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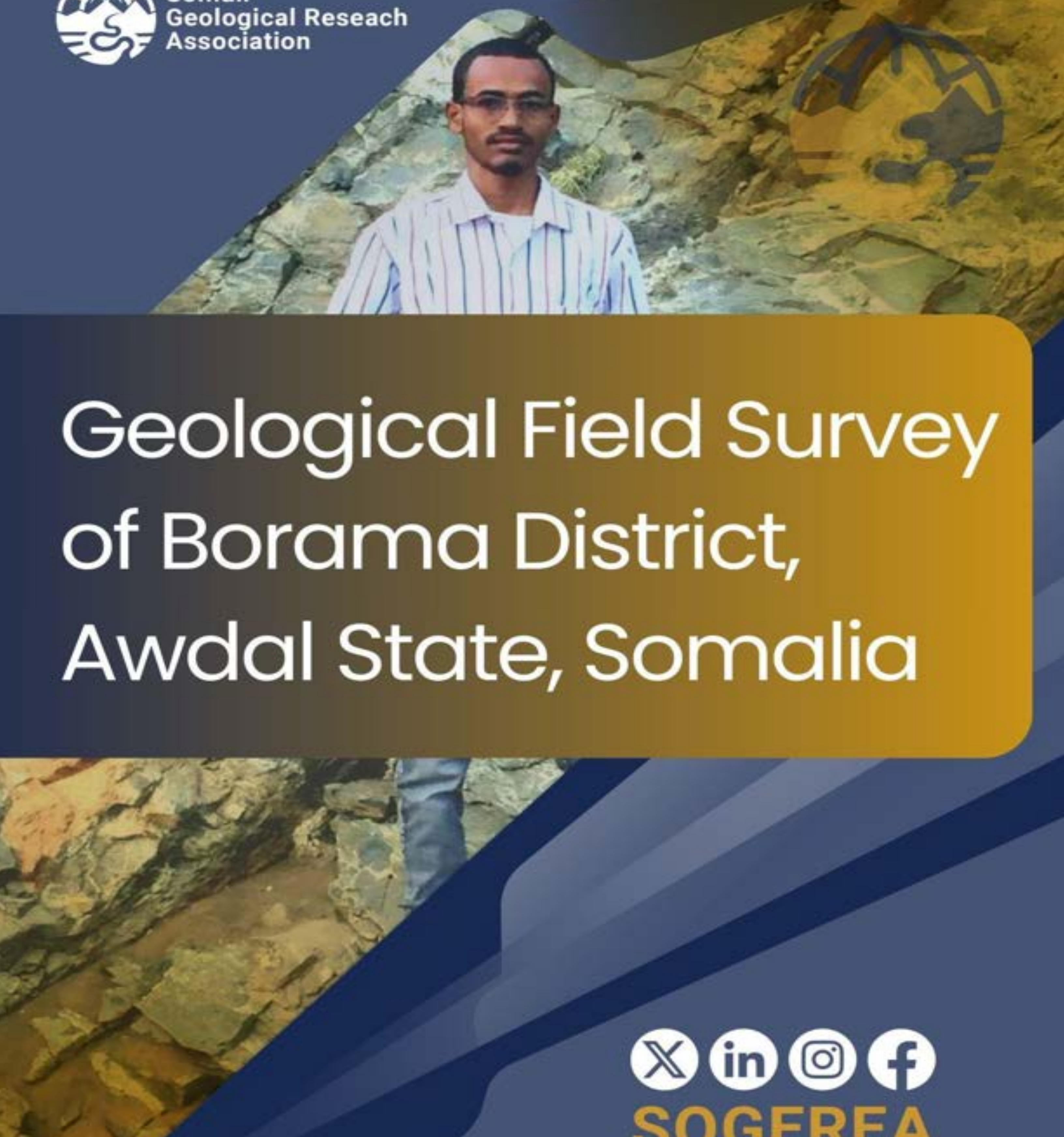

Geological Field Survey of Borama District, Awdal State, Somalia

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Somali Geological Research Association
International Journal of the Geology Sciences vol (1), issue 01, November 27, 2022
SOGERA: 10/IJGS11© 2022 Academic Journals
https://sogera.org/puplications/geology/2022.e10.59

Geological Field Survey of Borama District, Awdal State, Somalia

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Abstract

This report offers findings from a geological field survey undertaken in Borama region of Awdal State, Somalia, conducted in September of 2022. In total, the research dealt with nine selected sites, namely, Faraxyada Hills, Dunbuluq Mountain, CaraQoolaab Hill, Qoorgaab Valley, Hadmacan Mountains, Fuleyfule Mountain, Sharlaganaadi Mountain, Sheylaha Mountain and Sogsogley Mountain. These sites were selected for field investigations based on such criteria as diverse and complex geological features and potential resource exploration. The key objectives included rock types and mineral identification and characterizing geological formations, studying environmental challenges, and providing materials for future research. The survey revealed the area's complicated geological history characterized by multiplicities of metamorphic, igneous, and sedimentary rocks including schist, phyllite, gneiss, marble, basalt, granite, Diorite, tuff, and quartzite. Mapping of geological, hydrological, and environmental features constituting these sites will be undertaken using remote sensing techniques. Environmental issues, like those mentioned above, are discussed together with measures for sustainable management. The study further brings out the potential economic importance of the natural resources in this region in order building materials and stones. The study would describe the actions contributing to the general idea about tectonic magmatism and sedimentation processes of this region, while also providing pragmatic recommendations for administration of resources and conservation of environment.

Keywords: Borama geology, metamorphic rocks, igneous rocks, sedimentary formations, remote sensing, environmental impact.

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1. introduction

Geological studies are critical in understanding the history of Earth, resource potential, and environmental challenges. The geological diversity found in Somalia offers many possibilities for exploration and research. This report constitutes a geological field survey carried out in the Borama region of Awdal State with specific reference to nine distinctly defined sites from a geological perspective. The main objectives were to bring an account of rock types and minerals, characterize geological formations, recognize environmental problems, and provide a baseline for future research. This study strives for a contribution to the sustainable development of Somalia's available natural resources, which are primarily required by sustainable economic growth and environmental preservation.

Geological Surveys assume its capabilities in the formulation of Earth's history, provision of resource potential, and spells of environmental hazards alike, which could, in themselves, be valuable assets to mankind. Somalia, because of its diverse geological

enshrines, opens unanticipated possibilities for exploration and investigation. This report incorporates data from a field geological surveying in Borama, Awdal State in Somalia, conducted during September 2022. Specifically, the survey traversed the Faraxyada Hills, Dunbuluq Haya-Yaabe Mountain, CaraQoolaab Hill, Qoorgaab Valley, Hadmacan Mountains, Fuleyfule Mountain, Sharlaganaadi Mountain, Sheylaha Mountain, and Sogsogley Mountain. Certainly, these places were strategically chosen citing their similar geologic features and potential for resource exploration.

