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Conjunctive use of magnetic and radiometric surveys for mapping of ferruginous sandstone horizons in Yola area, Nigeria

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Abstract

As part of a community development based research, an integrated magnetic and radiometric survey was done in part of the Modibbo Adama University of Technology, Yola over areas of exposed /outcropping ferruginous sandstone belonging to Bima Formation of the Yola Rift Sedimentary Basin. The aim was to see if the magnetic/radiometric surveys can be used to effectively map such deposits which are locally quarried and used for construction purposes. A *proton precession magnetometer* and a *Gamma Scout radiometer* were used for each aspect of the survey. The radiometric survey served to reduce ambiguity in interpretation of the magnetic anomalies. Generally from field observations there is an inverse relationship between the ferruginous and the feldspar contents of the sandstone. Hence areas of high magnetic anomalies are some-times coincident with areas of low radiometry. A ground follow up of mapped anomalies showed that some magnetic anomalies coincide with ferruginous

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outcrops, while the rest of the magnetic anomalies are attributed to sub-cropping ferruginous sandstones. The magnetic exploration technique is recommended for the exploration of the sandstones in Yola area, this will help to prolong the lives of the existing quarries, fast track exploitation and economically empower the local populace.

Keywords: Magnetic, radiometric, exploration, ferruginous sandstone, exploration.

1 Introduction

This is part of community development based research and an attempt to locate by geophysical means deposits of ferruginous sandstone of Bima Formation which is locally quarried for building construction, and is known in the local construction parlance as *bush gravel.* The rock occurs commonly as reworked materials deposited on sandstone beds having very poor sorting (varying from rectangular fragments of about 30 cm to rounded and sub-rounded portions of <5cm). The poorly sorted portions may have been deposited during mass movement that affected the hilly slopes in past geologic times. It also occurs as capping on the in situ rock. For these reasons they are referred to in this study as *ferruginous sandstone horizons.* Both types are exploited and used in construction of pillar props, lintels and culverts. When mixed with laterite it increases the stabilization ability of the latter and is thus good for soil/road stabilization. The quarries are located at the plains that adjoin the Bagale hills, at the north bank of the Benue River (Figure 1 and 6b) along Yola- Mubi road of Adamawa state Nigeria.

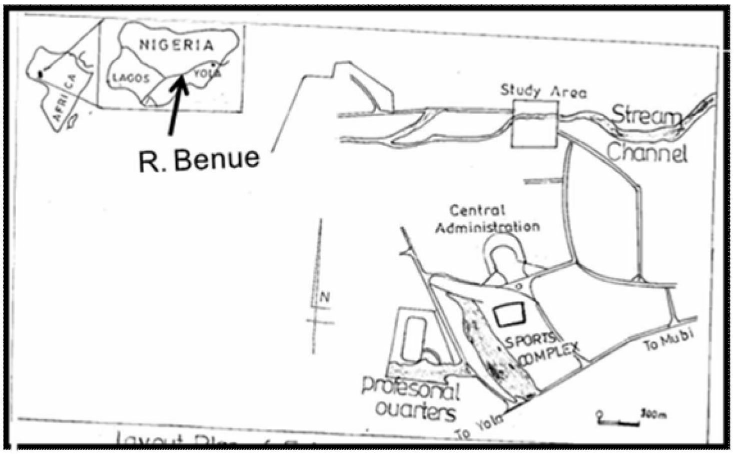


Figure 1: Lay out plan of Modibbo Adama University of Technology, Yola, Nigeria

The use of the rock for construction derives from the high mechanical strength imparted to it by its ferruginous content. The quarries provide employment for people across different age brackets. Presently the exploited deposits are mainly from outcrops/exposures. With time these would be exhausted hence to keep the quarries alive there is need to extend the reserves which can be done by geophysical mapping, which is the focus of this work.

The inspiration for this work came as the first author observed rocks from excavated drainage channels in the Modibbo Adama University of Technology, Yola. The observation showed that where the ferruginous content of the rock is high, the feldspar content is low and vice versa. Since feldspar contains potassium which is radioactive, it was assumed that areas of high radiometry will be area of low magnetism and vice versa. Hence the radiometric survey would serve as a check on the magnetic anomaly interpretation thereby reducing ambiguity inherent in potential field data analysis. It is hoped that the results/recommendation of this research when utilized will extend the life of the quarries, and keep the people economically empowered.

