

Full Length Research Paper

Application of electrical resistivity imaging (ERI) in delineating an non-conformity around Ijesha-ijebu, southwestern Nigeria

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Accepted 11 January, 2012

A geophysical study involving Electrical Resistivity Imaging (ERI) survey was carried out to delineate the unconformity between the Sedimentary and Basement rocks in Ijesha-Ijebu, Southwestern Nigeria. This area marks the contact zone between the basement rock of southwestern Nigeria and the sedimentary rocks of Dahomey Basin. Three ERI were carried out using Wenner array of first levels (i.e. $n=1$) of $a=10\text{m}$, 20m , 30m and the subsequent levels were chosen as the product of the level and the current separation of the first level, a total of 5-6 levels were probed for the traverse. This makes the traverse lines to cover between 0.5 to 1km in distance. Inversion method was carried out on the acquired pseudosection using DIPRO software with percentage error of less than 0.5. The lithologic section in the area revealed a conglomeratic layer of 5-10m thick lying unconformably on the banded gneiss, overlain by ferruginous sandstone of 7-10m thickness intercalated by oolitic ironstone of 0.3-0.5m thick. This is overlain by sandy topsoil of 0.8-2m. The result of the ERI showed a considerable agreement with the lithological section as it revealed three geoelectric layers; the sandy topsoil (500-1300 Ωm), the highly resistive conglomeratic layer ($>1350\ \Omega\text{m}$) and the weathered basement rock (400-1350 Ωm). Also, it showed that the conglomeratic layers which mark the basal part of the Ise Formation varied in depth from the surface to a depth of greater than 150m. The study has shown the relevance of ERI in mapping rock-contact, most especially in areas with few or no exposure.

Keywords: Electrical Resistivity Tomography, Unconformity, Geoelectric section,

INTRODUCTION

Mapping contact in an unconformity between the sedimentary and the basement rocks (non conformity) can be very difficult, most especially in areas with little or no outcrops and devoid of road cuttings. The cost and environmental impact of drilling numerous boreholes make it desirable to employ a less costly and more environmentally favorable techniques for probing the subsurface.

Although some authors in Nigeria had used an indirect geophysical method like gravity survey (Ojo and Ajakaiye, 1976) and aeromagnetic (Nwankwo, 2007 and Udensi, 2001) in delineating this type of

unconformity (non-conformity), Electrical resistivity, a less costly and environmental friendly method can be effectively uses in delineating non-conformity. This parameter is extremely sensitive to the presence of ore minerals, changes in clay content, porosity or pore fluid conductivity and weathered materials. Electrical methods in the past were restricted to electrical soundings, where the electrical structure is defined with depth at a single point; and electrical profiling, where average lateral variations in electrical resistivity are defined. The new Electrical Resistivity Tomography or Imaging (ERT or ERI) approach is essentially a combination of these sounding and profiling techniques. It has been made possible by implementing computer controlled data acquisition from arrays of electrodes and much more sophisticated computer algorithms to

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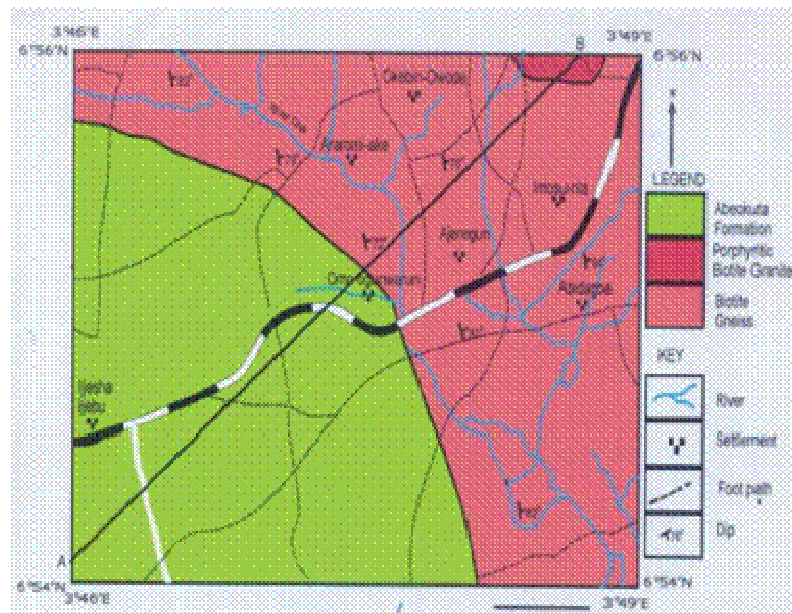


Figure 1. The Geology of the Study Area.

image the data. The output is a cross-sectional resistivity image, which is effectively a blurred rendition of the true cross-sectional electrical structure of the subsurface.