This survey had the following principal objectives:

1. To determine the rock types and record the mineralogy from each of the great palaces.

2. To study the formations to infer the tectonic history of the area.

3. To provide groundwork for future geological and mineral resource explorations in the region.

The significance of the study in contributing to sustainable utilization of Somalia's natural resources is paramount as these resources constitute fundamental prerequisites for both economic and environmental sustainability across the country.

2.Study area

The Borama region in Awdal State, located in northwestern Somalia, is part of the Northern Somali Basement (NSB), characterized by geological complexity brought about by differential sedimentation, metamorphism, and magmatism. This this chapter describes the geological field survey of the Borama district and its surroundings, showing the more important geological formations such as the Abdulkadir Complex, Mora Complex, and GabbroSyenite Belt, The chapter also presents an overview of the geology of some of the most important hills and mountains around Borama, which furnishes basic information concerning the tectonic, magmatic, and metamorphic histories of the area.

The few publications appeared in the 60’s represent an extension of this second stage (GREENWOOD, 1960, 1961; GELLATLY, 1961, 1963, 1964; DANIELS et al., 1965; GREENWOOD and BLEACLKEY, 1967; GREENWOOD et al., 1967): they present more detailed analyses and/or interpretation and/or descriptions of some aspects of the NSB, In generally, The Northern Somali Basement (NSB) is poorly understood, with scarce data on its structure, lithostratigraphy, and geological history. Its connections to nearby crystalline basements in Ethiopia, Kenya, the Arabian-Nubian Shield, and the Mozambique Belt are unclear, with most theories based on limited evidence. Additionally, there are few reliable radiometric age measurements from before 1987.

The NSB consists of seven main rock complexes, categorized into five metasedimentary sequences and two igneous, plutonic complexes. The metasedimentary sequences, ranging from medium to high-grade metamorphic rocks to greenschist-facies and low-grade rocks, include the Qabri Bahar, Mora, Abdulkadir, Mait, and Inda Ad complexes. The igneous complexes include the Gabbro-Syenite Belt and the Younger Granites, each contributing to the diverse geological history of the NSB. Many Geological field has conducted several surveys to map the country’s geological resources.

These surveys have identified significant mineral resources, including gold, copper, iron ore, and rare earth elements. However, much of Somalia’s geological potential remains underexplored due to historical and logistical challenges. These surveys have identified significant mineral resources, including gold, copper, iron ore, and rare earth elements. However, much of Somalia’s geological potential remains underexplored due to historical and logistical challenges. This survey builds on earlier research by providing updated data on the geological characteristics of specific mountainous areas around Borama. It aims to fill the knowledge gaps and provide a detailed understanding of the region’s geology, which is essential for effective resource management and environmental conservation.

2.1 Abdulkadir Complex

The Abdulkadir Complex, located in the Harira-Abdulkadir area west of Berbera, Somalia, is characterized by a sequence of less metamorphosed volcano-sedimentary rocks. These rocks are believed to unconformably overlie older, more metamorphosed basement rocks, such as those found in the Mora and Qabri Bahar Complexes, which exhibit a high degree of metamorphism. This stratigraphic relationship suggests a significant geological unconformity at the base of the 2.1 Abdulkadir Complex Abdulkadir Complex (E. ABBATE, 1993) The composition of the Abdulkadir Complex includes quartz-phyllites, muscovite-chlorite schists, quartz-rich schists, with minor intercalations of quartzites and marbles. The presence of metarhyolites & acidic metavolcanoclastics, alongside minor basic metavolcanics and metavolcanoclastics, points to a bimodal magmatic event. This bimodal magmatism is marked by a distinct compositional gap, between the acidic and basic rock types, reflecting a unique geodynamic setting during its formation (GREENWOOD J.E. 1961).

(SAID A.A. 1987) Petrographic studies indicate that the Abdulkadir Complex underwent a single metamorphic event under intermediate pressure conditions. Evidence of this is seen in the presence of kyanite in aluminum-rich quartzites at Damal and a variety of greenschist facies mineral assemblages in metabasites. The observed range of metamorphic grades suggests that some areas of the Abdulkadir Complex may have experienced medium to highgrade metamorphism. This variation in metamorphic conditions could complicate distinguishing the Abdulkadir Complex from the adjacent Mora Complex. Chemical analyses of the metarhyolites in the Abdulkadir Complex show significant compositional alterations, likely due to hydrothermal processes and chemical changes during metamorphism. These alterations add complexity to the geological interpretation of the complex.

The Abdulkadir Complex shares similarities with other low-grade volcano-sedimentary sequences within the Northern Somali Basement (NSB). For instance, a comparable sequence at Jirbi, consisting of metarhyolites, quartz phyllites, metasiltites, quartzites, and marbles, may have a common origin with the Abdulkadir Complex despite its structural complexity (Gatto et al., 1981).

2.2 The Mora Complex and Gabbro-Syenite Belt

The Mora Complex, primarily exposed in the westernmost NSB, comprises medium to high-grade metasedimentary rocks, including marbles, quartzites, and amphibolite, alongside migmatites and gneisses. It records a polymetamorphic history with evidence of granulite, amphibolite, and greenschist facies metamorphic events, indicating a prolonged and complex metamorphic evolution (SASSI F.P. and VISONÀ D. (1985).

The Gabbro-Syenite Belt, comprising numerous gabbroic and syenitic bodies, is notable for its non-ophiolitic nature, representing an ensialic magmatic activity likely linked to extensional tectonics following the main orogenic event. These bodies exhibit varying degrees of metamorphic overprint, including paedomorphic and foliation-producing metamorphic effects, which do not completely obliterate primary magmatic features (Dal Piaz et al., 1987).

