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THE ABAKALIKI VOLCANICLASTIC ROCKS: FIELD RELATIONS FROM RESISTIVITY PROFILES AND MAPPING

S. A. Ugwu and A. U. Okoro*

**Department of Geology, University of Port Harcourt*
ugwusa@yahoo.com

***Department of Geological Sciences,*
Nnamdi Azikiwe University, Awka
auokoro@unizik.edu.ng

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ABSTRACT

The Abakaliki pyroclastics are the best known volcaniclastic rocks in Nigeria. Resistivity profiling across Echara Unuhu and Amike Aba pyroclastic bodies and geological field descriptions of the rock reveal a relationship between apparent resistivity and the different lithotypes within the pyroclastic mass. Apparent resistivity of 50-210ohm-m indicates a group made up of lava flows. Field geological descriptions shows that these rocks are pumices interstratified with thin dark grey to bluish shales, amygdoloidal lapilli basalts and pillow basalts. Apparent resistivity values of 240-275 ohm m suggests the presence of coarse grained agglomerates, breccias and microbrecias with angular to subangular xenoliths of shally country rocks embedded in a groundmass of plagioclase and pyroxene. Quartz veins and enclaves as well as large leisegang rings (concretions) are associated with this lithotypes. Apparent resistivities of 275-434 ohm-m characterize the very fine grained lithic/welded tuff which is the most resistive litho type. The intimate interbedding of the pyroclastic flows with Albian Abakaliki shales as well as the presence of the shale xenoliths in the rocks indicates a contemporaneous age relationship. An Albian age is therefore suggested for the Abakaliki volcaniclastic events.

Key Words: Pyroclastic, Resistivity Profiling, Geology, Lithotype.

INTRODUCTION

Volcaniclastic rocks (pyroclastics) occur as prominent hills and inserlbergs within the vicinity of Abakaliki, between latitudes $6^{o}17$-$6^{o}19$'N and longitudes $8^{0}04$'-$8^{0}06$' E (fig1). These pyroclastic extrusives and flows provide ample evidence of widespread volcanic activity in the southern Benue Trough (Farington, (1952); Reyment, (1965) Olade, (1975), Uzuakpunwa.(1974). Okezie (1957) described these volcanic rocks as the "Abakaliki Pyroclastics" in his preliminary description of the geology of Abakaliki area. The rocks, consisting of magmatic products related to explosive mechanism include pyroclastic fall (ash) deposits, pyroclastic surge and pyroclastic flow deposits as well as tephra or ejecta materials.According to Uzuakpunwa (1974), Olade (1975) the dorminant lithotypes of the Abakaliki pyroclastics include pyroclastic lava flows (amygdaloidals), altered mafic/basic agglomerates, lithic tuffs, andesitic tuffs, intrusive breccias and submarine spillites and degraded alkali basalts .The application of geophysical methods in the study of the Benue trough geology has centered on mapping of regional structures of the trough using mainly gravity method (Cratchely and Jones, (1961); Artsbachev and kogbe, (1974);) and aeromagnetic interpretation (Ofoegbu,(1984); Ofoegbu and Onuoha, (1991). and Ugwu (2006) used resistivity and magnetic and Spontaneous Potential methods to study Lead-Zinc vein in Ishiagu and Abakaliki areas respectively.

Regional Geology

The sequence of events that led to the formation of the Benue trough and its component units are well documented (Burke et al, 1972; Nwachukwu, 1972; (Olade, 1975; Benkhelil, 1989; Ofoegbu, (1984); 1985). The southern Benue trough is underlain by a thick sedimentary sequence deposited during the early to late Cretaceous (Fig. 2). The Albian shales outcrop as inliers' in the core of the Abakaliki

