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Exploration of Ground Water in a Basement Area Using Electrical and Electromagnetic Surveys, Case Study: El Sunut, North Kordofan State

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Abstract

Two electromagnetic profiles together with other two vertical electrical soundings (VES) were applied in a basement area for groundwater exploration. The area, named El Sunut lies near El Obeid town, capital of North Kordofan State, Sudan. Geophysical surveys were applied in combination with geological and hydrogeological investigations in the study area. The study showed that the thickness of weathered basement is about 77m and it may reach up to 135m. The interpretation of vertical electrical sounding shows that the superficial deposits overlying the weathered basement are composed of sand, quartz or basement fragments. Drilled boreholes in the area showed yield more than 2000 g/h in some localities. From drilled boreholes data and geophysical interpretation results can be concluded that the valley in the area is an old buried channel.

Key words: Groundwater, Exploration Electrical resistivity Basement rocks

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This study has been conducted at El Sunut locality, near El Obeid town, North Kordofan State, Sudan. The main objectives of this study were to show the ability of electrical geophysical techniques and their application for groundwater exploration. The study area is bounded by latitudes 13^0 22' N and 13^0 05' N, and longitudes 30^0 20' and 30^0 21' E Figs (1 and 2). Generally, the area of El Obeid is a plain of low relief, broken occasionally with isolated hills, e.g. Jebel Kurbage and Jebel Kordofan. The altitude of the study area ranges between 520 and 615 m above mean sea level (a.m.s.l.) (Geotechnica, 1985). The climate is generally semi desert and the rainfall is seasonally from July to end of October and in form of thunder storms and showers and ranges from 161.7 to 665mm annually for the period of 1950-1992 (Sharief, 1993). The mean annually daily temperature is 27^0 C with temperature ranges between 10^0 C – 46^0 C. The mean relative humidity ranges from a low of about 12% during the dry season to an average of 75% during the rainy season (Strojexport, 1970, Sharief, 1993) The study area lies in a basement rock area. Groundwater for drinking purposes is a most important use. In many parts of the world, groundwater resources are the only source of water for the population, industry, or agricultural irrigation (Komatina, 1994). Electrical geophysical methods have been applied in groundwater exploration for decades (Chapellier et al., 1991). Electrical geophysical techniques were applied for groundwater exploration. The methods used were electromagnetic and electrical resistivity (namely vertical electrical sounding). Geophysical methods are used to obtain more accurate information about subsurface conditions, such as type and depth of materials (consolidated or unconsolidated), depth of weathered or fractured zone, depth to groundwater, depth to bedrock, and salt content of groundwater (Bouwer, 1978)).

Magnetic surveys have been used to study basalt aquifers and alluvial basins underlain by magnetic bedrock (Zohdy *et al*., 1974).

Electromagnetic methods and ground conductivity surveys were used as electrical geophysical tools together with hydrogeological investigations to trace contamination plumes in aquifers affected by landfilling (Matias *et al*, 1994).