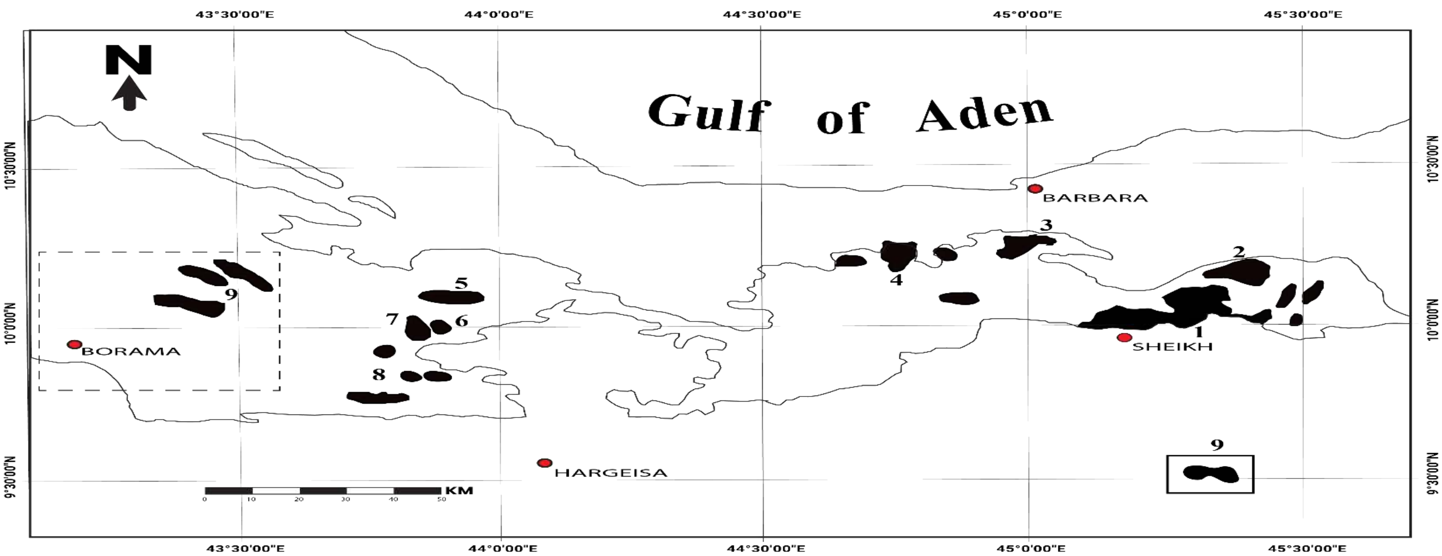

Fig. 1- Regional distribution of the main bodies making up the Gabbro-Syenite Belt in the notheast Borama and the Northern Somali Basement (taken from DANIELS et al. 1965)

Table 1. Chemical data concerning the Borama metarhyolites (Abdulkadir Complex) taken from (E. ABBETE, 1993).

SAMPLE	280	286	286/1	287	288	83-66	83-71	83-72	83-73	83-74	81-319
S102	71.3	76.98	78.63	76.67	76.93	74.78	74.78	73.4	71.36	78.03	74.83
T102	0.3	0.08	0.08	0.06	0.06	0.26	0.26	0.33	0.6	0.11	0.14
A1203	13.35	12.25	12.4	12.38	12.5	12.61	12.08	12.93	13.28	11.92	13.25
FE203	2.5	0.79	0.41	0.81	0.82	1.15	0.55	1.98	2.04	0.73	1.13
FE0	0.59	0.25	0.28	0.22	0.22	1.34	0.61	1.15	1.94	0.36	0.65
MNO	0.05	0.01	0.01	0.01	0.01	0.04	0.01	0.05	0.07	0.02	0.07
MG0	0.37	0.3	0.27	0.25	0.22	0.1	0.11	0.14	0.52	0.13	0.06
CAO	1.24	0.39	0.58	0.32	0.54	0.93	0.48	0.83	1.67	0.27	0.57
NA20	4.08	4.01	6.05	4.25	4.96	2.67	4.35	3.6	3.76	3.22	4.71
K20	1.82	3.65	0.39	3.31	2.15	5.63	2.56	5.16	4.02	4.44	3.94
P205	0.08	_	_	_	0.02	0.02	0.01	0.03	0.13	0.01	0.01
LOI	1.84	0.91	0.49	1.03	0.83	0.31	0.43	0.1	0.39	0.39	0.69
TOTAL	95.68	98.72	99.1	98.28	98.43	99.53	99.3	99.6	99.39	99.24	99.36
RB	50	90	17	84	51	119	78	164	126	175	_
SR	106	92	149	76	101	80	58	69	147	44	_

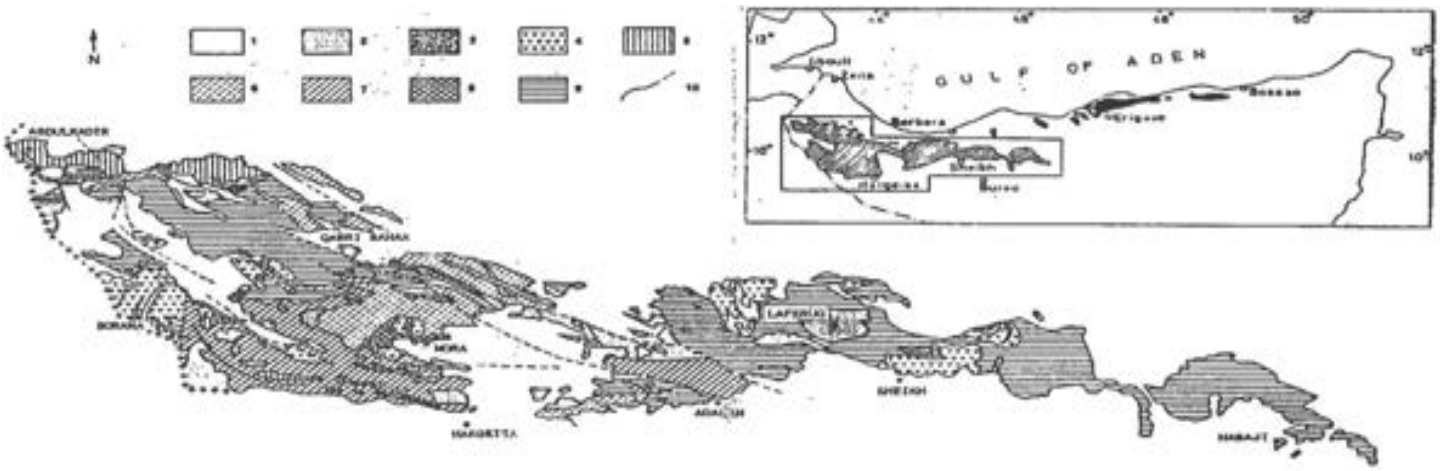

Fig. 2-Geological sketch of the Northern Somali Basement.

1: Non metamorphic cover.

2: Younger Granites.

3: Gabbro-Syenite Belt: main syenite bodies.

4: Gabbro-Syenite Belt: main gabbro bodies.

5: Abdulkadir Complex: metapelites, acidic and basic metavolcanites.

6: Mora Complex: metapsammites, gneisses and migmatites.