Anticlinorium and are continuous for about 180 km, stretching southwards from Oju (north of the Workum Hills in the middle Benue) through Abakaliki to Lokpaukwu in the southern limit of the Basin (Umeji, (2000). The rocks are packages of thinly layered, olive green to dark grey and bluish black shales which are frequently calcareous. Subordinate fine grained micaceous sandstones, micaceous siltstones, sandy shales and limestone are present. These sedimentary sequences were affected by large scale tectonic events which occurred in two phases and culminated in the folding of the sediments Nwachukwu, (1972).The fold axes are oriented in a NE-SW direction extending beyond the core of the Abakaliki Fold Belt. The compressional tectonics responsible for the large scale folding and cleavage was directed NI55E (Benkhelil, 1989). The compressional nature of the folds that developed during this period is revealed by their asymmetry and the reverse faults associated with them (Ofoegbu and Onuoha,(1991). The evolution of the geology of the Abakaliki area occurred in a complete orogenic cycle including sedimentation, magmatism, metamorphism and compressive tectonics. The sediments are heavily invaded by igneous bodies. The three major magmatic centres are the Workum-Wanakom-Izekwe centre, Abakaliki centre and the Ishiagu-Lokpaukwu centre (Umeji, (2000). The volcaniclastic rocks under study belong to the Abakaliki magmatic centre.

The purpose of this study is to use resistivity profiling and basic field geology in the mapping and characterization of the different pyroclastic lithotypes and to define their relationship with the country rocks. It will also show us a geophysical method to explore for intrusive pyroclastics because the extrusive pyroclastic rocks being quarried as aggregates for building and road constructions are fast depleting. The Echera Unuhu and Amike Aba pyroclastic masses have been chosen as case studies because of their prominence. Resistivity profiles have been run across these two bodies. Geological mapping and descriptions of these bodies were also done alongside resistivity profiling.

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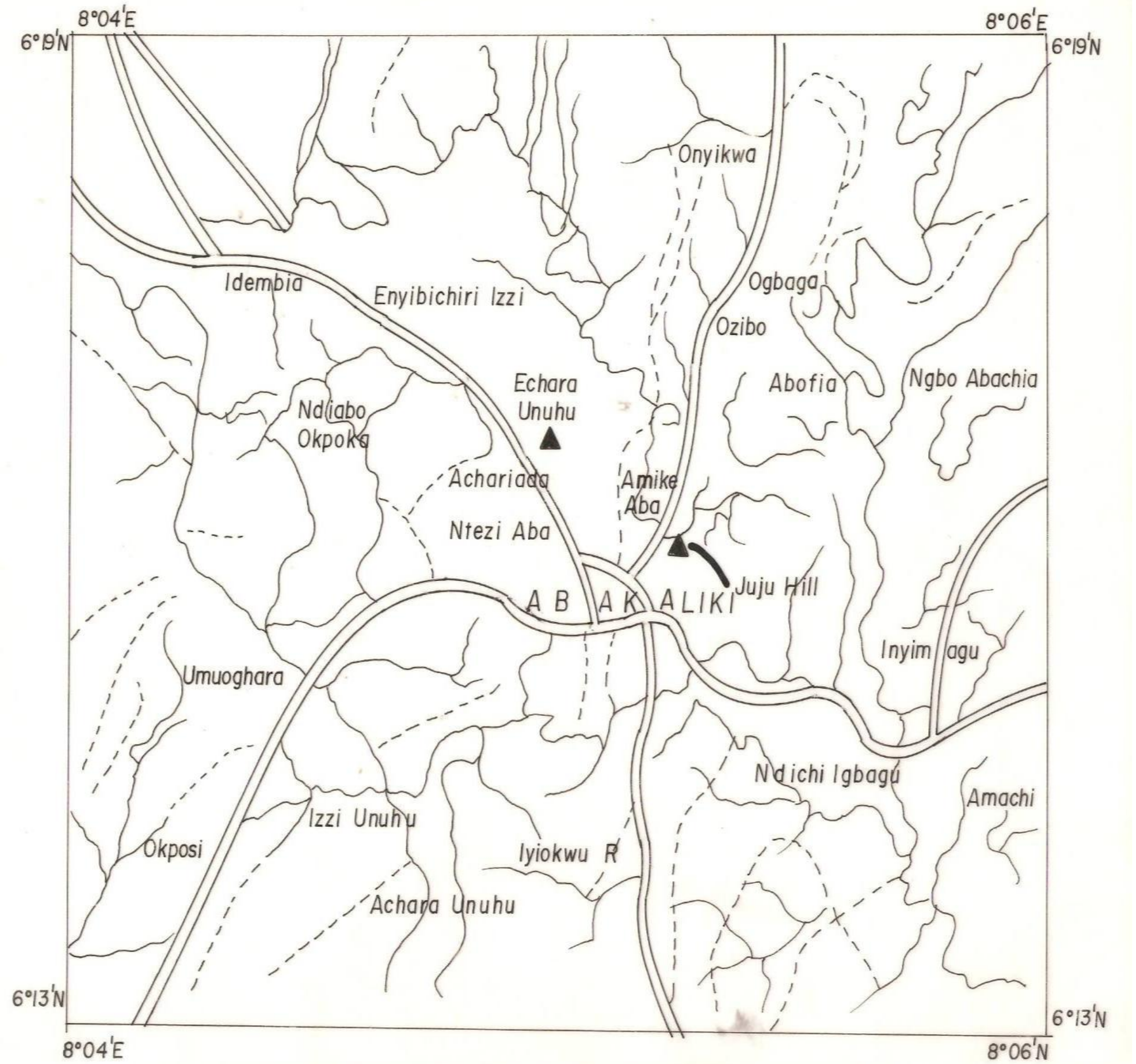