ERI for subsurface imaging is one of the promising new technologies developed and when used in conjunction with lithological information, can bring understanding and clarity of the subsurface.

The objective of this work is to evaluate the applicability of 2D electrical resistivity tomography or imaging (ERI) to delineate the transition zone between the basement and sedimentary rocks. The study area in Ijesha-ljebu, SW Nigeria is a transition terrain between the Dahomey Basin and the Basement complex areas of southwestern Nigeria. The imaging of this unconformity, especially in this area and similar other localities where the basal conglomerates and/or sands overlies the Basement is invaluable in view of the high borehole failure in these areas, despite favorable hydrogeological conditions such as high annual rainfall, presence of thick loose sands (Idowu et al., 1998).

The study area

The study area is within Ijesha-ljebu, which is located in southwestern Nigeria and lies between latitude 6° 54' and 6° 56' North and longitude 3° 46' and 3° 49' East. The relief of the study area is closely associated with underlying rocks (Jones and Hockeys, 1964). The contact between the basement rocks and the sedimentary rocks separates the rugged relief of the basement complex area from the gently undulating one

of the sedimentary terrain. Most prominent topographic features in the basement area of Ijesa-ljebu are controlled by the weathered gneiss that are prominent in the area. The relief of the area thus consists of residual hills and pediment slopes which at the break of slope pass into rejuvenated river valley.

The study area is characterized by high diurnal and annual temperature, lack of cold season, high precipitation, low pressure, high evaporation-transportation and high relative humidity. (Akanni, 1991). According to Adegoke, (1969) classification, the study area can be specifically placed in the humid tropical regional climate with district dry and wet seasons. The mean annual rainfall of the study area does exceed 2000mm. temperature ranges from a mean maximum of about 32°C in February and March to a mean of about 21°C in August. The natural vegetation in the study area is the rainforest type. However, most parts of the areas are covered by cultivated vegetation due to agricultural activities. The present vegetation consists of a combination of great variety of plant groups. Tall grasses, herbs, and small trees are common features. (Akanni, 1991).

Geology of the study area

The study area lies within the transitional zone of both sedimentary rocks and basement complex rocks (Figure 1). The sedimentary part of the study area is located within the Abeokuta Group (Ise Formation) in Dahomey Basin and the lithostratigraphy of this group has been subdivided into three distinct Formations. It

