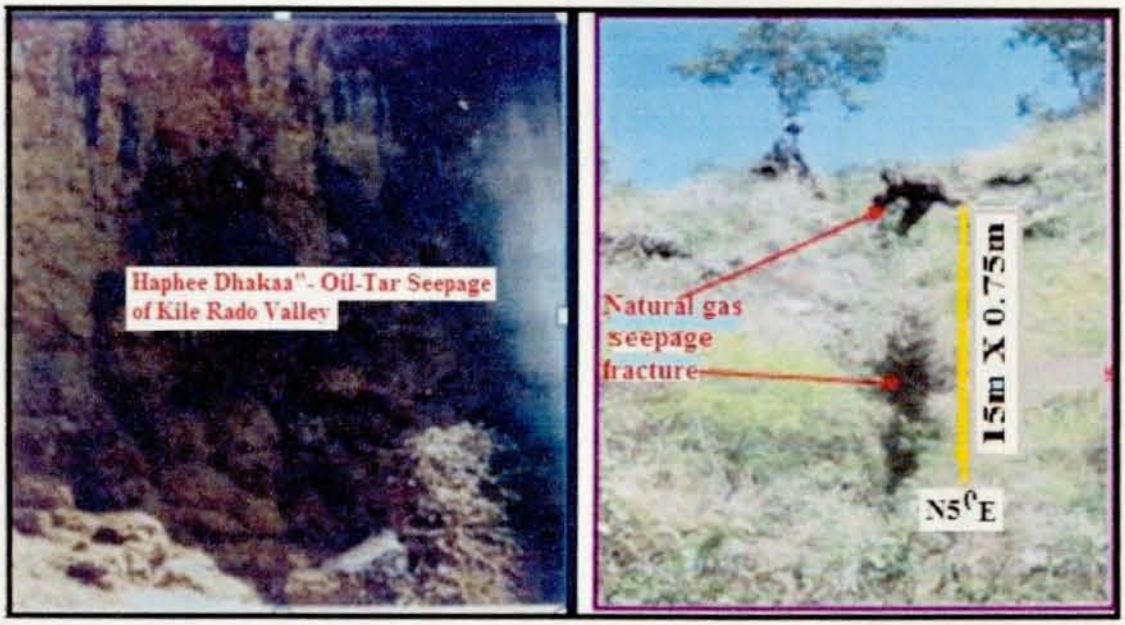
ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES DEPARTMENT OF EARTH SCIENCES

THE MIDDLE JURASSIC – EARLY CRETACEOUS SEDIMENTARY SUCCESSION OF "SAMMAR" (EAST ARSI, NORTH WESTERN OGADEN BASIN) WITH HYDROCARBON POTENTIALS (CENTRAL EAST ETHIOPIA)



By Mustafa Shayto

A Thesis submitted to School of Graduate Studies of Addis Ababa University for Partial Fulfillment of the Requirement for the Degree of Master of Science in Geology

June 2008
Addis Ababa, Ethiopia

Declaration

This thesis my original work and has not been presented for a degree in any other university and all sources of materials used for the thesis have been dully acknowledged.

Name Mustafa Shayto

Signature _____

Date of submission _____

This thesis has been submitted with my approvals as university advisor

Dr. Balemwal Atinafu _____

"Praise shall be to Allah (God) Lord of the Heavens, the Earth and Worlds" (Al Kor'an, 45:36); who gave me all the endurance to undertake this research.

In memory of the late Professor Getaneh Assefa, who passed away by a sudden uncompromising accident in early 2007. I was fortunately or unfortunately his last graduate student of this great man (Earth Scientist), that has taught hundreds of professionals all over the world.
MAY GOD BLESS HIM!

***nark:** Front cover page photo plate is : "Kile Rado" Oil tar Seepage (Left) vs Natural gas seeping facture on top of "Tulu Badhassoo" Ridge (Right), Iteyya Village, Sude Woreda, Arsi Zone of Oromia , Western Ogaden Basin .*

***:** Back cover page photo plate is: traditional transportation during the study due to accessibility problem (Today over 50% of the studied site can be accessed by vehicle).*

Declaration

This is to certify that this thesis entitled

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ubmitted in partial fulfillment of the requirements for the award of the Degree of M.Sc., **Geology** to the School of Graduate Studies, University of Addis Ababa University. The matter embodied in this oject work has not been submitted earlier for award of any Degree or Diploma to the best of my knowledge and lief.

ame of the student:

ustafa Shayto — Signature — 30 JUNE 200 Date

lemwal Atnafu (PhD) — Advisor — Signature — 30 June 2008 Date

ofessor Bekele Abebe(PhD) — Examiner — Signature — 30 June 2008 Date

olela Ahmed (PhD) — Examiner — Signature — 30 June 2008 Date



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The Ethiopian Geological Survey's (EGS) Chief Geologist Ato Amenti Abraha; the Geothermal Laboratory, Heads, Dr. Mesert has allowed me to borrowing scarce "Gas Sampling Equipments" and conducting free of charge Laboratory Analysis. The Central Geochemical Laboratory staffs are worth mentioned for their extraordinary effort and genuine compliance. Particularly, Ato Adise Mekonen (Mineralogical Department); and Ato Cheru Gelan's (Hydrocarbon Department) shall be thanked in their effort to separate the basalt smeared oil-tar samples in order to achieve the desired outcomes. The EGS Main Library head, Ato Girma, and his staffs are unforgettable in their usual cooperation to get necessary data. Solomon Geda, re- digitized the maps, sections and sketches to the presented standard, which otherwise was un-satisfying.

Ato Alemayehu Gudeya, the Oromiya Mineral and Energy Resource Development Agency Head, and Ato Adisu Geleta the Department Head, the Arsii Zone, Sudee, Robe, Aminya, Bele, and Seru District's administration general support during fieldworks are magnificent. The local community's cooperation in and around the study area is generally good enough and particularly: Sheik Abdurrahman (Sammariyee) and Ato Hailu Desta of Samar Kebele are too generous to be noted. Girma Negash cannot be ignored as he is the originator of the idea on oil-tar occurrences-seepages of Sammar Village.

Dr. Hassan Mama; Legesse Geda and Wolii Sheeka have to be mentioned and many unrecognized contributing individuals and friends to this work can be found ; as this acknowledgement is not inclusive, except being part of the greatest affections.

Finally, my wife, Fayka Sufiyan, my children: Nanathy; Abdurrahman (Obitti); Kenenni (Siham); and, Hammade (Aba kiya) shall receive my gratitude for their support, tolerance and sacrifices paid during my field works and study.

Thank You All !
May 2019

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Introduction

his part of the Ogaden Basin is not known to be regionally mapped by ground traverses; particularly, giving tention to the sedimentary basin and available hydrocarbon potentials (oil-tar or natural gas seepages). Regionally nducted mappings at the proximity of this site, like BECIP (1985) regionally (1:100,000 scale), mapped the stern flank of the Ogaden Basin without ground controls. V. Kazmin (1978) , also mapped at 1:250,000 scale rth of Manyna River as part of "Nazareth sheet" covering mostly the volcanic units.

any surface "oil-tar seepages", used as a traditional medicine by the name "Hamphee Dhaka" which means, ock's gum" in " Afaan Oromoo" were known in the northern Elelle River valleys' and around (" Sammar" bele (East Arsii)), since the last 40 years. Traversing across these valleys bearing Hamphee Dhaka, like "Kile do" were difficult due to sticky nature of the thick accumulation of Oil-tar ("Hamphee Dhaka"). Before about ty two years, a man from Gode Area (Somalia Region) came to "Sammar" and told the community, the use of mphee Dhaka as a traditional medicine for the cure of sever skin itching problems and stomach sicknesses. This ditional medicine was not only recommended for humans, but also for house hold animals. The wide use (humans d animals) of the Oil-tar (Hamphee Dhaka) as a traditional medicine, created wide market in all communities and gious gathering at: "Sekina"; "Abulkassim" ; "Dire Shek Hussen"; etc. Now " Hamphee Dhaka" - Oil-tar are available as thick accumulations, anywhere in the former the valleys; except thin black coatings smearing in essible localities only. So, nowadays to collect good sample of the oil-tar (Hamphee Dhaka) is difficult.

er long (over three cades) use of the Oil-tar as a traditional medicin by the community ; finally, around 2005, a red (Derge Regime) military man, sergeant Bekele, who was working in Asseb Petroleum refinery, came across traditional medicine "Hamphee Dhakaa" (Oil-tar) to remembered his experience in Asseb and suspected the ural tar to have some familiarity to products of the crude oil. Then, he send the oil-tar hand-specimen by a ditional medicine business woman named Turuyye to Girma Negash in Addis Ababa, who further took it to the istry of Mines , Petroleum Department.

sequently, after discussing with originator the Petroleum Department along with Girma send a group of logists to the locality, that visited one of Samar's oil-tar seepage valley called "Kile Abba Dhuferra". After the e day (too short) field work , the group field data was not available or known officially; but Girma , the inator , was told "the experts need to get to the site again and undertake the field observation, collecting data and e samplings to reach into definite conclusions"; which somehow unsatisfied the originator to pass over the rmation.

fter meeting Girma and communicating on the " Hamphee Dhakaa " case history , the author made proper ommunications and discussions to undertake the research on the locality (Sammar) in detail to establish thostratigraphic setting , facies analysis and mapping along with locating, associated community identified ydrocarbon potentials (oil-tar and natural gas seepages).

eologically "Sammar" Area is part of the north western flank of the Ogaden Mesozoic Sedimentary basin , partly in ontact with central Ethiopian Highland Plateau (Central Eastern Ethiopia). Moreover, the site covers: the Upper lanya flood plain (Lega Buna) to Upper Wabe Shebelle River gorge (road cut) in the north west to south east irection; and Sammar plateau to Lower Elelle River valley in the east west direction.

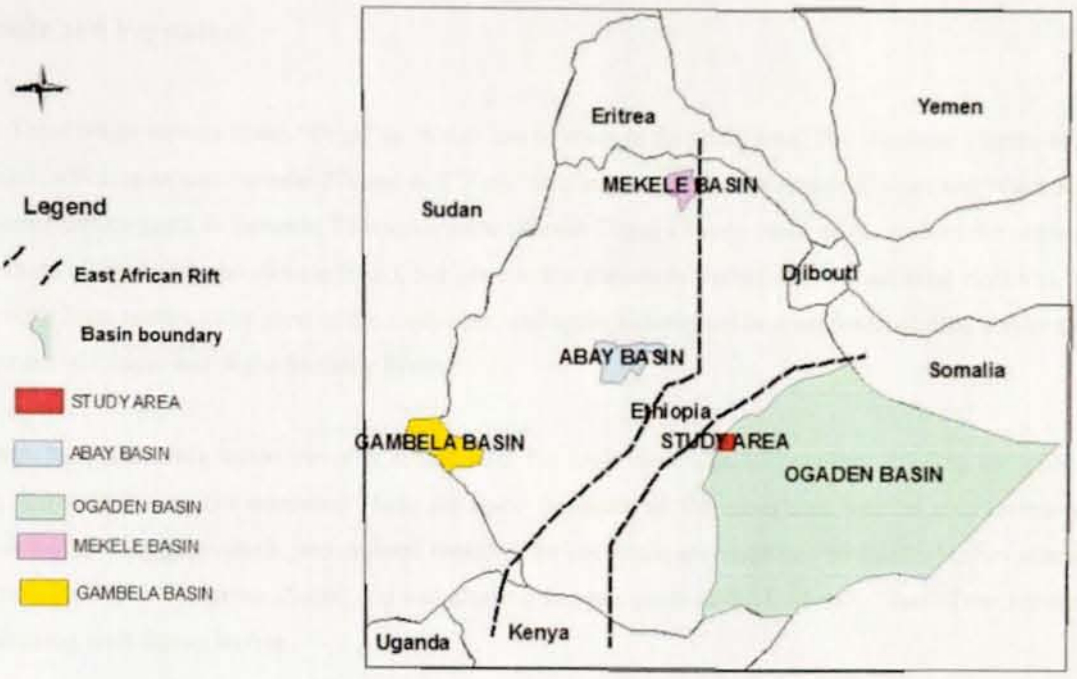
.1 Location and Accessibility

he mapped area is administratively located in different villages of Sude, Aminya, Bele, and Seru Districts, in Arsi one, Oromia National Regional State (Central eastern Ethiopia). One can roughly locate the area on the map by the llowing geographic coordinates:

7° 38' N - 8° 00' N ; and
39° 50' E - 40° 30' E.

Figure 1. Location Map of the Study Area

Figure 1. Location Map of the study area



ccessibility from Addis Ababa is by asphalt road of 145 km up to Iteya, via Adama Town; and around 110 km a eather road , branching north east at Hammida Diksiss town to Kula and finally through Qaree Haranfanmma o n reach Sammar Sammariyye village. Formerly, when this study was conducted after Kula Town all the 60 k ad to Sammar was a footpath and it was travelled by horse.

2 Objectives

ne general objective of this study is to map and describe the sedimentary successions, indicate and sample t rficial hydrocarbon and natural gas seepages. The main aims are:

- Prepare regional geological map of the area at 1:50,000 scale

- Re-construct the local litho-stratigraphic section, and make some facies analysis to somewhat determine the environment of deposition ;and
- Assess the surface hydrocarbon potentials(oil-tar and natural gas seepages).

.3. Climate and Vegetation

limate: Three major climate zones "Dega" to "Kola" can be meet in the study area. The Highland Plateau is a Cold one (Dega), which is around Sammar Plateau and "Kola" (the sub-tropical) is in Lower Shanan and Wabe Shaballe iver Basins (eastern part). In between Temperate zone (Woina Dega) climate exists at the foot of the plateau. The ommon sharp cliffs change the climate from Cold Zone in the plateau to Temperate in short areal distances. Rather e Temperate Zone covers many parts of the study area, and again Subtropical or semi desert climate can be meeting deep gorges of Dharro and Wabe Shebelle Rivers.

egetation: Indigenous vegetation cover is scarce over the high lands due to intensive clearing for agriculture. owever, Eucalyptus trees are common. There are some remnants of the devastated tropical rain forests around losques and Churches, graveyards, and cultural centers. The low lands are vegetated by thorny bushes acacia trees ith intense clearing in Temperate Zones, and less clearing in many parts of the lowlands. "Itan" Tree, are common lowland along with thorny bushes.

ainfall: this area has similar rainy season to central and north Ethiopian plateau; i.e. heavy rainfall called " Gana" "Kiremit" from June to August or early September and slight and occasional rainfall known as " Belgii" between ebruary and April. None occasional short rainfall can also occur in any part of the year.

4 People and Physiography

he indigenous people living in the area are Oromos, speaking Afan Oromo. Other minority groups from different bes of the country inhabit this locality. Among, the Amharas in the highland plateaus and Wora Dubee in the low nds dominate. Wora Dube Tribes have their native language and mainly live restricted to flood plains of Manya, elle, and Wabe Shaballe Rivers.

n the highlands people dominantly live on farming and cattle breeding but around "Woina Dega" (Temperate one), people, cultivate vegetation, cereals, and cash crops; with scarce land for cattle breeding. The flood plains, of e perennial rivers, are cultivated for cash crops like sugarcane, banana, etc. On the other cases, "Kola" (the sub-opical) are semi-nomads, living on cattle breeding, small farming.

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Previous work

nford (1879) member of the British Army, named the Lower Sandstone, as Adigrat Sandstone after a village ne in Tigray (North Ethiopia) Blanford , was probably the first person to observe the area (as a geologist) and he named the Upper Sandstone "Ambaradom" Formation after a locality name in Tigray; where he first noted the ; while **Capararu (1967)** has showed the occurrences of surficial oil seeps and a gas show in one deep well ladi Well) of eastern Ogaden Basin. He also noted and reported the presence of significant oil-tar seepages in ny parts of the Mesozoic Sedimentary basins of the country. **Dainelli G. (1943)** concluded that, the Upper dstone in Hararge (North Ogaden Basin) was deposited by rivers following the regression of the sea. He and his orkers also dated the pre-rift volcanism following marine transgression between 20-27ma.

itzer (1970) using fossils (ammonites) accomplished the regional co-correlation stratigraphy of the Ogaden in and the immediate northern and the southeastern part of the present area was mapped by Kazmin, et.al (1978), BEICIP (1985), at 1: 1,000,000 scale respectively. The northern part, mapped by (Kazmin, et.al., 1978) was ducted with the greatest emphasis to the petrography and structure of volcanic rocks only, rather than the mentary successions. The post rift volcanism is of Pliocene to Quaternary. Pre-rift volcanism is composed of ine-plagioclase basalt and concordant with sediments below and columnar type (Mt. Kundudo – northern part of mapped area) (Kazmin, et.al., 1978).The Land sat interpreted mapping of the Ogaden Basin was conducted by CIP (1985). However, these mappings had their own limitations; i.e., the recent field observations and mapping showed Urandab Shale is not out-cropping around Mt. Abul Kassim. It is rather the transitional unit (black stone) between Upper Gabradare and Lower Gabradare Limestone Formations . But Urandab shale outcrop in e Shabelle River Gorge, over laying Upper Hamanlei Limestone Formations .

CIP (1985) has mapped at 1: 100,000 scale the western part of the Ogaden Basin that include some part of the y area towards the southern part around Dharro and Upper Wabe Shebelle River basin. This mapping was, ever, based on the interpretations from Land sat satellite imagery and was not supported by ground traverse or kups. As a result, the Urandab Shale mapped by BEICIP (1985) around Mt. Abulkassim, made to be ropping-out ne plane surface is not actually Urandab Shale , but a transitional black limestone unit between Lower and Upper radare Limestone Formations. The actual Urandab Shale was observed to out-crop in the middle of Wabe balle River gorge overlaid by marly shale on top and under laid by compacted Upper Hamanilei Limestone. The ping of Urandab Shale by BECIP, 1985, as an exposed unit in western Ogaden Basin like in the currently ped area has actually discouraged many petroleum explorers, as Urandab Shale is the main source in the basin.

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, the author expect the reverting of this idea as Urandab Shale indicated in Wabe River Gorge rather tha
ching out.

vever, it's noted by (BEICIP, 1998) that, "Galemso oil-tar seeps" (few tens of kms north east of the mappe
) in NW Ogaden Basin are generated from Gabradare Limestone Formation assuming pinching of Urandal
le's in the western part of the Ogaden Basin , but actually the Gelemsso surfacial oil seep can be from Urandal
le or organic rich Lower Gabradare Limestone Formation (with black color).

reyohanis (1990) mapped the Mesozoic Sediments and overlaying Trappean Basaltic sequences in parts o
erge and Dire Dawa, i.e., the northern part of the Ogaden Basin. Gebreyohanis, then concluded that the source o
Upper Sandstone in the Ogaden basin is from the NE part the basin; **Russo, A. Getaneh Assefa, and Balemwa
afu (1994)** mapped and worked on detail Mesozoic Sedimentary succession of the Blue Nile (Abbay) Basin
many significant outcome and **Wolela (1997)** have worked on Stratigraphy and detailed and conclusive
ysis on hydrocarbon potentials of Abbay (Blue Nile).

aneh (1988) has made a Lopatin assessment of the source rocks of the Ogaden Basin. According to this Lopatin
ssment, the Bokh Shale and Hamanlei Formations are estimated to lie in oil-window (Getaneh,1988). The
ocarbon potentials of the Ogaden Basin is under extensive study since early 1940's (Fig. 2,3a & 3b). The
den Basin is the largest in East Africa and most of its part, which is about 350,000km^2 occurs in Ethiopia. Some
e past works in this basin are shown in Fig 2 down. The East-West section (Fig. 3a) of the Ogaden Basin shows
resence of over mature hydrocarbon (Natural gas) generation to mature (oil) bearing zones. The Western flank
s rather promising (West of Kelafo Hole) (?) than from the section in east Ogaden (from section analysis of the
s) (?).The NW-SE section (Fig. 3b) from Magan 2 to Garbi Hole shows the North West extension of the litho-
graphic units of the basin opposed to E-W section showing pinching towards the western margin.

gut (1998) have worked on sedimentology, basin evolution Stratigraphy and detailed and conclusive analysis on
ocarbon potentials of the Ogaden Basins. His Rock-Eval analysis has proved and he confirmed, "the Urandab
e is one of the best source rocks in the Ogaden Basin"; in support of Shegut (1998); and **Abiy Hunenyaw (1998)**
s literature review has also recommended that the Urandab Shale is the best source rock for oil and gas generated
e Upper Hamanlei or Lower Gabradare Formations.

, et. al, 2007, explained that, so far (up to 2008), about 48 deep wells were drilled in Ogaden Basin and the ificant results are the discovery of gas in Calub-1 and Hillala-1&-2 by Tenneco (1974), and afterwards by a ian Company named SEEP, respectively.

nearest deep well to Sammar Surfacial Hydrocarbon Seepage localities or the mapped area is Gerbi -1 well, ed for about 1974 meters by Tenneco, an American Oil Company. This well showed S_2 (Initial Petroleum ntial) of 20 Kg HC/ Tone of rock (may be the maximum result in the Ogaden Basin petroleum wells) from type erogen **(Abiy, 2007).** Nevertheless, the Gerbi Well petroleum exploration was not continued due to the early untering of the Basement Complex Rock in the hole (around 1974m depth).

Methods

specific methods mainly used during this study are:

- Literature review (secondary data analysis) ,Satellite Imagery, and aerial photo Interpretations
- Field primary data collection (field observations, litho-logic description, mapping and sampling) ; and
- Sample analysis and synthesis; data compilations and report writing.

