

1. INTRODUCTION

Background

Previously, the study area was not studied in a detailed scale and systematic methods. But reconnaissance earlier works, the compilation of “ Geological map of Ethiopia” at a scale of 1:2,000,000 (Kazmin, 1972) and “Geological map of Yavello area” at a scale of 1: 1,000,000 were conducted including the study area within the geographic coordinates in which the above geological maps enclosed. These geological maps were mainly produced by interpretation of aerial photographs of 1:50,000 scale and some ground checking traverses. These works did not contain sufficient geological information about the country.

Therefore, the Federal Democratic Republic of Ethiopia have planned to prepare a 1:250,000 scale geological maps of the country. This duty is given to Ethiopian Institute of Geological Surveys (EIGS). The EIGS gave the operation duty to Regional Geology and Geochemistry Department. Geological mapping was started by giving priority to the Precambrian metamorphic rocks of the country due to their geological favourable condition in having economic mineral potential useful for the future socio-economic development of the country. Therefore, the present work is conducted under the Yavello project, which is part of the long mapping program of the country.

1.1 Objective and scope of the work

The Regional Geology and Geochemistry Department is carrying out geological mapping at a scale of 1:250,000 to prepared geological maps and eventually cover the whole country. Therefore, the present work of the team is within this frame work and was aimed to prepare a geological map and report of Elweya subsheet (NB37-14/B) at a scale of 1:50,000 which is part of 1:250,000 scale geological mapping of Yavello sheet (NB37-14).

1.2 Geography

1.2.1 *Location*

Elweya is located at about 603 km from Addis Ababa and about 27 km west Yavello.

Elweya subsheet (NB37-14/B) is covering about 750 Sq.km. It is situated within Yavello district, Borona zone, Oromiya National State, Southern Ethiopia. It is bounded by latitudes $4^{\circ} 45'$ N and $5^{\circ} 00'$ N and longitudes $37^{\circ} 45'$ E and $38^{\circ} 00'$ E (Fig.1).

1.2.2 *Access*

Two routes are available to reach the survey area. These are:

1. Addis Ababa-shashemenie-Awasa-Dila-Ageremariam-Yavello-Elweya. The Addis Ababa-Yavello road (575 km) is asphalted highway, whereas Yavello-Elweya road is all weather gravel road and it passes through the northern part of the mapped area to Teltelle village out of the map sheet. One can reach the eastern margin of the study area after driving about 12 km from Yavello town.

2. Another alternative all weathered road is Addis Ababa-shashemene-Sodo-Arbaminch-Konso-Brinder-Elweya. Elweya is located between Konso and Yavello at about 72 km from konso. The road from Addis Ababa-Arbaminch is asphalt. The Arbaminch-Elweya road is gravel layer. There is road between Birinder village (in subsheet T of Ageremariam sheet) and Konso is a dry weather road, hence, four wheel drive vehicles is important.

For this reason the Addis Ababa-Dila-Yavello road is much preferable to reach Elweya.

Accessibility within the area is good. There are dry weather roads connecting different villages and some local micro-dams. These roads are constructed by Livestock Development and Care organization. Some of the seasonal road routes within the area that branch off from the main Yavello-Teltelle road are:

1. Elweya-Hidiale-Adegelchet-Utalo
2. Elweya village-Haro Surite and extends for about 10 km southwest.
3. Adegelchet-Haro Harmolu.
4. Adegelchet-Dega Werabesa and extends for about 4.5 km northwest direction.
5. Adegelchet-Sarite ranch (in subsheet A)-Haro Kundi, after Haro Kundi the road extends for about 7 km with nearly west-northwest trend. This dry weather road branches off before arriving Sarite Ranch to reach Haro Kundi.

In addition to the above dry weather roads numerous foot trails are available in the area. The Borena people breed many cattle and have very wide trails and some of the foot trails are useful to drive four wheel vehicles (Fig.2).

1.2.3 *Physiography*

The area is situated within the low land of southern Ethiopia. Therefore, large portion of the mapped area is characterized by flat to gentle lying topography. There are also highly and moderately rugged topographic terrains represented by highland crystalline rocks. The flat to gentle topography is occupied by Quaternary deposits, and some Tertiary volcanic rocks. This topographic terrain covers the southeastern, east central, western and west central parts of the mapped area. The central and eastern portion of the area is characterized by continuous highly rugged ridges and locally isolated ridges/hills of granitic gneiss trending either N-S or NW-SE.

In the west central and southern parts of the study area basaltic rocks or scoria represents the existing ridges/hills. A moderately rugged topographic position exists in the northern and southwestern parts of the area. Here interlayered gneiss capped with basalt and only basalt represent the ridges/hills.

In the north central part of the area a table land topography covered by basalt is encountered. Meti ridge is the highest peak with elevation about 2070 m and the lowest elevation is 995 m in the eastern and western margins of the mapped area respectively.

Deep gorges and valleys except Elweya, Meti and Belesa-Gotu streams that form deep gorges and valleys when they cross the granitic gneiss are not common in the area.

Generally, the elevation is gradually decreasing from the eastern to the western part of the area (Fig.3).

1.2.4 *Drainage*

All the streams in the study area are intermittent. The streams draining with respect to the major geographic position of the mapped area are listed below as follows.

1. Streams in the eastern part of the area are Belesa-Gotu, Meti, Mukulo, Daga Bora and they flow mainly towards west. The Belesa Gotu stream contains water at its upper course.
2. In the northern part of the area Elweya and its tributary Melka Bora, and the other Melka Bora not tributary of Elweya are found. They run with different flow direction at their starting and central courses and finally they have east-west direction.
3. In the western part of the area, the streams are Melka Dimtu, Boji and Kiloftu and they drain westwards. These streams die out forming alluvium fan after reaching flatter topography within the area. They look like structural (fault/fracture) controlled because they form parallel drainage pattern.
4. In the southern part of the area, the streams are Ado and Lemo. Ado stream drains from east to west and it is tributary of Lemo stream. Lemo stream flows towards southwest. Fulo Bura stream from the east central part of the area join Lemo stream with nearly north-south direction.

The drainage system is not well developed in the southeast, east central and western marginal parts of the mapped area. The well to moderate developed drainage systems are associated with granitic gneiss and interlayered gneisses. The other rock units reveal moderate to poor drainage system.

The predominant drainage pattern of the area is dendritic with associated parallel and radial patterns in the western and central parts of the area respectively (Fig.4).

The higher drainage density is observed associated with the granitic gneiss in the eastern and central parts of the area. Low to medium density is seen in the other rock units.

1.2.5 *Climate*

The area is found in the arid to semi-arid climatic condition. It is characterized by two rain seasons in autumn and spring, and dry and hot climate for the rest period of the year. The main rain season is from mid-February to the end of June. The second rain season is from September to October. The mean annual rain fall ranges from 750-900 mm (Ethiopian Mapping Agency, 1981). The maximum precipitation record falls in April (data source from the local Agricultural Bureau).

Temperature is hot both in the summer and winter seasons. The hottest season is from January to mid-February. The mean annual temperature is 17-20⁰c (Ethiopian Mapping Agency, 1981). Temperature is relatively high in the western, southeastern, southern and southwestern parts of the area.

1.2.6 *Vegetation*

Since the area is within the arid to semi-arid climate, it has different types of lowland trees such as bushes, thorny bushes, acacia and grass. Thorny bushes are mainly found in the western and southern parts of the area associated with dark brown soil and volcanic rocks. Locally, scattered evergreen trees like “Gersie” and “Ade” are encountered rarely within basaltic flows, and mainly along the stream with thick alluvial deposit and reddish brown eluvial soil.

Dense forests are observed at two localities. The first locality is around Utalo in the southeastern part of the area. The second locality is east of Haro Harwale in the central part of the area. In rare case the dense forests are also encountered along the banks of some seasonal streams.

1.2.7 *Wildlife*

Various types of wildlives such as monkey, ape, birds, Hyena, Fox, Antelope, gazelle, Zebra and warthog are found in the area. The number and kind increase in the western, southern and southwestern parts of the study area.

1.2.8 Population

Semi-nomadic tribes of majority Oromo (Borena) and minority Geri live in the area. The population density in the area is low to medium. The eastern and northeastern parts of the mapped area are relatively dense populated.

The Oromo tribes are live everywhere in the area, whereas the Somali tribes are living only south of Hidiale village. Both tribes speak Oromigna language. In addition to Oromigna the Geri tribes also speak Somali. The people mainly live in areas where there is enough grass for grazing. Water and farmland are not the main reasons of settlement, unlike the high land people of Ethiopia.

They herd cattle, goat, camel, donkey and rarely sheep. They grow maize sorghum and teff.

Their major means of subsistence is livestock products such as milk and its products and cereal crops of the above mentioned but not in the form of injera.

The people fetch water from ponds dug upto 2-3 m depth along some big streams such as Elweya and Gelchet. Two water well with motor pump are found in the area, one in Elweya village and the other is in Adegelchet village. Among the “Haros”(artefial ponds), the one located south of Hidiale village contains water, and the local people fetch water for drinking.

In Elweya village, the inhabitants are of different tribes, such as Oromo, Amara, Burgi and Guragie. The main language spoken by the people for communication is Oromigna. Their means of existence is trading and farming.

1.3 Methodology

Prior to field, in the office, aerial photographs of 1:50,000 scale were examined and interpreted using table stereoscope. During this investigation, photogeological map was produced by delineating major rock units such as volcanics, metamorphic rocks, eluvial and alluvial deposits. Photo structural features such as foliation and lineament are also traced out in the office. Finally, tentative traverse routes were also selected.