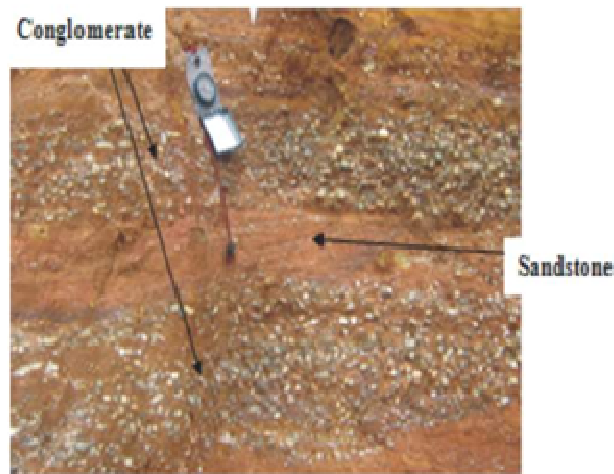


Figure 2. Exposed basal sedimentary section showing the lithologies

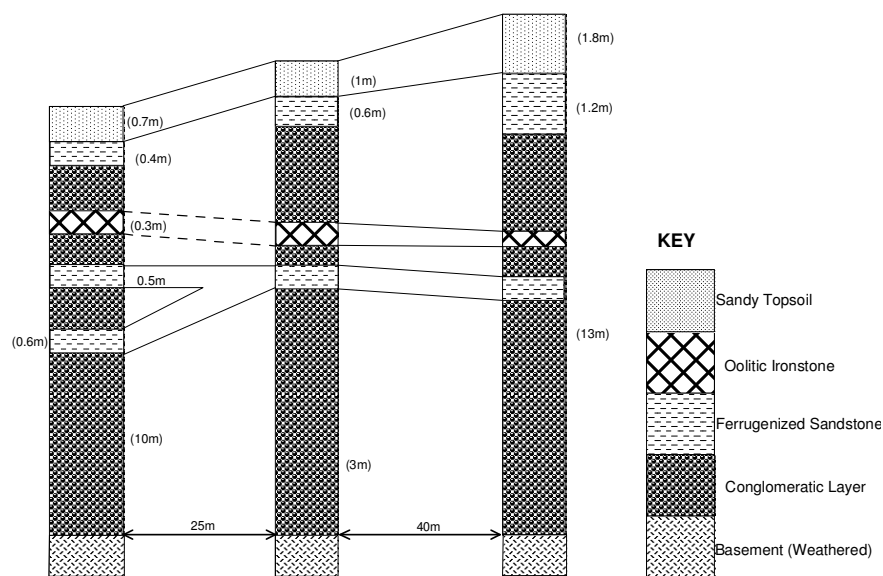


Figure 3. The three lithological sections logged at the exposed section in the study area

comprises of conglomerate at the base, gritty to medium loose sand, capped by kaolinite clays (Omatsola and Adegoke, 1981; Agagu, 1985). The sedimentary region has been laterized and the degree of laterization varies and this controls the colour of the soil. In places where laterization is advanced, the predominant colour is reddish brown which is attributed to the prolonged exposure and subsequent oxidation of the materials. (Ako et al, 1980). There also seems to be an intercalation of sandstone and ironstone in the sedimentary region. (Ogbe, 1970).

In the basement complex region of the study area, rock types observed are predominantly made up of granite gneiss and banded gneiss, most of which have

undergone series of weathering. (Rahaman, 1988)

Part of the study area had been excavated because of road construction going on in the area, thereby exposing the lithologic section of the sedimentary rocks in the area (Figure 2). At the base of the formation, pebbly conglomeratic sandstones were observed overlying the weathered basement. Overlying the conglomeratic sandstone is the gritty ferruginized sandstone (reddish brown in colour). At some part of the formation, sandstones strata were intercalated with thin dark bands of ironstone. The three points were all capped by sandy top soil with varying thickness (Figure 3). The basement rocks observed underlying this sedimentary section have undergone residual

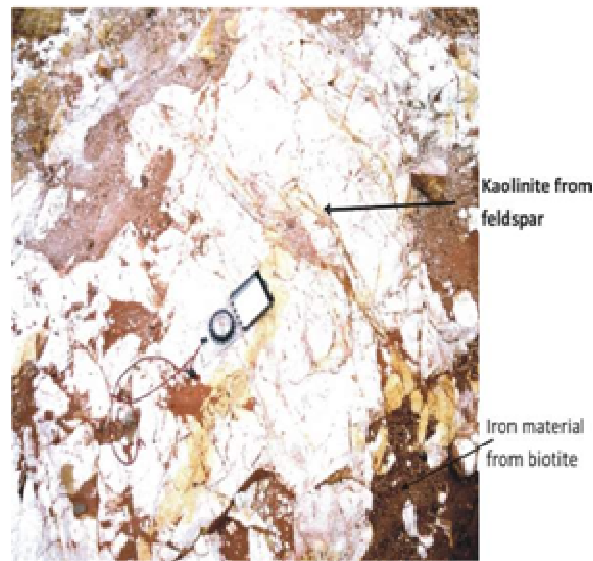


Figure 4. The weathered basement (gneiss) underlying the sedimentary rock.

weathering resulting into the white kaolinitic clay and other weathered materials such as quartz minerals (Figure 4).

METHODOLOGY

The area was logged from three different points on the exposed sedimentary section which consist essentially of Basal conglomerates and iron stone overlying the weathered basement. The 2-D electrical imaging survey is one of the newest developments in recent times. Its use in mapping areas with moderately complex geology has made it more field worthy and useful (Griffiths and Barker 1993). It is called ERT (Electrical Resistivity Tomography) or ERI (Electrical Resistivity Imaging) and it is a method of obtaining resistivity measurements that determines the electrical conductivity of the ground using subsurface electrodes (Zhou et al., 2002, Daily et al., 2004). These facts allow data to be collected and processed quickly so the electrical Resistivity Imaging surveys become a valuable tool in subsurface investigations (Zhou et al., 2000).

