The Use of Remote Sensing and Fractures Analysis for Investigating the Proposed Site for the Sabaloka Hydropower Dam Project, River Nile State, Sudan

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Abstract
This study was carried out to investigate the selected site for the proposed hydropower dam that located at the six cataract in the River Nile State, Sudan. The study based on the use of the enhanced landsat imageries and the structural analysis of the fractures in the investigated site. The River Nile bisects the Sabaloka volcanic plateau at the proposed dam site. The exposed rocks are Agglomerate, Rhyolite and Ignimbrite. The proposed dam axis is located in the relatively less fractured Agglomeratic rocks. The main fractures trends are NW and NE directions and cut, respectively the western and eastern flanks of the dam axis. The higher values in the fractures frequency and length density contour maps are considered to be as the most risky areas in the proposed reservoir, through which the water seepage is highly expected. The existence of the tensional fractures related to the Um Maraheik fault may affect the efficiency of the dam wall. Engineering mitigation measures are to be considered to increase the efficiency and stability of the proposed dam.

***Key words*:** remote sensing, fractures analysis, River Nile, Sabaloka dam, Sudan.

1. BACKGROUND

The proposed dam is located at the Sabaloka igneous complex on the sixth cataract of the River Nile. The storage capacity of the proposed dam is about 4000 million cubic meters, its lake extends southward to about 15 km and the water level is expected to rise 6 to 10 meters.

The Sabaloka dam is proposed for multi-purposes, mainly for hydro-power generation and irrigation in addition to help in minimizing the siltation for the Merwe dam to the north. Moreover, it will represent an excellent habitant for fisheries in the lake behind the dam.

2. THE STUDY AREA

The Sabaloka area is located in the southern part of the River Nile State between longitudes 32° – 32° 30" and latitudes 16° 15" – 16° 30" about 80 Km north of Khartoum (Figure1). This area is characterized by semi desert climatic conditions with average annual rainfalls range between 50 – 100 mm. The highest daily mean temperature is about 43˚C during the summer period from May to October, and the lowest mean temperature is about 16˚C during winter period from December to February.

The Sabaloka area being one of the most important Pre-Cambrian exposure in Sudan, attracted the interest of may geologists such as; Delany (1958), Kröner et al (1987), Dawoud & Sadig (1988) and Almond & Ahmed (1993) to study different geological aspects of this area.

Geologically, the area forms an inlier that consists of different type of rocks ranging from metamorphic (Gneiss and migmatites) through igneous (Sabaloka igneous complex) to sedimentary (Cretaceous sandstone). It represents a continental slope of the ancient continent during the Pan African time, Kröner et al. (1987). By early Paleozoic time the basement had been tectonically stabilized and reduced by erosion to a peneplain. The igneous activity; exemplified by the Sabaloka Igneous Complex is built up of felsic volcanoes which rise above the gneissose peneplain. The Sabaloka igneous plateau is consisted of basaltic lavas, agglomerate, rhyolite and ignimbrite, (figure 2).