Fig. 1: Map of Abakaliki Urban Showing the Study Areas

MATERIALS AND METHODS

Study Area

Figure 3 shows the geological map of the Abakaliki area. The pyroclastics occur as isolated, oval/domical and elongate mounds or ridges, rising 50-100m above the generally flat topography of the area, and are often caped by thick lateritic cover. They are aligned in a NE-SW trending strike concordant with the Abakaliki shales. The pyroclastic masses occur as isolated hills at Juju Hills, but as undulating low lands at Echara Unuhu, Amike Aba and Onyikwa areas (Fig.3). Field relationships indicate that these extrusive masses are stratigraphically interbedded with the shales.

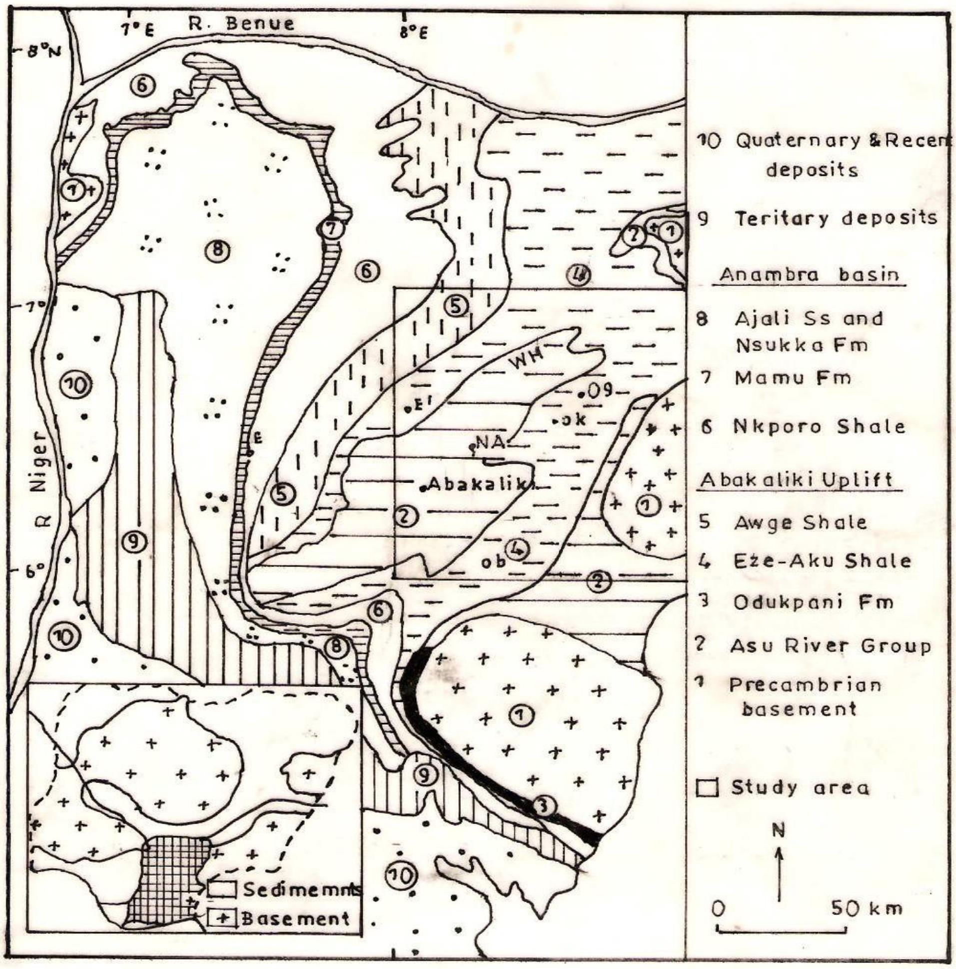

Fig 2 : GEOLOGICAL MAP OF SOUTH EASTERN NIGERIA (AFTER OFOEGBU AND ONUOHA 1991)