Such surveys are usually carried out using a large number of electrodes connected to a multi-core cable. Presently, field techniques and equipments used in carrying out 2-D resistivity surveys are fairly well developed. Normally a constant spacing between adjacent electrodes is used. The multi-core cable is attached to an electric switching unit which is connected to a laptop computer. (Loke, 1999a and Loke, 1999b). The sequence of measurements, the array types to use and other survey parameters is normally entered into a text file which can be read by a program in a laptop

computer. Different resistivity meters use different formats for the control file in a typical survey.

In the course of this study, the Wenner array survey method was employed with the aid of an ABEM TERRAMETER. The distance between the adjacent electrodes is represented as 'a'. A fixed point is selected at the centre of the survey line to represent the centre of the array where the terrameter is stationed and properly connected to the electrodes through a multi-core cable. During this survey, three different traverses were probed with their first levels (i.e. $n=1$) having a of 10m, 20m and 30m respectively. At traverse 1 (where $a=10\text{m}$ at the first level) and traverse 2 (where $a=20\text{m}$ at the first level), six levels were probed with a maximum of 46 and 23 electrodes to give a total profile length range of 460m to 500m respectively while 5 levels were probed for traverse 3 (where $a=30\text{m}$ at the first level) with a maximum of 33 electrodes and a total profile length of 990m was traversed. For each of the traverses, the electrode separation a for the subsequent levels (i.e. $n=2, 3, 4, 5$ and 6) was chosen using the formular na as done by Loke, 1999a where n is the level being probed and a is the current separation used for the first level. Thus, for traverse 2, the third level ($n=3$) will be 60m. The apparent resistivity results obtained along the three traverses for all the levels were iterated using DIPRO program with percentage error of less than 0.5 to obtain the 2D resistivity structure of the area.

RESULTS AND DISCUSSION

The ERI iterated results obtained from the three travers

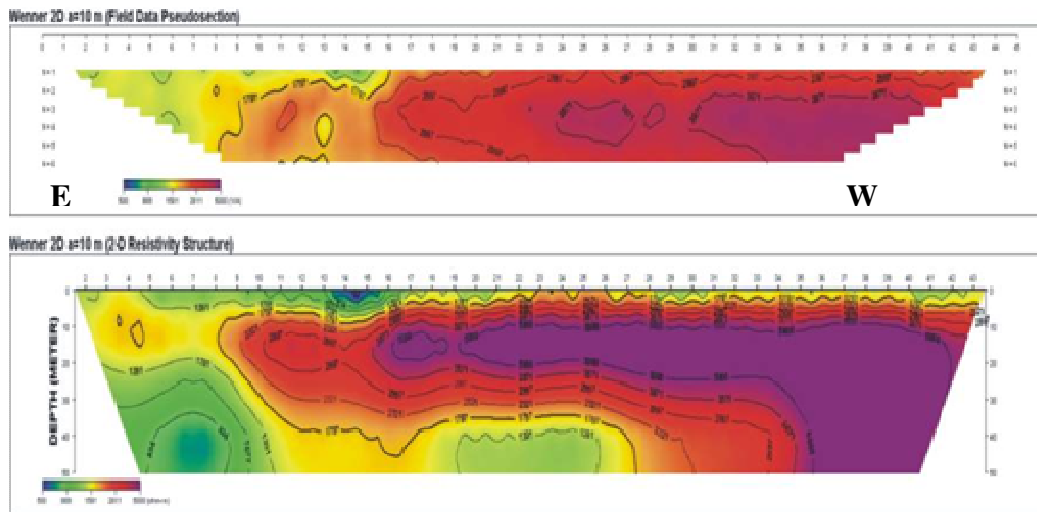


Figure 5. Pseudo-section (top) and the 2D resistivity model for traverse 1 in the study area