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ectonic Setting

Regional Tectonic Settings

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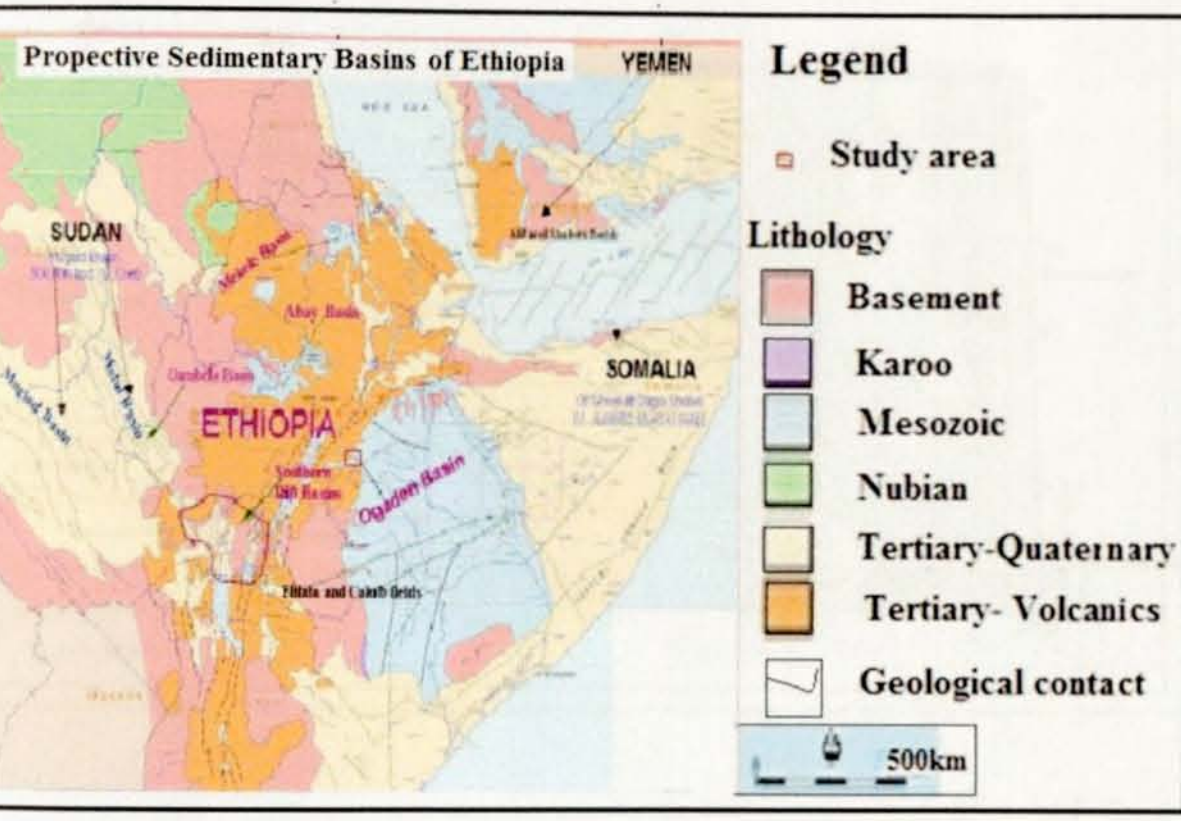
Basin, probably via Upper Wabe Shebelle, Mechara , and Galemso (with surface oil seep) localities. The thir
o Graben arm extends SW - towards the Mandhera Trough of North Kenya.

rding to Shigut, 1998 , the inter-cratonic Ogaden Basin has developed in response to pre-rift phase (Calu
ation), extensional phase (the Karoo sequence in inter-cratonic rift basin), and progressive subsidence (Adigra
ation), and the carbonate plat-form initiation (Hamanlei to Gabradare Limestone). The retrogressive uplift (sa
s) (Abiy, 1998) deposited Gorrahi to Kakar Formations. The highest rate of subsidence in the Ogaden Basi
g early Cretaceous (Van Hint et.al., 1978). (BEICIP 1985), suggests that the Ogaden Basin was an epi
nental basin, which developed and evolved on a relatively stable carton, controlled by separation of Madagasca
Africa.

hort, the oldest tectonic effect (Karoo triple graben) has favored the thickest deposit in the south central part o
asin (e.g. Bodele I deep well), with sequences from Calub to Gorrahi Formation (Shigut, 1998). Most sediment
e basin generally have maximum thickness over this south central part and the overall sedimentary section of th
len Basin is generally believed to be pinching E-W (Fig 3).

arm of the Karoo graben branching to NW connect to Abbay (Blue Nile) Basin ; somehow passing over Upper
e Shebelle River basin , Mechara and Gelemso that would create another thick Phanerozoic sediments like th
al Ogaden (around Calub) to be verified later. Moreover, these zone as its close to the Main Ethiopian Rift, th
t tectonic set up related to the rift must have affected it broadly. Normal Step faults along the western margin o
asin sediment's is common.

gure 2. Sedimentary Basins of Ethiopia, with respect to Study Site (Modified after Petroleum Licensing and dministration (2011))

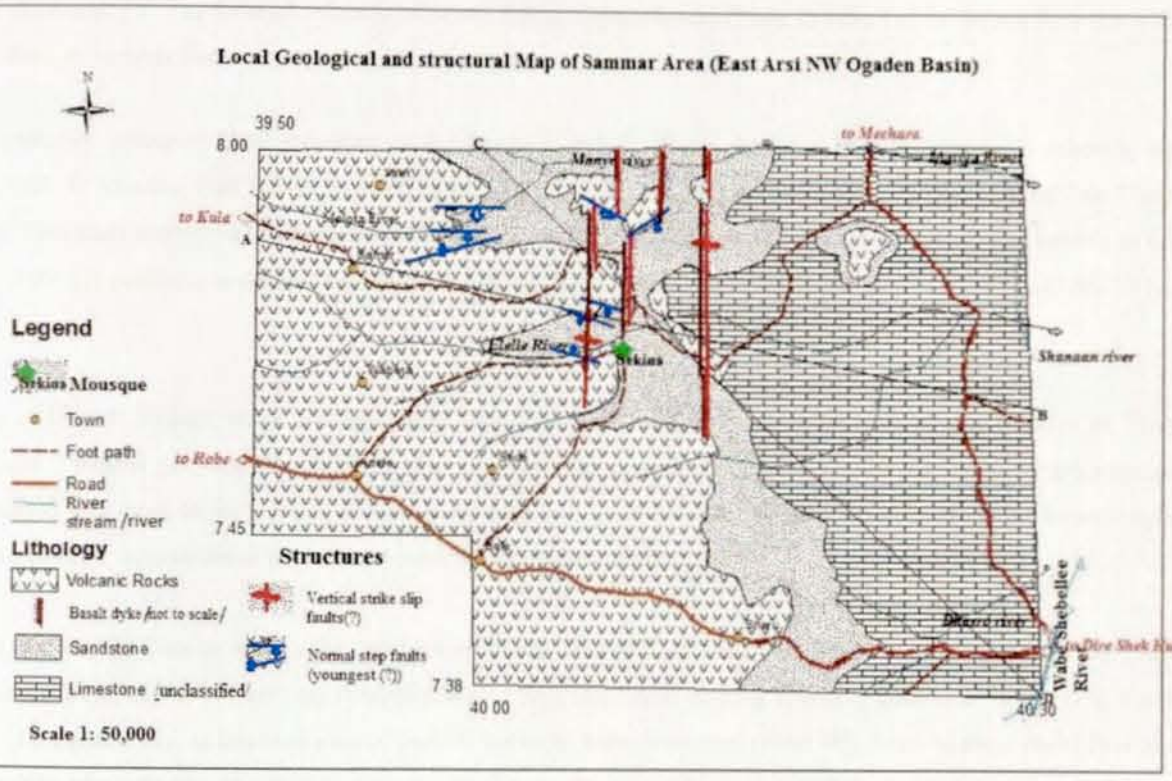


Local Tectonic Settings

napped 'Sammar Area" is part of the NW Ogaden Basin flank, which is affected by Trap Series basalt intru re 3.) below. Moreover, Sammar locality is at close proximity, to the Central Main Ethiopian Rift Valley ea , and it's inevitable to be affected by the rift tectonics, which is younger in age than the basin. Hence, many ures in the mapped area, directly or indirectly are associated to the main rift formations and assoc nisms.

equently, the prominent local structures observed and noted are joint sets, mega fractures, normal faults, n faults, etc. These structures have N-S, NNE-SSW, and NE-SW trends with similar to regional mega deform the Main Ethiopian Rift Valley. The size of the local structures observed rang in size from micro to meg d along the strike for kilometers, beyond the extent of the area mapped.

re 3. Local Geological and structural map of the study area.



bbe Stream (South Sammar), two types of fracture sets were mapped within the top part of the Upper Gabr stone Formation (Transitional zone). The first set is N-S, while the other is NW-SE without clear age differ flanks of Dharro River valley, Gabradare Limestone is observed to strike northeast and dipping south w ngle. The regional stream flows in this part of the mapped area reveal a dominant N-S structure.

nal step faults within the flood basalt occurring in river valleys of Elelle, Manya, Wabera, etc seems to b
ciated to the main rift generation structures. These faults have a general north-south trend and dip sub vertically
rds the east. Rarely, sub-vertically west dipping normal step faults are observed in northern Sammar around o
natural gas seeping "Tulu Badhassoo" Ridge. These vertical-normal faults are formed due to extensiona
rmation associated to the doming and rifting of East Africa in Miocene (Abiy, et.al.1998). The flood basalt
ring the western part of the mapped area bears numerous plaeosols and scoriacious mudflows that may indicat
structures (?). The forceful volcanic intrusion cutting the sandstone (Plate 2) observed in eastern Seru show th
ration of various fractures, minor faults and joints.

probably youngest local structure in the mapped area is shown by both dextral (Figure 3. Above), an
eralE-W trending fault (un-mappable); observed on a basaltic dyke trending NNW – SSE , west of Tulu Dimtu
e. This fault is observed to displacing a basaltic dyke, which trending N-S, and deep vertical. The extents of thi
dyke (?) continue north beyond Manya River and south up to Guratti Village (Lower Elele River Valley) o

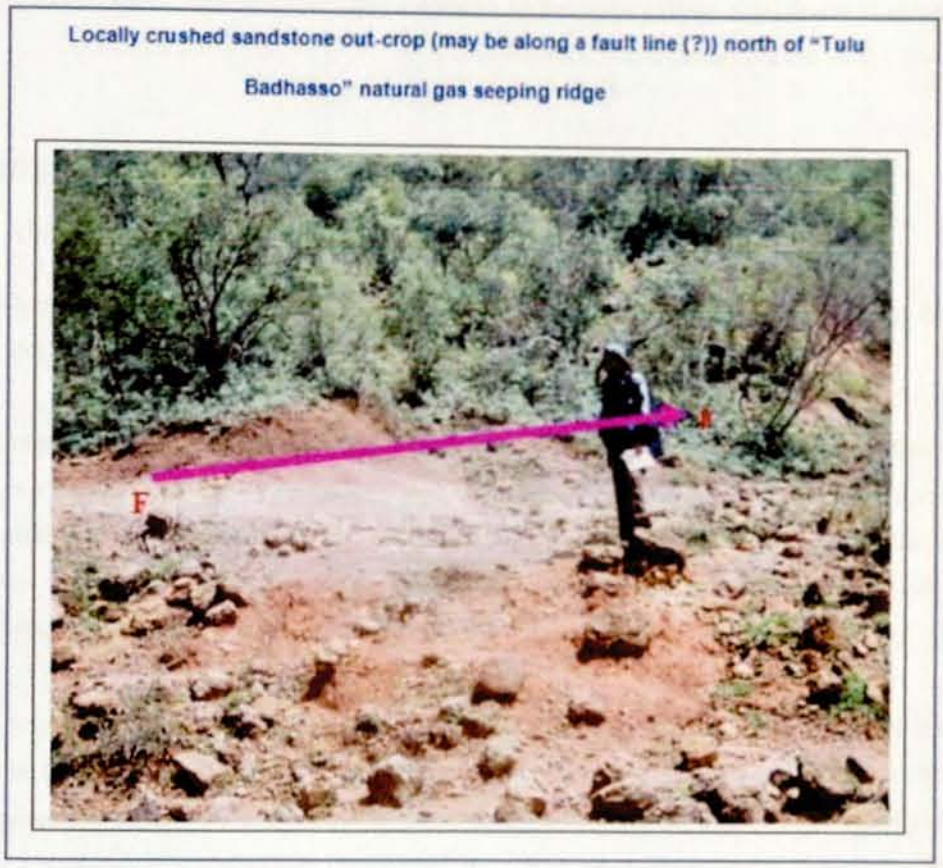
of Guratti Village, there is a open fault trending N-S and vertical, which parallel the fracture of "Tul
asso"/ natural gas seep bearing ridge/. Nevertheless, this open fracture is not showing any natural gas seepage
apped area close to flood basalt and the sedimentary succession contacts, the relation between the basaltic dyke
he fracture emplacement is not so far clear, except having similar trend.

of Sammar Plateau, within the sedimentary basins 1km NW of Iteya Village, there exists different fault sets
ing (north, and E-W) and sub vertically West , East and North dipping affecting Badhasso Ridge (Fig 6 and
10). Particularly, in this area a set of parallel fractures were developed (plate 10). Some of these faults bear gas
while others do not. In addition, a pre to syn-tectonic basaltic dyke is observed to out-crop, trending N-S in an
lating fashion crossing "Tulu Badhassoo Ridge" and continuing to north, may be beyond the study area.

bserved faults are of two major catagories; the oldest (?) are the NNW – SSE or the NNE-SSW faults vertical
elated to open faults , some with naural gas seepages and others free (typical examples of these observations is
lu Badhasso Ridge (with open fractures – gas seepping) and around Guratti village South of Tullu Dimtu Ridge
ut any gas seepage. The Guratti open fault (fracture) was currently closed by the community for safty poupoise.
ther common faults are Trap Series Volcanics related and its commonly a normal step faults (Elelle River

ey) cut by NNW – SSE vertical faults (figure 3.,above) with almost E-W strike but dip north and itionally. These normal step faults are younger than the first generally N-S vertical faults.

ate 1. Locally crushed Upper Sandstone outcrop / near Manya River flood plain (Sammar –Eastern Arsi ; NW gaden Basin)



te: This almost N-S striking crushed sandstone zone of 5-10m wide and undetermined length seems a fault trace ilar to other N-S striking mega – microstructures in the locality. This is an example of N-S faults which are olde , than the normal step faults associated to Trap Series volacnics only.

nically, Sammar (the mapped area) is associated to the Oligocene- Miocene volcanism and rifting zone. f lineaments (Plate 2), i.e. NW to SE and NE to SW occur dominantly, with deep-seated normal faults ca tensional deformation during the generation of the Main Ethiopia Rift. The NW arm of the bifurcated tria-r -graben extending to the Abbay (Blue Nile) Basin seems to partially accommodate, the eastern part o

ped area "Sammar" bearing thick central Ogden's sedimentary successions like Upper Hamanlei, Urandab Shale adare limestone Formations. Some deep sited mega structures , with strike length of many kilometers fested by mega dykes and fractures (Tulu Badhasso natural gas seeping ridge fracture) etc., striking NNW - SSE iscordant to the main Ethiopian Rift regional trend, which is almost NE – SW in this particular locality. These structures, which are numerous, parallel in the mapped area, and extend beyond are probably the manifestation e deep sited Paleo - Karoo Graben's NW arm, connected to the Abbay (Blue Nile) Basin as can be shown in 2 above).

itho-stratigraphy

Regional Litho-Stratigraphy

regional geology of the Ogaden Sedimentary Basin comprises Precambrian Basement Complex Rocks; Karoo Sediments; Mesozoic to Cenozoic Sediments and Tertiary volcanic rocks.

Basement Complex is divided formally in many parts of Ethiopia into Lower, Middle and Upper Complexes. The er Complex is a high-grade metamorphic rock of gneiss, amphibolites, quatzo-feldespatic gnesses and quartzites Middle Complex rocks are high to low grade metamorphic rocks constituting amphibolites, schists and iated granites and quartz veins. The Upper Complexes are low-grade metamorphic rocks of Chlorite – hibolite Schists, phyllites and associated grano-diorite to granite and pegmatite veins and veinlets.

Ogaden Basin, with total area coverage of about 400,000 km^2 , out of which 87.50% (350,000 km^2) is found hiopia and the remaining 12.5% (50,000 km^2) in Somalia and Kenya This basin in Ethiopia reveal, complete s of depositions from transgression to regression in different parts (central north, eastern and central south) axial f the basin.

o Sediments are mostly continental clastic sediments ranging in age from Carboniferous to Liassic (Shugut). In Ogaden Basin, Karoo sedimentary sequences are : Calub Sandstone; Bokha Shale and Gumburro Sandstone Mesozoic Sedimentary sequences of the Ogaden Basin starts with clastic sediments named lower sandstone or rat Sandstone (Blanford, 1879). The marine transgression begins by deposition of top part of Adigrat Sandstone ower Hamanlei Limestone Formations, followed by Middle to Upper Hamanlei Limestone. Urandab Shale, over g the Upper Hamanlei is deposited in Open Ocean at the maximum stage of the transgression. Gabradare stone is deposited over the Urandab Shale at the eve of regression during Upper Jurassic ((Shugut, 1995)). As egression of the sea continue the Late Cretaceous sediments over laying Gabradare limestone like Gorrahe ,

ahuil , Ferfer , Belt Un, Jessoma , Auradu, Taleh and Karkar are deposited (Ambaradm Formations (Blanford
).

NW arm of the Ogaden Basin is part of the Blue Nile (Abbay) Basin connecting zone depositing thick Upper
stone (Ambaaradom Formations), Gabradre Limestone, Urandab Shale and Upper Hamanlei Limestone
ations.

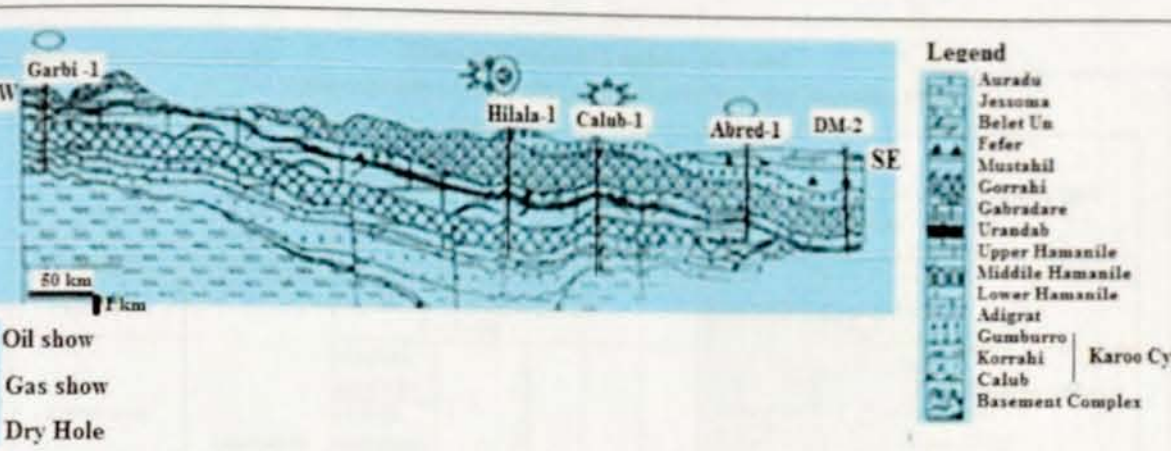
laying the Basement Complex, the pre-transgressional deposits are represented by Karoo Depositional cycles
classified as Calub, Bokah, and Gumburo Formations) localized to Karoo Graben (Fig 2), and over laid by
er/ Adigrat Sandstone Formations. Typical transgressional deposits begin by the deposition of Lower / Adigrat
stone, Formations that show Fluvial to shallow marine depositions from bottom to top. The formations showing
transgessional deposition in Ogaden Basin are upper part of the Adigrat Sandstone and the lower part of
anlei Carbonates.

ow marine to deep sea depositions generally comprise: Hamanlei Carbonates (sub-classified as Lower, Middle
Upper); Urandab Shale; Gabradare Carbonates (Sub classified as Lower and Upper). Common regressional
sitions are collectively named as Ambaaradom (Upper Sandstone Formation (Gorahhi, Muastahil, Ferfer, Belet
essoma,Tuleh, Auradu)); completing the cycle.

over the locally (northern Ogaden in West Harage like around Hirna Locality limestone successions may be
red to Tale & Karkar Formations out-crop. These formations may be local regression depositions, after the
r transgressional deposition explained above.

made the Phanerozoic Sediments of the Ogaden Basin to be as thick as 5000 m (Getaneh, 1988), while others
ate it to be around 3000m (Shigut,1998). But the current maximum sediments thickness is known to be as thick
000m or above in central Ogaden Basin. The major litho-stratigraphic successions of the Ogaden Basin are
what correlable to the major Mesozoic Sedimentary successions of the country (Getaneh, 1988).

igure 3 . SE - NW Geological Cross-section of the Ogaden Basin; modified after Shigut, 1998.



