downthrown block in the very proximity of the previous section shows the following pyroclastic sequence (Fig.8, column C).

Three different pyroclastic flows of considerable thicknesses terminate the succession above the basalt flow. The oldest of these is a grey ignimbrite, 20 - 25 m thick, with few, well - welded, but strongly weathered vitreous fiamme. It has a glassy groundmass with abundant phenocrysts of plagioclase feldspar. The fiamme are altered to palagonite around their rims. Hornblende, iron oxide and extremely few grains of zircon are also present.

This ignimbritic flow is overlapped by a slightly weathered pinkish ignimbrite with a small number of poorly developed glassy fiamme.

It is characterized by a mixed glass - microlite groundmass in which the feldspar microlites show spherulitic texture. Feldspar phenocrysts (oligoclase - andesine) in which zircon is rarely included are abundant. Palagonite rims around glass fragments are common and devitrification to feldspars is also frequent.

The youngest rock in this succession is a poorly consolidated, highly weathered tuffaceous material containing some foreign inclusions, mainly of basaltic composition. It continues for a small horizontal distance on the edge of the plateau and interfingers with other pyroclastic rocks.

60 - 70 meters of the 120 m thick succession consists of a greyish ignimbrite with abundant, fairly-welded perlitic fiamme and xenoliths of basalt. Mineralogically and texturally, it is the same as the greenish, compact ignimbrite between the two ash flows in the Bolkesa section.

A 1 m thick ashflow locally rests on this unit. The latter occurs under a grey, fresh tuff which in turn is covered by another layer of ash. A thin subparallel perlite layer overlaps the younger ash flow.

The perlite has a groundmass of glass and microlites. Fragments of glass, at times devitrified to feldspars, few iron oxide and amphibole grains are also present. The feldspar microlites sometimes show spherulitic texture.

The greenish-grey ignimbrite resting on the perlite is the same as the ignimbrite of the same color at section B.

The youngest flow in the sequence can be correlated with those of Bolkesa and Shorima¹.

NW of Kulumsa Town (D)

This section is situated outside the mapped area on the roadside to the rift.

Different pyroclastic rocks are exposed here, by a fault with a downthrow of 50 m due west (Fig.8, column D).

The bottom 15 m of the succession comprises a perlitic ignimbrite similar to those perlitic ignimbrites of sections A and C.

A strongly weathered tuff overlies this flow. After the deposition of the tuff, there was a period of quiescence during which a 50 cm thick reddish soil developed (Plate 1).

When volcanic activity started again, a pumiceous ignimbrite (30 m thick) was erupted with minor intercalations of an ash flow and a thin layer of perlite (Plate 2). This flow is poorly welded and is characterized by a fine grained groundmass with feldspar phenocrysts, abundant pumice fragments and basaltic inclusions.

Kulumsa River (E)

Along the course of the Kulumsa River, northwest of Chillalo and about 3 km east of the town of Kulumsa, the succession begins with the Chillalo Basalts and is followed by the trachybasalt flow within which a tongue of tuffaceous material, pinching out in the upstream direction, is interbedded (Fig. 8, column E).



Plate 1. A reddish soil that developed during a period of volcanic quiscence



Plate 2. The pyroclastic succession NW of Kulumsa Town (section D)

Overlying the trachybasalt is a light grey, slightly weathered ignimbrite with a glassy ground-mass, few elongated fiamme (mostly devitrified), plagioclase feldspar phenocrysts (oligoclase - andesine) and a few grains of cossyrite.

Borora (F)

At the upper course of the Tiliku Dosha River, The Chillalo basalts could be seen exposed by the erosion of the overlying trachyte (Fig.8, column F). Outcrops of the trachytic rocks continue upslope upto the summit of the mountain.

Ketar River (G)

A 25 m thick succession along the Ketar River (southeast of Asela) at a bridge on the road to Kersa shows a tuffaceous material flanked on either side by two younger ignimbritic flows (Fig. 8, column G).

The flow directly superimposed on either side of the tuff is a compact, unwelded ignimbrite, with well developed columnar joints and containing some foreign inclusions.

Mineralogically, both ignimbrites do not differ much from most of those already discussed.

The youngest and the oldest flows occur at about the same elevation on the top. This might have been due to the microtopography that existed a priori. The low resistance of the tuff to erosion could have produced microhills and troughs which were later covered by the ignimbrites. The latter were then eroded from the top of the microhill exposing the tuff. On one side, the tuff and the middle unit are related by a fault contact.

The waterfall along the Ketar River at this place, could have resulted from the easy removal of the tuff by erosion.

Based on the K/Ar age measurements of Morbidelli et al. (1975), an Upper Pliocene - Lower Pleistocene age was assigned by Meyer et al. (1975), to the "Nazareth Sereis" to which the plateau pyroclastics in the examined area belong. Both central (Mohr, 1967) and fissural (Meyer et al. 1975) origins have been suggested for these rocks.

The writer is of the opinion that Chillalo Volcano was not the source, because no trace of ignimbrites is observed at elevations higher than about 3000 m. Possible fissural sources are suggested in the next section.

The slopes of Chillalo and the rest of the plateau area upto the marginal escarpment, are affected by a number of faults (parallel to the strike of the rift) which are probably older than the main escarpment. The latter is of Pleistocene age according to Mohr (1967) and Meyer et al. (1975). The morphology of fault scarps gives an insight into their noncontemporaneity.

The faults which produced the marginal escarpment and those in the rift are almost always vertical, showing small or no deviation from their fault mirrors. In contradistinction to these, most of the plateau fault scarps are highly inclined. There exists a wide angular disposition between the scarps and their fault mirrors, suggesting a longer period of erosion (Fig. 9).

There were probably many ancient faults like these on the plateau which possibly issued the plateau pyroclastics. Later on, they were either covered by their own products or were obliterated by a long period of erosion, or both.

A typical example of such faults is encountered about 2 km east of the town of Kulumsa.

On the upthrown side of a fault, a yellowish, weathered ignimbrite directly rests on the Chillalo Basalts, while the downthrown block shows a thick jointed ignimbrite between the two different rocks (Fig. 10).

This situation might be explained in the following manner. The basalt flow was displaced by the fault prior to the eruption of the ignimbrites. Subsequent to this event, the ignimbrite in the middle issued through the fault and was deposited on the lower topography. Its absence on the uplifted side probably was due to the high gradient produced by the fault and by the original topography.

After all these events, the youngest flow which shows a characteristic westward thinning (Plate 3) erupted, probably from another fault located upslope and covered the two rocks.

The products of these old faults apparently did not always flow on the upthrown sides.

5.2.1.4. Main escarpment basalts

Basaltic rocks are subordinately associated with the plateau ignimbrites. They occur mainly

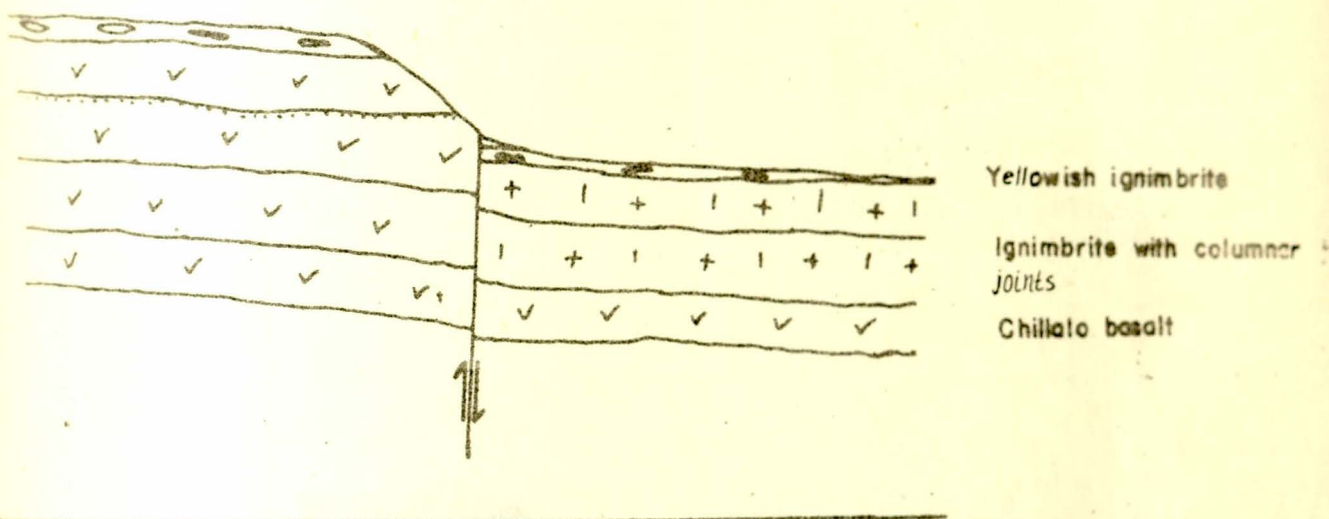


Fig.10 Model of old faults which erupted the plateau pyroclastics



Plate 3. A westward thinning ignimbrite, erupted from one of the old plateau faults

in the top parts of the high walls which delimitate the rift from the adjacent Eastern Plateau. Patchy occurrences of these basalts are also noticeable around Duna (SE of Asela) on the bed of some stream channels and on one side of a fault.

This basalt might be older than that of the main escarpment since the fault through which it issued is presumably older than the main escarpment.

The main escarpment basalts show an alignment paralleling the rift, which is suggestive of eruption from these gigantic faults. They are superimposed by scoriaceous cones also elongated in the same trend.

As in the Chillalo Basalts, aphyric, porphyritic, vesicular and scoriaceous varieties are observed. They are, however, typically dark, porphyritic feldspar basalts.

The groundmass is composed of feldspar microlites, iron oxide, pyroxene and olivine. The phenocrysts are plagioclase (Labradorite), occasionally zoned olivine with iddingsite rims.

These rocks are younger than the ignimbritic succession of the plateau, because they poured through the faults which cut the pyroclastics.

5.2.1.5. Rift floor pyroclastics

These are the oldest of the two rocks outcropping on the rift floor at the Asela area. Two major types have been identified: a greenish, compact ignimbrite containing a few, fairly welded, small fiamme and small inclusions of lithic fragments. Dominantly, it crops out at Deneba (northwest of Asela, near Deneba Farm) and at Dugda (southwestern part of the mapped area).

Petrographically, it is not at all different from the ignimbrites of the plateau. It is glassy and consists of feldspar phenocrysts, devitrified glassy fiamme and few inclusions.

Another important rock on the rift floor is an unwelded pumiceous rock containing abundant pumice and a small amount of lithic inclusions. A significant outcrop of this flow is found on a horst immediately east of Shetmata Marsh. Both of these rocks are associated with intercalations of volcanic ash.

The rift floor pyroclastics are intensely affected by the Wonji Type Faulting (discussed in the section on tectonics). The maximum thickness of these rocks is observed on the walls

of minor horsts and scarcely reaches 30 m.

No clear stratigraphic relationship does exist between the two flows and sufficient age determinations are also lacking. Mohr (1967) cumulatively gave an Upper Pliocene age both to the rift and plateau ignimbrites of Southern and Central Ethiopia. Morbidelli et al. (1975) pointed out (from K/Ar age determination) that the activity of Boseti Mountain in the Ethiopian Rift started less than 2 m.y. ago. Di Paola (1972) also suggested a Pliocene age. However, the fact that the pyroclastics in the rift portion of the area predate the Wonji Fault Belt (1.6-1.8 m.y. old, according to Meyer et al., 1975) stands clear.

Mentioning the absence of clear eruptive centers, Di Paola (1972) suggested a fissural origin for these rocks. In this paper also, it is taken that they must have issued through faults and fissures which were later buried by younger volcanic products and also obliterated beyond cognizance by the younger Wonji Fault Belt. The possibility is that some of these faults could still be existent, but their distinction becomes difficult.

In general the pyroclastic rocks of the area have similar mineralogical make up, even-though they differ in color, texture, structure and the degree of consolidation. All of them have in common vitric grains, undeformed lithic fragments and crystals of plagioclase feldspar (Oligoclase - Andesine) with glassy and sometimes microlitic groundmass.

5.2.1.6. Rift floor basalts

The rift floor basalts are the youngest rocks in the area and they show linearity of distribution paralleling the general strike of the rift. Their sources were mainly gaping fissures and faults with some small centers which prevalently erupted scoriaceous material. These basalts belong to the "Wonji Series" of Meyer et al. (1975).

In general, they have scoriaceous surfaces. Olivine and plagioclase feldspar are the common phenocrysts in a generally microlitic ground-mass. In the vesicular varieties, there is a spectacular upward increase in the number and size of vesicles and an evident decrease in their deformation (elongation). An interesting situation indicating a fault-source, has been encountered on a small

horst (about 1 km wide), northeast of Shetmata Marsh. The western half of the horst and the fault scarp on this side show basaltic rocks, while the eastern half and the scarp on the same side are entirely composed of ignimbritic rocks. A possible explanation could be that the ignimbrite was covered on the western half of the horst by the basalt flow of a small magnitude which poured from the fault on this side.

