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Geology and magnetic character of the Basement Complex rocks in Garun Kurama area, north central Nigeria

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Abstract

The volume magnetic susceptibility of the granitic gneiss and garnetiferous migmatite in Garum Kurama area was studied in situ, using Bartington MS2 magnetic susceptibility meter and its MS2D probe. The granitic gneiss is foliated and its constituent minerals include quartz, biotite, microcline, plagioclase feldspar and hornblende. The migmatite is gneissic in places and is strongly foliated. Its constituent minerals include quartz, orthoclase feldspar, biotite, hornblende and garnet. The magnetic susceptibility readings were taken along six E-W profiles at approximately 400m station interval. The coordinates of the stations were obtained with a Garmin 12 Global Positioning System (GPS). The resultant magnetic susceptibility map was then compared with the total intensity aeromagnetic map of the area in a Geographical Information System (GIS) environment using ILWIS and ARCVIEW softwares. The anomalies on both maps coincide. The magnetic susceptibilities are very low. They ranged from -0.09 to 1.88 cgs units. This suggests that both the granitic gneiss and migmatite are paramagnetic. However, they contain two narrow zones of diamagnetic rocks located N and NW of the Garun Kurama settlement. These diamagnetic zones are probably underlain by quartzitic veinstones which may contain gem-quality quartz crystals or topaz. The parent rocks that were regionally metamorphosed to get the granitic gneiss and migmatite were probably richer in felsic minerals than mafic minerals. One can also conclude that the Bartington MS2 magnetic susceptibility meter can effectively be used to map materials that exhibit different kinds of magnetic behavior, since magnetic susceptibility is an intrinsic property of all materials in the natural environment.

1. Introduction

The study area is part of the Basement Complex of Central Nigeria (Oyawoye, 1970). It is bound by latitudes 10^0 9’ 48” N and 10^0 12’ N, and longitudes 8^0 31’ 36” E and 8^0 35’ E’ (Figure 1). The most prominent settlement in the study area is Garun Kurama, in Lere LGA of Kaduna State. The area has an undulating topography. It is accessible through Saminaka-Kafanchan road, and is traversed by a number of foot paths and untarred roads. It presents a good location to study the magnetic character of the rocks of the Basement Complex using the Bartington MS2 magnetic susceptibility meter. Magnetic susceptibility is an intrinsic property of all materials in the natural environment. It is a measure of the ability of a material to be magnetized. It provides information about minerals in rocks, soils and dust, particularly iron-bearing minerals. It provides information similar to those produced by other mineralogical techniques like X-ray diffraction and heavy mineral analysis (Dearing, 1999).The results of the geological mapping and volume magnetic susceptibility measurements were compared with the total intensity magnetic field map of the area (GSN, 1976) to arrive at a plausible interpretation of the anomalies in the area.

1.1. Geology

The study area forms part of the Basement Complex of central Nigeria. It is underlain by granitic gneiss and migmatite (Figures 2 & 3). The granitic gneiss underlies the eastern half of the study area while the migmatite underlies the western half (Figure 4). The granite gneiss is foliated and has medium-to-coarse grained texture. Biotite grains define the foliation. The other minerals it contains include quartz, microcline, plagioclase feldspar and some hornblende (Figure 5). Many quartzo-feldspathic veins (30mm - 800mm long) abound, as well as some sinistral strike slip faults and shear zones. The quartzo-feldspathic veins trend mainly NNE-SSW. The trend of joints range from NNE-SSW to ENE-WSW and a minor NW-SW trend. This rock is a product of regional metamorphism of the amplibolite and granulite facies.

The migmatite is garnetiferous and strongly foliated. It is gneissic in places and shows lit-per-lit structure. It contains leucosomes and neosomes which measure up to 5m by 50m in size. Some of the neosomes occur in ptygmatitic folds. The folded structures in the migmatite consist of dykelets, veins and segregations of light coloured granitic materials buried in dark coloured amphiboles and biotite-rich melanosomes. The mineral constituents include quartz, orthoclase feldspar, biotite, hornblende and garnet (Figure 6). This rock is a high grade metamorphic rock with abundant almandine garnet crystals as can be seen on the outcrops at Geli and Rafin Dadi (Figure 3). It was probably formed under very high temperature and pressure. Joints in the migmatite trend mainly NNE-SSW.