The area of study lies in the north part of Modibbo University of Technology, Yola (Figure1), between longitudes E012^{O} 29.620 and E012 30.159, and latitudes N 09^{O} 21.100 and N 09^{O} 21.663 (Figure 2). It is part of the Yola Rift Basin, an arm of the Benue trough. The geology of the area has been presented severally by workers such as Carter et al. (1963), Offodile (1976), Offoegbu (1985). The Bima Formation is the base of the sedimentary succession in the Yola Rift and overlies the Basement Complex. Its thickness varies from 100- 300 m in places. It consists of coarse grained thick bedded feldspathic sandstone with intercalations of thin siltstone and mudstone. The Formation resulted from deposition of fluvial and deltaic sediments and is believed to be Albian- Cenomanian in age. The Bima sandstone is the dominant sedimentary unit in Yola area of the Benue Rift.

2 Materials and methods

The area surveyed is 1000 by 850 m i.e. 850,000 m^2, it stretches 1 km in the north-south and 850 m in the east- west direction (Figure 2). It is located in the plain

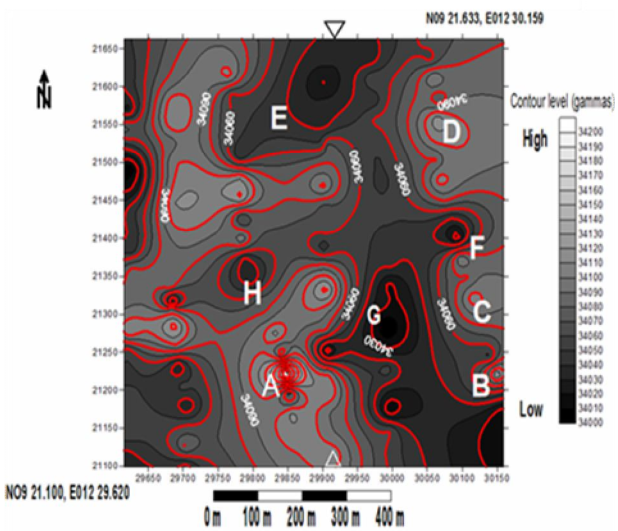


Figure 2: Magnetic map of total intensity over study area

land and relatively undeveloped part of the University (Figure 1). Electric power lines, water pipe lines etc are largely absent hence the results of the work can be confidently attributed to natural (geological) causes. The survey was done along six profiles with a separation of 150 m (along N-S direction perpendicular to E-W Yola Trough), with the exception of the last two traverses toward the west boundary which had a separation of 100 m because of a new building under construction that interfered with the regular (150 m) separation. Station spacing was 50 m, thus each profile had 20 stations. Station location was achieved by use of 100 m measuring tape and an *e trex Garmin*™ GPS. The data acquisition lasted for about one week from 10-18 June 2011. At each station both magnetic and radiometric readings were taken simultaneously. The proton precession magnetometer and the *Gamma Scout* (tuned to Geiger counter mode) were used for the magnetic and radiometric field measurements respectively. Only the gamma radiation was measured. A geological compass was used to define the base line of the survey area along the E-W direction. Time recording for possible diurnal correction was done with an electronic stop-watch. Since relatively few and short traverses were surveyed each day's survey was done in about two hours or less. Hence station reoccupation for diurnal correction was considered unnecessary. Telford et al. (1976) said that often times station reoccupation in mineral prospecting for the purpose of diurnal correction is not followed as the anomalies of interest are often >500 gammas. The anomalies encountered in this work are distinct though they are <500 gammas. Vegetation over the survey is grass and at the survey time was dry since the area lies in the northern Nigeria semi arid belt. In the course of the survey a magnetic storm was detected once and in response the work was suspended until the storm was over. Prior to the survey a test survey was done to determine the regional value of the magnetic field in the area. This was found to be about 34000 gammas. Similarly the back ground radiometric field was found to be about 10 counts per minute (cpm). Radiometric data at each station was observed over an interval of 3 minutes, this was later averaged to get the cpm. The magnetic and radiometric data were separately contoured using *surfer 8* software. Contoured maps are shown in Figures 2, 3, and 4. A ground check on the anomalies was done using the GPS to locate their positions on ground.

