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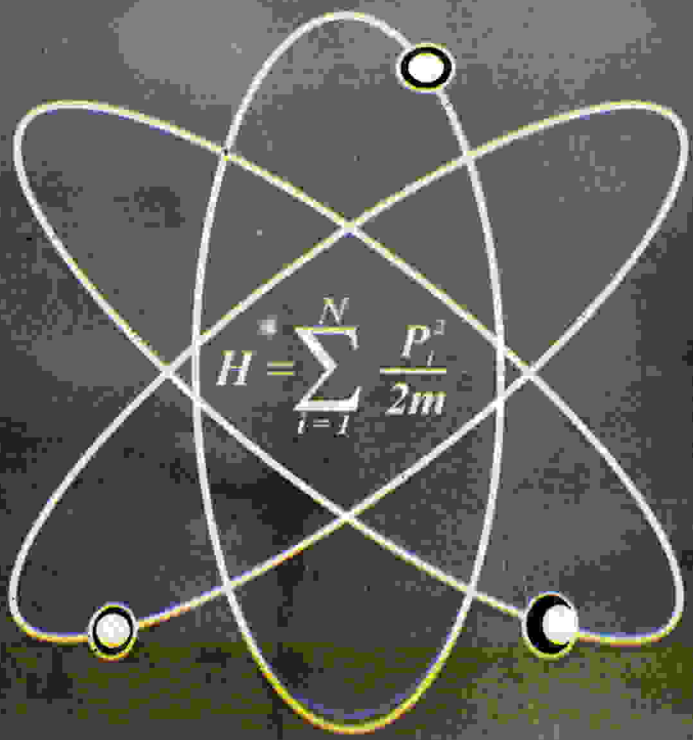

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A MULTIDISCIPLINARY APPROACH TO SUBSURFACE CHARACTERIZATION IN NORTHWEST OF MINNA, NIGER STATE, NIGERIA.

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Abstract

The subsurface structures of northwestern part of Minna, north-central Nigeria has been investigated with the aid of geological, hydrogeological, geophysical and remote sensing techniques. Schlumberger Electrode Configuration using Vertical Electrical Sounding (VES) in three azimuth directions was used to construct an Anisotropy polygon from which the nature of subsurface fractures of the area was interpreted. The radial geo-electric results have been confirmed by surface fracture mapping of the outcrops around the radial VES points. The radial geo-electric sounding results reveal two major fracture directions along the NW–SE and NE–SW fracture pattern. This was inferred from the dumb-bell shape of the anisotropy polygon and lineaments from satellite imagery. The surface fractures direction measurement of the outcrops around this location agrees with the interpretation of the geo-electrical sounding results.
Keywords: Multidisciplinary Approach, Subsurface Characterization, Minna, Nigeria.

Introduction

In Nigeria, the determination of subsurface fractures below the weathered layer during site investigations for siting dams, quarries, boreholes and other engineering foundation structures is not usually fully explored. This has gone a long way in contributing to failures and high cost of operations in such projects. Structural mapping of the basement complex terrain is usually demanding especially in areas with paucity of rocks or poor exposures. The importance of geological structures in mineral and groundwater exploration as well as in foundation investigation for engineering structures like dams, roads, bridges and buildings cannot be underestimated [1]. It has been shown that most river channels within the basement complex terrain are fracture controlled [2]. It illustrates that drainage patterns within the basement complex are good indicators of fracture geometry in the area. In the absence of river channels, other evidence of fracturing includes lineaments lithologic contact and fault zone. This paper is a demonstration of synergy in the understanding of basement complex fractures using geological, hydrogeological and geophysical methods.

Study Area Location

The study area lies between longitudes $6^{o}30^{1}$E and $6^{o}39^{1}$E of the Greenwich meridian and latitudes $9^{o}31^{1}$N to $9^{o}42^{1}$N of the equator. It covers a total area of about 300km^{2}. The area is accessible through Suleja road, Bida road, Zungeru road and Kuta road. The area is drained by river Chanchaga and its tributeries (Figure 1).

Climate and Physiography of the Area

The climate of Minna falls within the North-central climatic system. The daylight temperature ranges from about 24^{0}C at the climax of rainy season to about 35^{0}C at the peak of dry season. The average annual rainfall is about 250mm with a marked rainy season from April to October and dry season from November to March. The vegetation is mainly Guinea Savannah which is characterized by grasses, shrubs and trees. Along the river channels, the vegetation becomes more forested.

