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GEOPHYSICAL INVESTIGATION OF GROUND SUBSIDENCE: A CASE STUDY OF A BEVERAGE FACTORY SITE IN EDO STATE, NIGERIA.

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ABSTRACT

A geophysical investigation involving the electrical resistivity and gravity methods was carried out within the premises of a Beverage Factory in Edo State. The investigation was to enable the determination of the cause(s) of a ground subsidence within the premises of the boilers.
The vertical electrical sounding interpretation results show that the premises is underlain by sands with intercalation of clay/sandy clay in places. The layers show lateral continuity. The residual gravity anomalies are generally flat indicating near homogeneous subsurface sequence devoid of lateral discontinuities such as sinkholes/ cavities or faults.
A synthesis of the results show that the ground subsidence is not precipitated by collapsed geologic feature such as sinkholes/ cavities but boiler load induced differential settlement arising from near surface incompetent (clayey) substratum, in the premises of the boilers.

KEYWORDS: Ground subsidence, Vertical electrical sounding, Gravity anomalies, and Incompetent substratum.

INTRODUCTION

Ground subsidence has been noticed within the premises of a Beverage Factory Site in Edo State and most prominently in the premises of the Boilers. The settlement has manifested in terms of cracked foundation/wall in the adjacent office complex building.

The possible causes of this feature are subsoil differential settlement due to imposed load of the boilers and/or collapse of subsurface geologic features such as sinkholes/cavities.

A geophysical investigation involving the electrical resistivity and gravity methods (Olorunfemi and Mesida, 1987; Nelson and Haigh, 1990; Adams and Hinge, 1990 and Wenjin and Jiajian, 1990) was carried out at the site with the sole objective of delineating the subsurface lithologies and mapping possible subsidence precipitating geologic features such as air or water filled sinkholes/cavities or possible faults.

SITE DESCRIPTION

The survey site is located along Auchi Road at Benin City, Edo-State (Fig 1). It is part of the Niger delta of mid Western Nigeria. The area falls within the geographical co-ordinates of Latitudes 6^0 00^1N and 6^0 30^1 N Longitudes 5^0 30^1 E and 6^0 00^1 E. Two major rivers drain the area. These include river Osse at eastern part and river Osimomo at western part. The mean annual rainfall in the area is about 2006.6mm.

GEOLOGICAL SETTING

The survey site falls within the Niger Delta, which is one of the sedimentary basins in Nigeria. The Niger Delta is underlain by three (3) formations, which are deposited in high energy constructive deltaic environments and differentiated into continental Benin Formation (comprise coarse grained, granular sands with minor intercalations of clays), Paralic Agbada Formation (made up of sands and sandstones, intercalated with shales) and pro-deltaic marine Akata Formation, which is made up of predominantly shale with intercalation of sands and siltstone.

The Benin Formation underlies the study area directly. The formation contains sand and sandstone that are coarse grained and generally very poorly sorted. The grains are sub angular to well rounded. Composition, structure and grain size of the sequence indicate deposition in a continental probably upper deltaic environment.

FIELD MEASUREMENTS

Geophysical investigation involving the electrical resistivity and gravity methods was carried out.

