Precambrian Crystalline Basement rocks of Eritrea (N.E. Africa) Interpreted by Remote Sensing Technique

Rizwan Ahmad, Wolde Gabriel Genzebu, Tewolde Woldekidan

Abstract

The geological set up of Eritrea is made up of Precambrian basement rocks that are overlain un-conformably by predominantly Mesozoic sedimentary rocks and Tertiary to Quaternary volcanic and sedimentary rocks. The basement rocks are not well studied in the region despite their high mineral potential. In the present study broad geological maps cover the western part of the country (Geology of Gash River Area) and the southern part of the country (Geology of Mai Dima/Kohain Area). Compilation of geologic maps at 1:250,000 scale has recently been completed for four map sheets. Based largely on satellite image interpretation TM data aided by limited ground controls, suggest that the rocks can be subdivided into four tectonic blocks or segments, separated by tectonic boundaries. Three of these blocks, the western, central and eastern segments, underlie northern and central Eritrea, whilst the fourth, the Danakil segment, occurs in the southeastern part of the country.

Index Terms ANS, Basement rocks, Eritrea, Geology of Gash River Area, High grade rocks, Remote Sensing, Structures.

1. Introduction

Basements are rocks that make the basement, upon which all younger formations are deposited, and contain, the oldest rocks. Precambrian are crystalline rocks that comprise a wide variety of sedimentary, volcanic and intrusive rocks, which have been metamorphosed to varying degrees. The rocks are part of the ANS (Arabian Nubian Shield) which in turn, is now taken to be part of the EAO (East African Orogen) and exposed in most parts of Eritrea, covering ~ 60% of the country's soil. They have been the source of gold and base metals, since ancient times and are also potential source for other types of metals, like copper, zinc, chromium, nickel, rare earths metals and so on. Moreover these are part of a shield where modern type of plate tectonics setting is observed. This shield (ANS) has been relatively well studied in Saudi Arabia, Egypt and to some extent in Sudan and little in Ethiopia. In Eritrea relatively less detailed studies have been made, so far. Recently compiled geologic map of the whole country at 1:1,000,000 scale has divided the Precambrian basement rocks into 7 domains, 5 groups and 3 formations. It is rather a more detailed presentation of the rock units of the country.

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2 ARABIAN NUBIAN SHIELD (ANS)

ANS are assemblage of rocks that forms the suture between East and West Gondwana at the northern end of the East African Orogen (EAO). The main characteristics of the rocks, as seen in Red Hills of Sudan are a) Composed largely of volcanic rocks of calcalkaline affinity together with metasediments which include greywackes, slates pelagic limestones and cherts b) Except in zones of ductile shear, much of the primary fabric has survived deformation; metamorphism is mostly of low grade. c) A number of ophiolite complexes are associated with volcanic rocks and sediments; some are preserved more or less complete, others highly dismembered. d) The greenschists have been invaded by abundant granitioid rocks, diorites and gabbros. Most of the intrusive rocks are cal-alkaline, but peralkaline syenites and gabbros also occur, as well as rare undersaturated syenites [9] as shown (in Fig:1).

3 MOZAMBIQUE BELT (MB)

Studies have shown that these belts are represented by high-grade gneisses, involving quartzo-feldspathic biotite- and hornblende-bearing gneisses which have been metamorphosed and often magmatized in the amphibolites facies. In Sudan, the overylying metasedimentary group includes quartzofeldspahic gneisses, biotite and grphaite-schists, quartzites, marbles and amphibolites sheets. The belt is viewed as an ensialic mobile belt, polycyclic in origin but largely a product of late Precambrian deformation and metamorphism imposed upon by already ancient rocks.