Three major rock types and associations are exposed in the pits where the rocks are quarried for use as aggregates for building and road constructions. The rocks comprises of coarse grained agglomerates, very fine grained tuffacceous rocks, breccias, and scoriaceous pumices that were violently ejected into the atmosphere and deposited as blanket-like and dome shaped masses over the area. The agglomerates and breccias are dark grey in colour, and consist of the groundmass of fine ash and dark grey to black glass within which a chaotic assemblage of different sizes of angular to subangular, xenoliths of country rock and pyroclastic fragments are embedded. They are coarse to very coarse grained. The tuffs are the most widespread of the volcaniclastics and comprises of the lithic tuff, crystal vitric tuff, Lapilli tuff and vitric tuff. They vary in colour from light grey to grey as well as whitish. They are very fine grained, sometimes, with characteristic banding, resembling cross stratification.

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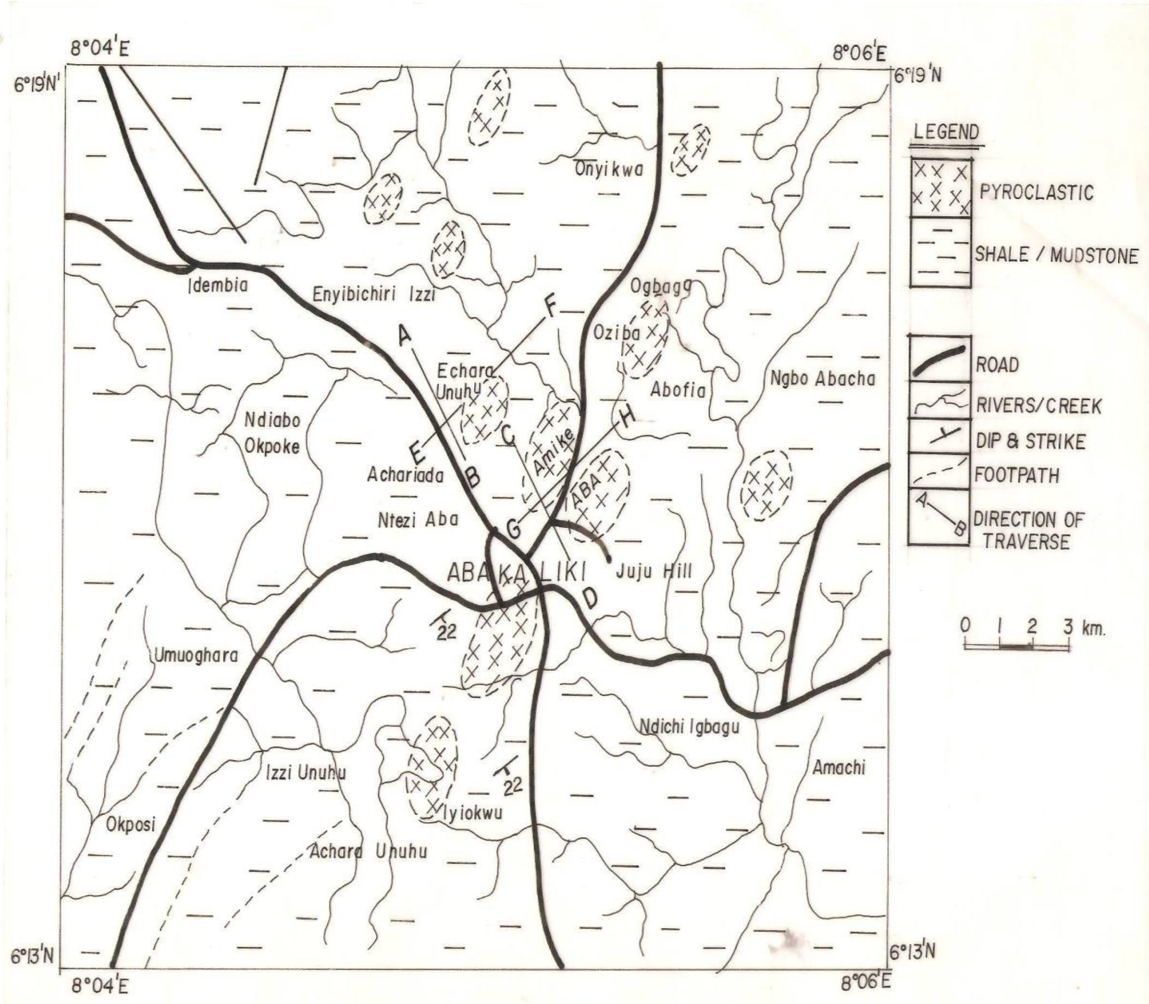