7: Mora Complex: marbles.

8: Mora Complex: amphibolite-rich sequences.

9: Qabri Bahar Complex: paragneisses, migmatites, amphibolites, etc.

10: main tectonic lineaments and faults. Inset; the black areas indicates the Inda Ad and Mait complexes.

3. Methodology

3.1Research Design

The study involved geological fieldwork to explore the geographical aspects existing within Borama, in Awdal State, Somalia. This study lasted for more than 35 days starting from August 27 to October 3, 2022. It was composed of field work and sample collection, laboratory analysis, and remote sensing techniques to understand the geology of the region, rock types, mineral ore deposits present, and structural characteristics.

3.2Study Area

The study focused on key locations in Borama, including Sogsogley Mountain, Sheylaha Mountain, Hadmacan Mountains, Dunbuluq Mountain, Faraxyada Hills, CaraQoolaab Hill, Fuleyfule Mountain, Sharlaganaadi Mountain, and Qoorgaab Valley. These areas were chosen for their unique geological characteristics and potential to provide insights into the region's geological history and mineral resources.

3.3 Data Collection

3.3.1 Field Surveys

Field surveys were conducted from September to December 2022 to map and sample rock types, minerals, and geological structures. GPS devices were used to record sample locations and geological features.

3.3.2 Sample Collection and Analysis

Rock and soil samples were collected from various geological formations within the study area. These samples were transported into **HERS Laboratories** in order to analysis the composition the rock and minerals.

Limitations

The study faced limitations such as challenging terrain and limited fieldwork duration, which impacted data collection and also its was very hard to get source of the third phase of the UNDP project (1972-1974). Future studies could benefit from extended fieldwork and advanced geophysical techniques. By integrating field surveys, sample analysis, and remote sensing, the study aimed to provide a comprehensive understanding of Borama's geology, supporting further research and sustainable resource management.

3.3.4 Remote Sensing and Mapping

Advanced remote sensing techniques, including satellite imagery were utilized to supplement field observations and provide a broader perspective of the study area's geological features. Digital elevation models (DEMs) and geological maps were created to visualize the topography and distribution of different rock types and geological structures. Geographic Information System (GIS) software was employed to integrate field data with remote sensing data, enhancing the accuracy of geological mapping and analysis.

4 Results and Discussion

4.0 Introduction

In this chapter, the geological formations and structures observed in several locations of the Borama District, Awdal State, Somalia, were studied. The survey term comprises the Faraxyada Hills, Fuleyfule Mountain, CaraQoolaab Hill, Hadmacan Mountains, Dunbuluq (Haya-Yaabe) Mountain, Sharlaganaadi Mountain, Qoorgaab Valley, Sogsogley Mountain, and Sheylaha Mountain. Each section described here-to follow discusses the geological features, rock types, mineral compositions, and tectonic history of each respective area.

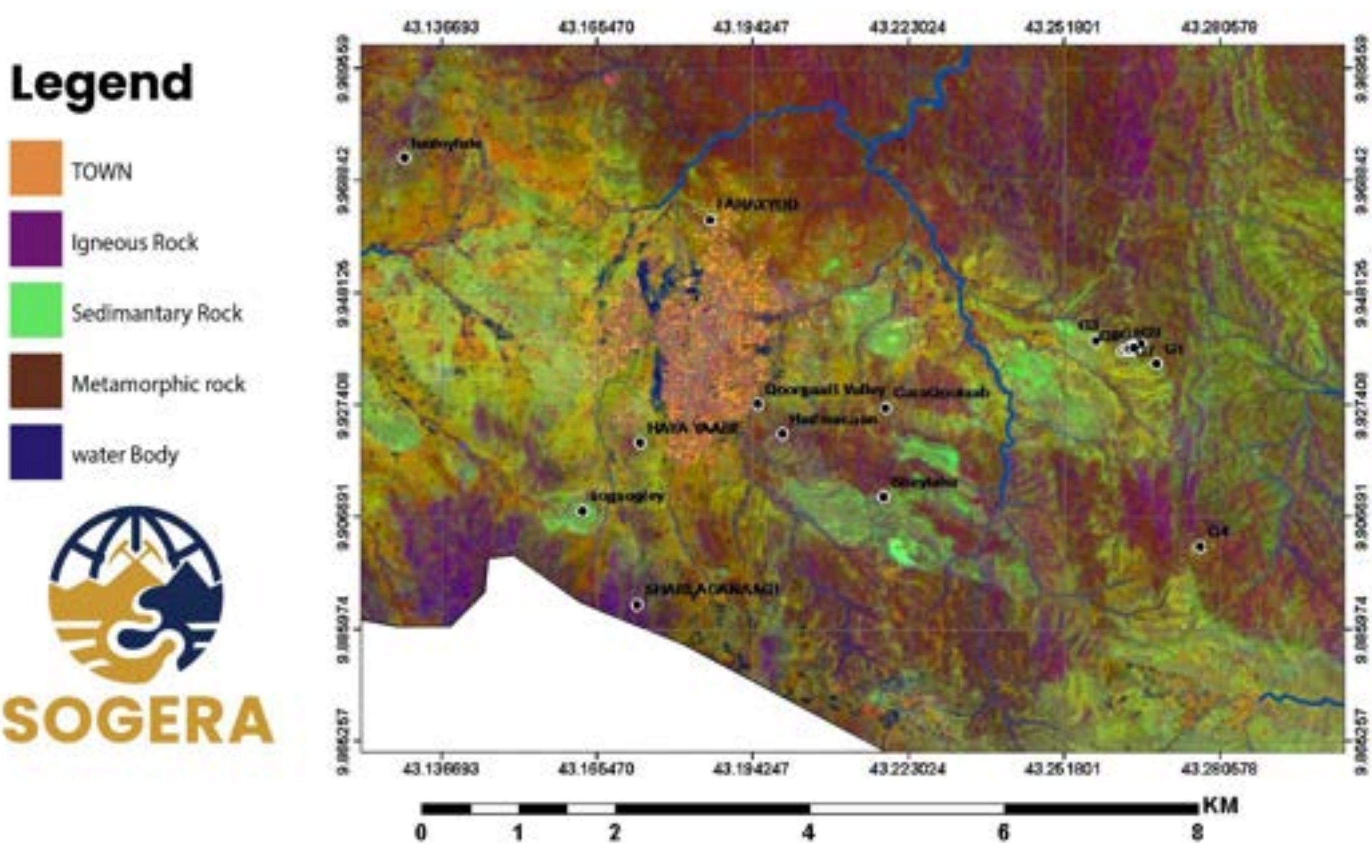

Fig. 1-Geological map of the Borama district

4.1 Faraxyada Hills

The Faraxyada Hills, located at the latitude of 9°57'42"N and longitude of 43°11'11"E in the north of Borama, are predominantly composed of metamorphic rocks such as schist and phyllite. These rocks are characterized by their foliated texture, indicating a history of significant pressure and heat during their formation. The schists in this area contain minerals like mica, quartz, and feldspars, which are common in metamorphic environments. Phyllite, a fine-grained metamorphic rock, is also present, with its characteristic silky sheen due to the alignment of microscopic mica flakes.