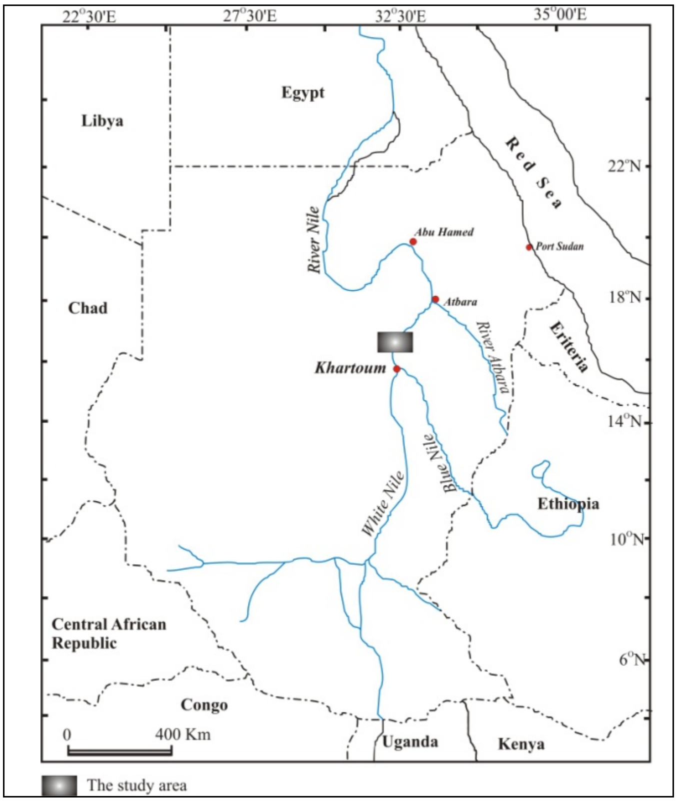


Figure 1: Location map of the study area

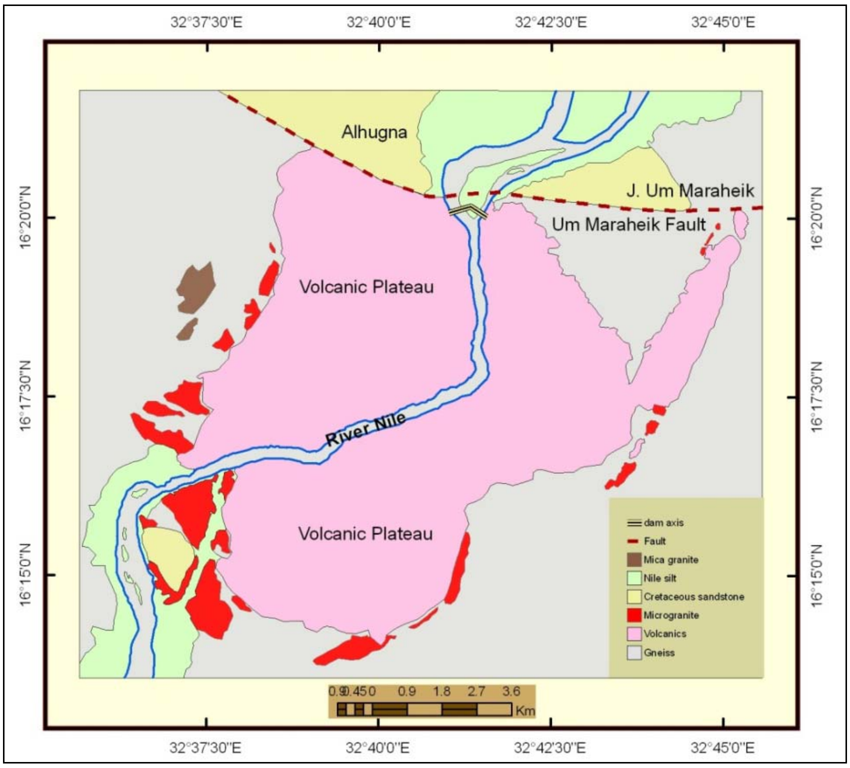


Figure 2: Geological map of the Sabaloka Igneous Complex

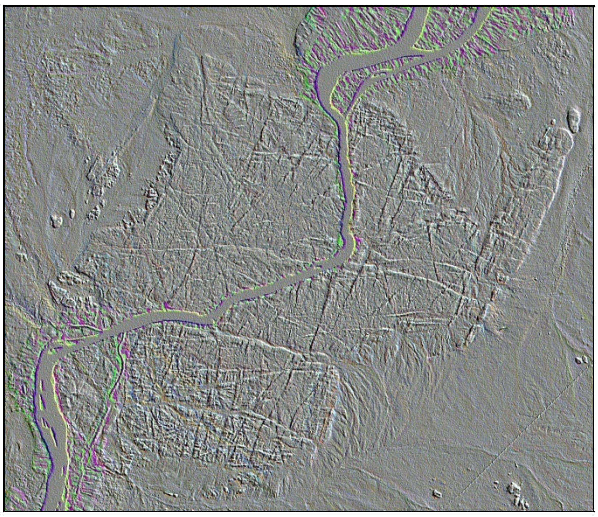
The aim of this study is to investigate the suitability of the suggested site for dam construction based mainly on the geological point of view using remote sensing, lithological identifications and structural analysis.