For contouring the data acquired, the software only accepts whole numbers hence the eastings (east coordinates) were inputted as 29620, 29650 to represent E012^{O} 29.620 and E012^{O} 29.650 etc. While northings represented as N09^{O} 21.100, N09^{O} 21.150 was inputed as 21100 and 21150 etc.

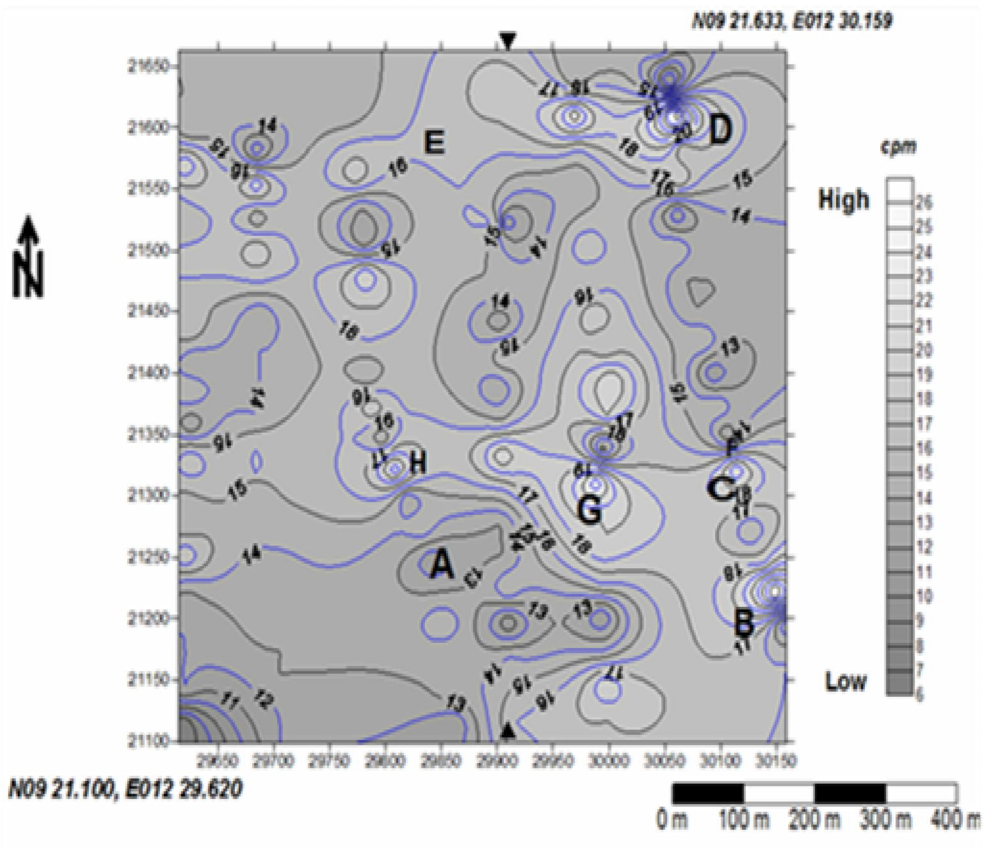
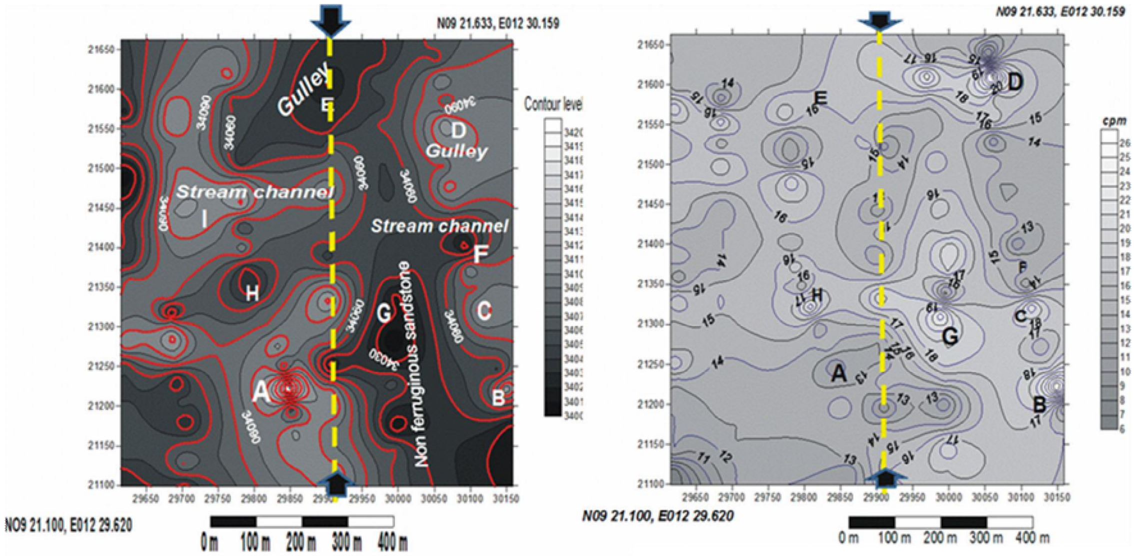