Fig. 3; Geological Map of Abakaliki and Environs

cleavage was directed NI55E (Benkhelil, (1989). The compressional nature of the folds that developed during this period is revealed by their asymmetry and the reverse faults associated with them (Ofoegbu and Onuoha,(1991). The evolution of the geology of the Abakaliki area occurred in a complete orogenic cycle including sedimentation, magmatism, metamorphism and compressive tectonics (Benkhelil, (1989). The sediments are heavily invaded by igneous bodies. The three major magmatic centres are the Workum-Wanakom-Izekwe centre, Abakaliki centre and the Ishiagu- Lokpaukwu centre (Umeji, (2000). The volcaniclastic rocks under study belong to the Abakaliki magmatic centre.

Geology of the Study Area

Figure 3 shows the geological map of the Abakaliki area. The pyroclastics occur as isolated, oval/domical and elongate mounds or ridges, rising 50-100m above the generally flat topography of the area, and are often caped by thick lateritic cover. They are aligned in a NE-SW trending strike concordant with the Abakaliki shales. The pyroclastic masses occur as isolated hills at Juju Hills, Ogbaga Hills and PWD quarry but as undulating low lands at Echara Unuhu, Amike Aba and Onyikwa areas (Fig.3).Field relationships indicate that these extrusive masses are stratigraphically interbedded with the shales. Three major rock types and associations are exposed in the pits where the rocks are quarried for use as aggregates for building and road constructions. The rocks comprises of coarse grained agglomerates, very fine grained tuffacceous rocks, breccias, and scoriaceous pumices that were violently ejected into the atmosphere and deposited as blanket-like and dome shaped masses over the area. The agglomerates and breccias are dark grey in colour, and consist of the groundmass of fine ash and dark grey to black glass, within which a chaotic assemblage of different sizes of angular to subangular, xenoliths of country rock and pyroclastic fragments are embedded. They are coarse to very coarse grained. The tuffs are the most widespread of the volcaniclastics and comprises of the lithic tuff, crystal vitric tuff, Lapilli tuff and vitric tuff. They vary in colour from light grey to grey as well as whitish. They are very fine grained, sometimes, with characteristic banding, resembling cross stratification. These bands may be evidence of flow. Olade (1975) referred to them as graded bedding. Pillow basalts with “ball and pillow” and load structures are also noted in most of the bodies studied. Quartz – filled veins occur as cross cutting structures mostly aligned in the northwest to southeast strikes. The contact relationship of the pyroclatic extrusive masses with the country rock is close. However pumiceous rocks interbred with thin dark grey to bluish shales occur where they are exposed. The scorias and pumices occur as relatively thin beds of vessicular brown rocks 10 to 30cm thick, interbedded with thin shales.

Choice of Geophysical Method

The choice of geophysical technique depends on the geology, purpose of investigation and the availability of equipment. The commonest lithotypes of the Abakaliki pyroclastic rocks are the volcanic agglomerates, breccias and the interstratified lava flows. The pyroclastics vary from very fine grained, well sorted and hard for the tuffs to very coarse porphyritic for the breccias and agglomerates. Generally, they appear very consolidated and hard. They are therefore, non-porous and contain/little or no water except where they are fractured. This renders the pyroclastics more resistive to the flow of electrical currents than the surrounding porous shales. Taking cognizance of this resistivity contrast, electrical resistivity technique was chosen for this study. This method is well suited to study geological contacts, layering and discontinuities within the pyroclastic masses and the electrical resistance of soils and rocks among others (Aspinwall and Walker, (1975) Evidences, from the quarry pits, in the areas, show that the extrusive pyroclastic rocks occur at relatively shallow depths of less than 15m. This encouraged the adoption of the resistivity profiling technique using the r Wenner array configuration because of its high sensitivity to resistivity contrast (in shales and pyroclastics).

