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Investigating the Effect of Dolomite Exploitation on Groundwater Condition of Ikpeshi, Akoko – Edo, Edo State, Nigeria

Saliu M.A.[1] and Komolafe K.[2]

Abstract

The various usefulness of dolomite and its abundance in Ikpeshi has given rise to massive expoitation of it in the community and its environs. The groundwater condition of Ikpeshi Dolomite deposit Edo State was investigated using electrical resistivity method. Vertical Electrical Sounding (VES) using schlumberger array was adopted to investigate the subsurface structure and the hydrological conditions of the area. The VES data interpretation revealed that there would be intrusion of water at a depth of 42m due to the presence of cracks and the dolomite deposit is a fresh basement which was believed to have an infinite depth to the crust. There is a sharp variation in the static water level in the Ikpeshi community. This phenomenon may be attributed to the presence of fracture basement which may be induced by heavy vibration as a result of blasting activities in the quarry. The ground water flow direction is towards NW at the Ikpeshi village and towards N at the Ago village which coincidentally serves as a control station. The overall flow direction as observed from the geoelectric sections indicates that water is flowing away from Ikpeshi towards Ago village.

Keywords: Statics, Water level, Hydrogeological, Destruction, Karst, aquifer, quarry.

1 Introduction

Exploitation of mineral resources has assumed prime importance in several developing countries including Nigeria. Nigeria is endowed with abundant mineral resources, which have contributed immensely to the national wealth with associated socio-economic benefits [1];[2]). The quest for exploitation of valuable mineral resources in the earth to satisfy human wants has given rise to technological development in mining industry.

[1]Department of Mining Engineering, The federal University of Technology, Akure, Ondo State, Nigeria
[2]Department of Mining Engineering, The federal University of Technology, Akure, Ondo State, Nigeria

Mining can be said to be the exploitation of all naturally occurring minerals from the earth surface for human consumption. The cardinal rule of mine planning for mineral exploitation is to select a mining method that best fit or matches the unique characteristics (natural, geological environmental e.t.c) of the mineral deposit which is to be mined within the limits imposed by safety, technology, and economics, with the lowest cost and return the maximum profit [3].
Since the only practical or pragmatic ways to extract minerals for industries is through mining, however, the impact of mining are not all favorable. It is know that the benefits of mining are well documented and its unfavorable effect on surface phenomena like land, water, air and man, but not much emphasis were placed on the damage done to the subsurface structures. Regardless of the small amount of quarried rock compared to the volume of an outcrop, removing the protective rock cover of an aquifer may cause some undesirable results. In many areas of quarries, the limestone bears a significant amount of groundwater resources. These potential resources are available in most places for domestic use. In the case of quarrying a limestone outcrop which acts as a protective cover for the underlying aquifer, two major changes may occur in the hydrogeological system related to water quality and the flow system. Where the groundwater flow is in conduit karst aquifers, or where the water table of a flooded fractured/fissured aquifer is near the surface, removal of the limestone outcrop leads to contamination. The scar created by a quarry may easily act as a sinkhole which conveys surface water to the groundwater system rapidly [4]. The other impact of a quarry is that quarry blasting may result in the destruction or disruption of groundwater flow paths, changes in the pattern of groundwater movement and changes in the quantity of water flowing through the karst system. The flow path may change direction and contribute to another karst subsystem or spring. Thus, the amount of water abstracted from boreholes fed by the system may decrease significantly.

2 Geographical Description of the Study Area

Freedom Limestone quarry, Noble Marble Limited and Fakunle (Geo-works) limestone quarry are located at Ikpeshi, a village along the Ibilo – Auchi expressway in Akoko Edo Local Government, Edo State, South Western Nigeria Figure 1.0. It lies on latitude 7^0 11’ and 7^0 06’ N and within the longitude 6^0 15’, 6^0 08’E. Of importance in this study area are the two principal seasons, which are wet and dry seasons. The wet (raining) season start in March and last till November with short break in August while the dry season starts in November and ends in March. The average annual rainfall is about 1300mm. There is a marked variation in sunshine hour of 3.3 hours, while increasing cloud cover causes decreasing sunshine hours between June and October. The temperature ranges from 25^0 C to 40^0 C. Although limestone hardly supports thick vegetation but due to heavy rainfall, the surrounding area of the outcrop is covered by thick green grass shrubs.

