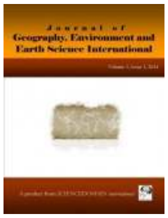

Journal of Geography, Environment and Earth Science International
4(1): 1-8, 2016; Article no.JGEESI.21383
ISSN: 2454-7352

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Fault Patterns and Implications on Madagali Hills, Hawal Basement Complex N. E. Nigeria

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Authors' contributions

This work was carried out in collaboration between authors NEB and JB. Author NEB designed the study and conducted earlier geological and structural mapping. While author JB wrote the first draft of the manuscript. Data analysis and management of literature searches were jointly done. Both authors read and approved the final manuscript.

Article Information

DOI:10.9734/JGEESI/2016/21383
Editor(s):
(1) Wen-Cheng Liu, Department of Civil and Disaster Prevention Engineering, National United University, Taiwan and Taiwan Typhoon and Flood Research Institute, Taipei, Taiwan.
Reviewers:
(1) Shandini Yves, University of Yaounde, Cameroon.
(2) Anonymous, Università degli Studi di Napoli "Federico II", Naples, Italy.
Complete Peer review History: http://sciencedomain.org/review-history/11715

Original Research Article

Received 14th August 2015
Accepted 17th September 2015
Published 7th October 2015

ABSTRACT

Fault mapping on Madagali Hills area (Longitudes 13°36'E to 13°41.5'E and Latitude 10°51'N to 10°57.5'N) was done with the objective of producing a structural map of the area and to see the implications of the fault patterns. The area is polygenic, having experienced magmatism, metamorphism and structural deformations. Oldest mapped rocks are gneiss, granite gneiss and schist. These are intruded by Pan African granites. The area has experience both low and high grade metamorphism as proven by the presence of schist and gneisses. Minor intrusive occur as basic and acidic dykes with NE, NW, E-W, and N-S orientations and affect all major rocks. Rock shearing is closely associated with fault zones. Field evidence shows that several drainage channels are fault controlled. Fault intersections are common features. Would the faults serve as good locations for productive bore holes in this semi arid region? Would the intersections serve as avenues for mineralization? These are some issues this paper seeks to address beside the structural data presented.

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Keywords: Basement complex; faulting; shear zones; lineaments; strain; groundwater.

1. INTRODUCTION

The study area lies between Longitudes 13°36’ E and 13°41.5’E and Latitude 10°51’N and 10°57.5’N (Fig. 1). Very few works have been done and published on Madagali area, some of the existing publications on the northern part of the Hawal Basement Complex and contigous to the present area of study are those of [1-4]. These authors have reported the geology of the area to consist of gneisses, migmatite, schist and granite. Bassey (op.cit) discussed the structures of Madagali hills using airborne magnetic, satellite and field geological data.

The present work was a follow up to [4] with the objective of producing a more detailed structural map based on field geological observations. The area is 12.1 by 10.1 km (122.2 km^2) in size. Mapping exercise was done in the dry season months of April and December 2004, December 2010 and October 2011. Interest in the study area was initiated as one of the authors (NEB) participated in an excursion organized by the Nigerian Mining and Geosciences conference held in Maiduguri in March 2004. The area is relatively semi-arid, this coupled with the dry seasons the survey done made it relatively easy to access rock outcrops and exposures with little vegetation challenges.

