

Exploring and Reserve Estimation for Industrial Mineral Potential in Parts of Calabar Area (Ewen/Iwuru/Agbangana Axis) Southern Nigeria

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Abstract

For a developing nation, industrial rocks can be said to be very essential. Limestone and marble are one of the principal raw materials for industrial rocks such as cement manufacture. In Nigeria, Limestone occurs in the sedimentary environment of Benue Trough, Sokoto, Dahomey and Borno (Chad) basins. This Limestone forming environments (shallow coastal marine conditions) appears to have re-occurred several times in the geological history of the basins. The deposits of the Benue trough appear to contain the most economically viable mineral resources including limestone in Nigeria. Nearly all the limestone deposits in the trough are used for industrial purposes such as cement. The Calabar Flank is one the main carbonate province in Nigerian Benue trough. Ibeto Cement Company obtained permit to explore the viability of limestone deposit in some parts of the Calabar flank area for the establishment of a Portland cement production plant. This research evaluated the presence and volumetric analysis of limestone occurrence recovered from core drilling holes in the area on Exploration Licenses (ELs) No. 17373 and part of No. 17374. Prior to subsurface core drilling investigation, surface reconnaissance survey was undertaken. Rockworks 16 software complimented with dilute Hydrochloric acid were used for this evaluation.

Keywords: Industrial rocks; Benue trough; Mineral; Calabar flank; Core drilling; Rockworks 16; Exploration

Introduction

Establishment of any factory requires a preliminary investigation for the availability of the foremost raw material, its quantity and quality. This prerequisite will inform other secondary complimentary geological surveillance for earth resource based industries. Low attention given to the industrial implication of proper preliminary investigation most often leads to imminent failure. Several workers [1-11] have reported the occurrence of limestone deposit in the Benue trough and Calabar flank in particular.

In geological exploration and evaluation of industrial mineral deposit such as limestone, the aim includes ascertaining (i) the relief/topography and vegetation of the area (ii) the geological structures and variations, (iii) the number and geometry of limestone beds (bands), (iv) the limestone reserves estimates of each bed, (v) the geology and hydrogeology of the deposits. This will direct the quarry design and the methods of quarry operations. To achieve this, there will be Base maps preparation of the area on a suitable scale, detailed geological mapping within the area of interest involving exploratory core-holes drilling and strata-logging, correlation based on geological mapping and core-holing work. There should also be Laboratory analysis of the cored samples. Establishment of limestone reserve estimates within each exploration lease and subsequently over all estimates of the deposits. Recommendation of suitable quarry design and methods of quarry works.

Geological Setting

The Calabar Flank is described as an epirogenic sedimentary basin of south eastern Nigeria [12] consists of NW – SE trending crustal blocks of horst and graben structures– the Ituk High and Ikang Trough (similar to tAngola and Gabon horst-and-graben structures) respectively. It is bounded by the Oban massif in the north and the Calabar Hinge line delineating the Niger Delta basin in the south (Figure 1) [13].

In the east, it extends up to the Cameroon volcanic line and the Ikpe platform bounds it in the west. Two major groups of sediments occur

in the Calabar Flank– the Lower Cretaceous and the Upper Cretaceous sediments. The former, a fluvio-deltaic, cross bedded Aptian (Early Cretaceous) sandstones– the Awi Formation [1]. The latter known as the Odukpani Group consists of the Mid–Albian Mfamosing limestone to Early Cenomanian Odukpani Formation [14] overlain by a thick sequence of grey – black, carbonaceous Cenomanian shale unit– the Ekenkpon shale [15]. This is overlain by a thick Coniacian, calcareous marl unit– the New Netim marl [16,17]. The New Netim marl is unconformably overlain by carbonaceous dark shale– the Nkporo shale [6]. These dark grey (carbonaceous), laminated, fissile and friable shales with intercalations of gypsum lenses was deposited during the Late Campanian – Maastrichtian times [14]. The lithostratigraphic development of the flank appears to have been controlled by vertical and lateral displacement of faulted blocks (the Ituk High and Ikang Trough) and their associated transgressive and regressive phases [18].

The cretaceous stratigraphic record of the Southern Benue trough is represented by sediments deposited by three main marine depositional cycles: Albian-Cenomanian; Turonian-Santonian and Campano-Maastrichtian [6]. The first marine transgression occurred in the middle Albian age with the deposition of the Asu river group sediments with type locality along the banks of Asu River [6]. The sediments consist of rather poorly bedded sandy shales with sandstone and sandy–limestone lenses. The regressive phase of the first marine transgression led to the deposition of the Cenomanian sediments. The beds of this age are located around Calabar with type locality assigned