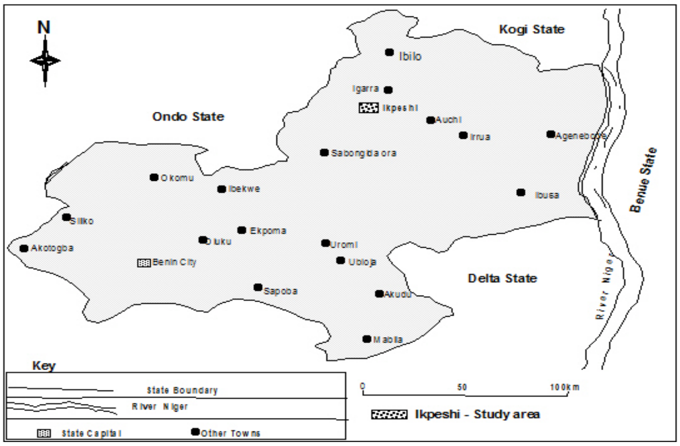

Figure 1: Map of Edo State showing Ikpeshi (The study area).

3 Local Geology of the Study Area

Odeyemi and Folami [5] carried out a detailed and systematic mapping of the basement part of the study area and has assigned the rocks in this area to three major groups as shown in Figure 3.

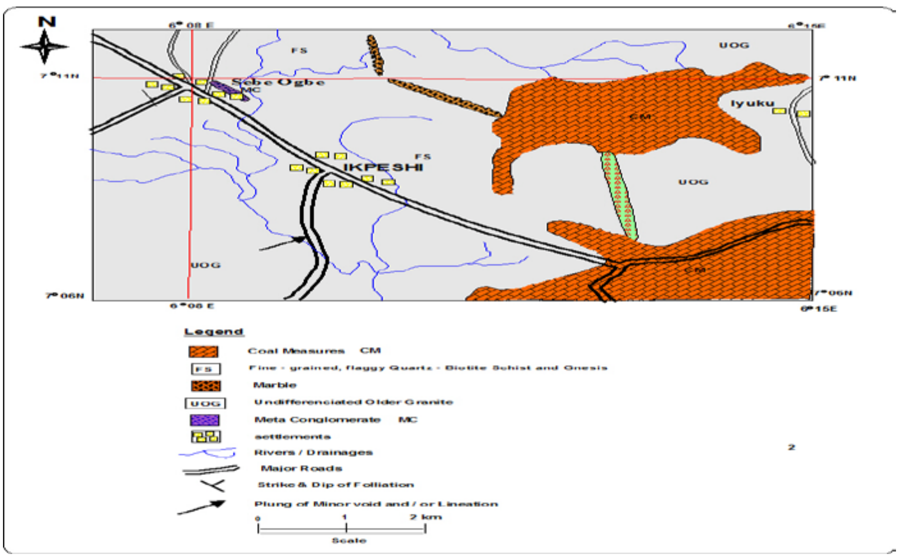

Figure 2: Geological Map of Ikpeshi Area(modified after Odeyemi and Folami[5]1978)

The three major groups consist from the youngest to the oldest as follows:

(i) syn- to late-tectonic porphyritic, biotite and biotite-hornblende granodiorites and adamelites, charnokites and gabbros; unmetamorphosed dolerites, pegmatite, aplite, lamprophyres and syenite dykes;

(ii) low-grade metasediments consisting of schists, calc-silicate gneisses, marbles, polymict metaconglomerates and quartzite; and

(iii) migmatites, biotite and biotite-hornblende gneisses.

Odeyemi and Folami [5] also reported that the metasedimentary successions in the area consist of four main rock units as follows: flaggy quartz-biotite schist and gneiss, mica schist, calc-silicate gneiss and marble, and metaconglomerates.