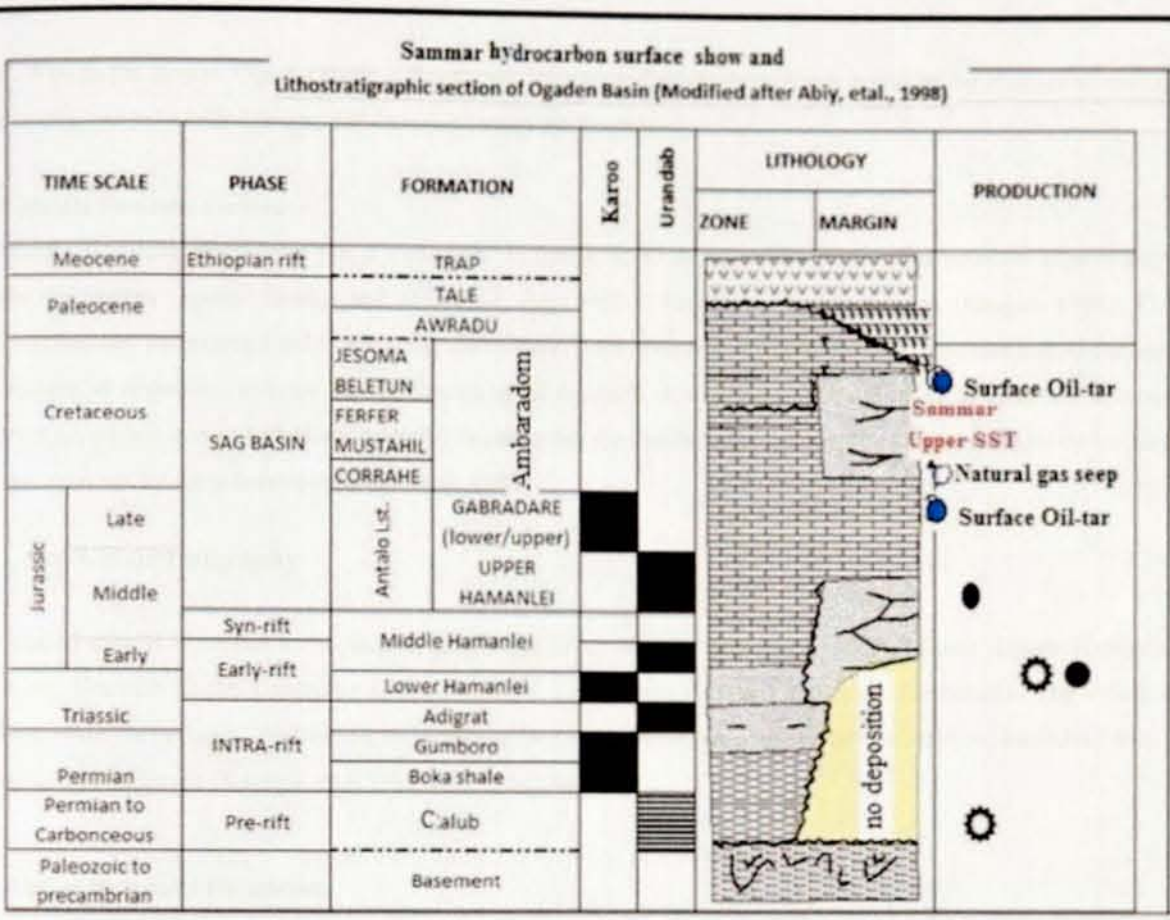
Karoo depositional cycles

o Cycles are the oldest sediments in the Ogaden Basin, sub-divided into Calub Sandstone(85m), Bokah
n) and Gumburo Sandstone (800m) **(Shugut, 1998)**.In the Ogaden Basin, Karoo depositional cycle
cted to graben , which shows a tria-radial shape (Fig 4). The name "Karoo" in East Africa means 'contin
cs' ranging in age from Carboniferous to Liassic **(Getaneh, 1988)**. Karoo Sediments are comparable t
ients of the Saudi Arabia, Yemen, and Kenya **(Shigut, 1998)**. A sedimentary deposit correlated to Gum
ation is observed in Abbay Basin.

Lower /Adigrat / Sandstone Formation

Adigrat Sandstone, named by Blanford (1970) in its typical locality observed " Adigrat" northern Tigray,
etamorphic Basement Complex rocks and is about 300-500m thick. In the Ogaden Basin, the Lower Sands
maximum thickness of about 480m, being conglomeratic at the base, clay, and shale at the top (transit
. The transgressional deposition in Ogaden Basin is believed to begin during the deposition of the upper pa
digrat Shale **(Shugut, 1998)**. The depositional environment of the Adigrat Sandstone in the Ogaden Bas
fluvial lower part to shallow marine top part .The contact between the Adigrat Sandstone and Lower Ham
ation is gradational **(Shugut, 1998)**, constituted by a transitional facies zone from fluvial to shallow marine

gure 4. General Litho-stratigraphic section of Ogaden Basin (Modified after modified after Abiy, et. al., 1998)



"Sammar Area " Upper SST over laid in the western flank by Trap Series basalt , bear Surface hydrocarbon (Oil-tar al gas) indications along structural weakness (fault zone) of the volcanic sequence from probably Gabradare Limes d /or Urandab Shale (?).

Hamanlei Formation

Hamanlei Limestone sub-divided in to three (Lower, Middle, and Upper) Formations is the thickest lime ssion measuring to about 1850 m in the Ogaden Basin. After transgression, the Hamanlei Formation impl stable time of deposition in the basin (Shugut, 1998). The middle Formation is the thickest (about 832m) wer formation is the thinnest (210m).

1 Lower Hamanlei Formation

Lower Hamanlei shows an upward coarsening shelly, bio-turbaned fine-grained limestone. The contact, wit ying carbonates and under laying Adigrat Sandstone is conformable. The thickness of Lower Ham ation decreases northeastwards (e.g., in Elkoran deep well it is 330m thick, while it is only 160m thi

li Well in the eastern Ogaden Basin.). Restricted circulation (lagoon facies) was indicated by absence of corals, iopods, and echinoids (Shigut, 1998) in this limestone formation.

2 Middle Hamanlei Formation

Middle Hamanlei Formation has a maximum thickness of 832m is in Bodle area and decrease significantly rds the eastern Ogaden Basin ; and at Bokh-1 deep well, it becomes only 375m thick (Shugut, 1998). The le Hamanlei comprises finely crystalline dolosltone, thick evaporates, intercalated with dolomitic limestone. onment of deposition indicate the shallowing up of the shelf. A widespread deposition of bedded sub aqueous orate deposition across a platform probably requires that the depositional site may be almost completely isolated the open sea by some barrier (Warrent et.al. 1989).

Local Lithostratigraphy

napped area is observed to be mainly constituted from the oldest to youngest as follows: Upper Hamanlei stone; Urandab Shale; Gabradare Limestone; and Ambaradom (Upper Sandstone) Formations. The volcanic nce, which is normally over laying or intruding the above-mentioned sedimentary succession, includes "Alaji" Aiba" Flood Basalt (Kazmin, et.al.1978) (Fig. : below).

Upper Hamanlei Formation

abe Shaballe Gorge, in the souther flank of mapped area, under laying the Urandab Shale , bout 200m thick r Hamanlei Limestone is observed to outcrop along new built all-weather road cut connecting Mechara tern Haragee) – Dire Shek Hussen (Bale).

Upper Hamanlei Limestone exposed is micritic to fine grain size, massive, greyish brown colored, highly acted and showing uniform texture to the river floor.

xposed thickness of the unit in Wabe gorge is about 200 m in the mapped area. Since, the Wabe Shebelle River does not cut down to the extent of exposing the whole section of the Upper Hamanlei formation, the thickness oned cannot be said it represent the succession in the study area.

generally representative samples (Wab.-01,-02, -03, and -04) were collected from top to bottom left side the Shaballe River valley along the newly constructed all weathered road / Mechara Town - Dire Shek Hussen ge to Robe (Bale Zone) of Oromia Region ,via Jaara Village . The samples from Lower Gabradare Limestone, dab Shale and Upper Hamanlei Limestone were collected to be submitted for thin-section preparations and

iptions to the Earth Science Department of Science Faculty, AAU . Due to completing of the academic year
8), before the Laboratory Analysis results were completed, to show here.

rtheless, from previous work the Upper Hamanlei Formation is a bioclastic limestone of Bathonian (?) to Lower
rdian age (**BEICIP, 1985**), gradationally changing upward to Urandab black shale and marl.

Urandab Shale Formation

laying the Upper Hamanlei , Urandab Shale, is observed to outcrop in the left flank of the Middle Wabe
elle River gorge section cut by all-weather newly constructed gravel road from Mechara (western Harage) to
Hussen Village (Bale). Urandab Shale is deeply black, fine and highly fissile. It's marly on the top (lower part
e Lower Gabradare) and sharply changing to light grey limestone (Upper Hamanlei. The contact nature of
dab Shale with overlying Lower Gabradare and underlying Upper Hamanlei is gradational and sharp,
ctively. Two samples (Wab.-1 & -2) were collected and submitted to Earth Science Department , Science
lty, AAU for analysis; not completed during the academic year.

IP (1985) map regionally (at 1: 100,000 scale) the southern part of currently mapped area around Mt.
lkassim" – Dharro river valley to Wabe Shebelle River gorge. The current mapping somehow confirmed the
BEICIP, 1985, had mapped as Urandab Shale pinching to the Dharro River valley flank surface was a black
acted limestone (transitional Unit) between Upper and Lower Gabradare formations.

ut (1998), explained that the Urandab Shale to be from a relatively uniform depositional environment, and is
icritic throughout, consisting of thin shell pelecypods, plank tonic foraminifer, crinoids-fragments and sparsely
rebutted pyrite. Urandab Shale of the Ogaden Basin was proved as the best source rocks to generate petroleum,
gut 1998) in Gabradare Limestone.

Gabradare Limestone Formation

adare Limestone Formation has received its name from a small village called Gabre Dahar (where it was
bly noted for the first time) in north central Somali Regional State. This limestone formation is sub classified
wo as : Lower and Upper Gabradare Formations. In general, Gabragare Limestone is outcropping from west of
u River to upper part of Wabe Shebelle River Gorges.

op most part of Gabradare Formation (transitional zone to Lower part of Upper Sandstone), which is about 60 m is observed not to be well bedded, arenaceous and macro- micro, unsorted fossils ((intertidal) (sea shore- ed by high tide and not by low tide)) . Under that a well bedded micritic limestone with large exposed cavity or y (Plate 4) , cherty nodules (following certain bedding plane), and at bottom bearing marl intercalation is seen. wing by middle grain size light grey limestone with dark inclusions , changing to more darker color dominated downward . Finally, a well compacted black limestone comes as a transitional zone to light grey, fine grained to limestone of Lower Gabradare Limestone, outcropping in the left flank of Dharoo River valley and around Mt. Kassim/highest volcanic peak in the basin/.

adare Limestone's environment of deposition generally cover, intertidal shallow marine (macro-micro ferrous) and clastic sediment (fine sandstone) intercalated top part, to pure water (micritic– cherty) , organic (black) and deep sea marly limestone lower part ; before changing gradationally to Urandab Shale open sea sition) with photic (black limestone zone) in between as transitional zone (maximum transgression and ning of regressional time (Shugut, 1995). Though there was no index fossil identified in laboratory study ntly; according to (Shugut, 1995), Upper Gabradare Limestone (?) is generally deposited in the beginning of ne regression during the Upper Jurassic.

1 Lower Gabradare

e mapped area the Lower Gabradare Limestone Formation is demarked on top by black compacted limestone sitional Zone) outcropping in the right hand flank of Dharoo River valley and black Urandab Shale in Wabe elle River gorge. This unit is generally light grey colored, fine to marly, compacted on top and highly nered and friable limestone in the lower part gradationally changing to Urandab Shale.

2 Transitional Black Gabradare Limestone

ower part of Upper Gabradare Limestone Formation is a black compacted (from field observation and thin on preparation and analysis) limestone, gradationally changing down ward to Lower Gabradare Limestone ation. This transitional black limestone out-crop between Burqaa River and left bank of Dharro River valleys . lack limestone thickness increase to the southeast from Burqaa to the left flank of Dharro River and the mum thickness is around Dharro is estimated to be over 75 m (?). This transitional black limestone was mapped EICIP, 1985 as Urandab Shale.

general environment of deposition of the Gabradare formation range from shallow marine (Upper Gabradare) en marine photic zone (transitional black limestone) and deep marine (Lower Gabradare with marly thick y zone) grading down to Urandab Shale.

.3 Upper Gabradare Limestone

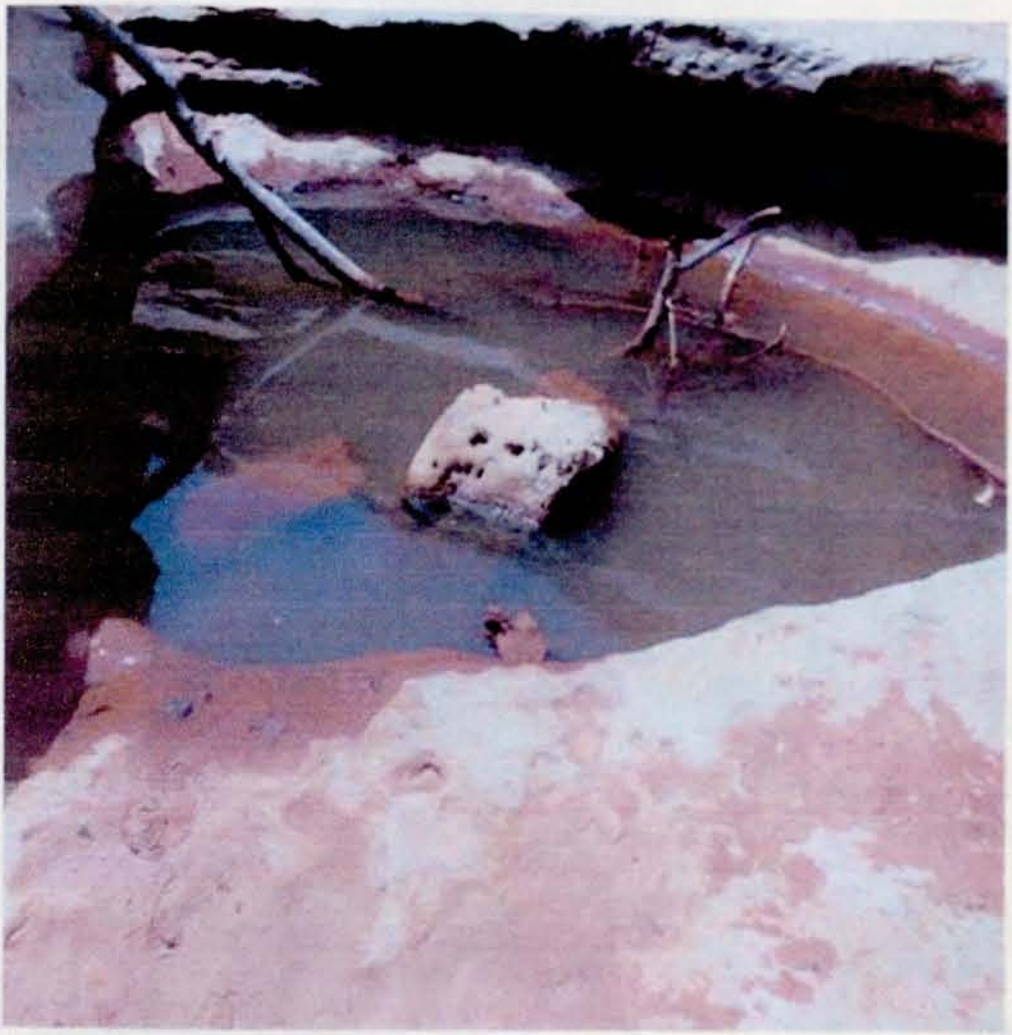
top part of Upper Gabradare Formation show fossilferrous limestone intercalations with arkosic sandstone, th lle micritic and cherty and the lower is compacted with dark color .

top Upper Gabradare is about 65 m thick in the mapped area. This is a crystalline medium grained, fed yellowis arenaceous limestone, exposed west of Werer, Dibe River and Dharro River valley. Color varies from fe w to grey, and grain size is between fine to medium grained but well sorted. No primary sedimentary structure bedding were observed in this unit. Fossils like gastropods (Plate 6A) (Annex) exist and composed of quart feldspar mainly. The samples collected and analyzed under thin section (Annexes), revealed this limestone uni thin (10-20cm) Arkosic sandstone intercalation.

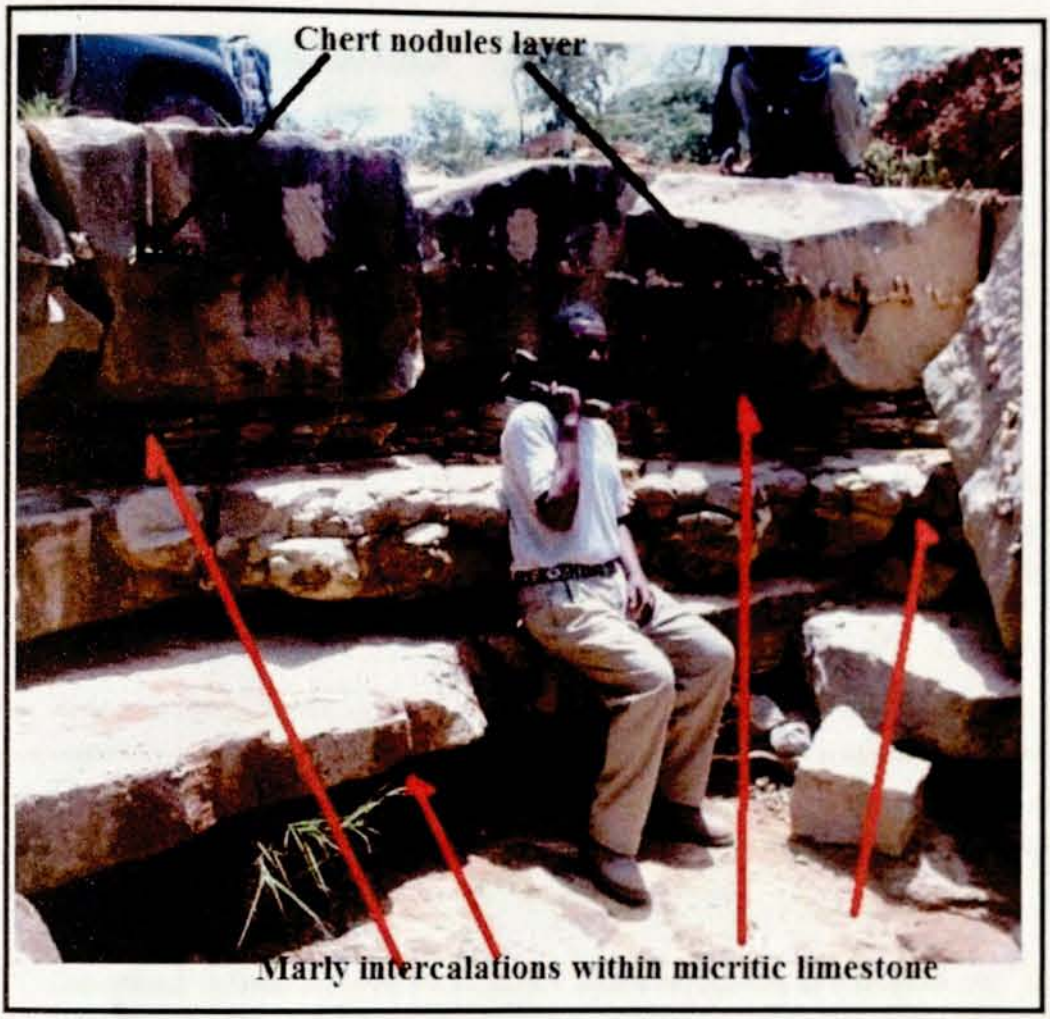
middle part of Upper Gabradare is garish white, micritic - limestone (very fine-grained) unit bears cherty bed e 4 below), with bed thickness of about 0.50 to 1.00 m. This limestone has also an intercalation of white colore shale with 10-15cm thickness.

lower part Upper Gabradare is fed yellowish grey limestone, with black limestone intercalation ending in th ern flank of Dharoo River valley.

ate 2. Wide cavity forming Upper Gabradare in Burqaa River valley (East Arsi), NW Ogaden Basin))



ate 3. Horizontal and un-deformed bedding of micritic cherty and marl Upper Gabradare Limestone, (Dibe Stre
hoto looking NNE).



the above succession is the middle part of Upper Gabradare Limestone; under laying the impure top pa
ging environmentally, from intertidal shallow marine to deep sea (marly intercalations).

e, the environmental deposition of this unit can be suggested to be a transitional unit from shallow marine
al deposition.

. Upper Sandstone (Ambaradom Formation)

e mapped area, Upper Sandstone (Ambaradom Formation) is represented by two distinct units : top variegated um grained Arkosic sandstone ; and lower light grey fine to medium-grained massive sandstone. Within the r sandstone mapped, fossiliferrious limestone intercalations are observed both in both top lower parts.

verage thickness of the Upper Sandstone Formation is around 360m, thinning generally SSE, being about 120m east of Seru village (Fig. 13: Fence diagram). Maximum thickness of compacted Arkosic Sandstone is noted ulu Dimtu" ridge after the color of the unit–red (in Afaan Oromo). The estimated maximum arkosic sandstone ut 140m.

graphic laboratory analysis conducted in Chemical laboratory of Geological Survey of Ethiopia show, the ge compositions of the top reddish sandstone as: quartz 62-71%; plagioclase (feldspars) 8-11 %; calcite 7% ; opaque 7-20%; and clay 5-15%. Hence, according to Pet John (1987) , the classification attributed to the tone composition indicate, typically Arkosic sandstone.

Arkosic sandstone's quartz constituent in some sandstone samples analyzed show, feldspar exceeding quartz nt compositionally, implying low maturity. The cementing material of the sandstone varies from iron- nates in the upper part to calcite in the lower part. The iron carbonate cementation gives the sandstone outcrop a sh weathered color. The calcite cementation on the other hand is responsible for light grey to whitish weathered on the sandstone unit intercalated within the Upper Gabradare Limestone.

verall compositional variation imply alluvial to shallow marine environment of depositions with significant tional facies zone in between, which for example, constitute, fossilliferrous limestone (in the upper part of the ic sandstone), and arkosic sandstone (in the top part of the Upper Gabradare Limestone Formation). The ct between the lower part the Upper Sandstone and underlying upper part of Upper Gabradare Limestone nate is gradational.

is no clear evidence of the presence of index microfossils like foraminifera common in the basin. The num age estimation of the Upper Sandstone (exposed near Iteya Village) is around 27ma (Lower Cretaceous) as ed from the flood basalt's age (Kazmin et.al., 1978) ; mapping of the ' Nazreth Sheet' (at 1: 50,000 scale).