2. Materials and methods

2.1. Magnetic character of minerals and materials

All matter is affected by the earth's magnetic field. The effect may be extremely weak or even negative. Therefore magnetic susceptibility data can be used to classify different types of materials, including rocks. For example, a rock like basalt with relatively high concentration of magnetite will have much higher magnetic susceptibility values than limestone which may not have magnetite crystals. Magnetic susceptibility measurements can also be used to identify iron-bearing minerals in a sample and estimate their concentration (Dearing, 1999).

The magnetic susceptibility of minerals (and other materials) depends on the configuration and interactions of the motions of all the electrons of the atoms that make up the minerals or materials. The electrons spin around their axes and also around the nuclei of the atoms in their orbits. Consequently materials have been classified based on their magnetic susceptibilities (Parasnis ,1972; Sheriff, 1980; Telford et. al, 1978). Thus we have diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic and ferrimagnetic materials. Diamagnetic materials (eg. quartz, gypsum, graphite, marble, salt) have negative magnetic susceptibiliiesy, while paramagnetic materials (eg. gneisses, pegmatites dolomites) have small positive magnetic susceptibilities. Ferromagnetic materials have relatively large positive magnetic susceptibility. There are no truly ferromagnetic rocks or rock minerals but items like rusty cans or metallic rubbish may give high positive magnetic susceptibility (Dearing, 1999). Antiferomagnetic materials (eg. hematite), have net magnetic moments of parallel and antiparallel subdomains which cancel each other in the material which would otherwise be ferromagnetic. The resultant susceptibility is very small and of the order of paramagnetic materials. Ferrimagnetic materials (eg. magnetite) show both ferromagnetic and antiferromagnetic properties because their ionic interactions consist of both parallel and antiparallel alignment of group magnetic moments.

2.2. Magnetic susceptibility survey of Garun Kurama and environs

The Bartington MS2 magnetic susceptibility meter with its MS2D probe (Figure 7), was used to take magnetic susceptibility measurements along six E-W profiles across the study area. Readings were taken at approximately 400m intervals. The coordinates of the observation stations were obtained with the aid of a Garmin 12 Global Positioning System (GPS). The MS2D probe measures the concentration of ferromagnetic minerals in the top 60mm of the ground. The rocks and soils are placed within the influence of a low frequency 100μT alternating magnetic field produced by the sensor of the probe. This weak magnetic field detects the magnetization of materials lying within it. The magnetic susceptibility of the rock and soil at the location is then calculated and the value is displayed in cgs units. Figure 8 shows the contour map of the resultant data, while Figure 9 shows the profile across the isolated anomaly in the north central part of the study area. The total intensity aeromagnetic field map (Figure 10) and a corresponding magnetic profile of the area (Figure 11) were compared with those of the magnetic susceptibility, with the aid of ILWIS and ARCVIEW softwares, in a Geographical Information System (GIS) environment.

3. Results and discussion

The volume magnetic susceptibility map shows an isolated anomaly pair with minimum and maximum values of -0.9 and 1.88 cgs units located northwest of Garun Kurama settlement (Figures 8 & 9). This anomaly pair is confirmed on the total intensity aeromagnetic field map of the area, and the corresponding profile (Figures 10 & 11). The anomaly does not occur as closures on the aeromagnetic map. This may be explained by the difference in the station (sampling) and contour intervals between the aeromagnetic survey and the ground magnetic susceptibility survey. It is likely that there is a significant accumulation of diamagnetic materials in this part of the study area. During the fieldwork it was observed that this area has significant accumulation of quartz and sand. The diamagnetic material may extend to deeper levels, possibly as veinstone, since this anomaly also features on the aeromagnetic map. A second zone of negative magnetic susceptibility extends eastwards from Geli settlement to Hayin Bande (north of Garun Kurama) and beyond (Figure 8). The positive magnetic susceptibility of rocks around Rafin Dadi (Figure 9) and the corresponding high magnetic intensity (Figure 11) may be due to the Fe-rich minerals like biotite and almandine garnet which they contain (Read, 1976). Generally the magnetic susceptibility values of the granitic gneiss and migmatite in the study area are quite low, with a maximum reading of 1.88 cgs units. This means that most of the rocks underlying the study area are paramagnetic. It also suggests that the parent rocks that were regionally metamorphosed to give the granitic gneiss and the migmatite, contained more felsic minerals than mafic minerals.

4. Conclusion

The results from the foregoing have shown that the Bartington MS2 magnetic susceptibility meter can effectively be used to map materials that exhibit different kinds of magnetic behavior. The Basement Complex rocks in Garun Kurama (granitic gneiss and migmatite) are paramagnetic. Diamagnetic materials occur in two narrow zones located north and northwest of the Garun Kurama settlement. These zones are probably underlain by veinstones which may contain gem-quality quartz crystals or topaz.