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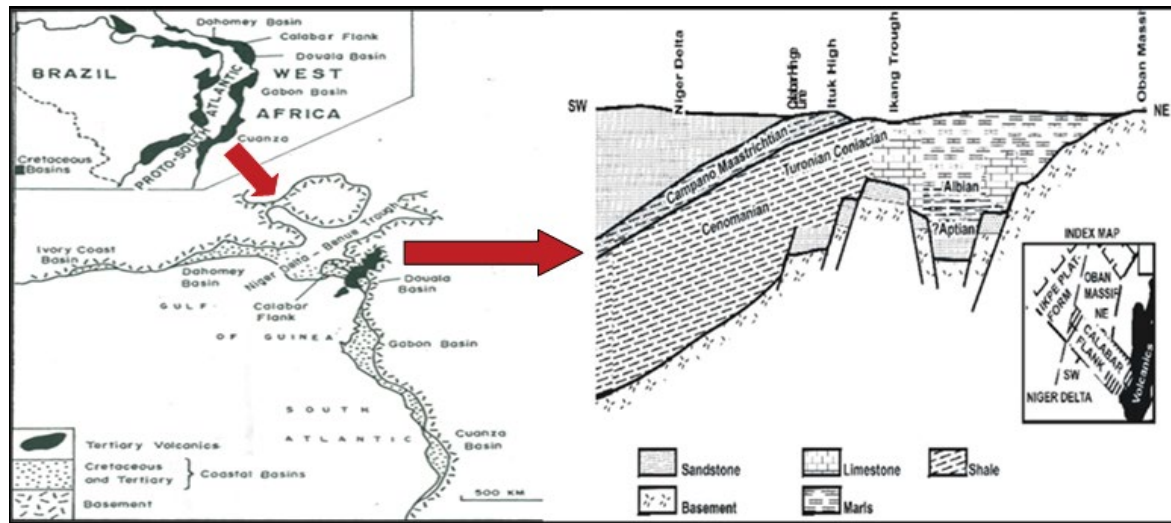


Figure 1: Map showing Gulf of Guinea, Benue trough and Calabar flank structure.

the Odukpani Formation [6]. It consist of arkosic sandstones, limestones and shales sequence. Deposition of fluvio-deltaic clastics (of early Cretaceous (Aptian?))– Awi Formation (Adeleye and Fayose, 1978) on a prograding deltaic margin marks the beginning of sedimentation on the Precambrian crystalline basement complex– the Oban Massif. The Mfamosing Limestone deposit overlies the Awi Formation in the mid Albian times as a product of first marine transgression. The Ekenkpon Shales unconformably overlie the rocks of Mfamosing Limestone. This thick shale unit is characterized by minor intercalation of marls, calcareous mudstones and oyster beds [19]. A nodular and basally shaly marl unit- New Netim Marl overlies the Ekenkpon Shales [16]. A late Campanian-Maastrichtian shale unit called Nkporo Formation (interbedded by marlstones and gypsum) unconformably overlies the New Netim Marls [6]. A pebbly sandstone unit of the Tertiary Benin Formation overlies the Nkporo Shale. Tertiary marine Nkporo shales and regressive sandstones overlie the Cretaceous succession. The sedimentary succession on the Calabar Flank comprises an ancient river-borne Awi sandstone Formation overlain by Albian to Late Cretaceous marine Odukpani Group and underlain by Northwest-southern trending Oban Basement complex. The Santonian age was heralded by a tectonic event. This tectonic epirogenic event led to the uplift, folding and widespread erosion of the pre-santonian sediment in the trough, (Figure 2).

Due to tectonic events that took place in the study area, rocks of the area have been folded into a geosynclines followed by accumulation of sediments, uplifting, folding, fracturing and faulting. The Cenomanian was a period of uplifting and non-deposition in some parts of the Benue Trough. At this time the Albian sediments in the Trough axis were slightly deformed, fractured, brecciated and intruded by mafic dykes [19,20]. In the Turonian, the Asu River Group was covered by sediments of the Eze-Aku Formation consisting of carbonaceous shales, limestones and siltstone which grade into sandstone [21]. The sequence stratigraphic unit indicate continuous “pendulumic” fluctuations in sea levels between shallow and deep marine environment. This is evident by monotonous repetition and similarity of facies composition in each successive parasequence with relatively minor facies shift and no clear long term trend. Based on microfacies and sequence stratigraphic interpretations, deposition in a low energy, protected lagoonal bay environment with continuous and repetitive sea level changes between

shallow and deep marine is inferred. Hence, it is suggested that the mineralization episodes were in pulses.

Materials and Methods

The survey was undertaken in phases- surface geological mapping, subsurface investigation, core logging and analysis. Prior to the core drilling for the subsurface investigation, intensive and extensive surface geological mapping of the area were undertaken. Subsurface investigation followed by plotting of pilot core drilling coordinates. Core drill points follow resource mineralization of interest trend after surface mapping plots on the base map (Figures 3 and 4).

