COOPI
Cooperazione Internazionale

"Emergency program to assist vulnerable people in Liben Zone - Somali Regional State Borena Zone - Oromiya Regional State"

Terminal Report

Funded by USAID/OFDA

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I Executive summary

Quarterly report

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Project Title: Emergency program to assist the vulnerable people in Liben and Filtu wereda.

Cooperative Agreement/grant N.: AOT-G-00-00-00115-00

Country/Regions: **Ethiopia/Oromo-Somali regions**

Disaster/Hazard: Drought

Period covered by this project: June 6, 2000 to April, 5 2002

Summary of the activities

Geological survey

The geological information and general data concerning the studied area are the result of a geological and hydro-geological survey carried out through field survey, interpretation of aerial photographs, vertical electric soundings (VES) surveys, pumping tests, water analysis tests etc. Information about existing drilled boreholes has been collected from Jijiga, Addis Ababa, Dire Dawa, Awasa, Negele water bureaux, and departments. All the information collected has been then elaborated, extrapolating supposing geological phenomena, which could have been valuable for the drilling of borehole and excavation of hand-dug wells. For the extents of the study, important was the interpretation of aerial photographs; this is mainly due to the geographic extension of both districts. The project also recognized the importance of purchasing a satellite image (landsat) for further investigation. As the geo-electric equipment used was capable of undertaking underground investigation at a maximum depth of 70 to 80 metres and the boreholes was supposed to have the aquifer at a deeper depth, the geo-electric investigation system could not find its right use within the investigation campaign for deep wells. The geo-electric equipment was instead used with good results for locating sites for hand-dug wells. Here, being the electric contrast of the beneath granitic/amphibolitic basement completely different than the overlaying alluvial and eluvial sediments the depth of the basement and the thickness of the aquifer could be identified rather easily. Most of the information for borehole drilling has been in any case extrapolated from geological observations. Many have been the sites visited, springs and hand dug wells surveyed. In different geographic positions, detailed stratigraphic sections have been done and finally geological information interpolated on lithological base and the geological units' trends interpreted. The use of GPS (Global Positioning System) has been of great help for the collection of geographical based information, such as geographic coordinates, tracks, etc. The geographic navigation and orientation would have been very difficult on a topographic 1:250,000 scale maps without the use of the GPS. Only lately new topographic 1:50,000 scale maps were edited and in any case only when the geological field work was almost accomplished. The information (Latitude, Longitude and Elevation) has been then stored into a geographic database software (Arcview) for further elaboration and graphic interpretation. Water quality tests have been done using Aquamerck field kits based on colorimetric methods and electric conductivity data acquired. The geological survey document is here included as Annex 1

Works

Construction of Qurale water scheme

The construction of Qurale water scheme began in July 2000. The following works were accomplished:

- ✓ Designing of the infrastructures
- ✓ Construction of one generator shade
- ✓ Construction of one animal through
- ✓ Construction of one water point
- ✓ Construction of 100 metres of fence
- ✓ Excavation for laying down the water line
- ✓ Construction of an iron-made stand for a 10 m^3 fibre-glass tank
- ✓ Construction of the foundation for the iron-made stand
- ✓ Purchasing of a 10 m^3 fibre-glass tank
- ✓ Set up of iron-made support and fibre-glass tank accomplished
- ✓ Installation of the generator and the submersed pump

Due to the remoteness of Qurale and its harsh climate condition, the work could not be done at a normal implementation time-rate. The security problems in the area delayed the work that was suspended and resumed in August 2000.

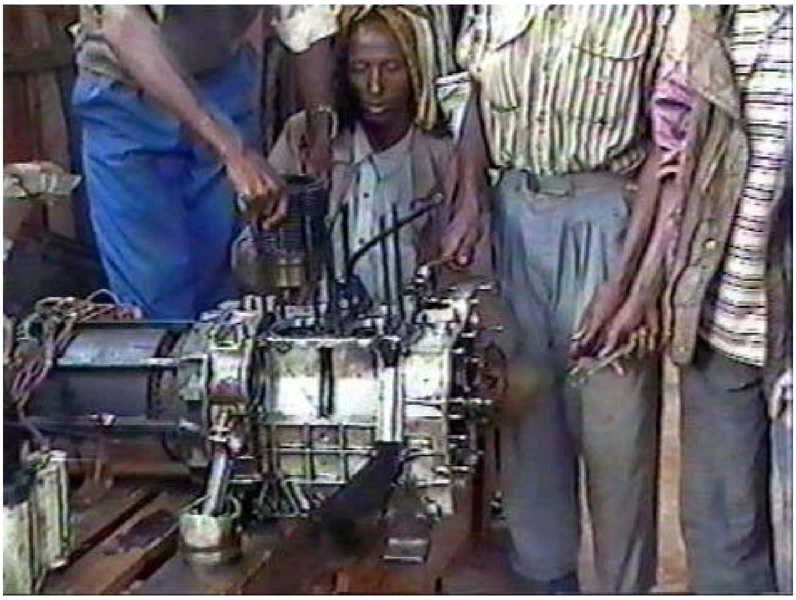


Figure 1: Generator operator of Qurale during the training course

The village water committee was formed before the starting of the works. The training of the committee was done in September 2000.

The training of two generator

operators was done in October 2000. A mechanic was hired as trainer. The trainees were trained about practical topics like:

- ✓ General Service for generators
- ✓ Ordinary generator maintenance
- ✓ Extraordinary generator maintenance

Follow-up of the operators was done through on-spot refreshment training and supplementary training sessions in COOPI Negele workshop.

The community of Qurale was visited different times by COOPI's sanitarian staffs and trained about sanitation topics. In this occasion community meetings have been held entertaining people on water related diseases and general hygiene/sanitation issues. To do this one social worker has been employed for a month and all COOPI social water workers (two in Filtu and one in Negele) attended a training course in Negele. The course that lasted for a week has been organized with the Borena Zone Health Department and conducted by a sanitarian of Negele hospital. This sanitation/hygienic program can be considered as an extra-ordinary work if compared to the ordinary one day by day carried out. The water committee of Qurale has been visited different times during the past quarter in order to sensitize them about sustainability matters related to opening a saving account. As result of this activity 2,000ETB have been deposited into the account of the Commercial Bank of Ethiopia in Negele Borena.

<u>Gobicha hand-dug well</u>

The digging of Gobicha well started in June 2000. A preliminary geological survey followed by an electric geophysic campaign allowed us to locate the suitable site for digging the well.

The following works have been accomplished:

- ✓ Digging of the well at a depth of 8.62 m
- ✓ Construction of 9 RCC (reinforced cement concrete) ring of 141 cm diameter
- ✓ Set up of the RCC rings into the well
- ✓ Packing of selected round-river-gravel into the gap between the RCC rings and the well
- ✓ Construction of RCC apron around the well and soak away system
- ✓ Construction of iron-made stand for a 10 m^3 fibre-glass tank started
- ✓ Construction of fence accomplished
- ✓ Construction of the water point accomplished
- ✓ Construction of the foundation for the iron-made stand accomplished
- ✓ Purchasing of a 10 m^3 fibre-glass tank
- ✓ Set up of the iron-made support and the fibre-glass tank accomplished
- ✓ Construction of shade for the solar drive accomplished

A pumping test was carried out and the hydraulic characteristic of the aquifer known. The Transmissivity value is 3.45x101 m^2/d and the Hydraulic Conductivity 7.13x100m/d. These values are good for exploiting water for a village like Gobicha; a total of 50m^3/d can be withdrawn from the well without any problem. The water has a conductivity value of 1550µS/cm and the pH value is about 7.5. As the hydraulic characteristics of the aquifer were good, the well was equipped with a solar pumping system. The capacity of the solar pumping system is of about 50 m^3 of water/day. The solar pumping system was installed on June 2001.

In the mean time the water committee was formed. A saving account opened and cash deposited (ETB 330). The water committee has deposited about 2,300 ETB into the saving account.

As the supplier of the solar pumping system delayed delivering it, COOPI temporarily supplied and installed a motor-pump to allow people benefiting from fetching safe water. The one of Gobicha can be considered a peri-urban community and as the community lives in the neighbourhood of Negele, they were excluded from some important services like water distribution. Thus, people were obliged to go to the town and fetch water from public water points or to go to the nearby stream and fetch unsafe water. With the construction of this water scheme more than two thousand people got the chance to get clean water very near to their houses. This in turn also helps the town water system in delivering more water to its citizens with an improvement of the sanitation conditions.

Figure 2: Gobicha water point

Visits to the community of Gobicha were carried out in order to advance the way the system is managed and improve its sustainability. The water committee members reported that due to the high running costs related to the use of a gasoline-powered motor-pump, they could not save any cash to be deposited in the current account.

Due to transport problems the solar system arrived without an essential part (solar drive) without which the scheme could not work delaying the installation process. The missed part of the solar pump system arrived in Addis Ababa at the end of December 2001. The custom process was started to clear the good from the custom office. So far, 3,675.00 ETB have been deposited into the bank account managed by the water committee.

<u>Kersamale hand-dug well</u>

The digging of Kersamale well started in September 2000. A preliminary geological survey allowed us to locate the suitable site for digging the well.

The following works were done:

- ✓ Formation of WMC
- ✓ Digging of the well at a depth of 8 m
- ✓ Construction of 9 RCC (reinforced cement concrete) ring of 141 cm diameter
- ✓ Set up of the RCC rings into the well
- ✓ Packing of selected round-river-gravel into the gap between the RCC rings and the well
- ✓ Transport of building materials
- ✓ Construction of RCC apron around the well and soak away system
- ✓ Construction of fence
- ✓ Training of WMC

The hydraulic characteristics of the aquifer are fair; and thus the well was equipped with a hand pump.

The work was finished in December 2000. In January 2001 the hand pump was supplied and installed. The handing over to Borena Zone water, Mineral and Energy Resources Department and communities has been done in January 2000 too. The training was organized together with the Borena zone water department and started on March 29, 2001. Since the beginning the social promotion work in Kersamale was been as easy as expected. The organized water committee was not doing a so good work like in other places. The bank account was not opened very soon as required.

The hand dug well of Kersamale has been working without problems. A pumping test of the well was carried out. The Transmissivity value is 2.51×10^{1} m^2/d and the Hydraulic Conductivity $6.17 \times 10^{0} m/d$. These values are good for exploiting water through a hand pump; a total of $10 m^3/d$ can be withdrawn from the well. The water has a conductivity value of $850 \mu S/cm$ and the pH value is about 7.5.

During our routine visits, the scheme was found in good condition. Different efforts were tried but no good result was obtained toward the financial sustainability. The water management committee is still showing weaknesses in management and no clear ways to overcome the problem has been found to now. Only 70 ETB were deposited into the bank account.

Adesa hand-dug well

Although security problem in the area, at last the decision to dig the HDW was taken; the agreement with the local community made. The community started digging and reached 3.6m. Then they were unable to continue so we continued with a contractor team up to 6.9. At 6.9m hard rock (limestone) was encountered and the team refused to dig deeper because of the rock's hardness. As no advanced digging tools were available for digging such kind of rock the work had to be abandoned.

Figure 3: Set up o f RCC rings into Kararo HDW

Kararo hand-dug well

Adadi Kararo is an encampment found at about 10 km from the small town Adadi. The encampment is on the top of a hill surrounded by wide valleys covered by alluvial deposits of 10 to 20m thickness. The alluvium constitutes a good underground reservoir of good quality water. Many are the wells present along the valley and all of them are exploited all over the year including the dry seasons. The static water level ranges between 5 to 8m. People use to fetch water from opened wells organically highly contaminated. The construction of a protected well and the fetching system through the use of a hand-pump increased the quality of the water thus decreasing the spreading of water born diseases.

This well had been started during the EGS COOPI activities and continued within the USAID/OFDA activities. Three technical staffs were assigned to follow up the excavation of the well and for the production of cement concrete rings. The community was involved in digging activities on EGS basis.

The handing over of the scheme to the community and the local counter parts was made in July 2001.

The following works were carried out:

- ✓ Social work with local community and administration
- ✓ Hygienic campaign
- ✓ 11m deep HDW
- ✓ Production and installation of 7 1.5m ϕ-RCC-pipes (blind and perforated)
- ✓ Packing of quartz drain (up to SWL) and, above it, packing of selected clay to isolate the aquifer against pollution
- ✓ Construction of RCC slab
- ✓ Construction of sanitation system
- ✓ Fencing
- ✓ Installation of Afridev pump
- ✓ Training of the WMC

At the end of the works, a pumping test of the well was carried out. The curve representing the test is showed in Figure 4. The Transmissivity value is 9.31x101 m2/d and the Hydraulic Conductivity 4.04x100m/d. These values are good for exploiting water through a hand pump; a total of 10m3/d can be withdrawn from the well. The water has a conductivity value of 1.720µS/cm and the pH value is about 6.5.

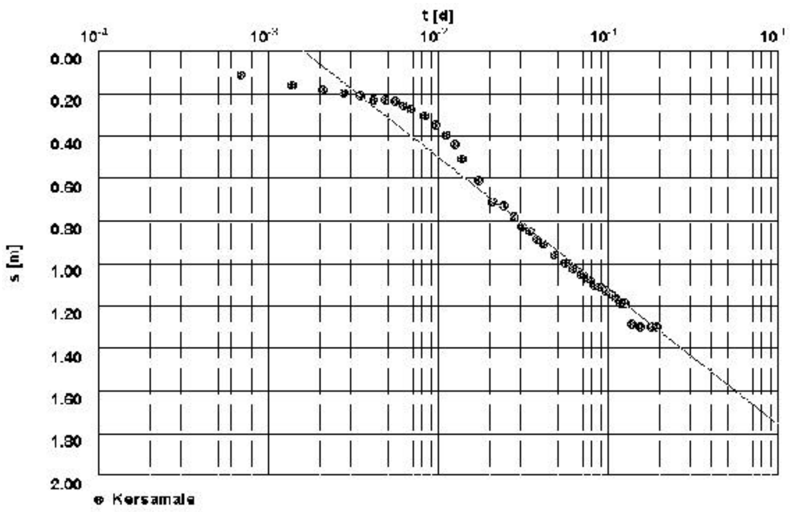


Figure 4: pumping test curve of Kararo well

The same consideration of Kersamale are valid for Kararo. Also the financial management is very deluding with a collection of 50 ETB only.

<u>Haydimtu borehole</u>

The technical difficulties for the implementation of Haydimtu borehole were the main reasons for the delaying of the implementation of this project. At the beginning the process for selecting the drilling company hindered the whole process. As the first selected company, Pile Foundation, was very late compared to their scheduled program (sharply every month rescheduled), we decided to look for other contractor agencies. Having gotten the information from Jijiga that in Addis Ababa a company named Yadot Engineering had recently imported drill rigs of high capacity, we immediately contacted them and began the negotiations. Yadot Engineering owns a British made drill rig called Dando model UMM Universal 6000. After having gotten the characteristics of the machine from Yadot Engineering and directly form the company in Great Britain, we decided that the rig could have been used for drilling the Haydimtu borehole. The rig has the capacity to drill up to 420m with drill rods of 4 ½“ and up to more than 500m with drill rods of 3 ½ “. A technical supervision to check the status of the drill rig has also been done. The status of the rig was found good with all the visible parts of the machine (mud pump, hydraulic hoses, rotary head, etc.) in good condition. At the end of this process, a contract was signed between COOPI and Yadot Engineering.