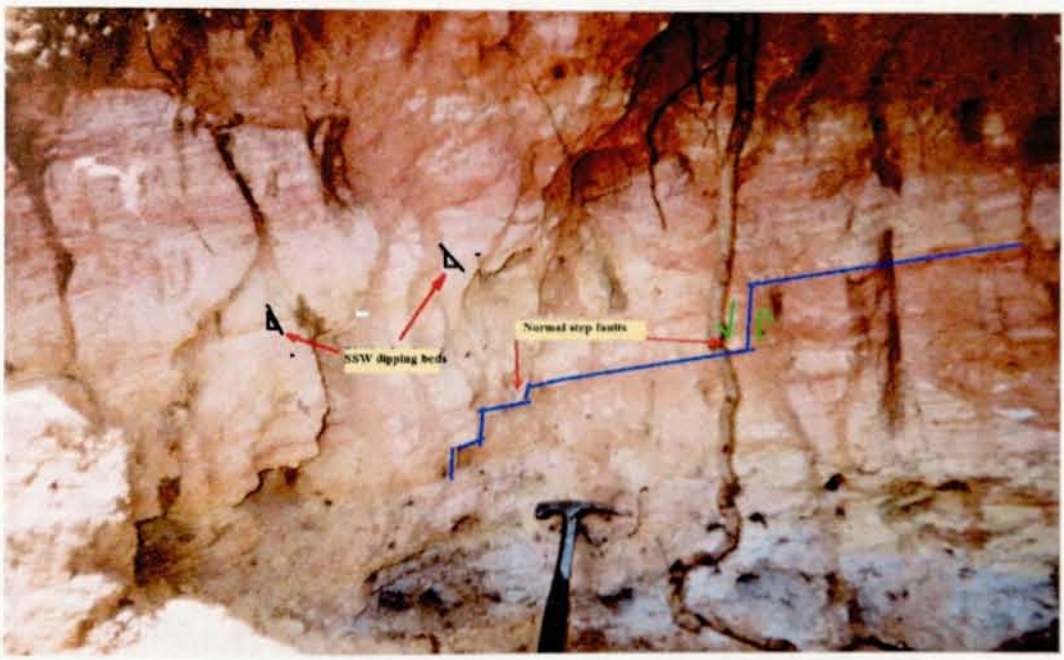
1 Fine light grey sandstone/ Lower part of Upper Sandstone/

er None-Variegated Sandstone, underlying the fossilferrous limestone within top Aarkosic sandstone, there
thick fine-medium grained, light grey, thickly bedded sandstone. This unit also bears, local laminations, a
beddings. The lowest part of this unit is a thinly (< 0.5m) bedded fine, fed yellowish grey sandstone with m
hale intercalation, having cyclic deposits; before grading to underlying Upper Gabradare Limestone formati
e southern part of the mapped area, where, about 120m limestone and sandstone intercalated units out-crop,
ct between the Upper Sandstone and the under lying Gabradare Limestone is checked to be a gradatio
ct.

2 Arkosic Sandstone / top part of Upper Sandstone/

sic sandstone outcrop around southwestern part of small village called Ittayya, underlying the Trap Ser
nic sequence. This unit is fine, friable to compacted , reddish, dull to pinkish red and variegated (multi-col
o dull reddish part to slightly variegate , verve , and friable sandstone lower part.

ate 4. Lower part of multi-color sandstone, NE Sammar , NW Ogaden Basin



***: This is the lower part of the variegated sandstone succession, over laying grayish white medium-grained sandsto
nicro structures observed on the plate seems to be associated to the structural set up on Tulu Badhassoo gas seepi
(?)***

arkosic sandstone intercalated within the carbonates units of the Upper Gabradare Limestone Formation l
e cementing differing from the over laying arkosic sandstone with siderite or ankarite cement. This unit b
ary sedimentary structures like laminations, cross bedding, etc., at a locality called Jeddah Kara (east of Ite
ge).

gure 5. General stratigraphic column of Southern Sammar (East of Seru Village to Dibbe River valley)

General staratigraphic column of Southern Sammar (Seru village to Diibe river valley) NW Ogaden Basin					
ple No.	Age (?)	Elevation (m)	Column	Thickness (m)	Lithologic Description
		2400-1840	V V V V V V V V V V V V	640	Massive vesicular and columnar basalt with scoracious mudflows and paleosoils in deposits breaks volcanic sequence
-01		1735		115	Ferrugnous highly compacted sandstone with bedded and rarely cemented with Ankerite
-02		1620		215	Brownish to grayish white fine sandstone
-03				25	Fine red colour sandstone
-04		1490		1	Sandstone with quartz grains
-06		1475		11	Fine light gray sandstone
-07		1465		16	Fine red-yellow limestne with sandstone intercalation
-08		1435		30	Arkosic sanstone with calcite cement
-09		1415		20	Fine whitish gray colour limestone
-10		1400		15	Fine gray limestone
-11		1390		10	Arkosic sanstone inetercalation with limestone
				15	Whitish gray colour limestone
-12		1375		20	Light gray to red-yellow fine limestone

ate 5: Fine multi -color (Variegated) sandstone /lower part of Arkosic SST/ SSW Tulu Badhassoo Ridge; north stern Sammar , NW Ogaden Basin/.



This is the lower part of multicolor sandstone, deeply weathered and fining down ward. Parts of this sandstone here bear fine poorly sorted fossiliferrous limestone (?).

(Fossilferrous limestone (Intercalation in Arkosic Sandstone)

in the top Arkosic sandstone successions, fine to macro size fossilferrous limestone (about 75m thickness) rved, as a local intercalation It's mainly outcropping, west of Iteya village (eastern Sammar). Another, at lea other cycles of fossilferrous limestone beds intercalating were roughly noted in the field within the lower part ariegated sandstone. These lower fossiliferrious limestone intercalation within the lower part of the Arkos stone are micro-fossils (very thin < 10mm) , well sorted and the bed thickness is around 0.5 m ; within t part of the Arkosic Sandstone , the second lowest fossiliferrous limestone intercalation in NE Sammar is al

ped (less than 0.5m). These two zones of micro fossiliferrious limestone intercalation, within the lower part of rkosic Sands is grading to light grey - whitish (weathered color) sandstone) discussed below.

able 1. Major fossils observed within the fossilferrous limestone.

.	Fossil name	Size (Cm)	Environment of Deposition	Unit	Formation	Remark
	Ammonites	Up to 5	Shallow marine	Intercalation within Upper Sandstone	Top part	Disturbed-Inter-tidal
	Mollusks (Bivalves)	Micro	Marine intertidal	>>	>>	>>
	Gastropods (Tullitella)	Macro	Shallow marine	>>	>>	>>

fossilferrous limestone within the Arkosic (upper and lower) part is observed to include fossils of gastropods, (bi-valves), etc. The sizes of the fossils vary from macro (5 cm) to micro sizes (mm). This fossilferrous tone intercalation shows a fining up ward sequence, from thin sections analysis (Plate 6A & 7A).

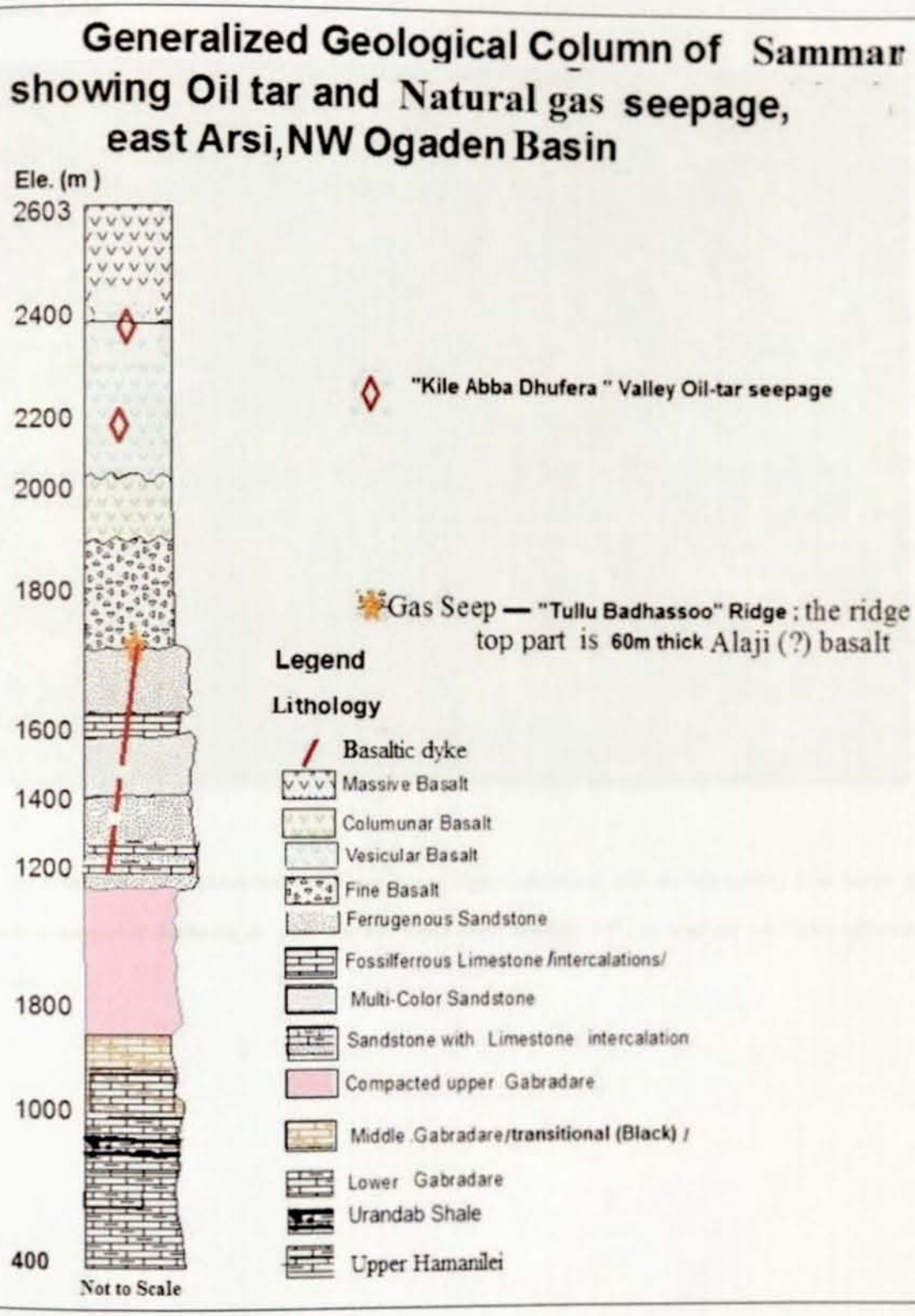
Volcanic Rock / Trap Series Flood Basalt /

volcanic sequences in the mapped area cap and intrude the sedimentary successions in western basin marign. lood basalt constitute massive, columnar, vesicular and scoracious and associated north south striking and sub-ally west dipping fine grained basaltic dykes. Palaeosols exist in many depositional breaks as partially mapped e of the deeply cut river valley of Elelle (Oil-tar seepage locality). The estimated general volcanic sequence; east-west normal step faults and north south vertical deep-seated faults (?) has maximum thickness of about 1.1

Sammar area Basalt series is part of the central highland plateau sub classified formerly as Alajii and Aiba lt (Kazmin, 1978). The Trap Series flood basalt / siliceous (Tarmaber Basalt) in the northwestern margin of the Ethiopian Rift is massive, columnar, and vesicular, generally; with many depositional break constituted by aceous flows (Kazmin et.al., 1978) ; similar in age to Middle-Late Oligocene Aiba Basalt (Mangasha, 1996).

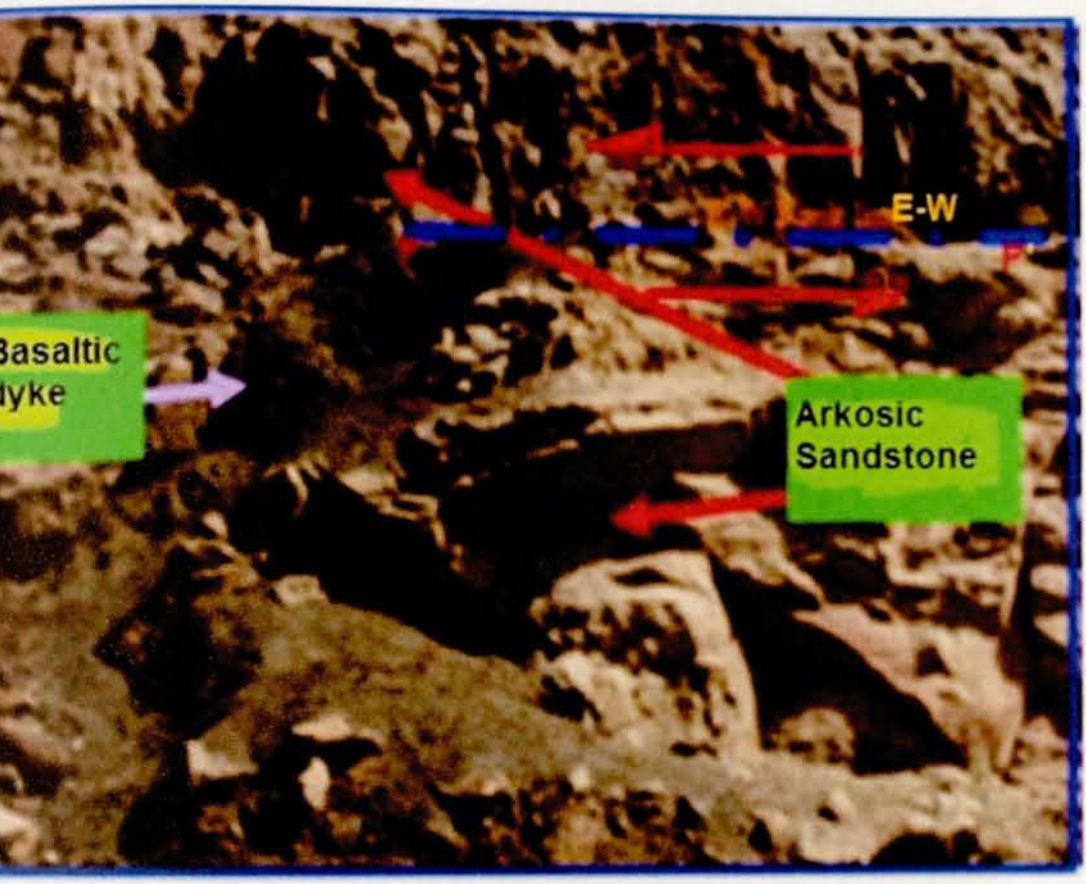
age determination by K-Ar method, for a nearby to Sammar Area oldest Basalt is 27ma (Kazmin et. al., 1978), h is Upper Cretaceous (?).

gure 6. Generalized Lithostratigrphic Column of "Sammar Area" (East Arsii) , NW Ogaden Basin



ıte 6. Top part of Upper Sandstone in contact with Volcanic Sequence of Trap Series Basalt, Eastern Seru, NW

ıaden Basin

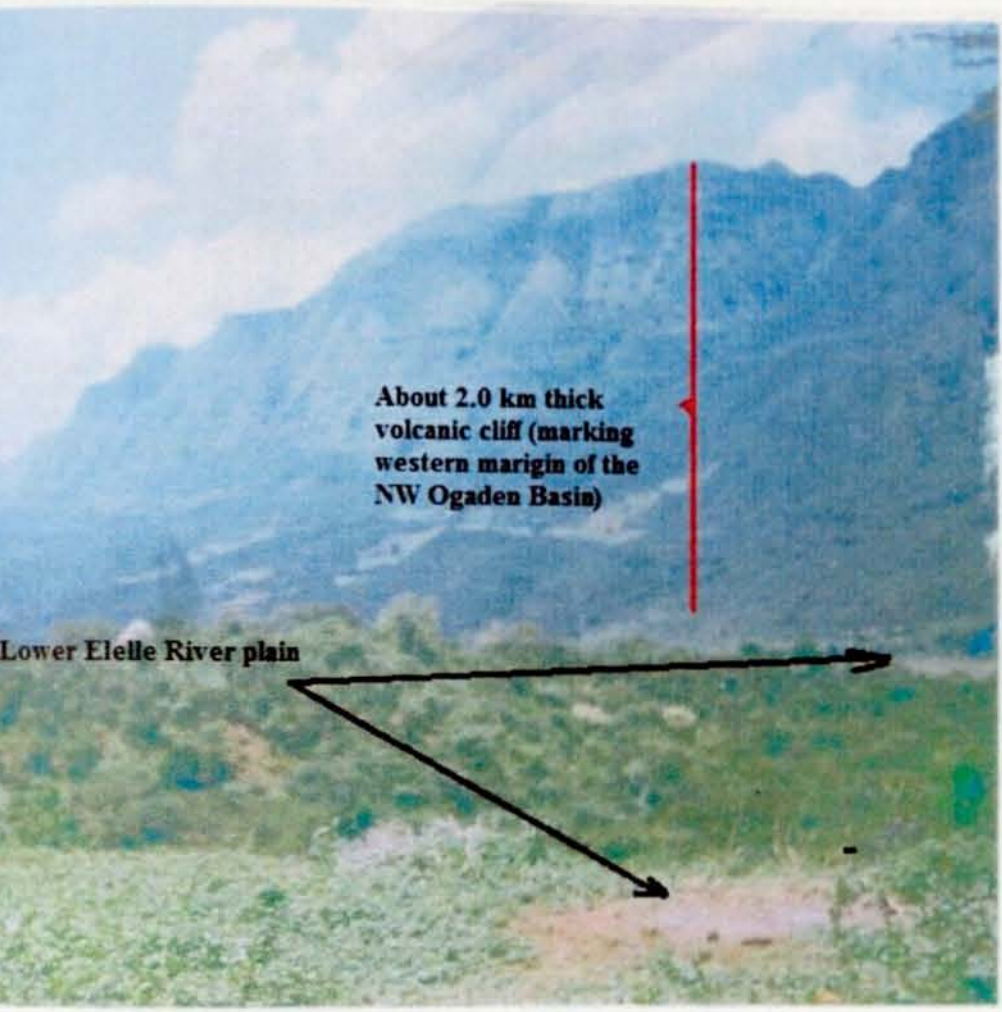


The contact nature of the arkosic sandstone / top of Upper Sandstone/ with the late coming Trap Series flood basalt

estern margin of the basin, as picked by the photo above (looking NW) in road cut ; is highly affected by volcan

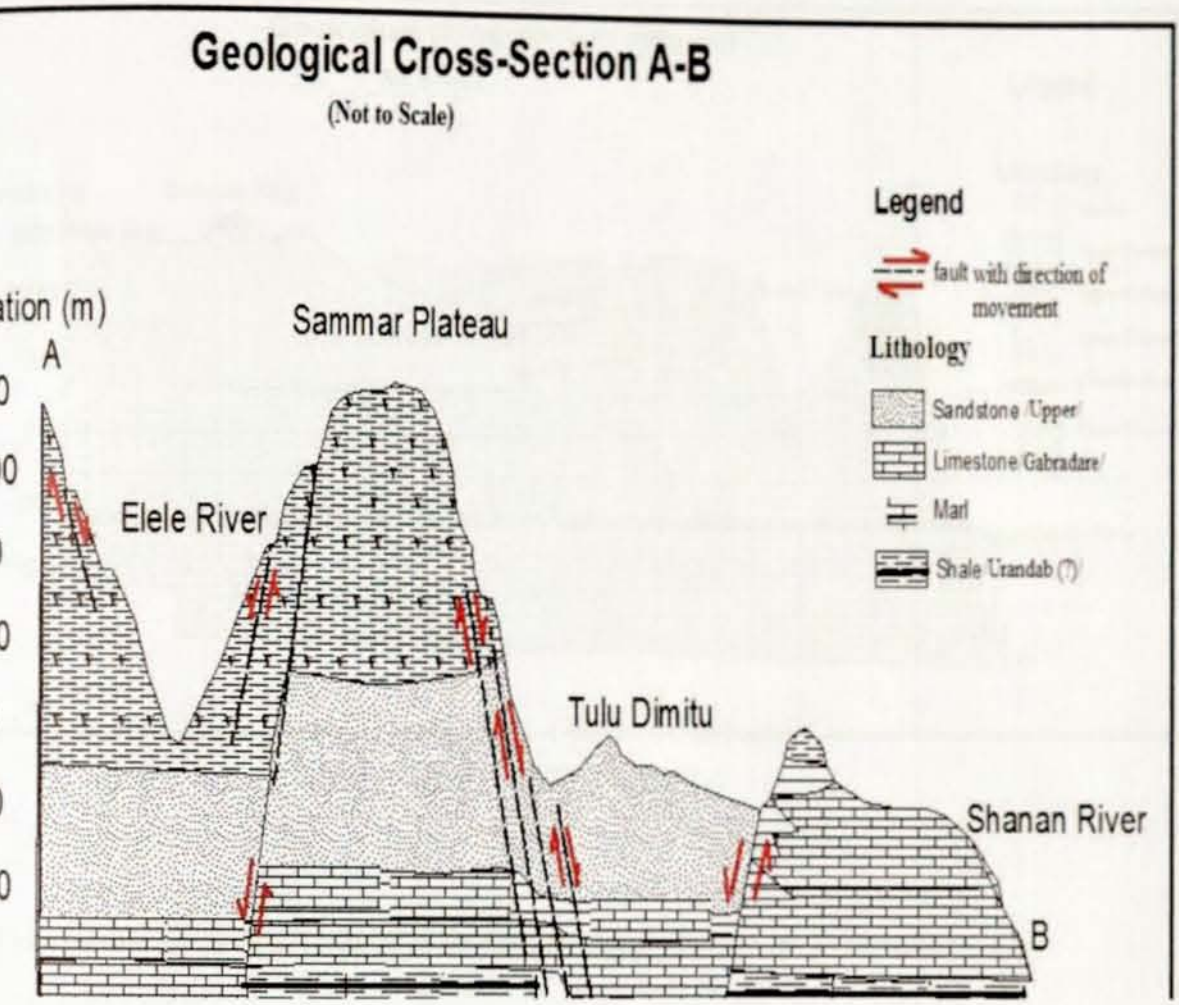
ions.

ate 7. Over view of Lower Elelle River valley floor and Trap Series volcanic cliff, below Bele Town, Eastern Arsii
outhern Sammar, NW Ogaden Basin)

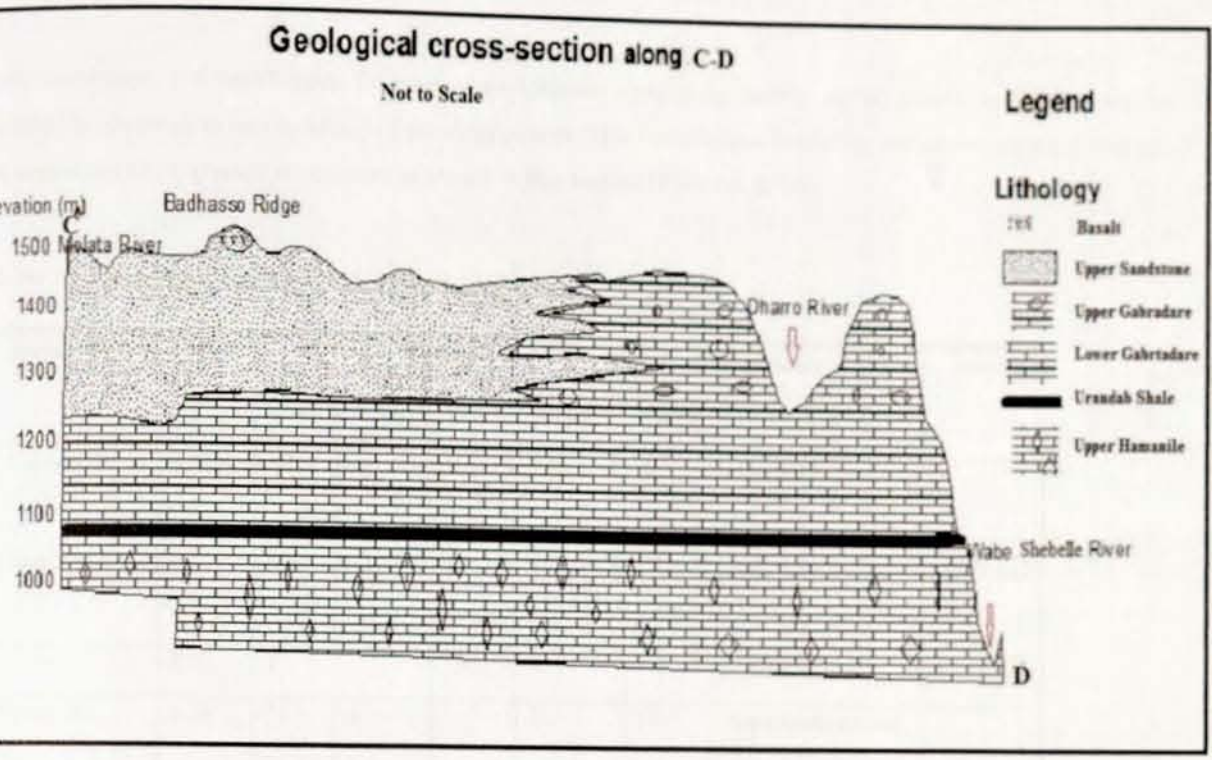


The thick (> 2 0 km) Trap Series basalt is partially intruding and over laying the sedimentary succession and marking the basin
n flank , lower Elelle River valley (Photo looking SSW).

igure 8 : East-West geological cross-section of Sammar, East Arsi, NW Ogaden Basin



igure 9. NW- SE geological cross-section of Sammar Area, East Arsii, NW Ogaden Basin



Thin-section analysis of Upper Sandstone and Upper Gabradare Formations

mples from southern Sammar (East Seru), and 6 samples from northern Sammar (Iteya), 3 samples from Dharro e, and 3 samples from Wabe Gorge were collected. However, only 9 samples from East Seru, 3 samples from (North Sammar), were successfully polished for thin-section analysis, and the content is shown in table (Table 2b). The Microphotographs and description of the thin sections are shown in (Appendix I & II). The polished sections for samples from Dharro and Wabe Gorge are not ready to include here.