In the office, some literatures have been surveyed in order to have an overview about the geology of the area and the surrounding regions. The literature includes the works of Megado region (Gilboy, 1970), Gariboro region (Chater, 1971), Yavello area (Kazmin, 1971) and the Geology of Ethiopia (Kazmin, 1972).

Field work was carried out from 10th of Hidar upto 6th of Yekatit 1992 E.C for about 3 months.

In the field, aerial photographs with 1:50,000 scale was used for navigation, plotting of observation points, to draw lithologic contacts, to trace out structural features and for interpretation. GPS (Garmin 12XL) and 1:50,000 scale topographic map were also used for navigation in places where there are no good physical features to control location. Geological data were transferred to 1:50,000 scale and 20 m contour interval topographic maps, which were used as base maps.

Traverse intervals spacing were made depending on the types of terranes. In metamorphic terrane, traverse routes were made across the general strike of the lithologic units. In the other terranes, traverse intervals were not constant and made along big streams and ridges/hills where rock exposures and sections were expected to be found. Normally, traverse spacing is about 2.5-3 km, but in the northern part of the area traverse intervals were spaced approximately 1-1.5 Km (App.7). Most of the time, observation points were made nearly at every 500 m interval, but it was also done depending on the change of lithology and structural complexity. Finally, fair copy of tentative geological map was produced in the field.

Sampling density is about 1 sample/ 8 km². A total of 90 fresh and representative rock samples were collected representing the interlayered gneiss, granitic gneiss and volcanic rocks. Out of 90 samples 43 rock samples were submitted to laboratory, for thin sections preparation and petrographic studies.

Classification of granitic gneiss is done based on Strekeisen (1976) QAPF diagram. Thin section description have been carried out using Kerr (1977) and Philpotts (1989), and metamorphic facies is classified based on Hyndman (1985) and Bucher and Frey (1994). Geological, geologic cross-section, observation points density map and drainage pattern maps of the area are digitized using MapInfo software version 5.0.

1.4 *Previous work*

So far, detailed geological mapping and geochemical exploration works for economic or academic interest have not been carried out in the study area. However, reconnaissance geological mapping was carried out by kazmin (1971) “Geological map of the Yavello area” at a scale of 1:000,000 and kazmin (1972) compiled the “Ethiopian geological map” at a scale of 1:2,000,000 with their an accompanying preliminary reports.

According to kazmin (1971) the area is underlain by two types of metamorphic rock units, Yavello gneiss and granite gneiss of Yavello type. Kazmin (1972) recognized three stratigraphic sequence such as Quaternary deposits, Tertiary volcanics and Precambrian rocks represented by Yavello gneiss and Awata gneiss.

As far as the recent works of the adjacent subsheets are considered subsheet C, the eastern adjacent was mapped by Ferede et al. (1999). They projected the following lithologic units such as granitic gneiss, granodioritic gneiss, and alluvial and eluvial deposits to be continued in the area of study. Except the granodioritic gneiss all the other mappable units are extended to the survey area.

Subsheet U of Ageremariam sheet northern adjacent was mapped by Weldegebrial et al. (1994) and they identified eluvial, alluvial, lower basalt (aphyric to porphyritic basalt), hornblende-biotite-quartz-feldspar gneiss intercalated with biotite-quartz-feldspar gneiss and biotite-meta granite rock units. Biotite-metagranite is not extended to the study area.

2. **REGIONAL GEOLOGY**

Many authors carried out geological mapping, exploration and research works at different scales for different purpose (economic and academic) at various geographic position on

Precambrian rocks of the Mozambique Belt and the Arabian Nubian shield of southern Ethiopia. Based on structural style, metamorphism and tectonic setting several classifications of the rocks were proposed by different authors.

Before discussing the geology of the Yavello area, it is important to have a general idea on the East Africa Orogen.

The East Africa Orogen (EAO) Comprises predominantly remobilized older crust of the Mozambique Belt (MB) in the Southern and predominantly juvenile crust of the Arabian Nubian shield (ANS) in the northern (stern, 1993).

In southern Ethiopian the rocks are subdivided in to high grade rocks and the lower grade metavolcano-metasediment rocks of the ANS. The ANS is represented by metavolcanics and metasedimentary rocks and the ultramafic of the Adola belt and the Moyale-Agal region (Hailu et al, 1989 and Mulugeta 1992).

According to Hailu et al. (1989) the Adola area comprises two main tectono-stratigraphic units that have undergone polyphase deformation and regional metamorphism. These are high grade gneiss intruded by syn to post tectonic granitoids and N-S trending volcano-sedimentary sequence and basic-ultrabasic rocks of greenschist to amphibolite facies. He suggested that this belt is underlain by sialic basement and that is developed from ensialic basin and not from Wilson cycle plate tectonic processes.

Baraki et al. (1995) indicated the Adola belt is the transition zone between the Neoproterozoic of the ANS and the MB.

According to Mulugta (1992) the Moyale-Agal region comprises polyphase metamorphosed and deformed mafic and ultramafic rocks, granodiorite and subordinate amount of metasedimentary. D₁ to D₄ phase of deformation and M₁ and M₂ metamorphic event are described in this region.

In the southern Ethiopia the rocks are subdivided into Lower complex, Middle complex and Upper complex (Kazmin, 1972). The Lower complex consists of Burji gneiss, Yavello gneiss, Awata gneiss, Alghe gneiss and Konso gneiss. The Middle complex

comprises the terrigenous rocks of the Wadara group. The Upper complex is represented by Adola group.

Kazmin et al. (1978) also recognized three folds classification i.e. the Lower complex consists of high grade gneiss, the Middle complex comprises clastic metasediments, and the Upper complex comprise low grade of ophiolitic rocks, andensitic metavolcanics and associated metasediments, clastic and to less extent carbonate sediments.

Amenti (1996) argued the Precambrian rocks of the southern Ethiopia form the northern part of the Mozambique Belt. He described the lithologic units of the southern Ethiopia into high grade gneiss, pelitic to psammitic as well as mafic to felsic that are partially migmatized. He identified M_1 and M_2 metamorphic events mostly middle to upper amphibolite facies, and he also indicated occurrence of granulite facies southeast of Jinka. He suggested five phases of deformation in which D_1 and D_2 are related to folding and D_3 , D_4 and D_5 are related to strike slip shear zones.

Gilboy (1970) and Chater (1971) who carried out a geological mapping, for their Ph.D thesis near to the eastern part of Yavello region on the Gariboro and Megado regions respectively. They classified the geology of the regions in to Lower Group, Middle Group and Upper group.

According to Gilboy (1970) the Lower Group consists of monotonous banded gneiss (biotite and biotite–hornblende gneiss), non-banded biotite gneiss and biotite– muscovite gneiss (frequently banded). The Middle Group consists of non-banded gneiss and schists (semi-pelitic/psammite assemblage, semi-pelitic/carbonate/pelitic assemblage and pelitic/amphibolite assemblage). The Upper Group is presented by rocks that commonly retains primary depositional features (phyllite, melanocratic amphibolite, and metamorphosed arkosic sandstone). These rocks are intruded by early and late intrusives based on the structural relation and metamorphic events.

Chater (1971) described the Precambrian rocks into three-folds in the Megado region. The Lower Group consists of biotite gneiss, the Middle Group, microcline-, muscovite-, biotite-, and hornblende bearing gneiss and the Upper Group amphibolite associated with ultramafic rocks interbedded with horizons of graphitic phyllite, arkosic grit and conglomerate.

Samual (1991) who did his MSc on Ageremariam sheet, suggested that the Archean rock with E–W foliation trend that are considered as craton by the earlier workers are not craton, but the rocks represent a Proterozoic supracrustal sequence. He classified the geology of the area to biotite-quartzofeldspathic gneiss and few intercalations of basic metavolcanics and at places intruded by plutons. He also suggested the protolith of the amphibolite and tonalite formed by Pan–African island arc magmatism over a west dipping late Proterozoic subduction zone. D₁ to D₃ episode of deformation responsible for the development of isoclinal to open upright folds are identified by him.

In the north (Ageremariam sheet) Woldegabriel et al. (1994) classified the geology of the area into Precambrian basement rocks, Cenozoic volcanics and Quaternary cover. They classified the volcanic rocks into pre-rift and post–rift volcanics.

Kazmin (1971) and Mengist et al, (1998) carried out geological mapping at 1:1,000,000 scale and age dating in the Yavello region respectively. According to Kazmin (1971) the region is under lain mainly by Precambrian metamorphic rocks of konso gneiss, Arero and Burji gneiss, Yavello gneiss, granitic gneiss of Yavello type, Adola group and associate intrusives. The Neogene–Quaternary volcanic are represented by mostly basaltic with subordinate acid varies and he classified them into lower, middle and upper units.

Mengist et al. (1998) identified three periods of magmatism based on single zircon

$^{207}\text{pb}/^{206}\text{pb}$, evaporation age; namely at 850, 750–700 and 650–550 Ma. Samples from southern Ethiopia labeled as ET9 and 6 were analyzed. TE-15 is taken from the eastern adjacent subsheet of the area within the Yavello gneiss (Kazmin, 1971). The determined age is 716.2 ± 1.2 Ma. Therefore, he suggested that the previous scheme of classification of Kazmin (1971) is incorrect.

3. **STRATIGRAPHY, LITHOLOGY AND PETROGRAPHY**

3.1 *Introduction*

Primarily based on degree of metamorphism, structural style and mineralogical composition, three major divisions are recognized in the area. These are Precambrian metamorphic rocks, Tertiary-Quaternary volcanic rocks and Quaternary deposits.

The Precambrian rock comprises high grade metamorphic rocks.