Due to different reasons, the company selected for carrying out the work time by time postponed the drilling of the Haydimtu borehole to the month of June 2001. Around mid of June 2001 clashes between Somali and Oromo groups started along the road Negele-Filtu so that the mobilization of the drill rig an equipment was again postponed to the mid of August 2001.

In the second half of September 2001, the mobilization of the drill rig from Addis Ababa to Haydimtu started. The mobilized rig is a THOR 5000 constructed in South Africa in 1997 instead of the above mentioned one. Therefore, an additional technical survey to the machine was made and it was found in good condition. It was high capacity rig able to rich up to 800m. The capacity in mobilizing and manage such equipment and the company commitment during the starting of the works was good promising a good result of the operation. At the end of September 2001, a depth of about 50m was reached. At the end of December 2001, 471m were drilled. At the depth of 290m, technical problems occurred (loss of circulation) so that the drilling continued "blindly" without understanding the geological formation crossed during progressing up to 471m. At this depth, due to insufficient compressed air circulation, the drilling cuttings could not be removed as efficiently as before so that occasionally the drilling tools stuck during pulling up operations. Thus, drilling was stopped and a pumping test was carried out. The results of the pumping test were not as good as expected and the well, which had static water level of 376m, dried up after 3 hours pumping at a discharge rate of about 0.5l/s. The water pumped during the test was fresh and clear with acceptable conductivity, which makes the water safe from the potable point of view. As a great part of the drilling was conducted without understanding the geological characteristics of the rocks, and the result of the pumping test was negative, an additional geological survey north of the site toward Genale River was done. The water bearing strata were found as they were supposed to be at 805m a.s.l. The elevation of the site where the borehole is being drilled, is 1,290m a.s.l. Thus, it was worth thinking that only few metres separate the bottom of the well from the main aquifer. In the past, certain geological phenomena were considered so that the depth of the aquifer was supposed to be higher. Reviewing the past geological hypothesis and confiding that the aquifer is some tens of metres below 471, we proposed to the drilling company to drill further few tens of metres until the main aquifer could be encountered. Agreement was made with Yadot and agreed to drill further only if a still casing had been installed to avoid problems of tools stuck in the borehole. On the other hand, the installation of still casing would have allowed recovering of cutting and collection of important geological information. The casing budget was supplied by the ECHO project on going in the same area after agreement between the parties involved. After the installation 471 metres of blind still casing, drilling could go ahead through the casing itself. Perforation was smooth and within few weeks the depth of 543 was reached. Cutting was recovered and geological information collected. After drilling was accomplished, the drilling tools were withdrawn and a pumping test was prepared. The pump was lowered through the casing at a depth of 440m and the pumping test started. The result of the pumping test was anyhow not different than the previous one thus demobilization of the drill rig ordered. During the operation of pumping test equipment withdrawal, the electric cable of the submersed pump got stuck and withdrawal operation made difficult. High capacity hydraulic jack were hired by Yadot and recovery operation started. The recovery operation was made in a way that both pumping test equipment and casing could be recovered. As the recovery operation was very low, only few metres of equipment and casing could be recovered within a month time. Due to this, the company decided to suspend the operation and demobilize the drill rig. The borehole can be finally considered non-productive or non-economically feasible through traditional pumping equipment (generator and electric submersed pump). Nowadays, the innovation in the solar energy powered systems could be a solution through system that can supply $2m^3$/day at 400 metres deep using multi-pump systems. As the presence of COOPI in the area is assured for the next three years, our technical staff will be able to follow up the matter and find technically feasible solutions also seeking for funds in case possible solutions are available.

Purchase of spare parts and back up equipment

In the project proposal the purchase of back up equipment was foreseen. Their procurement was delayed waiting for the result of Haydimtu. Finally when the result of this borehole was known and the available time before the deadline of the project was very short, it was decided to purchase a backup generator which could fit for all the boreholes present in the area in the case that one of them will fail to work. A locally research about such a kind of generator was made, and procurement done before the end of the project. A Lister Generator was purchased together with a stock of spare parts and transported to Filtu. Handing over procedures will take place in the near future.

Handing Over and Closing procedures

The terminal report for the local government was produced and the project officially closed. Handing over procedures to the local government has not been done yet. Dealing with the line departments will soon begin. An evaluation team will be formed by the regional government and sent to the sites for a final evaluation and draw handing over certificates. So far, handing over were made with Zonal counterparts and local communities in order to make the water available in the shortest time.

Objective: Increment of availability of water in the project area

Objective: Increment of availability of water in the project area

Indicator 7+7+20+90+50=174 m^3/day

Current measure 7+7+20+ 50 =77m^3/day

Resources:

Budget	346,004.64 US$	Expended in the project period:	32,011.58 US$
Cumulative expenditures to date:	325,042.27 US$	Balance	20,962.37 US$

II Program Overview

A Project goal and objectives

Goal: alleviation of the emergency in Liben and Filtu Woreda.

Objective: increment of water availability in the project area.

B Profile of the targeted population and the critical needs identified in the proposal

The beneficiaries belong to Oromo and Somali ethnic group. Pastoral is the production system based on an extensive animal husbandry characterised by seasonal movement, herd diversification and with overstocking tendency. Thus, livelihood of the pastoralists (over 96% of the pastoral community) is largely dependent on these livestock & livestock products either directly of indirectly. As a copping strategy against recurrent food shortage, the pastoralists shifted to agro-pastoral practices whereby some efforts are made to cultivate. Agriculture remains anyhow an opportunistic activity. Among the problems afflicting these communities, water (shortage and/or poor quality) is one of the most relevant one.

It is estimated that the population in need of assistance in the two Woreda are: 186.698

Woreda	**Total 1999 Population (Male + Female)**	**Beneficiaries**			
		Male	Female	Total	% of total population
Liban	129,669	51,263	49,477	100,740	77.69
Filtu	120,489	48,360	37,598	85,958	71.34
Total	***250,158***	***99,623***	***87,075***	***186,698***	***74.63***

Out of the 186,698 beneficiaries, 52,275 are estimated to be children under the age of five, lactating mothers pregnant women and aged people.

The numbers of the direct beneficiaries of this project are:

Three hand-dug well in Negele

2 fitted with hand pump (7 m3 /day)	1000 x 2	=2.000
1 fitted with solar pump system (20 m32 /day)	3000 x 1	=3.000
One pumping system, and distribution for Qurale		8,000
Drilling new borehole in Haydimtu		non productive

C Geographic location of all major activities

Geo-referencing data

Country: Ethiopia

Region	Zone	Kebele	Lat/Long	Sector/Activity	Start	End	Target POP.
Oromiya	Borena	Gobicha	N 05.32133° E 39.65505°	Water (HDW)	Mid of July	Waiting for solar drive (missed at the Addis Ababa custom)	3,000
Oromiya	Borena	Kersamale	N 05.35589° E 39.46874°	Water (HDW)	End of August	January 2001	1,000
Oromiya	Borena	Kararo	N 05.36560° E 39.42291°	Water (HDW)	February	June 2001	1,000
Somali	Liben	Qurale	N 05.23838° E 41.08092°	Water (Well)	Mid of July	Working since December 2001	8,000
Somali	Liben	Haydimtu	N 5.14512 E 40.47896	Water (Well)	Second mid of September 2001	471m reached. Due to low yield, it is proposed to deepen the well.	15,000

Map included as annex 2.

III Program performance

A Programme performance, vis-a-vis the program objective

1) Planned and cumulative achievements

Activities	Unit	Project plan Qty	Cumulative Accomplishment Qty	Description/remarks
Survey				
Hydrogeological and social survey	N	4	5	
Equipment				
Purchase of hand pumps	N	2	2	
Purchase of solar pumps	N	1	1	
Purchase of pumping equip. for Qurale	set	1	1	
Purchase of pumping equip. for Haydimtu	set	1	0	
Purchase of spare parts for generators and pumps	set	2	0	
Works				
Drilling of Haydimtu borehole	Borehole	1	1	
Construction of Haydimtu water scheme	Scheme	1	0	
Construction of Qurale water scheme	Scheme	1	1	
Construction of hand dug wells	N	3	3	
Construction of water schemes for HDW	N	3	3	
Hygienic campaign	months	11		The activity was on going along with the project
Village water committee organization	N	5	5	
VWC training	N	5	5	
Water scheme follow up	N	5	4	
Evaluation	N	1	1	

2) Why targets were not met and how impact has been, or will be addressed

<u>Qurale</u>

Due to the remoteness of Qurale and its harsh climate condition, the work could not be done at a normal implementation time-rate. The security problems in the area further delayed the work that was suspended and resumed. Due to the above problems, the activity target was accomplished with one-month delay.

Hayadimtu

The contract with the company selected for drilling of the Haydimtu borehole was signed. The selected company was PILE FOUNDATION. They were selected because they were the only one having heavy-duty drill rigs.

As per agreement, the drilling should have started in December 2000, but they did not keep up with their commitment so we were obliged to withdraw from the signed contract. After technical survey and evaluated the reliability of Yadot Engineering, a new contract was signed with the latter and mobilization of the drill rig should have started at the end of March 2001. As geological condition allowed perforation by air got advantage of the method such as high penetration rate, less use of drilling water (especially in case of loss of circulation), and more accurate reconstruction of the well log (the cuttings are very much courser and thus of easier identification).

The drilling of the borehole started anyhow only on August 2001. To overcome to the shortage of time for the implementation of the project it was agreed additional period extension could be accepted after October 5, 2001 (date of the end of the project after the first extension).

Due to mistake in geological interpretation the water bearing strata were supposed at shallower position than what they really are. As most of the work is done and good results were behind to be obtained, the proposed deepening of the well was essential to accomplish the effort successfully. Because the budget was not sufficient for deepening the well, we asked to the donor the possibility to use part of the other budget lines (generator, pumps and Pipes) to finalize the borehole drilling.

B Successful stories

The strength of the village water committee of Gobicha can be mentioned among stories of success within the framework of this project. The members are quite strong and anxious to receive explanation about doubtful points related to their water scheme.

C Unforeseen circumstances and their effects on the program performance

Security

In the second half of July 2000, clashes between Somali and Oromo clans occurred. The clashes happened near the borders between the two regions from Moyale to Negele. Although different peace efforts made by the government the clashes continued. During the first period of the fighting, the roads Negele - Yabelo and Negele – Filtu became risky. Thus, due to the security condition the project was suspended in Filtu Woreda for about a month.

Clashes between Somali and Oromo clans occurred later on nearby the site selected for HDW construction and the site had to be abandoned.

Again in June 2001 the road between Negele and Filtu was blocked for about 10 days due to fighting along the road and in the town of Haysuftu. The clashes between Oromo and Somali tribes started in June 2001 and continued in July 2001. Due to this, the drill rig could not be mobilized in June 2001 thus obliging the organization to rectify the timetable extending the end of the program for five additional months.

Intermittently, the clash between Somali and Oromo clans continued. Incursions of Borena in Somali lands and vice versa are reported during the reporting period. Many people lost their lives whose number was unknown. Many attempts were made by both administrative parts without obtaining a significant result until beginning of the 2002.

Due to the above mentioned reasons, the program delayed of some weeks.

Emergency

Both Filtu and Negele were among the Woreda affected by the drought and thus included into the year 2000 relief food appeal. COOPI (with a program founded by EU) is covered Negele Woreda with a distribution for about 87,000 people and Filtu Woreda with a distribution for 25,000 in the area. The food distribution went on until the March 2002. Due to economical constraints during the drought, the project was not able to raise funds for the sustainability of some water schemes.

Water: water availability both for livestock and human consumption is always the first question in Filtu district when dealing with the general and existing situation of the pastoralists of the district. It is the most limited and scarce resource in the district. Only starting from March 2001 the situation was normalized when good rain filled up al the ponds of the area also recharging the aquifers that feed the hand dug wells.

Due to this a migration of the Kenyan livestock (from Ramo,Sedde etc.) was noticed since the beginning of June 2001 into the Filtu district invading, the areas which were in better conditions competing for the water and pasture.

Filtu town was submitted different times to water shortage because the only water resource of the town, a pond, dried up.

Human Health: there were not reports of human health epidemics in the district except for the out breaks of "Hupping Cough" in Osobey which was the reason for the death of three(3) children according to the report of PCAE pastoralists education sector head.

Logistic

Sporadic shortage of diesel and chronic shortage of gasoline push us to look for time-taking alternative solutions.

Other problems such as hiring of rig drill had instead greatly affect the scheduled time.

IV Resource Use / Expenditures

Annex 1: Geological Report

GEOLOGICAL-HYDROGEOLOGICAL SURVEY

REPORT

NEGELE AND FILTU DISTRICTS

BY: FABIO GAGGI (GEOLOGIST) – COOPI

Update to: February 2002

Table of contents

1. Preface

This report is the result of a geological and hydrogeological survey done within the framework of the water project funded by the EU Food Security budget line. The project planned the drilling of 9 deep wells, digging of 9 hand dug wells, and construction/reconstruction of 14 artificial ponds. The survey has been done to allow the identification of underground water potentials of the area included within the administrative boundaries of Negele and Filtu districts. The first part of the surveys started in 1998 in Filtu while in Negele district, the survey began in 1999. The surveys have been carried out in different times and in discontinue way in relation with the project duties. They have been carried out in partial collaboration with the Water Resource Development Bureau of the Somali Region, and the Water Resources Development department of the Borena Zone – Oromyia Region for Negele district. Three days of survey have also been carried out with the participation of Professors A. Bosellini, A. Russo from the Italian Universities of Ferrara and Modena (Geological Science Department). One of the final surveys was done together with doctor M. Morsilli from the geological department of Ferrara University (Italy).

2. Methodology

The geological information and general data concerning the studied area described in the following sections of this document, are the result of a geological and hydro-geological survey carried out through field survey, interpretation of aerial photographs, vertical electric soundings (VES) surveys, pumping tests, water analysis tests etc. Information about existing drilled boreholes has been collected from Jijiga, Addis Ababa, Dire Dawa, Awasa, Negele water bureaux, and departments. All the information collected has been then elaborated, extrapolating and supposing geological phenomena, which could have been valuable for the drilling campaign. For the extents of the study, important was the interpretation of aerial photographs; this is mainly due to the geographic extension of both districts. The project also recognized the importance of purchasing a satellite image (landsat) for further investigation but, due to delay in recovering the image and burocratic processes, the image could not be fully used for the purpose. As the geo-electric equipment bought by the project was capable of undertaking underground investigation at a maximum depth of 70 to 80 metres and all of the boreholes have encountered the aquifer at a deeper depth, the geo-electric investigation system could not find its right use within the investigation campaign for deep wells. At the beginning of the project, the information previously collected showed a shallower depth of the boreholes and accordingly the equipment was bought. The geo-electric equipment was instead used with good results for locating sites for hand dug wells. Here, being the electric contrast of the beneath granitic/amphibolitic basement completely different than the overlaying alluvial and eluvial sediments the depth of the basement and the thickness of the aquifer could be identified rather easily. Most of the information for boreholes drilling has been in any case extrapolated from geological observations. Many have been the sites visited, springs and hand dug wells surveyed. In different geographic positions, detailed stratigraphic sections have been done and finally geological information interpolated on lithological base and the geological units trends interpreted. The use of GPS (Global Positioning System) has been of great help for the collection of geographical based information, such as geographic coordinates, tracks, etc. The geographic navigation and orientation would have been very difficult on a topographic 1:250,000 map based scale without the use of the GPS. Only lately new topographic 1:50,000 scale maps were edited and in any case only when the geological field works were almost accomplished. The information (Latitude, Longitude and Elevation) has been then stored into a geographic database software (Arcview) for further elaboration and graphic interpretation. Water quality tests have been done using Aquamerck field kits based on colorimeter methods and electric conductivity data acquired.