Acknowledgements

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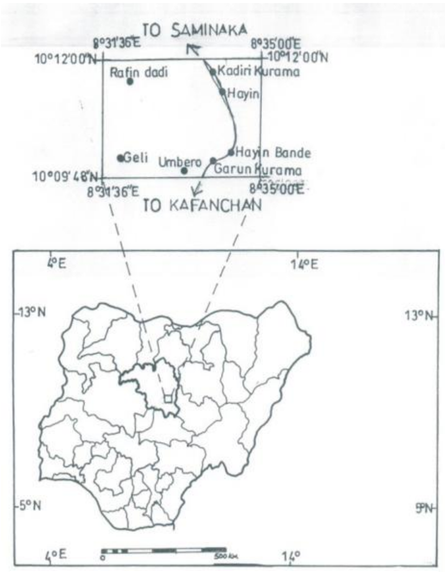

Fig. 1. Location map of Garun Kurama and environs.

Fig. 2. Outcrop of granitic gneiss at Garun Kurama.

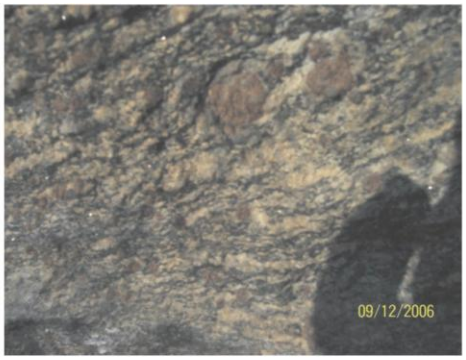

Fig. 3. Outcrop of migmatite at rafin Dadi. Notice the strong foliation and the grains of garnet.

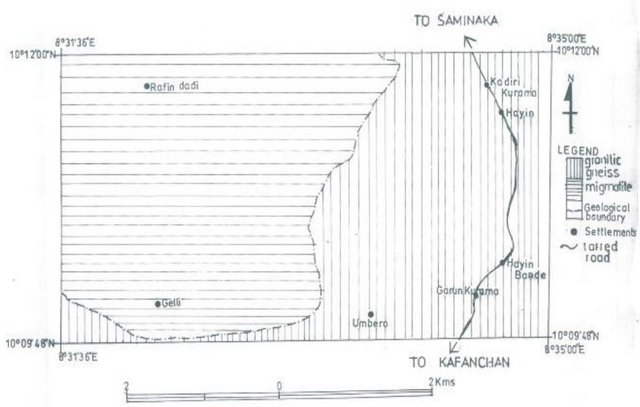

Fig. 4. Geological map of Garun Kurama and environs.

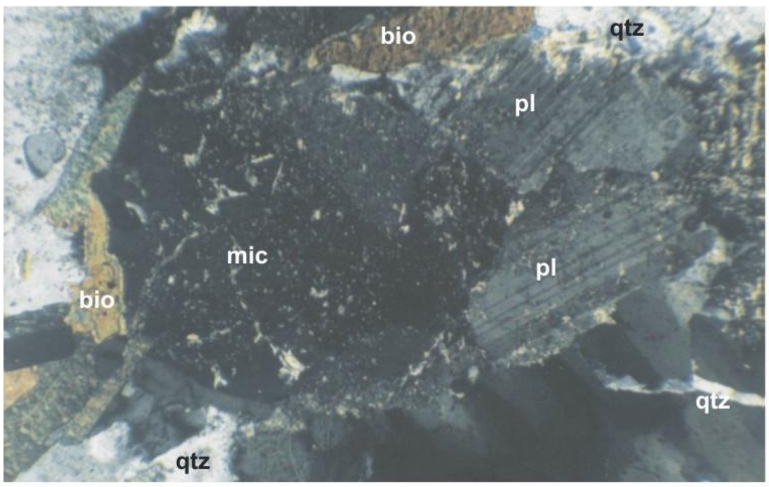

Fig. 5. Photomicrograph of the granitic gnesis from Garun Kurama under cross polarized light (X20) qtz-quartz, mc-microcline, bio-biotic, pl-plagioclase feldspar.