3. REMOTE SENSING APPLICATION

Digital Image Processing can be defined as the manipulation of digital data by the aid of computer in order to produce a more appealing image (Drudy, 1993). For the Sabaloka volcanic plateau two image-processing techniques were utilized to increase the sharpness of the image, to make the features more clear and obtain more reliable information related to this project. The first applied technique was image sharpening. This was applied through fusion of panchromatic band with the multispectral bands of Landsat ETM+ image. The fused image is presented in figure (3) as colour composite by assigning 7, 4, 1 to RGB, respectively. This image has the spatial resolution of 14.25m which enables the delineation of smaller linear features in the area.

Figure 3: Colour composite of the Plateau obtained using bands 7, 4, 1 in RGB, respectively

The second technique was the spatial filtering. In the current investigation, high pass filters of different window sizes and various kernels were applied to the image to enhance the linear features in the area. Based on the knowledge about the evolution and the tectonic history of the area, directional filtering was also applied in 330º and 50º directions, which represent the main structural trends of the investigated area is show in figure (4).



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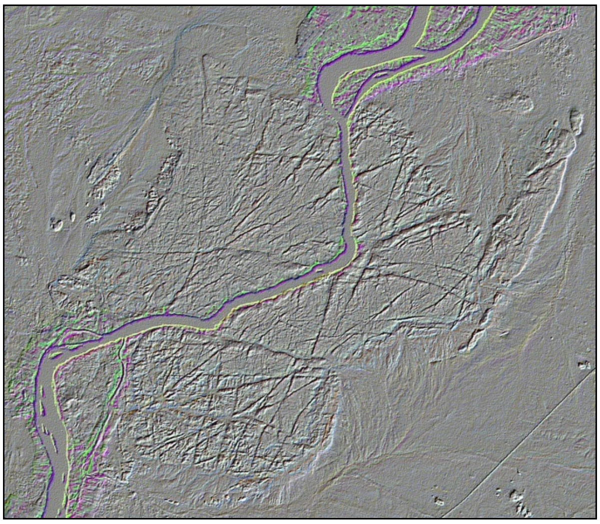

B

Figure 4: Directional filtering in: (a) 330º (b) 50º directions of the 741 RGB image

After applying different filtering techniques, the produced images were imported into the GIS software for further manipulations. Lineaments were delineated in the GIS framework to facilitate the production of a lineament map of the study area presented in figure (5).