The sites surveyed include Filtu, Melka-Libi, Lebbikolo, Bokoaka, Golbo, Hirin, Mesagid, Gololere, Qurale, Haydimtu, Gherf, Seru, Abera, Walladea, Haysuftu, Garbagal, Bodbod, Udet, Negele (surrounding of the town), Miesa Darole, Siminto, Boba, Hadesa, Gobicha, Hardot, etc.

3. INTRODUCTION

3.1 Location of the Area

The studied area is situated in southern Ethiopia, within the administrative boundaries of Negele and Filtu districts. Its geographic co-ordinate ranges from E 39° 00’ to E 41°30’ and from N 04°30’ to N 5°45’ (*Figure 1*). Negele is found about 570km south-south east of Addis Ababa along the road Addis Ababa Awasa, Wondo, Kibre Menghist. Filtu is about 120km east of Negele. The main road from Addis Ababa is an all-weather road. The secondary roads are instead mainly viable during the dry season and difficulty viable during the rain season.

Figure 1: Geographic location of the studied area

3.2 Climate and hydrology

The area is dominated by a semi-arid climate. Annuals mean temperature varies from 19-35°C with little seasonal variation and these decreases 1°C with each 200-m increase in elevation. Average annual rainfall varies from 300 to 800 mm distributed within two-rain seasons. Rainfall delivery is bimodal: 59% of annual precipitation occurs

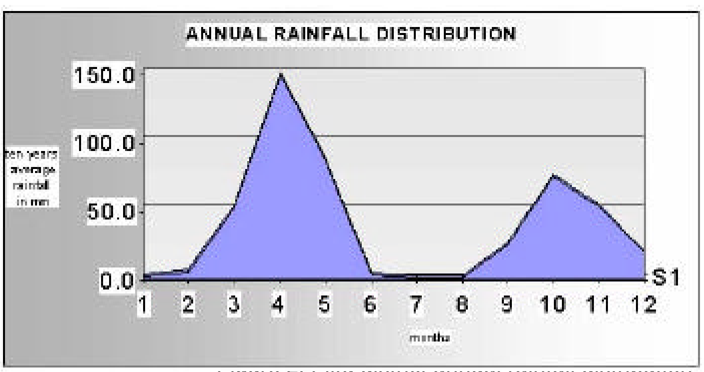


Figure 2: Filtu district annual rainfall distribution

from March to May and 27% from September to November. A dry year is defined as one in which annual rainfall is less than 75% of average and this may occur one year in five. The probability that two consecutive years will have average or above average rainfall, one dry year, or two dry years is thus 0.64, 0.32 and 0.04, respectively. At least two consecutive dry years constitute a drought.

In *Figure 2*, the chart represents the annual (x axis) rainfall distribution as an average of ten years data collection (y-axis).

3.3 Population characteristics

Most of the places inhabited in the area are villages along the Negele-Dolo road. Population

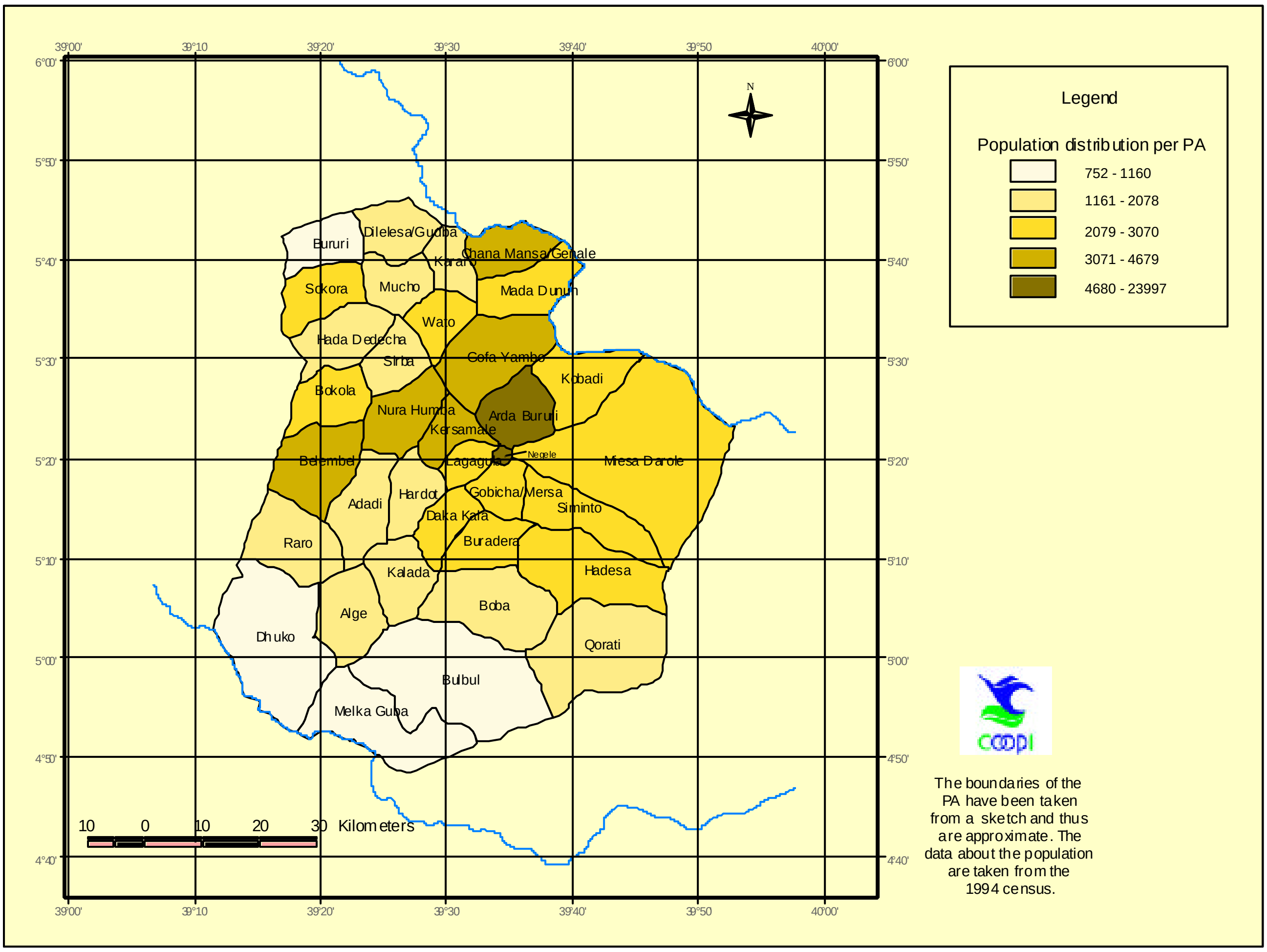


Figure 3: Negele population distribution per PA

density in this area is not high may be due to lack of sustainable water resources, harsh climatic conditions, and way of living (most of them are pastoralists). People in this area also earn their living by farming and trading. A geographical distribution of the sub-districts and population density in Negele area is shown in *Figure 3*. For Filtu districts the geographic distribution of the sub-districts is not available thus no maps could be produced.

The most prominent geographical feature of the district is made of sparsely populated rangelands supporting the overwhelming nomadic majority of the population. The pastoral country is covered with acacia trees, bushes and scarce surface grass. Along the banks of the two perennial rivers (Genale and Dawa), there is a thick vegetation, some palm groves and some permanent agricultural settlements are present.

The total population of Filtu district is estimated to be about 120,000 people divided in 32 villages. Returnees from Somalia represent an important part of the population, escaping civil war and drought related problems. The population of Negele district is estimated to be around 111,000 (according to the 1994 census).

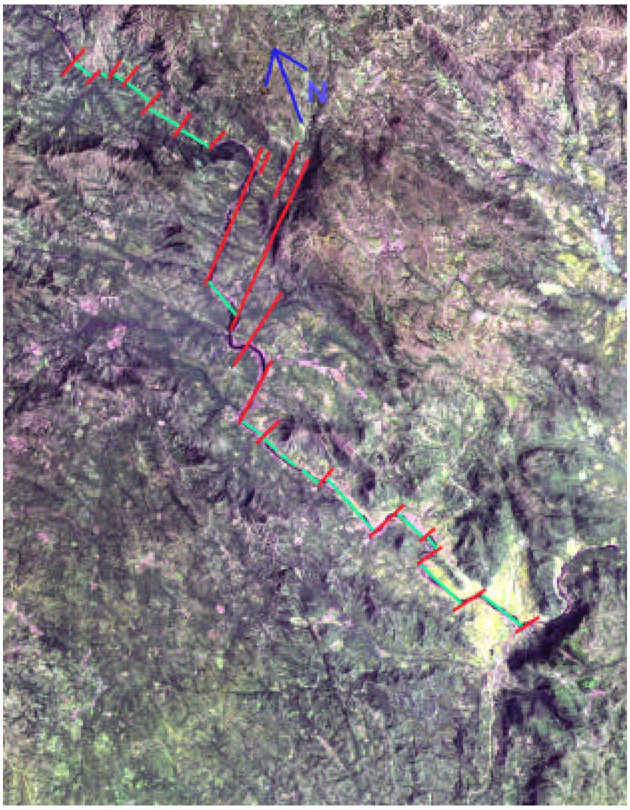
3.4 Phisiography

The area lies at the feet of the south and southeastward descending slope of the southeast plateau of Ethiopia. It is predominately composed of plain land and hill domes with summits not greater than 2,200m a.s.l. (western side of the area – to Wadera). North of the main road, going to Genale River the topography changes to somewhat rugged with more of dome features. The elevations degrade from west to east-south-east and from the watershed respectively to north and south direction. The main road lies on the watershed of the two rivers basins of Genale and Dawa. In the eastern part of the province the altitude reaches 800-700 m a.s.l in Ayinle and less than this along the rivers. Nearby the watershed, gentle slopes and wide valleys dominate the area. The morphology is a bit different going northward and southward from the main road where the valleys get deeper and narrower and steep cliffs often are present (*Figure 4*). At the border between the basement and the Mesozoic sedimentary succession, the discontinue system of ridges formed by the Precambrian rocks and the erosional remnants of Mesozoic rocks constitute an evident topographic feature. More resistant basement rocks and granitic intrusions coming up from the surrounding undulated plains dominate the west part of the area. The western part of Negele belongs to the Shakisso peneplanation surface while the southwest of Negele belongs to the Aflata planar surface (Kozirev et al. – 1985).

3.5 Drainage

In the area, there are perennial watercourses: Genale River, Dawa River, Awata River, and

Mormora River. All the others are intermittent watercourses. The Dawa River is perennial in Negele area but gets intermittent features in Filtu. During the dry season, the river gets dry in Golbo (south of Filtu) with water flowing into the riverbed deposits. In the west side of Negele, where the basement outcrops, the drainage pattern is tectonically controlled. N-S trends are common in the Kenticha belt where the Awata flows parallel to the Precambrian belt structures. The Dawa and Genale Rivers are also imposed on tectonic structures with WNW-ESE (green) trend dislocated by a more recent one with trend NE-SW (red) (*Figure 5*). In an area west of Negele, within the Alghe Group (Pbhg - Negele geological map), the drainage is more developed assuming a dendritic-type pattern. The east side of Negele is morphologically constituted by a plateau that is formed over limestone layers with no developed drainage pattern. A wide area within the plateau has the shape a big basin with internally draining system with no way out where. Here the waters are collected in a natural pond.



The remaining east part of the plateau to Filtu town and further there are two main drainage pattern. The first, due to the softness of the outcropping rocks' formation (in general marls and shales) gentle slopes and wide valleys mainly constitute the morphology. Thus, here the common drainage pattern is of dendritic type. The second is located on the watershed and surroundings where the drainage pattern is less developed with less evident streams. The third hydrographic province is the one developed on the upper carbonatic supersequence of the Jurassic. Here the drainage pattern is of trellis to dendritic type.

4. Previous works

Many works have been done within the understudied area. Among others the most important works that merit to be mentioned were made in the early 40's after the discovery of the Adola gold deposits. Division of low and high-grade series within the Adola group were made by Jelenc (1996). The Adola group was then divided into the Lower, Middle, and Upper Groups according to a three fold classification (Gilboy, 1970; Chater 1978). Kazmin (1972, 1975, 1978), and Kazmin et al. (1978) modified the groups into complexes ranging from Archean to Upper Proterozoic age. Since

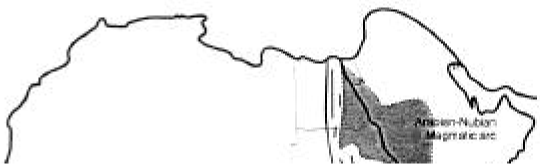
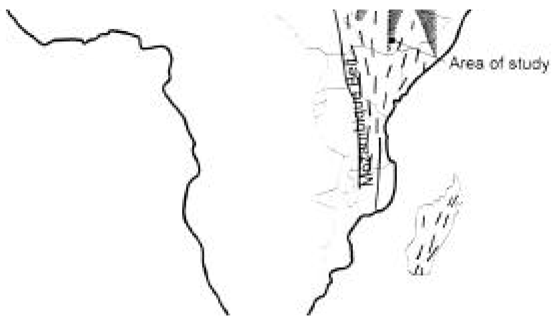


Figure 6: Proterozoic pan African Belt



the 1980's to early 1990's, systematic regional mapping took place for economic purposes (e.g. Kozirev et al. 1985; Teferi and Zhbanov 1991). Amenti et al. (1992) and Woldegabriel et al. (1994), classified the basement rocks in high and low grade and concluded that the high grade ones are at the lowest stratigraphic position in the region. Other works based on geo-chronological and isotopic studies (Ayalew et al. 1990, Ayalew and Gichile 1990, Gichile 1991, Worku 1996) classified the gneiss rocks to be Archean.

The gross stratigraphy of Ethiopia is quite simple and has been known since the pioneer work of Blandford (1870), and the synthesis of Dainelli (1943). The Dainelli study comprised the explanation of the stratigraphy of the Horn of Africa and was more or less accepted by the majority of the geologists who studied the sedimentary succession of Ethiopia.