Upper Sandstone Thin-section Analysis

hin section analysis, grain sorting, size, and cement type of the upper sandstone has showed high compactness e Arkosic sandstone (Appendix I, Plate 1A–5A), resulting in poor porosity and permeability; hence, poor voir. The arkosic sandstone has siderite (?) cement, implying syn-sedimentary to early digenesis, i.e., ocrystalline siderite, chamosite, and pyrite normally are syn-sedimentary to early digenetic origin. Within the

sic sandstone a fossilliferrous limestone intercalations containing poorly sorted macro to micro- fossils, sition is observed in two localities of the mapped area. This fossilferrous limestone succession shows fining up- l sequences (transgressed deposition) as shown in thin section (Plate 6A & 7A).

able 2a. Thin-section analysis result of Upper Sandstone

Formation	*Sample no.*	*Components in %*					*Rock name*	*Remark*
		Quartz	*Plagio-clase*	*Calcite*	*Opaque*	*Clay*		
Upper SST	R-01	67	8	-	20	5	arkosic sst	
(Intercalations)	R-02	3	-	60	8		macro-fossiliferrous Lst	30% fossil
>>	R-03	2	-	55	8		fossiliferrous Lst	44% fossil
Upper SST	S-04	71	4	-	7	15	Argillaceous arkosic SST	
>>	S-05	62	11	-	12	10	arkosic SST	
>>	S-07	63	10	7	8	7	>>	
Upper Gabradare	S-08	5	5	80	4	2	limestone	Transitional zone
Intercalation	S-09	70	10	15	5		arkosic SST	
Upper Gabradare	S-10	-	3	76	1		arkosic SST	

Upper Gabradare Limestone Thin –section Analysis

ratory analysis of the thin sections, i.e., grain sorting, size determination, and cement type identifying was on the samples from Upper Gabradare Limestone Formation (Appendix I, plate 8A – 12A). The analysis has ed high compactness resulting in poor porosity and permeability. Chemical composition of the lithology shows le 1b), that 76%- 85% is (calcite/ and micritic) and 10% Quartz, and rest clay. Clay is one the significantly dant mineral in sandstone and some impure limestone formations mapped around, implying some of the nents are impure and can be called ortho -chemical rocks (Fig 10).

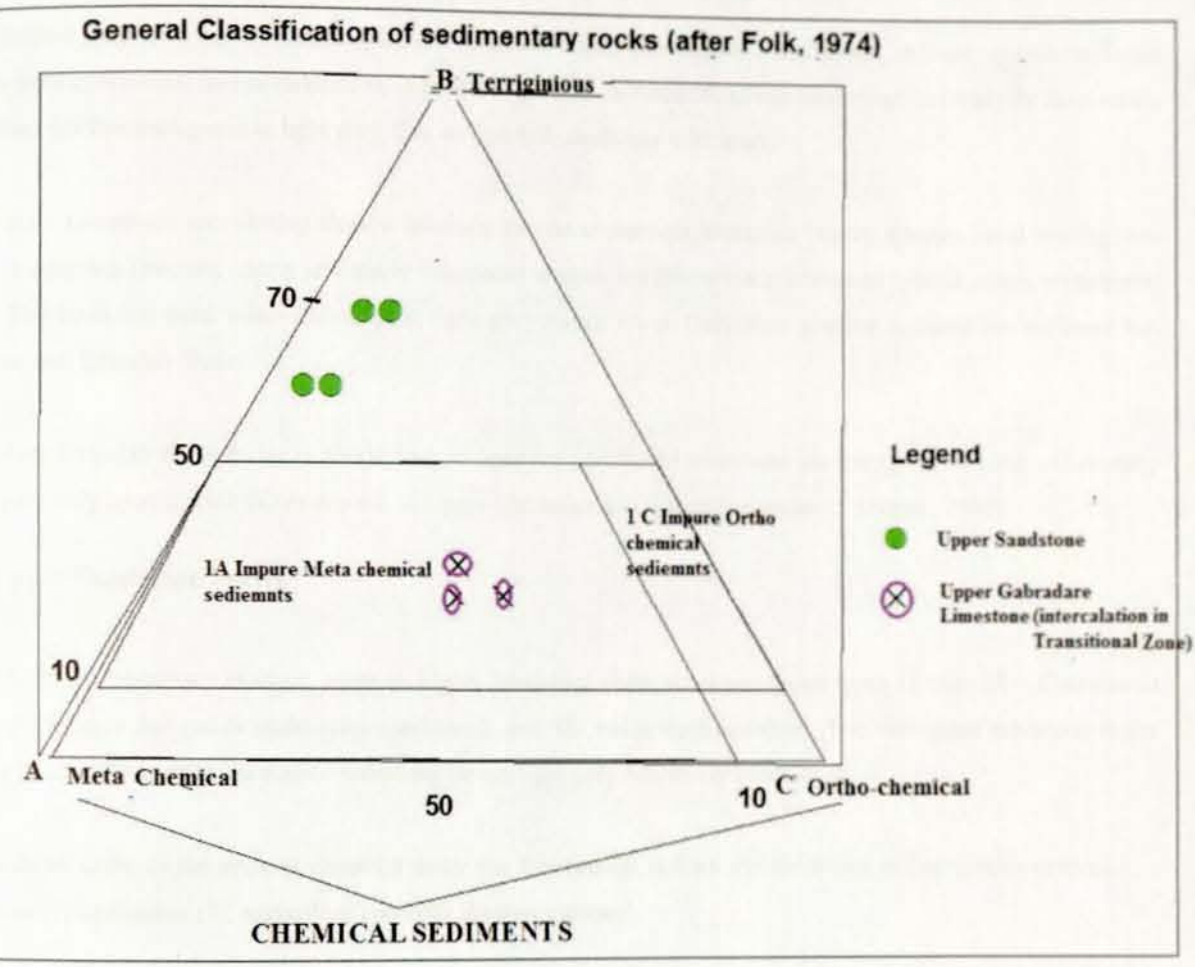
able 2b: Thin-section analysis result of Upper Gabradare Limestone

ormation	*Sample No.*	*Components in %*					*Rock name*	*Remark*
		Quartz	*Feldspar*	*Calcite*	*Opaque*	*Clay*		
pper abradare	*S-10*	-	*3*	*76*	*1*	-	*Fossilferrous limestone*	
>>	*S-10*	-	*2*	*46*	*2*	-	*Fossilferrous limestone*	
>>	*S-11*	*11*	*2*	*22*	*trace*		*Cherty limestone*	
>>	*S-11*	*1*	*5*	*45*	*2*		*Limestone*	

Classification of Sedimentary Rocks

der to classify the mapped sediments: for terrigenious and chemical sediments, the classification after Folk
4); and for carbonates the classification after Dunham (1962) is adopted. One of the general classification after
(1974) is shown in Fig. 10 below.

gure 10. General Classification of sedimentary rocks (after Folk, 1974)



r Gabradare limestone classification according to **Dunham's (1962)** is " bio-pack stone" for the fossilferrous tone intercalating the Upper Sandstone; "intra-grain stone" for none intercalating Gabradare limestone . **Folk (**) have classified the top one as "bio-micrite ", and the lower one as "intera-sparite".

Facies Analysis and Environment of Deposition

limited litho- and bio- facies analysis of "Sammar Area" sedimentary successions, indicate somehow facies s from continental fluvial (arkosic sandstones) to shallow marine (calcareous sandstone) to relatively deep stable shore (to fine variegated to light grey, fine well sorted sandstone with marl.

radare Limestone constituting shallow intertidal marine arenaceous limestone (macro – micro fossil bearing) top to deep sea (micritic cherty and marly limestone) to open sea facies black limestone (photic zone), transitional The open sea pure water facies (fine, light grey marly lower Gabradare grading to same environment but nic rich Urandab Shale.

black Urandab Shale facies is photic zone in open sea ; while the maximum sea transgression time sedimentary generally open marine facies deposit is Upper Hamanlei Limestone Formations (Shugut , 1995).

Upper Sandstone Facies

field and laboratory analysis made on Upper Sandstone show about two facies types : Facies IA – Continental ial (Arkosic dull red or multi-color sandstone); and IB: stable deep sea shore (fine variegated sandstone under g) ; shallow to deep sea marine sediments (lower light grey fine marly sandstone).

reddish color of the unit, as observed under the thin section is from the oxidation of ferruginous cement i.e., rite (?) or Siderite (?); suggesting generally shallow marine.

intertidal marine facies is constituted by Micro-macro fossiliferrous limestone (Plate 6A & 7A) intercalated n Arkosic sandstone.

s IC: Deep stable sea marine deposit- whitish grey, fine sandstone

ower upper part of the Upper Sandstone, grading to Gabradare Limestone is a massive unit , well sorted , fine , and bearing limited primary structures. It is a calcite cemented compacted unit with sub rounded particles, ating transgressional deposits.

2 Gabradare Limestone Facies Analysis

carbonate micro-facies analysis (after Wilson, 1975) is a new comprehensive approach to carbonate rock studies ugh not represented here below.

able 3 : Summarized facies types of Upper Sandstone to Lower Gabradare,Sammar, East Arsii, NW Ogaden Basin

Formation	Descriptions	Facies Zone
Upper Sandstone (Ambaaradom)	*Arkosic Sandstone: reddish coarse grained sand stone with cross bedding and grading down to fine variegated sandstone*	*Facies IA – Continental to Shallow marine*
>>	*Fine light grey, massive and locally marly sandstone Lower part grading to Upper Gabradare*	*IB: stable deep Facies IB : shallow to deep marine*
Upper Gabradare	*Fossillfferous limestone Upper Gabradare poorly sorted fossiliferrous limestone Shallow marine intertidal*	*sea shore (fine*
>>	*micritic, cherty limestone Bear marly intercalation*	*Shallow to deep pure and stable sea*
Upper Gabradare /Transitional zone /	*This black limestone gradually changed from light grey limestone in Burqaa River to Dharro . Its found between light grey Upper Gabradare and fine marly Lower Gabradare*	*IIA; deep marine photic zone Facies :*
Lower Gabradare	*Thick, light grey, fine, massive, marly limestone in the lower part ; grading to Urandab Shale*	*IIB: Open sea deep marine Facies*
Urandab Shale	*Black fine shale in Wabe Shebelle Gorge about 30-50m thick (?)*	*III Open sea photic marine*
Upper Hamanlei	*Light grey to fed yellow weathering color, massive limestone with uniform texture from top to bottom in Wabe Shebelle Gorge*	*IV Open sea and none photic zone*

ithological Correlations

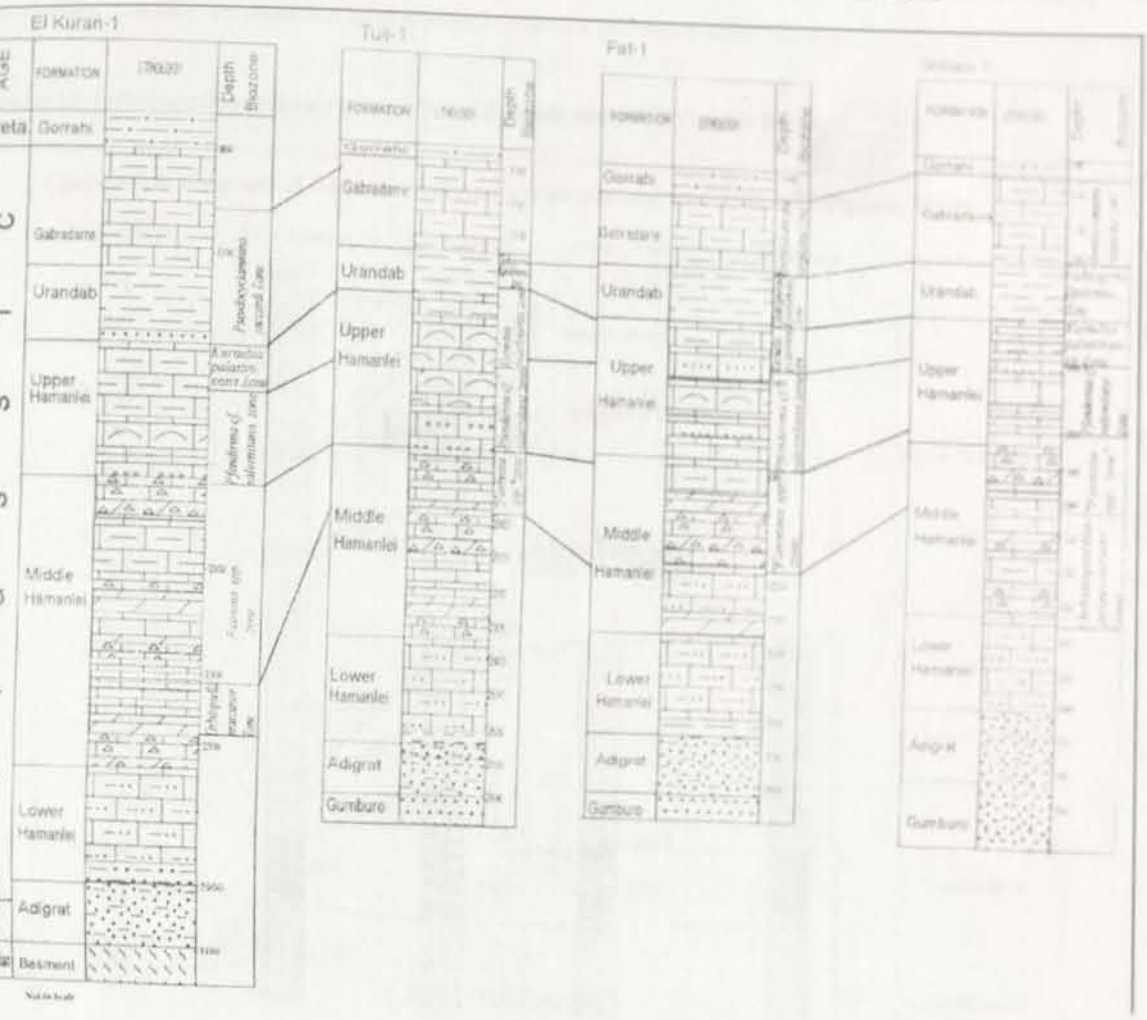
Regional Lithological Correlations

Ogaden Basin NW-SE general cross - section shows the existing of deep sedimentary successions in the central ern part of the basin around Shilabo-1 deep well (Fig.3); while possible thinning occurs along eastern or ern flank of the basin as can be expected. These general conclusions (pinching systematically east – west nor west- southeast) are not justified in localities within Tri-radial Karoo rift. This can be supported by some data ved in Genale River basin (thick Urandab Shale occurrence) and similar thick Upper Hamanlei and Urandab out-crop exposed along recently built Mechara - Dire Shek Hussen road cut (upper Wabe Shebelle River).

egional lithological correlations diagram along E-W deep hole data section of the south central Ogaden Basin is n in (Fig. 9 below). The section that starts in the left with El- Kuran deep well goes to Shilabo -1. The lation made by (Shugut 1998) does not generally show any significant lithological pinching. In the section, the est is Gorrahi at the top and the thickest is Middle Hamanlei in the middle. Lower Sandstone (Adigrat) is the unit uniformly thickening from East to West, i.e., El-Kuran to Shilabo-1

hi is thickest in El- Kuran well and thinnest in the next Tuli-1; Gabradare is thickest in El-Kuran-1 and almost r in the other holes; Urandab has almost same thickness proportion as Gabradare; Upper and Lower nlei is almost uniform in all holes correlated laterally , east-west. Middle Hamanlei is significantly thick in El- and similar in other deep holes.

Figure 11. General E-W Lithological Correlation of Central Ogaden Basin (After BECIP, 1985)