Only the high grade rocks are intruded by small and unmappable pegmatitic and/or aplitic dykes/sills and pegmatitic and/or quartz veins/vein lets with concordant and discordant orientation.

The Tertiary-Quaternary volcanic rocks are represented by volcanic lava flows and pyroclastic fall deposit rock types.

The Quaternary deposit consists of eluvial and alluvial soils.

Based on earlier works (kazmin, 1971 and 1972 and Weldegebrial et al., 1994), field evidence and petrographic studies of the present work, the following tentative stratigraphic sequence with their associated lithologic units is suggested from the oldest to the youngest as follows.

Precambrian metamorphic rocks

High grade metamorphic rocks

- Interlayered gneiss
- Granitic gneiss

Tertiary-Quaternary volcanic rocks

Tertiary volcanic lava flows

- Olivine phyric basalt, Plagioclase phyric basalt and Trachyte

Quaternary volcanic lava flow and pyroclastic fall deposit rocks

- Amygdaloidal-vesicular-phaneritic basalt
- Scoria

Quaternary soil deposits

- Eluvial deposit
- Alluvial deposit

3.2 *Precambrian metamorphic rocks*

3.2.1 *Introduction*

The Precambrian metamorphic rocks show variation in composition, structural style, degree of metamorphism and texture. Based on the above parameters the rocks are classified into high grade metamorphic rocks and low grade metamorphic rock.

Interlayered gneiss and granitic gneiss represent the high grade rocks. The interlayered gneiss is represented by biotite-quartz-feldspar gneiss, hornblende gneiss, biotite gneiss, marble and biotite-muscovite gneiss rock types. The low-grade rock consists of only metabasalt.

3.2.2 High grade metamorphic rocks

3.2.2.1 Interlayered gneiss (Pgn)

This unit is exposed in the northern part, west of Elweya village along Elweya-Teltelle road and around Surite ridges; in the western part along Elweya stream, and in southwestern part, northwest of Adegelchet along and around Kiloftu steram. It covers approximately 2% of the total area. In the northern and southwestern parts of the area, basaltic rocks occasionally cap this unit. This unit is terminated by granitic gneiss around Elweya village with tectonic (thrust) contact; i.e. the interlayered gneiss is thrust over the granitic gneiss.

This unit occupies small ridges/hills of moderately rugged topography with smooth surface and stream beds of Elweya and Melka Bora streams. It is found in both non-sheared zone and highly strained zone defined by simple and pure shear zones in which wrapping of foliation, lineated/boudinaged rocks, faults (normal and thrust) and folds are associated.

This unit is represented by intercalation of different types of rocks such as biotite-quartz-feldspar gneiss, hornblende gneiss, biotite gneiss, marble and muscovite-biotite gneiss in decreasing order of areal extent. The proportion of intercalation and the magnitude of the layers of each rock type are significantly variable from place to place.

The approximate percentage of each rock type is 70-80% biotite-quartz-feldspar gneiss, 15-20% hornblende gneiss, 5-10% biotite gneiss and < 1% for both marble and muscovite-biotite gneiss. Marble has large areal coverage as compared to the biotite-muscovite gneiss.

These rock types have almost the same texture, but they show variation in colour and composition. This unit is well foliated and occasionally show banding defined by felsic and mafic mineral segregation. The foliation shows variable trend. In the northern part of the area, the foliation trend varies from nearly north with little deviation to both east and west. In this part of the area locally, along Elweya stream and around Elweya village, foliation (S₄) with an E-W trend are encountered. In the southwestern part of the mapped area, the trend of the foliation is NW-SE.

Usually, this unit is invaded by pegmatitic veins/vein lets (1 mm-1 m) and pegmatitic dykes/sills (>1 m) and sometimes by veins and vein lets of quartz with concordant and discordant orientation.

Each rock types of this unit are described below as follows.

Biotite-quartz-feldspar gneiss

Biotite-quartz-feldspar gneiss is the dominant rock type in unit Pgn. Most of the time, this rock type is found dominantly over the other rock types, but in the southwestern part of the mapped area, it becomes small with respect to areal extent. Frequently, this rock type is found intimately intercalated with hornblende gneiss rather than the other rock types in unit Pgn. The thickness of each layer in the intercalation vary from a millimeter in the highly stained zone upto 10 meters out side the shear zone. Usually, the layers have attained their maximum thickness in the intercalations.

It is well foliated and locally banded. Banding is defined by segregation of felsic (quartz and feldspar) and mafic (biotite and/or hornblende) minerals. The bands range in width from 1-4 mm.

It is light gray to gray, medium to coarse grained. Usually, it is slightly weathered but sometimes, it is also moderately to highly weathered. The weathered colour is dark gray.

Thin section studies has revealed the average composition of this rock type to be 39% microcline and/or perthite, 31% plagioclase, 21% quartz and biotite 6%. The minor

minerals include 2% sericite+muscovite and 1% opaque, and trace amount of garnet in TH-1009, chlorite in TH-907 and epidote in TH-848. Sphene upto 1% is contained in TH-907. It revealed granoblastic with minor lepidoblastic texture. Some times poikiloblastic texture defined by inclusion of biotite in quartz and quartz in plagioclase is observed. The foliation is defined by preferred to slight orientation of biotite crystals. In thin section TH-907 some biotite grains are partly chloritized. In thin section TH-848 epidote is developed replacing plagioclase. Some biotite grains are marginally altered to muscovite. Some thin sections show myrmekitic intergrowth of quartz and plagioclase. Sericitization of feldspar is not common, but some feldspar grains in some thin sections are intensely sericitized.

Hornblende gneiss

Hornblende gneiss is next to biotite-quartz-feldspar gneiss in areal coverage in unit Pgn. This rock type occurs as lenses and occasionally as boudinage (discontinuous rock clasts) and also show pinching and swelling characteristics. These lenses (layers) range from 2-60 cm in width and locally reach upto 5 m. In the northern part of the mapped area, around surite ridge, along Elweya-Teltele road the boundinage reserves igneous texture (equigranular texture) and the other rock types such as biotite gneiss, biotite-quartz-feldspar gneiss and hornblende gneiss are anastomosing around it. At some localities, this rock type grades to both biotite-hornblende gneiss and hornblende-biotite gneiss.

At one locality, in the northern part of the area, along Elweya stream (at station, TH-860) this rock type covers a large areal extent than elsewhere in the study area.

It is strongly to moderately foliated with and without bands, but it is more banded as compared to the other intercalated rock types. The width of mineral segregated bands vary from 0.5-1mm.

Usually, the hornblende gneiss is dark gray and locally with lower amount of plagioclase and becomes darker. Texturally, it is medium to coarse grained. Most of the time, it is slightly epidotized. The felsic bands are relatively epidotized than the mafic ones. At places, e.g. in the northern part of the area, about 1 km west of Elweya village, along Elweya-Teltele road (at station TH-1032) epidotization is intensive.

Petrographically, hornblende gneiss shows an average composition of 43% hornblende, 29% plagioclase and 10% quartz. Less abundant minerals are 3% epidote and 2% diopside in TH-1041A and trace amount of biotite, opaque in most thin sections and sphene in thin section TH-1041A. It shows nematoblastic and granoblastic textures. The hornblende and epidote grains display the nematoblastic texture, whereas the granoblastic texture is display by quartz and feldspar crystals. The foliation is defined by alignments of prismatic crystals of hornblende and some quartz and plagioclase grains. Usually, hornblende is marginally altered to biotite and epidote. In some thin sections, the amount of epidote reaches upto 5%. In thin section TH-858 hornblende is altered to actinolite and the amount reaches upto 4%. In thin section TH-1041A retrograde metamorphism defined by an alteration of hornblende to biotite and epidote is seen (App.4). In thin section TH-1040B, sample taken from a relatively massive variety, equigranular texture is observed. Therefore, igneous texture is noted in this rock type.

Biotite gneiss

This rock type occurs as minor and thin lenses. The width of each layer ranges from 4-15 cm. It has large area coverage than both the marble and biotite-muscovite gneiss in interlayered gneiss. In the southwestern part of the area, locally this rock type grades into biotite schist and augen gneiss. It is the most frequently outcropping rock than the other rock types in southwestern part of the area.

It is gray to dark gray, medium to coarse grained and well foliated with local bands. It is slightly to moderately weathered. The weathered colour is dark gray.

Microscopically, biotite gneiss shows an average composition of 37% plagioclase, 30% quartz and 28% biotite. The minor minerals include 2% opaque, 2% sericite, 1% garnet and 1% muscovite. It has mainly granoblastic and lepidoblastic with minor porphyroblastic textures. Some biotite grains marginally altered to muscovite. The foliation is defined by preferred orientation of biotite and some elongated quartz and plagioclase grains. The opaque grains also show elongation parallel to the foliation. Microbands are seen defined by biotite rich layer.

In the augened biotite gneiss, biotite grains are anastomosed around plagioclase and garnet porphyroblasts (App.5). The plagioclase porphyroblasts are pre-deformational, whereas garnet porphyroblasts contain internal and external biotite grains of the same texture. Therefore, garnet is syn-deformational grown. Poikiloblastic texture defined by inclusion of small crystals of biotite, plagioclase and quartz within garnet grains is seen. Quartz stringer characterized by wavy extinction and fracture across the strike is identified. A slight alteration of plagioclase to sericite is observed. Marginally, recrystallization of quartz and plagioclase is also noted.

Marble

This rock type is only exposed in the southwestern part of the area along and around Kiloftu stream. It covers a small areal extent. The thickness of the marble ranges from 0.25 -6 m.