5.2.2. Tectonics

Faulting is the preponderant tectonic phenomenon that operated in the area. Faults of variable ages affected the region, with a declining intensity from the rift to the plateau. A general decrease in age of faults from the plateau to the rift is evident.

From the examination of fault scarp morphology, the oldest faults are those on the plateau, excepting the young minor post-calderic faults which disturbed the interior of Chillalo Caldera. Such old faults have been observed around the town of Asela and higher up on the slopes of Chillalo Mountain. Their typical feature as already stated before, is a high degree of erosional recession of the scarps which form wide angles with the vertical plane of the fault mirrors.

Their trend is persistently similar to that of the rift. Most of them extend over a long distance (upto 6 km). In general, they are straight and at times gently sinuous. The vertical drops mostly amount to a few tens of meters, which, most probably, do not represent the actual, original magnitude.

The observation that faulting was less intense on the plateau than in the rift, does not necessarily preclude the possibility that there was a greater number of faults in the former (than at present) before their obliteration.

The second oldest faults are those of the main escarpment which produced the existing elevation difference between the rift floor and the plateau. In the area studied, the southern portion of the marginal escarpment is constituted by a series of normal, step faults, (almost always downthrown west), which gradually descend to the rift floor. Northwards, it becomes a single fault scarp with throws that can easily exceed 200m. Farther north within the area, it dies out gradually, to continue again in an en echelon manner.

The rift portion is affected by a rift-in-rift system of structures which resulted in minor horsts and grabens upto 1 km wide and in the rejuvenation of the marginal escarpment faults.

These faults are generally NNE - SSW trending, scissor type, normal, step faults with small downthrows (upto about 30 m) to the west as well as to the east. They are mostly curvilinear and show an em echelon style of arrangement and they belong to the Wonji Fault Belt of Mohr (1967).

Some of the grabens have, partially or completely, turned into swamps (Plate 4). The Shetmata Marsh, on the western edge of the area is a typical example. Aerial photographs of the area indicate an ancient river channel, truncated by faulting. Meyer et al.(1975) pointed out that this was the old course of the Ketar River to Lake Zway.

The youngest faults in the area are those cutting some scoria cones on the floor of the rift. It is also possible that there are undetected faults younger than these.

The top part of Chillalo Mountain, especially the interior of the caldera, is affected by minor faults probably triggered by the activity in the rift.

Very few gapping fissures (upto 1 m wide) which issued basaltic lava, are also present within the rift valley. They show no vertical displacement.

In addition, the interior of Chillalo Caldera is an evident manifestation of post-calderic fissural



Plate 4. A graben which turned into a small lake

activity. The fissures are radially disposed within and outside the caldera. Trachytic dykes, which now formed wall-like and plug-like structures intrude these fissures. Mohr & Potter (1976) relate these plug-like dykes to the Sagatu Dyke Swarm of the Eastern Plateau.

The marginal eastern escarpment and the Wonji Fault Belt follow a general NNE - SSW strike and both suffer lateral displacement. Satellite imageries clearly indicate that, one such offset took place at about the latitude of Asela. At the same place, the NNE trend of the Eastern Escarpment could be seen swinging to NE. This fact was also observed by Meyer et al. (1975).

The elongation of Chillalo Volcano parallel to the rift might be ascribed to an influence of a line of weakness along the position of this volcano, which was initiated prior to the eruption. The outpouring Chillalo lavas, at least partially, were possibly guided by this line of weakness.

A general picture of the evolution of rifting seems that it was originally a wide and shallow graben and lately became restricted to a narrow zone with pronounced deepening.

The different stages of the volcano-tectonic events which took place in the area, can roughly be summarized as follows.

- 1) Chillalo Basalts erupted first, followed by trachybasalts and finally by trachytes.
- 2) The pyroclastic rocks of the plateau issued through old, plateau faults.
- 3) The marginal escarpment came into being by a major phase of faulting, which also exposed the two oldest rocks of Chillalo and the succession of the other plateau rocks.
- 4) Basaltic lavas poured through the escarpment faults and the associated cones.
- 5) The rift pyroclastics erupted from fissures and faults.
- 6) Pyroclastics of the rift were intensely faulted forming grabens and horsts; and
- 7) Basic volcanism strictly limited to the Wonji Fault Belt (which affected the rift pyroclastics) developed.

In the area, there was a general migration of volcano-tectonic activity from chillalo towards the rift. This is indicated by the subparallel belts of faults and rocks of decreasing ages in this direction. The decrease in the age of volcanics directed towards the Wonji Fault Belt has been shown for the Afar and the Main Ethiopian Rift by Zanettin and Justin-Visentin (1975).

6.1. Soil Forming Factors And The Soils Of The Study Area

Soil is an extremely complex system which possesses a large number of physical and chemical characteristics which are functionally related to five soil forming factors: parent material, climate, biology (organism), topography and time (age). These factors are found in nature in a great variety of constellations. All factors operate jointly and each contributes to the characteristics of the soils formed. Nevertheless, the relative significance of each factor differs from place to place. A given combination of the five factors of soil formation gives rise to a certain set of soil properties and a change in one of them shifts the trend of soil development, thus resulting in a new set of properties.

The difficulty in the field arises from the requirement of maintaining four of the five soil forming factors in order to ascertain the nature and influence of the variable factor on the properties of the soils (inherent fertility status in the present cases).

Eventhough it is very difficult to find this condition satisfied in nature, a reasonable approximation has been attempted in this survey. However, since all factors are simultaneously operative, the current study

and many other similar studies fall short of making definite statements pertaining to the existing relationships between soil properties and a given factor of soil formation.

In the Asela, the result of the intricate interactions among these factors was to produce different soil types with differing chemical and physical properties and hence with differing fertility status (Fig. 11).

In general, disregarding the soils of the mountainous area to which emphasis was not given, the following three major and two minor soil types could be identified in the study area.

1. The dark - dark greyish brown - dark brown soils constitute a very important soil unit, especially in terms of their large spatial extent. They occupy the area around and south of the town of Kulumsa, extending southwards on both sides of the main highway upto the northern limit of Asela. Southwards from this limit, they cease to appear on either side of the road, but dominate the fields northwest, west and southwest of the town. They also occur in the lowland in a very low proportion.

These soils develop on sites of arrested drainage (poorly drained - imperfectly drained), i.e., depressions and flat - almost flat surfaces with

slope usually less than 10 percent. Both runoff and internal drainage within the soil profiles are highly impeded.

When dry, the dark - dark brown soils show wide (upto 20 cm) and deep (upto 80 cm) cracks. Not uncommonly, they also show slickensides and gilgai microrelief.

Texturally they are found to be mostly clayey throughout the profile and very rarely clayloam somewhere within the profiles (Table 1).

Due to their high clay content, they show high water-retaining capacity but poor transmission. Permeability test on these soils at the Asela livestock area gave a value of 0.1 cm/hr.

2. Another important soil unit within the survey area comprises the reddish upland soils (commonly reddish brown). From the northern end of Asela, the dark - dark brown soils give place to the reddish soils. The latter cover both sides of the main highway through the area. They are more extensive to the well drained foothills of Chillalo than to the west wherein drainage condition becomes progressively poorer. Farther east, they are replaced by the brownish soils of the mountain. The valley bottoms within the regime of these soils, however, have developed darker soils.

Table 1

Profile No.	Depth (cm)	Texture				PH	Org. Matter %	Total N %	Avail. P Ppm	Avail K Ppm	Exch. Ca Meq/100 g Soil	Exch. Mg Meq/100g Soil	C.E.C. Meq/100g Soil
		Sand %	Silt %	Clay %	Description								
1	0-70	31.0	34.0	35.0	cl. loam	4.85	6.90	0.308	2.7	1250	24	3	39.6
	70-110	11.0	10.0	79.0	clay	6.15	0.35	0.042	7.2	750	"45"	5	44.6
	110-155	14.0	21.0	65.0	clay	7.05	0.52	0.042	8.1	1000	42	3	45.8
	155-240	15.0	26.0	59.0	clay	6.90	0.59	0.028	5.4	750	30	10	37.6
2					Sandy cl								
	0-15	51.0	24.0	25.0	loam	6.40	0.17	0.028	3.6	500	12	7	33.2
	15-25	81.0	12.0	7.0	loam san	6.70	0.79	0.070	1.8	1500	10	1	16.6
3	0-20	43.0	30.0	27.0	loam	6.05	0.35	0.042	4.5	1000	25	7	39.6
	0-30	7.0	16.0	77.0	clay	4.75	1.04	0.070	8.1	1000	8	2	35
4	0-30	7.0	16.0	77.0	clay	4.75	1.04	0.070	8.1	1000	8	2	35
	Bel. 30	9.0	16.0	75.0	clay	4.90	1.79	0.098	10.8	250	12	1	29.0
5	0-20	41.0	32.0	27.0	loam	4.65	9.59	0.490	nil	1000	5	3	36.8
	20-50	7.0	26.0	67.0	clay	4.80	1.48	0.070	nil	500	10	3	30.6
	50-90	22.2	27.4	50.4	clay	4.65	1.55	0.084	nil	500	5	5	33.4
6	0-30	41.0	30.0	29.0	cl. loam	4.85	7.94	0.280	nil	250	25	9	40.8
	30-90	9.0	12.0	79.0	clay	4.90	2.76	0.126	1.8	750	39	1	42.6
7	0-60	9.0	19.0	72.0	clay	5.00	2.76	0.112	nil	500	30	5	44.6
	Bel. 60	11.0	12.0	77.0	clay	6.60	1.45	0.098	9.0	125	30	15	43.8
8	0-20	39.0	23.0	38.0	cl. loam	5.60	4.14	0.196	11.7	1250	15	10	37.2
	0-40	37.0	24.0	39.0	cl. loam	4.95	7.73	0.336	10.8	250	11	3	35.2
9	0-40	37.0	24.0	39.0	cl. loam	4.95	7.73	0.336	10.8	250	11	3	35.2
	Bel. 40	13.0	10.0	77.0	clay	5.85	2.07	0.098	9.0	250	30	1	40.6
10	30-50	43.0	36.0	21.0	loam	7.20	10.01	0.476	9.9	750	"72"	3	43.6
	90-110	49.0	30.0	21.0	loam	7.45	5.87	0.23P	7.2	375	"60"	5	36.0

Table 1 cont'd

Soil No	Depth (cm)	Texture				PH	Org. Matter %	Total N %	Avail. P Ppm	Avail. K. Ppm	Exch. Ca Meg/100 g Soil	Exch. Mg Meg/100g Soil	C.E.C. Meg/100g Soil
		Sand %	Silt %	Clay %	Description								
1	25-60	33.0	28.0	39.0	Cl. loam	7.25	3.62	0.168	11.7	750	"60"	"10"	41.6
	80-100	25.0	22.0	53.0	Clay	7.05	3.07	0.126	10.8	1500	"58"	2	46.0
2	0-25	27.0	32.0	41.0	clay	5.55	4.52	0.295	8.1	1000	20	1	34.6
	35-60	13.0	14.0	73.0	clay	5.50	1.24	0.112	11.7	750	26	4	37.6
3	0-20	22.0	35.0	43.0	clay	6.40	3.93	0.182	10.8	750	30	1	38.0
	20-40	21.0	28.0	51.0	clay	6.45	2.24	0.140	9.0	500	37	1	39.4
4	0-20	35.0	32.0	33.0	cl. loam	6.80	3.93	0.182	6.3	750	30	10	41.0
	0-25	39.0	36.0	25.0	loam	6.35	5.00	0.210	5.4	1500	23	1	23.8
5	0-30	29.3	45.0	25.7	"	7.25	6.56	0.294	9.9	1500	25	4	32.6
	30-60	21.3	43.0	35.7	Cl. loam	6.70	3.11	0.154	11.7	1000	32	3	37.6
6	60-110	23.3	37.0	39.7	"	6.55	1.73	0.112	nil	1500	24	1	27.6
	0-30	21.3	15.0	63.7	Clay	6.30	2.35	0.126	nil	1000	30	5	42.0
7	30-60	15.3	15.0	69.7	"	7.30	1.59	0.070	1.8	1000	33	1	43.0
	0-20	37.3	37	25.7	loam	7.50	3.31	0.168	nil	1000	28	2	41.6
8	20-50	49.3	29.0	21.7	"	7.90	0.17	0.028	0.9	1500	40	3	31.6
	0-20	47.3	35.0	17.7	"	7.70	9.11	0.490	3.6	1500	35	1	31.6
9	20-50	45.3	39.0	15.7	"	7.60	5.66	0.266	nil	1500	39	2	41.6
	0-20	27.3	19.0	53.7	clay	5.45	4.52	0.224	0.9	1000	25	5	37.8
10	20-45	17.3	17	65.7	"	5.30	1.79	0.126	9.0	750	18	8	42.6
	0-30	27.3	31.0	41.7	"	5.55	2.48	0.140	nil	1000	20	7	36.4
11	30-60	21.3	27.0	51.7	"	6.70	2.42	0.098	0.9	500	40	2	46.0
	60-100	7.3	11.0	79.7	clay	7.10	0.55	0.042	nil	750	21	"19"	47

Table 1 Continued

Profile No	Depth (cm)	Texture				PH	org.Matter %	Total N %	Avail.P Ppm	Avail.K Ppm	Exch.Ca Meq/100 g Soil	Exch.Mg Meq/100 g Soil	C.E.C. Meq/100 g Soil
		Sand %	Silt %	Clay %	Description								
22	0-25	27.3	35.0	37.7	Cl.loam	6.40	2.76	0.112	nil	875	18	12	34.0
	25-50	25.3	29.0	45.7	Clay	6.20	1.93	0.084	nil	750	38	2	39.4
	50-90	21.3	19.0	59.7	Clay	6.90	0.90	0.056	7.2	1000	"46"	"19"	42.0
23*	0-25	19.0	22.0	59.0	Clay	6.8	4.48	0.164	8.0	--	--	--	--
24*	0-20	34.0	39.0	27.0	Loam	6.4	--	0.264	8.7	--	--	--	--
25*	0-15	48.0	25.0	27.0	Sandy Cl.loam	6.6	3.52	0.346	8.9	--	--	--	--
26*	0-20	34.0	21.0	45.0	Clay	6.0	4.5	0.223	--	--	--	--	--
27*	0-25	24.0	37.0	39.0	Cl.loam	6.1	4.2	0.189	8.1	--	--	--	--
28*	0-20	22.0	38.0	39.5	Cl.loam	6.3	4.31	0.248	9.2	--	--	--	--

Analyses done at ARDU soil Laboratory.