Geological Setting

The area investigated is part of the north-central Basement Complex of Nigeria which is composed of three lithological units: migmatite-gneiss complex, low grade schist belts and the older granite [3, 4]. Geological mapping revealed that the study area is underlain by granites, schist and gneiss with granites occupying greater portion of the area (Figure 1). The structural mapping carried out in the area shows two principal joint directions along NE-SW and NW-SE. The river Chanchaga at the southern part of the study area (Figure 1) which flows eastwards is structurally controlled [5].

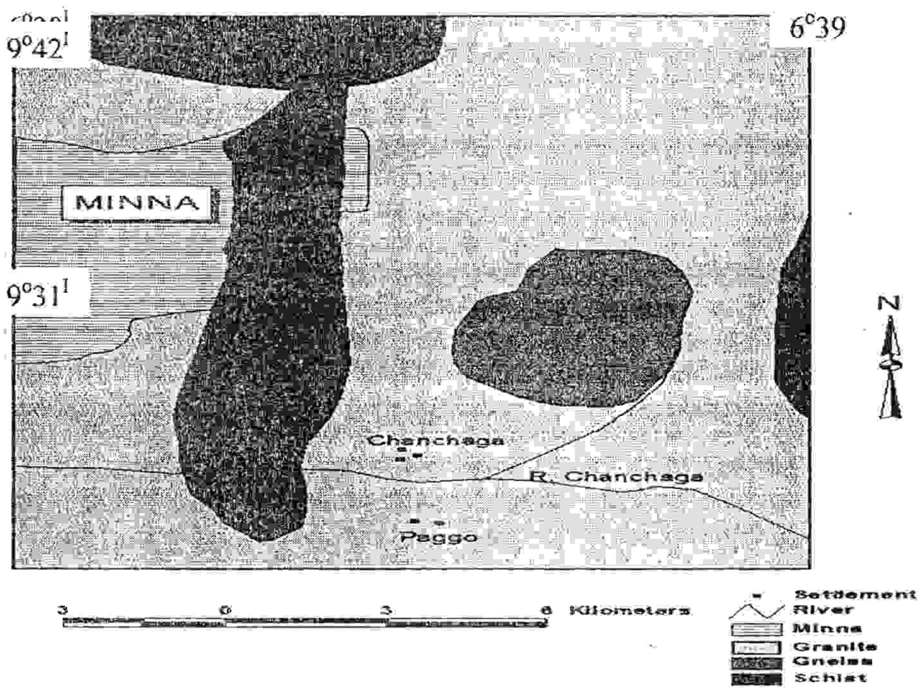
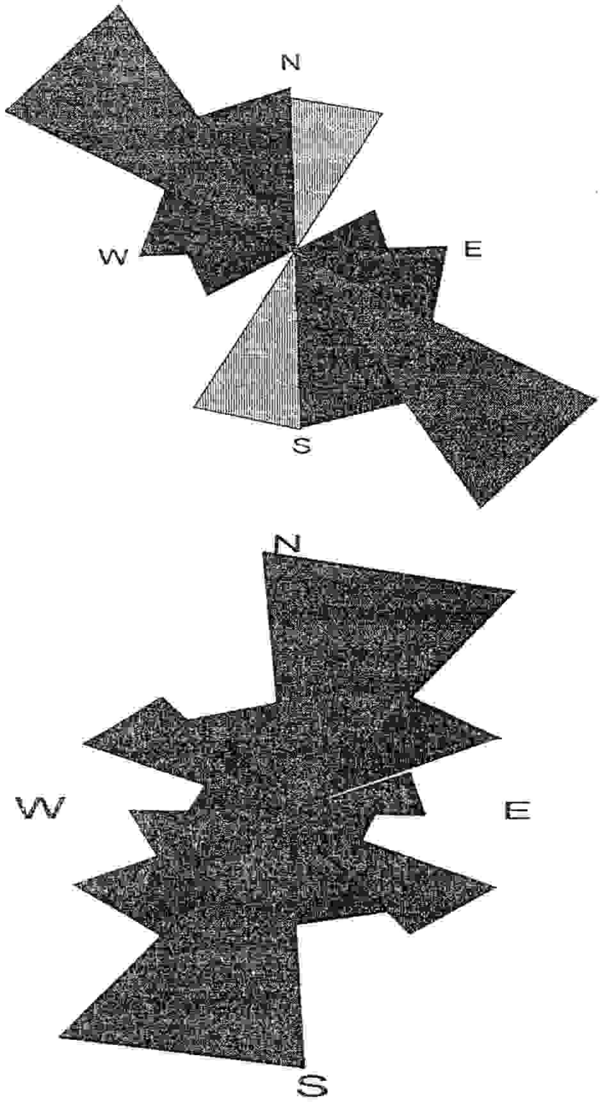