RESULTS

Data Acquisition

Two separate locations- the Echara Unuhu and Amike Aba pyroclastic masses have been selected as case studies (Figs 1 and 3). The orientations of the resistivity traverses, A-B (Echara Unuhu) and C-D (Amike Aba)

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which run normal to the contacts are also shown in Fig. 3. Resistivity profiles RT-1 and RT-2 run normal to the contacts in the southeast- Northwest direction while the tie traverses E-F (Echara Unuhu) and G-H (Amike Aba) run perpendicular to profiles RT-1 and RT-2 in the southwest –Northeast direction and these profiles are represented as RT-3 in figures 4 and 5. The Wenner electrode arrangement with current electrode separation of 60m was chosen for resistivity profiling. As a rule of thumb the depth of the Wenner array is approximately equal to the electrode spacing. Knowing that the depth to the pyroclastic is less than 15m, the current electrode separation is then 60m apart. This set up implies a 20m depth resolution if the rule of thumb is applied. The data were acquired using an Abem Terrameter SAS 300C.

Data Reduction

The apparent resistivity of Wenner electrode configuration is well known and is given as **$2\pi aR$** where R is the ground resistance as measured by the Terrameter and a = 20m, the electrode spacing. The geometric factor K was then 125.7m. Results of the measurements are plotted as profiles in Fig 4 (Echara Unuhu) and Fig 5 (Amike Aba) with the apparent resistivity (ohm-m) on the Y- axis and distance (m) on the X- axis.

DISCUSSION

The resistivity profiles RT-1 and RT-2 run normal to the contacts in the SE-NW direction. The tie traverses RT-3 are orthogonal to the RT-1 and RT-2 traverses and are oriented in the SW-NE direction (Fig 3). The resistivity profile RT-1, in each location represents the background resistivity values of the shale country rock where the pyroclatic rocks are not suspected. RT-2 resistivity profiles in the two locations exhibit two distinct resistivity anomalies each; namely; between the distance 90-270m, and 270-390m in Echara Unuhu (Fig.4) and from a distance of 30-150m and 150-330m in Amike Aba (Fig 5) respectively, RT – 1 resistivity values oscillate with reduced amplitude from 97.73.-26.92 Ohm starting from the southeast boarder to the northwest in Fig 4 and from 80.67-23.0 Ohm (Fig 5) following the same direction,- SE-NW. In Fig 4 Echara Unuhu) there is an increase in resistivity values (RT-2) near the southeast boarder from 140-250.7 ohm m, then it decreases to 190.80 ohm-m. From 190.80m it rises again to 434.0 ohm m and finally descended to 130 ohm in the two anomalies identified. In Fig. 5 (RT-2) also varies from a low background value of 51.0 Ohm m to a maximum of 275 ohm m before falling to 168.70 Ohm-m. From168.70 it rises up to 200 Ohm-m and finally decreases to 70.80 Ohm m in the two anomalies respectively. RT-3 resistivity profile is perpendicular to the RT-2 profiles at the two locations. The resistivity values increased near the southeast boarder from 100-250 Ohm m and then to 60.0 ohm m in the northeast (fig. 4) and from a low resistivity value of 48 to 285 Ohm m before decreasing to 25 ohm m from the southwest to northeast direction (fig. 5). The resistivity anomaly (RT-3) between 30 and 150m (Fig 4) is the same as the first resistivity anomaly of RT-2 between 90 and 270m also (Fig 4) but taken in a different direction. They are broader and dome shaped. In figure 5 the resistivity anomaly, RT-3, between 90 and 290m is also the same as (RT-2) resistivity anomaly between 30 and 150m but traversed through another direction SW-NE. These are shaper and cone shaped. Prior to these dome and cone shaped anomalies, there are other smaller anomalies with resistivity values little above the resistivity values of the shally country rock for instance, starting from the southeast between 30-90m; that is 210-140 ohmm, Fig 4 and between 30 and 60m (50-80 ohm) fig 5. This group has low resistivity values and they are lava flows interbedded with the shally country rock. They are pumices and verssicular basalts and occur at the base of the topography or the ridge. The variation in resistivity values could suggest a pyroclastics lithotype with similar texture and porosity. Field observation showed that the dome shaped pyroclastics. 90-270m (fig 4) and150-330m (Fig 5) of RT-2 contain coarse