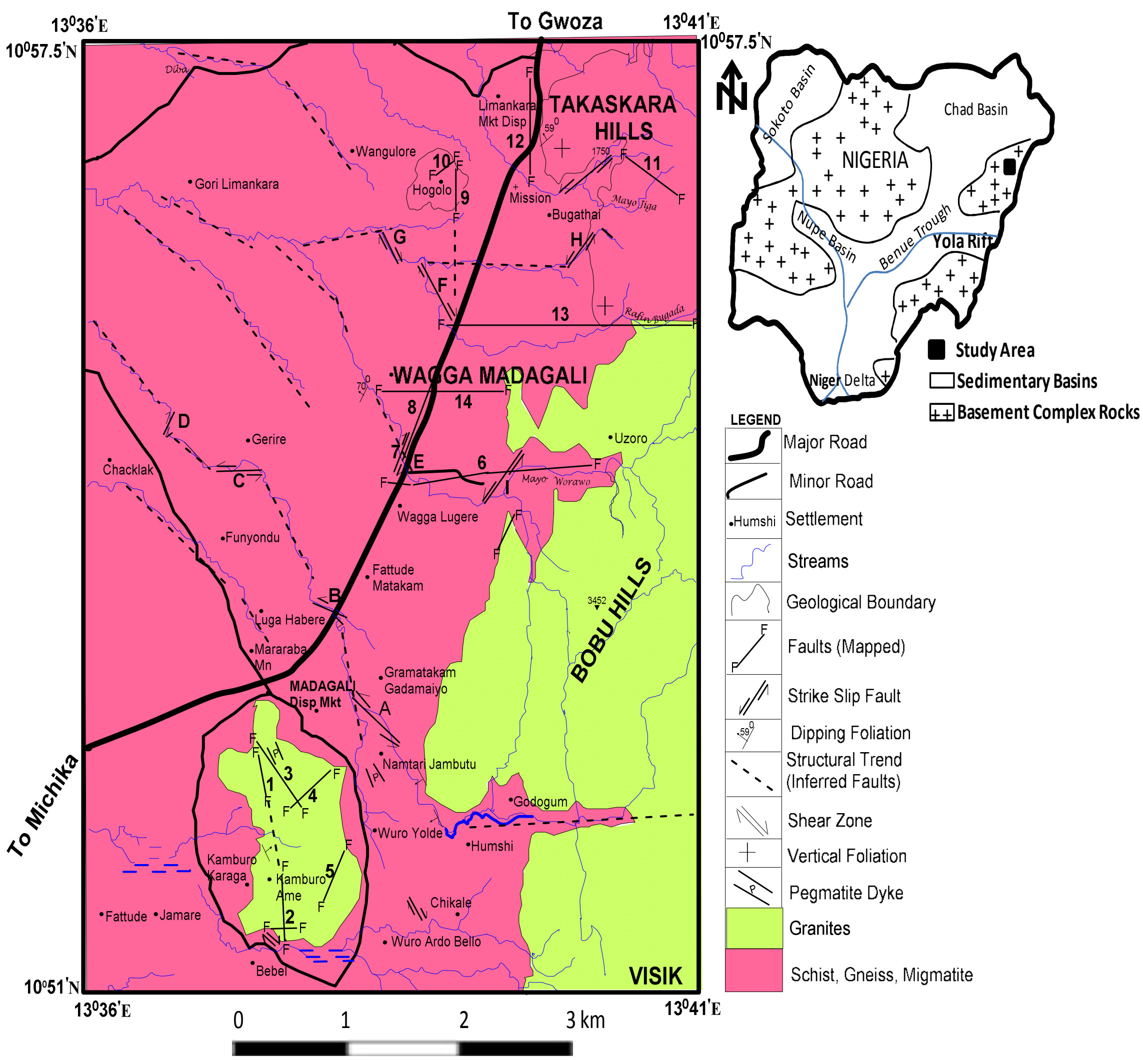

Fig. 1. Geological and structural map of Madagali and Environs

2. GEOLOGY OF THE STUDY AREA

2.1 Migmatite-Gneiss-Schist Complex

These are the oldest rock group and form the host to the granitic rocks and best exposed at Takaskara hill to the northeast of the study area. Here the rocks consist of slightly migmatized to unmigmatized gneisses and schist. The gneisses consist of banded type. Cleavage attitudes on the gneiss and schist is between N020°, 58°W and N195°, 60°W. The rocks are commonly sheared and jointed along E-W direction. A change from banded gneiss to mica schist is found at a location with GPS reference N010° 58.200 and E013° 40.402. This is along a river course flowing at about N060^0 direction. The schist extends southward where it outcrops to east of Wagga Madagali and has a cleavage attitude of N010°, 60°W at a GPS reference N010° 55.218 and E013° 39.886. Small outcrop of schist are found along the NW flowing river west of Wagga Madagali, where the schistocity is NE and dip 70° NW.