The geological formations in the Faraxyada Hills suggest a complex tectonic history likely linked to the East African Orogeny during the Neoproterozoic era. This event involved the collision and amalgamation of s everal microcontinents, forming the East African Orogenic Belt. The presence of schist and phyllite in this area confirms significant deformation and recrystallization events associated with this tectonic activity. Environmental challenges include deforestation, leading to soil erosion and loss of biodiversity.

Fig.3 Green schist of Faraxyada Hills in north Borama district.

4.2. Fuleyfule Mountain

The Fuleyfule mountain is located 10 km northwest of Borama. Its name comes from the Fuuleyfule village in Somali language, Geological coordinates 9°58'23.19"N and 43°7'47.40"E, being composed collectively of diorite, tuff, quartzites, and greywacke sandstones. Diorite is a coarse-grained igneous rock with a composition intermediate between that of granite and that of basalt. Tuff-a type of volcanic rock-forms by the compaction and lithification of volcanic ash and debris.

The presence of tuff in Fuleyfule Mountain suggests that the area has experienced volcanic events in the past. Quartzites, as mentioned earlier, are metamorphosed sandstones that are highly resistant to erosion. Greywacke sandstones are a type of sedimentary rock that contains a mix of sand-sized grains and finer material, indicating deposition in a high-energy environment such as a river or delta. The geological composition of Fuleyfule Mountain reflects a history of volcanic and sedimentary processes. The presence of diorite and tuff indicates past volcanic activity, while the quartzites and greywacke sandstones suggest ancient depositional environments that have been subsequently uplifted and metamorphosed.

Fig.4. Diorite rock at Fuleyfule Mountain in northwest Borama district.

4.3CaraQoolaab Hill

CaraQoolaab Hill is situated at 9°55'36.9"N latitude, 43°13'7.8"E longitude, this Hill is located approximately 5 km southeast of Borama, near the village of CaraQoolaab. The CaraQoolaab Hill, located to the southeast of Borama, is primarily composed of igneous rocks, including basalt, granite, and pumice. Basalt is a fine-grained volcanic rock that forms from the rapid cooling of lava at the Earth's surface. Granite, on the other hand, is a coarse-grained plutonic rock that forms from the slow cooling of magma at depth. Pumice, a highly vesicular volcanic rock, is indicative of explosive volcanic activity.

The presence of conglomerates at the base of CaraQoolaab Hill suggests the existence of a nearby stream or river that has transported and deposited these sedimentary rocks. Conglomerates are composed of rounded clasts embedded in a finer matrix, indicating that the clasts have been transported over some distance by water.

The geological features of CaraQoolaab Hill highlight the interplay between volcanic and sedimentary processes in the region. The basalt and pumice indicate past volcanic activity, while the conglomerates suggest the presence of fluvial processes. Understanding the relationship between these different rock types can provide insights into the region's geological history.

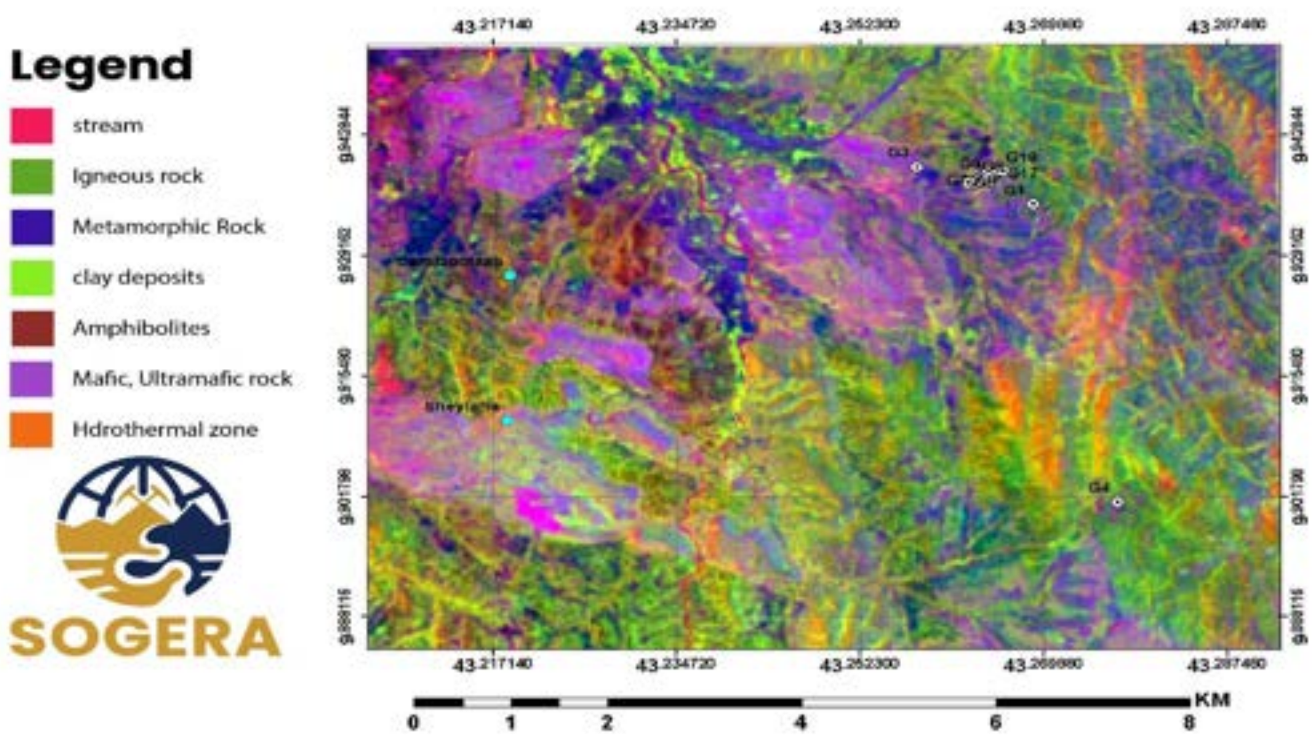

Fig.5 Remote sensing map in the study area (geology, water, vegetation, clay).