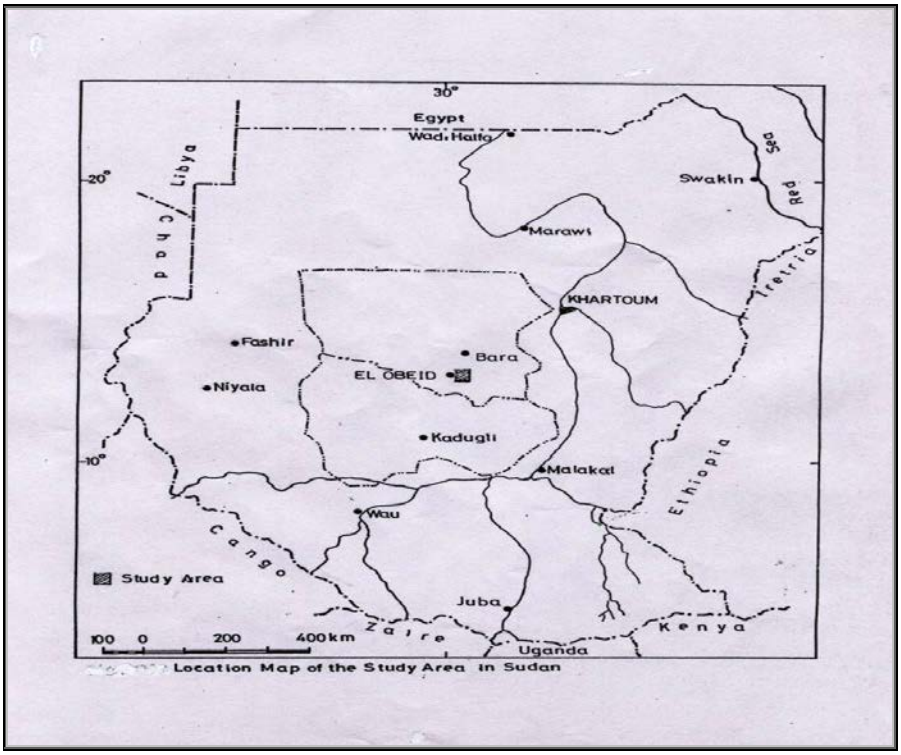

Fig 1: Location map of the study area in Sudan

Geology and Hydrogeology

The geology of the study area is composed of superficial deposits which consist of sand dunes, sands of different grain size, clays, gravels and boulders of thickness range between 3-6 m. These deposits overlies the weathered basement complex rocks which consist of gneisses, biotite schist, chlorite schist and granitic rocks. All

the above are lying on the fresh basement complex rocks. The latter rocks are weathered and fractured and the grade of weathering is decreasing when penetrate towards the bottom depth. Groundwater occurs in this locality in fractures and weathered zones of basement rocks. The drilled depth ranges between 45 to 72m. Discharge of boreholes ranges between 300 to 3000 g/h and the static water level ranges between 16.5 and 40 ms. It was noticed that the TDS (total dissolved solids) decrease towards the north and increase away from the runoff area.

