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Application of remote sensing for the survey of calcrete in the semi-arid region of Nigeria

Application de sensant éloigné pour l'arpentage de calcrète à la région sémi-aride du Nigéria

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SYNOPSIS In the North Eastern part of Nigeria, which is mostly semi-arid, the conventionally used hard stone for road construction is not locally available. It has to be transported from long distances, thereby increasing the cost of construction. With a view to achieving economy, due emphasis is now placed on the judicious use of locally available calcrete, a calcareous aggregate, locally termed jiglin.

Jiglin is generally found under an overburden of about one metre of sand or sandy soil. For the expeditious location of jiglin, Remote Sensing Techniques – the interpretation of aerial photographs, SLAR and LANDSAT imageries were used, covering an area of about 10,000km². The paper discusses the relative usefulness and limitations of these techniques for identification and location of hidden jiglin deposits in the planning, design and construction of future roads in North Eastern Nigeria.

INTRODUCTION:

For affecting economy in the cost of road construction, the exploitation of locally available construction materials, such as calcrete, is particularly valuable in part of the semi-arid region of N.E. Nigeria, where hard stone is not available within economical distance. These calcretes are locally known as Jiglin and consist of lumps of irregularly – shaped light grey materials. They are of different sizes and form deposits at shallow depth, under an overburden of loose sandy soil.

Although, Calcrete is used for road construction in many parts of the N.E. Nigeria, nevertheless there has not been any particular pattern for the location of hidden calcrete in the predominantly sandy terrain. Deposits are located by field method only. This is time consuming and labourious and the exact targets are often missed. In addition, the occurrence of high sand dunes and inaccessibility of terrain can hinder the progress of calcrete survey. With a view to assisting the construction industry for easy identification and location of hidden calcrete, the Nigerian Building and Road Research Institute has carried out this investigation, using Remote Sensing Techniques.

The use of air-photo interpretation and the study of SLAR and LANDSAT imageries to identify and classify calcrete-bearing landforms are discussed in this paper. Typical stereo pairs are also presented for clearly identifying the calcrete-bearing areas. The survey area is located around Gamawa (sheet No.62 & 40SE) and W. of Maiduguri (Sheet No.88 & 89) and covers an area of about 10,000km² as shown in Fig.1. The area is overlain by predominantly fluvial and aeolian sands, which are said to belong to the Quaternary sediments of the Chad formation (Matheis, 1976).

INTERPRETATION AND LIMITATION OF REMOTE SENSING TECHNIQUES:

Remote Sensing Images Interpretation have been restricted to those that are available in Nigeria. They are panchromatic black and white aerial photographs (scale 1:25,000), SLAR imageries (scale 1:250,000) and Landsat imageries (scale 1:250,000).

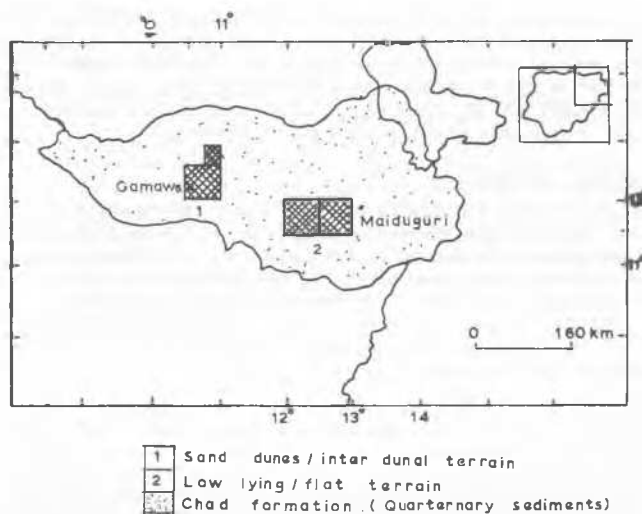


Fig.1
Sketch map of N.E. Nigeria showing the survey sites and adjoining potential area for calcareous deposits.