2.2 Granites and Pegmatite

The granites are intrusive to the migmatite-gneiss-schist rocks and occur as undeformed (fine, medium, coarse grained and pegmatitic varieties) and as deformed types. The Hills at Madagali town are granite hills. At Madagali town itself the rock is coarse grained, pinkish weakly foliated biotite granite. The rock changes texturally to medium grain on the western sector of the hill and southward at Bebel the rock is fine grained and largely tectonised.

Outcrop of granite is found at Chikale along a N120° trending ridge about 90 m long. Here the rock occurs whitish in colour with a fine grained texture. The fine grained granite occurs as dykes in places within the coarse grained type on the Madagali town hill.

The eastern hills are dominantly granitic and coarse grained and intruded in the N-S direction by fine grained granite dykes about 2 m width. Deformed variety of the granite is seen at Madagali hill at GPS N010° 53.108 and E013° 36.891. Across the Gwoza-Madagali Road to the west of Takaskara hill (Limankara area) the deformed granite is seen with well developed foliations. Here the rock has developed a mylonitic texture within the N-S direction which marks a fault zone.

Pegmatite dykes occur as intrusions in the area particularly they are seen in fault zones on the Hill in Madagali town. Eastward down slope near Namtari Jambutu another pegmatite dyke vertically dipping with a strike of N120° and width varying between 1-3 m, and an exposed length of about 62 m. Another one pegmatite with width about 7 m, strike E-W, and dip 90° is intensely sheared is found SE of Madagali town along the west bank of River Namtari Jambutu. The emplacement of the pegmatite dykes seems to mark the last phase of intrusion in the area.

3. MATERIALS AND METHODS

The field exercise was accomplished with the use of a base map extracted from a topographic map of the area with index number 136 NW (Madagali NW) and published by the Federal Survey of Nigeria on a scale of 1: 50,000. The map was photo-enlarged to suit the scale of present work. Since the structures targeted during this survey are megascopic in size. Field equipment used were conventional:- geological hammer and chisel, silver compass-clinometer, field camera, sample bag, field note book, a 5 metre measurement tape and an e-trex GPS.

Mapping was done by direct observation of outcrops to observe and document lithological changes and contacts. Fault identification and mapping were based on mainly features that characterize fault zones [5,6] such as presence of slickensides, fault breccias, mylonite and physiographic criteria such as presence of scarps. Inferred faults were made based on offset of streams. Shear zones, dykes, veins, rock foliation and schistosity are other structures that were observed and mapped. Attempt was made to assess strain across one of the prominent fault zone (Limankara fault zone) in the area by direct measurement of the X and Y axis of the strain ellipsoids of quartz and feldspar across the fault zone.

4. RESULTS

The lithologies observed during the field work as earlier discussed in the geology of the study area are dominantly gneisses, migmatite and schist. The gneisses consist of the banded type and granite gneiss. These rocks are found sometimes exposed at the base of granitic hills. The granites grade from fine grained to pegmatitic varieties and are intrusive to the metamorphic rocks. Outcrops of schist are found west of Wagga-Madagali along Madagali-Gwoza Road, on the northeast of the study area on Takaskara hills where it occurs in close association with gneiss. The boundaries of the gneisses, migmatite and schist are poorly exposed in the field hence in this work they are jointly represented as Gneiss-Migmatite-Schist Complex and largely underlies the western plain of the area. Where faulting affect the schist, the rocks has developed a highly crystalline nature. This was reported by [4].

The granite outcrops form most of the hills of the area. Madagali Town which is heavily populated lies at the base of granitic hill in the southwest of the area (Fig. 1). Pegmatite dykes intrude the granites in places. Almost all the N-S trending range of hills found east of the study area is of granitic composition.

Structurally the area has ductile and brittle features of deformation namely: Foliation, schistosity, shear zones and faults. Emplacement features are dykes and veins which are of basic or acidic in composition and are widely distributed though some were not mapped at the scale of the present work. Foliations are found within the gneiss-migmatie-schist complex at varying degrees of dip (moderate 43° to high 70°).