Figure 3: Radiometric map of study area



(a) (b)

Figure 4: (a) Magnetic and (b) radiometric map of study area as interpreted

3 Main Results

Generally broad magnetic anomalies of high and low amplitudes (34110-34210 and 34000- 34100 gammas) respectively are observed (Figure 2). The magnetic highs are found to the west and east respectively, with the lows between them. The lows extend N-S from about E29.950 to 30.150, with northeasterly arms (labeled E and H), and easterly arm (F). The magnetic highs also extend N-S in the northeast sector where it branches eastward along the N21.450 (labeled I). Another easterly segment of the magnetic high is between N21.250 and 21.300. In the south between E29.750 and 29.975 is another segment of the N-S magnetic high which branches E-W between N21.250 and 21.300, and northeast between N21.250 and 21.350. The broad magnetic highs and lows have superimposed smaller circular/elliptical anomalies. It seems the N-S magnetic low trend is superimposed on the easterly/northeasterly magnetic high.

The radiometric field map (Figure 3) has a range of 6-27 cpm. The major radiometric highs are labeled B,C,D, and G and have values between 18-27cpm, while the lows are <18 cpm and are majority. Both sets of anomalies generally align N-S and E-W over the area.

3.1 Discussion

Based on the ground follow up on some of the radiometric and magnetic anomalies the following interpretations are presented. Anomalies A, B C on the magnetic map are coincident with outcrops of ferruginous sandstone (Figure 4a). It will be recalled that Osazua et al. (1981) interpreted positive magnetic anomalies in Yola area of Adamawa state in terms of ferrogenous grit found along the bank of the Benue. Also Obiefuna and Orazulike (2011) in a geochemical classification of Bima sandstone of Yola area (study area inclusive) reported that the rock is basically made up of iron-rich sandstone (43.75%), subarkose-arkose class (31.25%) and sublithic – lithic class making the remaining 25%. These authors demonstrated that the iron rich variety constitutes the upper portion of the sandstone while the other varieties are below it. Thus substantiating the nomenclature *ferruginous sandstone horizon* used in this work. The anomaly amplitudes as observed in this work range from 34100-34210 gammas. Other anomalies of similar range but unexposed can be inferred to be caused by these sandstone deposits but covered by soil or loose sediments. The E-W trending anomaly in the northwest at N21.500$^{/}$ (labeled I) coincides with an E-W river channel with its associated gullies. The anomaly at the northeast margin labeled D also coincides with a gulley. It will be recalled that Bassey and Obiefuna (2005) reported the existence of a system of gullies associated with an E-W stream at the north section of Modibbo Adama University of Technology, Yola over a distance of about 800 m (see: Fig.1). The high amplitude anomaly over the E-W stream channel (Fig.4a) channel can be explained in terms of stream incision/gullying action which expose the ferruginous rock especially at the banks.

The low amplitude anomalies lettered E and F were also found to be coincident with gullies. Both are related to the stream channel. The N-S anomaly labeled G coincides with outcrops of non-ferruginous sandstone. Other anomaly highs/lows areas were all visited but they have no outcrops. Their sources may be similar to those explained above.

There are areas of inverse relationship between the magnetic and radiometric anomalies i.e. high magnetic anomalies coincide with low radiometric anomalies (Figures 4a and b). This means the more the iron content of the sandstone the less the feldspar content and vice versa. Examples are anomalies labeled A, G and H on both maps. The peak anomaly D on the magnetic map of 34110 correlates with a 'low' value 14 cpm on the radiometric map. Areas of high radiometry (>18 cpm) are best explained in terms of occurrence of feldspar sandstone.