Fig. 1: Geological Map of Parts of SW Minna [6]

Structural Mapping

Structural Geology is the study of structures in rocks. It deals with how rock bodies are organized or reconstructed in response to crustal deformation. It also investigates the shapes and fabric of rock bodies and the processes that have shaped them [7]. Deformation is response to applied forces. A structural geologist deals with the strength and mechanical properties of crustal material (rocks) and the processes that shaped them. Each rock type possesses different mechanical properties which depends on the condition of formation, which result in variation of response that manifest themselves in the different structures that are displaced in the outcrop. The architecture of the earth is commonly fashioned by the large scale faults and folds movement in the crust. Structures can be generated in different ways through compressional forces, tentional forces and gravitational forces. A typical fracture pattern (joints and faults) on an outcrop in the area is shown in Figure 2. The values of the joint directions taken during the structural mapping with the aid of compass and clinometer were used to plot the rosset-diagrams shown in Figure 3. The principal joint directions in the area are along NE-SW and NW-SE direction.

Fig. 2: Fractures on a granite outcrop in the area



NW-SE NE-SW

Fig. 3: Rosset-diagram showing NW-SE and NE-SW major joint directions

Hydrogeology of the Area

The value of the Static Water Levels (SWL) below the ground surface was subtracted from their corresponding elevation values to obtain the Static Water Level (SWL) above sea level. The longitude, latitude and elevation of the area were obtained using a Global Positioning System (GPS) device. The values of the corresponding longitude, latitude and SWL above sea level were used to generate groundwater flow direction in the area using Surfer-8 software. The groundwater in the area flows in NW-SE and NE-SW directions away from the high topographic area and converge towards the central portion. The convergence of the groundwater in the central portion areas (Figure 4) implies that groundwater flow in the area is fracture-controlled.