AERIAL PHOTOGRAPHS:

The aerial photographs (23cmx23cm size), when viewed stereoscopically, provide a three dimensional view of the terrain, resulting in a better work efficiency and a more detailed presentation of calcrete landforms than any of the other two imageries. Although, the scale is large and the land area covered on a single photograph is very small, thus making a reconnaissance study of the whole terrain difficult, nevertheless a fairly large area coverage can still be achieved by arranging air photo mosaics.

The elements of photo patterns considered for this interpretation include landforms, tone, texture, landuse and vegetation. They are easily observable under the stereo-

pairs. Aerial photographs also enhance a better tonal signature of calcrete-bearing sandy soils.

The semi-arid region of N.E. Nigeria is completely covered by black and white aerial photographs. Therefore, for the advantage of high resolution and stereoscopic coverage, it is possible that the result of this study would be applicable to the survey of calcrete in other areas of similar geological and physiographical conditions.

Though, different calcrete-bearing landforms have been interpreted and delineated from aerial photographs, even without access to the site, yet certain amount of ground verification is desirable to avoid any discrepancy and anomaly.

SLAR IMAGERY:

The choice of the SLAR imageries for the survey of calcrete in this area is significant, because of the sparse vegetation cover and ability to study the emittance and reflectance characteristics of soils, in terms of tone, texture, shape and pattern. Though, the scale is small and there is no stereoscopic vision to permit the location of typical calcrete platforms, yet it has been possible to identify areas of long narrow depression or erosional channels and sand dune ridges. Interpretation of aerial photographs has depicted the occurrence of calcrete in such regions.

In addition, calcrete-bearing sandy soils are lighter grey toned on SLAR imagery than areas devoid of calcrete. The entire area covered by this study has been viewed on two different black and white photographs (sheet Nos. NC 33-1&ND 32-16, each with 65cmx44cm size), resulting into a synoptic study of the whole terrain.

LANDSAT IMAGERY:

A false Colour Composite Landsat Imagery has been studied to ascertain the potentiality of Landsat imagery to the survey of calcrete in N.E. Nigeria. The imagery used is a small scale photograph and has Colour reflections in bands 4, 5, 6, and 7. The tonal variation between calcrete-bearing soil and other soil types is a reflection of the Colour contrasts, which is not quite obvious in this area.

Generally, the imageries have low colour contrast. The colour reflection of sandy soil is light brown with little bias towards the calcrete areas, particularly, where vegetation is fairly pronounced and along erosional channels or long depression. They are also capable of depicting regional linearments like the sand dune ridges, but without stereoscopic vision. Therefore, any further probe for the location of calcrete platforms is followed by the interpretation of aerial photographs. The lack of stereo coverage and the corresponding small scale are inherent problems associated with the interpretation of Landsat Imagery (Anthony Levis, 1974).

DEVELOPMENT OF AIR PHOTO PATTERN:

With a view to developing air photo pattern for the identification and location of hidden calcrete, a preliminary ground survey of part of the area has been carried out. Part of the survey sites have been identified on the photo mosaics with the help of topographical maps. Topographical and physiographical features of calcrete and non-calcrete terrains have been correlated with airphoto elements. Stereo-pairs depicting calcrete and non-calcrete areas including the dunal terrains have been examined for 3D view, using a pocket stereoscope. The pattern or character-

istic features typical of both areas have been recorded on aerial photographs, Imageries and field notebook. Diagnostic features such as Landform, relief, tone and Landuse and vegetation have been used for the identification and Classification of calcrete-bearing terrains.

IDENTIFICATION & CLASSIFICATION OF CALCRETE-BEARING TERRAINS, AND CALCRETE LANDFORMS:

Two major types of terrains have been identified and they offered a satisfactory means of classifying calcrete bearing landforms, in terms of the main physiographic features, in the semi-arid region of N.E. Nigeria.