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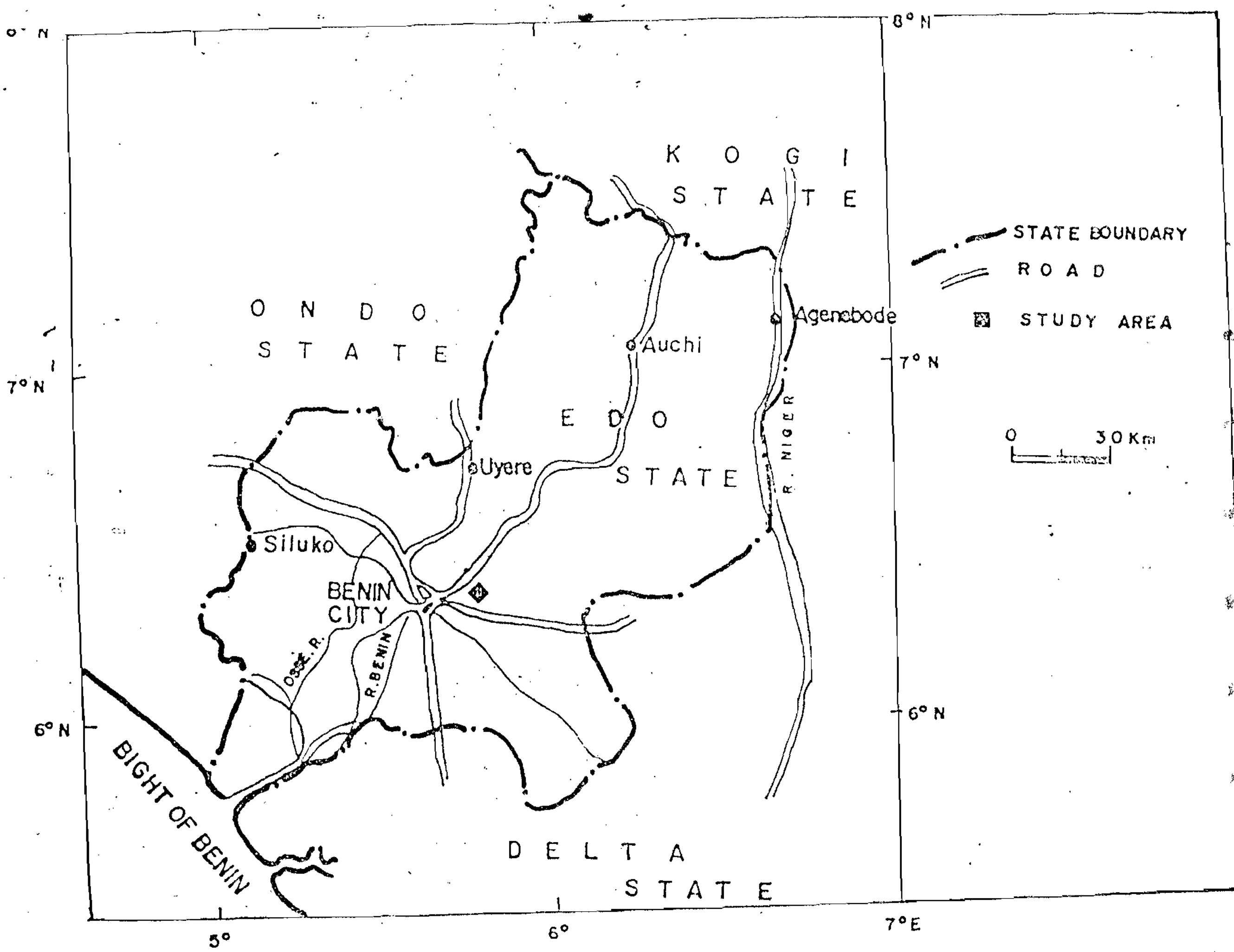

Figure 1 MAP OF EDO STATE SHOWING THE STUDY AREA

The former was adopted for the delineation of the subsurface geologic sequence while the latter was used for the mapping of possible geologic features such as air or water filled sinkholes/cavities or possible faults.

The resistivity method utilized the vertical electrical sounding (VES) technique with Wenner array (3 VES) and Schlumberger array (2 VES). The electrode spacing was varied from 1 to 20m. Three VES stations (VES 3 – 5) were located within the factory premises while two reference VES stations (VES 1 and 2) were located outside the factory site (Fig 2)

Gravity profiles were ran along twelve traverses (TR 1 – 12) each 63m long trending 260^0 within the distressed section of the factory site. Two traverses (TR 12 and 14) were located orthogonally to the former while a reference traverse TR 15 was located away from the site (See Fig 2). The station – station separation for TR 1 – 14 was 3m. Traverse-Traverse separation for TR 1 – 12 was 5m while for TR 13 – 14, was 12m. The station – station separation along TR 15 was 5m.

DATA PROCESSING AND INTERPRETATION

The VES data are presented as depth sounding curves (Figs 3 and 4). The VES curves were quantitatively interpreted by a method involving partial curve matching and computer iteration technique.

The field observed gravity data were corrected for instrument drift using the repeat base station technique. Since the premises of the survey area is relatively flat (i.e no significant elevation differential), free air and Bouguer corrections were not effected neither was there any need for terrain and latitude corrections within a block under 100 x 100m.