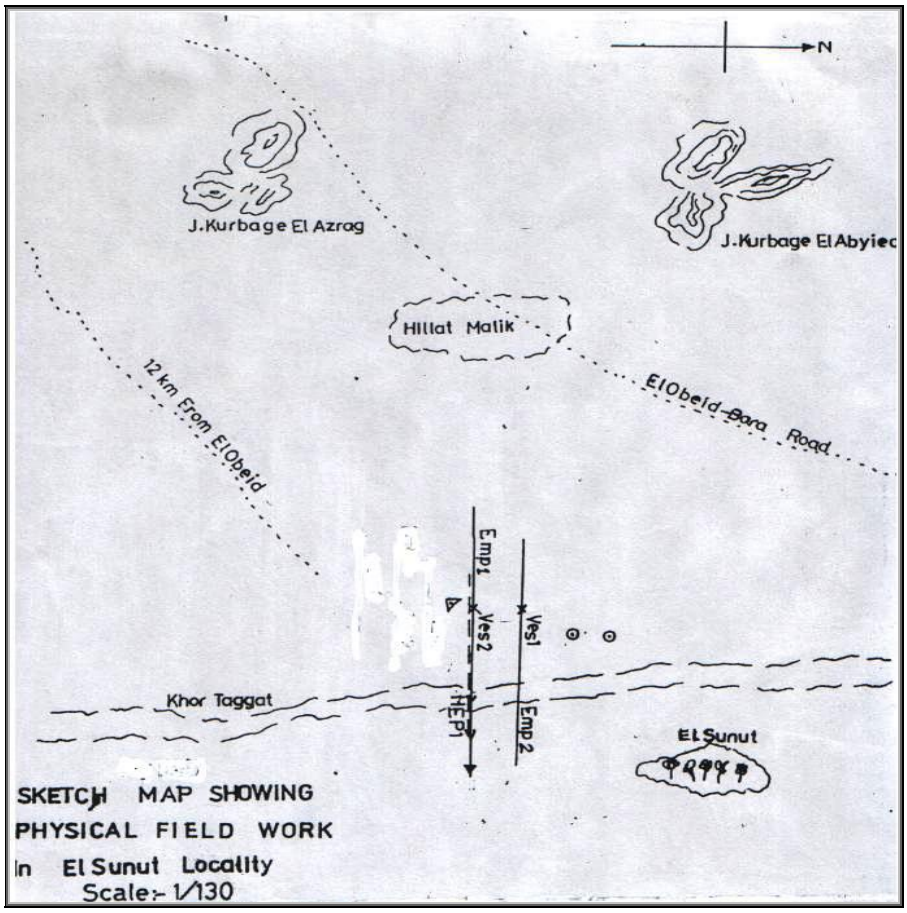

Fig 2: Sketch map showing Geophysical field work in El Sunut Locality

Methodology

Two electrical geophysical techniques were applied in this study. Electromagnetic (EM) and vertical electrical sounding (VES) techniques. The electromagnetic methods for reconnaissance surveys were applied in Sudan especially in the basement complex rocks in Kordofan, Darfur and Eastern states (Kheiralla, 2001).

For this study, measurements were done on Khor Taggat valley (El Sunut area), which is of low relief compared with the surrounding areas.

During this study two electromagnetic profiles were applied (EM1 and EM 2) as shown on Figures (3) and (4) respectively. The anomalies at these two profiles were verified by the vertical electrical soundings VES2 and VES1 respectively conducted at the anomalies centers in order to identify lithological units and structures present along and across \khor Taggat valley. The electromagnetic profile 1 (EM1) is 875 m long and was conducted across Khor Taggat valley (El Sunut area) and trending in W-E direction, the intercoil spacing is 100 m and station interval is 25 m. This profile was conducted to insure if there are anomalies present with or parallel to Khor Taggat stream's channel. The electromagnetic profile 2 (EM2) was 475 m long and was conducted north of EM1 and trending E-W direction The vertical electrical sounding no. 2 (VES2) (Fig (5) was conducted to verify the electromagnetic anomaly

of EM1 at station 11, while vertical electrical sounding no. 1 (VES1) was conducted at the area of a successful hand pump to confirm the anomaly shown by the electromagnetic profile no.2 (EM2) at station no.13. This VES was also important to detect the depth to fresh basement and made a comparison between the bore hole lithological description and vertical electrical sounding results.

Results and Discussion

The electromagnetic profile no.1 (EM1) shows a clear anomaly at station 11 Fig (3). The interpretation of the results of this profile shows that the anomaly width is 38 m, depth to the top of the conductor is 46 m and conductivity is 0.01299 mho/cm. This anomaly was verified by VES Fig (5)

The electromagnetic profile no. 2 (EM2) shows a clear anomaly at station no. 13 Fig (4) This indicates the continuation of the geological structures located by station 11 at EM1 Fig (3). It also insures that it is the same structure trending north – south parallel to Khor Taggat strem's channel. The profile interpretation shows a width of 38 m, depth to the top of the conductor of 46 m and conductivity of 0.0286 mho/cm.

Vertical electrical technique was conducted and this helps in the determination of tectonic features (i.e., faults, fractures etc), thickness of weathered and fractured rocks and the lithological descriptions of the formation above the fresh basement rocks. VES no.1 shows three

layers of different lithological units. These include the superficial deposits of sands of different grain size and gravels (thickness of 7 m and resistivity value 41-58 ohm-m), fragments of weathered basement rocks (thickness of 23 m and resistivity value 10 ohm-m), and low grade of weathering with saturated fractured basement complexes (thickness 105 m and resistivity value ranging between 50 and 345 ohm-m. The fresh or hard basement rocks indicate resistivity value of 975 ohm-m and at a depth of 135 m. The interpretation of VES2 shows probably two lithological units that overly the fresh basement. The upper one is the superficial deposits of sand and fragments of highly weathered basement rocks of thickness 10 m and resistivity value of 42 ohm-m. These overly the fresh basement of resistivity values of about 400 ohm-m. VES2 also shows a depth of about 50 m to the fresh basement rocks Fig(5).