*Possibly Contaminated Values.

Despite their clayey texture, they enjoy good aeration, because they occur on moderately - well drained surfaces.

These soils form deep profiles (upto 4 meters and sometimes more) which are characterized by homogeneity of color mostly throughout their depths.

3. A very high proportion of the rift portion of the study area is occupied by an important soil type: the dark brown - dark yellowish brown with common tendency towards grey. Texturally, they vary from loam to clay loam and clay and they are higher in sand and silt than the plateau soils. For this reason, they are said to possess good water absorbing and transmitting capacity. Besides, they show stony and rocky surfaces.

One of the minor soils in the area - the hydromorphic soils - may be considered as a subunit of the rift valley soils. This is owing to the fact that they strongly resemble the latter, differing only in that they are permanently water saturated. They occupy a considerable surface area in some grabens.

The second minor soil unit comprises those which developed on small scoriaceous hills belonging to the basalts of the main escarpment. They have poorly developed profiles resting on moderately steep slopes. The slope condition has strongly inhibited profile

development in terms of both depth and differentiation into horizons. It has also aided in the erosion of the existing soil, by sheet wash, gravity and to some extent by wind on the windward sides of the hills. The various properties of the soils heretofore discussed are the net products of several sets of combinations of the soil forming factors.

Inasmuch as soil fertility status is one of the properties of soils, it is but natural that it is subject to the laws in which the factors of soil formation operate.

The following chapters are devoted to a generalized qualitative and semi-quantitative evaluation of the inherent fertility status of the soils in the area and of their relationships with the factors which brought them into being. Attempts are made, without going to a lengthy excursion in the field of soil - plant interactions, to examine the influence of each factor on one or more of the fertility factors (such as pH, Ca^{++} and CEC) and on the gross inherent fertility as a whole.

6.2. Fertility

The term soil fertility may be defined as the state of physical and chemical excellence of a soil for plant growth.

The physical aspect of fertility of a soil generally includes its workability which is determined by its texture and structure and its fitness in fulfilling land preparation requirements (slope, soil thickness, stoniness and rockiness).

The inherent fertility status (chemical fertility) on the other hand is a measure of the amount and availability of plant nutrients.

Each physical and chemical factor of fertility is discussed in the following sections. Nevertheless, the classification of the soils of the study area into categories of fertility status is based only on the weighted average of five chemical parameters: soil reaction (pH), cation exchange capacity (CEC), organic matter content, available phosphorus and available potassium (Table 2, 3 and 4). The evaluated samples were mainly taken from depth of 0 - 25 cm and in a few cases from greater or lesser depths.

6.2.1. Workability

6.2.1.1. Texture

With the exception of three samples (two sandy clay loam and one loamy sand), all soils fall in the textural classes of clay, loam and clay loam. However, as soil

Table 2 - Inherent Fertility Ratings For Top Soils
(average 0 - 25 cm)

Profile No.	pH	Weighted average in the top soils				Fertility
		CEC meq/100g soil	Organic matter%	Avail. P ppm	Avail. K ppm	
1	L(4.85)*	H(39.6)	H(6.90)	L(2.7)	H(1250)	Medium
2	H(6.40)	H(33.2)	L(0.028)	L(3.6)	H(500)	Medium
3	H(6.05)	H(39.6)	L(0.35)	L(4.5)	H(1000)	Medium
4	L(4.75)	H(35.0)	M(10.4)	M(8.1)	H(1000)	Medium
5	L(4.65)	H(36.8)	H(9.59)	L(nil)	H(1000)	Medium
6	L(4.85)	H(40.8)	H(7.94)	L(nil)	H(250)	Medium
7	M(5.00)	H(44.6)	M(2.76)	L(nil)	H(500)	Medium
8	M(5.60)	H(37.2)	H(4.14)	H(11.7)	H(1250)	Very High
9	L(4.95)	H(35.2)	H(7.73)	H(10.8)	H(250)	High
10	H(7.20)	H(43.6)	H(10.01)	M(9.9)	H(750)	Very High
11	H(7.25)	H(41.6)	H(3.62)	H(11.7)	H(750)	Very High
12	M(5.55)	H(34.6)	H(4.52)	M(8.1)	H(1000)	High
13	H(6.40)	H(38.0)	H(3.93)	H(10.8)	H(750)	Very High
14	H(6.80)	H(41.0)	H(3.93)	M(6.3)	H(750)	Very High
15	H(6.35)	M(23.8)	H(5.0)	M(5.4)	H(1500)	High
16	H(7.25)	H(32.6)	H(6.56)	M(9.9)	H(1500)	Very High
17	H(6.30)	H(42.0)	M(2.35)	L(nil)	H(1000)	High
18	H(7.50)	H(41.6)	H(3.31)	L(nil)	H(1000)	High
19	H(7.70)	H(31.6)	H(9.11)	L(3.6)	H(1500)	High
20	M(5.45)	H(37.8)	H(4.52)	L(0.9)	H(1000)	High
21	M(5.55)	H(36.4)	M(2.48)	L(nil)	H(1000)	Medium
22	H(6.40)	H(34.0)	M(2.76)	L(nil)	H(875)	High
23	H(6.80)	ND	H(4.48)	M(8.0)	ND	High
24	M(5.40)	ND	ND	M(8.7)	ND	Medium
25	M(5.60)	ND	H(3.52)	M(8.9)	ND	Medium
26	M(6.00)	ND	H(4.50)	ND	ND	High
27	H(6.10)	ND	H(4.20)	M(8.1)	ND	High
28	H(6.3)	ND	H(4.31)	M(9.2)	ND	High

* Weighted average within parenthesis ; ND - Not Determined

Table 3 - Levels of fertility factors used to evaluate
The Inherent Fertility of top soils
(Modified after 'Soil and land appraisal and
training project, Phillipiness' 1977)

Fertility Factor	R a t i n g		
	Low	Medium	High
pH	Less than 5	5 - 6	More than 6
CEC (meq/100g soil)	Less than 16	16 - 25	More than 25
Organic matter (%)	Less than 1	1 - 3	More than 3
Available K (ppm)	Less than 50	50 - 100	More than 100
Available P (ppm)	Less than 5	5 - 10	More than 10

Table 4 - Key to evaluate Inherent Fertility of top soil

Inherent fertility status	Description of fertility status
Very high fertility	Four factors high, one factor medium.
High fertility	Four factors high, one factor low or three factors high, two factors medium. For samples 23 - 28, two factors high and one medium or two factors high.
Medium fertility	Three factors high, two factors low or two factors high, two medium and one low. For samples 23 - 28, two factors medium and one factor high or two factors medium.

is an anisotropic system, lateral and vertical variations in the percentages of the three textural separates (sand, silt and clay) are recognizable. There is a general proclivity towards relatively higher proportion of sand and lower proportion of clay in the lowland (rift valley) soils than in the upland soils. Out of nineteen samples from the plateau, eleven showed clay content of over 50 percent while only five out of the same number of samples from the rift contained above 50 percent of clay. The soils of the scoriaceous hills on the plateau (especially profile 2) exhibit very high amount of light fraction.

The vertical variation in texture is expressed by a general increase in the clay and decrease in sand for a larger number of the profiles. Maximum content of clay occurs near the bottom of the profiles or less commonly in the middle. The reverse generally holds true for the sand fraction.

That the soils except on erosional surfaces such as hills and mountain slopes developed from both in situ and transported (alluvial or colluvial) material will be discussed in latter sections.

Important is that transported parent material apparently was less significant on the plateau than in the rift. This might be ascribed to the considerably high relief and to concentration of runoff mainly in deeply - incised channels. These factors minimize the deposition of weathering products from the rocks of Chillalo on the flat - gently riftward inclined upland surface. On the other hand, a higher percentage of river load (dissolved, suspended and traction load), together with colluvial material is deposited on the rift floor. However, it should be noticed that little or nothing is presumably deposited on horsts, volcanic cones and fault terraces (in the rift) which stand above the level of deposition.

It is true that the basic and intermediate volcanic products of Chillalo Mountain are richer than the pyroclastics in minerals that weather to produce heavy - textured soils (plagioclase feldspar and mafic minerals). However, as mentioned earlier, the localization of drainage and the high relief within the plateau do not allow considerable accumulation of the weathering products on the

highland. This in turn minimizes the influence of these rocks on the lateral variation of texture.

Despite their similar mineralogy (lithic and vitric fragments, glass and feldspars) and chemistry which is also said to be the same (Di Paola, personal communication), both the plateau and rift ignimbrites underlie soils considerably different in texture.

The samples compared are located on similar microtopographic surfaces (flat-gently sloping) but the age of the plateau and of the rift pyroclastics, the vegetation, the rainfall and temperature are considerably different.

Since the microtopography and the bedrock on which the profiles rest are nearly constant, one or more of the three remaining factors should have dominantly influenced the lateral textural variation.

The factor of time is known to be important in weathering and soil development (it should be known that a very old rock could not necessarily have produced a very old and well developed soil). It is also known that the erosion of soils over a long period of

time means soil degradation. These opposing phenomena, however, are governed by the other factors: density of vegetation, topography, the type of parent material and climate.

Because the plateau pyroclastics are older than those of the rift, the longer period of weathering could have contributed to the differences in the textures of the soils formed on them. Besides, even though it has been mentioned that the disintegration products of Chillalo rocks contributed significantly their contribution of minerals like plagioclase over an extended period of time could have amounted to something.

The higher density of vegetation and abundant rainfall on the plateau make chemical weathering faster as compared to the rift.

The heavy texture of the upland soils situated on the flat - gently sloping topography could, therefore, be due to a higher rate and a longer period of chemical weathering of the underlying pyroclastics and with the small but perhaps continuous addition of disintegration products from Chillalo rocks. One cause for the comparatively higher sand content of the rift valley

soils could be lower intensity of chemical weathering and the shorter period for it to act. Secondly, the overall topography generally favours erosion of the upland soils and deposition in the rift. As the clay fraction is carried in suspension, it is highly probable that most of it is carried farther from the study area to be deposited may be in the Lake Zway where the area drains to. On the other hand, most of the sand and possibly some silt get easily deposited in the lowland, thus resulting in a relatively lighter texture. In addition to this, anthropic influences (deforestation and cultivation) enhance the winnowing of the fine fraction from the surface by wind.

The high proportion of sand in the soils of the scoria cones (near the marginal escarpment) is attributed to the topography which is unfavourable for chemical weathering (because water is wasted as runoff) and secondly to the removal of the fine fraction, relatively enriching the soil in sand. On the plateau, soils on flat surfaces and underlain by basalt, show no textural differences from those underlain by ignimbrites.

The general downward increase in the clay fraction in most profiles is due to its translocation from the upper parts by percolating water which leaves relatively more sand. Besides this, deposition of sand on the top soil raises its amount. The latter is more important in the lowland soils.

From the above discussion, it may be concluded that vertical change in soil texture is due mainly to rainfall (climate) and topography, while lateral variation is due to the combined influence of climate (it controls the vegetation) and the overall topographic difference between the two regions which causes removal of material from one and deposition on the other. As the topography influences the climate and this in turn the vegetation, it seems reasonable that the textural distribution of the soils is governed dominantly by the topography of the area.

6.2.1.2. Structure

Soil structure refers to the forms assumed by the aggregates of soil particles. It is therefore primarily dependent upon the texture. It is significantly controlled by

the kind and amount of clay and by the moisture content of the soil.

The dark - dark brown soils are mainly prismatic and occasionally show angular blocky structure. Eventhough the structural partings could provide openings for water circulation, the high clay content and generally poor drainage condition result in puddling of the ground and possibly also in collapse of the structures during rainy seasons. This makes ploughing very difficult. When dry, they develop wide and deep cracks. As a result working on these soils becomes again problematic. ✓

The reddish brown soils around Asela bear textural resemblance to the above soils. In spite of their comparable amount of clay, the slopes on which they occur favour drainage. Because of this reason, they do not hinder operation (not mechanized) during rainy season, but they are liable to thorough drying in the absence of rain.