This rock type is light gray and coarse grained. It is massive to foliated and locally, banded. The bands are defined by dark tints within white to light gray background colour. Petrographically, the marble is composed mainly of 97% calcite, 2% phlogopite and 1% quartz. It has granoblastic with minor poikiloblastic texture. The poikiloblastic texture is defined by phlogopite and quartz grains inclusion within big crystals of calcite. Some quartz grains show subround morphology. The calcite grains show some twining lamellae.

Biotite-muscovite gneiss

This rock type is restricted only to the southwestern part of the area. It covers a least areal coverage as compared to the other rock types in the intercalations. It is exposed on a

slope of a small hill that is capped by olivine phyric basalt at about a few meters from Kiloftu stream on the right side going upslope of the stream.

Biotite-muscovite gneiss is light gray when fresh and slightly weathered. It is medium to coarse grained in texture.

Thin section studies of this rock type show composition of 50% muscovite, 29% plagioclase, 15% quartz, 10% microcline and 6% biotite and trace amount of sericite. The foliation is defined by preferred orientation of biotite and muscovite. Only very few biotite and muscovite grains are found at some angle to the foliation. Plagioclase grains are slightly altered to sericite. It has lepidoblastic and granoblastic textures. A felsic rich layer with some grains of muscovite and biotite is also observed.

3.2.2.2 *Granitic gneiss (PGtgn)*

This unit is exposed in the eastern and central parts of the mapped area. It covers approximately 10% of the total area. This unit is an extension of granitic gneiss of subsheet C (Ferede et al., 1999) or granitic gneiss of Yavello type (Kazmin, 1971).

The granitic gneiss is highly jointed. It has blocky and bouldery outcrop nature developed by two sets of oriented and other randomly oriented joints/fractures. It forms higher topographic terrain defined by continuous chain of ridges with many peaks. These chain of ridges are represented by Tinika ridge in the central part with NNW-SSE elongation direction, Arer Guda in the northeastern with NW-SE, and Meti, Arer Tika and Mole ridges in the eastern part with nearly N-S maximum trend. Mukulo, Teso-Gelchet, Dega Werabesa and Somaya represent the isolated hills. At Elweya village and its surrounding, this unit crops out forming a moderately high topography and the blocks and boulders are found as sheet. At this locality, well pronounced banding defined by felsic (quartz and feldspar) and mafic (magnetite and/or biotite) mineral segregation are encountered.

Locally, strongly deformed /sheared/ variety ranging in size from 0.07-1.5 m to the north of Arer Tika, Teso-Gelchet and Elweya village are seen. This rock type contains high amount of biotite than the relatively less deformed variety.

The granitic gneiss is commonly homogeneous, but sometimes, it is slightly inhomogeneous in structure, texture, colour and composition. The amount of K-feldspar, quartz and magnetite vary from place to place. At Aneni ridge the amount of magnetite increases, but the amount of quartz decrease from south to north along the strike of the ridge. High amount of quartz (silicification?) is seen at the southern flank of Tinika ridge. Deformation decreases from north to south along Tinika ridge in the central part and from Aneni to Mole ridge in the eastern part. As far as, the central and marginal parts of this unit are considered, the central part is relatively less deformed than the marginal part. Pegmatitic and aplitic dykes/sills are seen within this unit with abundant occurrence in certain area. These are common at Aneni, Arer and Elweya ridges. At Tinika, Mole and Meti ridges this unit is almost deprived of the dykes.

Structurally, it varies from strongly foliated and locally banded to massive. At places, e.g. at Aneni ridge the massive to less deformed variety has preserved the igneous texture (equigranular texture). Usually, foliation is defined by discontinuous concentration of magnetite and/or biotite grains. Locally, these bands are defined by felsic (quartz and feldspar) and mafic (magnetite and/or biotite) mineral segregation. In a rare cases, very thin (millimeter scale) magnetite vein lets parallel to the local foliation are encountered.

This unit shows variegated colour in the fresh and on the weathered surfaces. The fresh colour is gray, light gray, yellowish gray and pinkish gray in decreasing order of abundance of occurrence within the unit. The yellowish gray colour is common at Tinika ridge. The other colours are seen everywhere within this unit without defining certain area/zone/. Texturally, it is medium to coarse grained. This unit is slightly altered and the weathered colour is dark to dark brown with locally pinkish, pinkish gray and dark gray. At places, this unit contains yellowish brown colour spots resulted from the oxidation of magnetite and/or biotite. The modal percentage of this unit is plotted in QAPF diagram (Fig.5).

Thin section description of this unit shows an average composition 40% microcline and/or perthite, 31% plagioclase and 26% quartz. The minor minerals are 1% hornblende and 1% opaque (magnetite) and trace amount of biotite, epidote and sericite also occur. It is granoblastic in texture. Foliation is mainly displayed by preferred to slight orientation

of biotite and hornblende and rarely opaque (magnetite) crystals. Often hornblende is marginally altered to biotite and sometimes to epidote. Epidote is also developed from plagioclase. Poikiloblastic texture defined by inclusion of small crystals of quartz in big crystals of feldspar is common. Sericitization of feldspar is rarely observed. Only very few thin sections show intense sericitization of feldspars.

3.3 TERTIARY-QUATERNARY VOLCANIC ROCKS

3.3.1 Introduction

The Tertiary-Quaternary volcanic rocks in the area comprise volcanic lava flows and pyroclastic fall deposits. They occupy flat to gentle topographic terrain. They unconformably overlay the basement rocks. They are the dominant rock units and cover above half of the study area. These rocks show considerable variation in thickness and texture. The variation in thickness may show pre-Tertiary and pre-Quaternary topographic terrain. Paleosoil is not seen between the different rock units or types of basalts within the area. Subdivision of the volcanic rocks of the area is based on the volcanic rock classification in the northern adjacent sheet (Ageremariam sheet) Weldegebriel et al. (1994). According to their work volcanic rocks of the area are classified into pre-rift (Tertiary) and post-rift (Quaternary). A section observed in the western adjacent subsheet (subsheet A), at the Sarite rigde Tsegaye Abebe (personal communication) also supports this classification.

Therefore, based on the above data the volcanic rocks of the study area are grouped into pre-rift (Tertiary) and post-rift (Quaternary).

Olivine phyric basalt, plagioclase phyric basalt and trachyte represent the Tertiary volcanic lava flows.

The Quaternary volcanic lava flow and pyroclastic fall deposit are represented by amygdaloidal-vesicular-phaneritic basalt and scoria respectively.

3.3.2 Tertiary volcanic lava flows

3.3.2.1 *Plagioclase phyric basalt (Tvp)*

This unit occurs on the northern part of the area. It covers about 0.27% of the total mapped area. Some of the hills form flat top terrain. Usually, this unit covers the interlayered gneiss. It outcrops in boulders, cobbles and pebbles forms. The fragments are usually angular to subangular and locally, rounded to subrounded. This unit forms moderately rugged topography, represented by Surite, Abe and some other hills. The average thickness is about 50 m around Surite and reaches upto 90 m west of Abe hill. This thickness is calculated from a 1:50,000 scale topographic map of 20 m contour interval. The minimum thickness of this unit is approximated 10-15 m around the locality

where the maximum thickness is estimated. Generally, the thickness of this unit increases from Surite hill towards Abe hill.

At Abe hill, the size of the phenocrysts varies from a millimeter to 0.5-1 cm and their shape is elliptical to semi-circular.

The plagioclase phyric basalt is light to dark gray when fresh and dark to dark brown on the weathered surface.

Microscopically, the average composition of the plagioclase phyric basalt is 34% plagioclase, 30% augite 22% opaque and 12% olivine. It shows mainly porphyritic and ophitic to subophitic with minor subtrachytic textures. The intergrowth of mafic (pyroxene and olivine) and plagioclase grains display the ophitic to subophitic texture. Most of the olivine grains are altered to serpentine. The amount of serpentine ranges from trace up to 2%. Olivine grains are found as microphenocrysts and microlites. In the fine grained groundmass, the pyroxene microlites fill the interstices of plagioclase, opaque and olivine grains.

3.3.2.2 *Olivine phyric basalt (Tvo)*

This unit crops out in the northwestern corner, southwestern central parts of the area. It covers approximately 0.87% of the total mapped area. The outcrop nature of this unit is in form of boulders, pebbles and cobbles. The morphology of the boulders is mainly angular to sub-angular and rarely rounded to subrounded. It occupies a moderately rugged topography particularly in the southwestern part developed by dissected small hills, and isolated small hills in the northwestern corner part of the area. In the southwestern part of the area this unit contains nodules that are rich in olivine and/or pyroxene crystals. This unit has about 25 m and 65 m thickness in southwestern and northwestern corner of the area respectively. This thickness is calculated from a topographic map.

The primary structure, columnar jointing is only observed at one station (TH-1005) along Kiloftu stream. The alignment of the columnar joint is moderate to steep in attitude. The columnarly jointed boulders show six-sided face.

It is light gray when fresh and dark to dark brown on the weathered surface. The weathered surface contains voids as a result of leaching out of olivine crystals. Some of the phenocrysts of olivine crystals are altered to yellowish or yellowish brown material (iddingsite?).

The average modal composition of this unit is 40% opaque, 35% plagioclase, 25% olivine and 20% augite. It is commonly porphyritic with minor subophitic and trachytic texture (App.4). An alteration of olivine to serpentine and iddingsite is commonly observed. Olivine grains are partly altered along the fracture plane and marginal part of the crystal with some relict at the core of the crystals to the above mentioned secondary minerals. In thin section TH-998 the groundmass is made up of several microlites such as black (opaque), reddish-, and yellowish-brown (pyroxene and olivine) and gray (plagioclase). In some thin sections, the plagioclase laths have encircled the olivine phenocrysts to show flow texture during solidification of the magma. In thin section TH-998 much of the olivine crystals are altered to iddingsite and its amount reaches upto 10%.