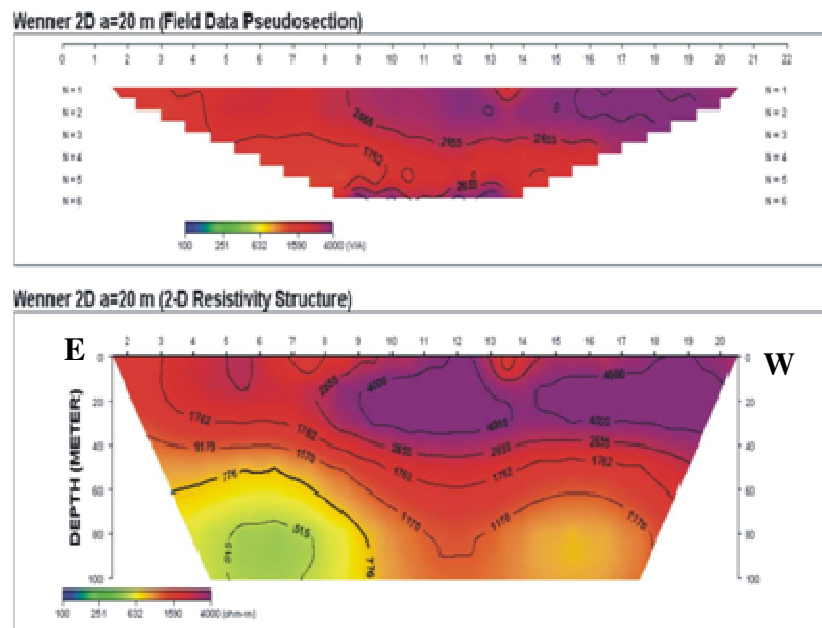


Figure 6. Pseudo-section (top) and the 2D resistivity model for traverse 2 in the study area

are presented in [Figure 5](#). The results of the contoured apparent resistivity pseudosection give the subsurface resistivity distribution in the study area while the 2D resistivity structure gives the computed resistivity of the area with depth after the inversion of the resistivity pseudosection.

These three results revealed the electrical resistivity characteristics of the probed subsurface at various depths. The electrode separation, 'a' is usually proportional to the depth of probe. (Dahlin and Loke, 1998). This implies that the results obtained at traverse

3 probed to a deeper depth and length when compared to results of traverse 2 and traverse 1.

The resistivity values of ERI of traverse 1 as shown in [Figure 5](#) varies from 500 - 5000 ohm-m while traverse 2 ([Figure 6](#)), has resistivity values range from 500 - 4000 ohm-m, also the resistivity values of traverse 3 ([Figure 7](#)) range from 400 - 22,000 ohm-m. Different rocks of different components tend to have varying resistivity characteristics, thus, showing different resistivity values when measured. Preliminary ERI interpretation for sedimentological studies in natural settings should be

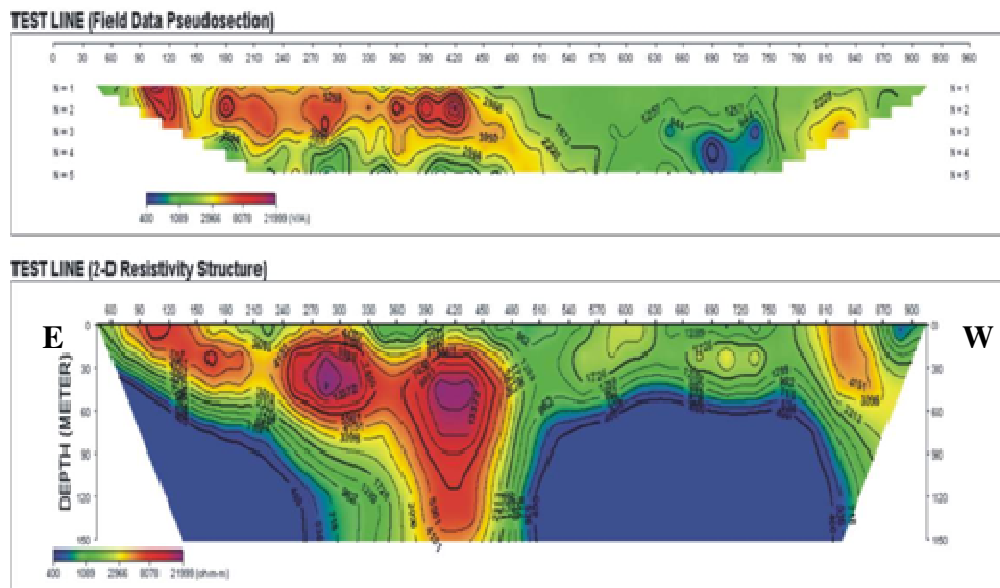


Figure 7. Pseudo-section (top) and the 2D resistivity model for traverse 3 in the study area