The lowland soils are sandy and the aggregates the particles form are generally small. Therefore, they are supposed to have better workability (they crumble

easily). Their higher porosity and permeability (as expected from their texture) also makes them easily workable.

The structure being strongly governed by the texture, the factors which controlled the latter must have determined the former.

In conclusion, the workability of the soils in the Asela is controlled dominantly by the topography which in turn controls and operates jointly with climate and vegetation.

Land Preparation Requirements

Slope

Flat and almost flat soil surfaces facilitate land preparation for subsequent utilization far better than soils on sloping topography. In this aspect the dark - dark brown soils around Kulumsa and Asela and most of the lowland soils are better than the reddish soils of the plateau and the poorly developed soils of the small volcanic cones. The marsh soils are not useable (unless land management practices are conducted on them) and no evaluating remarks seem necessary. If, however, they could be partially drained for the growth of water - liking crops like rice, the slope condition poses no

problem. The slope parameter owes its variation in the area to topography.

Thickness

The thickness of a soil is governed by the weatherability of the parent material, by the intensity and duration of action of the climatic elements (temperature and rainfall), by the biotic factor and by the topography.

Eventhough it may not be considered as a conclusive remark applying to all the soils in the area, there exists an inveres functional relation between soil depth and slope angle of the site on which the profiles are situated (Fig. 12). This is because water does not remain long in contact with the parent material on surfaces of high gradient, thus minimizing chemical weathering. In addition, the existing thin soil layer is easily eroded.

In terms of depth, the two major upland soils are significant. The rift valley soils rarely exceed 100 cm in thickness. This is because the rocks on the rift valley are younger than those on the plateau and hence there was a shorter period of weathering.

...fertility in terms of soil
...dark and reddish soils provide
...especially to those plants with roots
...top soil. This helps plants to
...water from depth.

...in the thickness of the soils is
...result of mainly topographic and
...conditions.

...rockiness

...of stones and rock outcrops per unit

...higher in the lowland soils than in

...studied water soils. Within the low-

...the scorie ridges and the area in the

...succeedingly stony and fairly rocky.

...because there was no enough time.

...climatic and biotic variation.

...especially chemical) of these soils.

...thus be concluded that soil

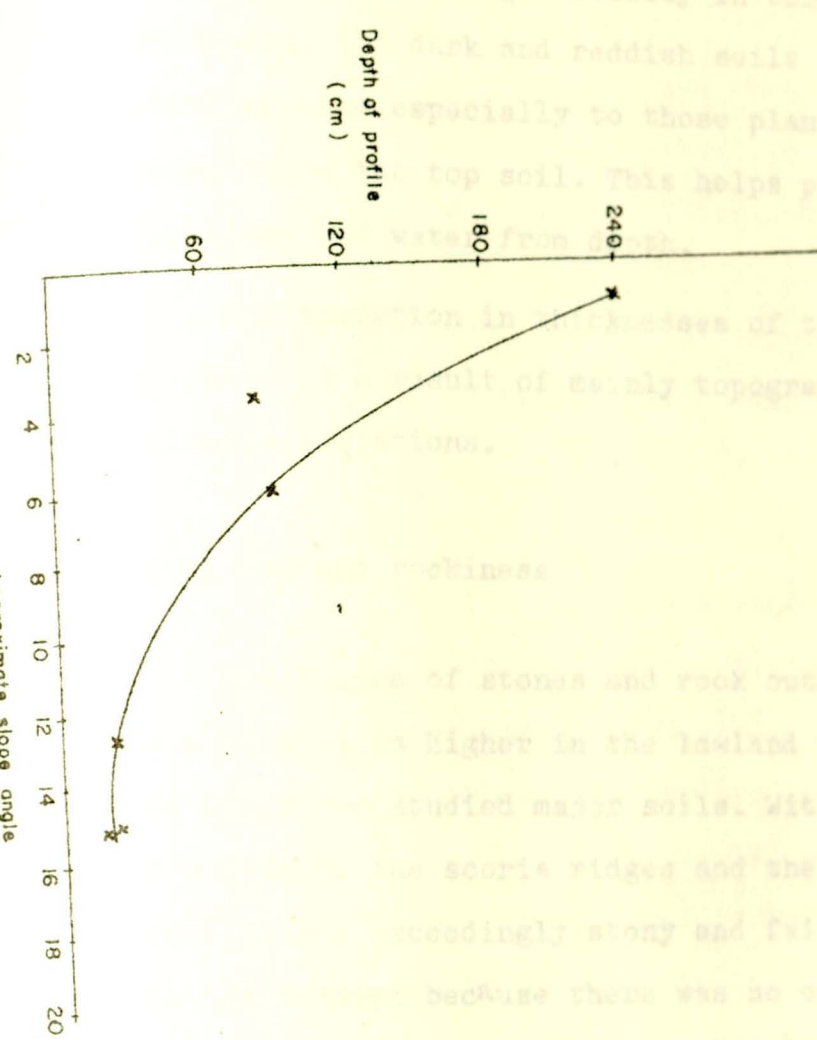
...dominantly climatic and

...parameters.

...of the existing

...of the

Fig. 12 Relationship between slope angle & profile depth (in soil profiles)



When considering fertility in terms of soil thickness, the dark and reddish soils provide good plant rooting especially to those plants with roots going below the top soil. This helps plants to draw nutrients and water from depth.

The variation in thicknesses of the soils in the area is a result of mainly topographic and climatic variations.

Stoniness and rockiness

The volume of stones and rock outcrops per unit area of soil is higher in the lowland soils than in the other two studied major soils. Within the lowland itself, the scoria ridges and the area in the vicinity are exceedingly stony and fairly rocky. This is perhaps because there was not enough time, under the existing climatic and biotic situation, for weathering (especially chemical) of this scoriaeous rock. It may thus be concluded that stoniness and rockiness are dominantly climosequential and chronosequential parameters. The factor of topography is also important in determining the existing climatic differences between the plateau and the rift floor.

6.2.2. Inherent Fertility Status

It has been stated earlier that the studied soils were classified into categories of fertility status on the basis of pH, cation exchange capacity, organic matter, available K and P. Each of these parameters show more or less patterned distribution with the area as discussed hereunder.

pH (Soil Reaction)

The influence of pH on the availability of plant nutrients has been widely discussed in several works (Jenny 1941; Adler 1947; Black 1967 & others).

The major exchangeable cations in soils are Ca^{2+} , Mg^{2+} , K^+ , Na^+ (basic cations) and H^+ . They occur adsorbed on the surfaces of colloidal clay and humus particles. A shift in the proportion between hydrogen and the basic cations alters the soil reaction. Hydrogen, if abundant in the soil system, substitutes a considerable number of basic cations from the surfaces of particles of clay colloids and humus. These cations form compounds, mainly hydroxides and bicarbonates which are leached out by percolating rain water (Jenny 1941).

In the present survey, dominantly high pH values (>6) were recorded for the lowland soils.

On the other hand, a more pronounced shift towards lower pH (higher acidity) was exhibited by the upland soils. Out of eight top soils from the latter (profiles 1 - 8), four showed low pH (<5), two medium (5 - 6) and two high. out of the same number of measurements in the lowland, six were found to be high in pH, one low and one medium.

When the profiles as a whole are considered, thirteen out of eighteen indicated vertical variation in soil acidity (decrease with depth).

The thick, well-drained reddish soils (profiles 4 & 5) indicate uniformly low pH throughout the profiles - a property less evident in the adjacent dark - dark brown soils. Since climate, time, parent material (ignimbrite) and the biotic factor are nearly identical, the difference in the acidity of these soils owes its existence essentially to topographic variations causing poor drainage in the dark - dark brown soils and good drainage in the other. The condition in the latter enhances the leaching of basic cations, accounting for their low pH values.

Different factors have contributed to the difference in the level of soil reaction between the upland area and the lowland.

The upland area has prolific rainfall and luxuriant vegetation (forest and grass land) compared to the other; chemical weathering and leaching are correspondingly more intense. Because of the topography, erosion is very important on the plateau and deposition in the rift. There could also be significant contribution to the enrichment in basic cations of the rift valley soils from the volcanic rocks of Chillalo which contain abundant minerals containing these elements. Additional contribution also comes from the pyroclastics of the plateau.

In the survey area, a general negative correlation between pH and mean annual precipitation is noticeable: increase in pH of soils from Asela to Kulumsa and from the latter to the rift floor (Fig. 13).

The rising of pH with depth in soils is due to the downward translocation of the basic cations from the top soils. The acidity of the water decreases as it percolates downwards, because a lot of H^+ is held in the interaction to replace the bases.

Rainfall and temperature data were available for four representative sites (Asela, Kulumsa, Arata and Dugda). For sample sites out of these four, extrapolation has been made from the data of the nearest station by making allowances for elevation.

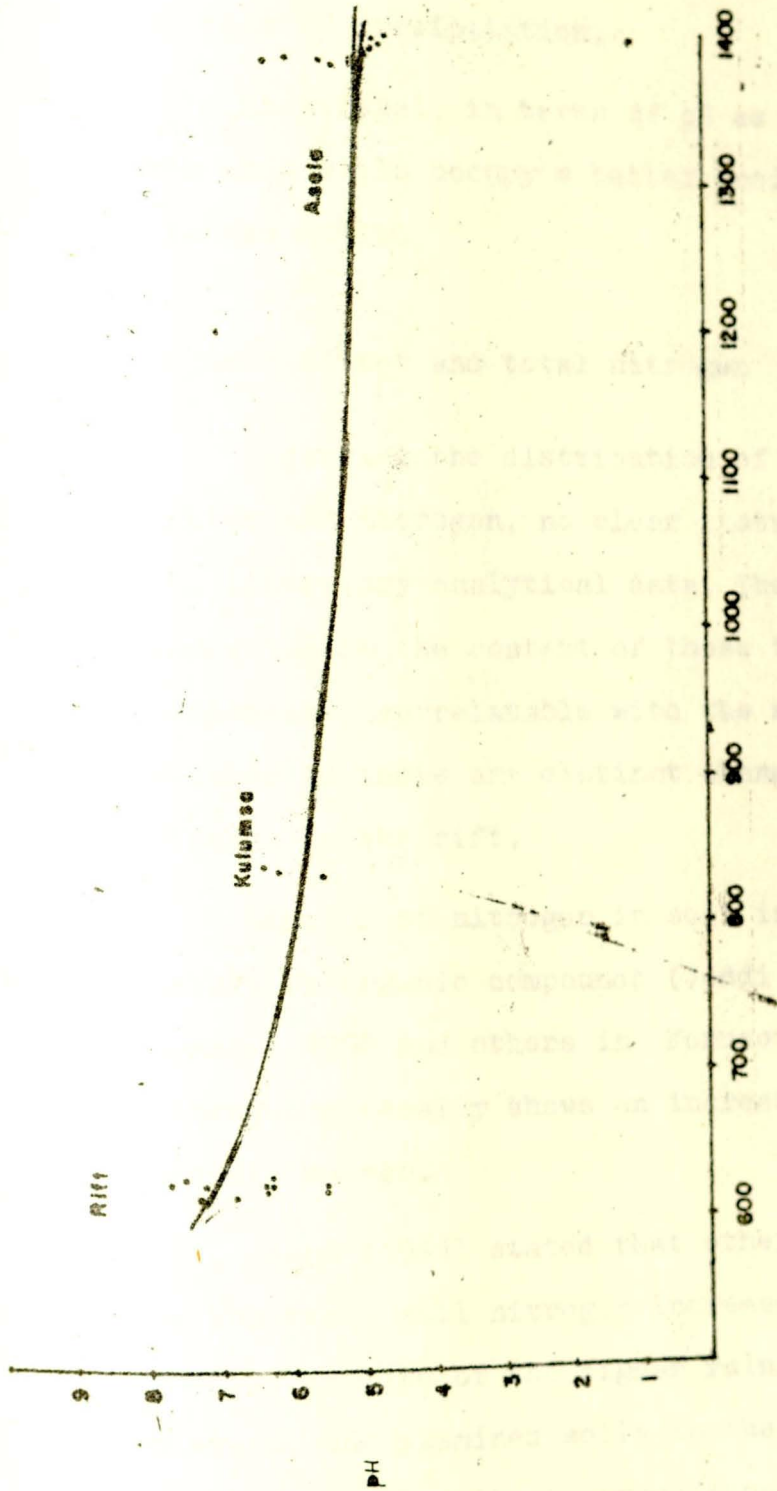


Fig. 13 pH-rainfall-relation for the soils of Asels area.
 Each point represents the analysis of one soil sample

differences. The effect of temperature is opposite to that of precipitation.

In general, in terms of pH as a fertility factor, the rift soils occupy a better position than the plateau soils.

Organic matter and total nitrogen

Regarding the distribution of soil organic matter and nitrogen, no clear picture emerges from the laboratory analytical data. There is no clear variation in the content of these two significant components, correlatable with the soil types. Neither is there any distinct change from the plateau to the rift.