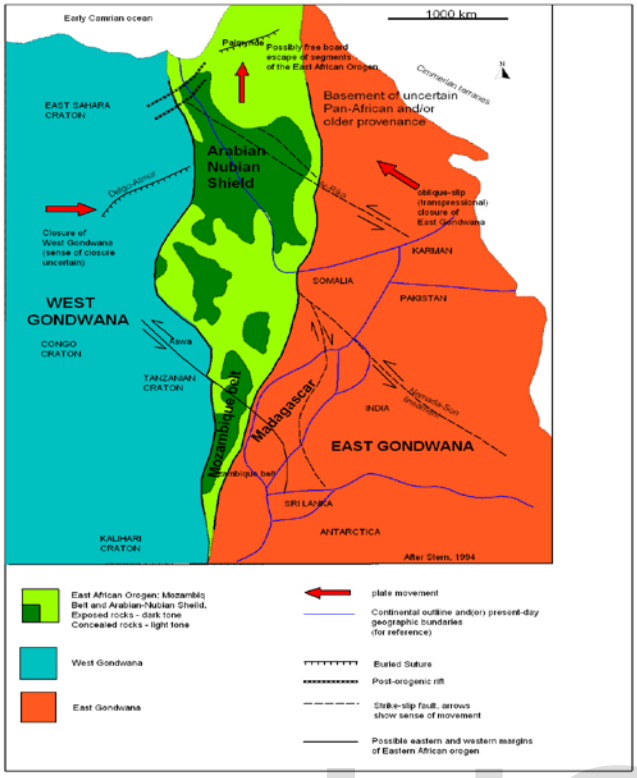
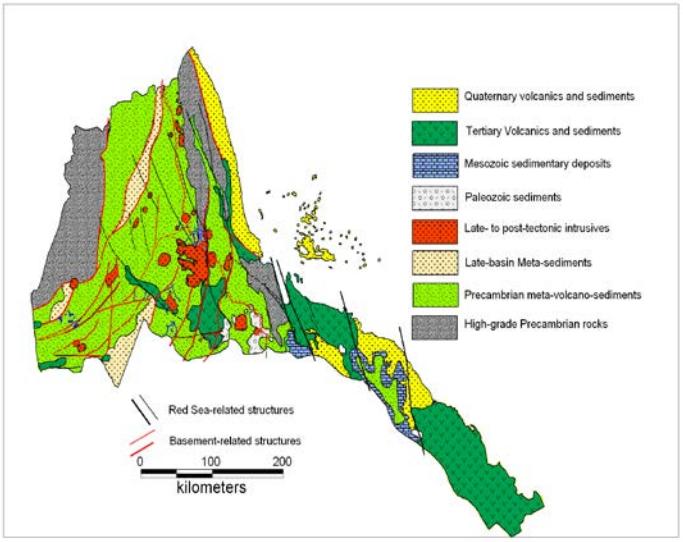


Fig.1. The region between East and West Gondwana about 550 million year (Ma) showing the Arabian-Nubian Shield and the Mozambique Belt and other parts of the East African orogen (EAO). (after [6])

The geological setup of Eritrea has undergone many transient changes; they are listed as under (Fig.2).:



1- Precambrian Basement rocks
a) High-grade rocks
b) Low-grade rocks
-formed during Pan-African
(Tectono-thermal event 900-550 Ma)
2-Paleozoic-Mesozoic Sedimentary Rocks
a) Paleozoic Glacial deposits
(Late Ordovician-Silurian)
455 - 400 Ma
b) Mesozoic sedimentary rocks
(Late Triassic –Cretaceous)
~ 230 – 65 Ma
3- Red-Sea Rift-related Volcanic and Sedimentary rocks
~ 30 – till present

3.1 Earlier studies:

Earlier studies from 1933 to 1991 were made by various researchers in regional geological mapping, prospercting, for base metals and hydrocarbons as well as for hydrogeology primarly covering the region of Horn of Africa. However, in the 1980's some geological works were conducted by the Erittrean geologists in the liberated areas of Eritrea.

Fig.2. Simplified geological map of Eritrea (Modified, after [3])

3.2 Recent studies

No geologic studies have been made for about 30 years because of the aftermath of war between Eritrea and Ethiopia. However, because of good exposure over extensive areas, remote-sensing can be efficiently used. Most of the information on the formation and evolution of the rocks in Eritrea is based on the works carried out in adjoining areas of Arabia and in the Sudan and Egypt. Little work has been made by department of mines & energy after independence of Eritrea.

4 High-grade rocks of Eritrea

4.1 Location:

It lies in west of Eritrea and west of Barka River, and referred to as Barka Terrane by [2]. Also seen, in the region of northeastern Eritrea which is exposed along the coast and reaching the central high land area, designated as Arag Terrane by [3], taken as eastern gneisses by [2]. High grade rocks are also found in eastern Eritrea in Ghedem area extending in south, (Fig:3).