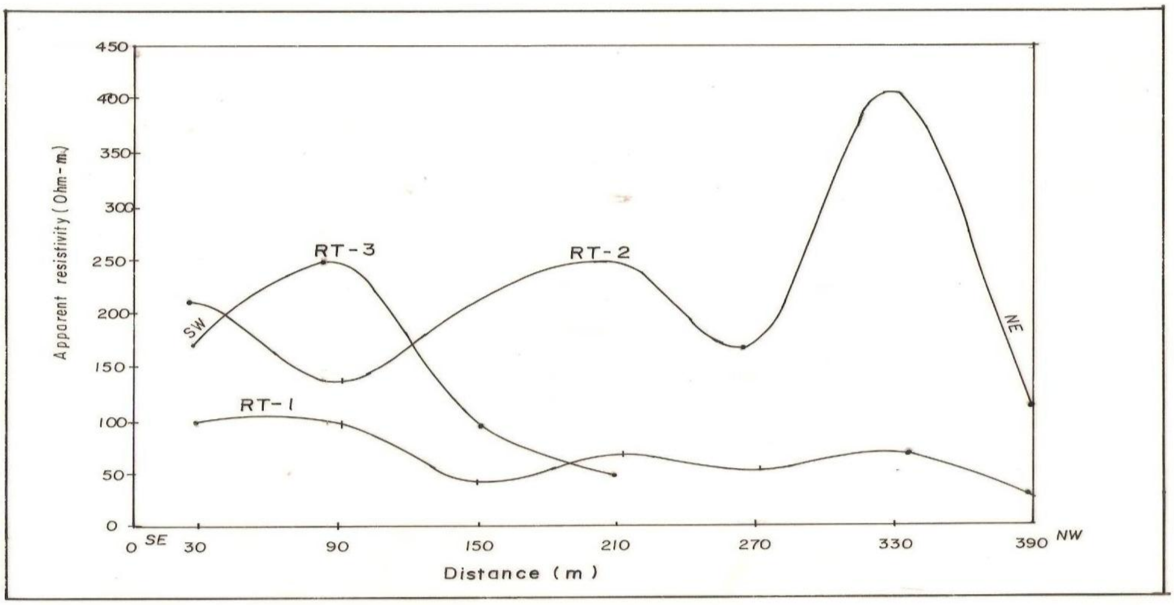

Fig. 4; Resistivity Profiles across pyroclastic rocks at Echara Unuhu.