Shear deformation is common especially on the granites and is closely associated with fault zones in space and orientation. Chikale a settlement in the south is an area with intense shear deformation and faulting on its hill [4]. The hill is a granite ridge about 90 m long. Faults on the ridge have produced smooth fracture planes. Slicken sides and mylonite are found within the fault zones. Fault breccia within fault planes varies between 0.3 to 20 cm. At least three directions of faulting/shearing are evident on this ridge viz: E-W (070° - 110°). NW (160°) and N-S (170°).

Fourteen fault were identified and mapped and presented in Table 1. Others have been inferred based on offset of streams. The deformational (strain) gradient across the N-S Limankara fault is presented in Fig. 2. The measurements of the X,Y axes of strain ellipsoid was done perpendicular to the fault exposed along the Gwoza-Madagali highway. The distance of measurement across the fault zone was 200 cm (0.2 m).

5. DISCUSSION

From the strike of the 14 mapped faults of Table 1, the general trends are N-S, E-W, NE-SW, NW-SE. The easterly trending fault and the dominantly north-westerly inferred faults constitute parallel fault and are generally equidistant from each other. Their spacing varies between 1-2 km, this regularity of spacing indicates that the stress regime that produces them were uniform in magnitude and direction [7].

Some mapped faults e.g. faults 6, 8, 10 and 13 (Fig. 1 and Table 1), influence or control river course. Inferred faults follow river courses (western part of Fig. 1). The mapped and inferred strike-slip faults lettered A-I (Fig. 1), deflect river courses. Rock structures (foliation) also influences river direction such as NW flowing river near Namtari Jambutu in the south of the study area (Fig. 1). Alignment/location of settlement generally follows availability of water resources (surface and underground). In the study area settlements follows or generally align with the NW- SE, E-W flowing rivers. This alignment of rivers must be lineament controlled (Since this is a basement region, electromagnetic reconnaissance survey for ground water should consider the dominant directions of river flow observed in this study in the orientation of the survey profiles). The NW flowing rivers have a length between 3-8 km, this is an indication that the subsurface lineaments that control their courses are of deep crustal origin. [8] showed the importance of lineaments in ground water accumulation in basement areas, stating that it is related to the length and intersection of the lineaments. The longer a lineament the more deep seated it is and this provide more favourable sites for ground water accumulation. These facts have been practically demonstrated in Malumfashi area northwest Nigeria [9] and southern Sweden [8].

Fault intersections are common features of the study area such as on the southwestern hills of Madagali, and centrally from Wagga Lugere to Hogolo hills. These intersections could be favourable for large scale municipal groundwater abstraction as they are likely to have higher borehole yield than other areas. The intersections are also attractive sites for mineral exploration.

Table 1. Faults data in the study area

S/ No	Location of fault	Rock type	Identification features on fault plane	Attitude of fault plane		Type of fault	Remark
				Strike	Dip		
1.	Hill at Madagali Town N10°52', E13°36'	Fine Grained Granite	Striation, slicken sides.	N-S	Vertical		
2.	Hill near Babel N10°52'.314'', E13°36'.136''	Fine Grained Granite	Striation, Breccias	E-W (080°)	64°	Normal with lateral component	Fault zone has mylonite, slicken sides orientation in vertical direction. Width 5 m
3.	Plain west of Madagali Town	Granite-Gneiss	Slicken sides and Breccias	NW-SE (130°)	45°	Reverse with Normal and lateral component	Slicken sides orientation show evidence of normal, reverse and lateral fault zone. Width 1.64 m
4.	South of Madagali N10°53'.102'', E13°37'.349''	Granite	Slickensides	NE-SW (050°)	Vertical	Unclassified	Intersection with N130° fault forming a valley. Width is between <1-5 m. mylonite occur in fault zone.
5.	Toward east slope of southern Madagali Hill	Coarse Grained Granite	Slicken sides, Striation	NE-SW (060°)	Vertical	Unclassified	Fault zone is about 10 m in width. Large boulders of pegmatite align fault zone.
6.	Across Road north of Wagga Lugere N10°58'.368'', E13°40'.054''	Gneiss-Schist Complex	Slicken sides, Striation	E-W (100°)	Vertical	PStrike- slip	Presence of intensely sheared mylonite in fault zone.
7.	Across Road north of Wagga Lugere N10°58'.368'', E13°40'.054''	Gneiss	Slicken sides	N-S (020°)	70°	Normal with lateral component	The fault intersects E-W fault of No.6. Width of N-S fault zone is about 25 m.
8.	South of Wagga Madagali N10°58'.922'', E13°39'.973''	Schist	Striation	N-S (020°)	Vertical	Unclassified	Part of a long N-S fault that extends to Hogolo hill about 6 km in length.
9.	Hogolo hill N10°59'.890'', E13°39'.503''	Granite	Striation	N-S	Vertical	Unclassified	Extension of N-S fault zone of No. 7 and 8.
10.	Hogolo hill N10°59'.890'', E13°39'.503''	Granite	Striation	NE-SW (040°)	?	Strike- slip	A strike slip fault intersects No. 9 fault and displaces river.
11.	East Bugathal	Banded	Slicken sides, Striation.	NW-SE	Vertical	Normal with lateral	Shear deformation is associated