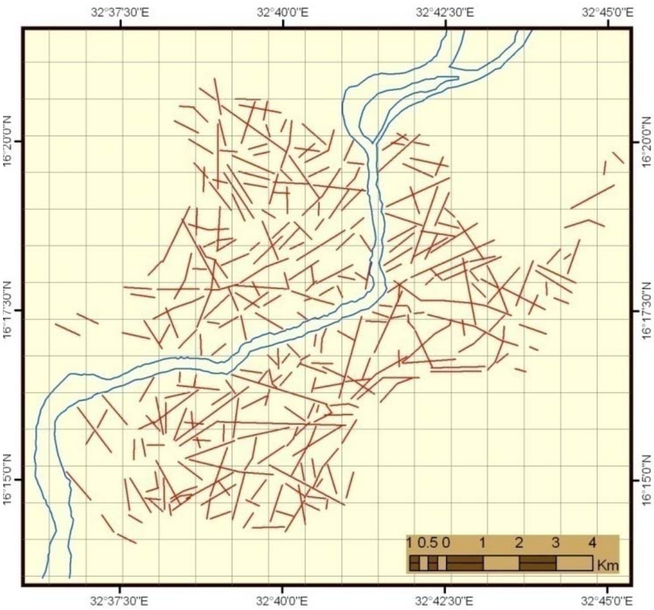

Figure 5: Lineament map of the Sabaloka volcanic plateau

4. FRACTURES ANALYSIS

Fractures are surfaces along which rocks or minerals have broken. Most outcrops of rocks exhibit many fractures that show very small or unobservable displacement normal to their surfaces, and such fractures called joints. Because the cohesion of the rocks is lost across fracture surfaces, they are considered to be planes of weakness that may effects the efficiency of the dam. From this point of view, the fractures in the volcanic rocks at the dam site area were studied in details.

At the proposed dam site, the fractures in volcanic rocks are not of tectonic origin; rather they are mainly cooling joints. Moreover, there are some fractures related to the post Cretaceous local faulting such as Um Maraheik fault. Umm Maraheik fault is a rotational fault bisects the cauldron complex with E-W trend. The largest component of displacement is a dextral strike slip movement of nearly 2 Km, with significant element of down throw to the north. This vertical component increases westward from Jebel Umm Maraheik to reach a maximum value in the trans-tensional basin (graben) at Elhugna area west of the Nile, (Fig.2). According to gravity evidence, this basin maintains a vertical thickness of about 1.35 Km of sediment accumulations (Dawoud and Sadig, 1988).

4.1. The lineaments of the Sabaloka Plateau

Lineaments that represent the fractures pattern are important factors that must be taken into account when constructing a dam because they affect both the foundations and the storage capacity of the dam lake resulting into collapse and seepage, respectively.

The Sabaloka plateau shows joints of different types but the most common are extension and columnar joints due to the cooling of the volcanic rocks. Some joints that related to Um Mraheik fault are observed near the proposed dam axis. These joints are clearly discernible from the spatially enhanced space image. The conducted fieldwork confirmed the presence of these joints and provided more detailed measurements regarding fractures in the investigated area. From the field readings of the plateau fractures, rose diagram was created to present the most common fracture trends throughout the area, Fig (6).

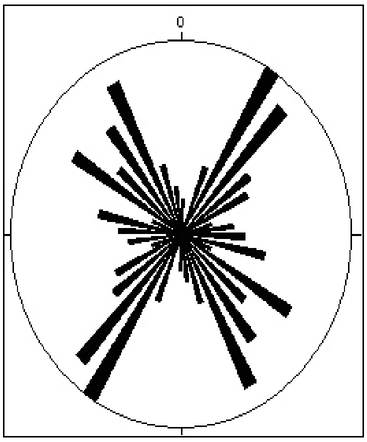

Figure 6: Rose Diagram shows the main trends of fractures in the Sabaloka Plateau

4.2. Lineament Frequency Contour Map

Lineament frequency (Lf) defined as the number of visible lineaments per unit area, Edet et al. (1998) was calculated using the equation below. The result of this computation is the frequency contour map presented in Figure (7).

$$Lf = \sum_{I=1}^{i=n} Ln / A \quad (m^{-2}) \qquad (1)$$

Where $\sum_{i=1}^{i=n} Ln$ is the total number of all lineaments and A is an area (m^2)