The control core holes were along the mineralization strike direction at 1 km apart and others across the control core holes across the strike (i.e. along dip) at 200 m apart respectively. Coring on these points depends on actual geological condition of the immediate environment on field. Some of the points that fell on difficult terrains such as water logged, steeply slopes are repositioned but not to more than 50 m the diameter of the supposed position. Drilling was completed throughout the deposit on such a variable spacing and depths between 23 to 73 m. GX-Y-1, 16 hp rotary rig with a diamond impregnated bit attached to core recovery barrel is used. A 0.065 m diameter core was produced from a 0.0777 m diameter hole using IEX-size diamond bits. Water is used for the drilling fluid to avoid contaminating the core sample. Groundwater condition especially groundwater table, recharge and drawdown were monitored. Depth to groundwater in the cored hole were measured and at intervals. This helps to understudy groundwater condition and movement of the environment. Occasionally vugs/sparry cement, fractured breccias, intraclastic mud (gouge in-fillings) and splitting of the core wedge in the core barrel. When wedging occurred it was necessary to pull the drill stem and clear the core from the core barrel before continuing the drilling. All samples recovered were boxed prior to geostatistical analysis.

All rock core sample chips were logged for lithology, alterations, weathering and mineralisation in accordance with core logging procedure. Colour, RQD and any additional qualitative comments were also recorded. Core samples were subjected to dilute Hcl acid preliminary testing. This was complimented by scanning with point analyses using portable X-ray fluorescence spectrometry (XRF, Phillips

Age	Lower Benue		
Quaternary	Third tectonic phase	Niger Delta	Benin
Pliocene			Agbada
Miocene			
Oligocene			
Eocene	Second tectonic phase	Anambra Basin	Akata Nanka
Palaeocene			Ameki Imo Nsukka
Mastrichtian			Ajali Owelli Mamu
Campanian			Nkporo Enugu
Santonian	First tectonic phase	Cross Basin Group	Agbani
Coniacian			Nkalagu
Turonian			Agala
Cenomanian			Odukpani
Albian			Asu River Group Mfamosing
Pre-Albian			Basement Abakaliki

■ Unconformity
■ Santonian deformation
■ Transitional boundary

Figure 2: Lower Benue trough lithostratigraphic units.

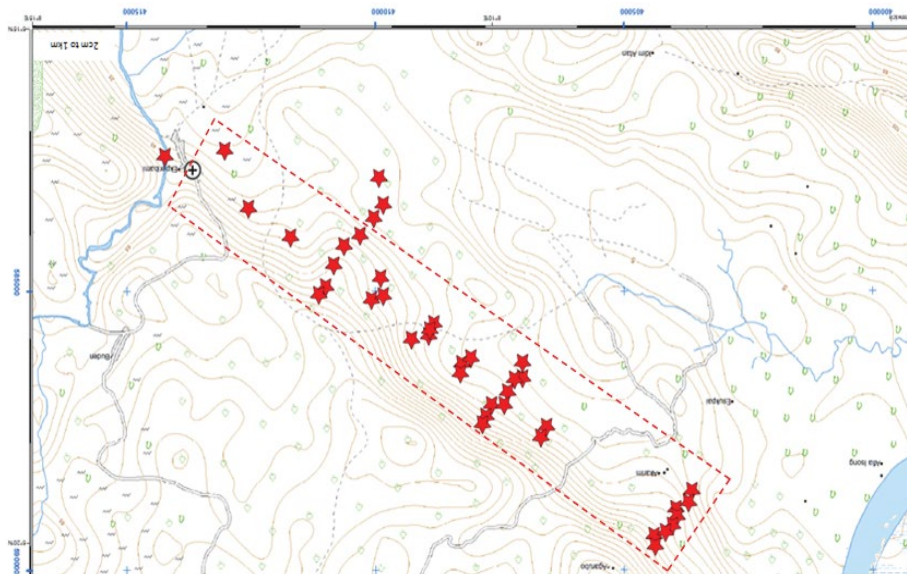


Figure 3: Pilot core drill location coordinates plot on topomap of the area.

PW 1400). Magnifying hand lens and measuring tape were further used to take measurement of the litho unit thickness of the rock types surveyed. The geodata so measured is recorded in a proforma data sheet and subsequently imported into the Rockworks 16 software platform for interpretation (Figure 5).

Forty-two (42) borehole cores were logged and analysed, twenty-five (25) showed between two (2) to five (5) high-calcium interbedded limestone bands of more than 1 m thickness. Bands having considerable limestone bed thickness of ≥ 0.5 m and strip ratio of at most 2:1 were used as economical representative and used to estimate each block

reserve. The following figures are interpretation generated from the geo data.

Borehole evidence as revealed by the core logs show that mineralization in the area is laterally and vertically not homogenous. They are heterogeneity in thickness, number in sequence and geochemistry. This spatial anomalies makes reserve estimation complicated hence delineation of the mineralized window into blocks and using a representative bed to evaluate or estimate the reserve of a block with a control borehole core log. The boundary of each block is inferred using the last productive border core drill holes of a block