4 Effects of Quarrying Activities on Groundwater Conditions

About 80% of Akoko Edo community is underlain by carbonate rocks that are lithologically suitable for domestic and industrial purposes. The site for a quarry should be studied in detail for hydrogeological, economic, geological, and technological aspects, which, until the last decade, have often been ignored. Carbonate rocks that cover productive aquifers in many places particularly where there is karstification are well developed. Removal of this cover through quarrying may result in dramatic changes not only in the groundwater regime but also in the quality of the karst water. In the case of quarrying a dolomitic outcrop which acts as a protective cover for the underlying aquifer, two major changes may occur in the hydrogeological system related to water quality and the flow system. Where the groundwater flow is in conduit karst aquifers, or where the water table of a flooded fractured/fissured aquifer is near the surface, removal of the limestone outcrop leads to changes in groundwater flowing conditions. The other impact of a quarry is that quarry blasting may result in the destruction or disruption of groundwater flow paths, changes in the pattern of groundwater movement and changes in the quantity of water flowing through the karst system as demonstrated in Figure 3.0. The flow path may change direction and contribute to another karst subsystem or spring. Thus the amount of water abstracted from boreholes fed by the system may decrease significantly.

Recent studies has shown that in the last few years, out of total monitoring wells, 55% showed depletion in water table depth especially during the dry season [6]. This leads to the associated problem of lowering tubewell depth and drying of open dug wells in these areas. Few areas with associated problems of lowering tubewell depth and drying of open dug wells have become the major issue.

This also indicated the decreasing trend of groundwater table depth over a period of time. The possible reason could be increase in groundwater draft due to population growth, low groundwater recharge etc. As the demand increases, it may not be feasible to check the draft of groundwater resources but there is a chance to increase the recharge rate to the aquifer by suitable means. Water scarcity is the prevalent challenge of the people living around the study area. This problem may not be unconnected with the impact of a quarry activities especially blasting, which may lead to the destruction or disruption of groundwater flow paths, changes in the pattern of groundwater movement and changes in the quantity of water flowing through the karst system. The flow path may change direction and contribute to another karst conditions. The other impact of a quarry is that quarry blasting may result in the destruction or disruption of groundwater flow paths, changes in the pattern of groundwater movement and changes in the quantity of water flowing through the karst system as demonstrated in Figure 3.0. The flow path may change direction and contribute to another karst subsystem or spring. Thus the amount of water abstracted from boreholes fed by the system may decrease significantly.

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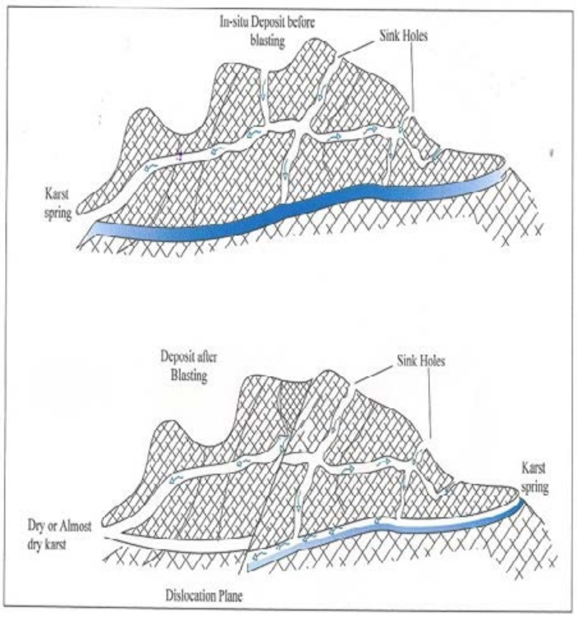

Figure 3: Showing the impact of quarring operation on a Karst groundwater flow system before blasting and after blasting activities on modeled rock section.

5 Materials and Methods

5.1 Electrical Resistivity Equipment

Measurements of resistivity were made using D.C Resistivity meter Model R-50. This equipment has accuracy in reading up to a depth of over 180 meters and was used along with four metal electrodes, voltmeter, hammers, four reels of connecting cables, measuring tape, Global positioning system (GPS) and clips. Four electrodes were employed for the survey, two current electrodes for passing current into the ground and two potential electrodes for the resultant potential difference measurement. Four reels of electrical cable were used in which two were attached to the potential electrodes while the other two each with a clip were attached to the current electrodes which take the current from a 12-volt rechargeable battery.