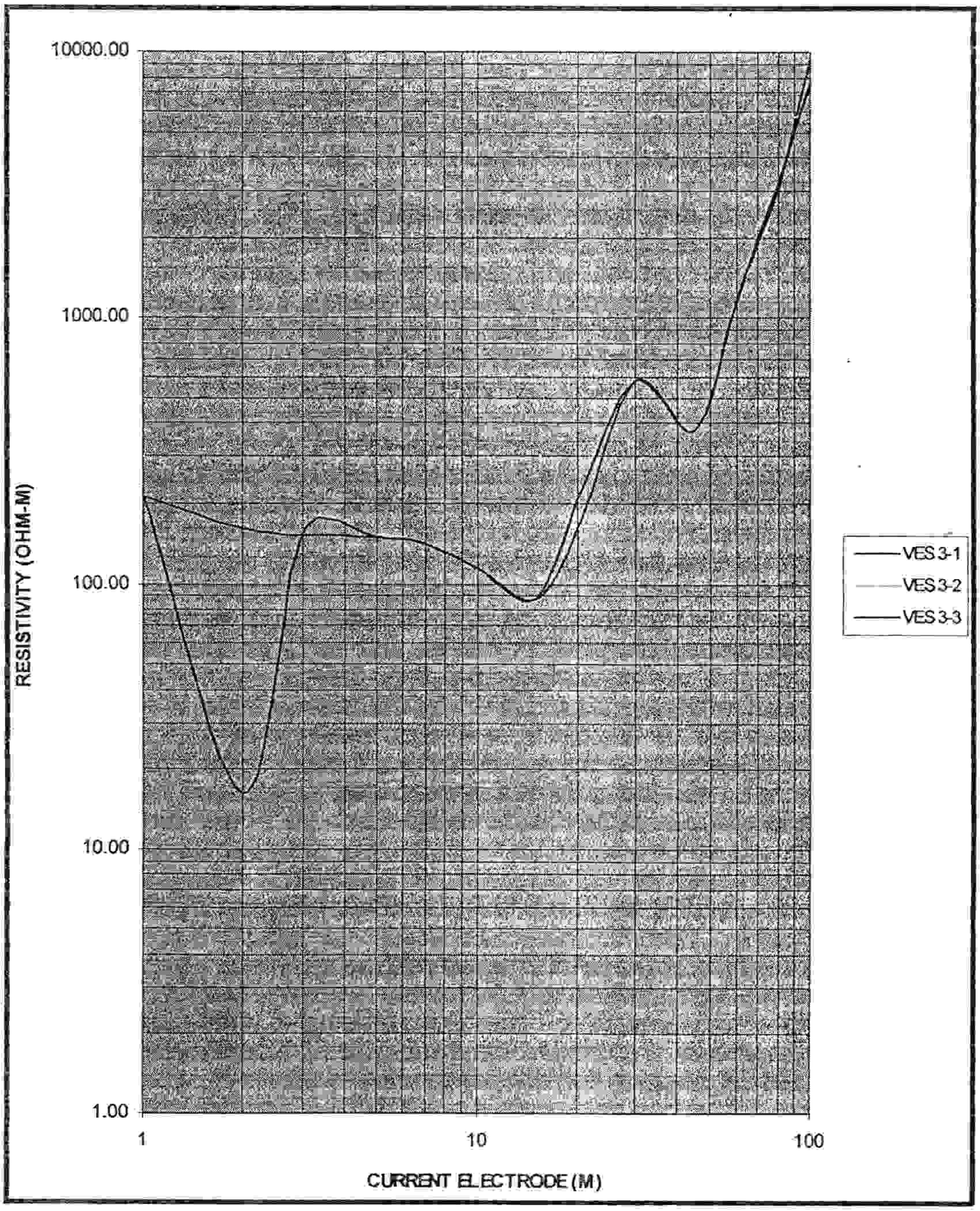


Fig. 4: Ves Curves For Radial Geo-Electrical Sounding

Radial geo-electric sounding

The results of the radial geo-electric sounding carried out in some locations in the study area were used in determining the fracture patterns. The concept of the radial geo-electric sounding is that, lowest resistivity values are obtained along directions where fractures and weathering have taken place. It should be noted that the earth is anisotropic and non-homogenous. This implies that when VES are done in three different coordinates, the lowest resistivity values are obtained along the direction where fractures and weathering have taken place. This implies that the polygon drawn from the radial geo-electric soundings will have a short axis along the fracture directions [8, 9]. A typical anisotropy polygon of the area is shown in Figure 5.