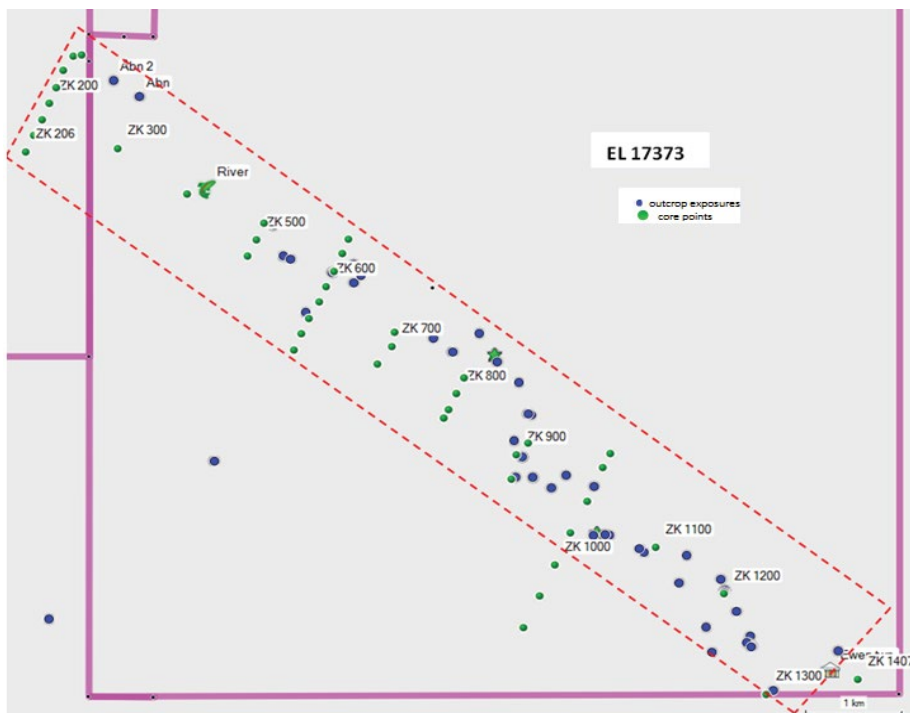


Figure 4: Pilot core drill location coordinates plot on Map source software.