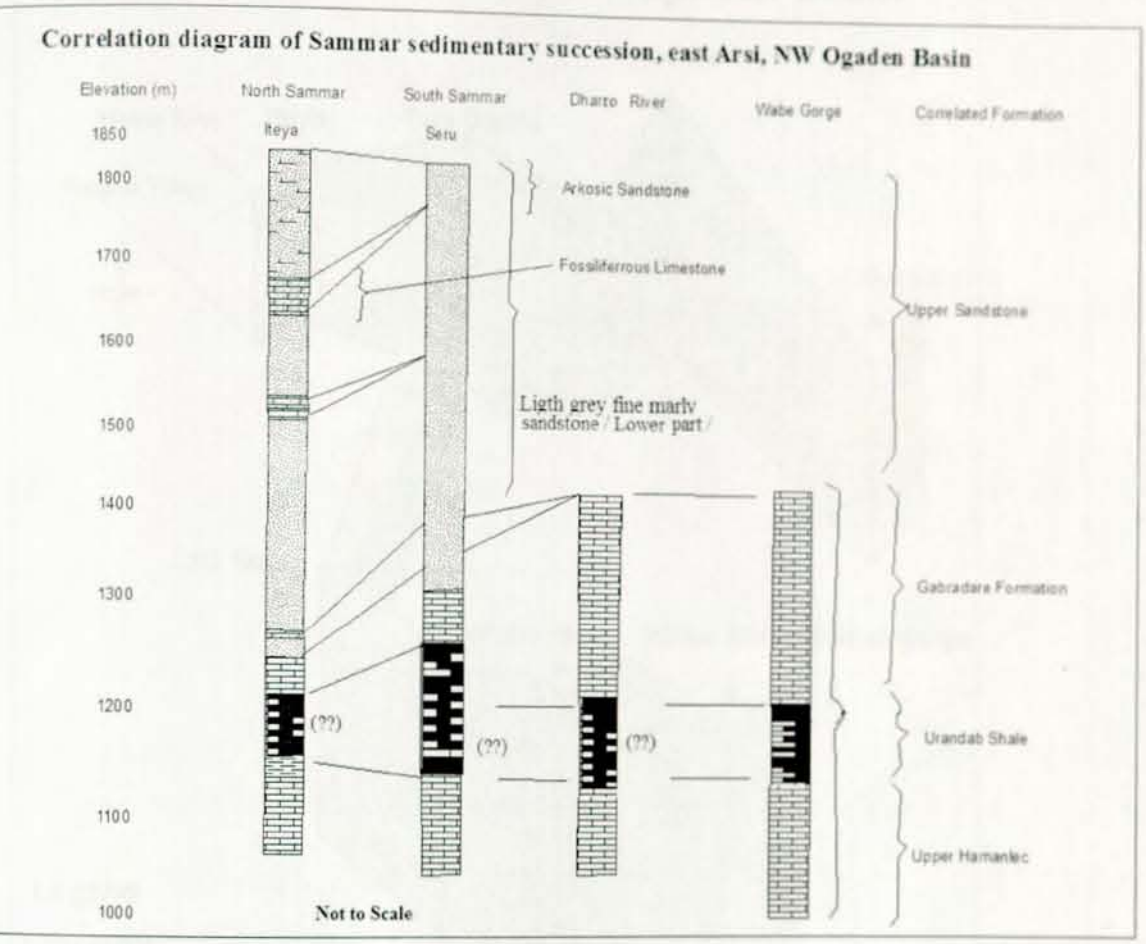


Local Lithological Correlations

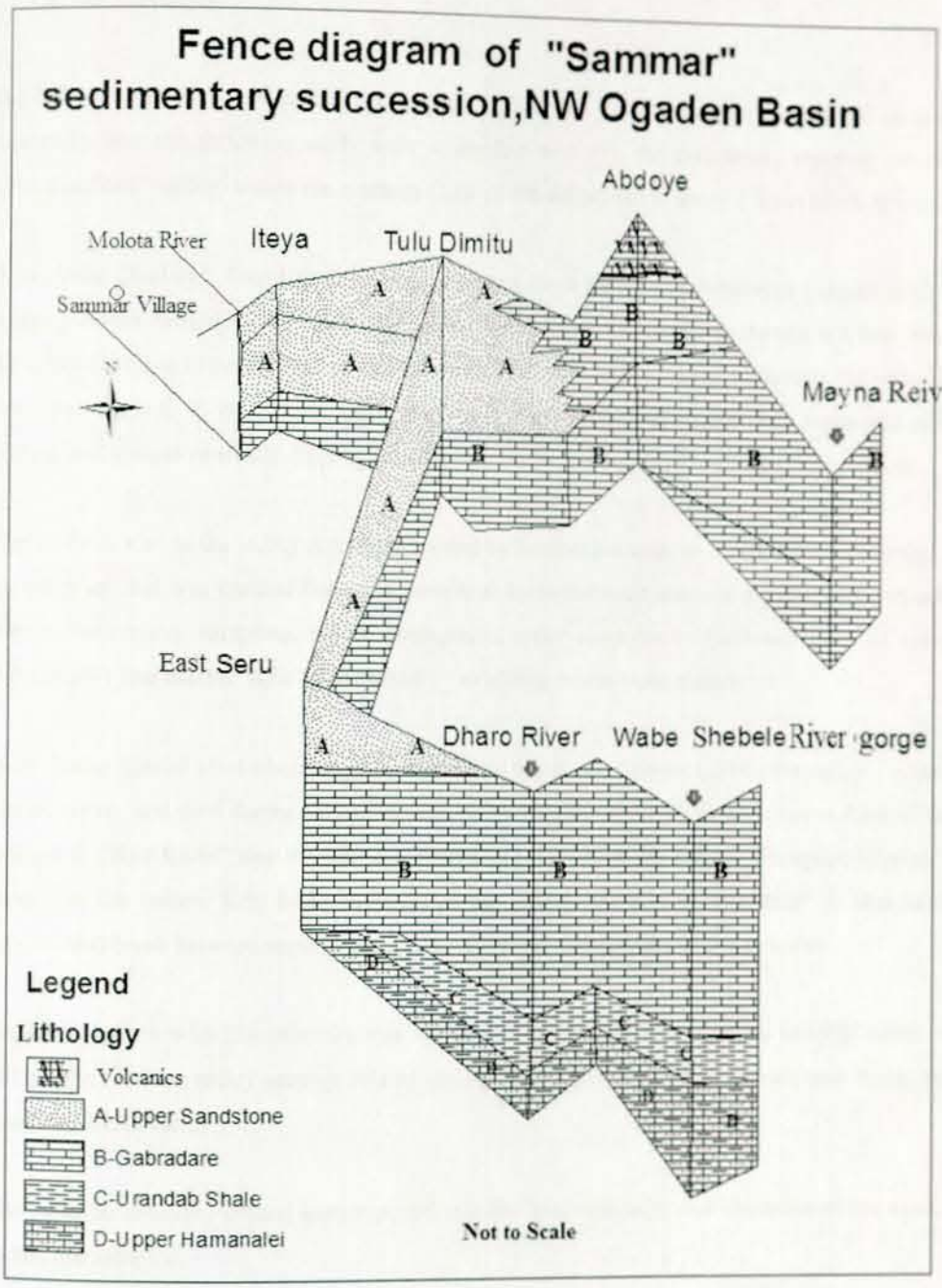
stratigraphic correlation along NW (Iteya Area) to SE (Wabe Shebelle River gorge) is sown in (Fig. 10 v). The correlation diagram has showed us; for example, the fossilferrous limestone intercalations that occur n Upper Sandstone, in North Sammar is pinching out to the south Sammar (Seru side). The Upper Sandstone s generally to be thicker in the north and thinning southward. The Gabradare Formation has rather a reverse onship, i.e., it's getting thicker towards the south Sammar (eastern Seru) and thinner to the North Sammar. The vest relationship of Upper Sandstone and Lower Sandstone in Transitional zone the sediments is manifested by

calation of the sandstone with limestone. The limestone is also shale and marl intercalated, indicating some s change, that may be important as stratigraphic traps for petroleum accumulation.

igure 12. Lithological correlation along NW to SE Study area , NW Ogaden Basin.



gure 13. Major sedimentary succession's Fence diagram of "Sammar" study area, NW Ogaden Basin



. Hydrocarbon Potentials (Oil –tar and Natural Gas Seepage) of Sammar

.1 Oil tar seepages

he NW flank of the Ogaden Basin is not widely explored for hydrocarbon (surface oil-tar and natural gas) otentials. But, the following study were made first to verify the community reported occurrence in "Kile bba Dhuferra" valley, within the northern flank of the deeply cut to about 1.1 km Elelle River valley.

Kile Abba Dhufera", found at about 1km distance from Sammar Sammariyye peasant association western illage , center named " Rob – gebeyya" towards the south. The access to the site is a foot- track with deeply ut valley that was normally faulted facing south. The main Ethiopian rift formation and volcanism associated ructures, such as E-W striking and sub-vertically south dipping normal step faults and older NNE-SSW riking and almost vertically dipping longitudinal faults that parallel the rift structures locally.

he difficult trail to the valley is traversed aided by local community to check the seep position and observed e black tar that was emitted from a depositional break between massive upper basalt and columnar . After roper observation, sampling, taking photographs other seepages in the lower level of same longitudinal NNE-SSW) line named "Kile Rado "(Plate __ available below) was visited.

Kile Rado" named after a woman, that committed suicide by throwing down the valley , when here husband ipped down and died during harvesting honey from traditional beehive on a tree at flank of the valley. This epage at "Kile Rado" was the first discovered in old days of the former "Hamphee Dhakaa" now 'oil-tar' story in the valley. Kile Rado seepage, as the former "Kile Abba Dhuferra" is also occurring from a epositional break between upper columnar basalt and underlying massive fine basalt.

imilar seepages with less intensity was visited in a stream valley at Wabera locality; south of Elelle River lley. The Wabera valley seepage related structures (normal step faults, depositional break, etc.) were also milar to Elelle valley.

lany similar seepages around were reported and due in accessibility and limitation of the work; they was not sited nor sampled.

fter seepage site observations within the volcanic terrain (western flank of the basin) ; the eastern Sammar wland was traversed by horse back and on foot. Then additional information about slightly pungent natural s seepage on "Tulu Badhassoo" was reported from the community. This tectonically highly affected small dge has $N20^0E$ strike dipping sub vertically towards the west. The youngest normal step faults, which have

ffected the ridge in three directions, must have obscured the oldest structures (?). that seems to facilitate the eformed (striking N-S and laterally faulted , etc) ridge standing on the Upper Sandstone succession and apped by 60m thick Alaji Basalt (V.Kazmin, 1978) is in basin floor.

etails field observations and samplings are presented as follows:

.1.1 "Kile Abba Dhuferra" Surfacial oil -tar seeps

early 2007, preliminary analysis is made on oil-tar seep from "Kile Banjawaa" valley seepage. The analysis clude proximate (moisture, volatile matter, fixed carbon and ash); calorific value, specific gravity and stillation. The results showed calorific values from liquid residual, and gum to be 1600 Ca/gm, and 1700 al/gm, respectively. The test somewhat showed the oil tar (hydrocarbon) characteristics of the "Hamphee-haka" (black-waxy substance) of Sammar for the first time. The only explored oil seeps in our country so far e Ware-Ellu oil seep of Eastern Abbay Basin, and Darkle Oil seep of Genale River in South West Ogaden asin.

fter organic rich shale is buried to a sufficient depth hydrocarbon generation (typical petroleum systems) itiates (Winfried, 1995). The occurrence of oil seeps and natural gas leaks in Sammar and the surrounding ithin Mesozoic Sedimentary terrains, and/or the Trappean volcanic rocks, indicate two types of petroleum stems.

- Oil-tar generated from thermally matured source rock due to igneous dyke - Atypical petroleum system (flood basalt sequence related seeps); and
- Oil-tar generated from thermally matured source rock due to depth of burial - Typical petroleum system(sedimentary basin hosted seeps);

1.2 Field Observation

he first oil-tar seepage visited by geologists is "Kile Abba Dhuferra" valley. This seep is associated to normal ep faults with significant down throw (few hundreds of meters).The observed oil-tar seeps are hosted by ood basalt (vesicular, scoraceous, and columnar basalt sequences), that over laying the sedimentary

uccessions of the area.. The oil-tar seeps of Sammar are exposed in volcanic sequences deeply cut by Elelle, Alona, and Wabera River valleys.

The Elele River valley seeps are controlled by N-S normal step faults with vertical to sub vertical dip. The orth south alignment of some seeps "Kile Abba Dhufera, versus. " Kile Rado"; and "Kile Banjaawa"; versus "Kile Chalalaka", etc, indicate alignment of the seeps on certain fault line.

n addition, saline cold springs are associated to large seeps like Banjawa, Radoo, and Wabera. The probable Manya River seep is also one of the saline springs bearing site. Manya, Shanan, and Dharro River River alleys are also exposing some seepage hosted by the sedimentary successions.

Manya river sands around the confluence of Molota and Laga Buna; and Lower Shanan (Kile Adi) and Lower Elele River (Guratti), and Lilo Gurrati valley (Dharro River valley) are known to be seeps from Upper Gabradare Limestone.

Fresh oil seeps are dark brown to red brown and less vicious (easily flowing). Gradually it becomes more iscous and denser, turning to solid black tar. The odor of the seep is disagreeable (may be immature oil) and issolves in benzene. However, in water, may be due to high contamination and age, the whole material is issolving ending with non-dissolving flowing quill layers. It is this sample, after filtering that showed 769.93Cal/gm readings. Most seep samples are highly contaminated, resulting in low volatile, and calorific alues.

.1.3 Summary of the field observations of Elelle River Valley oil –tar seeps

Kelle Ababa Dhufeera" Seep (?): it is the first surficial oil seep visited by the author and geologists from etroleum Department of Geological Survey of Ethiopia. The occurrence is at elevations between 2350-2380 a.s.l. located at 07° 55' 51"N and 39° 54' 04". Here the lateral extension of the seep line is around 20m hile the weak zone thickness is about 3m. One cannot see the seep line closely, because the height of the alley cliff is over 10m. A ladder of 10m or above is essential.

Kille Radoo"Seep (?): this comprises rather a broad valley and more seepage volume. Rado valley has an levation of 1839m a.s.l. located by 07° 55' 51" N and 39° 53' 15" E. The lateral seep line is estimated to be ore than 40m while the vertical weak zone of scoriaceous mudflow is around 35mts. The Abba Dhufera alley and Kile Rado are on almost the same strike NNE-SSW alignment.

"Kile Banjawa Seep": Banjawa Valley oil seep may be the biggest both on size and on deep volume. It can be located on a map y 07° 55' 50" N and 30° 52' 09" E coordinates, and the elevation is 1759 a.s.l. The lateral extent of the seep line is 60m or more. The weak zone is similar to Rado valley i.e. around 5m constituted by scoriaceous flow sandwiched between columnar basalt sequences.

"Kele Chalaleka Seep" (?): the altitude of this seep is about 1843 located at 7° 56' 03" and 39° 52' 52". This seep is among the smallest ones in size. The top course of this stream is known as Kacha stream holding three seeps in two branching valleys of few to tens of meters.

There are three seeps in the upper course of this stream named "Kile" shumbo I and II and "Kile Dima" "Kile" Dima and "Kile" Shumbo II have comparable altitude of 2358m and 2350m respectively. "Kile" Shumburo II is the only oil seep at such high altitude of 2460ma.s.l.

Kile Adi and Kile Lilo Guratti seeps, these are the seeps found in Manya and Dharro River Valleys. What makes them similar is that Upper Gabradare Limestone Formation hosts both, while their difference may be the locations and associations to the nearby volcanic peaks like Mt. Abul Kasissm , i.e., petroleum system(?). The Dharro River Valley oil-tar seepage seems from Typical Petroleum System (Close to Mt. Abulkassim), and the Kile Adi Seep is Atypical Petroleum System (Oil seep generated from petrpleum reservior due to organic rich unit maturity by depth of burial)

Plate 8 . "Kile Rado" oil-tar seepage



lote. The black smearing of the valley wall. The bottom part is termites pile indicating weak zones.

7. 1.4 Type Models of Sammar Oil –Tar Seeps

7. 1.4.1 An Atypical petroleum system

In general, the oil tar seep associated with the volcanic sequence seems an atypical petroleum system whose oil originates from a source rock that is thermally matured by an igneous dike (Magon, et.al.1982) (Fig 22).The source rock here is the Urandab Shale cut by recent volcanic dykes. Typical example, here may be the oil-tar seep around Mt. Abulkassim, in Dharro River Valley. Mt. Abulkassim with peak height of 2060m a.s.l. is an already known volcanic center in the area.

7.1.4.2 Typical petroleum system

"Sammar" surficial oil show, may be oil system generated whose source rock is thermally matured during deep burial by the over burden rock. Ogaden Basin has a general thickness of 2500 – 5000m (Getaneh, 1998), and there are identified and proved source rocks in Ogaden Basin; like Bokh Shale, parts of Hamanlei Carbonates, and Urandab Shale.

In western Ogaden Basin, generally, and in Sammar Plateau, especially, two factors seems to favor the source rock maturity. These factors are heat supply by the volcanic rocks and/ or thick overburden. It is clear that, heat supply by the emplacement of igneous rocks increase the geothermal gradient, which may compensate age and depth factors, for petroleum generation. The additional thick volcanic rock overburden (nearly 1Km) above source rocks, increase the depth of burial over the sediments (e.g. for Urandab source rock out-cropping in Wabe Gorge to be buried around 2 km under the plateaus).

7.3 Oil-tar Laboratory Analysis Results

The samples of oil seeps from "Kile Banjawa" were submitted to hydrocarbon department of the Central Laboratory of Geological Survey of Ethiopia for the analysis of Proximate; Ultimate; Calorific value and Specific Gravity determination; and distillation. Unfortunately, Ultimate analysis was not working at the time. The liquid sample was first treated by centrifuging to separate the supernatant; but failed technically. Then, the liquid sample was separated by math - 42 filter paper; and analyzed for proximate analysis and calorific value.

The basaltic rock chip samples coated by oil-tar was first crushed as a whole, and analyzed for calorific value, but read none. To check, further, the gum from the sample were carefully removed and analyzed reading the highest calorific value of 1690.25 cal/ gm or 3042 BTU **(Appendix C)**. This is an inflammable calorific value in open atmospheric conditions /personal communication with the Ethiopian Petroleum Enterprise chemists /.

Distillation of the filtered liquid showed boiling of water at 93°C. The remaining fluid was strongly foaming to conduct further distillation, for some not clear reasons. The foaming case has been observed also during thin-section preparations.

7.2 Natural gas seeps

7.2.1 Field Observations

Local people in time memorial discovered "Tulu Badhasoo", natural gas leak. Some old men with an age of early 80-90 years, remember their childhood, throwing stones into the gas fracture, and enjoying the sound nd the gas taste. The Oromiffa name "inquftu" which means unfilled or unsatisfied was given to the gas ridge ince then. Still people are throwing stones in to the fracture, yet not filling. The change noticed by local eople so far is ' the intensity of the natural gas leak ' , which was formerly very strong enough to swing rasses and small plants on the mouth of the fracture. Now the intensity of the gas leak has decreased, to the xtent, not felt well in the day times. However, in the evening, through the night and early in the morning the as feeling increases. During the daytime, a warm gas rush can even be felt occasionally if one stands at the acture mouth, and dropping a boulder into the fracture. The best gas rush can be felt, after dropping bigger oulder. The best location for the gas to be felt is just on the highest part of the fracture length (but very angerous).The test of the leaking gas is agreeable, may be with some H_2S (Hydrogen sulfide) content.

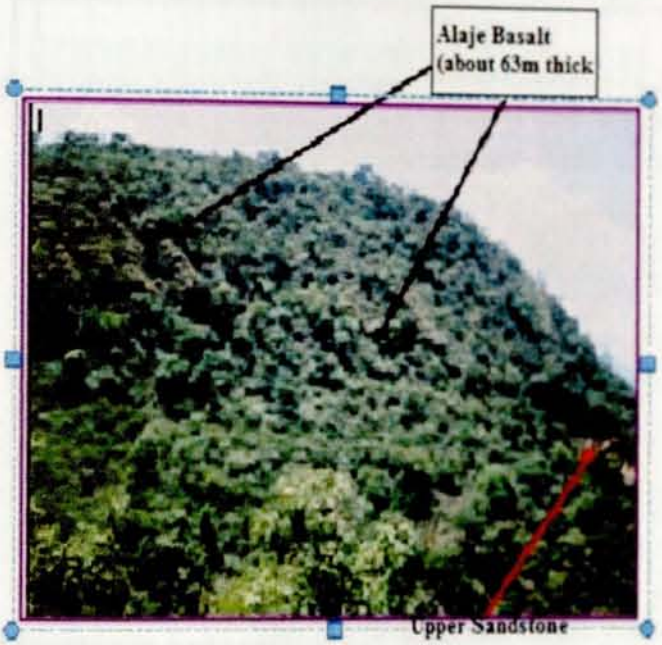
he natural gas seep is from a fracture on "Tulu Badhaaso" Ridge, NW of Iteya village at approximately 1.5 m distance. This ridge is affected by normal faults from almost all sides giving the ridge unique topographic ppearances (Fig. 31) and (Plate 01). On the map Tulu Badhassoo, gas field can be located E 618495 and N 78042(UTM) (Fig.31), and named after Sheik Badhassoo, a man practicing cultural activities on the ridge in ne memorials.

ne natural gas seeping fracture (plate 8) is trending $N5^0E$ and sub- vertically west dipping. The measured size the fracture is around (0.5x15) m. This natural gas was sampled by the author of this paper leading to the poratory analysis failures, due to technical problems. From the field observations made "Badhassoo" Ridge's tural gas seep may be an "associated gas" / hydrocarbon gas, i.e. a gas related to some under lying petroleum servoirs. In another way, the gas ridge site is observed to bear a basaltic dyke trending nearly N-S. This dyke osses Badhasso Ridge capped by about 55m thick basalt (Alaji Basalt). The relation between the natural gas epage and the basaltic dyke and the ridge capped basalt and the basaltic dyke is not clear. Nevertheless, the ke may simply show some deep-seated (?) structure.

e gas leakage might have been started after the recent step faults in the area. These faults have affected the saltic dyke associated to the flood basalt, hence imply post volcanic age. These occurrences might give us o other options of assuming the gas to be a 'volcanic gas' (?).

ulu Badhasso gas seeping hill has unique structural set up, i.e. the three sides are affected by normal step aults, of actually different throws. The western side shows the highest throw of about 100m, while the orthern side is least. The eastern side of the hill has a down throw of about 80m, but, without step faults. The as fracture with 0.50m wide and 15m length and trending N50E and sub-vertically west dipping is on the top f the ridge generally striking N500E. The northwestern side of the ridge has exposed parallel fracture sets, but ithout gas seeps.

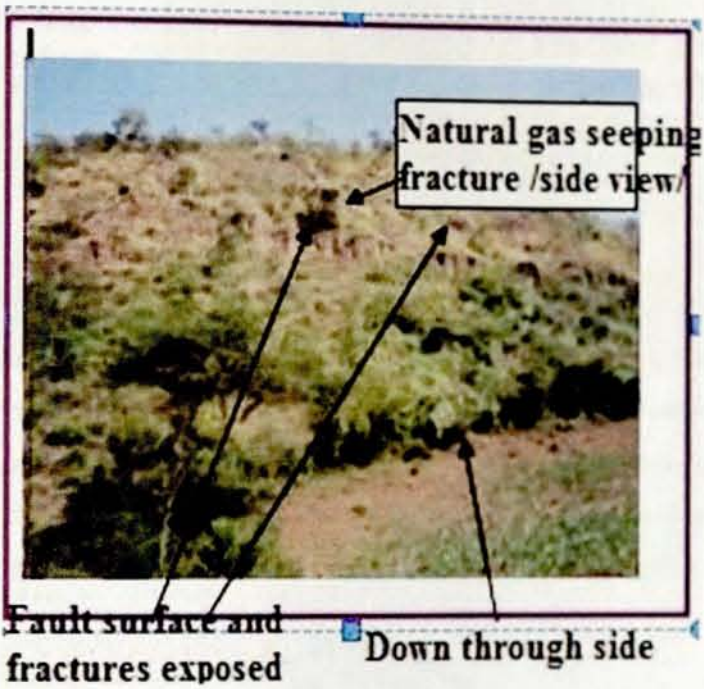
Plate 9. The SSE side of "Tulu Badhaasoo" Ridge, with normal step faults North Sammar, NW Ogaden Basin



ote: the white out-crop at the lower right corner is part of Upper Sandstone Formation, over-laid by Alaji Flood Basalt. Compare the structural difference of this plate with plate 10, which shows the NW part of e same ridge.