Since most nitrogen in soil is represented mainly by organic compounds (Joddi 1910; Shumk 1914; Bremner 1950 and others in; Kononova 1961), total nitrogen generally shows an increase with increasing organic matter.

Jenny (1941) stated that other factors remaining constant, soil nitrogen increases with water supply. In spite of the higher rainfall on the plateau, the examined soils in the latter do not excel the rift soils in organic matter and total nitrogen.

The better condition of grassland and forest vegetation on the highland is also expected to produce in the soils a better status of organic matter and nitrogen. But this is not reflected in their amounts in the soils.

In terms of total nitrogen, a greater proportion of the top soils (about 75%) showed high content.

Since both organic matter and nitrogen do not show systematic distribution over the area, it becomes very difficult to make qualitative or quantitative statements about the role each soil forming factor played to produce the status of the two.

Available Phosphorus

Phosphorus is classed as one of the macro-nutrients in soils and is derived from weathering of primary phosphorus-bearing minerals and from plant residues.

The amount of phosphorus in the top soils suggests that this nutrient might be more important as a limiting factor than the others. Out of nine samples from the upland soils (profiles 1 - 8, 19), seven (about 78%) were low in phosphorus, whereas

only five out of fourteen samples (35%) in the rift were in this category.

In this case, as with pH, there is a tendency of increase in available phosphorus from the upland to the lowland. When available phosphorus is plotted against mean annual precipitation (Fig.14), the curve, though not very well defined and with low slope, gives an idea about the existence of an inverse relationship between the two (rainfall and available phosphorus).

Teuscher (1974) indicated that the availability of phosphorus is controlled by pH. At decreased pH values, it is said to occur as an insoluble phosphate and hence less available to plants. Higher pH being prevalent in the lowland soils, phosphorus has a better chance of solubility and therefore, higher availability.

Eventhough not conclusive, the presence of apatite in profile 5, is indicative of contribution to soil phosphorus from the basalts.

In general, it might be said that the soil forming factors control available phosphorus in soils, through their influence on soil reaction.

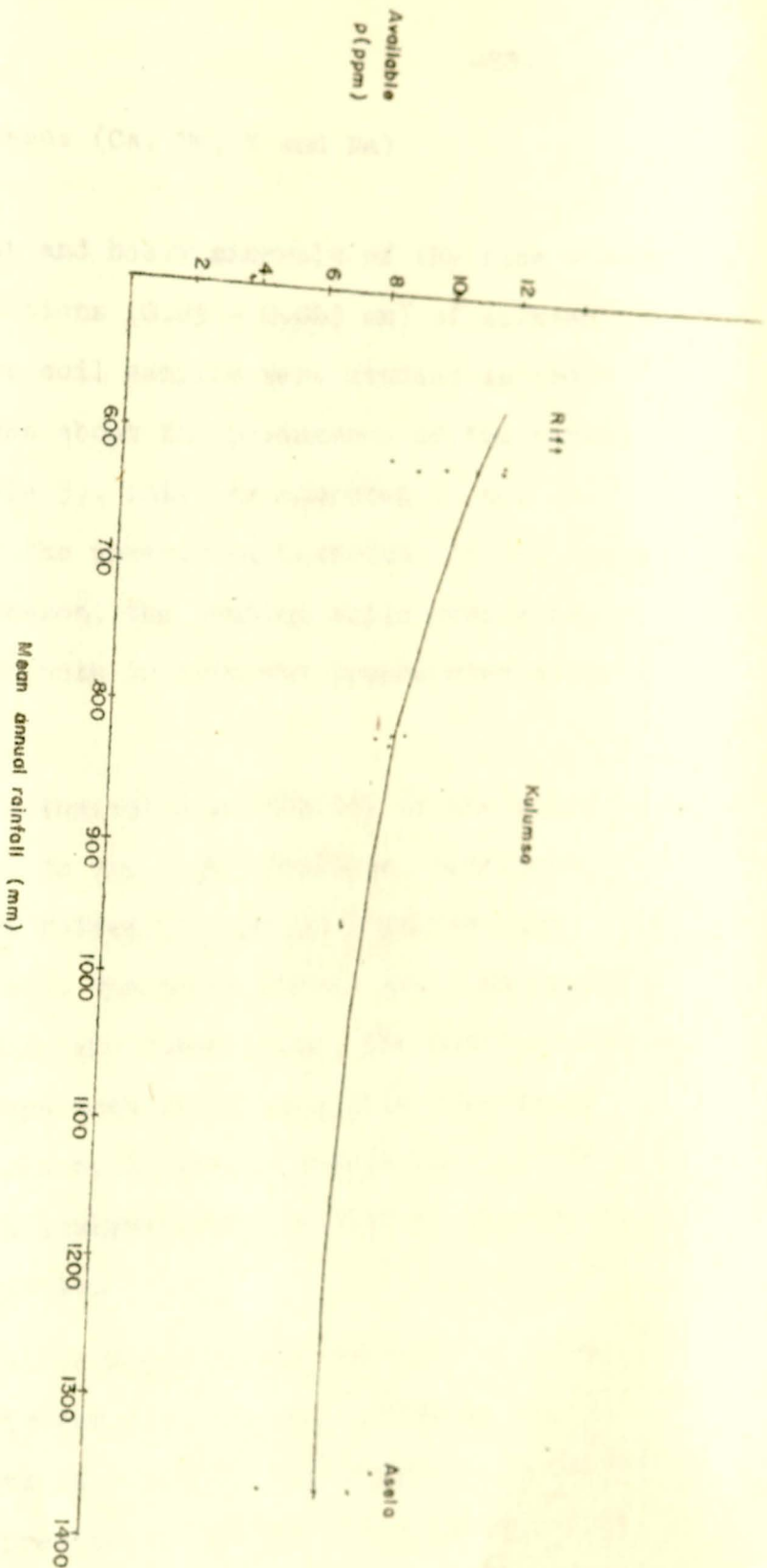


Fig. 14 Available P - rainfall function for the soils of Asalo area. Each point represents the analysis of one soil sample.

Exchangeable bases (Ca, Mg, K and Na)

The light and heavy minerals of the fine - very fine sand fractions (0.25 - 0.063 mm) of sixteen representative soil samples were studied in order to have an idea about the provenance of the parent material (Table 5). This was compared to the mineralogy of the underlying bedrocks. It was found that in most cases, the studied soils generally developed from both in situ and transported materials.

The mineralogical constitution of the soils is monotonous. In the light fraction, feldspars (mainly alkali feldspars) are preponderant and quartz is second. Unaltered lithic and less commonly vitric fragments are subordinate. The heavy fractions almost always consist of magnetite associated with minor ilmenite in some profiles and in a very few cases with insignificant amounts of hornblende, apatite and rutile.

No lateral or vertical variation is clearly seen in all sixteen samples. The occurrence of abundant quartz in profiles overlying basalt (9,22) suggests the presence of material transported from the ignimbrites and tuffs, because quartz is absent in basalts. As the basalts, trachybasalt and

Table 5

Weight % of minerals in the fine-very fine
(0.25-0.063 mm) sand fraction of soils

<u>Profile No.</u>	<u>Depth (cm)</u>	<u>Light fraction</u>	<u>Heavy fraction</u>
1	0-70	Quartz - 47% subangular - subrounded, white, slight limonite coating Feldspar - 40% Rock fragments - 3%	Magnetite - 9% Ilmenite - 1%
	70-110	Quartz - 40% Feldspar - 15% Rock fragments - 15% Glass - 25%	Magnetite - 5%
	155-240	Quartz - 35% Feldspar - 35% Rock fragments - 15% Glass - 7%	Magnetite - 8% Rutile (?) << 1%
5	0-20	Quartz - 25% Feldspar - 40% Rock fragments - 25%	Magnetite - 10%
	20-50	Quartz - 30% Feldspar - 45% Rock fragments - 15% Glass - 5%	Magnetite - 5%
	50-90	Quartz - 35% Feldspar - 50% Rock fragments - 6%	Magnetite - 7% Ilmenite - 2% Apatite (?) << 1%
9	0-40	Quartz - 43% ; milky, sometimes pitted Feldspar - 35% Rock fragments - 14%	Magnetite - 6% Ilmenite - 2%
	Below 40	Quartz - 25% Feldspar - 25% Rock fragments - 45%	Magnetite } Ilmenite } 5% Hornblende }

Table 5 contd.

<u>Profile No.</u>	<u>Depth (cm)</u>	<u>Light fraction</u>	<u>Heavy fraction</u>
12	0-25	Quartz - 36% Feldspar - 54% Rock fragments - 6%	Magnetite - 3% Ilmenite - 3%
	35-60	Quartz - 35% Feldspar - 40% Rock fragments - 17%	Magnetite - 7% Ilmenite 4 1% Hornblende
21	0-30	Quartz - 30%, sacchroidal texture Feldspar - 60% Rock fragment - 3%	Magnetite - 7%
	30-60	Quartz - 35% Feldspar - 52% Rock fragments - 5%	Magnetite - 7% Ilmenite } 1% Hornblende)
	60-100	Quartz - 40% Feldspar - 56%	Magnetite - 4%, partially coated with limonite Hornblende << 0.5%
22	0-25	Quartz - 35%, milky, pearly limonite coated Feldspar - 46% Rock fragments - 10% (reddish brown)	Magnetite - 5% Ilmenite - 4%
	25-50	Quartz - 50% Feldspar - 55% Glass - 7%	Magnetite, 8% Ilmenite /
	50-90	Quartz - 38% Feldspar - 52% Rock fragments - 2%	Magnetite - 8%

trachytes contain a good deal of magnetite (very low in the pyroclastics), its unexpected abundance in soils underlain by pyroclastic bedrock is suggestive of additional source from the former. On the other hand, minerals identified in thin sections of the bedrocks are also well-represented in the overlying soils. This is an evidence of in situ parent material.

Because the soils are derived from mixed parent materials, it becomes very difficult to relate the fertility status with the rock types. When all samples are examined, all basic cations but magnesium, show a distribution in the upland and lowland soils similar to that observed for phosphorus i.e. commonly higher Ca, K and Na in the rift soils than in those of the plateau. When the top soils alone are considered, Ca, clearly maintains this relationship and K less clearly.

The possible sources of Ca in the soils are mainly plagioclase feldspar and augite which are common constituents of the basalts, trachybasalts and trachytes. Less important sources could be amphiboles, hypersthene and apatite which occur in one or the other rock in small quantities.

The accumulation of weathering products of rocks on the plateau and leaching from the upland soils are important sources of the relative calcium enrichment of the lowland soils. Some profiles show a greyish white, powdery coating mostly below depths of 20 cm. This could be due to the translocation of Ca ions from the upper parts of the profiles to be deposited may be as calcium carbonate.

In profile 18, large, elongate carbonate nodules (upto 20 cm long) were found at a depth of 50 cm. These nodules could be of the same origin as the carbonate coatings in other profiles. In this case, however, there seem to have been a highly concentrated solution which, while moving downward through the profile, precipitated Ca possibly as calcium carbonate. The deposition of calcium carbonate could be due to an encounter with the bedrock which prevented further movement and may also be because of the decrease in soil acidity. The latter is important because, calcium carbonate is soluble in the presence of abundant H^+ . An abrupt rise in the amount of exchangeable calcium with depth is observed in this profile (Fig.15).

Potassium is an abundant nutrient in all the soils. Biotite is a good source of potassium and it occurs in the basalts, trachytes and trachybasalts.

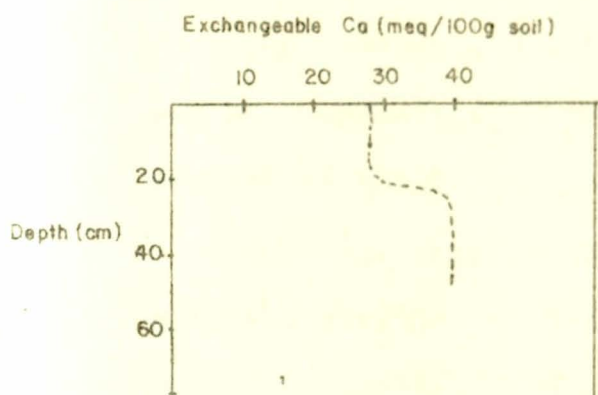


Fig.15 Vertical distribution of exchangeable Calcium in profile 1B.

Sanidine is abundant in the trachytes and together with glass which is a major constituent of the pyroclastics (alkali feldspars as one of its main components), supply potassium.

The extensive occurrence of the pyroclastics may be responsible for the very high potassium content of the soils.

When the relative abundance within the two climatic regions (plateau and rift) is considered, potassium shows the same distribution as calcium (Fig.16). The causes of this relative enrichment are again leaching from the plateau soils and accumulation in the lowland. Alemayehu Mengistu (1975) mentioned that the salt content of the lowland soils is also higher (about 18%). In the determination of potassium, there could have been addition from these salts contributing, to a certain extent, to the very high potassium values.

Magnesium, as already mentioned, does not show distinct variation throughout the area.

Eventhough it does not show up in the top soils, examination of all samples indicated relatively high Mg values in the lowland soils. This could be attributed to similar causes as for the other basic cations.