They are:-

- (i) Slightly depressed to flat terrain
- (ii) Dunal terrain.

Each terrain is sub-divided into component calcrete landforms. The classification of these landforms has been based on the recognition of distinctive pattern of land types, physical form and other different components that make up the natural environment. This is based on evidence obtained mainly from field survey, the interpretation of Aerial Photograph and to a lesser extent on features recognisable on SLAR and Landsat imageries.

(1) Slightly Depressed to Flat Terrain:

This terrain is characterised by a flat topography, with slightly elevated and uneven surface of sand. This is punctuated by gentle slopes and shallow depressions. Typical calcrete-bearing landforms are classified into two types:-

(a) Gentle Slopes, Low-lying Areas and Shallow Depressions:

The shapes of these calcrete landforms vary from oval and circular low-lying areas to long narrow depressions and erosional channels, with a low terrace around the margin. They are similar to the calcrete-bearing pans of Botswana Kalahari desert (Lawrence, 1984). The land area ranges from 12 Km² to 200Km². Generally, they support fairly pronounced natural vegetation of shrubs and trees as well as moderate cultivation. Sometimes, they are characterised by the deposition of sulphate and are therefore devoid of cultivation and natural vegetation. Landuse aspects are often concentrated at the adjoining slopes, where the occurrence of calcrete and sulphate are less pronounced.

The silty and clayey sands are of light/medium grey tone on aerial photographs. Whitish grey tone and smooth texture are additionally imparted to the soil, due to the occurrence of calcrete and sulphate as illustrated in fig.2.

Such sites are often targets for the precipitation and accumulation of salts and calcrete.

The photo patterns differ greatly from the predominantly medium grey tone and rough texture of a non-calcrete-bearing sand of a similar environment or from the light/medium grey tone of the adjoining slope, where the occurrence of calcrete is less pronounced.

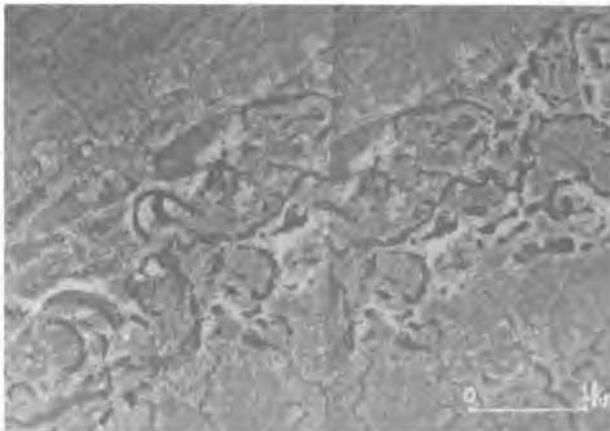


Fig. 2

Stereo-pair showing depressed site for calcrete accumulation, with pronounced whitish grey tone due to the occurrence of sulphate.



Fig. 3

Ground photograph of flat sandy terrain depicting whitish tinge associated with hidden calcrete horizon.

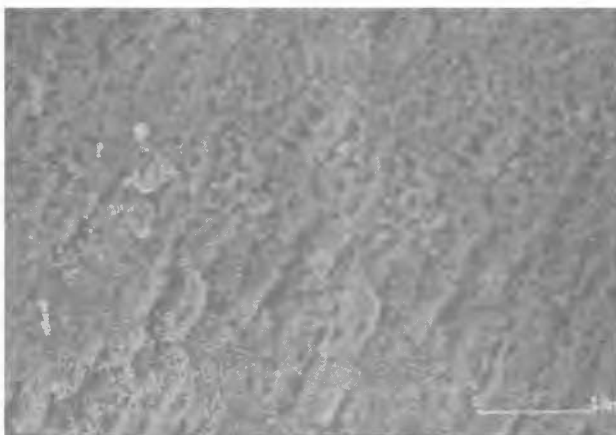


Fig. 4

A calcrete-bearing flat landform with diffused whitish-grey spots. (Stereo-pair).