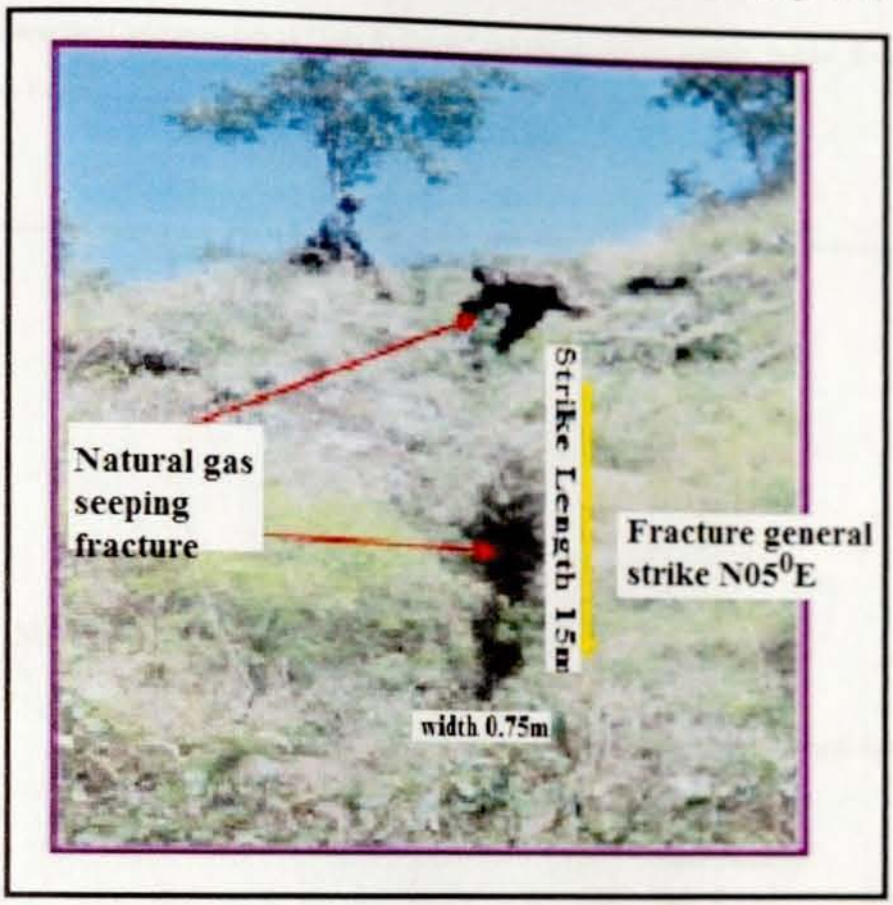
can most probably be an associated gas i.e., a natural gas capping oil reservoirs. "Tulu Badhassoo" or nquftu", (which means a never filled hole or deep fracture) is covered by about 63m thick basaltic sequence Alaji Basalt (Kazmin 1978) / capping the underlying sedimentary successions (here on Badhasso Ridge pper Sandstone). The root of the basaltic cap is observed to be a vertical dyke extending from the main flood asalt the form the Sammar Plateau (Arsi-Central Ethiopian Plateau). Similar thin dykes parallel with Tullu adhassoo Ridge with about 0.50m thickness cover the Iteyya locality (NNE Sammar Village) . This is also early seen in and aerial photo of the locality. The reason behind the gas leak is a fracture developed recently, normal step faults, which affected the ridge in both east and west sides; striking north and sub vertically est and east dipping (Fig 17). The down throw side can be seen NNW of the ridge (Plate 8).

Plate 10. Parallel fracture setting of NW side of 'Tulu Badhaasoo" Ridge North Sammar, NW Ogaden Basin



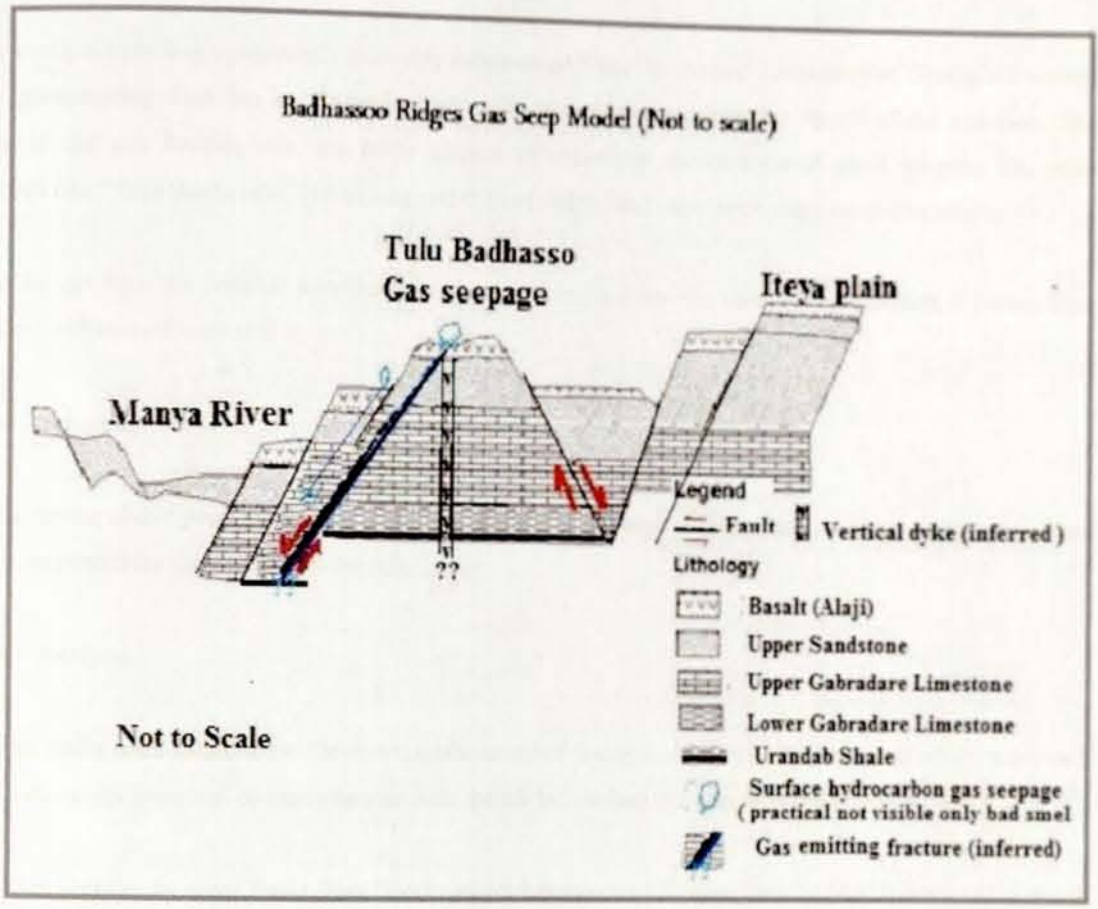
ote: the parallel fractures observed above are not gas emitting, but a peasant crossed a fracture with minor s seep on the down throw side of the ridge. This may be an extension of the main fracture or another ep-seated parallel fracture seeping gas

Plate 11. The natural gas seeping fracture top of Badhasoo Ridge North Sammar,NW Ogaden Basin



ote: The north trending opened fracture is (0.75x15) meter size, and similar fracture is observed on the wn through side of the ridge, by a peasant farming his plot on the down threouhgh side. The discovered ening emits natural gas but re-closed for safety purposes / personal communication with the local people/.

Figure 14. Structural interpretation of "Tulu Badhasso" and the nearby gas seepage, Iteyya , Sude , East Arsii, NW Ogaden Basin



.2.2 Natural gas Laboratory Analysis

- Procedures:

)nly two gas sampling equipment's were able to borrowed from Geothermal Laboratory of Geological Survey The gas-sampling flask has an evacuating system to absorb any gas from the mouth of the emission. The arrower the gas fracture/hole, the better chance of collecting uncontaminated good samples. On wide ractures like "Tulu Badhassoo" (15 m long and 0.75 m wide) , and on an open ridge cannot be simple.

After the gas from the possible mouth of the emission is sucked into the vacuumed glass flask, a rubber head ttached will immediately seal it.

- Sampling:

ollowing the above procedure given from the Geothermal Laboratory technicians, the two flasks were filled y gas emitted from the fracture on the ridge.

- Analysis

he two flasks were submitted to Geothermal laboratory of Geological Survey laboratory and results were only ace indications (personal communications with the lab technician) that cannot be delivered officially.

)ther gas samples by some flasks from Geochemistry laboratory of Science Faculty (AAU) were failed due to jection problems to the gas chromatography in Geochemistry department of the Science Faculty (AAU), and e meet total technical failure at geothermal laboratory of Ethiopian Geological Survey.

Results: Both laboratories cannot achieve any results due to: improper gas collection , contamination (?) roblems and fitting of flasks to gas chromatography in Geothermal laboratory and Geochemistry laboratory respectively.

- Suggestions:

e-sampling the natural gas aided by experts from Geothermal Laboratory (Geological Survey) and/or eochemistry laboratory of Science Faculty (AAU).

8. Discussions and Interpretations

8.1. Discussions

nitially, the interest of the study emerged from community reported Oil-tar ("Hamphee Dakkaa") seepage at "Kile Abba Dhuferra" valley in Sammar Sammariyye Kebele of Sude Woreda (East Arsii) , Oromia Regional State, Central Eastern Ethiopia; at about 265 km distance east of Addis Ababa. The studied locality "Sammar" is geologically part of the Mesozoic Sedimentary Basin of NW Ogaden flank. It is constituted from bottom to top by micritic Upper Hamanlei Limestone; Urandab shale; Lower and Upper Gabradare Limestone and finally Arkosic to Calcarious Upper Sandstone (Ambaradom Formation) of Late to Middle Jurassic age , caped and intruded by Tertiary Trap Series Flood basalt. In "Kilee Abba Dhuuferra" valley (north western part of mapped area) within northern Elele River valley flank, a semi dried black gum (locally named "hamphee dhaagaa", which means "Rock Gum" in "Afaan Oromo" was sampled carefully as : the fluid gum (oil-tar) separately; the gum coated volcanic rock; and the host rock without gum coatings. The geologically mapped and studied area under the name "Sammar Area" is targeted to establish the local stratigraphic set-up and identify the associated hydrocarbon (Oil-tar and Natural gas Seepages) potentials reported by the community. The selected area covers localities from Upper Manya flood plain to upper Wabe Shebelle River gorge (NW to SE) ; and Sammar plateau to lower Elelle flood plain (Guratti). The Hydrocarbon Laboratory analysis result reported: liquid residue showing 1672.35 and 1769.93 Cal/gm and gum from rock showing 1690.25 and 1560.07 Cal/gm); while the host rock becomes basalt. The analysis proved that the formerly known traditional medicine locally named "Hamphee Dhakaa" (Rock–gum) hosted by volcanic rock (basalt) sequence is then somehow proved to be an oil-tar seepage of atypical petroleum systems (?).The natural gas seep on top of "Tulu Badhasso Ridge" (northeastern Sammar) is from 15 m long and 0.75m wide-open fracture, trending $N5^0E$, paralleling the major basin floor structures trend locally."Tulu Badhaassoo" is a small ridge constituted by Upper Sandstone capped by 60m thick Alajei (?) Basalt, striking almost NNE-SSW and sub vertically west dipping.

The discussions made below mainly focus: previous works (uses and limitations); results achieved and suggestions.

There was no regional (1: 250,000) to semi-regional (1:50,000) mapping work available over the area mapped locality. The only work reported on nearby locality are regional mappings, at (1:250,000 scale) by V. Kazmin (1978) and 1:100,000 scale by BECIP (1985). The former mapped north of Manya, while the later mapped south of Dharro , based satellite and aerial photo interpretations. Unfortunately BECIP, 1985 interpretation based mapping has assigned a thick limestone (transitional unit between Upper and Lower Gabradare Limestone Formation) as Urandab Shale. However, Urandab Shale is not out-cropping on the flanks of Dharro River valley and around (Abulkassim Mt) but in the Shabelle river gorge ; exposed on new built Mechar (West Harage) – Dire Shek Hussen (Bale) all-weather road

The shortcomings include, not only V. Kazmin, 1978 was mapping an area beyond the current mapping, but also focuses also on volcanic rock geochemistry and sequences only. BECIP 1985, mapping is not also covering many parts the current area; but only a small part in the southern flank. Moreover, BECIP, 1985 mapping ground traverses and controls but only Land Sat Satellite and air photo interpretations. As a result, the mapping by BEICIP (1985) at 1: 1,000,000 scale from Land sat satellite imagery interpretation only around Mt. Abul Kassim , between Dharro River and Wabe River Gorge showed Urandab Shale, to out-copping. But, now, this isb turned out to be "Transitional Zone with black limestone beds (?) occurring between Upper Gabradare (intertidal to shallow marine) facies and Lower Gabradare Limestone of deep sea facies.

However, Urandab Shale is observed to out-crop in the nearby Wabe Shebelle River gorge, over laid by the Lower Gabradare Limestone and under laid by Upper Hamanlei; in agreement with the regional established formal stratigraphic succession of the Ogaden Basin. This author's conclusion's may require more mappings and samplings anyway, which must be further verified.

Many parts of the central and eastern Ogaden Basin is somewhat better explored by private petroleum companies as compared to northwestern parts of the basin like "Sammar area". Few data available on southern and eastern parts of the mapped area is only from Land Sat Satellite interpretations, without ground traverse controls ; and had drow backs like the Urandab Shale out-cropping map of BECIP 1985, for example.

The established stratigraphic set up of the mapped locality was strongly favored by new buolt road cut from Mechara to Dire Shek Hussen village (Bale). Mappings without regional reference were significantly confusing, especially in the carbonate areas. However, the easily recognizable Upper Sandstone was a good marker horizon to establish the following successions (from general litho-strtagraphic set of the basin). The traverse from Seru to Dharro on dry weather road and the all-weather truck road section from Dharro to Wabe Shebelle Gorge were of significant value to see cross-sections. Under all this constrains and limitations the mapping conducted and lithostratigraphic section can fill some data gaps for future works.

- Oil-tar seepages of Sammar Study area.

The possible generation of oil/tar seepages can be a point of discussion also. The possible source rock, here is Urandab Shale and Hamanlei limestone Formation (?). If we suggest Urandab Shale, the depth of burial seems critical to generate petroleum. But, the total thickness of the sedimentary succession and the overlaying the volcanic sequence on top Urandab Shale will be can be estimated to be about 1.7 km. But, since this locality is close to or surrounded by volcanic centers, the geothermal gradient can be high enough to generate petroleum (?) from Urandab Shale. Additionally, beyond the above background, the existence the proved Gelemso Oil/tar seep in similar formation, NNE of Sammar Oil/tar site, support the possible petroleum generation around.

This study is expected to have revealed new ideas, proved past works, and filled data gaps in this part of the Ogaden Basin to be discussed as follows. Some incomplete or questioning ideas are also discussed to be considered as a base for further studies.

- Natural gas seepage

The community discovered oil-tar and natural gas seepages were some of the new works to undertake during the study. Mapping and sampling along with accessibility was a challenge. Limitations of the work to one or two field trip program have made to incomplete; analysis results tried in vain. Initially the Geothermal laboratory technicians and Geochemistry lab group of Science Faculty suggested doing samplings by their experts; which was unaffordable; beyond the inaccessibility of the terrain.

Theoretically, such surface hydrocarbon indications hosted by flood basalt, can be from igneous intruded matured (organic rich) sedimentary successions, classified may be as ***Atypical petroleum system***, i.e., oil -tar seepages from igneous intrusion cutting organic rich beds. Moreover, the observed seepage being along deep seated (?) north-south verses east-west normal step fault systems. Hence, the "Sammar" oil-tar indication can be assumed from deep-seated oil reservoirs that developed normally (***Typical petroleum systems (?)***). Other similar oil-tar seepages reported by the community, worth considered include Dharro – Kile Guratti; Lilo- Kile Guratti (lower Manya and Shanan River) and lower Elelle River (Guratti) valley; not visited by the author. These basin floor surface occurrences can be associated to Delemso Oil-seep from Gabradare Limestone located few tens of km from "Sammar" towards NNE.

Finally, the hydrocarbon (oil-tar or natural gas seepages) of Sammar Area mapped or beyond along the zone, hence, seems somehow reasonable to speculate the possible petroleum formations factors: Source Rock- Gandab Shale; Reservoir-Lower/Middle Upper Gabradare; Trap–stratigraphic type; and Cap Rock- Lower part of the Upper Gabradare Limestone or the volcanic associated structures in western margins).

2. Interpretations

From the sedimentary succession's general stratigraphic position of the Ogaden Basin, and few marine fossils observed and previous data on the nearby lithology (V.Kazmin, 1978) age of the mapped sedimentary units are assumed to be within Middle to Late Jurassic and Lower Cretaceous age .

The field data gathering and sampling of Sammar's lithostratigraphic successions, and hydrocarbon indications not only from inaccessible sites but also from highly rugged terrains; making the work difficult and limitted. The areal extent of the interesting locality (community information on seepages) is even very wide, and previous data is scarce. The lithostratigraphic formations mapped and hydrocarbon indications studied are from limited field observations, laboratory data, and previous work. Nevertheless, the existence of limestone intercalation within the top part the Upper Sandstone Formation and the gradational contact exists between the

pper Sandstone and Upper Gabradare Limestone Formation. may suggest us to think of some new ideas on e age, facies analysis and environment deposition of this formation. Moreover, some structural disturbances ere observed around the localities where the fossiliferous limestone intercalate the Upper Sandstone. evertheless, the sandstone units out-cropping on top and bottom of fossiliferous limestone intercalation are rmal. Additionally, the natural gas seeping Badhasoo Ridge is at the foot of the Upper Sandstone units with ssiliferous limestone intercalation. The gas ridge is actually observed to be affected by series of normal step ults, which its relation with fossiliferous limestone intercalation hosted sandstone unit is not clear. Therefore, the fossiliferous limestone intercalation within the Upper Sandstone depositional or structural emplacement). Is the structure that affects "Tulu Badhasoo" same with structure that affects fossilliferous limestone tercalation hosted sandstone unit (?). What is the possible relation between the gas seepage and structures ound (?).

. Conclusions and Recommendations

.1 Conclusions

he litho-stratigraphic and structural mapping and geochemical sampling conducted at Sammar and its rrounding, has showed the existence Mid to Early Cretaceous Sedimentary successions, comprising the pper Sandstone, Upper Gabradare and Lower Gabradare Limestone , Urandab Shale , and Upper Hamanlei imestone Formations having an overall maximum exposed thickness of 1km. All contacts between the edimentary successions are gradational, including Upper Gabradare and lower part the Upper Sandstone ormations ; Contrarily to previous assumptions.

he other major outcomes of the study is to map and sample surfacial hydrocarbon indications in lower and pper Elele River valley flanks and its tributaries; Dharro and Shenana River valleys. The natural gas seepages nay hydrocarbon gas) is discovered emitting from a north- south striking mega fracture on Tulu Badhasso nall ridge capped by 60 m basat in the main basin floor.

ne Tertiary Flood basalt, partially covering and intruding the sedimentary successions in the western margins the mapped locality is observed to have some relations with major oil-tar seepages of Sammar to consider ere. There may be thicker volcanic sequence pile in the flank of basin margin but, an overall maximum ickness of about 1.1 km as seen in the Elelle River valley.

ne hydrocarbon indications observed includes surficial oil-tar seeps, and natural gas (?) within the Trap eries basalts and Upper Gabradare Limestone Formations (?). The surficial natural gas seepage of Tulu adhasoo Ridge is from a sedimentary succession capped by 60m (Alaji) Basalt (Kazmin, 1978). The mpling of this gas was in vain, due to problems in sampling techniques.

ne mapping showed the out-cropping of Urandab Shale (important matured petroleum source rock in Central gaden) in Wabe Gorge, which helps to suggest about the possible Sammar Oil/tar and Natural gas source ck generations. The Gelemso Oil seep that occur NNE Sammar can be also explained similarly.

short, the present mapping established the lithostratigraphic succession of the locality, explained the facies alysis and determined the possible environment of depositions of the sediments.

The two petroleum systems suggested are: Atypical Petroleum Systems, for oil/tar seeps within flood basalt of Elelle River valley and the surroundings; and 'Typical Petroleum System' for oil/tar seeps and natural gas (?) within the sedimentary succession, like Upper Gabradare Limestone Formation.

Surface oil-tar and natural gas seeps are commonly associated to normal step faults of various orientations; but generally trending North-South and sub vertically east, west, north, or south dipping. Some of these structures are related to the main Ethiopian Rift generating structures, or younger. Hence, most structures that possibly affected the cap rock in the surrounding is rift related (?).

5.2 Recommendations

The area studied was new and hence, the theoretical achievements (mapping, data generated , etc) , proof of the community reported hydrocarbon potentials (oil-tar and natural gas) can have some significance in filling geological information gaps . More over this work as compared to what shall be accomplished can be very small, due to scope of the work and capacity.

Hence , taking what was done as a spring board , many: geological; geochemical; structural ; hydrocarbon (oil and natural gas), occurrences; etc can be widely and deeply undertaken to reveal what is available or upgrade what is accomplished.

Nevertheless, taking into consideration about the general idea recommended, the following particular recommendations were given:

A. Geological mapping and sampling shall be extended and refined in or around the current study area, uncovered by past workers;

B. Two types hydrocarbon (oil-tar) field occurrences , with respect to hosting lithology are available, requiring further detail study; volcanic sequences hosted or associated seepages like : upper Elelle River valley , etc.); 2. Basin floor hosted (within sedimentary successions) seepages, like "Gile Guratti, Dharro, "Kile Adi" , etc. Both occurrences need wide study (from surficial to sub-surficial) to understand the origin, formations, etc and determine how to use (economic resources).

C. The Natural gas seepage of "Tulu Badhasso ", which at most is hydrocarbon and economic (?) require immediate study (gas sampling by Geothermal Technicians or AAU, Science Faculty Earth Science and Geochemistry Departments, etc. and sample analysis (in house or abroad) ;

D. The hydrocarbon surface occurrences are not restricted to the currently mapped locality only. It has a wide area coverage extending to Gelemso oil seepage (known by Ministry).

E. The above, NW Ogaden Basin extension zone is part of the NW Karoo Graben arm (?) connecting to Blue Nile Basin (?).So, the assumed pinching central Ogaden Basin thick and deep sediments including Urandab Shale (best source rock) westward of Gerbi-1 well (Petroleum) require significant reconsideration (as the litho-stratigraphic mapping in Wabe Shebele Gorge –across newly built Mechar (West Harage) to Dire Shek Hussen village (Bale) , reveals opposite , i.e., thick Upper Hamanlei, Urandab Shale and Lower Gabradare Formations (?). along with this the BECIP 1985 , regional interpretation map shall be revised (?).

F. Many of the works mentioned above may need foreign investments or may demand huge capitals, to advertise and invite foreign petroleum companies.