4.2 Lithology:

a) Western (Barka Domain)

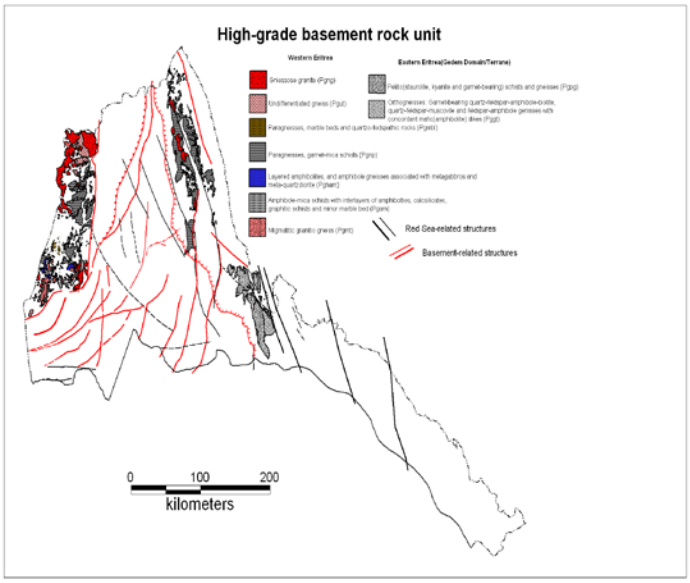


Fig.3. Distribution of the different high-grade basement rock in Eritrea.

The lithological units that have been observed in Barka domain are Gneisse granite and undifferentiated gneiss, migmatitic gneiss, parageneises which includes, marble beds and quartzo-feldspathic rocks, Garnet-mica schists, and layered amphibolites and amphibole gneisses associated with meta-gabbro and meta-quartz diorite. Amphibole-mica schists with interlayer of amphibolites, calcsilicates, graphitic schists and marble bed have also been found in this region.

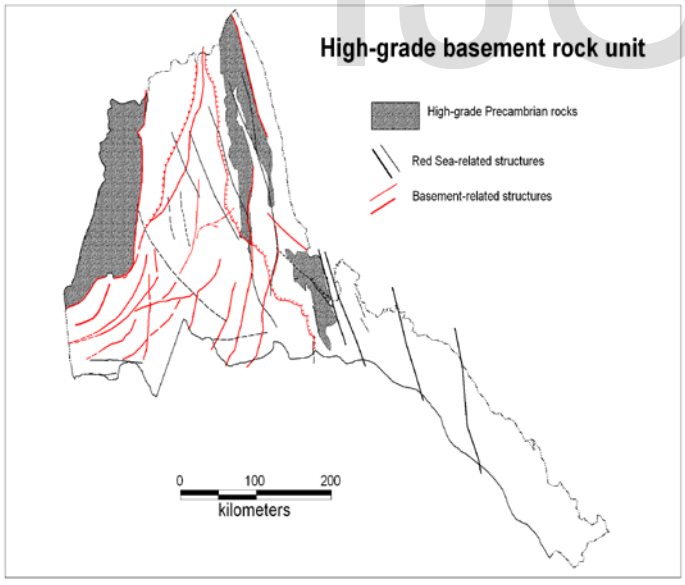


Fig.4 Distribution of the different high-grade basement rock units in Eritrea.

Metamorphism in study area: High-Pressure, High-Temperature upper amphibolite facies (Kyanite-, staurolite- and silimanite-bearing) locally amphibolites (600-800^{0}C, 7.5-10 kbar [3]

Earlier researchers have grouped the high-grade basement rocks as following: (Fig:4)

- Granitic gneisses and migmatites
- Paraschists
- Amphibole schists and amphibolites
- Some ultramafic rocks
- Deformed granitoid bodies
- Para- and ortho-genesis

b) Eastern Eritrea (Arag and Ghedem Terranes)

It involves two main lithologic types:

Pelitic (staurolite, kyanite and garnet bearing) schists and secondly, gneisses believed to be of metasedimentary origin and structurally underlain by Orthogneisses i.e. garnet-bearing qtz-feldspar-amphibole-biotite, qtz-feldspar-muscovite and feldspar-amphibole gneisses

4.3 Boundary/contact:

In the west, the Barka Domain makes a sharp structural contact and is marked by a shear zone and interpreted in TM data (Fig:5) to be a thrust zone along which reveals the crust consisting the low-grade rocks subducted to the west below.