4.4 Hadmacan Mountains

The Hadmacan Mountains display an abundance of igneous and metamorphic rocks such as granite, basalt, gneiss, greenschist, and sandstone. While granite and basalt point to deep-seated magmatic processes, gneiss and greenschist witnessed the great metamorphism. Sandstone, a sedimentary rock, evidences an ancient depositional environment.

Fig 6 Oxidized green schist rock in Hadmacan mountain.

The Hadmacan one, also known as Sararta Mountain located at the 9°55'19.42"N latitude, 43°11'59.15"E longitude, I collected samples at different sides of Hadmacan-one, I found granite rocks and basalt are major components also I found sandstone rock which shows information about the surrounding area closing sedimentary basement because sandstone gives an expectation of gravel, mudstone and limestone should be close to it. Also, we saw layers of mudstones, gravel, and sandstones in the Qorgab Valley, as we see this Hadmacan granite is similar Caraqolab one which far away 1.8 km which gives us this are area happened same tectonic activity on the other side the information about dikes and batholith formation.

At the top of Hadmacan-two Mountain at the 9°55'20.8"N, 43°12'5.52"E, there is a small cave, at 2 meters deep, containing minerals such as calcite, actinolite, feldspars, and quartz. The surrounding rocks include granite, gneiss, green schists, marble, and amphibolite, indicating potential for other minerals like diopside, epidote, and garnet. From Hadmacan 1 and 2, I collected various igneous and metamorphic rocks, including granite, basalt, diorite, marble, gneiss, greenschist, and sandstone, highlighting their significance as potential gemstone sources.

Fig 7. Actinolite and calcite in Hadmacan Two mountain.

Some common minerals found in the Hadmacan Mountains include biotite, muscovite, feldspar, calcite, epidote, actinolite, quartz, and amphibolite. Biotite and muscovite are distracting members of the mica group, generally occurring in metamorphic rocks.Feldspars are an eminent group of silicate minerals occurring abundantly in both igneous and metamorphic rocks.Calcite signifies the presence of marble or limestone.Epidote and actinolite are generally present in metamorphic rocks, whereas quartz and amphibolite are present in both igneous and metamorphic rock types. The geological composition of the Hadmacan Mountains reveals a complex history of magmatic and tectonic processes. The presence of granite and basalt suggests magmatic activity, while gneiss and greenschist suggest significant metamorphism.The sandstone layers indicate ancient sedimentary environments, subsequently uplifted and metamorphosed.

4.4Dunbuluq (Haya-Yaabe) Mountain

Dunbuluq Mountain, also known as Haya-Yaabe Mountain, is situated at Sheikh Osman village in Borama. The Dunbuluq mountain lies at latitude 9° 55’ 13.3’’N and longitude 43° 10’ 24.5’’E towards the southwest of Borama. Slate to schist to marble is a geological description of this mountain. The schist of Dunbuluq is indicative of medium-grade metamorphism with a rich content of minerals which include chlorite and mica. That marble considered metamorphic limestone also explains the historical existence of carbonate rocks in the geological chronology of this region.

The formation of these rocks is attributed to tectonic activity at shallow depths. The presence of slate, schist and marble suggests that the area has experienced significant metamorphism, possibly related to the same tectonic events that affected the Faraxyada Hills. This Dunbuluq Mountain indicate that it formed medium metamorphism phase and next to igneous mountians include Sharaganadi montain in the south of Borama district approximately 3km.

Fig 7. Slate rock in Dunbuluq mountain.

4.5Sharlaganaadi Mountain

The mountains observed are on the west of the Sharlaganaadi mountain. This mountain towards southwest Borama. It geographically occurs at 09°53'25.64"N and 43°10'22.65"E. The Sharlaganaadi Mountain features granite, sandstone, tuff, quartzites, marble, and limestone, which are all representative of plutonic igneous rocks. Granite, in earlier study, indicates deep-seated magmatic events; sandstone, tuff, and quartzites reflect the outcome of mixed volcanic and sedimentary processes. Marble and limestone point to the carbonates existing within the geological history of the region.

The presence of various rock types in Sharlaganaadi Mountain provides insights into the region's geological history, linked to tectonic activity related to the East African Rift Valley. The East African Rift Valley is a major tectonic feature that has significantly influenced the geology of the Horn of Africa. It is characterized by extensive faulting, volcanic activity, and the formation of large rift valleys. The presence of granite and tuff in Sharlaganaadi Mountain suggests past magmatic and volcanic activity, while the sandstone, quartzites, marble, and limestone indicate ancient depositional environments. The geological diversity of the area highlights the complex interplay between tectonic, magmatic, and sedimentary processes.