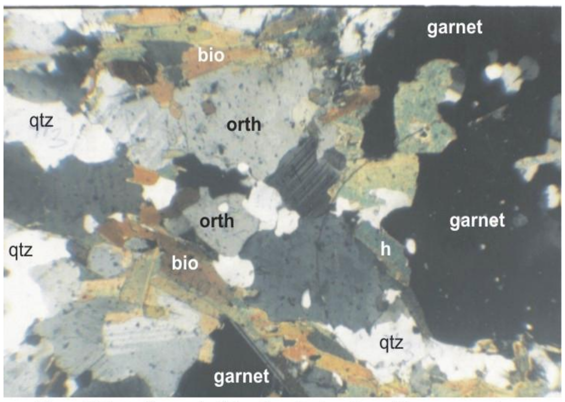

Fig. 6. Photomicrograph of the migmatite from Garun Kurama area under cross polarize light (X10) qtz-quartz, bio-biotite, ortho-orthoclase feldspar, h-hornblende, garnet.

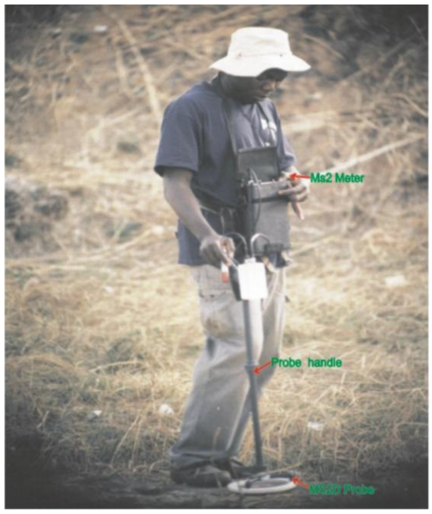

Fig. 7. The Bartington MS2 magnetic susceptibility meter and its MS2D probe in use in Garun Kurama area.

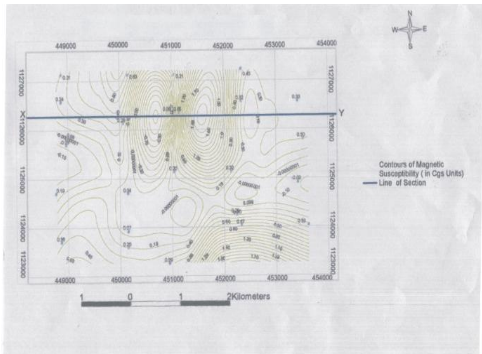

Fig. 8. Map of volume magnetic susceptibility of Garnu Kurama area.

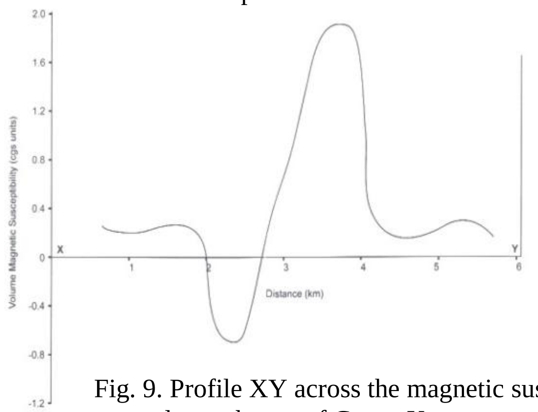

Fig. 9. Profile XY across the magnetic susceptibility anomaly northwest of Garun Kurama.

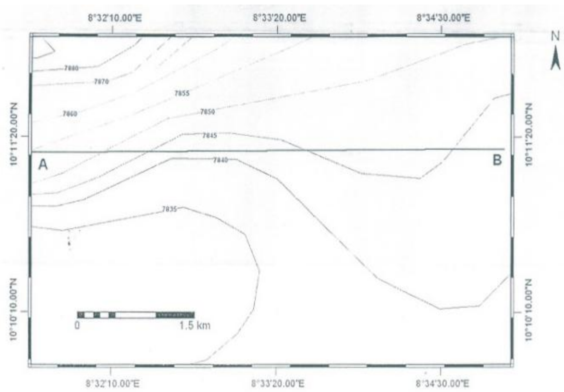

Fig. 10. Total intensity aeromagnetic map of Garun Kurama area (GSN, 1976).

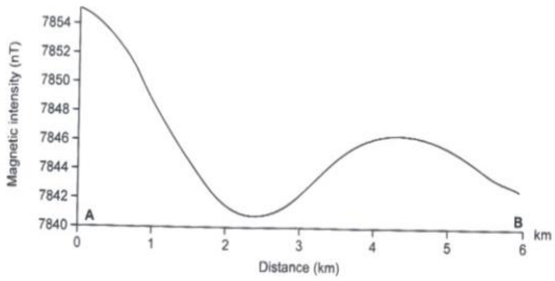

Fig. 11. Profile AB of the total intensity magnetic field northwest of Garun Kurama.