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nnexes

nnexes (A) – Plates: Microphotograph of thin-sections

nnex AI : Plates of Upper Sandstone

nnex AII: Plates of Upper Gabradare Limestone

nnex IA - Plates of Upper Sandstone

ate 1A to 5A; Upper sandstone (top part) from Iteyya Village (NE Sammar), and East Seru

1. Plate 1A (10x): Arkosic (coarse grain and reddish) SST (Top of Upper SST) ; NE Sammar, Near Iteyya Village
2. Plate 1B (10x , XPL): Arkosic (coarse grain and reddish) SST (Top of Upper SST) ; NE Sammar, Near Iteyya Village
3. Plate IA (5x): Arkosic (Lower fine variegated) SST (Top middle Upper SST) ; NE Sammar, Near Iteyya Village
4. Plate IB (5x , XPL): Arkosic (Lower fine variegated) SST (Top middle Upper SST); NE Sammar, Near Iteyya Village

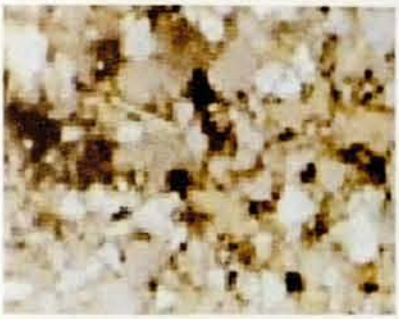


Plate 1A(10x)

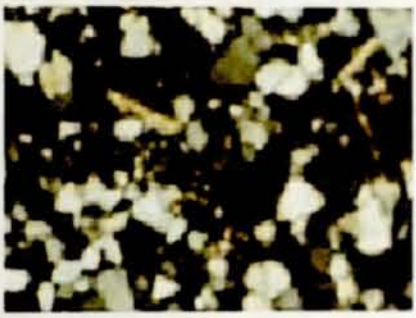


Plate 1B (10x, XPL)

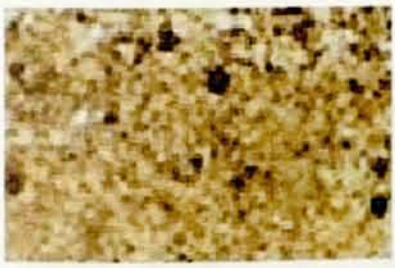


Plate IA (5x)

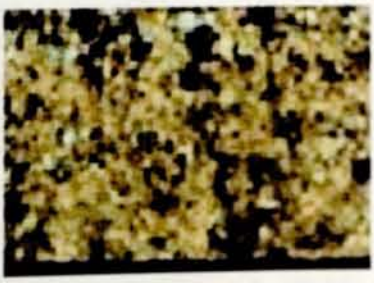


Plate IB (5x, XPL)

tes 3A to 5A: Variegated fine sandstone undelaying the top Arkosic Sandstone

ate 3A (10x): Arkosic (coarse grain and reddish) SST (Top of Upper SST) ; East Seru, (Road cut).

ate 3B (10x , XPL): Arkosic (coarse grain and reddish) SST (Top of Upper SST) ; East Seru, (Road cut).

ate 4A (5x): Arkosic (lower coarse variegated) SST (Top middle Upper SST) ; East Seru, (Road cut).

ate 4B (5x , XPL): Arkosic (lower coarse variegated) SST (Top middle Upper SST); East Seru, (Road cut).

ate 5A (5x): Arkosic (lower fine calcareous) SST (Top middle Upper SST) ; East Seru, (Road cut).

ate 5B (5x , XPL): Arkosic (lower fine calcareous) SST (Top middle Upper SST); East Seru, (Road cut).

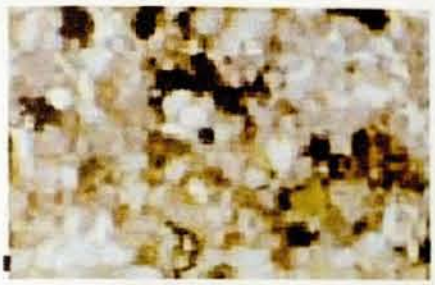


Plate 3A (10x)

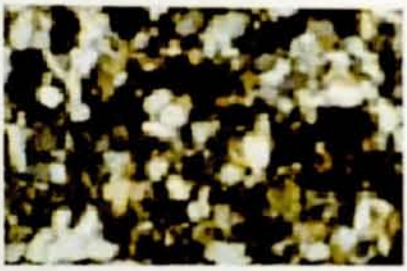


Plate 3B (10x , XPL)

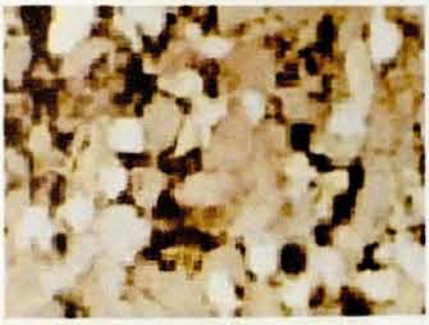


Plate 4A (10x)



Plate 4B (10x, XPL)

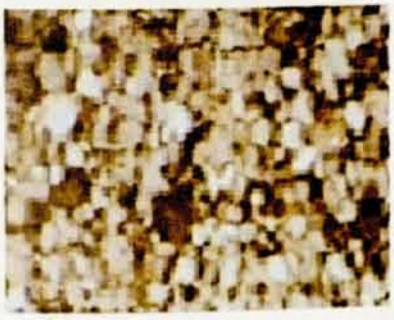


Plate 5A (5x)

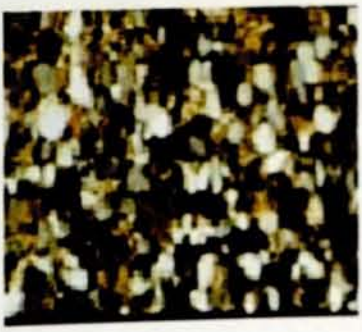


Plate 5B (5x, XPL)

nnex IIA - Limestone Plates

tes 6A to 7A: Fossiliferrous limestone (intercalation within the Arkosic sandstone, locally (SW of yya Village, NE Sammar).

Plate 6A (5x , XPL): Coarse poorly sorted limestone (intertidal)

Plate 7A : (5x) Medium grain sorted limestone (intertidal)

Plate 7B:. (5x, XPL) : Medium grain sorted limestone (intertidal)



Plate 6A (5x, XPL)

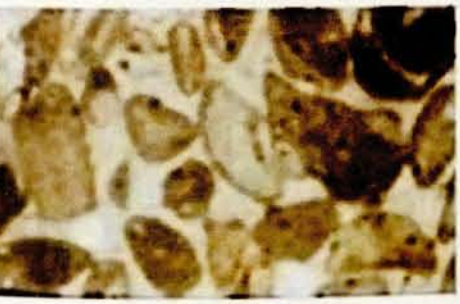


Plate 7A (5x)



Plate 7B (5x, XPL)

te 8A , Plat 8B; Plate 9A to Plate 9C: Top part of Upper Gabradare fossilferrous Limestone rmation

Transitional zone between Upper Gabradare and Upper Sandstone (Lower part of Upper Sandstone).

Plate 8A (10x) Top part Upper Gabradare (macro fossiliferrous limestone (intercalation within the Arkosic dstone).

Plate 8B (10x , XPL) Top part Upper Gabradare (macro fossiliferrous limestone (intercalation within the kosic sandstone).

Plate 9A (10x , XPL) ; Fossil (?) from macro fossiliferrous limestone (intercalation within the Arkosic dstone) (Top part Upper Gabradare)

late 9B (10x): Fossil (?) from macro fossiliferrous limestone (intercalation within the Arkosic sandstone) p part Upper Gabradare)

Plate 9C (10x): Fossil (?) from macro fossiliferrous limestone (intercalation within the Arkosic sandstone) p part Upper Gabradare)

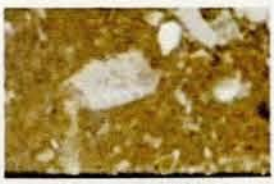


Plate 8A (10x)



Plates 8B (10x, XPL



Plate 9A (10x, XPL)



Plate 9B (10x)



Plate 9C (10x)

Note : fractures filled by calcite

e 10A and Plate 10B: Middle part of Upper Gabradare (micro fossilferrous limestone(East Seru
n- Road Cut out-crop)



Plate 10A (10x)



Plate 10B (10x, XPL)

e 11A and Plate 11B: Middle part of Upper Gabradare (micritic fossilferrous limestone(East Seru
n-Road Cut out-crop))



Plate 11A (10x)

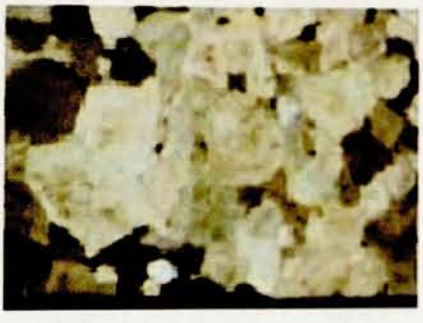
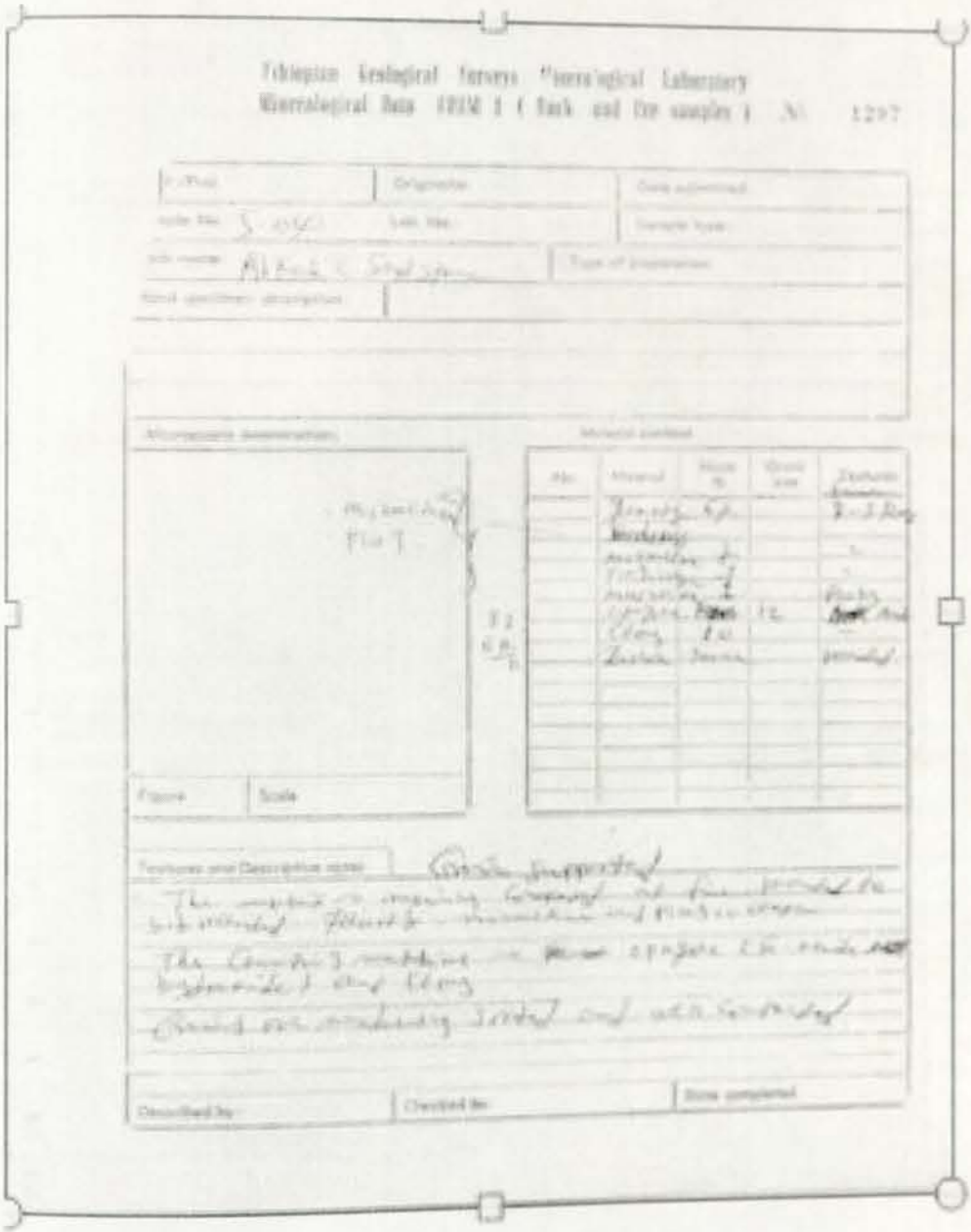


Plate 11B (10x, XPL)

nnexes (B)

thological laboratory analysis descriptions of thin-sections.



Fitchburg Geological Survey Petrological Laboratory
Mineralogical Data FORM I (Rock and Ore samples) No. 1297

	Originator	Date submitted
# No. S-05	Lab. No.	Sample size
# name Black Slate		Type of preservation
Field specimen description		

Microscopic examination

Figure | Scale

Mineral content

No.	Mineral	Mode %	Grain size	Texture
	Graphite	20		Fine
	Pyrite	5		
	Muscovite	5		
	Clays	70		
Fr. Thin	Opaque	10		
	Biotite	Trace		

Texture and Descriptive notes: Clastic Sediment

Medium to fine grained, Thinly laminated, Graphitic Clay Slate (Fe oxide stained)

The laminations are due to clay and graphite

Grains are well sorted & well rounded

Described by | Checked by | Date completed

Ethiopian Geological Surveys Mineralogical Laboratory
Mineralogical Data FORM I (Rock and Ore samples) No. [illegible]

Dept./Div.	Originator	Date submitted
Sample No. S-912	Lab. No.	Sample type
Rock name: [illegible]	Type of preparation	
Hand specimen description		

Microscopic examination:

Mineral content

No.	Mineral	Mode %	Grain size	Remarks
	[illegible]	83		[illegible]
	[illegible]	7		S. [illegible]
	[illegible]	3		V. [illegible]
	[illegible]	5		S. [illegible]

Figure | Scale

Textures and Descriptive note

[illegible] Consists of fine grained [illegible] Calcite [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]

Described by: | Checked by: | Date completed

Ethiopian Geological Surveys Mineralogical Laboratory
Mineralogical Data FORM I (Rock and Ore samples) No. 1297

Dept./Proj.	Originator	Date submitted
Sample No.	Lab. No.	Sample type
Rock name		Type of preparation
Hand specimen description		

Microscopic examination

Mineral content

No.	Mineral	Modal %	Grain size	Textures

Figure | Scale

Textures and Descriptive notes

Hand by | Checked by | Date completed

Ethiopian Geological Survey Mineralogical Laboratory
Mineralogical Data 10/88 [illegible] Rock and Ore samples [illegible] 1991

Client / Proj.	Originator	Date submitted
Sample No.	Lab. No.	Sample type
Rock name:		Type of preparation
Hand specimen description:		

Microscopic examination

Mineral content

Abn.	Mineral	Mode %	Grain size	Textures

Figure | Scale

Textures and Description notes:

Described by | Checked by | Date completed

Ethiopian Geological Surveys Mineralogical Laboratory
Mineralogical Data FORM I (Rock and Ore samples) N: 1298

Dept./Proj.	Originator	Date submitted
Sample No. S-10	Lab. No.:	Sample type:
Rock name: fossiliferous micrite (Biomicrite)	Type of preparation	
Hand specimen description:		

Microscopic examination:

74
76

Fe oxide on

Mineral content

Abr.	Mineral	Mode %	Grain size	Textures
	Micrite	76		V.V.fine
	Fossils	20		
	Feldspar	3		V.fine
	opaque	1		V.fine

Figure | Scale

Textures and Descriptive notes: Microcrystalline texture. The matrix is composed of microcrystalline calcite (micrite). Fossils of Brachiopods, Gastropods are suspended of the micritic matrix. The shell of some of the fossils is made of fine calcite crystals

Described by: | Checked by: | Date completed

Ethiopian Geological Survey Mineralogical Laboratory
Mineralogical Data FORM 1 (Rock and Ore samples) No 1001

Client / Prob.	Originator	Date submitted
Sample No. S-09	Lab. No.	Sample type
Rock name: Micrite limestone		Type of preparation
Hand specimen description:		

Microscopic examination:



Figure | Scale

Mineral content

Abr.	Mineral	Mode %	Grain size	Textures
	Micrite	80	5T	Allotrio
	Quartz	10		Q-f R
	Calcite	25		V fine
	Opaques	trace		V fine
	Hematite			
	Limonite			
	Siltstone	10		Fine S R

Textures and Descriptive notes: Microcrystalline texture. Patches of calcite dominantly fill the matrix. Some details of calcite grains are seen over the matrix.

Described by: | Checked by: | Date completed:

Ethiopian Geological Survey Mineralogical Laboratory
Mineralogical Data FORM 1 | Rock and Ore samples | No. 1297

Depot / Prod.	Originator	Date submitted
Sample No. S. of B	Lab. No.	Sample type
Rock name A Highly Sand Stone	Type of preparation	
Hand specimen description		

Microscopic examination

Mineral content

No.	Mineral	Mode %	Grain size	Texture
	[illegible]			[illegible]
	[illegible]			[illegible]
	[illegible]			[illegible]
	[illegible]			[illegible]
	[illegible]			[illegible]
	[illegible]			[illegible]
	[illegible]			[illegible]

Figure | Scale

Textures and Descriptive notes

[illegible]

Described by | Checked by | Date completed

Ethiopian Geological Surveys Mineralogical Laboratory
Mineralogical Data 1978 ( ) Rock and Ore samples ( ) N: 1297

Chart (Prof.) | Originator | Date submitted

Sample No: S-078 | Lab. No.: | Sample type

Rock name: A Hard Sand Stone | Type of preparation

Hand specimen description:

Microscopic examination

Mineral content

Abr.	Mineral	Mode %	Grain size	Texture
	Qtz	70		P.S.A.
	Feldspars	5		
	Plagioclase			
	Muscovite	2		Flaky
	Zircon	Rare		Anhedral
	Carbonate	5		Anhedral
	Opaques	5		Anhedral

(Quartz) Subrounded

Figure | Scale

Textures and Descriptive notes: Grain Supported

This is an arenite composed of fine Detrital grains mineralogically Feldspathic

The Cementing material is Carbonate & Calcite and Sericite (?) and some opaque (Fe oxides & hydroxides)

Grain size: Well Sorted and well Rounded

Described by: | Checked By: | Date completed:

Annex (C)

Laboratory analysis result of Oil-tar seepages /Hydrocarbon/ from Kile Aba Dhuferra Valley Samar (Northern face of Elelle River Valley)

Central Geological Laboratory
Hydrocarbon Laboratory Data Coding Form

Dept/Proj: PET
File Name:034/2001
Originator: Mustafa Sherie *Number Of Samples: 2*
Approved By: Head Of C.G.L *Nature Of Samples: Basalt rock chip and black viscous liquid*

Area (of : SE30 48, 50 20, E 43 7 48 0)
Date Recd: 2/06/99 (08/2007)
Analysis Required: Proximate Analysis (Moisture, Volatile matter, Fixed carbon and Ash), Calorific value(Cal/gm) Specific gravity and Distillation.

Collector's Sample No.	Laboratory No.	Moisture %	Volatile matter %	Fixed carbon %	Ash %	Calorific value Cal/gm	Specific gravity gm/cm^3
Jr-04 Liquid-Residual	034/2001	3.10	42.14	3.32	49.83	1872.10	1.0 gm/cm^3
Jr-04 Liquid Residue F	034/Dup	3.61	49.31	1.71	46.13	1769.93	1.06 gm/cm^3
Jr-04 Solid	034/2001	1.98	11.89	<0.01	86.97	<24	2.90
Jr-04 Solid	034/Dup	2.34	11.85	<0.01	85.16	<24	2.88
Core from rock	034/	3.37	12.33	<0.01	85.28	1890.25	2.61
Core from rock	034/Dup	3.39	12.36	<0.01	84.29	1560.87	-
Jr-04 Liquid distillate (top) Residual	034/2001	7.62	37.68	1.41	53.43	<24	-
Jr-04 Liquid distillate mat Residual	034/2001	17.83	44.43	0.7	37.08	<24	-

Distillation Results: - From 250 ml of Black viscous liquid is distilled 170 ml of water at 91°
- Above 91° the viscous Liquid was difficult to distil because of foaming

Date Completed: 07/07/1999 (14/03/2007)

Checked by:

Analysis: Hydrocarbon Group *Chief Chemist*

Head of Hydrocarbon Lab

Back cover page photo plate Traditional Transportation / Accessibility/

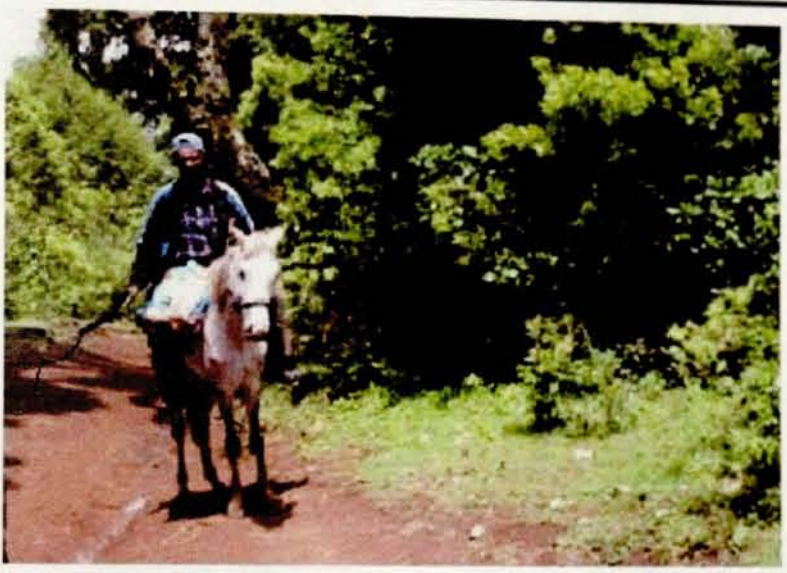


Plate : Traditional transp[ortation during the feild work, Hula Gadii Locality, Sammar Kebele, Sude Woreda, Arsi Zone.