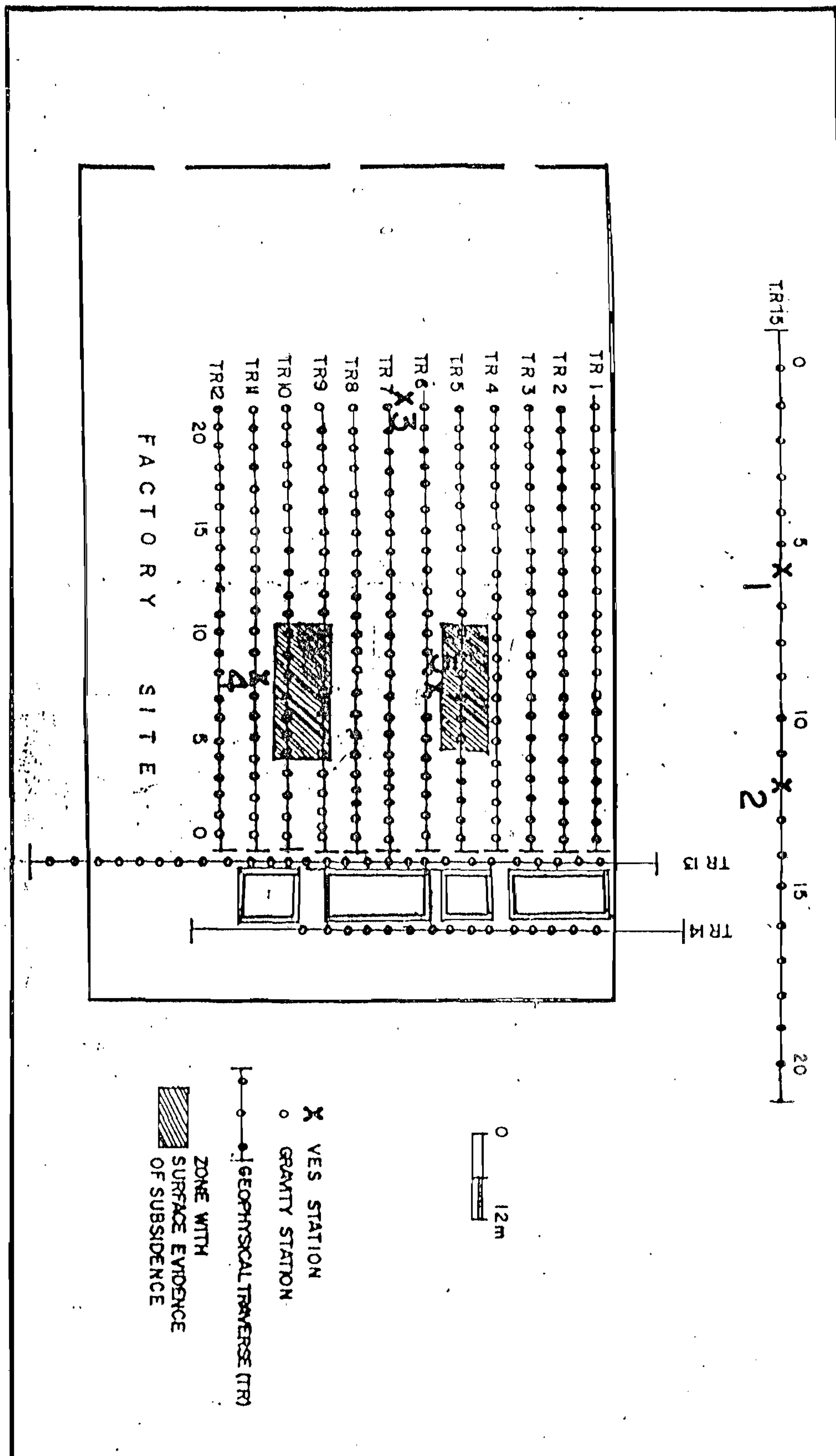

Figure 2 GEOPHYSICAL DATA ACQUISITION MAP

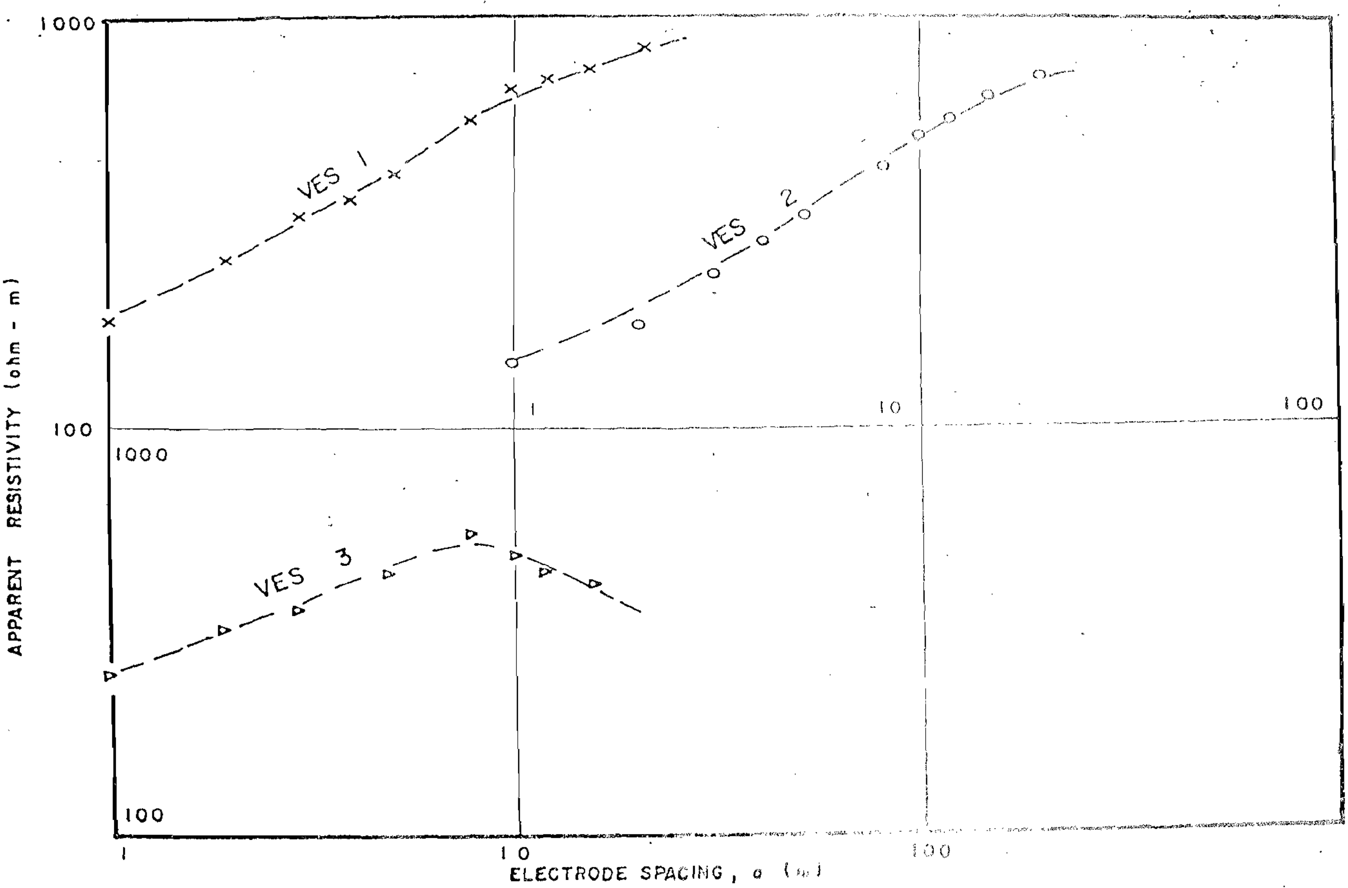

Figure 3 OBSERVED WENNER SOUNDING CURVES

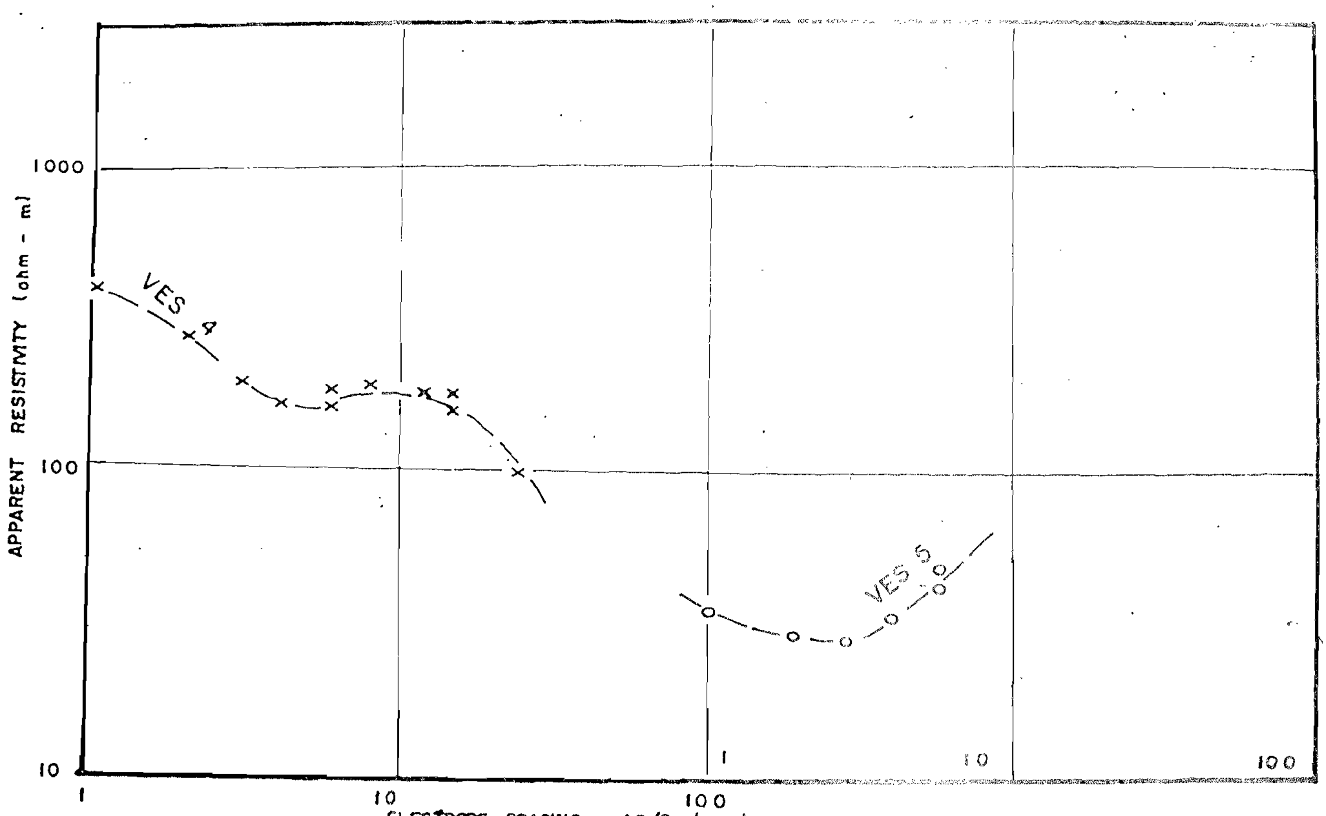

Figure 4 OBSERVED SCHLUMBERGER SOUNDING CURVES

The interpretation of the gravity anomaly was qualitative and this involved inspection of the gravity residual anomaly for signature (significant gravity low) typical of a density deficient sinkholes/cavities or clay pocket in sand or S shaped signature typical of a faulted zone.

DISCUSSION OF RESULTS

The vertical electrical sounding results are presented as geoelectric section and fence diagram (Figs 5 & 6). The sections identify four geoelectric/geologic layers from the ground surface to a depth of about 15.0m.

The first layer is the topsoil composed of clay, sand clay and clayey sand with resistivity values ranging from 35 to 411 ohm-m. The layer thickness is between 0.9 and 1.9m.

The second layer is made up of clay/sandy clay formation, which has resistivity value varying from 20 to 135 ohm-m and thickness of between 2.1