Figure 5 is an attempt to graphically illustrate the inverse relationship between the magnetic and radiometric fields across a section (arrowed) on Figures 2 and 3. Figure 6 shows 3-D plots of radiometric and magnetometric fields of the study area. The anomalous zones show as peaks and the sub anomalies as troughs. In the graphs the magnetic and radiometric profiles are shown through a distance of 1000 m. From 0 and 250 m the magnetic profile is generally high with a peak value of 34100 gammas. This coincides with a radiometric low region with a minimum of 11 cpm. Between 300 to 500 m the magnetic peak is 34115 gammas, this correlates with a radiometric peak of 19 cpm. From 500 to 600 m both profiles are generally low, while from 600 m to <800 m a magnetic peak of 34090 gammas is coincident with a radiometric depression of 13 cpm. In the last segment the magnetic profile reduces to a minimum of 34030 gammas while the

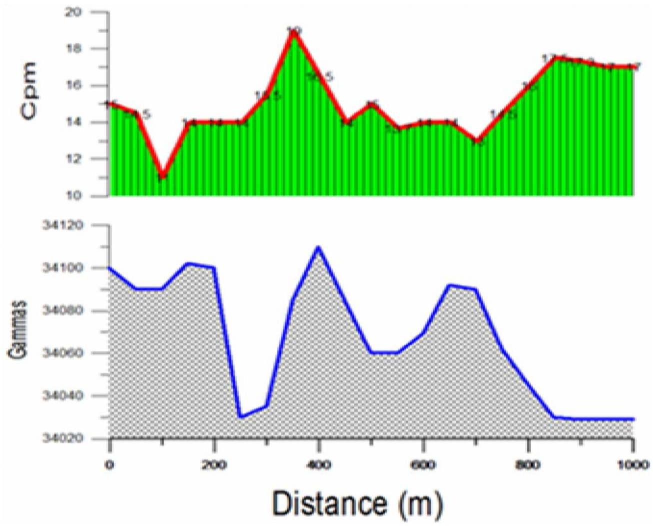


Figure 5: Radiometric (top) and magnetic (bottom) profiles along

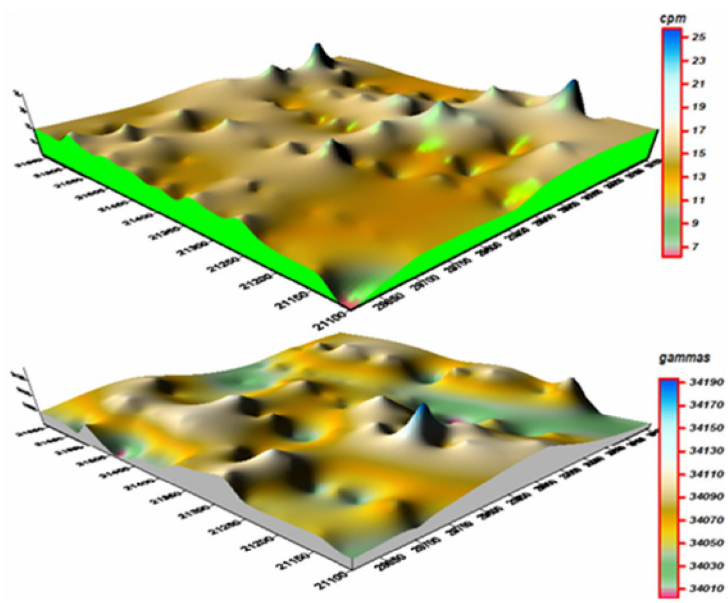


Figure 6: 3-D plots of radiometric and magnetic fields of study area

arrowed sections of figure 4 radiometric graph rises to a peak of 17.5 cpm. Where there is a peak to peak relationship between the profiles it can be explained based on field observation. The loose ferruginous deposit either overlies the feldspar sandstone or occurs as a hard capping on it **(see: Figures 7a and 7c below).** Hence such a place exhibits both magnetic and radiometric highs. Figure 7b shows the site of a sandstone quarry in Yola area, while 7d shows a worker in a pit extracting the *bush gravel.*