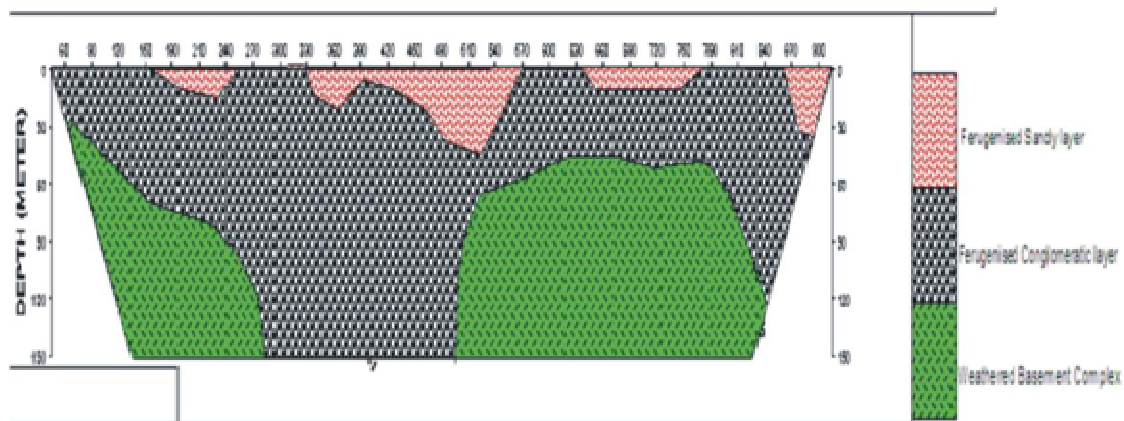


Figure 8. Geoelectric section model showing the possible lithologic section along traverse 3 of the Study area

based on the relationship between grain size and resistivity. Under any particular set of moisture conditions, gravel always has a higher resistivity than sand. Similarly, sand has a higher resistivity than silt, and silt has a higher resistivity than clay (Baines et al., 2002).

The results of the ERI were correlated with the lithological logs of the area in [Figure 8](#), to develop a model of the subsurface from the ERI results. Closer observation of the three ERI results showed three distinct geoelectric layers; a relatively lower resistivity values which ranges between 500 to 1300 Ωm and corresponds to the friable sandy topsoil. Underlying this is a relatively higher resistivity layer of resistivity values greater than 1350 Ωm and it corresponds to the

conglomeratic layer that usually marks the top of the unconformity in the Dahomey Basin. Underlying this highly resistive conglomeratic layer is a lower resistivity layer with resistivity range of 400 to 1350 Ωm , the resistivity values of this layer correspond to the weathered part of the basement in this area. Because of the increase in the depth of probe of traverse 3, which reveal more information of the subsurface in the area, the information is used to produce geological model of the subsurface and it is shown in [Figure 8](#). Although the resistivity of sandstone is distinct from that of the conglomerate, but because the sandstone in this area is not of a considerable thickness (<5m), this layer could not be separated from the conglomeratic layer by their resistivity values. From this model, the ERI

revealed a variation in thickness of the conglomeratic layer, it shows that the layer extends deeper at the centre of the traverse, especially between the distance of 270m and 510m of the traverse. It also showed that the conglomeratic layer occurs in depth of about 30m at the eastern and western part of the traverse to more than 150m at the center. This model however agrees with the lithological logs (Figure 3) of the area mapped and the section produced.

CONCLUSION

In contact zones, where the presence of unconformity and/or basement relief influences successes of boreholes and/or structural stability, Electrical Resistivity Imaging (ERI) provides a cheap and effective technique to delineate basement-sedimentary contact. As demonstrated in this study ERI employing Wenner array technique complimented with logs (borehole, pits or road cuts) can efficiently map rock types and their boundaries using their resistivity values within the subsurface.

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