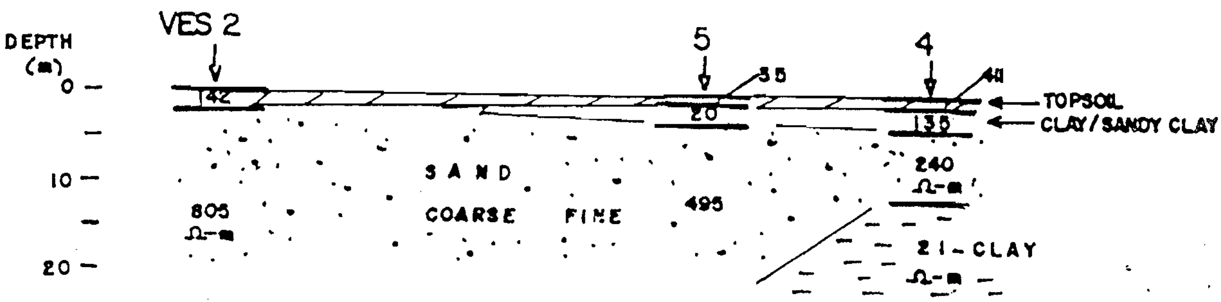

Figure 5 GEOELECTRIC SECTION RELATING VES 2, 5 AND 4

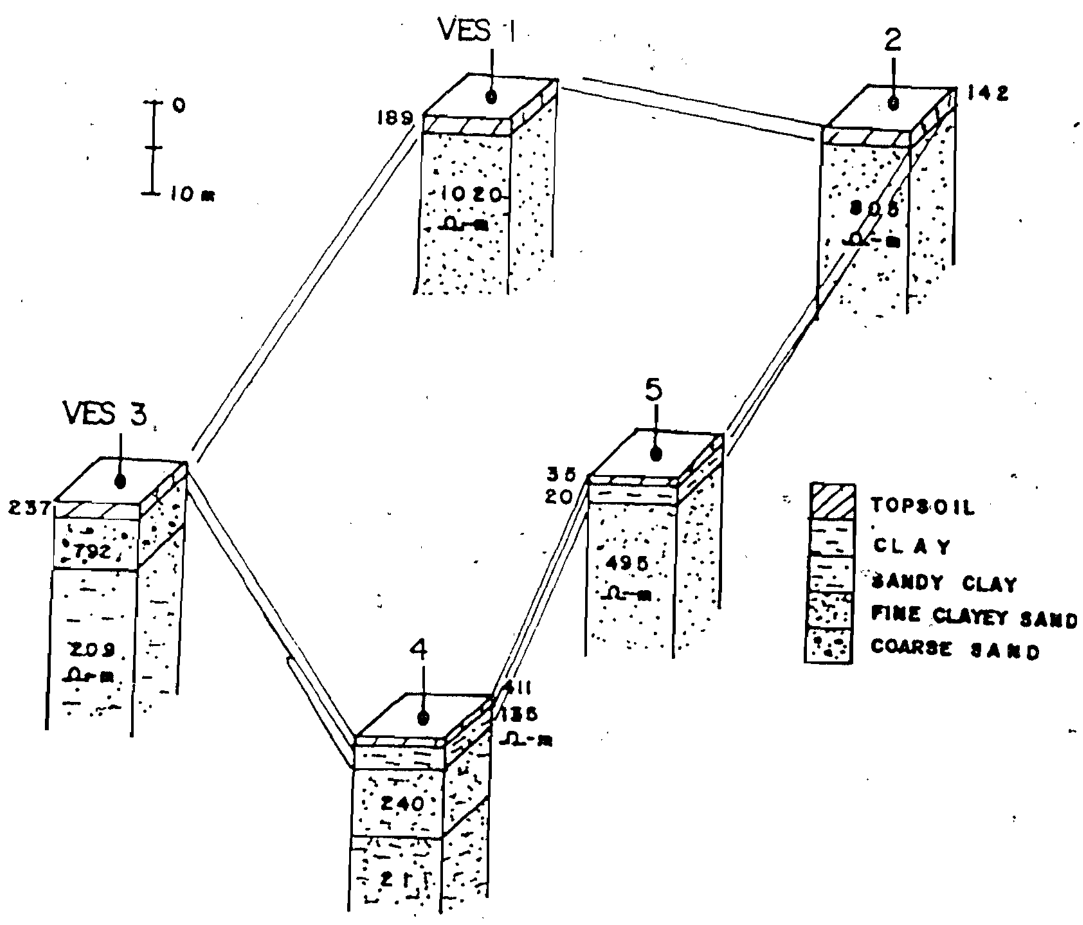

Figure 6 GEOELECTRIC FENCE DIAGRAM RELATING VES 3, 1, 2, 5 AND 4

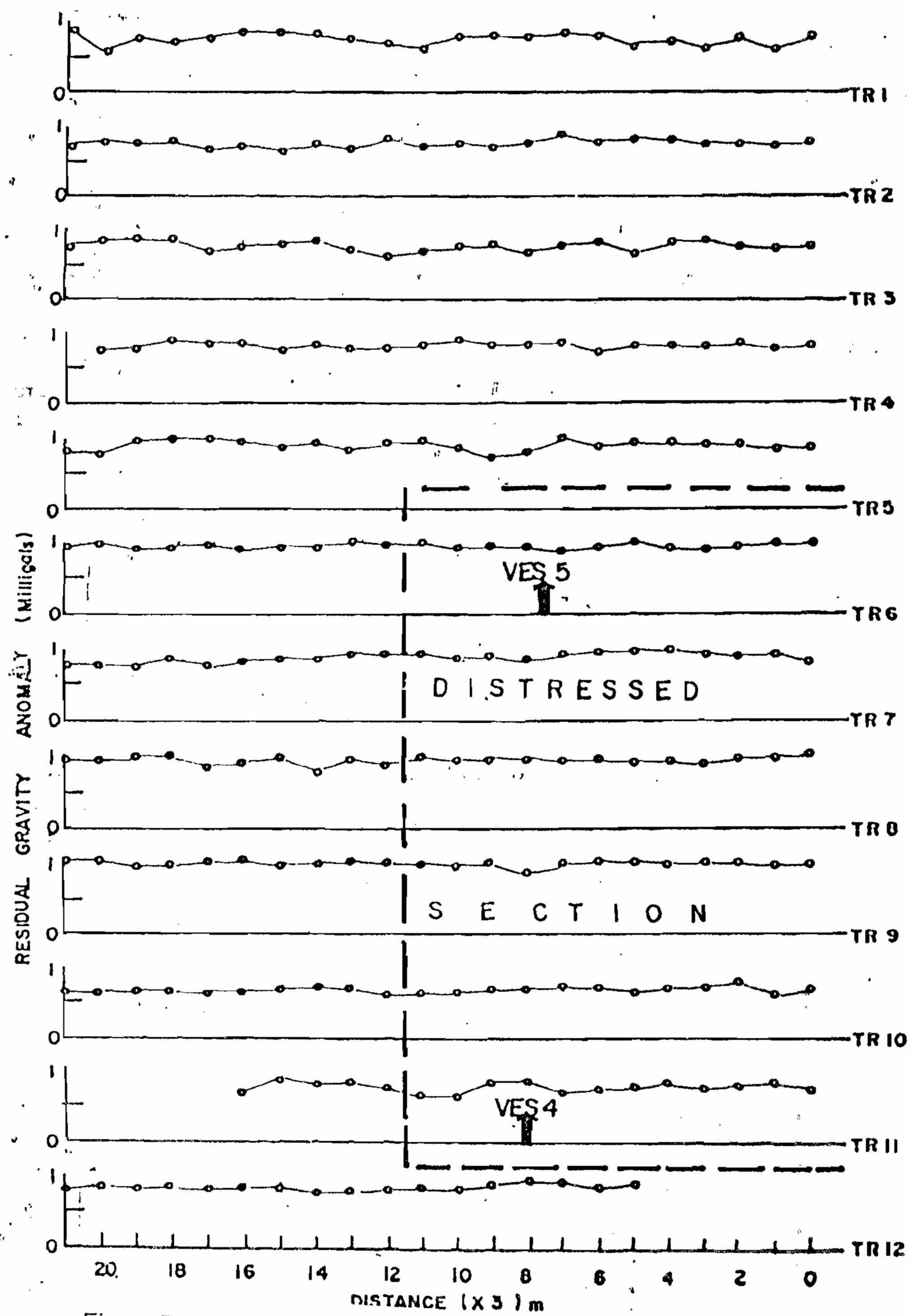

Figure 7 *RESIDUAL GRAVITY ANOMALY ALONG TRAVERSES TR-12*

and 2.6m. This layer was only observed beneath VES 4 and VES 5. Beneath the second layer, there is a thick sand formation with resistivity value ranging from 240 to 1020 ohm-m. The formation may be clayey in places. The layer thickness ranges from 5.6 to 7.8m.

The last layer delineated by the VES survey is composed of clay/sandy clay formation. The layer has resistivity value that vary from 21 to 209 ohm-m. The low resistivity value of this formation beneath VES 4 is diagnostic of its high clay content. The formation is observed only beneath VES 3 and VES 4. Depth to top of the layer ranges from 7.3m to 11.3m.