3.3.2.3 *Trachyte (Tvt)*

This unit is only found in limited area in the northwestern central part of the mapped area. It covers about 0.03% of the total area. It forms one small and elongated hill. This hill has an outcrop outline in northwest-southeast trend. It is strongly fractured with two sets that are orthogonal to each other and some boulders are found in the exposure. It is found as island within eluvial deposit. Therefore, it is difficult to see its contact nature with the other rock units.

It is light dark in fresh and dark brown on weathered surface, and fine to medium grained. In rare case, plagioclase grains are found as porphyroblasts in-set within a mafic matrix.

Petrographically, this unit is composed of 62% microlite, 20% aegirine-augite, 10% opaque and 8% sanidine as phenocrysts. It commonly shows trachytic texture (App.3). Reddish brown materials (clay?) are commonly seen. Sanidine crystals are of two generations (early formed big phenocrysts and those crystallized during or after eruption are smaller phenocrysts or laths) are observed.

3.3.3 Quaternary volcanic flow and pyroclastic fall deposit

3.3.3.1 *Amygdaloidal-vesicular-Phaneritic basalt (Qavp)*

This unit occupies the northern, east central, southern, southeastern and southwestern parts of the mapped area. It covers an extensive area than the other basaltic units. It occupies approximately 50.1% of the total area. This unit forms north-south running belt in the central part and extends towards south and gets wider with a small break at Adegelchet village, but in the northwestern this unit extends towards south without any discontinuity. This unit exists mainly as boulders and rarely as pebble and cobble size fragments. In the southwestern margin, southeastern and around Adegelchet, this unit is represented by dark brown, silty-clay in texture soil and floats of basalts of pebble and cobble size. It is difficult to map the different rock types as mappable units separately due to their intimate association. The proportion of association is not uniform from one station to another station. They occur one predominate over the other.

This unit occupies both the moderate and flat to gentle lying topographic positions. The moderate topography covered by this unit is found around Fulo Bura stream in east central and east of Elweya village in the northern parts of the area. The flat to gentle lying terrain occupies the southeastern, south central, and southwestern marginal parts of the area.

Thickness of this unit varies from place to place. This unit also varies from vesicular to non-vesicular in texture. The maximum thickness estimated at Boji stream from the topographic map of 1:50,000 scale and 20 m contour interval ranges from 100-140 m.

The different rock types in decreasing frequency of occurrence are described below.

Phaneritic basalt

This rock type is the dominant and wide spread rock type in rock unit (Qavp). This rock type covers large areal extent in the east and northeast of Melka Dimtu stream, in west central, at locality north of Elweya village, in the north central and north of Fulo Bura stream in east central parts of the area. It consists of about 70% of the total volume of the unit. It is strongly fractured and exists as boulders and sometimes as blocks. The blocks and boulders are angular to subangular with minor rounded to subrounded in morphology. The boulders and blocks show different number of side. At Elweya stream in the northern part of the area relatively fresh basalt exposed on both side of the bank with two set of joint and horizontal to subhorizontal ($4^0/270^0$) bedding plane? is encountered. Locally, flow lamination defined by layers of redish brown on weathered and light greenish in fresh surfaces with thickness ranging from 0.5-1.5 mm are seen.

At Boji stream on a cliff near to the stream bank an alternative layers of phaneritic basalt and scoriaceous basalt are observed. The contact between these layers is gradational (Fig.7). The scoriaceous basalt contains fragments of chilled basalt and host rock. Another section is seen east of Melka Dimtu stream in the western part of the area. Here on a small cliff with a vertical section view, scoriaceous basalt sandwiched between vesicular basalt at the base and massive, compacted and dense basalt at the top is observed. The contact is gradational and the phaneritic basalt shows bedding plane defined by weak zone with horizontal attitude.

The phaneritic basalt is usually massive with locally minor vesicles. The vesicles range in size from <1 mm to 4 mm. At places, the vesicles are filled mainly with white powder and rarely with olive greenish colour materials.

It is light grey and locally dark gray. Generally, it is fine to medium grained. At one locality (south west of Hidiale village) hypabyssal rock type equivalent in mineral composition to the phaneritic basalt with medium to coarse grained is observed. The weathered colour is mainly dark to dark brown and locally vary to reddish brown. At

places, limonitic relicts near to the altered surface, spheroidal weathering and porphyroclasts of plagioclase are seen.

Petrographically, it has an average composition of 38% plagioclase, 27% augite, 23% opaque, 12% olivine and trace amount of iddingsite. It shows commonly porphyritic with minor intergranular, subophitic and tracytic texture. Plagioclase and olivine grains display the microporphyritic texture. Some olivine crystals are slightly altered to iddingsite mainly along fracture plane and marginal part of the crystals. In thin sections TH-990 and TH-978 the groundmass is fine grained and consists of 88% and 65% of the composition respectively. The ground mass is represented by microlites of different colour minerals. Reddish-, and yellowish-brown colours are assumed to be mafic minerals (olivine and pyroxene), dark opaque and gray plagioclase. In thin section TH-990 and TH-978 microcrystals of olivine are contained 2% and 15%, and plagioclase 10% and 20% respectively. In thin section TH-960, the vesicles make up about 5% of the thin section by volume.

Amygdaloidal-vesicular basalt

This rock type is the second abundant to phaneritic basalt in areal extent. It represents about 20% by areal coverage of the rock types in unit Qavp. It is found scattered in many parts of the area, except at localities north of Adegelchet in the central, west of Haro Kundi in the western and east of Elweya village in the northern parts of the mapped area. It occurs mainly as big blocks, boulders and sometimes as cobble and pebble fragments. Two types of soils, reddish brown and dark brown are developed from this rock type. The reddish brown soil is observed at a locality about 5 km east of Elweya village.

It is highly vesiculated. The vesicles have different in sizes 3 mm to 5 mm. Shape of the vesicles are mainly spheroidal with some circular to semi-circular. In the central part of the area, at about 1 km northwest of Adegelchet the maximum width and length for the elliptical shaped vesicles are 4 cm and 5.5 cm respectively. In the northern part of the area, at about 5 km east of Elweya village the circular to semi-circular vesicles have diameter ranging from 3-4 cm. The fine to medium size vesicles have 0.5-1.5 cm width and 2-4 cm length.

It is light dark, fine to medium and the weathered colour is dark to dark brown. Most of the voids are filled with white and olive greenish powder materials.

Microscopic studies revealed this rock type has an average composition of 32% opaque, 24% augite and 6% olivine. It shows microporphyritic, hypocystalline and intersertal texture. Some of the vesicles in the thin section are partly and wholly filled with secondary calcite and form amygdules. The calcite ranges in amount from trace upto 5%. The vesicles consist of 15-20% of the thin section by volume. Most of the olivine grains are altered to iddingsite and this iddingsite is contained upto 2%. The plagioclase grains occur as microphenocrysts and laths.

Vesicular basalt

This rock type represents highly vesiculated basalt without any amygdules. It is the least in areal coverage about 10% as compared to the other rock types in unit Qavp. It is common in occurrence in the western part of the area and it forms Bule Mersa hill. It is lighter in weight and occurs as boulders in the slightly weathered, but in the highly weathered part of the rock it also exist as pebble and cobble. The vesicles are fine to medium and their shape is elliptical to semi-circular.

It is light to dark gray, fine to medium and the weathered colour is dark brown to dark.

Thin section studies of the vesicular basalt revealed an average composition of 31% plagioclase, 30% opaque, 29% augite, 5% iddingsite and 4% olivine. It shows commonly porphyritic and rarely hypocrySTALLINE and intersertal textures. Olivine is commonly altered to iddingsite. Most of the iddingsite are found as partial or complete substitution of olivine crystals, because some olivine relict has still remained in the core and rarely near to the marginal part of the crystals. In thin section Th-878 iddingsite contained upto 10%. The vesicles make up 20% of the thin section by volume. Both plagioclase and olivine grains are found as microphenocrysts and microlites in the groundmass.

3.3.3.2 *Scoria (Qsc)*

This unit is exposed in the southern, southeastern and northeastern parts of the area. It covers approximately 0.1% of the total area. It forms three distinct hills. In rare case in the southern and southwestern part of the area this unit is also found as patches/lenses outcrop nature within the phaneritic basalt and it is unmappable at 50,000 scale. It contains pebble and cobble size of lithic materials of basalt lava. It forms a steep slope cliff on the western side and moderate slope on northeastern side of the hill. At Sometele hill this unit shows a primary structure (graded bedding) represented by fining upward of basaltic fragments as seen on a vertical section view on a steep slope cliff of the hill (Fig.6).

At the locality west of Arer Guda ridge in the northeastern part of the area, this unit is represented by scoraceous basalt with minor massive (phaneritic) basalt at the center as observed on a quarry section exposed by Sunshine Construction Company for the

purpose of road construction. The phaneritic basalt grades into reddish brown vesiculated basalt and this rock type also grades to friable loosely compacted scoraceous material (laterite?). At this spot xenoliths of granitic gneiss are encountered.

Two prominent sets of joints with vertical dip are observed at Sometele hill. Some of the joints are filled with calcareous veins.

This unit shows reddish brown in fresh and dark brown colour on the weathered surface.

This unit is mostly friable with less compacted and vesiculated varieties.

Microscopically, this unit is composed of 87% groundmass, 5% plagioclase, 3% sanidine, 3% inddingsite and 2% augite. All minerals are found as microphenocrysts, but the plagioclase grains also occur as laths. The groundmass is estimated to be consists of opaque, altered brownish materials (volcanic glass?) and fine grained crystals of the above minerals. Texturally, it vesicular and microporphyritic. The vesicles make up about 50% of the thin section by volume.