In eastern domain, according to [4] the boundary is characterized by a "Terrane boundary or transition zone" that has an average width of 2-3km and is marked by a shear zone that is sub horizontal to moderately westward-dipping and locally cut (superposed) by low-angle semi-brittle detachments with top-to-east sense of shear.

4.4 Structure:

The western domain (Barka): is characterized by ductile folds on scales of up to tens of Kms, Complex early thrusting and polyphase tight to isoclinal sheath folding affecting all the rock types is observed in this domain.

Eastern Domain: Three phases of deformation characterized by different attitude of axial planar surfaces of steep, sub horizontal and shear-related steep foliation planes have been recorded. According to [2], the presence of large

garnet-amphibolite dykes that cut the gneisses but are absent from the similar and lower grade rocks of the Northern terrene, may suggest an earlier crustal segment or an exotic terrene.

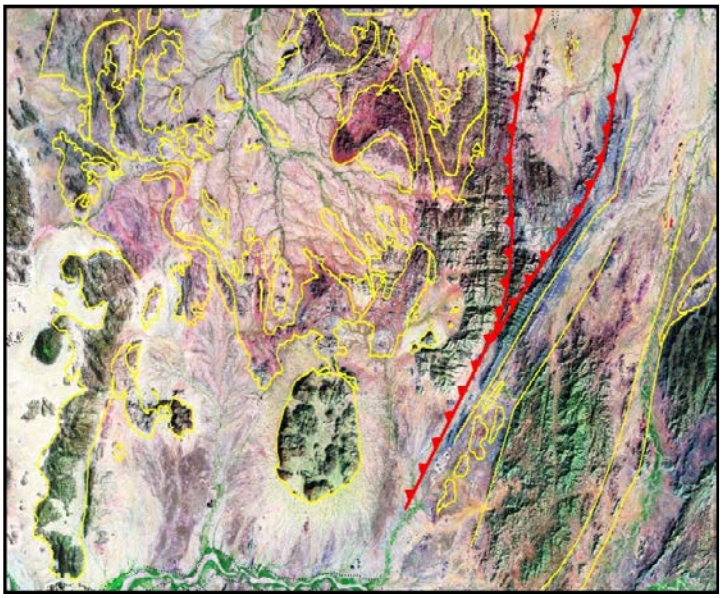


Fig.5. Thematic Mapper (TM) Satellite image of high-grade rocks (E-W distance is 94 km).

4.5 Dating and stratigraphy of study area:

-Beyth et al. (1997) has observed -1.26 to 0,99 Ga, Rb-Sr whole rock geochronology and Rb-Sr errochron of 666+/- 136 Ma as approximating the age of metamorphism of the rocks in the Red Sea lowlands [1].

-Teklay (1997) reported a 207Pb-206Pb age of 796 +/- 0.7 from evaporation of single zircons from a sample of garnet-muscovite gneiss [8].

-Ghebreab et al. (2005) reported peak metamorphism at 597+/- 5 Ma [5].

5 Low-grade Basement Rocks:

Two main units of rocks are reported, first is Serpentinite lenses with metabasalts & metasediments, Olistostrome lenses (bodies) (disrupted oceanic crust) and the second one is Pillowed metabasalt, subordinate chlorite schists, phyllites with iron-manganese chert horizones & impure marble.(Fig:6)

6 Correlation:

The high-grade rocks of western Eritrea (Barka Domain) extend into Sudan where they are regarded as Haya Terrane [6]. The eastern high grade rocks have been correlated with those of Arabia (Saudi and Yemen) Baish region consisting of greenschists and Bahah region consisting of metasedimentary amphibolites. They have the same relationship as those of the Nacfa Terrane and Arag or Gedem Terrane's schists and gneisses. They are similar in ages as well.