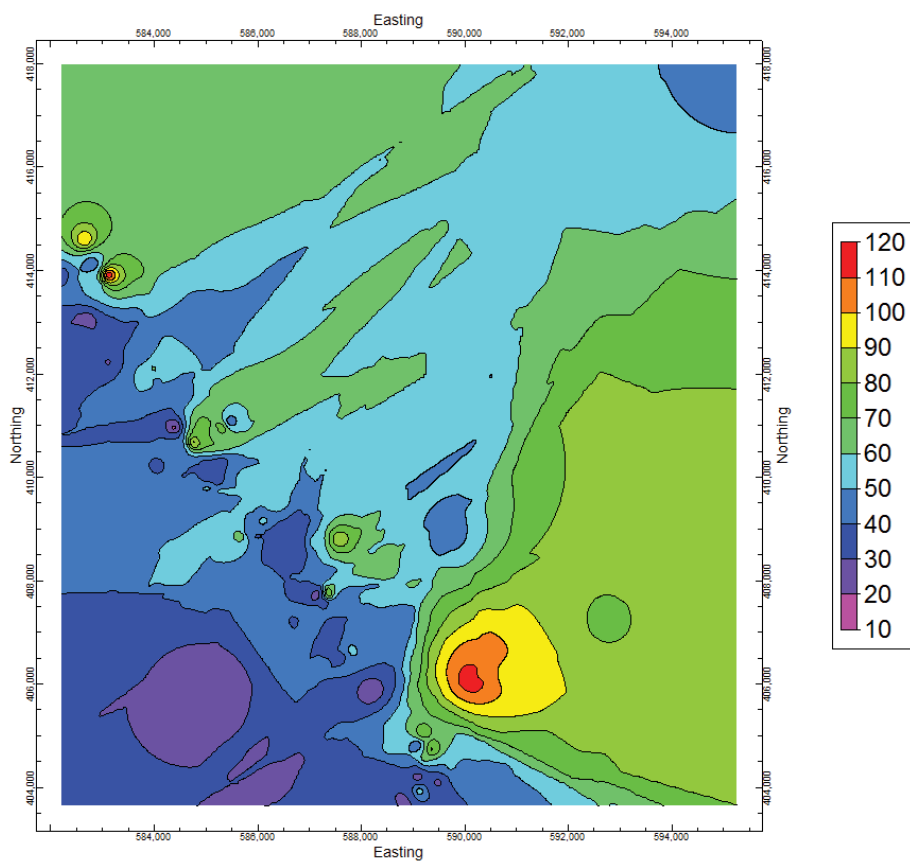
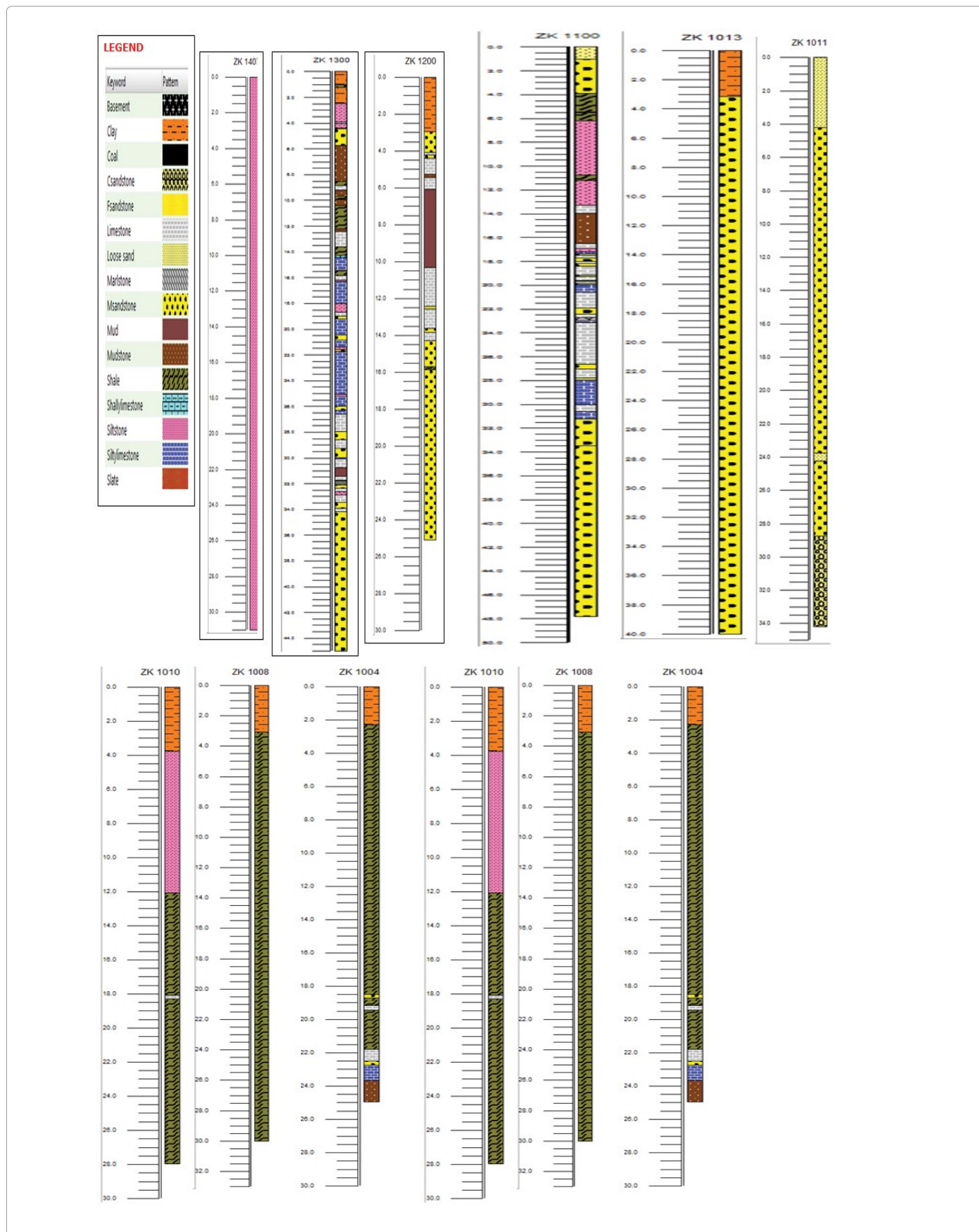