The resistivity data on all the VES stations were obtained with the soil test R-50DC resistivity meter as traverses were made along roads and foot paths. The Vertical Electrical Sounding (VES) using the Schlumberger configuration was adopted for this survey with a maximum current electrode separation of 200m as electrodes were arranged along a straight line with the potential electrodes placed in between the current electrode. Also, in this configuration, the potential electrodes remain fixed and the current electrodes are expanded symmetrically about the centre of the spread. When the distance between the current electrodes get too large, it becomes necessary to increase distance between the potential electrodes in order to have a measurable potential difference. Hand held CX-70 Garmin System GPS was used on the field to determine the orientations and elevations above sea level at every VES point.

6 Vertical Electrical Sounding (VES) Data Presentation

The VES data were collected at seven locations, in which three of the location is within the freedom quarry, The remaining four VES points were located outside the quarry in which VES point 4 and 5 were taken within the Ikpeshi settlement while VES point 6 and 7 were locations 20km away from Ikpeshi to serve as a control station as shown in Figure 4.0.

A total of 7 resistivity sounding curves were quantitatively interpreted, using the partial curve matching method. In the partial curve matching method, each curve generated was matched segment by segment while this in progress, the axes of both the field curves and the model resistivity curve (schlumberger) must be in parallel. The theoretical curves (schlumberger) are basically two. This interpretation is based on the separation or replacement resistivity. The procedure involves superimposing the field curve on the theorectical curve while the axis remains parallel to each other. The steps are repeated for all segments of the field curve and finally it is placed back on the bi-log paper where values of the various reflection coefficients are read to obtain the thickness and resistivity of the various layer.

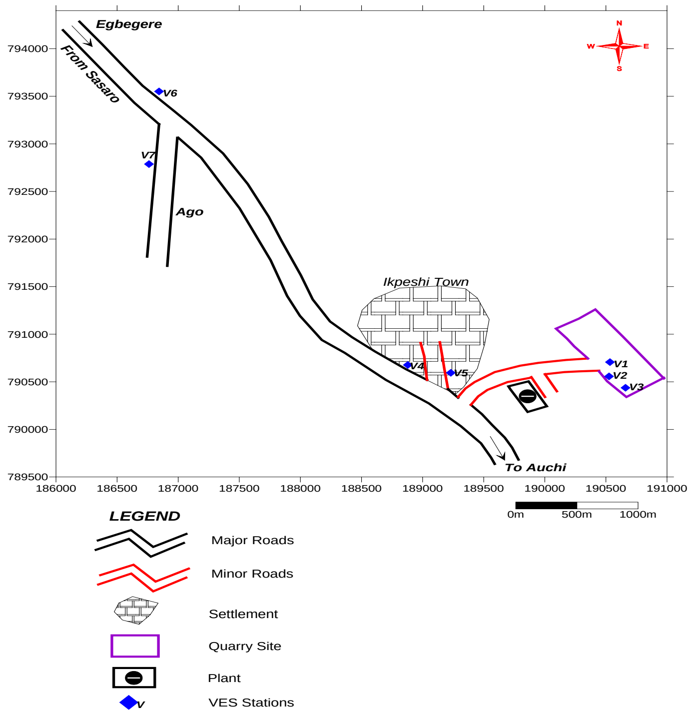

Figure 4: Base map of study area and the VES points.

7 Discussion of Results

In order to evolve a subsurface geological model at each of the investigated sounding points as shown in Figure 4, the VES interpretation result was used to prepare 2-D geoelectric sections along the delineated transverses. These sections give respective layer resistivity values and thicknesses. The sections identified three geoelectric/geologic subsurface layers comprising the topsoil, weathered layer, and the fresh basement bedrock as shown in Figure 5 along the transverses NW and SE. The geologic subsurface characteristics are the following:

Topsoil: The topsoil varies in composition from clay, lateritic clayey and laterite with resistivity varying from 5.6 Ω-m to 16.7 Ω-m. The topsoil thickness varies from 0.4 m to 2.1 m as presented in Figure 5. The shallow thickness of this area made it possible for the use of artisan tools for the removal of this top soil as overburden that lies on the deposit. The work is made easier during the rainy season due to the absorbent property of the topsoil.