(b) A Flat Landform:

This is comprised of a flat topography, punctuated by slightly uneven surface of sand. The shapes of the landforms are commonly irregular, with land areas ranging from 10Km² - 50Km² or more. Vegetation is made up of mainly grassland and shrubs with scattered trees. Occasionally, vegetation concentration in the N.E. - S.W. direction tends to give an indication of a sand dune surface, but this is not obvious in the topography. Small batches of sandy soil that is devoid of vegetation are common. These photo-patterns have also been identified to be associated with the occurrence of calcrete in a similar environment in N.E. Nigeria (NERRI, 1983 Madedor et al, 1984). The features of a calcrete-bearing terrain are shown in Figs.3 and 4.

Soil is mostly silty sand, with some deposition of sulphate. The tonal signature of sandy soil is a mixture of light grey tone and numerous whitish grey spots. Pronounced whitish grey tone is common in pen holes and excavation sites and areas devoid of vegetation. Although, field investigation has shown that the thickness of calcrete horizon in flat landform is $\leq 1.3m$, nevertheless the terrain differs from non-calcrete-bearing flat platform, where all the characteristics of calcrete areas mentioned above are absent. Typical features of non-calcrete flat terrain include the occurrence of natural grass-land vegetation and accumulation of sand.

(ii) Dunal Terrain:

The Land system at the dunal terrain consists of the dune surface, dune side-slope and inter-dunal hollow and plain. They belong to the Gajiram Land System in Bornu province, formed from a fixed dune system of Pleistocene age (Dowling & Williams, 1964; Dowling, 1968). Topography over the region is characterised by prominent sand dune ridges, oriented in the N.E. - S.W. direction. Two types of calcrete-bearing landforms have been identified from the aerial photographs.

They are:

- (a) Inter-dunal hollow
- (b) Inter-dunal sandy plain

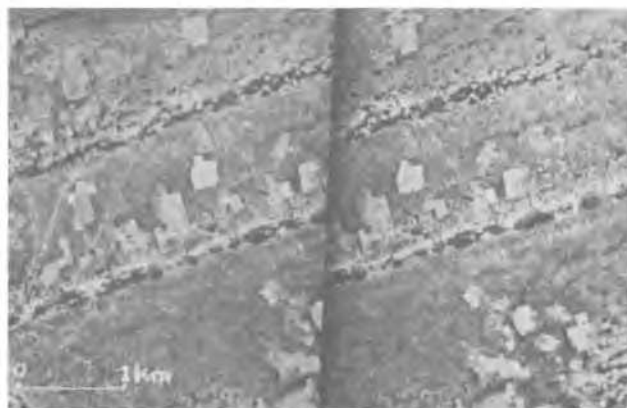


Fig. 5

Inter-dunal hollows with whitish grey tone (targets for calcareous deposits) and adjoining areas of sand dunes (stereo-pair).