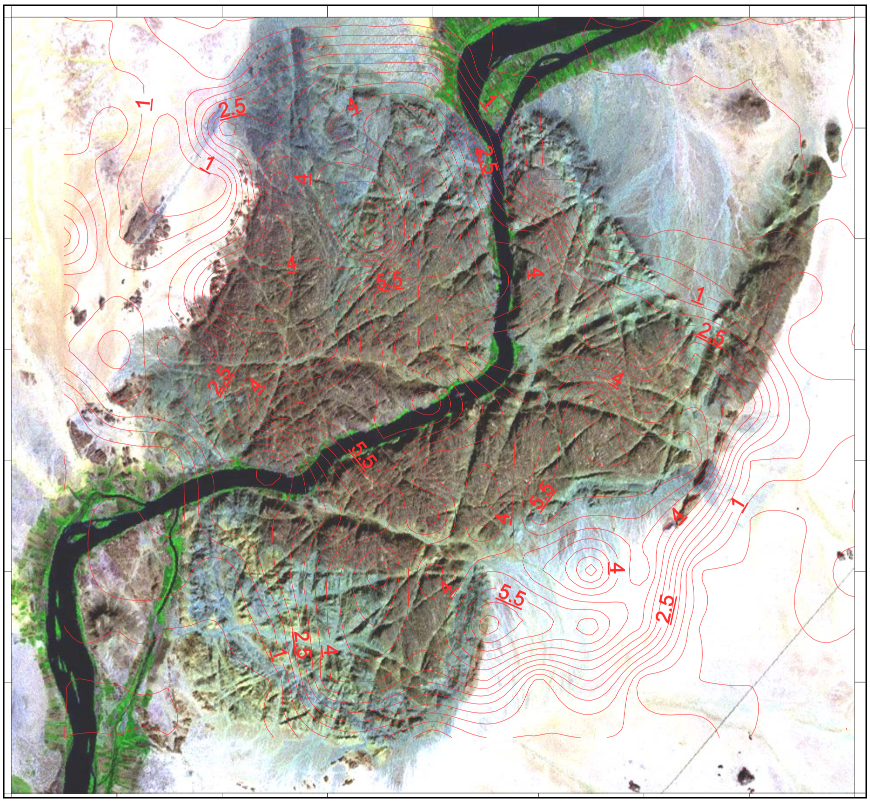

Figure 7: Lineament frequency contour density map of the Sabaloka plateau

4.3. Lineaments Density Contour Map

The lineament-length density (Ld) contour map can be obtained by measuring the lineaments length per unite area from the lineament map of the Sabaloka volcanic, using the below equation (Edet et al., 1998) to obtain the fractures length density map shown in Figure (8).

$$Ld = \sum_{i=1}^{i=n} Li / A \quad (m^{-1}) \qquad (2)$$

Where $\sum_{i=1}^{i=n} Li$ is the total length (Li) of all lineaments and A is the area (m^2)

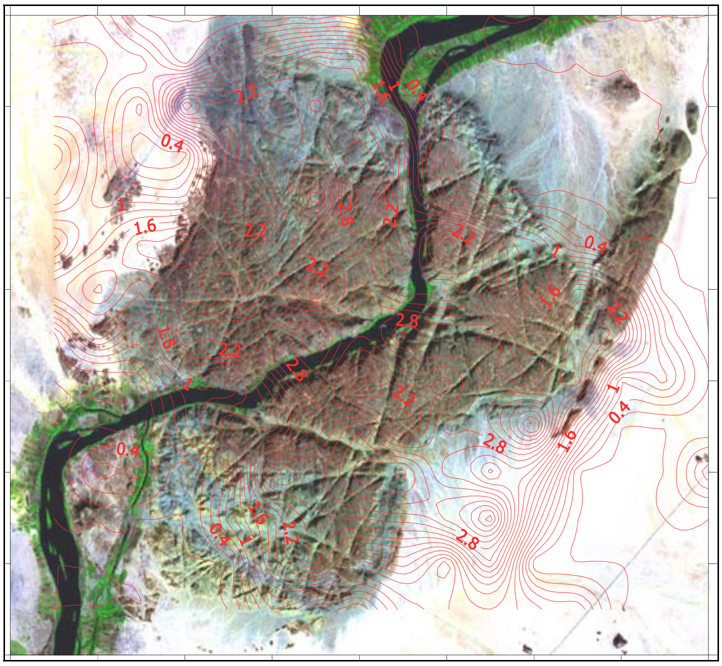

Figure 8: The Lineament Length density contour map of the plateau

In the lineament frequency and length density maps of the Sabaloka volcanic plateau, the high and the low values in both maps, represent risky and low risk areas for water storage along the reservoir, respectively.