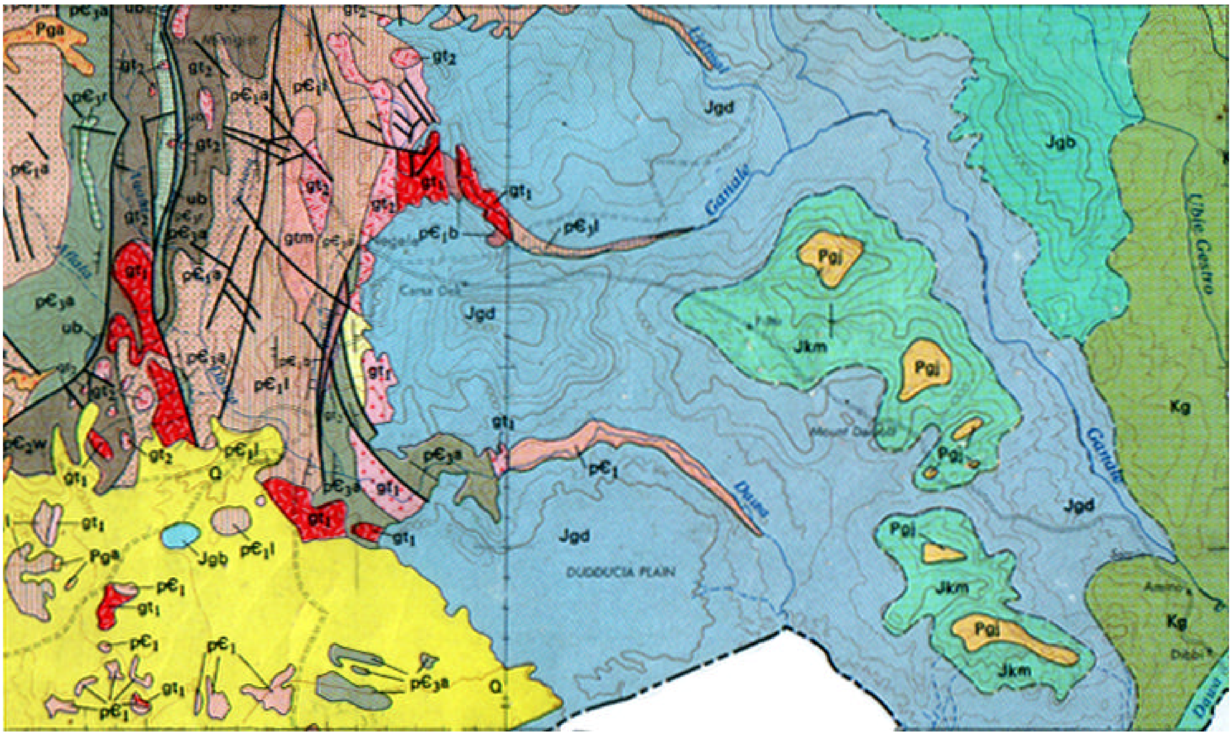
Bosellini (1989) has exhaustively dealt with the lithostratigraphic sequence of the continental margin of Somalia and the surrounding regions. In his works, an intermittent basin evolution is proposed to be caused by episodic subsequence and uplifts associated with the major catastrophic events in the horn of Africa during the Mesozoic era. We know now that the Adigrat Sandstone is fluviatile in Ethiopia (Beuchamp, 1977; Assefa, 1991) in Somali and Kenya (Bruni and Fazzuoli, 1997; Bosellini 1989, 1992) while the upper sandstone (Amba Aradan or Debre Libanos in Ethihopia, Jesomma in Somalia, Ambar in southwest of Somalia and Kenya) is certainly fluviatile in Tigray (Shumburo, 1968; Bosellini, et al., 1995), Showa (Assefa, 1995), and Somalia (Bosellini 1989, 1992).

One of the last works, which give maybe the first detailed information about the Mesozoic sedimentary succession in the area, is the Geology of the Negele Area (Tedesse and Melaku 1998). The latter gives detailed information about the lithostratigraphic sequences starting from the basal clastic rocks overlying the Proterozoic basement to the Jurassic successions outcropping in the eastern part of the 1:250,000 sheet of Negele. Although satisfactory explanation of the overall situation, it is to be noted that the interpretation of the conglomerate rocks within the Bera Kabye limestone had been erroneously interpreted as intra-formational rocks thus distorting the overall view of the tectonic regional dynamics of the late Jurassic. The authors assumed the conglomerate to be lying in unconformity over the Jerder limestone succession. The unconformity surface was supposed to be 30° inclined toward east. During our field visits, no evidences of this kind were noted.

Previous works differently described the Jurassic formations, changing their names from time to time. In the geological map of Ethiopia 1:2,000,000, compiled by V. Kazmin (1972), the Mesozoic formations were divided into, at the base, the Genale Doria Formation and, at the top, the Mount Filtu Formation. Then, in the geological map of Ethiopia 1:2,000,000 compiled by M. Tefera et al. (1990), the Mesozoic formations have more or less the same trend, but their name chance. The Doria Genale Formation became the Hamanlei Formation, and the Mount Filtu Formation became the Urandab Formation. Finally, in the geological map of Negele Borena 1:250,000 compiled by Workneh Haro, C. Wossen, etc. (1996), the lower part of the Jurassic sediments (the first 60-70m) take the name of Jerder Limestone, and the remaining take the name of Melmel Limestone.

The angular unconformity described by Kazmin between the Doria Genale Formation and the Mount Filtu Formation is not observable and totally arbitrary as well as the limits between the the Jerder Limestone and the Melemel Limestone are greatly debatable. In this report, the justification given by Bosellini in 'The Mesozoic Succession of the Makele Outlier" (1997), that merges together the Antalo Limestone and the Agula Shale is considered a good way to avoid nomenclature misunderstandings. Therefore, the whole Jurassic sediments between the Adigrat Sandstone and the Jessoma Sandstone will be referred as a whole to a carbonatic Supersequence.

5. Regional Geology



The study area is underlain by Proterozoic crystalline basement complexes, covered by marine Jurassic to early fluviatile Caenozoic and successions and Tertiary volcanic flows west of Negele, Hadessa, Qurale, and Gobicha. The basement complexes (gneissic terrane and narrow low grade belts) are designated as parts of the Mozambique belt and the Arabian-Nubian Shield, respectively (De Wit and Chewaka, 1981; Gichile, 1991; Stern and Dawoud, 1994; Worku, 1996; Shackleton, 1996 and others). These rocks are then intruded by syn-and post-tectonic orogenic plutons.

The crystalline basement rocks are suggested to be affected by the late Proterozoic (Pan-African - *Figure 6*) deformation, metamorphism, and magmatism (Shackleton, 1986) and are contemporaneously intruded by syn and post tectonic basic to acid intrusive rocks. Thrust contacts between the gneissic terrane and low-grade belts, are often marked by a N-S

[1] Pga, gt, pEya, etc.: Precambrian basement
Jgd: Jurassic sedimentary succession
Jkm: Cretaceous sedimentary succession
Pgj: Cainozoic sedimentary succession
Q: quaternary deposits

trending regional lineaments and associated shear zones accompanied with an easterly and westerly dipping mylonitic foliation and reverse drag folds (Tedesse Y and Melaku T., 1998). Adola, Bulbul, and Moyale are also interpreted to be dismembered ophiolite sequences (Kazmin, 1976; Vail, 1976; Shackleton, 1986; Stern, 1994), accreted, folded and chaotically assembled either at final collisional suture along which several terrains are welded together or could possibly be allocthonous nappes obducted for several hundred kilometres from the main collisional suture zone. The presence of extensive ultramylonite proximal to Kenticha and Bulbul low grade belts, thrust related shear zones at thrust contacts and moderate to steeply dipping thrust sheets in the low grade belts, pop-up structure, tectonic melange in the Kenticha belt, suggest a possible rooted suture zone (Shackleton, 1996).

Gichile (1991, 1992) recognized that these rocks are late Proterozoic regionally metamorphosed Mozambiquean granulites, representing the root zone of the supracrustal sequence in the Pan-African collision zone, which were consecutively thrusted / uplifted to a higher level during late tectonic stage.

Following this line of interpretation W / Haimanot and Behrmann (1995) and Worku (1996), suggested the Precambrian rocks of southern Ethiopia to constitute a transitional zone between the low grade volcano-sedimentary rocks and the mafic-ultramafic complexes of the Arabian-Nubian Shield, and high grade gneisses, migmatite and intercalated schists of the Mozambique Belt.

The late Triassic is a time of regional subsidence during which rifting begins. During this period the progression in the Karroo rifting (see *Figure 8*) allowed the deposition of a thick clastic rocks of continental origin thicker and ticker toward the central part of the rift. After a long period of subsidence, in the Callovian early Oxfordian the sea floor spreading began (separation of east Gondwana from west Gondwana). The floor spreading ended in the early Hauterivian (121-120Ma). According to Dainelli, the Jurassic transgression came from the southeast, reaching its maximum limit in western Ethiopia and Eritrea during the Kimmeridgian. This transgression deposited a sandy formation (Adigrat Sandstone), followed by neritic sediments composed mainly by thick limestones.

From the Hauterivian to the early Tertiary, is a time of crustal uplifting and consecutive formation of the Upper Sandstone due to a forced regression of the sea.

Tertiary uplift of the Arabian-Ethiopian swell was accompanied by laterization processes and followed by eruption of trap volcanics.

6. Precambrian rocks

In Negele area the basement rocks comprises rock units of the Alge, Awata, and Wadera group; the low-grade belts are constituted by rocks belonging to the Adola and Mormora group. The lithostratigraphic sequences of the meta-volcano sedimentary and mafic-ultramafic complexes at Kenticha and Bulbul low-grade belts are difficult due to the chaotic assemblage of rocks in the form of tectonic melange and thrust sheets of volcanics and sediments along internal thrust planes. The basement shows general trend E-SE (120°) and dipping ranging between 1° to 2°.

6.1 Gneiss, migmatite, and intercalated schists

Constitute a wide gneissic terrane with minor intercalation of schists and migmatite. They occur at Alge, Awata, and Wadera groups, included in the lower and Middle Complexes of Archean to Mid Proterozoic age (Kazmin, 1972; Kozyrev et al., 1985; Mengesha et al., 1996). Structural and metamorphic discontinuities can be observed along the Kenticha and Bulbul thrust contacts with the rocks of gneissic terrane. Within this terrane, Tedesse and Melaku (Geology of Negele area, 1998) recognized the following lithotypes:

- **Biotite-hornblende gneiss (Pbhg)**: major map unit exposed in the west-central part of Negele 1:250,000 sheet. The contacts with adjacent gneissic units are mostly not distinct. It is often cut by discordant pegmatitic and quartz veins and veinlets. The main lithotype of this units are:
  - Biotite-hornblende gneiss: dominant rock type. Light to dark grey, fine to medium grained, foliated and often banded, locally migmatized. Slightly to highly weathered.
  - Biotite gneiss: grey to dark grey, fine to medium grained (1-3mm), foliated, often banded and locally migmatized. Often weathered
  - Quartzofelspathic gneiss: minor rock type. Pinkish grey, fine to medium grained (1-3mm) locally sheared with N-S and NW-SE foliation.
  - Hornblende gneiss: Dark grey, medium grained (1-3mm). Foliated and often banded (3-4mm).
  - Tremolite-talc schist: Greenish grey, medium grained (2-3mm). Schistose and often weathered.
  - Biotite granite: occurs as lenses. Pinkish grey, medium grained (2-4mm), leucocratic and massive.
- **Biotite gneiss (Pbg)**: is primarily constituted by biotite gneiss, intercalated with hornblende-biotite gneiss, minor quartzofeldspatic gneiss and pockets of biotite granite. It is exposed in a north-south trending narrow zone to the west of Wedera shear zone. The contact with adjacent units is not clear and compositional banding, migmatitic structures, and mineralogical compositions were used for discrimination. Foliation is often NW-SE and dipping to NE and SW truncated by post-tectonic biotite granite.
  - Biotite gneiss: dominant rock type. Grey to dark grey, fine to medium grained (1-3mm), foliated and at places banded (2-5mm). Commonly weathered and chloritized. At places intensely sheared and mylonitized. Locally silicified. Transposed boudins of quartz veins, asymmetric quartz and feldspar porphyroblasts are common.
  - Hornblende-biotite gneiss: dark grey, fine to medium grained (<1-3mm) foliated, locally banded and migmatized. Often weathered, occurs as lenses and boudins.
  - Quartzofelspathic gneiss: light to pinkish grey, fine to medium grained (1-4mm). N-S tending foliation.

- Biotite granite pinkish grey, medium to fine grained (3-5mm), massive and inequigranular.

- **Migmatite (Pmgt):** extensively exposed in the southwest of Negele. Constituted by biotite-hornblende gneiss, biotite gneiss, deformed and undeformed biotite granites. Very similar to Pbhg which limits with it are not distinct. Kazmin included it into the Alge gneiss. Field evidences indicate that migmatic structures and granitic intrusions are derived from partial melting and mobilization of Pbhg and Pbg at elevated P-T conditions (Tedesse, Melaku, 1998)

- **Biotite-plagioclase-microcline-quartz mylonite (Pqkg):** predominantly biotite-microcline-plagioclase-quartz mylonite with the presence of migmatized hornblende-biotite gneiss and hornblende gneiss. The contacts with adjacent rocks are not well distinct. Asymmetric quartz and feldspar porphyroblasts, indicating sinistral sense of movement, are abundant.

  - Biotite-plagioclase-microcline-quartz mylonite: dominant rock type. Pinkish grey to dark grey, medium to coarse grained (3-7mm). Mesocratic. Foliation dipping steeply to W and E.
  - Hornblende-biotite gneiss: dark grey, medium grained (2-3mm). Commonly banded and show migmatitic structures. Slightly weathered and at place sheared.
  - Hornblende gneiss: locally occurs interleaved with biotite-plagioclase-microcline-quartz mylonite. Gradational contacts with adjacent rocks. Dark grey to black, medium grained (3-4mm) commonly banded (4-5mm).

- **Quartzofelspathic mylonite (Pqfm):** Extensively exposed in the west part of the area, juxtaposed with the rocks of the Kenticha low-grade belt. Dips to west and is interpreted to have been gently under thrust beneath the Kenticha low-grade rocks. It forms N-S trending ridges, parallel to the regional foliation. The main lithotypes constituting these rocks are:

  - Quartzofelspathic mylonite: pinkish grey to grey, whitish grey when weathered. Very fine to fine grained (<1mm). Strongly sheared and appears an ultramylonite with high proportion of quartz-rich matrix.
  - Quartzofelspathic gneiss: pinkish grey, medium grained (2-4mm), slightly foliated, leucocratic (>10). At places feldspar are kaolinized.
  - Biotite-plagioclase-microcline-quartz gneiss: pinkish grey to grey, medium to coarse grained (2-5mm) and foliated. Often constitutes asymmetric porphyroblasts of quartz and feldspar (5-7mm).
  - Biotite granite: minor granitic intrusions within Quartzofelspathic mylonite. Grey medium grained (2-3mm), high presence of quartz and less of biotite.