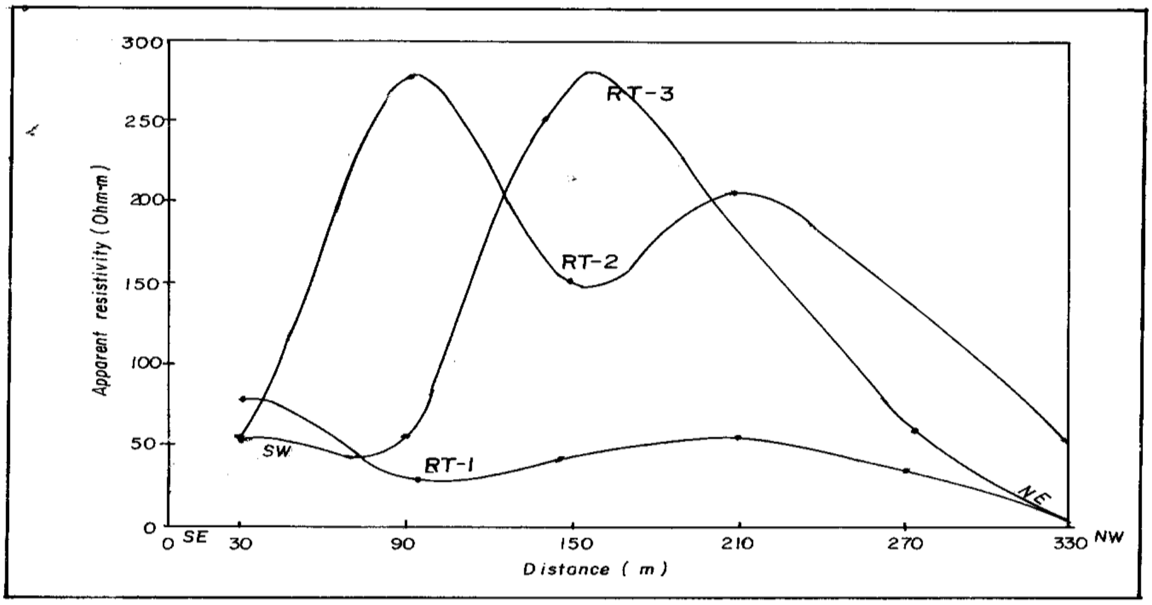

Fig. 5; Resistivity Profiles across pyroclastic rocks at Amike Aba

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grained agglomerates, breccias and microbreccias with angular to subangular xenoliths of shally country rocks and pyroclastic fragments embedded in a black basaltic groundmass. The two sharper prominent cone shaped pyroclastics 270-390m (Fig 4) and 30-150m (Fig 5) of RT-2 appear to be the finest texture, well sorted and the driest of the masses with the highest apparent resistivity values of 275 and 434 ohmm respectively. Field mapping shows that these values correlate with areas underlain by fine grained lithic and crystal vitric tuff. The apparent resistivity of the host shale, RT-1, (Figs 4 and 5) is about 120 ohmm and this with the inflexion points at the resistivity profiles of RT-2 (Figs 4 and 5) define the contact between the pyroclastics and the surrounding host, shale.
The tectonic significance and the stratigraphic dispositions of the Abakaliki pyroclastics have remained controversial Uzuakpunwa (1974) hold the view that they are pre-Albian or Alptian in age. They therefore considered the pyroclastics to be older than the first sediments to be deposited after the opening of the trough and are directly overlying the basement complex. McConnell (1949) and De Swardt (1950) reported the pyroclastics to be interstratified with the Albian shales. Observations in this study reveal the presence of xenoliths and shaly country rocks within the pyroclastic rocks. This suggests that volcanic ejecta extruded and incorporated fragments of already existing rocks. And Obiora and Umeji (1995) had earlier arrived at this conclusion. This study has shown that the argument for a pre-Albian age (Uzuakpunwa, (1974); for the pyroclastics fails. The presence of mudstone and shale xenoliths of the Abakaliki shales embedded in the pyroclastics deflates that argument. An Albian or possibly post Abian age is suggested. However the interbedded relationship of the Albian shales and the pyroclastic dispositions noted in this study strongly supports an Albian age for the Abakaliki pyroclastics.

The geophysical techniques has subdivided the pyroclastic rocks around Abakaliki into three based on the electrical resistivity characteristics. The first group is the low resistivity pyroclastic rocks which are the lava flows interbedded with shales. These are pumices and vesicular basalts and occur mostly at the lower most topographic level of the elongate ridges or conical/dome shaped masses. The second group is that with higher resistivities (dome shaped), these are the breccias/agglomerates and microbrecias consisting of chaotic assemblage of angular and subangular fragments and blocks of shales and pyroclastics in a groundmass of fine ash/tuff and amorphous “glass”. The third group with the highest resistivity values (cone shaped) is the lithic and crystal vitric tuff which appear very fine grained and moderately to well sorted and therefore the least porous.

In the present study Electrical resistivity profiling using Wenner array configuration has proved to be a useful geophysical technique in the investigation of the extrustive volcaniclastic rocks alongside field geological mapping. It equally demonstrated that it can be used to locate intrusive volcaniclastics. This technique will come handy when the extrusive pyroclastic rocks, being quarried as aggregates for road and building constructions have been exhausted. In the Abakaliki area, the technique has yielded apparent resistivity curves which distinguish three groups of pyroclastic rocks correlatable in the field to pyroclastic rocks with different textures porosities and compositions. A cut off resistivity value of 120 ohm has also been found to define contrasts between the shally country rock and the pyroclastic rock masses at Echara Unuhu and Amike Aba.

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