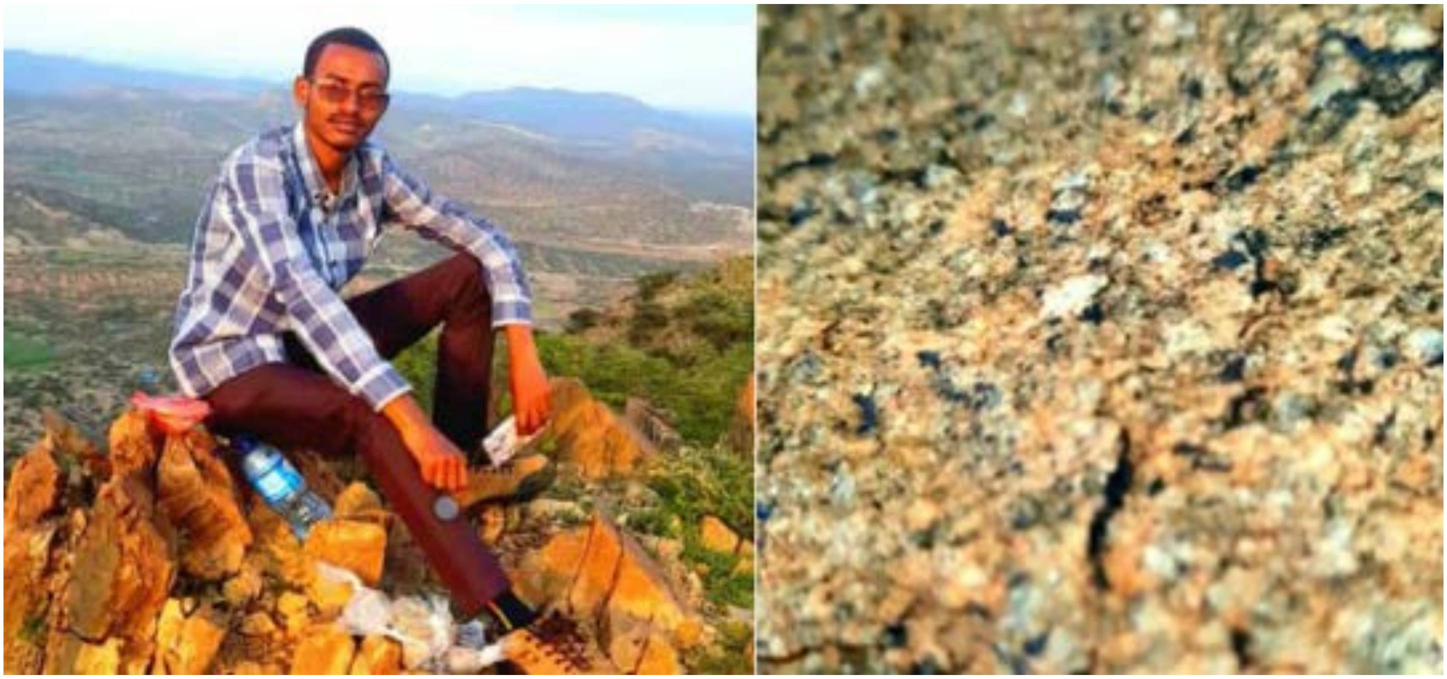

Fig 8. Red Granite rock in Sharagnadi mountain.

4.6Qoorgaab Valley

The Qoorgaab Valley is located southeast of Borama Geologically at 9°55'39.1"N and 43°11'42.52"E, a place where the features a great variety of rock types basalts, granites, marbles, gneiss, green schists, rhyolite, phyllite, conglomerates, breccia, and quartzites. This diversity episodes the complex geological history of the area involving tectonic activities in the Borama district.

Basalts and rhyolites are volcanic rocks that from the cooling of lava at the Earth's surface. Basalts are typically fine-grained and dark-colored, while rhyolites are lighter in color and have a higher silica content. Granites and gneiss, as previously mentioned, are plutonic and metamorphic rocks, respectively, indicating the presence of deep-seated magmatic and tectonic processes. Green schists, phyllite, and quartzites are metamorphic rocks that have undergone varying degrees of metamorphism. Green schists are characterized by the presence of green minerals such as chlorite and epidote, while phyllite has a silky sheen due to the alignment of mica flakes. Quartzites, which are metamorphosed sandstones, are highly resistant to erosion and weathering. Conglomerates and breccia are sedimentary rocks that form from the deposition of clastic material. Conglomerates have rounded clasts, while breccia has angular clasts, indicating different transport and depositional environments.

The dry nature of QoorgaaB Valley and its dependency on the rainy season highlight environmental challenges related to water availability. The valley's diverse geological composition also suggests the presence of aquifers that could be utilized for water resources. Government intervention is needed to develop sustainable water management strategies, such as rainwater harvesting and groundwater extraction.

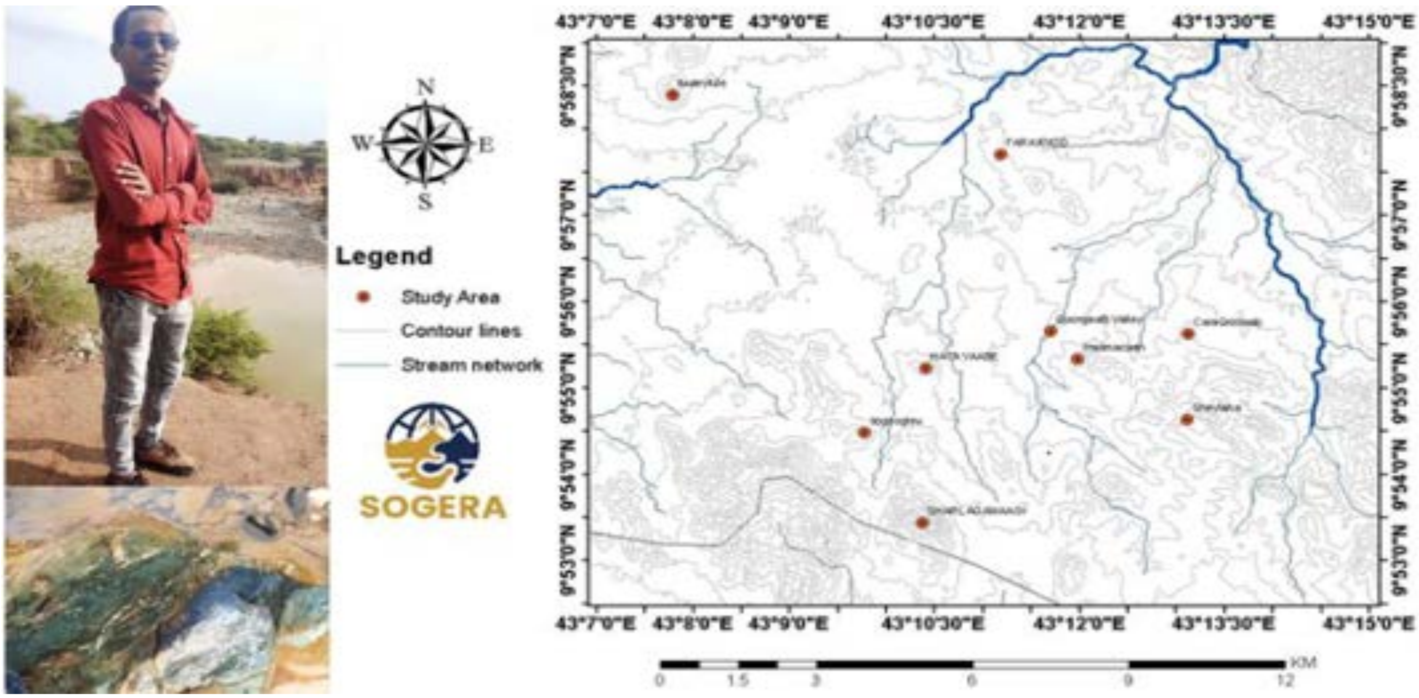

Fig 9. Contour line and stream network in the study area.

4.7Sogsogley Mountain

The survey of Sogsogley Mountain, located southwest of Borama at the 9°54'28.38"N, 43°9'46.46"E, revealed its significant potential for various studies due to its economic value in agriculture, well locations, and building materials. This mountain is important in paleontology, sedimentology, and stratigraphy, providing the geological history of Borama. The variety of rock types and minerals found in Sogsogley Mountain indicates resource exploration and development potential.