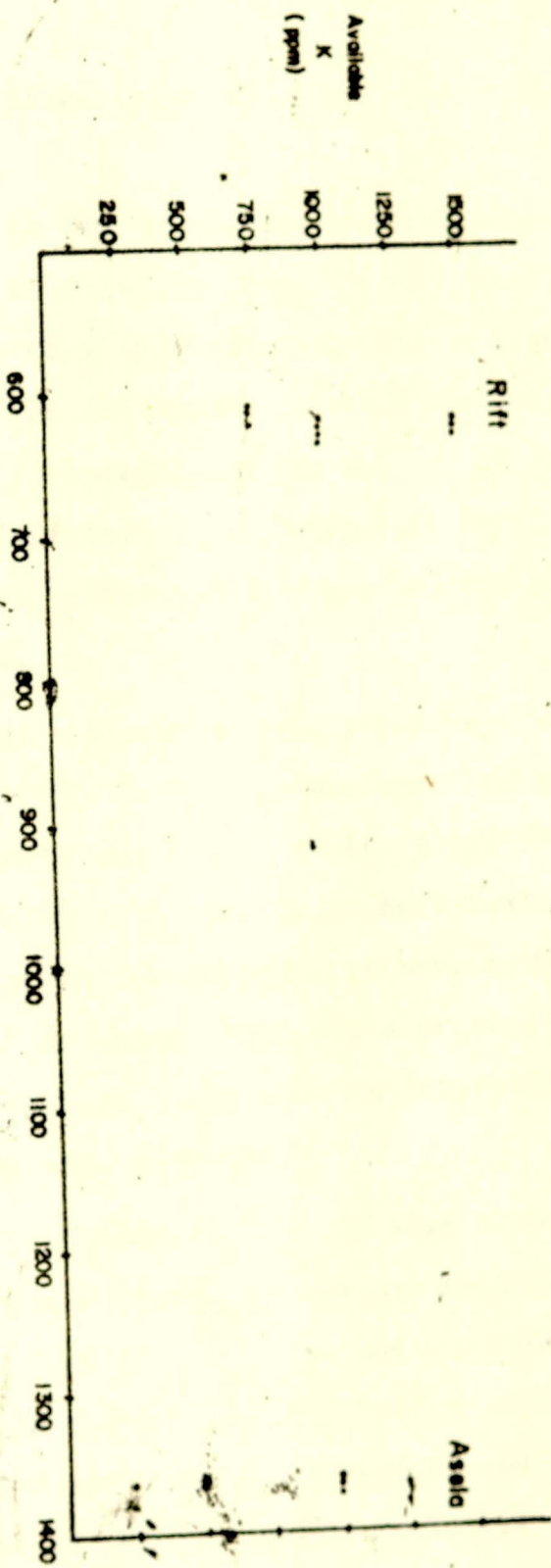


Fig. 16. Mean annual rainfall (mm) vs. Available K (ppm)-rainfall relationship for the soils of Asolo and Rift. Each point represents the analysis of one soil sample.

Cation exchange capacity is also related to soil mineralogy. The relationship is

This is the total amount of exchangeable cations expressed in meq/100g soil. In all the top soils but one, cation exchange capacity is high (more than 25). The uniformity in this property makes it difficult to examine the nature of the relationships with the different soil forming factors. Neither lateral nor vertical variation in this parameter is evident.

Cation exchange capacity has been shown to increase with rise in surface area per unit weight of soil (Whitt and Baver 1930 in; Black 1967). This indicates its relationship to soil texture; heavy-textured soils are expected to have higher CEC than light textured ones. Soils organic matter is also of profound importance in determining its cation exchange capacity.

Despite their relatively high content of clay, and the better source of organic matter replenishment, the dark - dark brown and the reddish soils do not show a status in CEC better than the lowland soils which are coarser in texture and lower in the amount of organic matter replenishing them.

Cation exchange capacity is also dependant on and varies with soil mineralogy. The mineralogy of the soils, at least in the fine - very fine sand fractions was shown to be uniform, thus contributing to the uniform distribution of CEC values in the soils.

6.2.3. Agricultural land Capability

Using some modifications on the Malawi system of land capability classification (Dent and Young, 1981), the study area may be roughly divided into various capability classes (Fig.17).

In the present case, the permanent limitations used to classify the area are, slope, degree of dissection, surface hindrances (rockiness and stoniness), wetness and depth of the soils (Table 6).

Correspondence between the classes of inherent fertility status and those of land capability is extremely poor and might be considered nonexistent i.e. high inherent fertility status does not correspond with the best land capability class.

No portion of the area fulfills the requirements to be assigned to class I. Only a small area around the town of Kulumsa falls into class II. The third class : consist of the flat-gently sloping and slightly dissected southern corner of the mapped area. To the fourth class belong two small areas in the rift (Arata and Deneba), where relatively large farms are found. A large part of the rift floor has abundant surface hind rances and also the soils are generally thin. This portion falls into class V. Class VI includes the moderately-highly dissected eastern

Table 6. Agricultural land capability classification of the Asela area
(Modified after Dent and Young, 1981)

		<u>Limitation</u>									
Worst	1. Slope (degree)	1	2½	4½	6½	11	11	any	any	any	
Permissible	2. Dissection	nil	mod.	mod.	sev.	mod.	sev.	sev.	any	any	
value	3. Rockiness &/or	10	10	25	50	10	50	50	any	any	
symbol in	stoniness (%)										
each class	4. Wetness	nil	nil	short	cons.	nil	cons.	cons.	cons.	cons.	
				periods	per.		per.	per.	per.	per.	
	5. Depth (cm)	90	50 90	50 25 50 25	25 25	50	50 90	25 50	any	any	

segment of the study area and the depression west and southwest of Asela. The small volcanic cones (on the plateau) with their thin soil cover and highly sloping surfaces could be assigned to class VII.

Despite the very high fertility of their soils, the swamps in the rift valley occupy a very low status (class VIII) with respect to their capability for agriculture. These areas could not be used without proper land management practices. If the water is drained partially or completely, use can be made of these highly fertile soils for different crops, preferably rice.

To the last class of land capability belong the fault scarps and other bare rock surfaces.

7. CONCLUSION

A given soil may be termed "ideal" with respect to fertility ^{if} it possesses the best of both physical and chemical parameters of fertility in combination. This situation is mostly unattainable in nature.

The sum of both of these parameters determines soil fertility in regards to productivity. For instance, a soil with good inherent fertility status (chemical fertility) becomes highly productive when associated with good physical conditions (slope, texture, rockiness etc.) and shows low productivity when one or more of these conditions is unfavourable.

Nevertheless, the present study is limited entirely to inherent fertility status of the studied soils, the evaluation of which was based on the five fertility factors (pH, CEC, K, P and organic matter).

Available potassium and cation exchange capacity are almost always invariably high in all soils. In terms of pH, a greater number of the top soils from the plateau show low fertility. Organic matter is generally high in all soils. Compared to the other factors of rating, phosphorus seems to be a limiting factor.

When the over all fertility of the soils is taken into account, 21% of the top soils are very highly fertile, 35% medium and 43% high. Deficiency in the macronutrients is not a problem.

In a generalized manner, the rift valley soils have better inherent fertility status than the plateau soils.

The most important processes which determined this distinct difference are mainly removal and addition. Weathering of different rocks on the plateau liberates a number of products which are removed from this region and added to the lowland. Translocation is also another process which produced the vertical variation observed in the profiles.

The factor/s which dominantly determined the variations in the inherent fertility status in the area are, therefore, directly attributed to the factor/s which governed the above processes.

Time is important for the soil formers to act on parent materials to form soils, but the length of time in which a certain soil forms depends on the weatherability of the parent material, biological activity in the soil, climate and topography. The factor of time can also be important in soil degradation provided that it is favoured by the other factors.

The author is of the opinion that inasmuch as its role is determined by the other soil forming factors, rather than an independent soil forming factor, it may be taken as a sort of a medium, with no entity of influence (on soil property - fertility in the present case) on its own right, but in which the other factors operate. Based on this, time as a soil forming factor affecting inherent fertility is left aside here.

The fact that there are only insignificant occurrences of sedentary soils makes it difficult to relate the soil fertility status with the rock type. This type of soils are the ones that developed on hill sides and crests.

It is clear that the sources of the various plant nutrients are the different rocks in the area. The absence of correlation between the mineralogy of each soil and that of the bedrock beneath it (this situation is expected from soils formed on in situ parent material) indicates the dominance of one or more of the factors, climate, topography and biology.

These three are so intimately associated that it becomes very difficult to separate the role each one exercised on the processes of removal, addition and translocation, which in turn were responsible for the overall variation in the inherent fertility status of the soils.

The topography on the plateau, with its high elevation above sea level effected high rainfall and relatively low temperature. The high rainfall in turn produced dense vegetation of numerous plant species. Weathering of rocks was hastened by abundant rainfall and organic acids from vegetation decay. The removal of weathered products was enhanced both by topography and by the abundant rainfall which fed streams and rivers.

A good deal of the material removed from the highland is added to the soils in the lowland (because of the flat

topographic surface at low elevation), thus producing enrichment here in the added constituents. The removal left behind it soils, poorer in the lost nutrients and higher in acidity.

The vertical variation in the fertility status is due to elluviation from the top soils. The variation of the physical parameters used to evaluate the land capability owe their existence mainly to topography, time and climate.

The slope condition is an element of topography and influences the degree of dissection (past erosion), wetness and soil depth. The rainfall again controls erosion, the wetness and the rate of soil formation. The shallowness and the abundance of rocks and stones on the rift soils is due mainly to the relatively short period of weathering of the rocks here.

From the preceeding discussion, it can be concluded that topography and climate were the most important factors in influencing the inherent fertility status of the soils in the Asela area. The biology (mainly vegetation) being dependent on these two, is second in importance.

When the overall fertility (chemical and physical) is taken into consideration, topography, climate and time are the most important in controlling the variation within the area.

Description of Soils

Profile 1

Location:- SSW of Asela, roadside to Lole.

Elevation and climate ... 2540m, cool, moist, annual rainfall about 1400mm.

Landform flat

Parent material apparently derived in situ from ignimbrite

Drainage imperfectly drained

Soil moisture 0 - 70 cm dry

Vegetation or land use .. short grass, cultivation.

0 - 70 cm	Black (10 YR 2/1 moist and Vdk gr br dry, clay loam, prismatic, very sticky, plastic, firm, many fine and medium roots, cylindrical worm casts, wide cracks, stickenside, many fine-medium pores.
70 - 110 cm	Vdk gr br (10 YR 3/2) moist and dk gr br (10 YR 4/2), clay, cracks.
110 - 155 cm	dk br (10 YR 3/3) moist and dk br (10 YR 3/3) dry, clay, moist.
155 - 240 cm	dk br (7.5 YR 3/2) moist and br (7.5 YR 4/4) dry, clay.

Profile 2

Location Chebi, SE Asela, SE facing side
 Elevation & climate..... 2300
 Landform hillside
 Slope moderately steep
 Parent material scoriaceous basalt
 Drainage perfect
 Soil moisture dry throughout
 Vegetation or land use . surrounding area cultivated

0 - 50 cm dk rd br (5 YR 3/3) moist & dk rd br
 (5 YR 3/3) dry, sandy clay loam, very
 stony, shallow

50 - 70 cm dk rd br (2.5 YR 2/4) moist and dusty
 red (2.5 YR 3/2) dry, loamy sand

Profile 3

Location Chebi hill, SE Asela, NW facing side
 Elevation & climate .. 2330m, cool, moist
 Landform hillside
 Slope moderately steep
 Parent material, scoriaceous basalt
 Drainage perfect
 Soil moisture dry throughout
 Vegetation or land use ,. surrounding area cultivated

0 -20 cm dk rd br (2.5 YR 2/4) moist & dusty red
(2.5 YR 3/2) dry, loam, other features
same as Profile 2.

Profile 4

Location S Assela, Dosh, roadside
Elevation & climate 2490m; moist, cool
Landform rolling
Slope Gently sloping
Parent material Ignimbrite
Drainage well drained
Soil moisture dry throughout
Vegetation or land use .. Eucalyptus, Juniper, short grass

0 - 30 cm dk rd br (2.5 YR 2/4) moist and yrd
(5 YR 4/6) dry; clay, firm, sticky,
slightly hard, many medium to fine roots,
ignimbrite fragments, dark reddish mottles
uniform profile, thick, iron oxides
accumulation

Below 30 cm dk rd br (2.5 YR 3/4) moist & y rd
(5 YR 4/8) dry, clay, other features
same as upper part of profile.

Profile 5

Location 2½ km S of Assela, side of main road
 Elevation & climate cool moist, 2600m
 Landform undulating
 Slope Gently sloping
 Parent material apparently derived in situ from ignimbrite
 Drainage well drained
 Soil moisture dry throughout
 Vegetation or land use .. Podocarpus, Juniper, also cultivated

0 - 20 cm

dk rd br (5 YR 2/2) moist & dk br
 (7.5 YR 3/2) dry, loam, prismatic, sticky,
 friable, slightly hard, no stones, dark
 red mottles, uniform throughout profile)
 iron oxides accumulation.