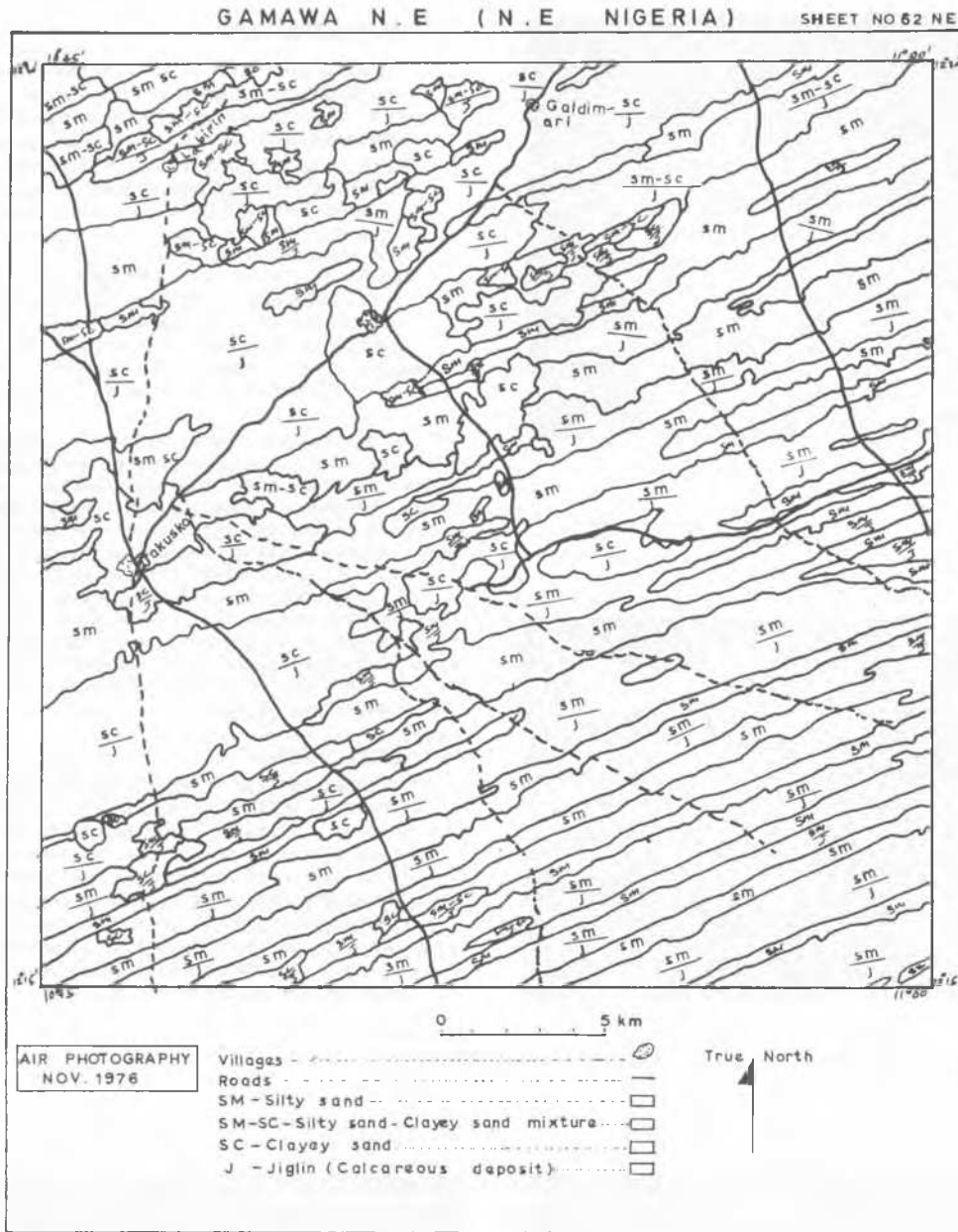


Fig. 6
Engineering Soil Map of Gamawa N.E. (a dunal terrain), showing
Calcrete-bearing areas (inter-dunal hollows and sandy plains).

(a) Inter-dunal Hollows:

The Inter-dunal hollows are the most prolific in terms of deposition of calcareous deposit. They are characterised by whitish grey silty sand and light/medium grey clayey sand, with little or no deposition of expansive clay. The whitish grey tone is very pronounced because of large occurrence of calcrete. Although, the hollows support a concentration of vegetation, nevertheless they are devoid of cultivation due to the deposition of calcrete and some sulphate which render the soil infertile and unsuitable for agriculture. The

expression of the undulating topography with the calcrete-bearing inter-dunal areas is shown in Fig. 5.

The hollows run more or less parallel to the N.E. - S.W. oriented sand dunes and contain thick accumulation of calcrete, $\leq 3m$ thick along their length. The widths of the hollows vary from 0.2 - 1.5Km.

(b) Inter-dunal Sandy Plains:

Inter-dunal calcrete-bearing sandy plains are sometimes encountered within the dunal terrain.