The gravity anomaly within the factory premises (TR 1 – 14) varies between 181.57 – 182.10

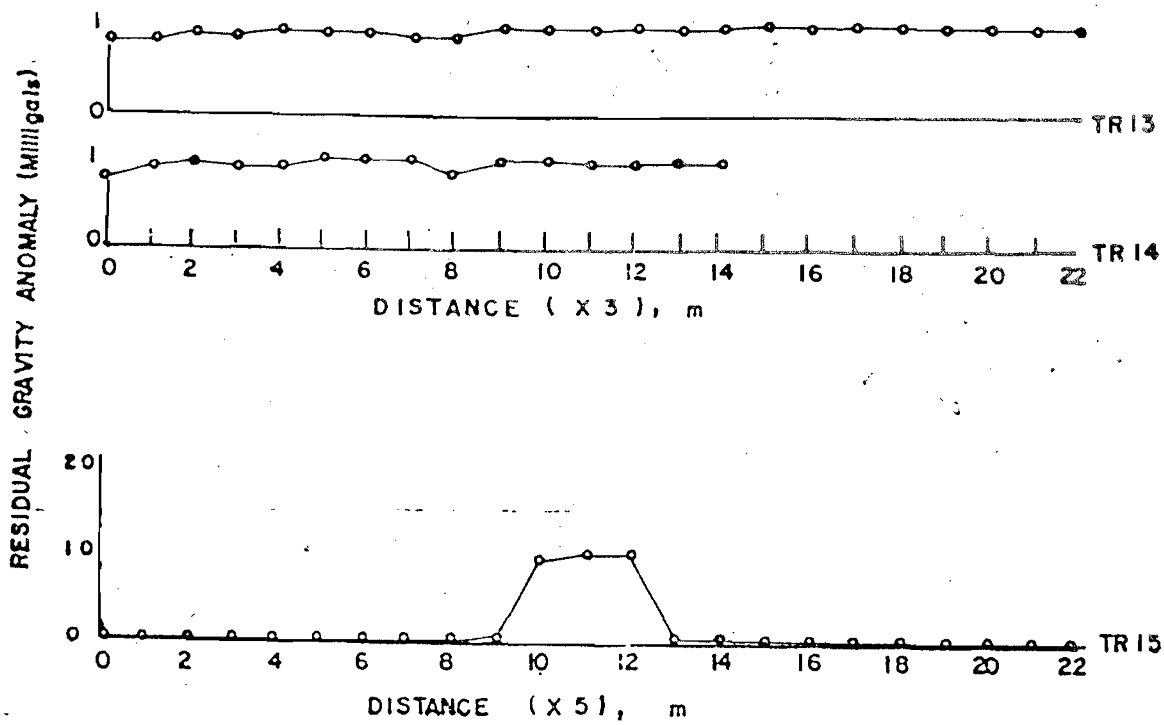

Figure 8 RESIDUAL GRAVITY ANOMALY ALONG TRAVERSES TR 13 - 15

milligals with a maximum differential of 0.53 milligals. The range along the reference traverse TR 15 is 182.03 – 191.59 milligals with a differential of 9.56 milligals. The residual gravity anomaly profiles (adopting a background anomaly of 181.0 milligals for factory site and 182.0 milligals for outside) are shown in Figures 7 and 8. The residual gravity anomaly profiles along traverses TR 1 – 14 (Fig 7 and 8) show relatively flat gravity anomalies with amplitudes of less than 1 milligals. The flat anomalies are indicative of a layered homogeneous substratum with no visible subsurface geologic structures or features particularly within the distresses zone marked out in Figure 7. The gravity profile along traverse TR 15 outside the Factory Site shows a local gravity high between stations 9 and 13, which may be due to a buried concrete slab or pipe.

CONCLUSION

The vertical electrical sounding (VES) interpretation results show a subsurface sequence composed of sands with intercalations of clays and sandy clay typical of the Benin Formation. A 2.1 – 2.6m thick column of incompetent clayey horizon was identified beneath VES 4 and 5 located within the distressed section of the Factory Site. VES 1, 2, and 3 located outside showed more competent substratum in sands with higher resistivity values.

The geoelectric section/fence diagram shows no evidence of cavity/sinkhole.

The residual gravity anomalies are relatively flat indicating relatively flat, near homogeneous subsurface sequence with no indication of lateral discontinuities such as sinkholes/cavities or faults.

The subsidence currently being experienced within the Factory Site is not precipitated by foundation failure arising from collapse geologic features such as sinkholes/cavities but boiler load induced differential settlement arising from near-surface incompetent (clayey) substratum in the premises of the Boilers.

It is not impossible that the incompetent near-surface substratum is precipitated by caustic soda infiltration into the subsurface through failed or leaky drainage channels.

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The Schlumberger array was adopted within the factory premises because of constraints of space. Because the electrode holes had to be drilled into concrete pavement within the factory premises, the Schlumberger array requires fewer of such holes than the Wenner array where four electrodes had to be moved after each measurement.

The base station is the station 0 (zero) along each traverse.

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