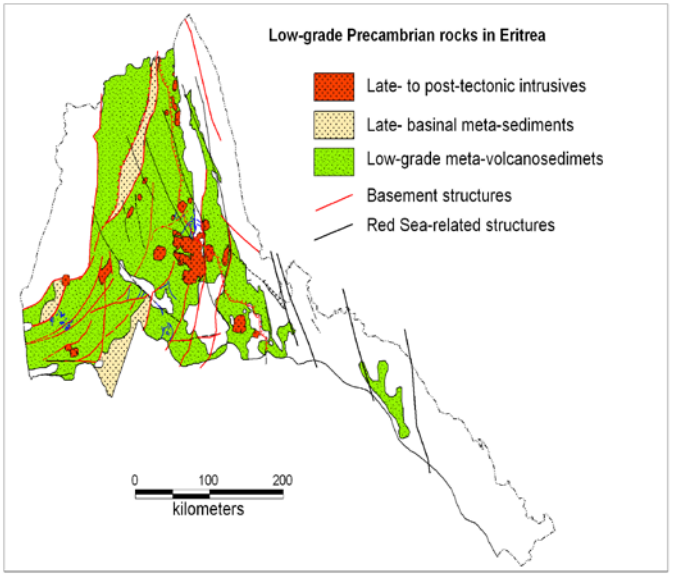


Fig.6. Exposure is of low-grade metamorphic basement rocks

6.1 Deformation History:

In Ghedem Terrane three major Pan-African Deformation phases have been identified based on field observations and thin-section studies.

7 Conclusion:

Basement rocks in Eritrea cover more than 60% of the surface of the country. The basement rocks of Eritrea are part of the Arabian Nubian Shield (ANS) which are exposed in north east Africa (Egypt, Sudan, Eritrea, and Ethiopia) and in Saudi Arabia, northern and northwestern parts of Yemen and part of the western Middle East. The shield is believed to represent a mega suture between East and West Gondwana [7]. Archean and Paleoproterozoic continental crust rocks that makes the older components of the shield and occupy a very small part of the basement rocks. The major part of the shield consists of Neoproterozoic (c. 870- 670 Ma) continental-marginal and juvenile Intra-oceanic magmatic-arc rocks.

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References:

[1] Beyth, M., Stern, R., Matthews, A., 1997. Significance of high-grade metasediments from the Neoproterozoic basement of Eritrea. Precambrian Res. 86, 45–58.

[2] Drury, S.A., Berhe, S.M., 1993. Accretion tectonics in northern Eritrea revealed by remotely sensed imagery. Geological Magazine 130, 170–190.

[3] De Souza Filho, C.R., Drury, S.A., 1998. A Neoproterozoic supra-subduction terrane in northern Eritrea, NE Africa. Journal of the Geological Society of London 155, 551–566.

[4] Ghebreab, W., 1999. Tectono-metamorphic history of neoprotrozoic rocks in eastern Eritrea. Precambrian Res. 98, 83–105.

[5] Ghebreab, W., Talbot, C.J., Page, L., 2005. Time constrains on exhumation of the East African Orogen from field observations and Ar40/Ar39 cooling ages of low-angle mylonites in Eritrea. Precambrian Research 139, 20–41.

[6] Johnson, P.R., Woldehaimanot, B., 2003. Development of the Arabian–Nubian Shield: perspectives on the accretion and deformation in the northern East African Orogen and the assembly of Gondwana. In: Yoshida, M., Windley, B.F., Dasgupta, S. (Eds.), Proterozoic East Gondwana: Supercontinent Assembly and Break-up, vol. 206. Geological Society of London, Special Publication, pp. 289–325.

[7] Tadesse, T. 1996. Structures across a possible intra-oceanic suture zone in the low-grade Pan-African rocks of northern Ethiopia. J. African Earth Sc, 23, 375-381

[8] Teklay, M., 1997. Petrology, geochemistry and geochronology of Neoproterozoic magmatic arc rocks from Eritrea: implications for crustal evolution in the southern Nubian Shield Department of Mines, Eritrea Memoir no. 1, p. 125.

[9] Vail, J.R. 1985. Pan-African (Late Precambrian) Tectonic terrains and the reconstruction of the Arabian-Nubian Shield. *Geology* 13: 839-42

[10] Wolde Haimanot, B. 1995.Structural Geology and Geochemistry of the Neoproterozoic Adobha and

[11] Adola Belts (Eritrea and Ethiopia). Ph. Thesis. Lenz-Verlag Giessen. No. 54 (2185).

[12] Dept. of Mines, Unpublished works.