6.2 Metavolcano-sedimentary and mafic-ultramafic complexes:

These associated rocks are confined in a narrow north-south trending Kenticha and Bulbul fold-and-thrust belts. The Bulbul low-grade belt gets wider toward south and the continuity is traced up to south of Dawa River by Saudokov et al. (1988). It also indicated to get wider toward south and appears to extend south to Moyale. This unit is grouped into the late Proterozoic of the Adola and Mormora Groups (Upper Complex by Kazmin, 1972). These igneous and sedimentary rocks are chaotically assembled with each other in the form of thrust slice/sheets, representing a typical tectonic melange at Kenticha thrust belt. In this belt, upward thrusting and reverse shear were predominant tectonic events, which resulted in thrusting of one unit over the other along the internal thrust planes. These deformed mafic-ultramafic and metavolcano-sedimentary sequences show a remarkable pinch and swell structures along the axes of the low-grade belts. Similar structures are also present in the Bulbul low-grade belt. The thrust contacts are defined by the persistent often-marshy regional lineaments. The swinging feature is referred to the frequency of ramp-and-flat structures at the sole thrust plane and to the effect of the differential movements of the overriding plate along the shallow and vertical E-W faults. The following lithotype compose this unit:

- **Serpentinite**: This unit is exposed in the western part of the map area, as elliptical bodies with the longer axis being north-south, forming domal ridges and hills. The hills underlain by serpentinite are characteristically devoid of vegetation. Is principally dominated by serpentinite, which marginally grades to talcose serpentinite, chlorite-talc and tremolite-talc schists. Serpentinite is pale green to greenish grey on fresh rocks and yellowish grey to buff when weathered, medium grained (2-3 mm) and massive. It is often dark green, mottled and locally bears nests of quartz stringers (interlacing chalcedony). At places, this rock unit also exhibits honey-comb (box-work) structure often tilled by brown iron oxide.

- **Metagabbro**: this unit is exposed as patches exclusively in the low-grade belts. The frequent Metagabbro outcrops are notable, especially in Bulbul low-grade belt. Large gabbroid rocks are indicated south of the map area, at a number of places around and to the north of Dawa river in the geological map of Bulbul area by Saudokov et al. (1988). The contact with other units is mostly not distinct, partly due to poor exposure and presence of slight textural and compositional variations in the unit.

- **Talc, chlorite, tremolite-chlorite-talc, chlorite-actinolite and actinolite schists**: This unit consists of an association of talc schist, chlorite schist, chlorite-tremolite-talc schist chlorite-actinolite and actinolite schists. It is exposed at Kenticha low-grade belt, in association with serpentinite and metasediments. It also occurs forming ridge around Bulbul village and as minor lenses in units Pcas, Pbhg and Pbg, elsewhere in the area. The contact with unit Psrp is not distinct. This unit is intruded by post-tectonic biotite granite and pegmatite, at Kenticha. In these places the schistosity of rocks is pushed aside by the granite bodies and seems to wrap the granite hills. Talc schist: shares the largest occurrence among other rock types in unit Ptts. It is light grey to buff grey and weathers to brownish grey, generally medium grained (2-3 mm) and schistose. At some places, the schistosity is found crenulated and sheared.
  - <u>Chlorite schist</u>: occurs frequently intercalated with talc schist. It is green medium grained (2-3 mm), with often-crenulated schistosity.
  - <u>Tremolite-chlorite-talc schist</u>: it is greenish grey to light grey, medium grained (2-

3 mm), schistose and commonly sheared.

- Chlorite-actinolite schist: it is yellowish grey to greenish grey fine to medium grained (1-3 mm) and schistose.
- Actinolite schist: is a minor intercalation within unit Ptts.

- **Actinolite schists and actinolite-quartz-epidote schists**: This map unit is exposed in the Kenticha and Bulbul low-grade belts, in association with units Ptts and Pqbs. At Bulbul, unit Pcas becomes extensive and is frequently truncated by deformed and often altered biotite granite in several places and is unconformably covered by Jurassic-Cretaceous limestone successions to the east. This unit pinches out, north of Negele town and widens southward outside the map area. It also occurs as lenses within units Pqfm, Pbhg and Pqbs and also as a roof pendant over units Pfgt and Pgt.

  - Actinolite schist: is the dominant rock type in the unit. It is dark green to dark grey and buff when weathered, fine to medium grained (l-3 mm) and schistose. At places, it tends to show compositional layering. This rock type is strongly sheared towards tile contact with unit Pbhg, all along the Bulbul low-grade belt. However, towards the southeast it becomes less schistose and appears metabasalt. Disseminated pyrite mineralization is common.
  - Actinolite-quartz-epidote schist: is dominant in localized zones, especially in the Bulbul Low grade belt and rarely in Kenticha. It is yellowish green, fine grained (1mm) and schistose.

- **Quarts-biotite, quartz-sericite and garnet-staurolite-quartz-biotite schist (Pqbs):** constituted of quartz-biotite schist, quartz-sericite schist and garnet-staurolite quartz-biotite schist with minor intercalated actinolite and chlorite schists. Extensively exposed in the Kenticha and Bulbul low-grade. This rock unit is strongly sheared and foliations are often crenulated

  - Quartz-biotite schist: is the dominant rock type within the unit. It is finely grained (<1mm), ashy brown to dark brown and highly schistose. Intrafolial z-folds are common, especially around Buradera and Bulbul villages. At places quartz dominate biotite. Locally, intense epidotization is seen.
  - Quartz-sericite schist: is ashy white to silvery grey, fine grained (<1 mm) and highly schistose. Stretched and transposed quartz veins are common.
  - Garnet-staurolite-quartz-biotitic schist: this rock type becomes a common intercalation in the unit, especially around Awata River and Kenticha villages. Subsequently, this rock type progressively dominates towards south within the Kenticha low-grade belt, where the elevation decreases significantly within the Mormora catchment area. It is ashy grey to shiny grey, fine grained (<1mm), strongly schistose with porphyroblasts of garnet and staurolite (2-4 cm across).
  - Actinolite and chlorite schists: occur as minor intercalation within the unit Pqbs.

- **Quartz-graphite schist with intercalated marble and quartz-sericite schist (Pgs):** is constituted of quartz-graphite schist intercalated with minor marble and sericite schist. Unit Pgs is exposed in the Kenticha low-grade belt, forming about 300 m wide north-south trending, sharp crested ridge.

- Quartz-graphite schist: is a major component of unit Pgs. It is dark grey to black, fine to medium grained (1-2 mm), strongly schistose sometimes showing massive texture. Zonally disseminated sulphide (pyrite) minerals are abundant. Pre to syn-deformational quartz veins cut it concordantly. These quartz veins together with the schistosity form mesoscopic intrafolial Z-folds in several places.
- Marble: in unit Pgs presents as lenses of impure marble. It is light grey to yellowish grey, sometimes layered and commonly fine grained. Graphite partings give mottled appearance. It is massive in texture. The faint layering parallel to the general trend of the rock is due to graphite grain incorporation.

6.3 Granitic intrusive rocks:

These are mainly granitic in composition, with occasional variation in the relative abundance of quartz, k-feldspar and plagioclase crystals. They are granitic rocks of variable dimensions intruded in various gneissic and migmatitic rocks of the gneissic terrane, as well as mafic-ultramafic and volcano-sedimentary rocks of the low grade belts. Large granitic outcrops are dominant toward north within the gneissic terrane. Internal textural and structural evidences show that these granitic bodies have syn and post-deformational emplacement history. Large and small gneissic roof pendants are common over the granitic rocks. The frequent presence of gneissic enclaves in granites and absence of distinct contacts in several places may indicate that the granitic intrusive bodies are possibly derived by partial melting from the ensialic continental crust during collision and crustal thickening. Worku (1996) indicated that west of Negele the granites are calcalkaline in composition. Three distinct granitic rocks are identified:

- **Syn-tectonic biotite granite (Pfgt)**: is exposed forming north-south trending elliptical, but mostly isolated ridges. Particularly around Bulbul, Negele, Gofa Yambo, Arda Lemecha and Oda Boly villages. Is pinkish grey, medium to coarse grained {3-6 mm) and weakly foliated. It is leucocratic (< 5). This granitic rock at places appears massive in hand specimen, but shows a pervasive penetrative planar surface wherever it is exposed.

- **Post-tectonic biotite granite (Pgt)**: grey, medium to coarsely grained (3-6 mm) inequigranular and massive. It is leucocratic with colour index not more than 6. The contact of this pluton with the intruded country rocks is generally not sharp. The effect of granitic bodies during intrusion on the orientation of rocks is significant in the less competent low-grade rocks, but is less in the relatively quartz- and feldspar-rich gneissic units. Nevertheless, the peculiar NW-SE trending foliation of unit Pqfm at Sokora Harte, is probably due to the effect of the nearby granitic intrusion. The effect of granites on the mineralogy of the host rock is nowhere observed, because of poor exposures at the contacts.

- **Post-tectonic pegmatoidal granite (Ppgt):** is characterized by large grains of microcline (2-3 cm in diameter, sometimes exceeding 3 cm). The randomly and abundantly distributed coarse microcline, plagioclase and quartz phenocrystals impart pegmatitic appearance to the rock. Ppgt is light pink to pinkish grey, coarsely grained (>5 mm) inequigranular and massive. It is leucocratic (index not more than 7).

7. Phanerozoic rocks

Phanerozoic rocks in Negele-Filtu district are represented by Paleozoic glacial deposits, Mesozoic marine sediments, and Tertiary continental sediments and basaltic flows. Unlike other sedimentary provinces of Ethiopia, the stratigraphic succession and the evolution history of the Genale river depositional basin is more related to the Mandera-Lugh depositional basin of northeast Kenya and southwest Somalia (Kazmin, 1972; Worku and

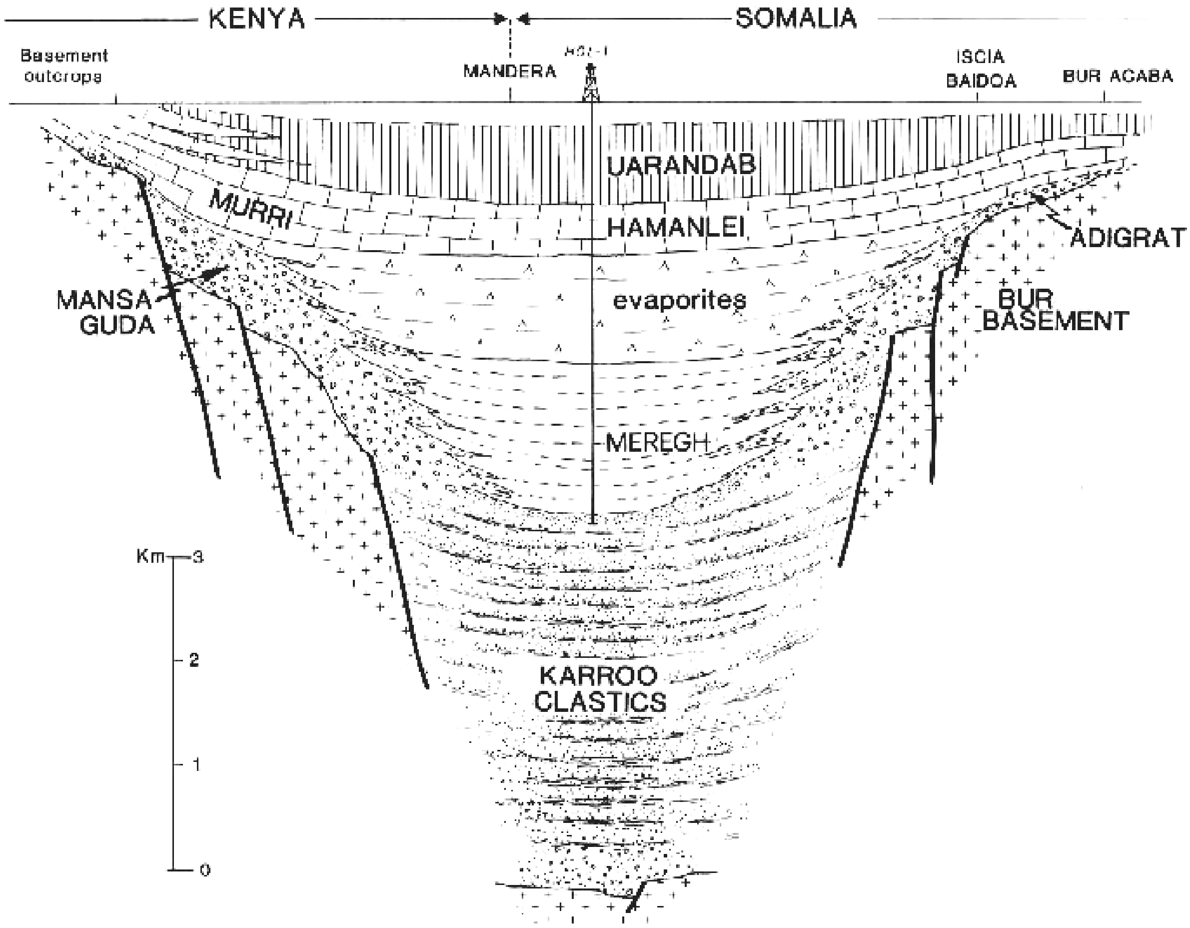


Figure 8: Cross section of the Mandera - Lugh Basin, interpreted as the aborted Karroo rift (from continental margin of Somalia – Bosellini, 1989

Astin, 1992). The Mandera-Lugh basin (*Figure 8*) is interpreted as an aborted rift, of which more than half filled, by Karroo sediments. From seismic lines, more than 9,000m of total fill is present.

The sedimentary succession underlying the Jurassic carbonate rocks and overlying the metamorphic basement, generally considered as Precambrian in age, was described by Blandford (1870) as a single formation called Adigrat Sandstone. In this sense, the term was used by other geologists (Stefanini, 1933; Merla and Minucci, 1938; Dainelli, 1943; Mohr 1962; among others). More recently (Dow et al., 1971; Saxena and Assefa, 1983), two different formations of Paleozoic age (Ordovician) were recognized in the lower part of the former Adigrat Sandstone. The present definition of Adigrat Sandstone is therefore limited to the upper part of the basal succession.