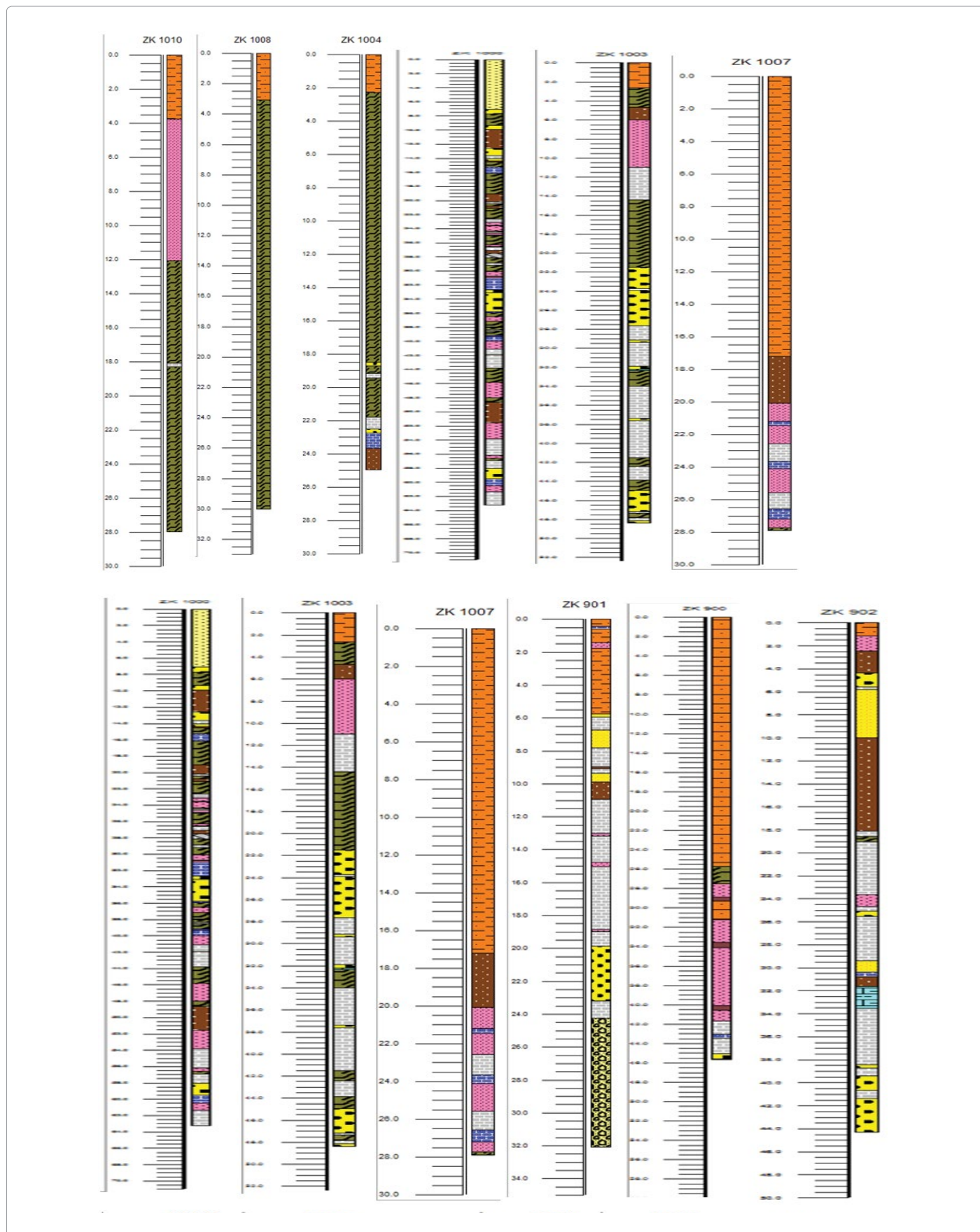