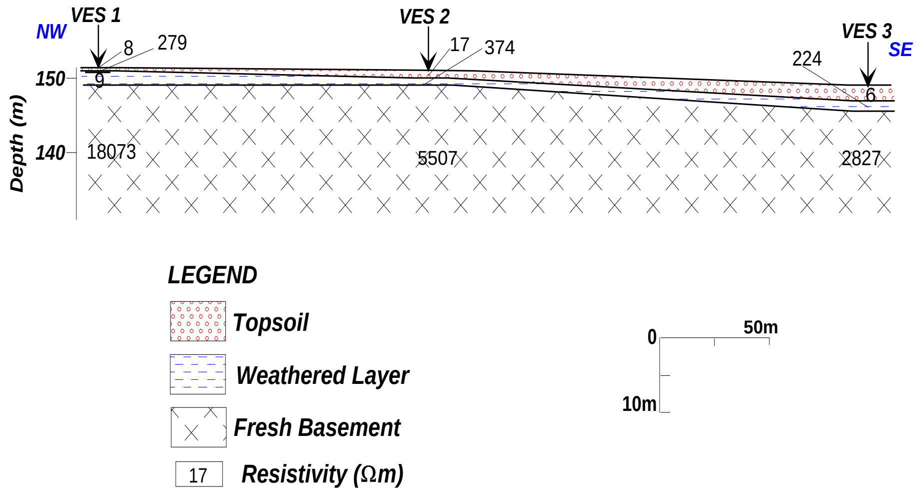

Figure 5: Geoelectric sections showing subsurface layers at the quarry pit.

Weathered Layer: The weathered layer is characterized by resistivity ranging from 243 to 373.9.1Ω-m as shown in Figure 5 along the transverses NW and SE. The thickness of this unit varies from 0.2 m to 1.2 m. This layer is compose of weathered dolomitic complex which could be referred to as low grade dolomite characterised by its weak strength as a result of weathering activities due to thin covering of topsoil overburden above it. The stripping ratio of this quarry is in favour of the good grade dolomite due to the sharp transition of the weathered layers to the dolomitic deposit.

Fresh Basement: The resistivity of the fresh basement is of infinity ohm-m as shown in Figure 5, indicating fresh bedrock to an infinity depth. The depth from the surface to the fresh basement varies from 2.0m to 3.4m. This makes this deposit highly economically viable for exploitation to a considerable depth suited for surface mining.

7.1 Groundwater Conditions of the Area

There is no recorded presence of subsidence precipitating voids and cavities arising from chemical dissolution of the dolomite in the study area. The VES data interpretation revealed that there would be intrusion of water at a depth of 42m due to the presence of fractures and faults. Fractures and faults were observed in the fresh basements in the Ikpeshi area closer to the quarry, where VES 4 and 5 were carried out as shown in Figure 6. However, these may have been due to the vibration and stress generated by velocity of detonation of the explosives during blasting operation in the freedom quarry.

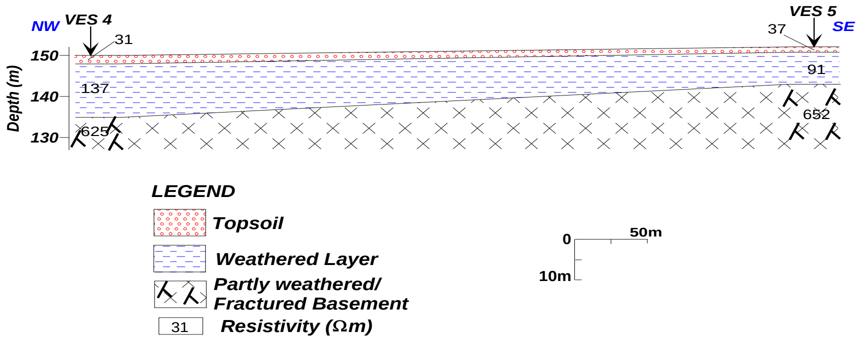

Figure 6: Showing the geosection of VES 4 & VES 5

The data interpretation revealed the presence of fractured basement which may be due to the impact of blasting activities in the quarry as against the undisturbed subsurface structure of Ago village which serves as a control station illustrated in Figure 7.