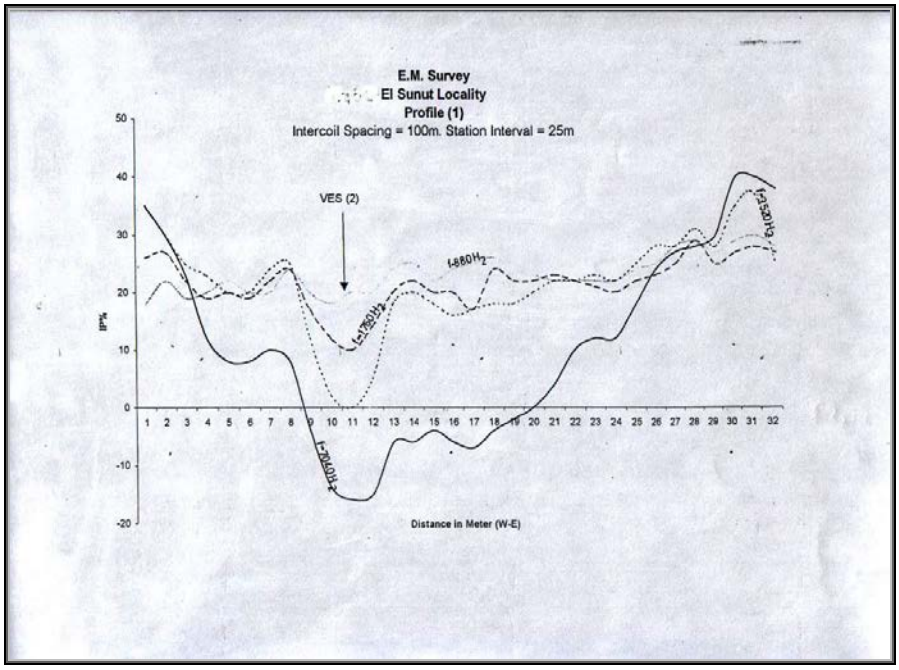

Fig 3: Electromagnetic profile No. 1 (EM1) at El Sunut Locality

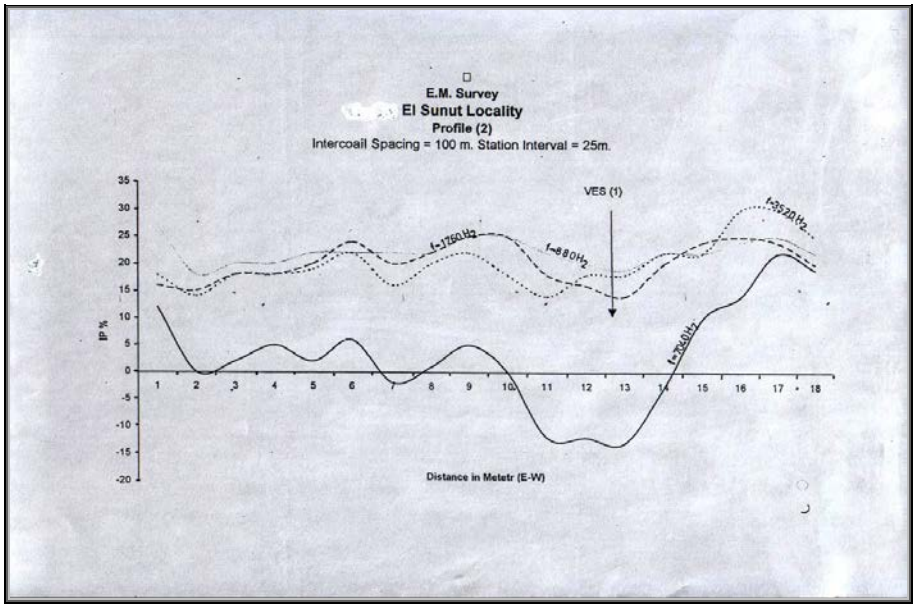

Fig 4: Electromagnetic profile No. 2 (EM2) at El Sunut Locality

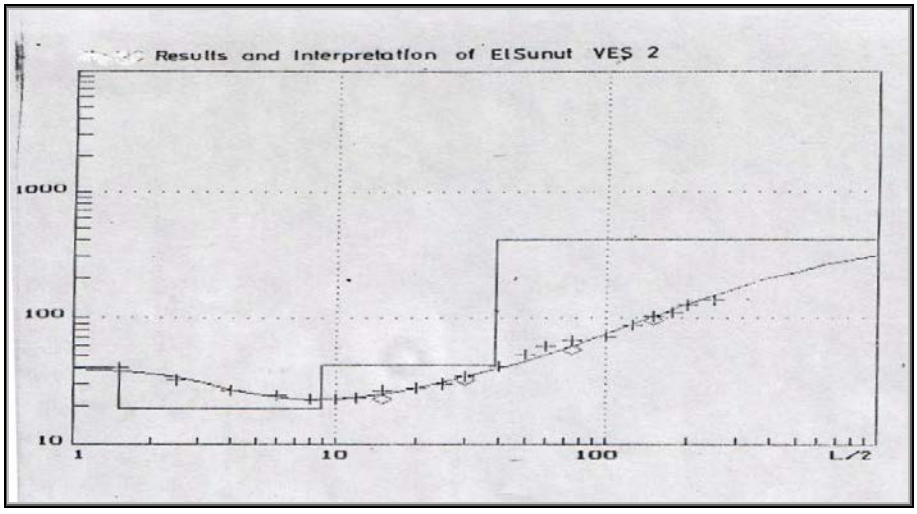

Fig 5: Vertical electrical sounding profile no.2 (VES2) at El Sunut locality