They have flat topography with light grey tone, showing signs of wind erosion without any remarkable vegetation. The flat plains are similar to those of the Kankar deposits in the desert area of India (Nanda, 1970 & 1982). They are commonly oval shaped and fairly extensive, with thickness of calcrete horizon $\leq 1.3\text{m}$.

Typical Interpreted and delineated soil map showing calcrete-bearing sites in dunal terrain is illustrated in Fig.6.

GROUND VERIFICATION AND DESCRIPTION OF FIELD OCCURRENCES:

A sample ground checking has been carried out to correlate interpreted calcrete sites with ground features. The selected sites have been investigated by observing quarries and digging of pits where necessary. The accuracy of interpretation has been found to be of the order of 90%.

The lumps of calcrete are usually set in a sand or sandy clay matrix. They occur at shallow depth, with $\leq 1.5\text{m}$ over-burden of loose silty sand or clayey sand. The thickness of the deposit of calcrete varies from 1m at the flat terrain to 3m at depressions and inter-dunal hollows. They are light greyish coloured and of different shapes and sizes as shown in Fig.7. Analysis at the Road Research Laboratory of calcareous gravels from similar area of N.E. Nigeria have shown total calcium carbonate contents between 20 and 30 per cent (Clark & Beaven 1962).

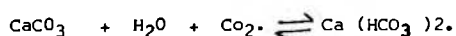


Fig. 7

Specimens of calcrete with variable shapes and sizes.

Calcrete is being used in many parts of N.E. Nigeria on gravel roads, as well as base and sub-base materials, like the new Maiduguri to Damboa road and Maiduguri old air-field runways.

The deposits of calcrete in arid and semi-arid region of tropical countries are said to be formed by the process of calcification. Carbonated rain water dissolves calcium carbonate (CaCO_3) present in the local soil, converting it to a soluble calcium bicarbonate ($\text{Ca}(\text{HCO}_3)_2$). The later is then washed down the slopes of depressions and hollows of undulating topography to form calcium carbonate, after water and carbon dioxide have been evaporated, as illustrated in the equation below:-



A soil profile comprising calcrete horizon, 1m thick, under an overburden of 1-1.5m of sandy soil is given in Fig. 8.



Fig. 8

Calcareous deposits under an overburden of sandy soil.

CONCLUSIONS:

- (1) The survey of material resources can be conducted with the help of Remote Sensing without access to the site. Thus, the technique has great potentiality in surveying the areas which are even inaccessible. However, certain amount of ground verification is desirable to avoid any discrepancy or anomaly.
- (2) Both SLAR and Landsat Imageries, by their synoptic view, are capable of depicting large areas of sand dune ridges and long narrow depressions or erosional channels, thereby providing some information about the potential areas for the survey of calcrete. But they lack stereoscopic view of the terrain, which is essential for the interpretation of subsurface calcrete.
- (3) Aerial photographs provide the most detail information about calcrete-bearing terrain by virtue of their high resolution and stereoscopic capability. Hence they are suitable for the identification and location of all calcrete landforms.
- (4) The air photo pattern of identification of calcrete in semi-arid region has been classified, which consists of inter-dunal hollows and sandy plains, low-lying areas or depressions, showing pronounced light grey or whitish tone. Though, the areal extent of calcrete landforms can be delineated from the aerial photographs, but it is not possible to ascertain the quantity of calcareous deposits, except by field investigation.
- (5) Apart from the positive information about the hidden deposit of calcrete in a particular area, there is added advantage that airphoto interpretation will eliminate ground survey of large non-calcrete area, thereby accelerating the progress of calcrete survey and minimizing the cost of exploration.
- (6) With the information and diagnostic features given on calcrete-bearing terrain, it is probable

that the findings of this survey will have applicability and future scope in areas of similar geologic and physiographic conditions, not only in Nigeria but also in other developing countries.

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