3.4 **QUATERNARY DEPOSITS**

3.4.1 **Introduction**

The Quaternary deposit is represented by residual and transported deposits of eluvial and alluvial soils respectively.

3.4.2 ***Eluvial deposit (Qe)***

This unit is found in the northern, eastern, northwestern, central and east central parts of the study area. It covers approximately 35.5% of the total area. This unit represents residual and some transported soils along the bank of some streams/creeks. It occupies mainly flat to gentle terrain with some positive terrain in the northern part of the mapped area. It is not possible to know the actual thickness of this deposit, because the base is not exposed. The observed maximum thickness is about 2 m to the east of Tinika ridge in the central and around Utalo village in the southeastern and 5 m north of Gotu Onu stream in the northeastern part of the area.

A significant complete soil horizon sequence is not developed in the area under consideration. The most common soil horizon developed in this deposit is B-horizon. But along Melka Bora stream both A-, and B- horizons are encountered.

Depending on texture, colour and degree of compactness the eluvial deposit is classified into two types of soils.

1. Reddish brown locally reddish colour and sandy-clay in texture. This soil covers a large areal extent and is found in all the above mentioned geographic position except in the northwestern part of the area. This soil is moderately compacted and at places, it contains fragments of quartz of pebble size. In the northern part of the area, west of Melka Bora stream, this soil is found as residual soil with fragments of pegmatite and quartz of pebble and cobble size. At this locality, it covers an elevated topographic position than elsewhere in the area.
2. This soil type is dark brown and silty-clay in grain size. It is found in the northwestern part of the area.

It is moderately compacted and slightly to highly cracked. At places, long grasses that have grown on this soil are encountered. This soil does not contain quartz and other rock fragments. Thorny bushes are mainly associated with this type of soil.

3.4.3 *Alluvial deposit (Qa)*

This deposit is developed along stream courses with gentle to moderate slope such as Elweya stream in the western, Belesa Gotu in the eastern, Gerdo stream in the northern margin, Gotu Onu in the northeastern and Boji stream in western parts of the mapped area. This deposit is represented by unconsolidated sediment and consists of sandy-clay soil and angular to subangular and at place rounded to sub-round fragments of pebble and cobble size of quartz, pegmatite, basalt, granitic gneiss and interlayered gneiss. It covers about 1.33% of the total area. Except Gotu Onu stream all streams die out forming an alluvium fan deposit within the area. The thickness of the alluvium deposit varies from place to place. The maximum thickness is about 16 m at Elweya stream and the minimum thickness is about 2.3 m at Gerdo stream. At places, this deposit shows different layer defined by unconsolidated gravel layer and soil horizons with some disseminated rock fragments.

At Gerodo the thickness of the gravel layer reaches up to 70 cm and sandy-clay horizon is about 1.5 m.

At Elweya stream 3 to 4 gravel and soil horizons characterized by different colour and composition are encountered.

4. **STRUCTURE**

4.1 **Introduction**

The Precambrian rocks of the southern Ethiopia are subjected to polyphase of deformation and metamorphism (Gilboy, 1970, Chater, 1971 and Kazmin, 1971 and 1972).

Amenti (1996) suggested that the various structures in the Precambrian rocks of the southern Ethiopia have suffered D₁ to D₅ events of deformation.

The Precambrian metamorphic rocks of the study area are subjected to polyphase of deformations. The rocks revealed various secondary planar and linear structural features such as foliations, folds, faults, shear zones, lineaments and joints/fractures.

Based on structural analysis and different orientation of planar and linear structural elements, six deformational events designated as D₁, D₂, D₃, D₄, D₅ and D₆ are identified in the area. Most of the deformational events are locally developed in interlayered gneiss within the highly strained zone.

Folds are commonly seen in the interlayered gneiss. The granitic gneiss is not affected by folding event except F₅ folds defined by wrapping of foliation around Elweya stream in the northern part of the area.

The primary structures of the volcanic rocks such as bedding plane, lamination, graded bedding and columnar jointing are described in the lithologic section with respect to the rock units in which the structures are associated.

Based on some consideration of the earlier works and mainly after structural analysis and interpretation from the present work, the different deformational events with associated structural features are described below as follows.

4.2 ***The first deformational event (D₁)***

This episode of deformation produced the compositional banding and schistosity of S₁-foliation in the interlayered gneiss, granitic gneiss. This structural element is assumed to be the earliest planar feature in the study area.

4.2.1 *Foliation (S₁)*

The regional foliation of the Precambrian rocks in the area is defined by compositional banding of segregation of felsic (quartz and feldspar) and mafic (biotite, hornblende and/or magnetite) minerals and schistosity defined by biotite, hornblende and magnetite especially found in the granitic gneiss. This planar structural element is dominant and it shows variable attitude. The trend of the regional foliation swings between NNE and NNW and dips gently (10° - 20°) mostly towards northwest and rarely towards southwest. The NNW trend foliation is not associated with interlayered gneiss, but it is common in granitic gneiss.

In the southwestern part of the area the foliation trend is NW and dips moderately (30° - 45°) towards southwest. All the foliations are plotted in a stereographic plot (Fig.10).

4.3 *The second deformational event (D₂)*

This event is restricted within the interlayered gneiss in the highly strained zone. It is represented by small simple shear zone and associated non-cylindrical asymmetric tight to close folds (F₂), axial-planar/surface cleavage foliation (S₂) and lineation (L₂) defined by boudins.

4.3.1 *Foliation (S₂)*

Foliation of this generation is axial-planar cleavage parallel to F₂ axial surface. It is measured at the fold hinges of F₂ folds associated with a simple shear zone. Foliation (S₂) is observed on a vertical section along Elweya-Teltele road.

4.3.2 *Folds (F₂)*

The tight to close non-cylindrical mesoscopic folds are assumed to be the earlier folds developed by folding of S₁ foliation affecting different rock layers (Fig.13b). Generally, it is encountered within highly strained zone in interlayered gneiss. The folds show almost similar Plunge. Generally, the fold axes plunge shallowly (4°-5°) towards south-south-west. The fold axes are plotted in a stereoplot (Fig.12).

4.3.3 *shear zone*

Simple shear zone with sinistral sense of movement is observed in the high strained zone within interleyred unit at about 1 km west of Elweya village along Elweya-Teltele road (Fig.13).

Strongly sheared mylonitic rock types that are relatively less deformed out of this zone characterize this shear zone.

4.3.4 *Boudin (L₂)*

This lineation is defined by competent layers of mafic (gabbaroic in composition) and pegmatitic veins. These boudins are observed within interlayered gneiss at about 5 km west of Elweya village along Elweya-Teltele road. A mafic boudin with sinistral sense of movement is encountered. Some of the mafic rich boudins reserve igneous texture. The maximum magnitude of the boudins is parallel with the extensional plane whereas the minimum magnitude is parallel with the compressional plane (Fig.17).

4.4 *The third deformational event (D₃)*

During this deformational event pure shear zone and associated lineation (boudins) are developed.

4.4.1 *Pure shear zone*

This shear zone is characterized by compressional and extensional deformational component along z-axis and x-axis respectively. In the compressional plane M-shaped pegmatitic fold is encountered (Fig.14).

4.4.1.1 *Boudins (L₃)*

Pegmatitic and mafic layers that are flattened and stretched/elongated along the extensional plane (x-axis) represent these boudins. Some of the boudins show swelling and pinching characteristic along the extensional plane (x-axis) when the strength contrast is low (Fig.14).

4.5 *The fourth deformational event (D₄)*

Thrust (reverse fault) with thrust plane dipping shallowly to moderately (0° - 30°) towards northwest is observed at about 1 km west of Elweya village. This variation of dip amount shows flat and ramp surface along the thrust plane. The associated structures are dragged and recumbent folds (F₄) at this locality. This thrust shows top towards the south-south-east.

In addition to the above structures this thrust is also supported by evidence at about 200 m east of Elweya village with unusual tectonic contact between interlayered gneiss and granitic gneiss and associated lineations (L₄) (mineral aggregate and striation lineations) and foliation (S₄).

4.5.1 *Foliation (S₄)*

An E-W trend local foliation (S₄) is encountered around Ewlweya village and along Elweya stream in the northern part of the mapped area. It is associated with thrust. This

foliation dips gently towards north and north-north-west i.e. nearly similar to the plunge direction of the lineations.

4.5.2 *Folds (F₄)*

Folds (F₄) are represented by dragged and recumbent folds that are seen only at locality about 1 km west of Elweya village in the place where thrust is observed. They are characterized by long and flat limbs nearly parallel to the thrust plane. They form synform on the foot wall and antiform on the hanging wall of thrust plane, but now filled with pegmatitic veins (Fig. 13a).

4.5.3 *Lineations (L₄)*

Two types of lineations (mineral aggregate and striation (groove) lineations) are faintly developed mainly in interlayered gneiss and locally in granitic gneiss near to the contact with the interlayered gneiss. It is observed east of Elweya village along Elweya stream a few 100 meters above the bridge.

The mineral aggregate lineation is defined by elongated and flattened quartz and feldspar and preferred orientation of biotite, hornblende and/or magnetite. Usually both lineations plunge shallowly to gently (4°-10°) towards north-northwest and rarely towards north (Fig.11). The dip direction of the local foliation (S₄) is nearly parallel to the plunge direction of the lineations.

4.6 *The fifth deformational event (D₅)*

The effect of D₅ is seen developed mesoscopic open to gentle subhorizontal to horizontal upright folds (F₅). Usually, they are characterized by synform and antiform structures resulted from repeated wrapping of the previous foliations. Locally, they are seen as defined folds with good geometry.