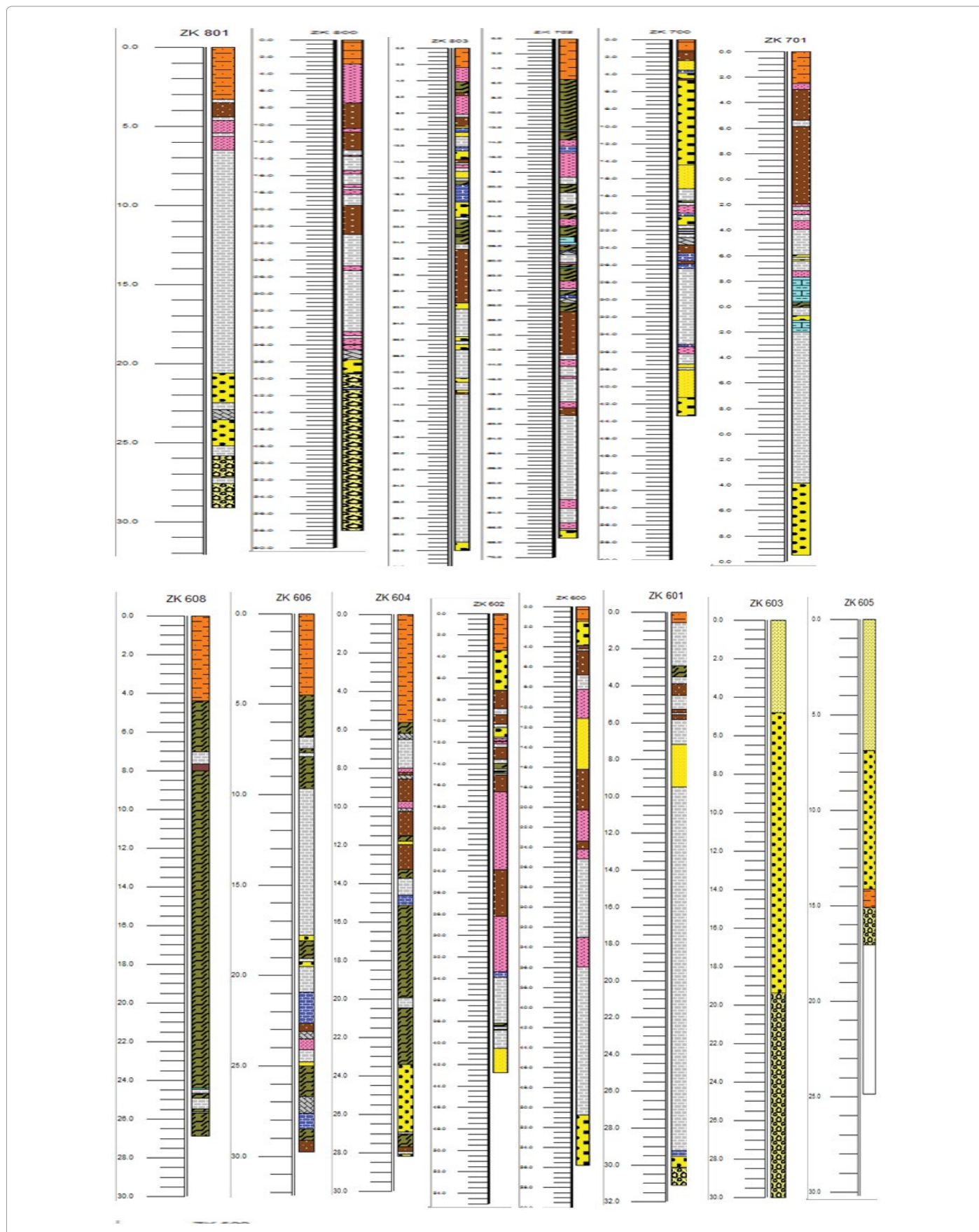
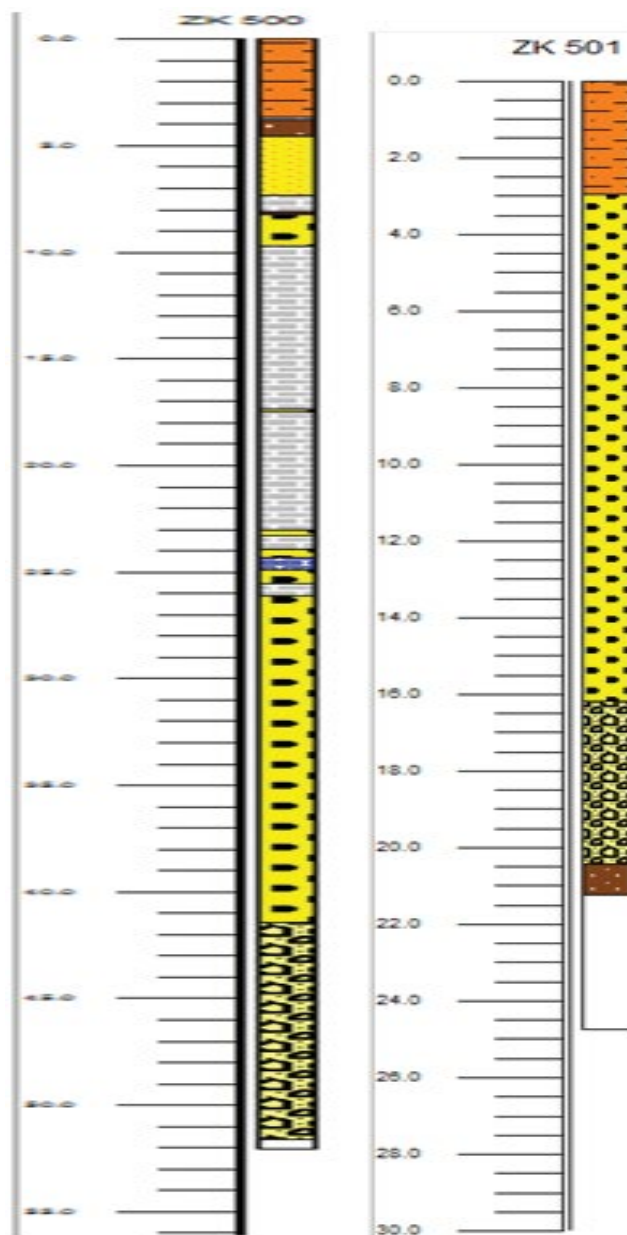