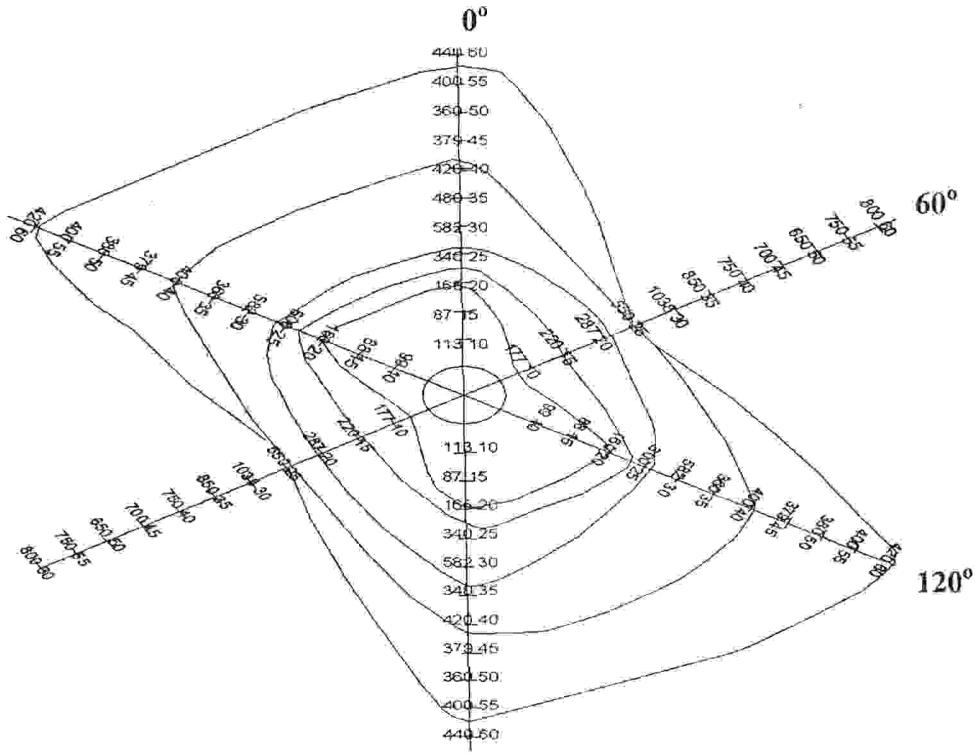


Fig. 5: Resistivity anisotropy polygon of part of the Minna

Electrical Resistivity Pseudosection

Using the electrical resistivity pseudo-sections, fractures are interpreted at places with tight contours. The pseudo-section of the study area had been made along the profiles A-A' in a NW – SE direction, (Figure 6). The section show variation of resistivity values in the horizontal and vertical directions. The resistivity values increases downward along both profiles. They contour value of between 200ohm-m and 1,000ohm-m are found in the profile A-A' in a NW – SE direction which coincides with thick weathering found in the geo-electric section (Figure 7). This implies that lower resistivity values coincide with thick weathering. It is a common knowledge that fractures aid weathering in the tropics [10, 11] hence these thick weathering zones are likely to be fracture controlled.

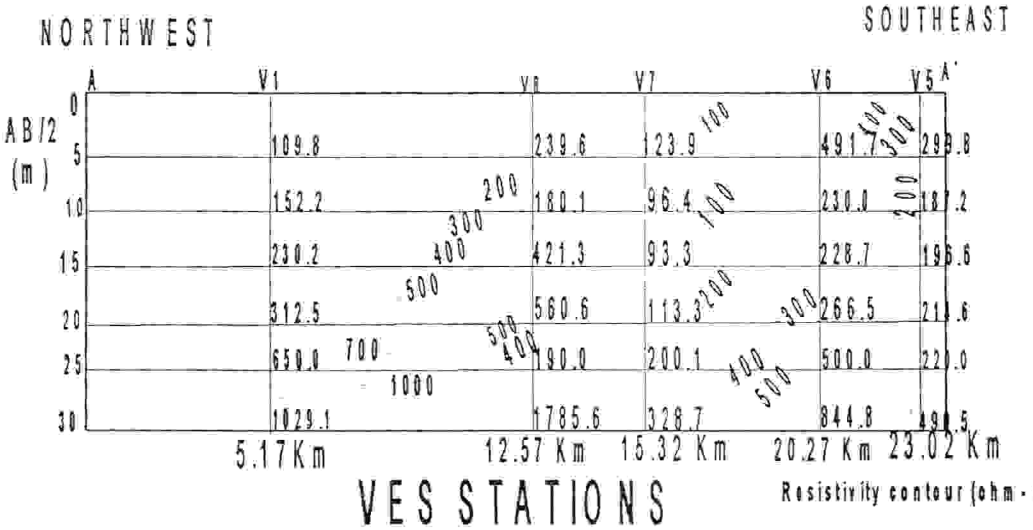


Fig. 6: A typical Electrical Resistivity Pseudo–section across profile A - A'

Geo-Electric Sections

In the geo-electric section across profile B-B', the top soil has a mean value of 2.6 m, the fractured basement ranges from 4.5 m–35.1 m while the depth to fresh basement starts from 5.4 m, though these values varies from location to location depending on the depth to weathering. The geo-electric section reveals three distinct layers which include the top soil, weathered/fractured zone and the fresh bedrock as illustrated in Figure 7.

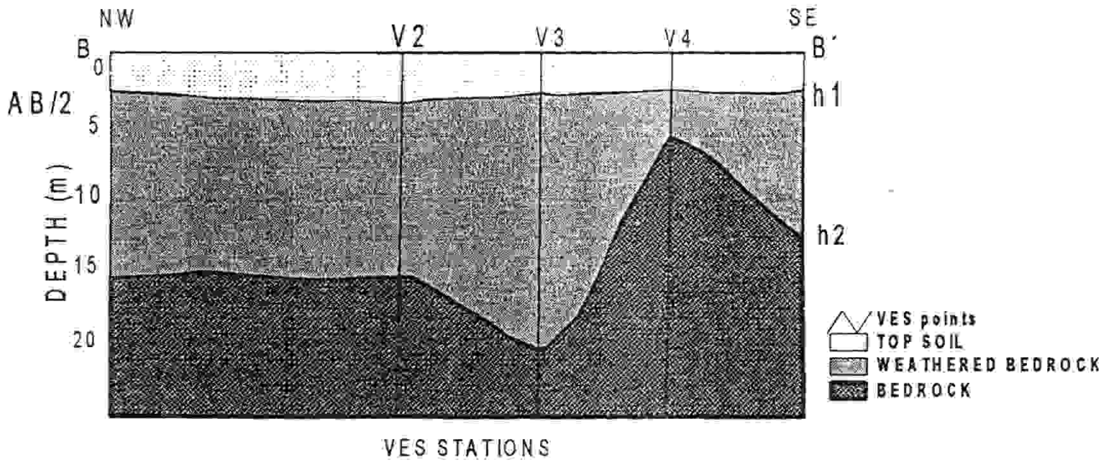


Fig. 7: A typical Geo-electric Sections across profiles B-B'