4.6.1 *Folds (F₅)*

Mesoscopic open to gentle subhorizontal to horizontal upright folds are observed at Elweya stream and Elweya village in the northern part of the area. On the western flank of Elweya village an open subhorizontal upright fold with rounded and fractured hinge

zone is encountered. The limbs show different amount of attitude. The northwestern limb dips moderately to steep whereas the southeastern limb dips moderately to gently and finally becomes flat. The trend of fold axis is NE-NW (Fig.15).

At localities west of Aleka village and at about 4 km east of Elweya village along Elweya-Yavello road in the northern part of the area, these folds are represented by synform and antiform structures. They plunge subhorizontal to horizontal with N-S fold axes (Fig.16 a and b).

4.7 The sixth deformational event (D_6)

This deformational event is represented by brittle-ductile strike slip shear deformation cutting the D_5 structures and have produced fault gouge and mylonitic foliation. .

4.7.1 Shear zone

4.7.1.1 Fault gouge

At the locality about 1 km west of Elweya village narrow shear zone evidenced by brittle-ductile-strike slip fault with marginal dragged foliation in a dextral sense is observed. This fault is represented by fault gouge consists of altered clay materials as fine matrix and very few rock fragments rich in quartz and feldspar and it trends NE-SW (Fig.20).

4.7.1.2 Foliation (S_6)

South of the fault gouge on the other side of the road a local and very narrow (40 cm width) shear zone characterized by fine grained rock type and mylonitic foliation with subvertical to vertical dip and it has NE-SW trend (Fig.18). This type of foliation is not seen elsewhere in the area.

4.8 Faults

Mesoscopic normal faults are observed within the interlayered gneiss. These faults are seen at Elweya stream in the western and about 1 km west of Elweya village along Elweya-Teltele road in the northern parts of the area. Mafic layer (hornblende and/or biotite gneiss) and pegmatitic vein mark the displacement with inconsistency displacement in the order of a centimeter. The maximum magnitude of the displacement at Elweya stream and east of Elweya village is 20 cm and 70 cm respectively (Fig.19a and b). The fault axial plane dips $55^{\circ}/65^{\circ}$ - 80° .

4.9 *Photo lineaments*

The photo lineaments are mostly represented by stream course with nearly straight drainage system and rarely by sharp edges of ridges/hills. These lineaments are associated with all units but dominant in the granitic gneiss. The lineaments have different orientation and magnitude. The lineaments associated with granitic gneiss in the central, northeastern and eastern parts of the area show dominantly NW-SE trend. In the southwestern part an E-W trend and in the southern and central parts of the area NNE-SSW to NE-SW trend lineaments are associated with basaltic unit. The maximum lineament is about 7.5 km long and is found in the central part of the area associated with granitic gneiss. In the eastern part of the area NE-SW oriented lineament is displaced dextrally by NW-SE trend lineament.

4.10 *Joints/fractures*

Two orthogonally intersected sets of joints designated as J_1 for the older set and J_2 for the younger set are mainly observed in granitic gneiss. Very few joints are detected in the interlayered gneiss. The older joint (J_1) has mostly NE-SW and NW-SE and rarely E-W trend. The younger joint (J_2) has mostly NW-SE and NE-SW and rarely N-S. All the joints dip subvertical to vertical. They are not filled with any vein/vein lets. At the locality south of Fulo Bura stream J_1 joints are spaced 0.70-1.5 m and J_2 joints are spaced 4-5 m. J_1 joints are displaced with a millimeter displacement magnitude and mainly with dextral and rarely sinistral sense at south of Fulo Bura stream. At Elweya stream, south of Elweya village and south of Arer Guda joint spacing ranges from 60-70 cm and 0.3 cm–1m respectively. The orientation data for these joints are plotted in rose diagram (Fig.21, 22 and 23).

5. METAMORPHISM

5.1 Introduction

As far as only the metamorphic units are concerned, the area consists of two gneisses (interlayered gneiss and granitic gneiss). There is no clear relationship between phases of deformation and metamorphism. At least two phases of metamorphism are identified in the study area and they are designated as M_1 and M_2 . The first metamorphic phase (M_1) is associated with high grade regional metamorphism. The second metamorphic phase (M_2) is characterized by regional retrogressive metamorphism.

5.2 Prograde metamorphism (M_1)

There are no diagnostic mineral assemblages that indicate a specific metamorphic facies. But metamorphic mineral assemblages that are petrographically determined from the representative thin sections of each gneiss of the high grade metamorphic unit are listed below.

1. Unit Pgn

This unit consists of various rock types. The different rock types and their respective mineral assemblage are represented as follows.

a. Biotite gneiss

-Microcline +plagioclase +biotite + quartz + muscovite \pm garnet

b. Biotite-quartz-feldspar gneiss

-Microcline + plagioclase + biotite + quartz \pm garnet \pm sphene \pm opaque

c. Hornblende gneiss

-Plagioclase + quartz + hornblende \pm diopside? \pm sphene \pm opaque

d. Biotite-muscovite gneiss

- Muscovite + microcline + plagioclase + biotite + quartz

e. Marble

-Calcite + phlogopite + Quartz

2. Unit PGtgn

This unit does not show intercalation. Therefore, the mineral assemblage of this unit is given below.

Microcline + plagioclase + Quartz + opaque ± biotite ± hornblende ± perthite

The above metamorphic mineral assemblages a, b, c, and d of unit Pgn, and unit PGtgn are characterized by minerals that are found in a wide range of temperature and pressure conditions. The parameters that are used to estimate the metamorphic grade are:

1. The mineral assemblage in “e” of unit Pgn, are indicating minerals that are found in metamorphosed calcareous rocks of amphibolite facies (Hyndman, 1985).
2. The hornblende grains show green colour.
3. Texturally, some of these units show banding in a meso-, and microscopic scale.
4. The presence of clinopyroxene (diopside) may defined the boundary to the upper amphibolite facies (Bucher and Frey, 1994).

Therefore, based on the above 1-4 evidences, it is suggested that the metamorphic rocks of the mapped area have attained possibly high grade metamorphism (at least amphibolite facies).

5.3 Retrograde metamorphism (M₂).

This metamorphic phase is characterized by regional retrogression that is seen in all high grade metamorphic units. It is characterized by transformation of metamorphic minerals that were stable in M₁ phase of metamorphism to post metamorphic alteration products/secondary minerals under lower P-T condition. The alteration with respect to each unit is shown as following.

1. Unit Pgn

| <u>Rock type</u> | <u>Primary/source/ mineral</u> | <u>Alteration product</u> |
|-------------------------|---------------------------------------|----------------------------------|
|-------------------------|---------------------------------------|----------------------------------|

- | | | |
|-----------------------------------|-----------------------------|----------------------------------|
| a. Biotite gneiss | -Plagioclase | -Sericite |
| b. Biotite-quartz-feldspar gneiss | -Plagioclase and microcline | -Sericite |
| | -Biotite | -Muscovite and chlorite |
| | -Plagioclase | -Epidote |
| c. Hornblende gneiss | -Hornblende | -Biotite, epidote and actinolite |
| | -Plagioclase | -Sericite |
| d. Biotite-muscovite gneiss | - Plagioclase | - Sericite |
| e. Marble | -No alteration | |

2. *Unit PGtgn*

Granitic gneiss

- | | |
|--------------|------------------------|
| - Hornblende | - Biotite and epidote |
| -Plagioclase | - Sericite and epidote |
| -Microcline | -Sericite |

6. DISCUSSION AND INTERPETATION

The study area comprises polydeformed and metamorphosed high grade metamorphic rocks (interlayered gneiss and granitic gneiss) intruded by two phases of pegmatites and quartz veins, Tertiary-Quaternary volcanic rocks, and Quaternary eluvial and alluvial soil deposits.

The interlayered gneiss is considered to be the oldest unit in the study area. This unit has suffered several phases of deformation as compared to the granitic gneiss. The interlayered gneiss is assumed that it is derived from plutonic complexes ranging from granitoid to gabbroic in composition. The earliest phase of deformation transformed these igneous rocks to the interlayered gneiss. This transformation is clearly indicated by the presence of a relatively massive (gabbroic in composition) body changing to the banded hornblende gneiss in the high strain zone in the northern part of the area. Petrographic studies of these rocks revealed much plagioclase. But in the western part of the area the interlayered gneiss is volcano-sedimentary in origin. The sedimentary rock is represented by marble, and the volcanic rocks are the same as the rock types in the northern part of the area. Therefore, the marble is interpreted as roof pendant or mega-xenolith.

The granitic gneiss is poor in structural elements. The foliation that is produced by D_1 deformation is the prominent structure in this unit. The other structural features especially D_2 , D_3 and D_6 are not observed in the granitic gneiss. The emplacement of the granitic gneiss in relation to the deformational events is not clear. But from S_1 foliation that is the prominent regional foliation observed within interlayered gneiss and granitic gneiss revealed more or less the same trend in both units suggested that the granitic gneiss is probably syn- D_1 deformation. The contact between the granitic gneiss and interlayered gneiss is tectonic (thrust) type.

Both the interlayered gneiss and granitic gneiss are intruded by two phases of pegmatites and quartz veins. The first phase of pegmatites and quartz veins are pre- D_1 deformation. They are deformed and became parallel to the general foliation trend. The second emplacement of pegmatites and quartz veins occurred after all deformational events ceased. They are massive and discordant to the foliation trend.

This work compares with the previous works of the area, and adjacent subsheets and sheet. The granitic gneiss is correlated with the granitic gneiss of subsheet C Ferede et al.