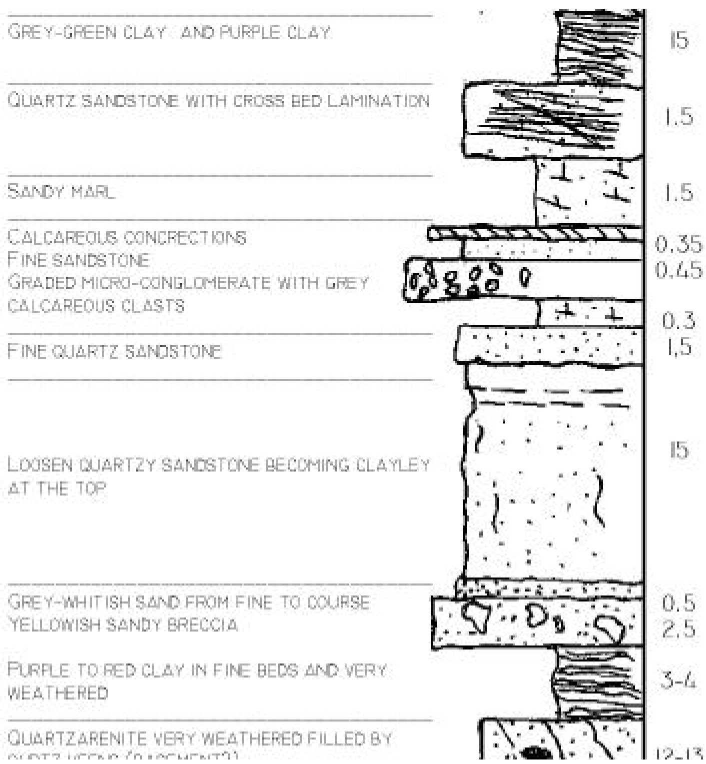
7.1 Paleozoic sedimentary rocks

These formation is discontinue and patchy in occurrence. This rock unit ahs been divided by Tadesse and Melaku (Geology of Negele area, 1998) in the following way:

- **Glacial tillite:** patchy and discontinue outcrops of limited aerial extension. It caps the basement with flat lying 2.5 to 10m thick, massive, sub-angular to angular blocks completely unsorted rocks varieties. Basement and limestone boulders (35cm size) are present. These rocks are similar to the Paleozoic glacial rocks of the northern Ethiopia as described by Dow et al. (1971). The upper age boundary of this unit is much older than the overlying cross-bedded sandstone.

- **Cross-bedded sandstone:** It is of fluviatile origin, as shown by the occurrence of point bar sequences (nearby Negele town, Kobadi site). The sandstone beds rests unconformably on the basement rocks, and at places on the glacial tillites. The thickness is very variable and in some places is very thin or even missing. According to Tadesse and Melaku (Geology of Negele area, 1998), the best exposure sites are at Negele town, Gobicha, El Kabye, and Menekubsa. Thickness decreases toward west ranging from 15 to 5m. The stratigraphic position of the cross-bedded sandstone makes it equivalent to the Adigrat Sandstone of north Ethiopia and the Mansa Guda formation of northwest Kenya. Both the lower and the upper boundaries of the succession are likely diachronous (Bosellini, 1992). The age of the lower boundary is practically impossible to date: it was controlled by the Gondwana relief and by rifting. The age of the upper boundary, which roughly should be taken as the age of the transgression, was dictated by the Jurassic rifting and by gradual on-lapping of marine sediments onto the east African continent (Bosellini, 1997).

- **Transitional beds:** the boundary between the Cross-bedded sandstone (Adigrat) and the overlying carbonates (Antalo?) is transitional and it occurs through about 20m of shale with intercalation of limestone and sandstone beds. This unit is also discontinue in occurrence and therefore unmappable. It can be observed at Negele town, Boba, El Kabye, etc. The basal part of Boba section (*Figure 9*) is mainly constituted by terrigenous depositions like sandstone and clay belonging to this unit. The western side of the top most transitional beds is always constituted by variegated clay which thickness is about 15m. The transitional beds north of Haysuftu (*Figure 10*) appear to have a carbonatic component too showing an eastward facies change. Common

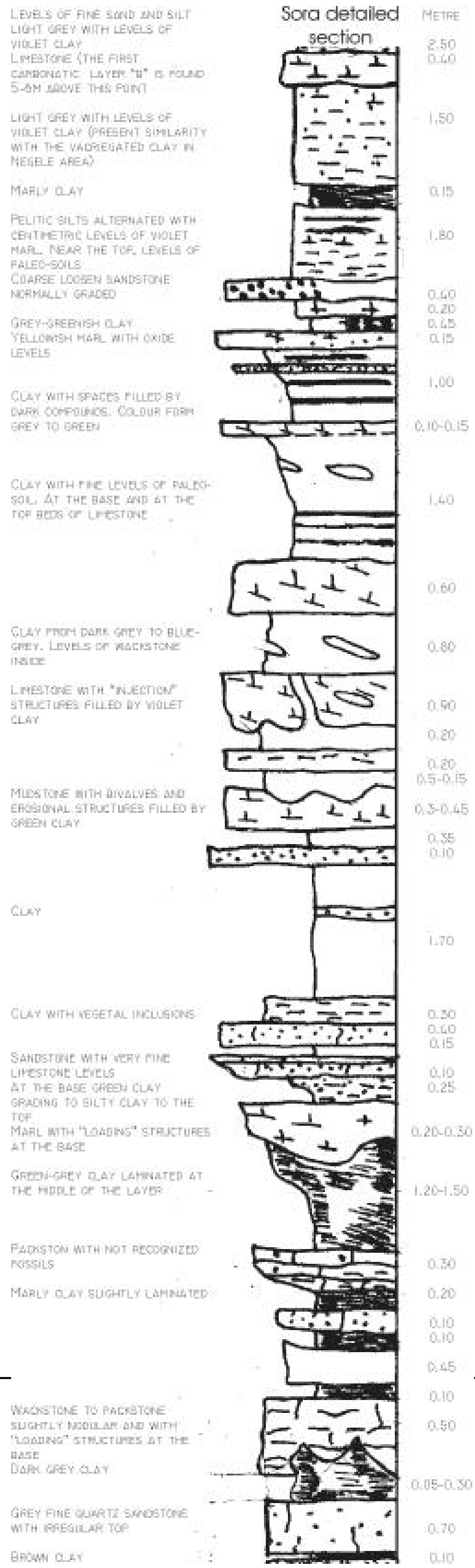


are the inter-beddings between carbonate rocks and clay and sandstone. The lower part of the section is characterized by mainly quartz sandstone and clay beds. Conglomerate are also present. These are very fine grained with carbonate clasts.

Another example of transitional beds exposure is found north of Haysuftu (*Figure 10*). Its carbonate rocks component is higher than the previous although the terrigenous component is still the prevalent one. Very common are the injections of clay into the overlying carbonate beds (loading structures). The presence of paleo-soils interbedding testify emerging periods during the deposition phases. The top most part of the succession has similar characteristics with the Boba one. Grey to violet clay seal the upper part of the section where the first sequence (A1) appears some metres above.

7.2 *Mesozoic sedimentary rocks*

In literature, the Mesozoic sedimentary rocks have been divided into two different successions on the base of their presumable age and limits. The lower carbonate succession is referred to be Jurassic (Kimmeridgian) while the upper carbonate succession is considered to be of Jurassic to Cretaceous age (Kimmeridgian to Cenomanian). Between the two, a very slight unconformity was referred to exist by Kazmin. Although this, no field evidences were noted and being the limit totally transitional and arbitrary, the two successions will be treated as a single geological unit of Mesozoic age in general. The general trend is about 120° (E-SE) with a dipping of about 1° to 2°.



The carbonate succession occurs in Negele town bordering the basement rocks with a north-south trend. Nearby Negele town the lowest thickness of the succession is recorded. The maximum thickness of this succession is considered to reach about 700m in the surrounding of Filtu. It is a carbonate sequence constituted by mudstone to grainstone interlayered/interbedded with shale, marl, etc. At places, the thickness of the shale can reach the order of tens of metres including thin centimetric beds of limestone. The lower part of the sequence is at the base divided into at least three depositional sequences (A1, A2 and A3) that appear constituted of parasequences (thickening and shallowing up cycles). The parasequences are supposed to be produced by relative sea level changes on a short time frame of 10,000-100,000 years (4^{th}-5^{th} order cycles). Parasequences are generally the result of transgressive-regressive events, which may be due to allocyclic processes, such as orbital forcing in the Milanovich band of Jerky subsidence of autocyclic processes. The general deposition characteristic of a parasequence is a coarsening/shallowing-upward vertical facies association (Bosellini 1999). The gradual shallowing is followed by abrupt deepening which produces the marine-flooding surface forming the parasequences boundary.

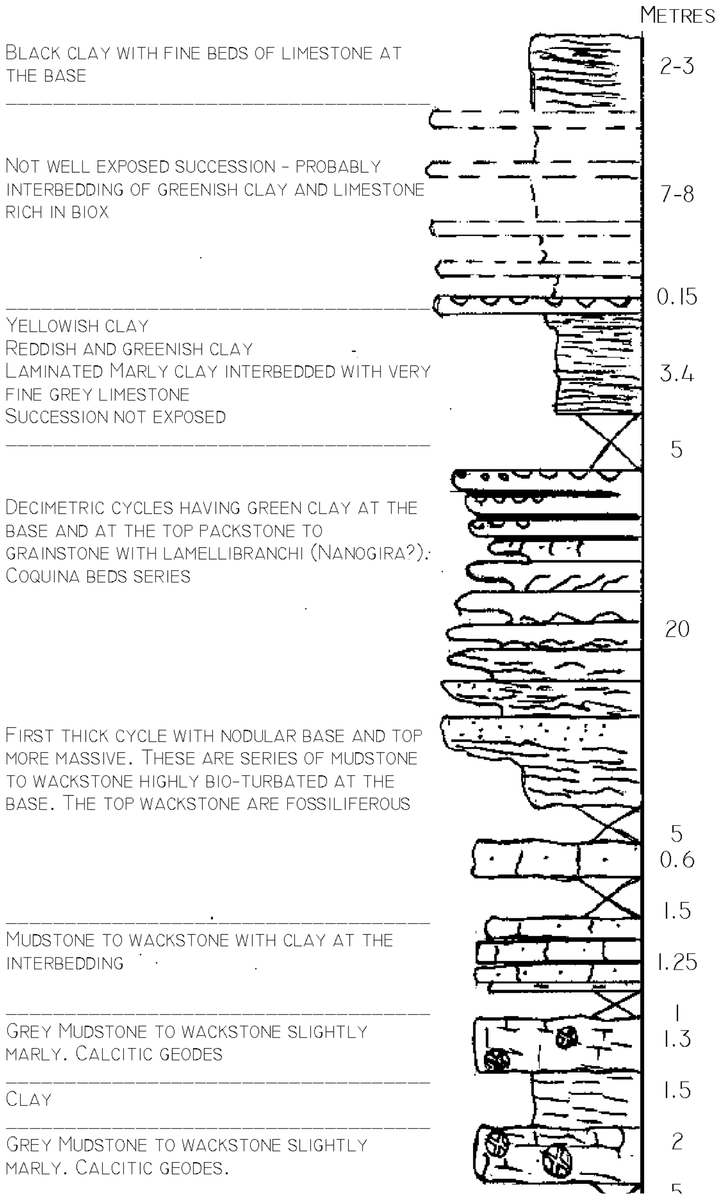
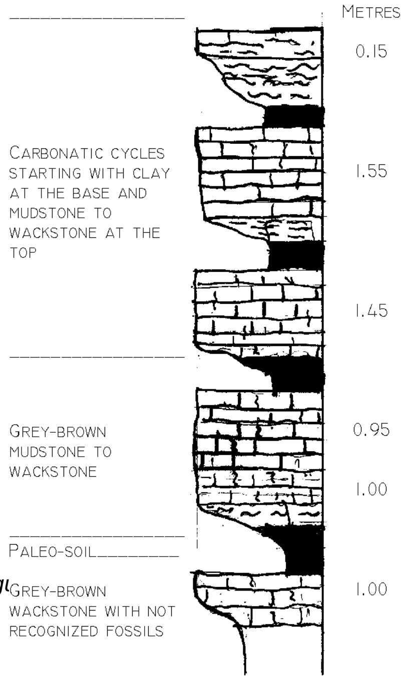


Figure 11: Boba detailed stratigraphic section of A1 cycle

The characteristic A1 stratigraphic sequence is shown in figure *Figure 11*. This section refers to the outcrop at the Boba escarpment along the Negele-Wachile road. Other outcrops are found along the Genale and Dawa rivers escarpments. Slight lithological and thickness variation are reported eastward.

The A1 cycle is also very well exposed in Walladea, a locality about 15 km north of Haysuftu. In *Figure 12* is shown the central part of the depositional sequence A1. Each parasequence start at the bottom with very fine beds of clay of some centimetre of thickness (up to 30). Overlying the clay there are nodular mudstone becoming massive upward. The carbonate component varies from grey-brown mudstone to wackstone. The thickness of the parasequences varies from about 1 to 1.5m. Thin paleo-soils levels are sometime present at the top.

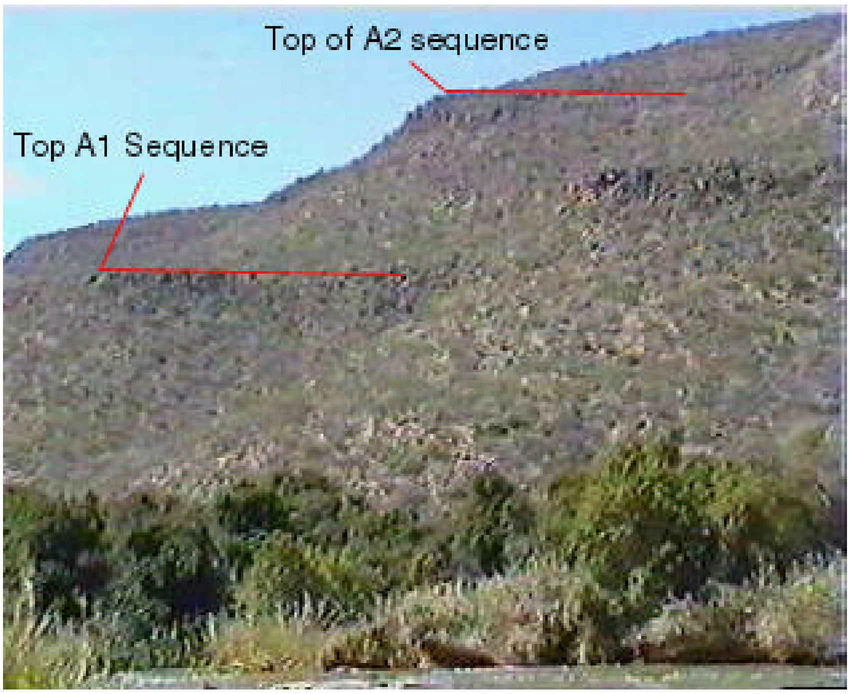


Fig

The A1 sequence abruptly and sharply break and a strong lithological change takes place. The A2 cycle has lithological variation according to the localities. As general trend the carbonatic components increases eastward. The basal part of the cycle A2 is mainly constituted by shale with thin beds of limestone interbedded. The thickness of the basal part of A2 is about 50 to 70 m. In the eastern part of the sedimentary province, this is constituted by 70m of black shale with beds of mudstone to grainstone of decimetric thickness. The clay is mainly black in colour with variation to grey and violet. Going eastward the terrigenous component decrease leaving place to marly rocks.

On top of this, the parasequences are well developed. Good outcrops of these parasequences are found along the escarpment of the Genale River. Here the alternating of many parasequences originates a "massive" hard rock sequence, which forms steep cliffs of tens of metres (see *Figure 4*).