Figure 5: Contoured top map (elevation) of the study area generated from surface mapping data.









Figures 6: Height (elevation or altitude) in meters above mean sea level.

or an outstanding outcrop exposure on either side of the control (representative) hole. They are used to infer the lateral boundary of each block, (Figures 6).

Reserve window and estimate

The reserve window is the area within the inferred boundary or the economically viable belt to be used to calculate the mineral reserve. The polygonal method in which the core litholog data of the representative drill hole at the centre of a polygon is used to estimate the reserve in that polygon.

Using the core log of the boreholes description as a guide, the reserve window of the limestone is put at Zk 1004 - Zk 1007 for traverse 'A', Line Zk 1000; between Zk 606 - Zk 601 for traverse 'Bii' Line Zk

600 and between Zk 203 - Zk 206 for traverse 'C' Line 200; this gave rise to blocks 'A', 'B' and 'C' respectively. Block Bi is an extended Bii to accommodate a limestone cave and outcrop exposures recorded during surface mapping.

Using the formulae/equation:

$$RE=L \times W \times T \times D \text{ (or } RE=LWTD)$$

where,

RE=reserve estimate,

L=bed's length

W=minable width

T=bed's thickness

D=density of limestone.

Results

Chipped samples collected and analyzed yielded different rock types- limestone, marlstone, shale, and sandstone including granitic rocks. The samples are heavily fossilified except the granitic rocks. Structural features include bioturbation, solution cavities, there are vertical, horizontal, parallel and cross-cutting joints and faults. Core sample contain vugs/sparry cement of calcite. Certain samples contain breccias and intraclasts of carbonate mud hence suggesting fault presence. The drill core logs reveal rock types sequence with gradational or sharp contacts. The Limestone in the area is not uniformly distributed in terms vertical and lateral extent, it showed variable thickness, narrow linear window trending along the strike (Figure 7). The limestone are dark grey-light grey, brownish, nodular, lenses, porous, sandy-silty and/or shally. The sandstone are brownish-reddish and in some places conglomeratic, friable and false bedded. Iron is present as oxide coatings and occasionally as pyrite on the limestone and sandstone especially where they are exposed or fractured showing brownish coloration. The shales are dark grey-bluish grey, fissile and structurally deformed. Exposed shales are friable. Outcrops of ferruginized iron stone exposures were also in some locations. The limestones are localized and have limited areal extent. The limestones are surrounded and at some places capped by sandstones formation and to the north of the study area by shales with marls unit inter-fingering. The sandstone are poorly sorted containing sub-angular grains, in which quartz, as monocrystalline unstrained grains is the major constituent and beds fine upwards. Also present are grains of strained quartz, quartz grains showing intergrown 'hydrothermal' textures, fine quartzite, microcline, albite and orthoclase.

The reserve estimate of the area studied is as follows:-

For block 'A', Zk 1003 core log data were used as the representative drill hole for the estimation. Within the 52.40 m depth drilled, the hole has six limestone beds interbedded by other rock types. From the bottom, the beds thicknesses are: 1.44 m, 3.93 m, 3.38 m, 2.50 m, 1.50 m, and 3.40 m.

Total thickness, T=16.15 m

Length, L=3600 m

Width, W=1400 m

Limestone density, D=2.71

Block 'A': RE=16.15 × 3600 × 1400 × 2.71=220,583,160 m.

Depth drilled, the hole has seven limestone beds within the sequence interbedded by other rock types, but has only one minable bed.

Total thickness, T=14.12 m

Length, L=2000 m

Width, W=1200 m

Limestone density, D=2.71

Block 'Bi': RE=14.2 × 2000 × 1200 × 2.71=91,836,480 m.

For block 'Bii', Zk 601 core log data were used as the representative drill hole for the estimation. Within the 31.11 m depth drilled, the hole has five limestone beds interbedded by other rock types. From the bottom, the beds thicknesses are: 19.75 m, 1.35 m, 0.76 m, 0.37 m, and 2.34 m. The minable beds are those with more than 0.5 m thickness at reasonable depth (stripe ratio).

Total thickness, T=23.44 m

Length, L=2000 m

Width, W=1000 m

Limestone density, D=2.71

Block 'Bii': RE=23.44 × 2000 × 1000 × 2.71=127,044,800 m

For block 'C', Zk 203 core log data were used as the representative drill hole for the estimation. Within the 23.05 m depth drilled, the hole has five limestone beds in the sequence interbedded by other rock types. From the bottom, the beds' thicknesses are: 0.98 m, 0.50 m, 3.50 m, 0.34 m, and 5.54 m.

Total Thickness, T=10.02 m

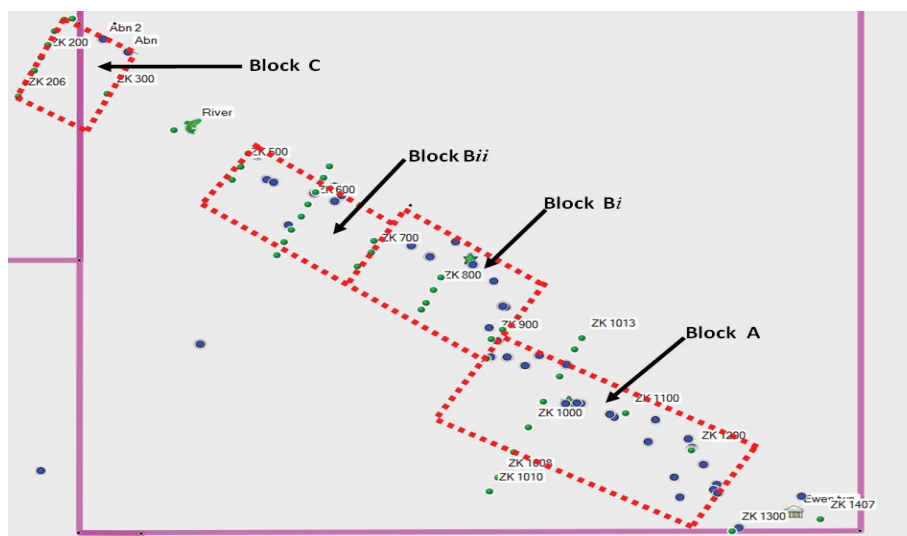


Figure 7: Mineral target reserve window blocks.

Length, L=1000 m

Width, W=800 m

Limestone density, D=2.71

Block 'C': RE=10.02 × 1000 × 800 × 2.71=21,723,360 m.

Total RE=220,583,160 + 91,836,480 + 127,044,800 + 21,723,360=461,187,800.00 m

Conclusion

The reconnaissance and core analyses of the study area compares satisfactorily, indicate capability and possibility to supply quantitatively limestone raw material for industrial use. However, a geochemical, socio-economic and environmental condition of the area is pertinent and needed further investigation.

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