Remote Sensing

The data come in the form of aerial photos, multispectral satellite imagery and radar imagery [12]. The effectiveness of remote sensing technique in geological and structural mapping (fracture delineation) cannot be underestimated. Understanding structures is the key to mineral and groundwater exploration as

well as interpreting crustal movements [13]. The remote sensing imageries of the study area were obtained and the following were interpreted: (**1**) A major river, River Chanchaga, was identified at the southern part of the study area (Fig.8). This and Bosso dam which is located at the extreme North Western part of the study area were identified on the processed band 4 imagery. (**2**) Three major rock types were identified in the study area: N-S trending schist in the west and around river Chanchaga and Bosso Dam, gneiss in the centre and granite in the northern and southern parts. (**3**) The major structural features in the study area were fractures and lineaments.
In the north, the lineaments trend NE-SW direction while in the south, close to the river Chanchaga, lineaments trend NW-SE. This implies that the flow of the river is structurally controlled as reflected in Figures 8.

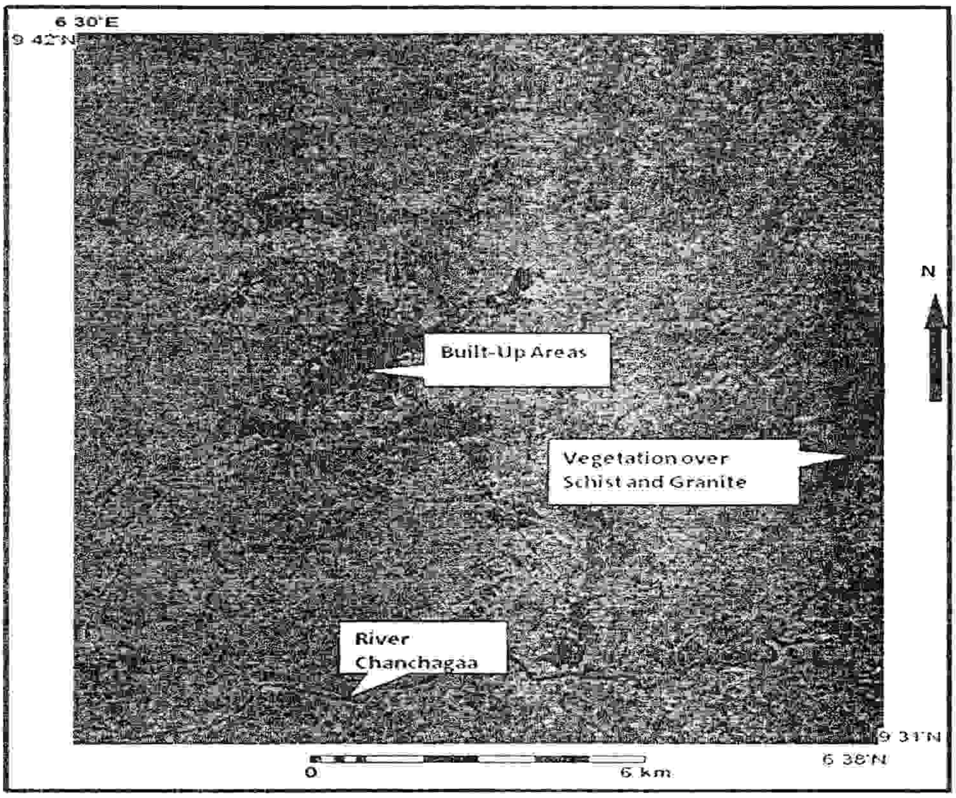


Fig.8: Interpreted Band Four Imagery On Stretching [14]

Conclusion

The area has been investigated through the combined geological, hydrogeological, geophysical and remote sensing techniques. The study revealed two major fracture patterns for the area which runs in a NW–SE and NE–SW direction. The Chanchaga River flows in a NW–SE direction parallel to the principal joint direction in the area. It authenticated the idea that the flow of River Chanchaga is structurally controlled. Ore mineral and groundwater exploration in the area should be concentrated along NW–SE and NE–SW direction since their presence is fracture driven. The use of more than a single method in carefully delineating the fracture patterns in the area has shown to be more effective than any singular method, and has reduced errors arising from a single method.

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