The two sequences are very well distinguishable morphologically all over the area during the field surveys as well as during aerial photograph and satellite image interpretation (*Figure 13*). The most top of the sequences are constituted by harder rocks thus resisting to the action of the erosion agents resulting in relief profiles. The middle rocks, softer and more eroded, are instead covered by sediments.



The upper part of the A2 sequence is represented in *Figure 14*. The parasequences are constituted by mudstone to grainstone rocks and oolites are very common. The colour is from grey to yellowish. Sometimes the bases of the parasequences are nodular due to bioturbation while toward the

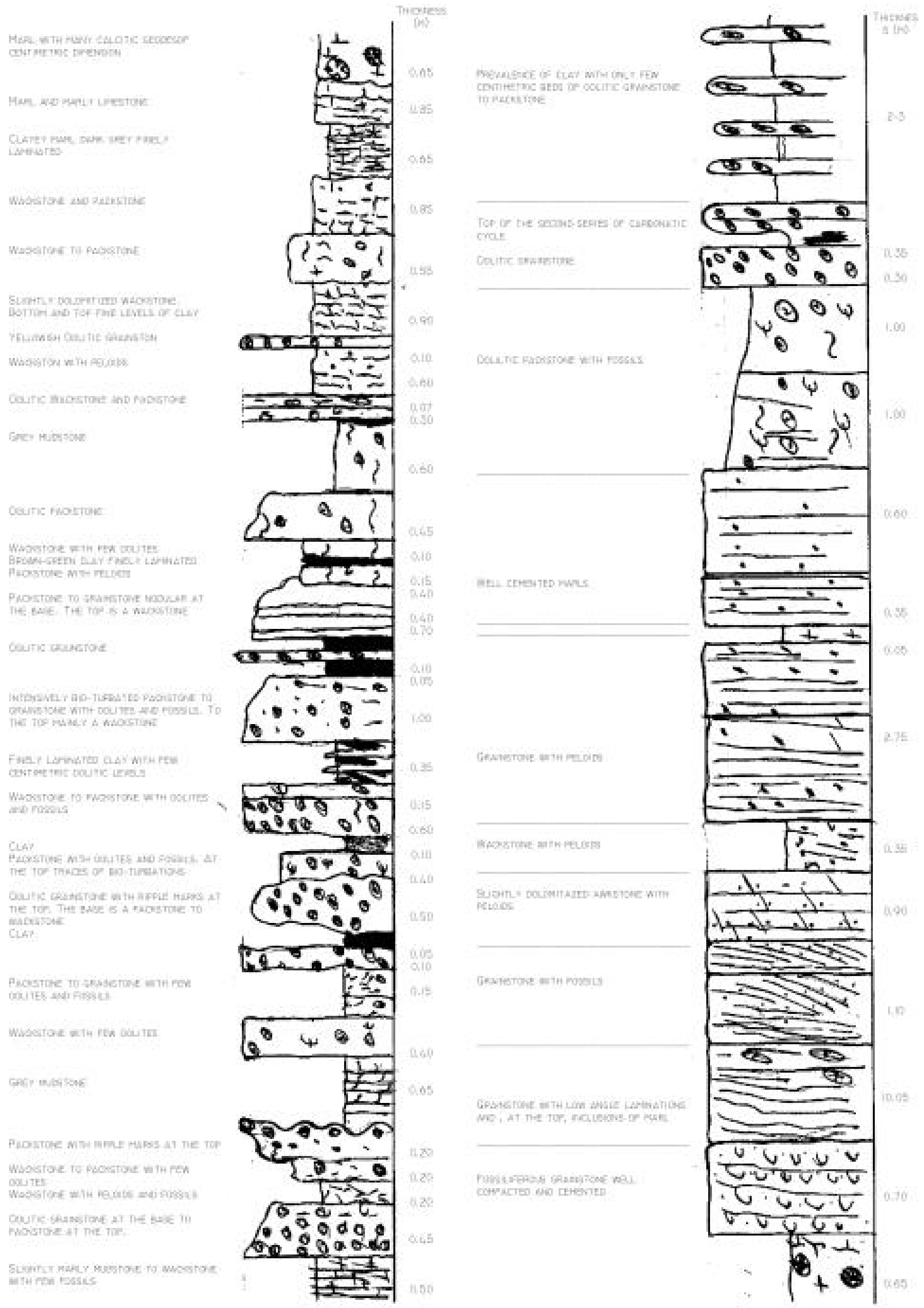


Figure 14: Upper part of A2 sequence

top the limestone become more compact.

Above the sequence A2, the formation continue with a similar trend. 20-30m above the top most of the A2 sequence, other parasequences are present, but the relief is only of some metres (no more than 15m). The upper part of this group is not very much known because it was not into the area of interest of this study. In past publications, the overlaying rocks were referred to the Mt. Filtu Formation although the way of distinguishing was not clear. Lithologically they are similar and both constituted by carbonatic cycles piled up in parasequences.

7.3 Cainozoic sedimentary rocks

Jessoma Sandstone formation: this is mainly present in the eastern Ogaden, although outliers have been mapped farther west in Bale and Sidamo provinces. The Jessoma Sandstone may once have extended as a continues deposit as west as the Rift Valley. It consists of grey and variegated quartz sandstones with intercalation of variegated shale. The Jessoma Sandstone formation is of fluvial continental origin in the west. Its thickness varies from 100 metres in the west to 300 metres in the east. It is a trasgressive formation that lies unconformably on older formation. The Jessoma Sandstone formation is not important for the purpose of our work and it is only mentioned because it outcrops in limited places within the studied area (see *Figure 7*).

7.4 Tertiary volcanic rocks

The Tertiary basaltic flows of Oligocene to Miocene age (Kazmin, 1979; Merla et al., 1979) outcrop at the west of Negele town nearby Bitata on the main road, south of Negele in Gobicha, in Hadesa, on the top of the hill along the Genale river 85km east of Filtu. Sometimes outcrops occur directly on the Precamprian rocks and some other on the Mesozoic ones. It is mainly constituted by olivine basalt very dark grey in colour and brown-reddish when weathered. The main basalt outcrop is found at 10 to 15 Km west north-west from Negele along the main road. It constitutes a dome overlaying directly on the basement. The basalts are erosional remnants of lava erupted during the tertiary basaltic flows.

7.5 Quaternary rocks

Continental Quaternary formations: as the quaternary deposits are well extended, they had a certain importance for the implementation of the project for the construction of artificial basins, and hand dug wells. We can distinguish different types of quaternary deposits:

- **Eluvial and colluvial deposits:** loosen, silty, clayey deposits of few metres of thickness. These are abundant in the studied area and are interesting for the project activities for the construction of artificial basins for surface water collection.

- **Alluvial deposits:** include clayey gravel, gravel and sand. In Udet these deposits constitutes a wide fluvial terraces while, elsewhere, for example in Mesagid and Qurale, they constitute a thin deposit on the fluvial erosive terraces. In Filtu area, the thickness is of few metres while in Udet area these can be of up to 6-7m 9or more). The area surrounding Filtu is mainly dominated by erosion. Thin alluvial deposits are located in the upper parts of hard rock thresholds. The remaining of the banks and riverbeds are under erosion regime. Due to the aridity of the climatic conditions, the alluvial deposits are often mixed with salts' deposits. These are formed due to water capillarity that transports salt toward the upper part of the deposits, concentrating them in defined layers. Thus, the lithyfication process results accelerated with formation of well-cemented conglomerates.

- **Travertine:** deposits of travertine are associated with the Precambrian Basement, and massive limestone layers (A1 and A2) outcrops. The travertine is made up of vegetal of which woods are the main parts. These deposits were associates with spring water circulation indicating paleo-climate situations, water circulation in the water bearing strata, etc.

8. Tectonic

The surveyed area is located almost 300 km far from the axis of the Rift valley. Therefore, it is situated in an almost stable regional tectonic context. The Mesozoic layers are sub-horizontal or anyhow very blandly dipping to east south-east (1° to 2°). The tectonic is in general characterised by fractures and normal fault with very limited reject.

The main systems' fractures are almost vertical and have the following strike:

I	strike N 60° E	dip: Sub-vertical
II	strike N 30° W	dip: Sub-vertical
III	strike N-S	dip: Sub-vertical
IV	strike E-W	dip: Sub-vertical

All these fractures' systems have been found to be common almost everywhere in the studied area.

Other tectonic evidences are the very ancient ones of the Precambrian mainly recognizable where the basement outcrops. The main structures include folds, foliations, lineations, shear zones, faults, and lineaments. All these structures were developed during the progressive syn-orogenic (folding and thrusting) and post–orogenic (shearing) deformations. East-west deformational stress produced north-south oriented antiforms and synforms together with thrusts and shear zones. These structures can be easily identified through aerial photographs and satellite image interpretation. The east-west compressional forces ended with the east African orogenic in the late Proterozoic with the collision of the east and west Gondwana (Vail, 1976; Shackleton 1986, 1994, 1996).

Faults have been described by Tedesse and Melaku, 1996, as ductile, brittle-ductile generated throughout different deformational episodes of deformation of the basement rocks. The trends of the fault and lineaments are prominently N-S, NW-SE, E-W, and NNW-SSE.

N-S faults are abundant in the basement and their occurrence increase going westward. Most of them are restricted to the Wadera Shear Zone, within which the N-S faults can reach a length of 10Km.

NW-SE and E-W faults are also present in the Wadera Shear Zone with length of up to 40km interpreted by Tedesse and Melaku as antithetic (Hada Tedecha and Alghe faults) and synthetic (Utulu faults).

N-S, E-W, NW-SE, and less frequently NE-SW linear features increase of intensity toward west; their length go from few hundred meters up to 15Km. The lineaments are well recognizable through aerial photographs. They are associated to the last deformation phase of the East African Orogenesis.

9. Hydrogeology and hydrochemestry

Precambrian Basement: in general, the Precambrian Basement has not well developed aquifers. Due to the basement rocks' characteristics (ductile, massive, absence of porosity, etc.) they are not good water bearing rocks. The only aquifers that might be encountered are the ones developed through the tectonic structure systems or the ones supported by the basement into the alluvium and eluvium deposited over it. Many were the attempts made in the past to exploit the aquifers of the basement with many failures. Most of the time during drilling, fresh gneiss or schists were encountered and drilling abandoned. The only borehole supposed to be productive (but no data are available) was the one drilled into the fracture crossing Harakalo but nowadays out of order. Among the boreholes drilled into the basement, there are strong evidences that although the boreholes penetrated for some metres the basement rocks the water was anyhow percolating from the aquifer over it (Udet and Mugayo boreholes for example). Drilling boreholes in the basement would involve accurate geological interpretation and knowledge of the tectonic structures potential from the hydrogeological point of view. Geophysic survey should be carried out to identify the extension of the faults or shear zones in order to understand better their hydrogeological characteristics.

The water of the aquifers of the basement is in general of good quality with low salts contents, anyhow, wherever possible water exploitation of the aquifer into the alluvium or eluvium would be preferable because of its easy implementation. Depth of the basement (or thickness of the sediment over it) and aquifer characteristic can be interpreted through electric geophysic investigation, which is cost effective and easy to implement. Digging of hand-dug well is also easier than the technical knowledge, risks, and cost required by drilling borehole with drill rig. As the basement outcrop west of Negele town, where the rainfall patter is quite good compared to other places, the colluvium and the eluvium can be considered good for surface water development (ponds). Where the clay or silt deposits are consistent enough, and the characteristic of the hydrological basins are good, then good rain water harvesting systems can be drawn. South of Negele in the Precambrian province, where the rain patterns are very scattered and poor in precipitation quantities, rather than surface water harvesting system is better to develop the water resources through hand-dug wells; the main problem here is related to the water quality of the aquifers, which is slightly to highly salty.

Mesozoic formations: only A1 cycle and the top of the A2 cycle are good water bearing strata exploitable through boreholes. Due to the thickness of the relatively massive carbonatic layers with few and thin shale inter-layered, the entity of the fractures, the inter-layer spaces, and the karst structures, good aquifers can be found. The hydraulic characteristic of both the aquifers are good with transmissivity around 5.59x10^{-3} m^2/min and above. The aquifer of the A1 cycle, has better hydraulic and hydrochemistry characteristics. The top of the A2 cycle has thin evaporites beds, which make the water saltier. In the surrounding of Negele for example the water exploited from the Debeno borehole (within the A1 cycle but also very near to the recharging area) the water has conductivity of only about 800µS/cm, while the water exploited from the top of the A2 cycle for example in Kilta Godo (again near the recharging area) is above 2000 µS/cm. The two carbonatic cycles are quite uniform and continue. They can be found outcropping in Negele and overlaid by hundreds of metres of other Mesozoic rocks in Filtu area. Anyhow, everywhere they are the only good aquifers within the Mesozoic formations. Attention should be paid in identifying charging and discharging areas. Within the latter, is always problematic to identify whether the rocks are bearing water or the water is already percolated out and the rocks are dry. Thus, one should consider that the areas around the Dawa River are discharging ones and drilling around there could be risky. Loss of circulation during drilling has been reported especially at the top of the A2 carbonatic cycle. The losses of circulation are attributed to karst structures, which in some places have the characteristic of karstic caves. Within the carbonatic plateau east of Negele up to Ogoba escarpment, there is a great hydrological basin with internal drainage. Here, the morphology is characterized by many depressions do to collapsing of karst structures and represented by dolinas. Within this area, it is highly probable that the aquifer of the A2 cycle is recharged through karst conducts with rainwater. The whole area in fact has an internal drainage pattern without any way out to the hydrological basins of Dawa and Genale rivers. As the upper (A2) and the lower (A1) aquifers are separated by about 70 m of shale with thin beds of limestone, it is supposed that there is not communication between the two thus, the recharging area (within the area of the plateau) of the aquifer contained into the A1 cycle is considered to be the borders of the Genale river as well as the north-south escarpment at the contact between Mesozoic and Precambrian rocks where they are largely exposed. In the part of Ogoba escarpment toward east, the recharging area is supposed to be along the escarpment of the Genale River where these rocks (both A1 and A2) are largely exposed. Following the dipping of the layers the hypothesis is that also in this case the discharging area is toward the Dawa River. Thus, drilling site selection this is a factor to be taken into consideration. The dipping of the Mesozoic formations (120° - 1 to 2°) makes these deeper and deeper eastward accompanied by the morphology that is higher and higher up to the M. Filtu where the aquifers are hypnotised to be at many hundreds metres below the ground surface. North of Filtu town, along the Genale riverbanks, the A1 and A2 cycles still persist then immerging under the river getting recharge by the river itself. South of Filtu town the elevation decreases reaching about 800m asl at Ayinle and eastside about 600m asl in Qurale where the aquifers are nearer to the topographic levels (300-400m deep). The hydrochemistry characteristic of the water here does not satisfy the standards for potable water having conductivity within the range of 5,000 to 7500 µS/cm. Being the aquifer of regional extension, no problems are foreseen for their exploitation in the long run.