20 - 50 cm

dk rd br (2.5 YR 3/2) moist & y rd (2.5
 YR 4/8) dry, clay, prismatic, other
 features like above

50 - 90 cm

dk rd (2.5 YR 3/6) moist & y rd (2.5
 YR 5/8) dry, clay, some fragments of ignim-
 brite, uniform throughout profile

Profile 6

Location SE Assela, Duna
 Elevation & climate 2420m; cool, moist

Profile 5

Location 2½ km S of Assela, side of main road
Elevation & climate cool moist, 2600m
Landform undulating
Slope Gently sloping
Parent material apparently derived in situ from ignimbrite
Drainage well drained
Soil moisture dry throughout
Vegetation or land use .. Podocarpus, Juniper, also cultivated

0 - 20 cm dk rd br (5 YR 2/2) moist & dk br
(7.5 YR 3/2) dry, loam, prismatic, sticky,
friable, slightly hard, no stones, dark
red mottles, uniform throughout profile)
iron oxides accumulation.

20 - 50 cm dk rd br (2.5 YR 3/2) moist & y rd (2.5
YR 4/8) dry, clay, prismatic, other
features like above

50 - 90 cm dk rd (2.5 YR 3/6) moist & y rd (2.5
YR 5/8) dry, clay, some fragments of ignim-
brite, uniform throughout profile

Profile 6

Location SE Assela, Duna
Elevation & climate 2420m; cool, moist

Landform almost flat
Slope almost flat
Parent material apparently derived from basalt
Drainage imperfect
Soil moisture condition .. 0 - 30 cm dry
Vegetation or land use .. short grass

0 - 30 cm

V dk gr (10 YR 3/1) moist & V dk gr br
(10 YR 3/2) dry; clay loam, angular
blocky, very sticky, plastic, very firm,
very hard, slickensides, many fine pores,
fairly stony

30 - 90

V dk gr br (10 YR 3/2) moist & dk br
(10 YR 3/3) dry, clay, few Ignimbrite frag-
ments, medium roots

Profile 7

Location W of Duna, SE Asela
Elevation & climate ... 2195m
Landform depression
Slope flat
Parent material apparently ignimbrite
Drainage poorly drained
Soil moisture in profile .. 0 - 60 cm dry
Vegetation or land use ... grassland, uncultivated

0 - 60 V dk gr br (10 YR 3/2) moist & dk gr br
 (10 YR 4/2) dry, clay, prismatic, very
 sticky, very plastic, friable, very hard
 cracks 60 cm deep, slickensides, very fine
 pores, fine roots,

Below 60 cm V dk gr br (10 YR 3/2) moist & dk gr br
 (10 YR 4/2) dry; clay, gravel size ignim-
 brite fragments.

Profile 8

Location Near the main escarpment, SW of Asela
 Elevation & climate ... 2250m
 Landform Hillside
 Slope Moderately steep
 Parent material Scoria
 Drainage Somewhat excessively drained
 Soil moisture dry throughout
 Vegetation or land use .. cultivated surrounding, scattered Acacia

0 - 20 dk rd br (5 YR 3/3) moist & dk rd br
 (5 YR 3/4) dry, clay loam, sticky, plastic,
 friable, hard, few fine pores, fine-medium
 roots, shallow

Profile 9

Location Kuche hill, W Asela
 Elevation & climate 2210m
 Landform Hilly, convex slope
 Slope Gently sloping
 Parent material Porphyritic feldspar basalt
 Drainage imperfect
 Soil moisture 0 - 40 cm dry
 Vegetation or land use .. Acacia, Podocarpus, grass & shrubs

0 - 40 cm

V dk gr (10 YR 3/1) moist & V dk gr br
 (10 YR 3/2) dry, clay loam, prismatic,
 sticky, plastic, friable, very hard, medium
 roots common

Below 40 cm

V dk gr (10YR 3/1) moist & dk gr br
 (10 YR 4/2) dry, clay

Profile 10

Location Rift Valley, near Arata eastern edge of
 Shetmata Marsh
 Elevation & climate 1720m, warm, dry
 Landform graben (structural depression)
 Slope Flat
 Parent material possibly ignimbrite
 Drainage very poorly drained

Soil moisture	moist throughout
Vegetation or land use ..	swamp grass & other tree species
30 - 50 cm	V dk gr br (10 YR 3/2) moist & light br gr (10 YR 6/2) dry, loam, nstructurelen
90 - 110 cm	dk gr br (10 YR 4/2) moist & light br gr (10 YR 6/2) dry, loam

Profile 11

Location	Rift Valley, north-eastern edge of Shetmata Marsh
Elevation & climate ...	1720m, warm, dry
landform	graben (structural depression)
Slope	flat
Parent material	possibly ignimbrite
Drainage	very poorly drained
Soil moisture	moist throughout
Vegetation or land use ..	swamp grass & other tree species
25 - 60 cm	V dk gr br (10 YR 3/2) moist & dk br (10 YR 3/3) dry, clay loam
80 - 100 cm	V dk gr br (10 YR 3/2) moist & dk br (10 YR 3/3) dry, clay

Profile 12

Location	Rift Valley, N of Dugda Balewold Church
Elevation & climate ...	1800m, warm, dry
Landform	fault terrace
Slope	almost flat
Parent material	Greenish ignimbrite
Drainage	poorly drained
Soil moisture	0 - 20 cm dry
Vegetation or land-use .	Savanna type vegetation

0 - 25 cm

V dk br (10 YR 2/2) moist & dk y br
 (10 YR 3/4) dry, clay, moderate grade
 spherical structure, (crumb) slightly
 sticky, slightly plastic, firm, slightly
 hard, fine-medium root common, mole
 burrow present

35 - 60 cm

dk rd br (5 YR 3/3) moist & dk rd br
 (5 YR 3/4) dry, clay

Profile 13

Location	33 km from Asela, in the Rift, S Arata
Elevation & climate	1830m, warm, dry
Landform	almost flat fault terrace
Slope	almost flat
Parent material	Ignimbrite
Drainage	Imperfect

Soil moisture top 15 cm dry
Vegetation or land use ... savanna type

0 - 20 cm V dr br (10 YR 2/2) moist & dk y br
(10 YR 3/4) dry, clay spherical, slightly
sticky, slightly plastic, firm, slightly
hard, fairly stony, mole burrow

20 - 40 cm dk rd br (5 YR 3/2) moist & dk rd br
(5 YR 3/4) dry, clay, ignimbritic frag-
ments, fine medium roots common

Profile 14

Location 34½ km from Asela, in the Rift
Elevation & climate 1780m, warm, dry
Landform almost flat
Slope almost flat
Parent material apparently derived in situ from ignimbrite
Drainage poorly drained
Soil moisture top 20 cm dry
Vegetation or land use .. Scattered Podocarpus, Acacia, short grass

0 - 20 V dk gr br (10 YR 3/2) moist & dk y br
(10 YR 3/4) dry, clay loam, spherical,
dark mottles, stony

Profile 15

Location 33½ km from Asela, adjacent to profile 13
Elevation & climate 1840m
Landform almost flat fault terrace
Slope almost flat
Parent material Rift ignimbrite
Drainage poorly drained
Soil moisture 0 - 10 cm dry
Vegetation or land use .. cultivated

0 - 25 cm

V dk br (10 YR 2/2) moist & dk y br
(10 YR 3/4) dry, loam, slightly sticky
slightly plastic, friable, slightly
hard, fairly rocky

Profile 16

Location Near Deneba Farm
Elevation & climate ... 1820
Landform almost flat, flood plain
Slope almost flat
Parent material alluvium
Drainage poorly drained
Soil moisture 0 - 20 cm dry
Vegetation or land use . cultivation, Acacia & other trees
(Savanna type vegetation)

0 - 30 V dk br (10 YR 2/2) moist & dk br
(10 YR 3/3) dry, loam, prismatic, sticky,
plastic, friable, hard, deep, uniform
profile

30 60 V dk gr (10 YR 3/1 moist & dk br (10 YR
3/3) dry, clay loam

60 - 110 V dk br (10 YR 2/2) moist & dk br
(10 YR 3/3) dry, clay loam

Profile 17

Location 38 km from Assela, SE Shetmata Marsh
Elevation & climate 1850
Landform almost flat
Slope almost flat
Parent material pumiceous ignimbrite
Drainage poorly drained
Soil moisture 0 - 10 cm dry
Vegetation or land use .. dominantly Acacia

0 - 30 V dk gr br (10 YR 3/2) moist & dk br
(10 YR 3/3) dry, clay, sticky, slightly
plastic, firm, very hard

30 - 60 V dk br (10 YR 2/2) moist & dk br (10 YR 3/3) dry, clay

Profile 18

Location 38½ km from Asela, SE of Shetemata Marsh
Elevation & climate 1870m
Landform Horst
Slope gently sloping
Parent material Pumiceous ignimbrite
Drainage poorly drained
Soil moisture 0 - 5 cm dry
Vegetation or land use Acacia, also cultivated

0 - 35 cm V dk gr br (10 YR 3/2) moist and dk br (10 YR 3/3) dry, loam, blocky, slightly plastic, sticky, firm, slightly hard, exceedingly stony, fairly rocky

35 - 70 cm dk y br (10 YR 4/4) moist & light y br (10 YR 6/4) dry, loam, large nodules of Ca Co₃ at 65 cm depth

Profile 19

Location Foot of the main escarpment, near Bolkeso waterfall
Elevation & climate ... 1830m, warm & dry

Land-form almost flat, bound by fault scarp on
one side
Slope almost flat
Parent material Colluvial
Drainage poorly drained
Soil moisture 0 - 10 cm dry
Vegetation or land use Savanna

0 - 20 cm
br black (10 YR 3/1) moist & brownish
black (10 YR 3/2) dry, loam, spherical,
slightly sticky, slightly plastic, loose,
soft, basaltic & ignimbritic fragments
present, dark grey loose material (looking
like firewood ash) at a depth of 15 cm,
fairly rocky, exceedingly stony

20 - 50 cm
br black (10 YR 2/2) moist & dark br
(10 YR 3/3) dry, loam

Profile 20

Location Rift shoulder, W of Kuche hill
Elevation & climate 2120m,
Landform fault terrace
Slope almost flat
Parent material apparently derived in situ from ignimbrite
Drainage Poorly drained

Soil moisture 0 - 10 cm dry
Vegetation or land use ... Eucalyptus, Acacia, short grass

0 - 20 cm Black (10 YR 2/1) moist & V dk gr br
 (10 YR 3/2) dry, clay, cracks upto 10
 cm wide, prismatic, very sticky, plastic,
 very firm, very hard, many fine pores

20 - 45 cm Black (10 YR 2/1) moist & V dk gr br
 (10 YR 3/2) dry, clay

Profile 21

Location 34 km from Assela, in the Rift
Elevation & climate 1815m, warm, dry
Landform fault terrace
Slope almost flat
Parent material ignimbrite
Drainage poorly drained
Moisture condition 0 - 15 cm dry
Vegetation or land use .. Grazing, Podocarpus, Acacia trees

0 - 30
 V dk gr (10 YR 3/1) moist & dark br
 (10 YR 3/3) dry, clay, prismatic, firm
 hard, very stony, a greyish white layer, may
 be of carbonate, cracked, slickensides
 present

30 - 60 V dk gr br (10 YR 3/2) moist & dk br
(10 YR 4/2) dry, clay

60 - 100 dk br (7.5 YR 3/2) moist & dk br (7.5
YR 3/2) dry, clay

Profile 22

Location NE of Arata, 150 m west of the road to
Arata
Elevation & climate ... warm & dry
Landform Flat
Slope Flat
Parent material Basalt
Drainage Poorly drained
Soil moisture 0 - 20 cm dry
Vegetation or land use .. Scattered tree grassland with dominat
Acacia

0 - 25 cm V dk br (10 YR 2/2) moist & dk br (10 YR
3/2) dry, clay loam, prismatic, slightly
plastic, sticky, greyish white carbonate
accumulation at 15 cm depth, accumulation
of sesquioxides, reddish mottles.