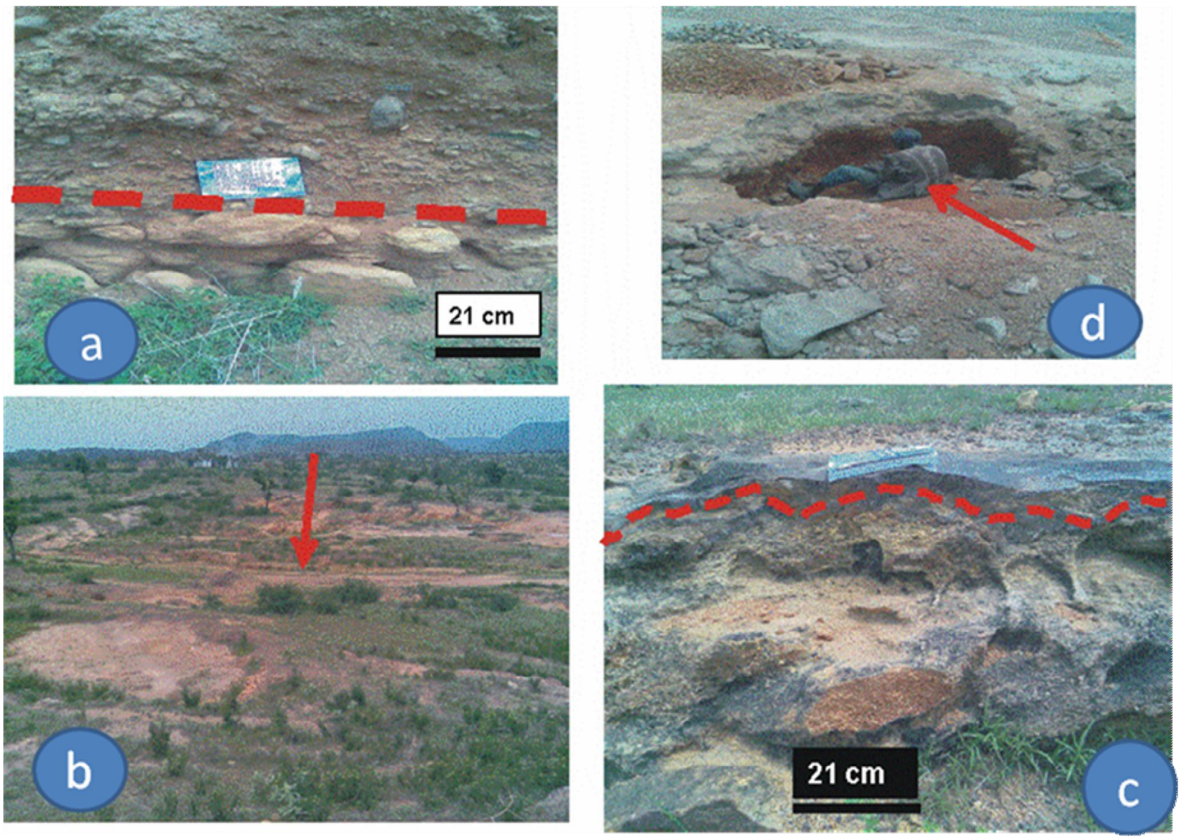


Figure 7: (a) Loose Ferruginous (above broken line) sandstone overlying the feldspathic sandstone(b) Part of the sandstone quarry (arrowed) in Yola, at the background are Bagale hills, c) shows hard capping ferruginous rock (above broken line) while d) a quarry worker in an extraction pit

With continuous extraction of the ferruginous rock for construction in Yola town and environs the easily accessible and outcropping deposits will be exhausted one day. Magnetic technique of exploration will be a necessary tool to discover more deposits. With this the quarrying business will continue. Besides if more areas of the Yola rift are explored and more *bush gravel* deposits discovered, more workers can be attracted to the business thus fast tracking the quarrying operations.

5 Conclusions

This study has shown that the magnetic survey can be used to locate effectively ferruginous sandstone deposits a material used locally in construction. To reduce ambiguity in interpretation of acquired data, it can be combined with radiometric survey. These geophysical techniques have the potential to fast track small scale quarrying operations and bring about economic empowerment for the people.

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