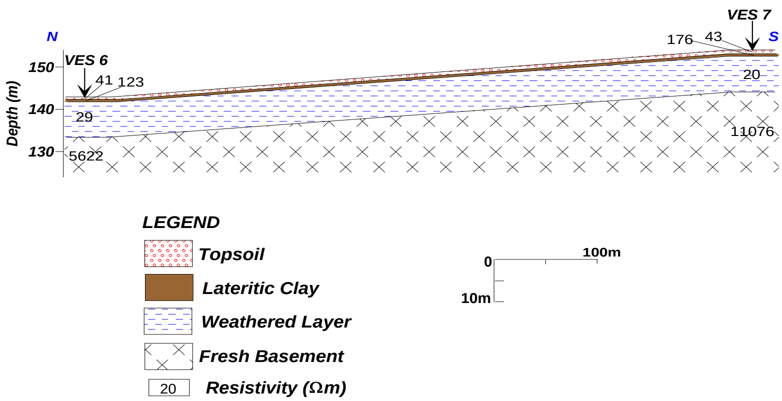

Figure 7: Geosection of VES 6 and VES 7 in Ago village (a control station)

The fracture or the cracks in the basement may be open up to increase the flow of ground water or closed up to divert the groundwater flow direction to another path. This will definitely reflect the variation in the level of groundwater static level in the surrounding environment of the area. As a result of this phenomenon, some well may got dried up in the dry season and some wells may still little quantity of water. The clayey nature of the formations gives the ground water turbid characteristics which aid it to flow away along the flow direction. However, some lenses of sand and clayey sand are reportedly confined by clay. Artesian flows have been obtained from some of this restricted aquifer [7]. Fractured dolomite Columns manifesting as low resistivity layers, are known to yield handful ground water which may be suitable for hand dug wells. However, the fractured may also be dried due to closure of the cracks as a result of vibrations generated by blasting activities.

7.2 Static Water Level and Ground Water Flow Direction

Hand dug wells were investigated in some residential buildings close to the quarry to assess the static water level of the area. It was observed that the water level in the area varies during the rainy and the dry seasons between 18m to 27m respectively.

The major source of aquifer recharge in the study area is surface precipitation (rainfall). Other sources include lateral groundwater movement and base flow from the other rivers in the area, seepages from fractured limestone aquifer confined groundwater that is opened up by excavation works at the quarry face, run off and evapo-transpiration. The level of the water in the quarry is currently being lowered by direct evacuation of water using electrical pump into a network of poorly formed drainage channels. The dewatering exercise is important since the maximum depth the quarry floor can reach to work in dry and safe conditions is dependent on the level of water in the quarry.

7.3 Flow Direction

The knowledge of ground water flow direction can be useful in the management of groundwater level, most especially if it has to involve dewatering wells [8].The ground water flow direction at the quarry face is Bi-directional due to the pivot at VES 2. The flow direction is towards SE and when the flow is turbulent the flow direction is toward both sides ie SE and NW but the larger volume flows along SE. The flow direction is towards NW at the Ikpeshi village where VES 4 and 5 were sounded. The flow direction is towards N at the Ago village which serves as a control station. The overall flow direction as observed the geoelectric sections illustrated in Figure 5, Figure 6 and Figure 7 which indicates that the water is flowing away from Ikpeshi towards Ago village.

8 Conclusion

Effective management of quarry water requires that the groundwater level and flow direction in the area around the quarry are known. The groundwater table needs to be monitored through monitoring wells all year round for the determination of both the peak and bottom water levels during the rainy and dry season respectively. These levels determine the natural safe depth of operation at the quarry. Mining operation within the quarry and below the bottom level will depend on the management of the groundwater. The lowest elevation level at the freedom quarry is currently at elevation of 21m above the sea level.

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