25 - 50 V dk gr (10 YR 3/1) moist & dk gr br
(10 YR 4/2) dry, clay

50 - 90 cm

V dk rd br (5 YR 2/3) moist & dk rd br
(5 YR 4/2) dry, clay

Profile 23

Location	Dugda area in the Rift
Elevation & climate ...	1780 m warm & dry
Landform	almost flat
Slope	almost flat
Parent material	Rift pyroclastics
Drainage	imperfect
Vegetation or land use .	Savanna type

0 - 25 cm

V dk gr br (10 YR 3/2) moist & dk gr
(10 YR 4/1) dry, clay

Profile 24

Location	North of Asela about 1½ km
Elevation	2300m, cool, moist
Landform	hillside
Slope	Gently sloping
Parent material	apparently ignimbrite
Drainage	well drained

0 - 20 cm

dk br (10 YR 3/3) moist & dk br (7.5 YR
4/4) dry, loam

Profile 25

Location E of the main A.A. - Assela road, about
4½ km N Assela

Landform convex slope

Drainage well drained

0 - 15 cm V dk gr (10 YR 3/1) moist & dk gr
(10 YR 4/1) dry, loam

Profile 26

Location 3 km SE Assela, ARDU campus

Elevation 2370m

Landform undulating

Slope gently sloping

Parent material ignimbrite

Drainage moderately well drained

0 - 20 cm dk rd br (5 YR 3/3) moist & rd br
(5 YR 4/4) dry, clay

9. REFERENCES

- Alemayehu Mengistu, 1975, Grassland condition in the Chillalo Awraja. CADU publication No. 112, Asela, 107p.
- Bahat, D., 1979, On the African Rift System, theoretical and experimental study. Earth Planetary Sci. Jour. 45, No. 2.
- Bizouard, H., Barberi, F. and Varet, J., 1980, Mineralogy and Petrology of Erta Ale Boina Volcanic Series. Afar Rift, Ethiopia. Jour. Petr. No. 2.
- Black, C.A., 1967. Soil-plant relationships. John Wiley & Sons, Inc., N.Y.
- Black, R., Morton, W.H. and Varet, J., 1972. New data on Afar tectonics. Nature, Physical science, vol. 240, No. 104, pp 170-173
- Brewer, R. and Kreiger, K.E., 1975, Fabric and Mineral analysis of soils. Huntigton, N.Y.
- Buol, S.W., Hole, F.D. and McCracken, R.J., 1975, Soil genesis and classification. Oxford & IBH Publishing Co., New Delhi.
- Buringh, K., 1970, Introduction to the study of soils in tropical regions. Oxford & IBH Publishing Co., New Delhi.
- Burke, K. and Dewey, J.T., 1973, Plume generated triple junction J. Geol. 81, pp 406-433.
- Carroll, D., 1959, Sedimentary studies in the Middle River Drainage basin of the Shenandoah Valley of Virginia, Geological survey professional paper 314 - F, pp 125-154.
- Chapman, H.D., 1971, Evaluation of the micronutrient status of soils. International symposium on soil fertility status, proceedings, New Delhi, pp 927-947.

- Christiansen, T.B., Schaefer, H.U. and Schonfeld, M., 1975, Geology of Southern and central Afar, Ethiopia. In: Pilger, A. and Rosler, A., (editors), Afar Depression of Ethiopia. Schweizerbart, Stuttgart, pp259-277
- Clarke, G.R., 1936, The study of soils in the field. The Clarendon Press, Oxford.
- Cooke, R.U. and Doornkamp, J.C., 1974, Geomorphology in environmental management. Clarendon Press, Oxford.
- Dent, D. and Young, A., 1981, Soil survey and land evaluation. George Allen and Unwin, London.
- Di Paola, G.M., 1972, Geology of Corbetti Caldera (Main Ethiopian Rift). Bull. Volc. T35, 2.
- Di Paola, G.M., 1972, The Ethiopian Rift Valley (Between 7°00' and 8°40' lat. North). Bull. Volc., T36, 2. pp 518-560.
- Di Paola, G.M., 1976, Geological Map of the Tulu Moje area.
- Di Paola, & Seife Michael Berhe, 1979, The Kella horst. Preprint.
- FAO, 1977, Guidelines for soil profile description (second edition), Rome.
- Gass, I.G., 1970, Tectonic and Magmatic evolution of the Afro-Arabian Dome. In: Clifford, T.N., and Gass I.G. (editors), African Magmatism and Tectonics, pp 285-300.
- Geze, F., 1975, New data on ancient Galla Lake Levels. Bull. Geophys. Obs., Addis Ababa, No. 15, pp 119-124.
- Gibson, I.L., 1967, Preliminary account of the Volcanic geology of the Fant-Ale (Shoa). Bull. Geophys. Obs., Addis Ababa, No. 10

- Gibson, I.L., 1970, Quaternary Pantelleritic Volcanism in the Main Ethiopian Rift. Fourteenth annual report of the Research Institute of African Geology, University of Leeds, Department of Earth Science.
- Goss, D.N. and Stewart, B.A., 1979, Efficiency of phosphorus utilization by alfalfa from manure and superphosphate, Soil Sci. jour. Am., 43.
- Gregnanin, A., Piccirillo, E.M. and Alebachew Endeshaw, 1973, The subdivision of volcanic series in the Ethiopian Plateau: New geologic interpretation of the Dessie - Kombolcha Area. Bull. Soc. Geol. It. 22.
- Hammer, O., 1974, Fertilization with phosphorus on different soils. CADU Publication No. 104, Asela, 30p.
- Hatch, F.H., Wells, A.K. and Wells, M.K., 1961, Petrology of the igneous rocks. Vol. 1, Thomas Murby & Co., London.
- Hunt, C.B., 1972, Geology of soils: their evolution, classification and uses, Freeman W.H., & Co., San Francisco.
- Jackson, M.L., 1973, Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi.
- Jenny, H., 1941, Factors of soil formation. McGraw-Hill Book Co., Inc., N.Y. and London.
- Jones, P.W. and Rex, D.C., 1974, New data from the Ethiopian Plateau Volcanics. Nature 252, No. 5480, pp 218-219.

- Jones, R.J.A. and Jinsley, J., 1980. Hill land studies in the Grampian Region of Scotland. I. Effects of soil parent material, altitude and aspect on the herbage yields, composition and responses to fertilizer treatment in the Upper Don Basin. *Jour. soil. Sci.* 31, No. 2, pp 343-370.
- Juch, D., 1975, Geology of the South-Eastern Escarpment of Ethiopia between 39° and 42° long. East. In: Pilger, A. and Rosler, A. (editors), *Afar Depression of Ethiopia*. Schweizerbart, Stuttgart, pp 310-316.
- Kazmin, V. and Seife Michael Berhe, 1978, Geology and development of the Nazareth Area, Northern Ethiopian Rift. EIGS Note No. 100, 26p.
- Kebede Tato, 1970, A preliminary survey of soil erosion in the Chillalo Awraja. CADU special study 1, 41p.
- Kerr, P.F., 1959, *Optical Mineralogy*. McGraw-Hill Book Co.
- King, B.C., 1970, Vulcanicity and rift tectonics in East Africa. In: Clifford, T.N. and Gass, I.G. (editors), *African magmatism and tectonics*, pp 263-284.
- Kononova, M.M., 1961, *Soil organic matter - its nature, its role in soil formation and soil fertility*. Pergamon Press, N.Y.
- Kuno, H., 1953, Formation of calderas. *Amer. Geophys. Union*, 34, No. 2, pp 267-280.
- Kunz, K., Kreuzer, H. and Miller, P., 1975, Potassium-Argon age determinations of the Trap Basalt of South-Eastern part of Afar. In: Pilger, A. and Rosler, A. (editors), *Afar Depression of Ethiopia*, Schweizerbart, Stuttgart, pp 370-374.

Lill and Lundgren, B., 1969, The Munessa Forest - a plant ecological study.

Mahputra, I.C., and Patrick, W.H., Jr., 1971, Evaluation of phosphate fertility in water-logged soils. International Symposium on soil fertility evaluation proceedings, New Delhi, pp 53-61.

McConnel, H.G., 1980, A resurgent taphrogenic lineament of Precambrian Origin in Eastern Africa. Jour. Geol. Soc. 137, Part 4. pp 483-489.

McDonald, R. and Gibson, I.L., 1969. Pantelleretic obsidian from the Volcano Chabbi (Ethiopia) Contr. Mineral and Petrol. 24.

McKenzie, D.P. and Davis, P., 1970, Plate tectonics of the Red Sea and East Africa. Nature, 226, pp243-248.

Mergue, G.H., Norton, E. and Strangway, D.W., 1972. Tectonic history of the Ethiopian Rift as deduced by K-Ar ages and paleomagnetic measurements of basaltic dikes. Jour. Geophys. Res. 77, pp 5744-5754.

Merla, G., Abatte, E., Azzaroli, A., Bruni, P., Canuti, P., Fazzuoli, M., Sagri, M. and Tacconi, P., 1979, A Geological Map of Ethiopia and Somalia and Comment. CNR, 95p.

Meyer, W., Pilger, A., Rosler, A. and Stets, J., 1975, Tectonic evolution of the northern part of the Main Ethiopian Rift in Southern Ethiopia. In: Pilger, A. and Rosler, A. (editors), Afar Depression of Ethiopia. Schweizerbart Stuttgart, pp 352-362.

- Miller, J.A. and Mohr, P.A., 1966, Age of the Wachacha Trachy carbonatite volcanic center. Bull. Geophys. Obs. Addis Ababa, 9.
- Mohr, P.A., 1962, The Geology of Ethiopia. Univ. Coll. Addis Ababa Press, Addis Ababa, 268p.
- Mohr, P.A., 1963, The Ethiopian Cainozoic lavas - a preliminary study of some trends: spatial, temporal, and chemical. Bull. Geophys. Obs. Addis Ababa, 3, No. 2, pp 103-144.
- Mohr, P.A., 1966, Chabbi volcano (Ethiopia). Bull. Volc. T29, pp 797-816.
- Mohr, P.A., 1967, The Ethiopian Rift System. Bull. Geophys. Obs. Addis Ababa, 11, 65p.
- Mohr, P.A., 1970, Volcanic composition in relation to tectonics in the Ethiopian Rift System - a preliminary investigation. Bull. Volc. T34, pp 141-157.
- Mohr, P.A., and Potter, E.C., 1976, The Sagatu dyke swarm, Ethiopian Rift System. J. Volcanol. Geotherm. Res. 1.
- Morbidelli, L. and Piccirillo, E.M., 1973, Tectonics and volcanism in the Main Ethiopian Rift (Preliminary report) Bull. Soc. Geol. It. 92, pp 273-286.
- Morbidelli, L., Nicoletti, M., Petruccianni, C. and Piccirillo, E.M., 1975, Ethiopian South-Eastern Plateau and related edcarpment: K/Ar ages of the main volcanic events (Main Ethiopian Rift from 8°10' to 9°00' lat. north), In: Pilger, A. and Rosler, A. (editors), Afar Depression of Ethiopia. Schweizerbart, Stuttgart.

- Morgan, W.J., 1971, Convection plumes in the lower mantle. Nature, 230, pp 42-43
- Muller, A. and Van Baren, F.A., 1971, A standard method of soil characterization as a first approach of the evaluation of soil fertility. International Symposium on soil fertility evaluation proceedings, New Delhi, pp
- Murphy, H.F., 1968, A report on the fertility status and other data on some soils in Ethiopia. Coll. Agri. HSIU Experm. St. Bull. No. 44, 551p.
- Page, N., Taieb, M. and Faure, H., 1971. List of Radiometric ages from Ethiopia. Bull. Geophys. Obs. Addis Ababa, No
- Poulsen, G., 1969, Some reflections on water erosion in Chillalo Awraja.
- Power, J.F., 1980, Response of semiarid grassland to nitrogen fertilization. I. Plant growth and water use soil Sci. Jour. Soc. Am. 44, No. 3.
- Raunett, M., 1974, Morpho-pedological reconnaissance survey the Awasa area. Soil Survey of Awasa Farm, IRAT.
- Rex, D.C., Gibson, I.L. and Dakin, F., 1971, Age of the Ethiopian Flood Basalt Succession. Nature, physical science, 230.
- Russel, E.W., 1973, Soil conditions and plant growth. Longman London and N.Y.
- Searle, R., and Gouin, P., 1972, A gravity survey of the central part of the Ethiopian Rift Valley. Tectonophysics, 15, pp 41-52.

- Soil Survey Staff, 1975, Soil Taxonomy - A basic system of soil classification for making and interpreting soil surveys. Agricultural Handbook, No. 436.
- Suthern, R.J., 1980, Origin of some bedded welded tuffs. Bull. Volc. 43, 1, pp 61-71.
- Tazieff, H., Varet, J., Barberi, F. and Giglia, G., 1972, Tectonic significance of the Afar (or Danakil Depression). Reprint from Nature, 235, No. 5334, pp 144-147.
- Teuscher, H, and Adler, R., 1960, The soil and its fertility. Reinhold Publishing corporation, N.Y.
- Thompson, L.M., and Frederick, R.T., 1978, Soils and soil fertility. McGraw-Hill, N.Y.
- Trapp, C., 1974, Inventory of soils in the Rift Valley Region of Chillalo Awraja. CADU minor research Task, No. 11, Asela, 31p.
- Vlodavetz, V.I., 1970, On the terms 'Ignimbrite' and 'Ignimbritic Deposits'. Bull. Volc. T. 29, pp 141-145.
- Williams, H. and McBirney, A.R., 1979, Volcanology. Freeman, Cooper & Co., San Francisco.
- Yoder, H.S. and Tilley, C.E., 1962, Origin of basalt magma: an experimental study of natural and synthetic rock systems. Jour. Petrol. 3, pp 342-532.
- Zanettin, B., Gregnanin, A., Justin-Visentin, E., Mezzacaa, G. and Piccirillo, E.M., 1974, Petrochemistry of the volcanic series of the Central Eastern Ethiopian Plateau and relationships between tectonics and magmatology; Mem. Ist. Min. Univ. Padova, 31, pp 1-35.

DECLARATION

I, the undersigned declare that this thesis is my work and that all sources of material used for the thesis have been duly acknowledged.

Name _____

Signature _____

Place and date of submission _____