(x-axis represents distance (AB/2) in ms, y-axis is the apparent resistivity in ohm-m)

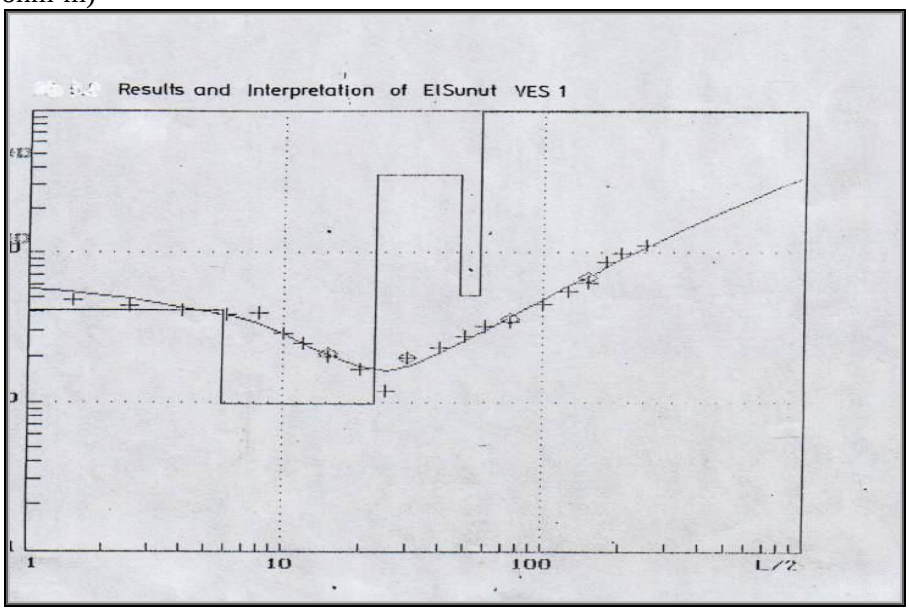

Fig 6: Vertical electrical sounding profile No.1 (VES1) at El Sunut locality

(x-axis represents distance (AB/2) in ms (i.e., 10, 100 and 1000ms), y-axis is the apparent resistivity in ohm-m)