In the sandstone of Sogsogley Mountain which, again, is medium to coarse-grained and well-sorted as to be cemented in layers, a sedimentary origin is indicated. The grain is a direct reflection of the time and events that took place in its formation. This mountain, made of sedimentary layers like sandstone, limestone, conglomerate, breccia, and mudstone, speaks volumes about Borama's geological history and paleo-environments.

The similarities in sedimentary composition with the Sheylaha Mountains suggest a shared history, with the older layers at the bottom and younger layers on top, reflecting sediment accumulation. This area is crucial for further studies in stratigraphy, sedimentation, and paleontology, and it is also a vital water source for Borama.

Fig10. stratigraphic layers of Sogsogley mountain in the West Borama district.

4.8 Sheylaha Mountain

Geologically, they lie at the 9°54'37.6"N and 43°13'06.7"E in the southeast region of Borama, is the Sheylaha Mountain. The main types of rock that build the Mountain are sedimentary rocks, including limestone, sandstone, conglomerates, and slate. Limestone, a carbonate rock, indicates an ancient marine environment, while sandstone and conglomeratespoints toward fluvial or deltaic environments. Slate, a fine-grained metamorphic rock, indicates low-grade metamorphism of shale or mudstone.

The visible layers in the Sheylaha Mountain indicate fault activity due to past earthquakes. Faults are fractures in the Earth's crust where rocks have moved relative to each other. The presence of faults in the Sheylaha Mountain suggesting significant tectonic activity, possibly related to the East African Rift system The geological features of the Sheylaha Mountain make the stratigraphy and sedimentology of the region very evident.The distribution and arrangement of the various rock types inform about the sedimentary environments and tectonic history of the area.

Fig. 11 sedimentary layers of Sheylaha Mountain in the East Borama district.

Finally, the geological field survey of the Borama District has revealed a complex interplay of volcanic, magmatic, sedimentary, and tectonic processes. The diversity of rock types and geological formations across the surveyed areas highlights the rich geological history of the region. Further research in these areas is crucial for understanding the geological evolution of the Borama District and its potential for resource exploration and development.

Table 2. summary of Geological survey in Awdal region.

No	Sample	Occurrence	Coordinates	ROCK TYPE
1	BR1-9	Faraxyada Hills	9°57'42"N, 43°11'11"E	schist and phyllite
2	BOR10-19	Dunbuluq (Haya-Yaabe) Mountain	9° 55' 13.3"N, 43° 10' 24.5"E	schist, gneiss, and marble
3	BOR20-39	CaraQoolaab Hill	9°55'36.9"N, 43°13'7.8"E	basalt, granite, and pumice
4	BOR30-39	Qoorgaab Valley	9°55'39.1"N, 43°11'42.52"E	green schists, rhyolite
5	BOR40-49	Hadmacan Mountains	9°55'19.42"N, 43°11'59.15"E	Basalt, and green schists
6	BOR50-59	Fuleyfule Mountain	9°58'23.19"N, 43°7'47.40"E	Diorite, Tuff, Quartzites
7	BOR60-69	Sharlaganaadi Mountain	9°53'25.64"N, 43°10'22.65"E	granite, sandstone, tuff, quartzites
8	BOR70-79	Sheylaha Mountain	9°54'37.6"N, 43°13'06.7"E	limestone, sandstone, conglomerates,
9	BOR80-89	Sogsogley Mountain	9°54'28.38"N, 43°9'46.46"E	sandstone, limestone, conglomerate, breccia,

5. Conclusion and Recommendations

5.1 Conclusion

Geological field surveys conducted in the Borama region of the Awdal State in Somalia have revealed much of the area's diversely composed geological history. A complex interplay among igneous, metamorphic, and sedimentary rocks permits reflection upon an impressive developmental geological history influenced by tectonic, magmatic, and sedimentary processes.

Most of the Faraxyada Hills, Dunbuluq Mountain, and the Hadmacan Mountains are covered by schist, gneiss, and marble rocks, which are representative of a history based on intense pressure, heat, and tectonic activity related to a likely regional metamorphism and the East African Orogeny. Foliated textures and minerals such as mica, quartz, and feldspar confirm a rather complex geological past dominated by both magmatic and metamorphic processes.

The igneous rocks very much populate such places as CaraQoolaab Hill, the Hadmacan Mountains, and Qoorgaab Valley, whose lithological composition suggests a dynamic volcanic history ranging from basalt and granite to pumice and diorite. The features such as tuff and rhyolite attest to present volcanic activity, while granite and basalt show magmatic intrusion. Further, these areas showcase evidence for fluvial processes and sediment deposition as suggested by conglomerates and sandstones, which depict a history of volcanic eruptions alternating with sedimentary processes.

Sedimentary rocks, including sandstone, limestone, conglomerate, and shale, are significant in Sogsogley Mountain, Sheylaha Mountain, and Sharlaganaadi Mountain. These rocks provide insights into the paleo-environments and the depositional history of the region, with visible fault lines and stratigraphic layers highlighting the tectonic activity associated with the East African Rift system. The diversity of rock types in these mountains underscores the complex interplay between volcanic, magmatic, and sedimentary processes in shaping the region's geological framework.

Overall, this research contributes significantly to an understanding of the geological framework of Borama but also lays a solid foundation for future research and development initiatives. With its potential for resource exploitation and environmental conservation, it serves as an important area of continual interest in science and sustainable management.

5.2 Recommendations

To enhance the understanding and sustainable management of Borama's geological resources, several actions are recommended:

1. Conduct detailed geological, stratigraphic, and paleontological studies in Sogsogley and Sheylaha Mountains to better understand the region's ancient environments and tectonic history.

2. Explore mineral extraction opportunities in the Hadmacan and Dunbuluq Mountains, focusing on gemstones, building stones, and valuable minerals like calcite, feldspar, and quartz. Sustainable mining practices are essential to minimize environmental impact.

3. Implement reforestation and sustainable land use practices to combat deforestation and soil erosion, particularly in the Faraxyada Hills, to preserve biodiversity and soil fertility.

4. Develop sustainable water management strategies, such as rainwater harvesting and efficient irrigation, to address water scarcity in Qoorgaab Valley and support local agriculture.

5. Use advanced remote sensing and mapping techniques to identify geological features and mineral resources, improving planning and management.

6. Engage local communities in research and resource management, and promote education on sustainable practices.

7. Collaborate with international geological experts to enhance regional geological understanding and develop strategies for sustainable resource use.

These recommendations will help Borama harness its geological resources sustainably, supporting economic growth and environmental preservation.

5.3 Acknowledgements

The author would like to thank the Somali Geological Research Association (SOGERA) for their support and collaboration in this study. Special thanks to the local communities in the South Awdal region for their assistance and cooperation during fieldwork.

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