4.4. Dam Axis

For a more detailed study of fractures at the dam axis site, intensive field measurements were conducted using millimetric papers. The river bed at the dam axis is underlain by the Agglomeratic rocks of widely spaced joints with average joint space range between 1 to 2 meters. The eastern and western banks of Nile at the dam axis are covered by Rhyolitic rocks that shows closely spaced joints (10 -20 cm). Figure (9) shows that the major joint sets are in NW and NE directions, and the dip values of these fractures are mostly vertical to sub vertical. This main trends of the fractures cut across the axis of the proposed dam.

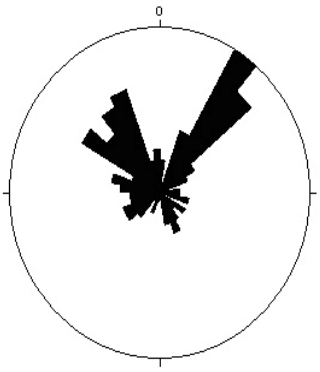

Figure 9: Rose diagram shows the main fractures trends at the dam axis, based on field measurements

5. CONCLUSION AND RECOMMENDATIONS

The study was conducted to examine the suitability of the selected site for the proposed hydro-power dam that located on the River Nile at about 80 km north of Khartoum town. The site is located at the narrow gorge of the River Nile on the volcanic plateau that mainly occupied by acid volcanic rocks characterized by highly jointed rocks. The main fractures trends are in NW and NE that need to be considered during the dam implementation. The dam axis is located on the relatively less fractured Agglomeratic rocks, but the existence of the tensional fractures related to Um Maraheik fault may affect the efficiency of the dam wall. These fractures cross the eastern flank of the dam axis in NE direction, where they cross the western flank in the NW direction.

This study has recommended that; the head of the dam must not exceed the height of 10 meters to avoid the risk of water seepage through the intensive fractures of the volcanic rocks. The high density fractures areas that shown in the maps must be tackled through the engineering solution and the expected seepage in the NW and NE fractures systems across the dam axis must be considered and solved.

6. ACKNOWLEGDEMENT

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7. REFERENCES

1. Almond, D. C. and Ahmed, F. (1993), *Field guide to the geology of the Sabaloka Inlier, Central Sudan*, Khartoum University Press, Khartoum Sudan.
2. Dawoud, A. S. and Sadig, A. A. (1988), *Structural and gravity evidence for uplifted Pan-African granulite terrain in the Sabaloka inlier*, Sudan. Journal of African Earth Sciences, 7, 789-794.
3. Delany, F. M. (1958), *Observations on the Sabaloka Series of Sudan,* Transactions of the geology Society of South Africa, 61, 111-124.
4. Drury, S. A. (1993*), Image interpretation in geology*. 2nd ed., -271 pp., (Chapman and Hall), London.
5. Edet, A. E., Teme S.C., Okcreke C.S., Esueo (1998), *Application of Remote Sensing data to groundwater exploration: A case study of the Cross River State, southeastern Nigeria,* Hydrogeology Journal (1998): 6, page 394-404. Springer Verlag.
6. Kröner, A., Stern, R. J., Dawoud, A. S., Compston, W. and Reischmann, T. (1987), *The Pan-African continental margin in northeastern Africa: evidence from the geochronological study of granulite at Sabaloka, Sudan,* Earth and Planetary Science Letters, 85, 91-104.
7. Lillesand, T. M. and Kiefer, P. W. (2000), *Remote Sensing and Image Interpretation,* 4th edition. John Wiley & Sons Inc.

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