In the upper part of the Mesozoic carbonatic formations (i.e. north of Filtu), where the elevations are the highest of the district with better rainfall pattern than the surrounding areas, the rainwater collected through the drainage patterns (valleys, streams, etc.) allow the water to filter and percolate into thin carbonatic cycles (compared to A1 and to of A2 which are thicker) constituting perched and aerially limited aquifers. These aquifers have not good hydraulic characteristic but their exploitation is made possible through “cistern” had-dug wells, which accumulate water in the night to make it available in the daytime to the people. The water quality is not also very good with conductivity ranging between 1,000 to 5,500 µS/cm. The limited water accumulated into these “water-bearing” strata is highly dependent on the rainfall. The characteristic alternation between limestone and shale that constitutes the whole upper Mesozoic formations with their poor hydraulic features, makes it possible and advantageous the construction of surface water harvesting systems through artificial basins, which can hold water for long time due to the very low underground infiltration rate.

Quaternary alluvial deposits: these deposits generally constitute good aquifers being composed by gravel and sand, like in Udet. Anyhow, attention should be paid for the selection of the sites because the salts’ content of these waters is usually very high especially south of Negele (Bulbul, Boba, Udet, etc). In these areas, it usual to find underground whitish salts deposits mainly constituted by sulphates, which are very soluble in presence of water. Again, in Udet area, the water quality worsens with the depth in relation with the presence of salts deposits that increase with the depth. Due to fluctuation of the aquifers levels in these semi-arid areas, one cannot rely upon the exploitation of the most superficial waters. In fact, in case of prolonged droughts the static water level can drastically decrease (up to 2-3m) leaving the hand dug wells dry. On the other hand, deeper water exploitation gives water of worse quality. The far recharging areas are the ones of the Arero highlands easterly bordering the Udet-Wachile plains where the rainfall patterns are better distributed and the quantity is higher. Due to the distances between the recharging area and the Wachile-Udet plains, there is an out-of-phase recharging cycle, which makes the lowest static water level correspondent with the rain seasons, and the highest static water level with the dry seasons. From good to fairly good are instead the hydrochemistry and hydraulic characteristics of these kinds of aquifers west of Negele.

Water conductivity distribution and water resources distribution

During the geological surveys, more than two hundred water sample were collected and geographically elaborated (see *Figure 15*). The water points where the water was taken from included boreholes, opened and protected hand-dug wells, springs, and ponds. The assumptions for the interpretation of the map are the following:

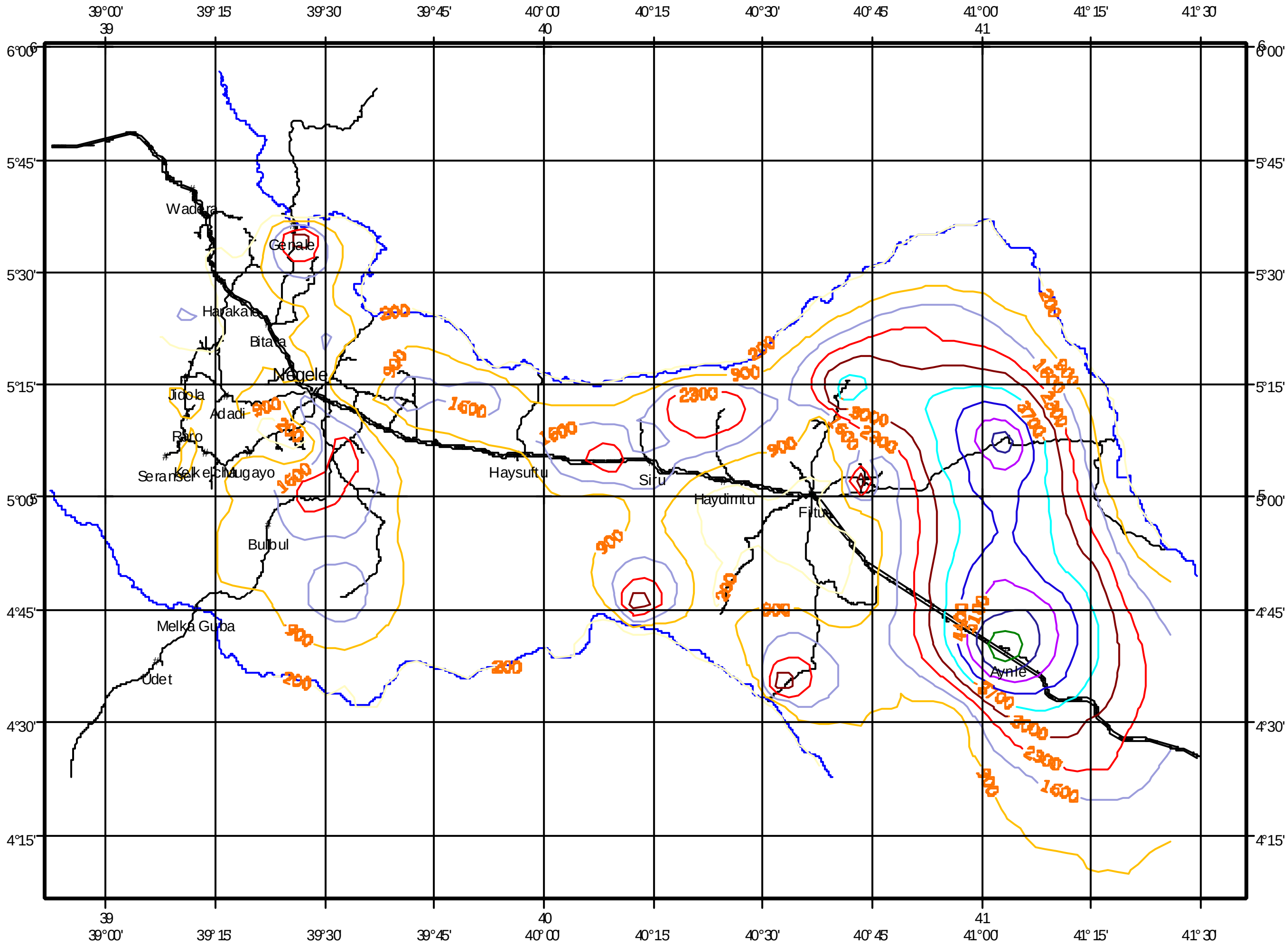


Figure 15: Water conductivity map

- The maps only represent the quality of the water from the conductivity point of view without any linkage with the aquifers
- The conductivity map refers to a period where all the water sources supply water (rain seasons or just few weeks after it)
- To complete the upper (N) and the lower part (S) of the map the rivers waters of Dawa and Genale were assumed to have a conductivity of 200 μS / cm
- It says if one live for example in Filtu town when the pond contains water then he would drink water with conductivity of less than 900 μS / cm, and when the pond dry up then he would get water let us say from Seru borehole with conductivity of

about 2,500 µS/cm.

In the below map, all the water resources mapped during the surveys are plotted according to their geographical coordinates and type of water source.

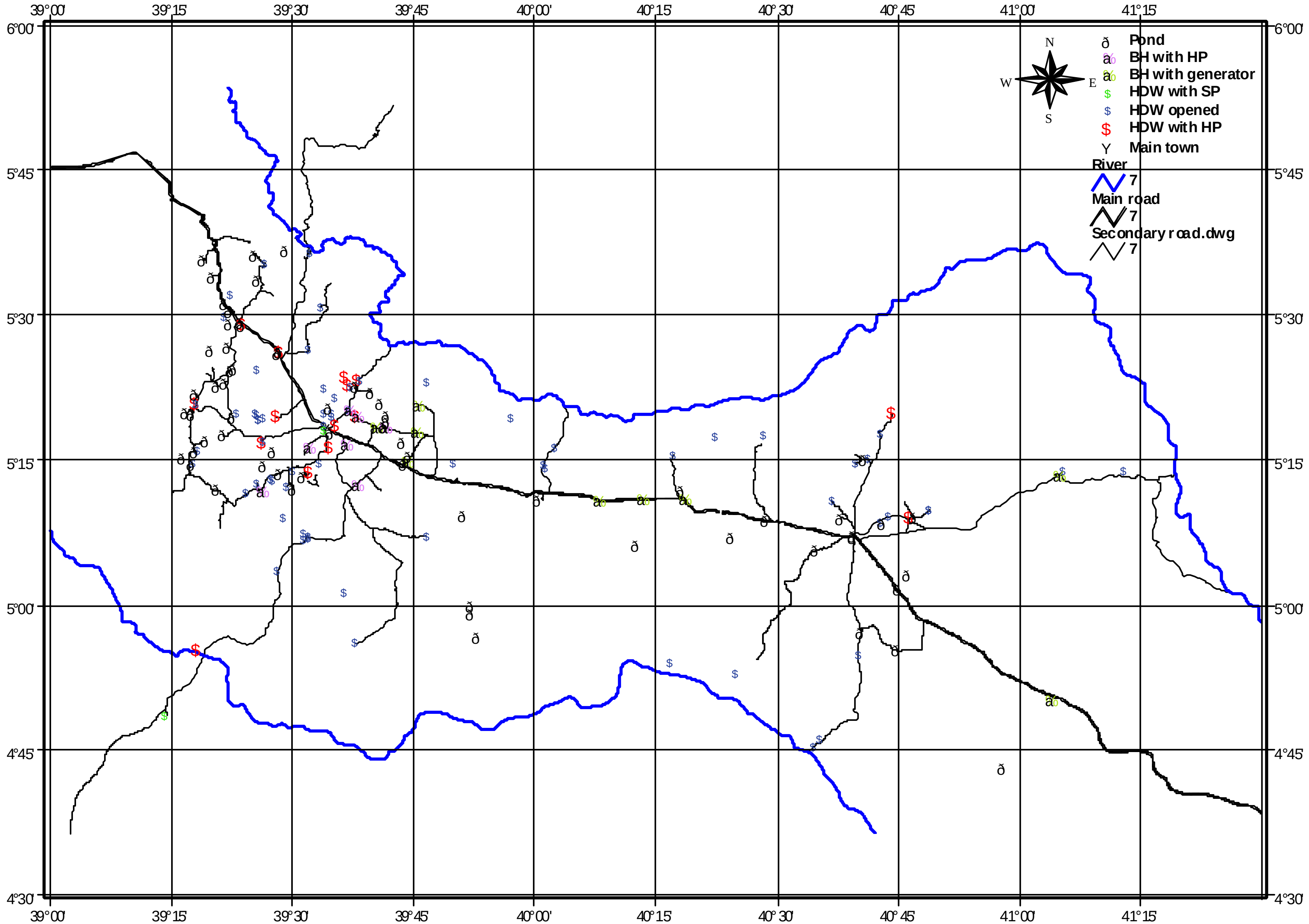
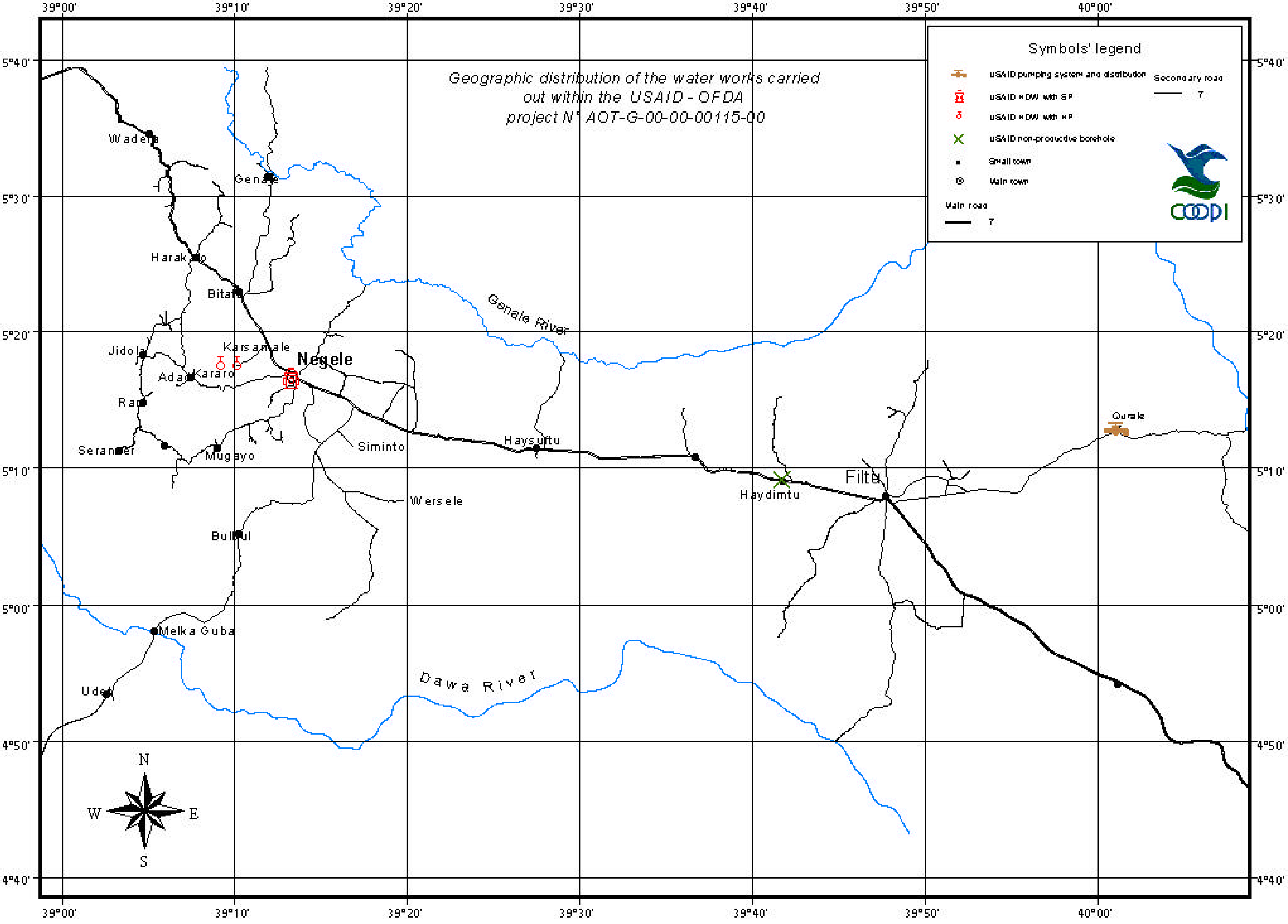


Figure 16: Water resources map

Annex 2: Water Points Map


Geographic distribution of the water works carried out within the USAID - OFDA project N° AOT-G-00-00-00115-00
Symbols' legend
USAID pumping system and distribution
USAID HDW with SP
USAID HDW with HP
USAID non-productive borehole
Small town
Main town
Main road
Secondary road
COOPI
Wadera
Genale
Bitata
Karsamale
Negele
Jidola
Kararo
Mugayo
Siminto
Wersele
Melka Guba
Genale River
Dawa River
Haydimtu
Filtu
Qurale
N
W
E
S
39°00'
39°10'
39°20'
39°30'
39°40'
39°50'
40°00'
5°40'
5°30'
5°20'
5°10'
5°00'
4°50'
4°40'