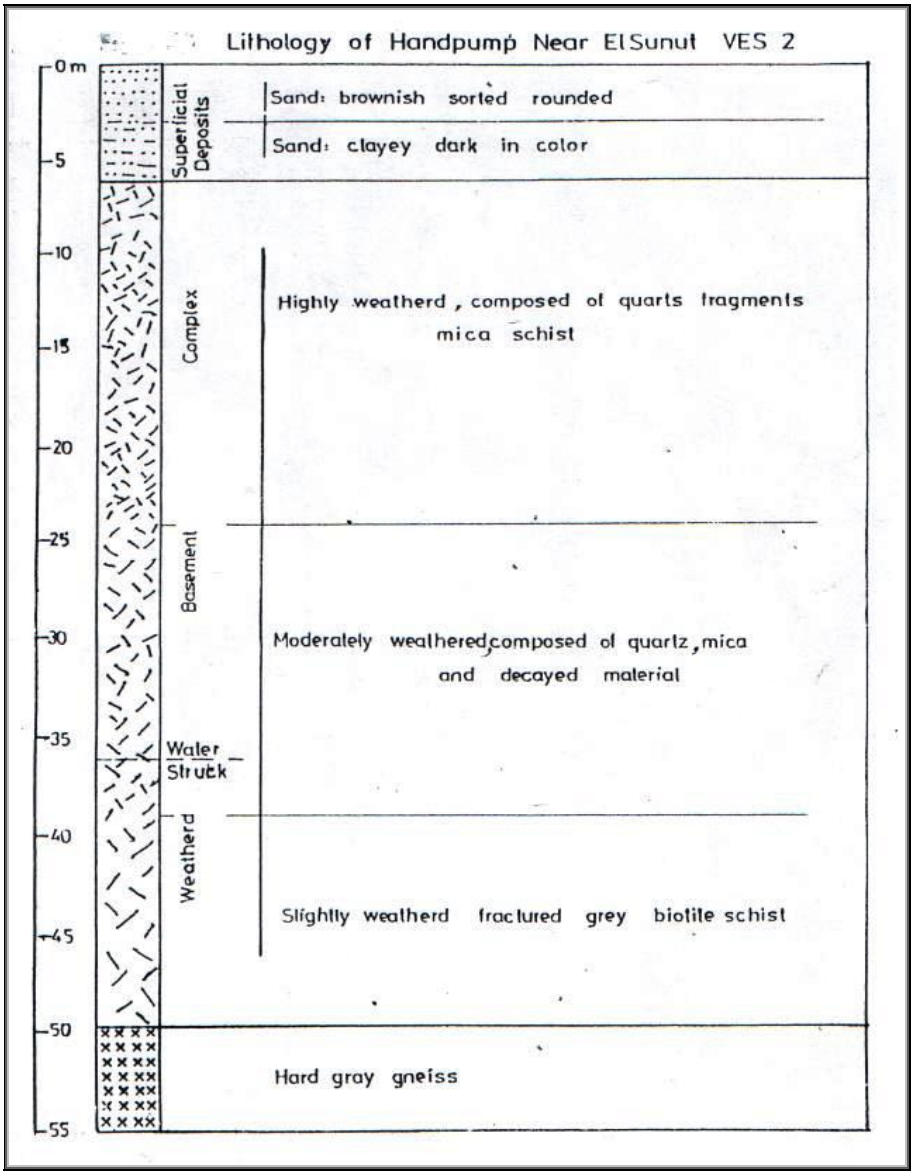

Fig 7: Lithological description of a borehole near VES2

Conclusion

The hydrogeological investigations at El Sunut area can be summarized as follows:

- The thickness of weathered and fractured basement rocks above the fresh ones is about 77 m and it may reaches up to 135 m if drilling goes to deeper depths, where an another aquifer may be existing.
- The center of the structure is trending in north - south direction and oriented parallel to the Khor channel in the western side.
- The VES's interpretation showed that the superficial deposits which overlain the weathered basement rocks are sand, quartz or basement fragments.
- The drilled bore holes show a yield more than 2000 gal/hr in some localities in the study area.
- The geological structure is not coinciding with Khor Taggat channel and its strike in the same direction of the stream.
- Drilled bore hole data and geophysical interpretation results, showed that the valley in the area is an old buried channel.

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