(1999) and granitic gneiss of Yavello Group (Kazmin, 1971). The interlayered gneiss is correlated with the Yavello gneiss of the Lower complex (Kazmin, 1971), but in this scheme of classification, the hornblende gneiss was missed from the intercalations.

The area is subjected to six deformational events and produced folds, shear zones, faults, lineations and foliations. The intensity of deformation is variable with the rock units of the high grade metamorphic rocks. As mentioned above the first deformational event affected the interlayered gneiss and granitic gneiss and produced the S_1 foliation. Except this deformational event, all the rest deformational events are observed within limited areas and narrow zones, mostly in a highly strained zone within the interlayered gneiss. The gneissic layers (S_1 foliation) in the interlayered gneiss are affected by D_2 deformation and is characterized by simple shear zone, and associated F_2 -folds and S_2 foliation (axial-planar cleavage). Later D_2 deformation pegmatitic veins were intruded cross-cutting the F_2 -folds. Successively, these pegmatitic veins were affected by D_3 deformation and produced pure shear zone evidenced by M-shaped asymmetric mesoscopic folds parallel to the compressional plane (Z-axis), and swelling and pinching of pegmatitic veins and mafic layers and their boudins along the extensional plane (X-axis). D_4 is related to thrust and is characterized by striation and mineral lineations, dragged folds and E-W foliation (S_4). It is proved that these lineations are not related to the determined fold axis from the stereoplot of composite foliation. This means that, the pie axis and the plunge of the lineations do not fall on the same axis. After thrusting a regional wrapping of foliation (D_5) is observed. The last phase of deformation (D_6) is brittle-ductile strike slip shear zone with dextral sense of movement and produced the mylonitic foliation and fault gouge.

There is no a clear relationship between deformation and metamorphism. The minerals assemblage in the petrographic study show metamorphism at low to high P-T conditions. Form the field and some microscopic evidences, there is indication of at least amphibolite facies at D_1 deformation and continues in all deformational events. Retrogressive metamorphism (M_2) is not related to any deformational event, probably related to later hydrothermal and/or low temperature alterations.

Tertiary-Quaternary volcanic lava flows and pyroclastic fall cover large area overlying unconformably the basement rocks. There is difficulty to establish lithologic age sequence of the Tertiary-Quaternary volcanic rocks in the area, because no unconformity between the different rock units has been observed. But the present classification Tertiary-Quaternary is based on the correlation with the work carried out by Weldegebriel et al. (1994) in the northern adjacent sheet (Ageremariam sheet), and they classified the volcanic rocks into pre-rift (Tertiary) and post-rift (Quaternary). According to their classification the pre-rift volcanic rocks are represented by aphyric, microporphyritic and porphyritic basalts. Olivine and plagioclase are the most common phenocrysts. Post-rift volcanic rocks consist of vesicular, porphyritic with phenocrysts of plagioclase and scoriaceous basalts and scoria. Pre-rift and post-rift volcanic rocks are also observed in the Sarite hill in the western adjacent subsheet (subsheet A) Tsegaye Abebe (personal communication). Based on these data volcanic rocks of the area are classified into pre-rift (Tertiary) that consists of olivine and plagioclase phyric basalts and trachyte. The post-rift (Quaternary) volcanics are represented by amygdaloidal-vesicular-phaneritic basalt and scoria.

Finally, eluvial and alluvial Quaternary deposit occur as a result of intensive weathering, erosion and deposition.

7. **ECONOMIC GEOLOGY**

Metamorphic rocks, Quaternary deposits and volcanic rocks underlie the area. From the metamorphic rocks, granitic gneiss and marble are important. Massive basalt (phaneritic basalt) and scoria from the volcanic rocks and eluvial soil from the Quaternary deposits are considered as economic interest. Magnetite hosted in granitic gneiss and sand derived from granitoid gneisses in the study area and its vicinity are also important from economic point of view. These economic rocks and mineral are not of great economic value in the study area. Further detailed study of each deposit is required to know their valuable economic potential for small-scale production. The above materials and mineral are grouped into construction materials (granitic gneiss, marble, basalt, scoria and sand), agricultural potential (eluvial) and metallic mineral (magnetite).

The brief and short description of the afore-mentioned materials and mineral is given below.

7.1 *Construction materials*

7.1.1 *Granitic gneiss*

This unit is locally used for foundation at Elweya village. At Elweya village, this unit exists as sheet and it is easy to shape to the appropriate size by splitting along the foliation plane. It is important for local building, because it is easy to shape using simple equipment and with a minimum of labour.

7.1.2 *Basalt*

So far, the basalts have been not used by the local people for construction. It is useful for foundation during local building and is also useful in road construction, mix with the asphalt and to make concrete fill. This material is mainly found east of Elweya village and southwest of Adegelchet.

7.1.3 *Scoria*

This unit is useful for road construction. Sunshine Company exploited scoria in the area for road during Yavello-Teltele road construction. The quarry is observed at about 5.5 km east of Elweya near to Are Guda ridge. This material is found as considerable size at Sometele hill and may be useful as selected material fill for road construction in the future.

7.1.4 *Marble*

It is minor in occurrence and not recommendable to be exploited in a large-scale production. It may be important for the local building and decoration. Further study is useful to determine its quality.

7.1.5 *Sand*

It is found along Elweya, Meka Bora, Gotu Onu Gelchet and Gerdo stream. The sand is white and of good quality. Among the streams Gerdo and Elweya streams have much sand deposit along their beds. This sand is derived from the granitoid gneisses/bodies in the area and its surrounding from which the streams have sources.

7.2 *Metallic mineral*

7.2.1 *Magnetite*

This mineral is hosted in granitic gneiss and some pegmatitic veins. It is found mostly as discontinuous concentration and in disseminated fashion in less deformed granitic gneiss and locally as very thin vein lets. This may be important for iron ore mineral.

7.3 *Eluvial soil*

This soil covers a flat to gentle lying topographic terrain. It is thick, well developed and seems fertile. The area also contains much grass. Therefore, it has a potential for agriculture (farming and grazing). Sometimes, a shortage of rain fall happed in the study area. It may be possible to construct dams across the big streams such as Elweya, Melka Bora, Gerdo and Belesa Gotu useful for local irrigation. In the western subsheet (subsheet A), Sarite Ranch is found and it is managed by Oromiya National State, Live

Stock Development Enterprise. This indicates that there is a possibility to breed animals in a large scale and modernization.

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Appendix.1 List of thin sectioned rock samples

| | |
|----------|----------|
| TH-961 | TH-907 |
| TH-950 | TH-1041A |
| TH-927 | TH-1040B |
| TH-998 | TH-953B |
| TH-906 | TH-1008B |
| TH-1106 | TH-858 |
| TH-995 | TH-1000 |
| TH-1092A | TH-1003 |
| TH-948 | TH-945 |
| TH-878 | TH-889 |
| TH-1069 | TH-983 |
| TH-874A | TH-944 |
| TH-941 | TH-1052 |
| TH-941 | TH-872 |
| TH-1061 | TH-891 |
| TH-1057 | TH-1021 |
| TH-990 | TH-973 |
| TH-978 | TH-953A |
| TH-1009 | TH-881 |
| TH-1004 | TH-1047 |
| TH-1008A | TH-991 |
| TH-1012 | |
| TH-848 | |

Appendix.2 List of locality names in the report and/or on the map

Villages

| <u>In English</u> | <u>In Amharic</u> |
|-------------------|-------------------|
| Elweya | ኤልወያ |
| Hidiale | ዚዲያል |
| Adegelchet | አደገልጋት |
| Utalo | ኡታሎ |
| Aleka | አለቃ |

Ridges/hills

| <u>In English</u> | <u>In Amharic</u> |
|-------------------|-------------------|
| Aneni | አነኒ |
| BuleKalo | ቡሌቃሎ |
| Arer Guda | አረር ጉዳ |
| Arer Tika | አረጢቃ |
| Meti | መቲ |
| Mole | ሞሌ |
| Somaya | ሶማያ |
| Tinika | ጢኒቃ |
| Elweya | ኤልወያ |
| Abe | አበ |
| Surite | ሣራይት |
| Sometele | ሶመቴሌ |
| Mukulo | ሙሉኮ |
| Teso Gelchet | { Z Î@ጋት |

Appendix.2 List of locality names in the report and/or on the map

| | |
|---------------|-----------|
| Bule Tedecha | ቡሉቴድጅቻኮከሳ |
| Kokesa | |
| Dega Werabesa | ዴጋወራቤሳ |
| Bule Mersa | ቡሉ መርሳ |

Streams

| <u>In English</u> | <u>In Amharic</u> |
|--------------------------|--------------------------|
| Lemo | ሊጦ |
| Ado | አዶ |
| Dega | ዴጋ ቦራ |
| Bora | |
| Meti | ሙቲ |
| Belesa Gotu | በለሳ ጎቱ |
| Mukulo | ሙከሎ |
| Bunyata | ቡንያታ |
| Melka Bora | መልካ ቦራ |
| Elweya | ኢልወያ |
| Kiloftu | ኪሎፎቱ |
| Boji | ቦጂ |
| Rero | ራሮ |
| Melka Dimtu | መልካ ዲምቱ |
| Fulo Bura | ፊሎ ቡራ |

Microdam

| <u>In English</u> | <u>In Amharic</u> |
|--------------------------|--------------------------|
| Surite | ሣራይት |
| Rero | ራሮ |
| Kundi | አንዲ |

**Appendix.2 List of locality names in the report
and/or on the map**

| | |
|-------------|--------|
| Bule Dekera | ቡሉ ዴክራ |
| Harmolu | ዘርዎሉ |
| Buke | ቡኩ |
| Harwale | ዘርዋለ |
| Hidale | ዚዳለ |