S/ No	Location of fault	Rock type	Identification features on fault plane	Attitude of fault plane		Type of fault	Remark
				Strike	Dip		
	N10°59'.545'', E13°40'.941''	Gneiss/Pegmatite Granite		(140°)		component	with fault, dolerite intrudes gneiss at fault zone.
12.	NE of Madagali Town	Granite	Slicken sides, Scap with smooth fault plane	N-S	Vertical	Normal	Segment of a northerly system of fault.
13.	North of Wagga Madagali	Schist	Scap, Slicken sides	E-W (090°)	Vertical	Normal	Fault controls east-west flowing river.
14.	South of Wagga Madagali. N10°59'.632'', E13°39'.721''	Schist		E-W (090°)	Vertical	Unclassified	Intersects N-S fault of No.8.

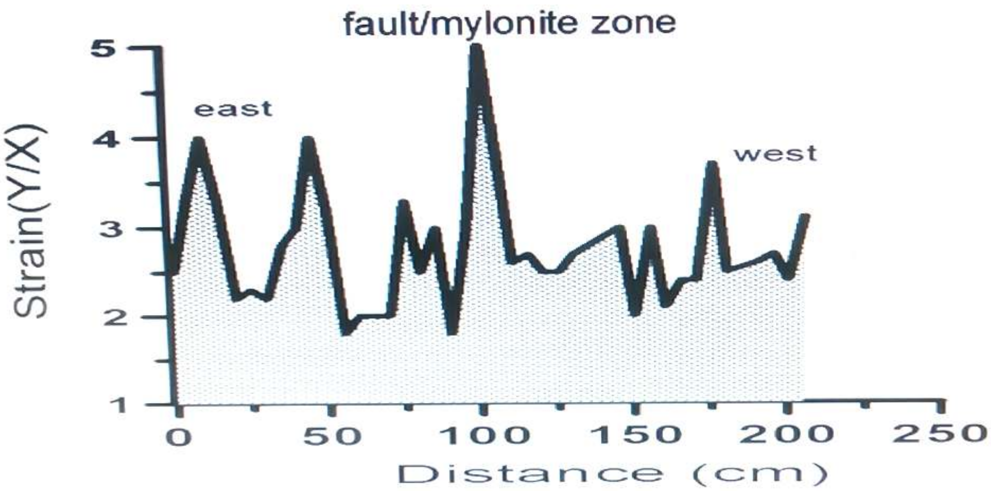

Fig. 2. Deformational (strain) graph across N-S trending Limankara fault

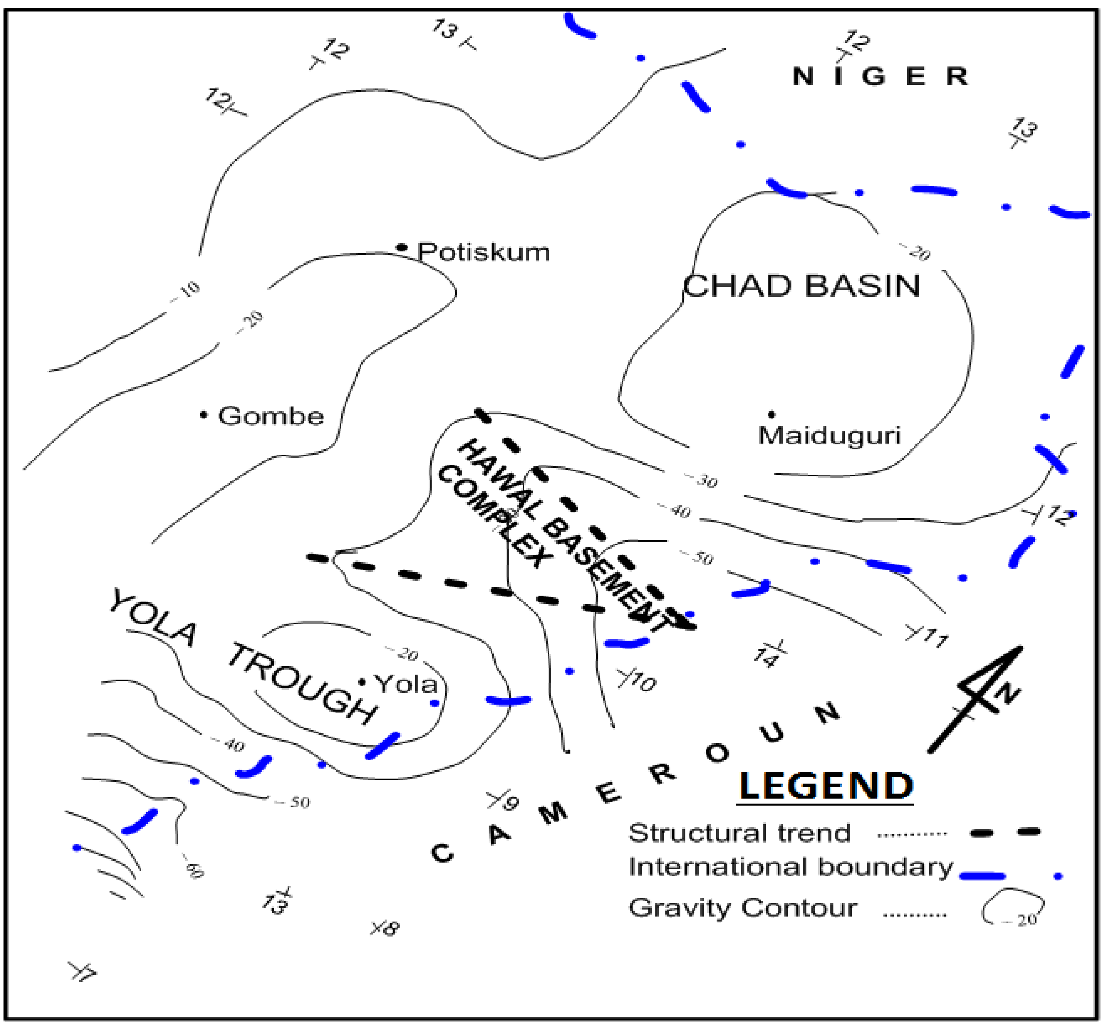

Fig. 3. Gravity map of N.E. Nigeria [11]

The north-westerly flow of streams in the present study is reflective of the structural disposition of Hawal Basement Complex as reported by [10], he posited that they are expression of faults, foliation, shear zones and other lineaments. This NW trend correlate with the gravity structural trend of the Hawal Basement Complex (Fig. 3) as published by [11]. The evolution of the plains in the area whose present elevation above sea level is between 1350-1750 ft (405-510 m) would have been preceded by intersections of fault systems mapped in the study area. Denudation being more effective at intersection zones. From Fig. 2 (which shows a plot of X/Y against distance across the fault), it is observed that highest zone of strain is at the centre. This is where faulting is intense and mylonite has developed. The quartz and feldspar crystals experience highest deformation here. The fault is in deformed granite.

6. CONCLUSION

The study is a brief presentation of faults distribution and implications in Madagali and environs. The study is not exhaustive. Further investigations or geo-exploration targets should be on the faults and their intersections to know if they have potential for high water yield for boreholes for the municipal population. Also available records show that such intersections harbour uranium mineralization in a similar geological environment close to Nigeria-Cameroun border.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/11715