

## Middle Cretaceous Sequence Stratigraphy at the Ashaka Cement Quarry in Gongola Basin of the Upper Benue Trough, Northeast Nigeria

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**Abstract:** The Kanawa Member of the Pindiga Formation at Ashaka Cement Quarry forms a Type – one sequence. The lower sequence boundary is a thin ferruginous crust on top of the Upper Bima Sandstone which is also a transgressive surface since the intervening Yolde Formation is absent. The upper boundary of the sequence is a correlative conformity within the Deba-Fulani Member. The transgressive systems tract and the highstand systems tract are identifiable within the sequence. They both comprises parasequence sets and parasequences showing smaller scale units produce by relative sea level changes on shorter time frame. The transgressive systems tract is within the Kanawa Member while the highstand systems tract encompasses the upper part of the Kanawa Member and basal Deba-Fulani Member. The lowstand systems tract preceding the transgressive systems tract of the sequence is missing, indicating the marginal position of the Ashaka Cement Quarry sequence of the depositional basin.

**Key words:** Cretaceous, Kanawa Member, Sequence boundary, Transgressive systems, Parasequences.

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### I. Introduction

The Ashaka Cement Quarry is located within the N-S aligned Gongola Basin of the Upper Benue Trough northeastern Nigeria. The area is geologically bounded to the south by the “Wuyo-Kaltungo High” which is the median zone of the Upper Benue Trough and also the area separating the Gongola Basin from the Yola Arm. The Wuyo-Kaltungo High is characterized by four major NE-SW and N-S trending sinistral strike-slip faults, the Gombe, Bima-Teli, Kaltungo and the Burashika Faults. These are basement faults reactivated during Early Cretaceous times. This group of faults, together with NW-SE and N-S trending faults are believed to have played a major role in the development of Early Cretaceous sub-basins in the Upper Benue Trough (Guiraud, 1990).

The northern border of the Ashaka area is the Dumbulwa-Bage High which is also the northern border of the Gongola Basin, separating it from the Bornu Basin. Zaborski et al. (1998) described the Dumbulwa-Bage High as shoal area during the Late Cenomanian-Early Turonian and indicated that it was an area of persistent uplift subsequent to the deposition of Lower Bima Sandstone. This is shown by the wedging out of the Middle Bima, Upper Bima and Yolde Formations and the attenuation of the Kanawa Member in the Dumbulwa-Bage High. To the east and west of the Ashaka area are the Biu Plateau and the Kerri-Kerri Basin respectively (Fig. 1).

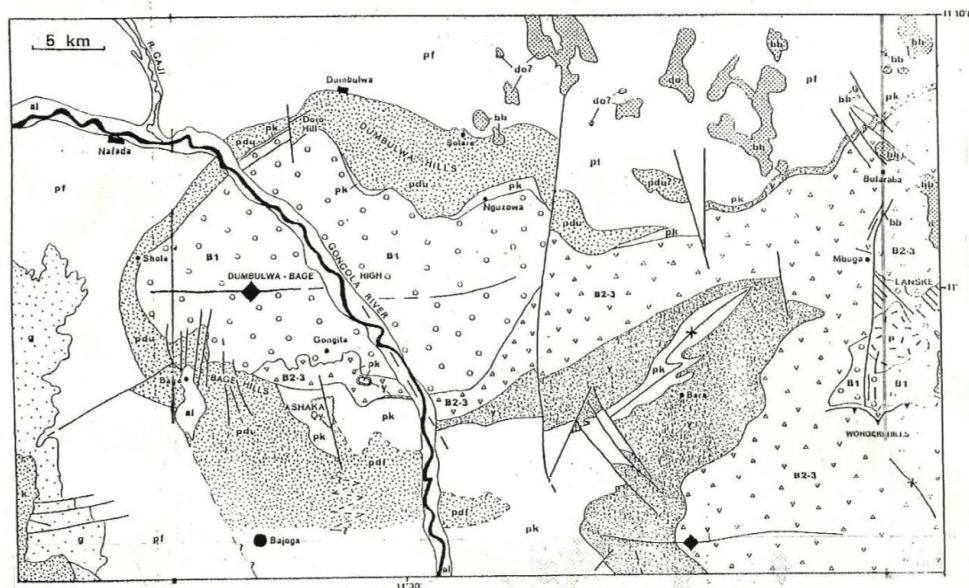


Fig. 1 Geological map of the northern portion of the Gongola Basin showing the position of Ashaka area after Zaborski et al. (1998)

## II. Geology Of The Study Area

The exposed stratigraphic succession in the Ashaka area begins with the Bima Sandstone (Fig. 2). The Bima Sandstone can be recognized in both the Wuyo-Kaltungo High and Dumbulwa-Bage High. It also forms the floor of the Ashaka Cement Quarry section and is separated from the overlying Pindiga Formation (Kanawa Member) by a thin ferruginous crust without the transitional Yolde Formation. The Yolde Formation is almost absent in the Ashaka area. Zaborski et al. (1998) reported that the Yolde Formation wedges out in the western part of the Dumbulwa-Bage High where synsedimentary uplift also resulted in the attenuation of the “Middle and Upper Bima Sandstones”. Like the Yolde Formation the overlying Kanawa Member has been eroded over the large part of the Ashaka area.

Carter et al. (1963) referred to the equivalents of the Pindiga Formation to the Gongila Formation and Fika Shales. Zaborski et al. (1998) subdivided the Pindiga Formation into Kanawa – Dumbulwa – Fika Members in the area. Over the Dumbulwa-Bage High the Kanawa Member is greatly attenuated, lacks significant argillaceous lithologies and in some places often absent altogether. Around Nguzowa village, the



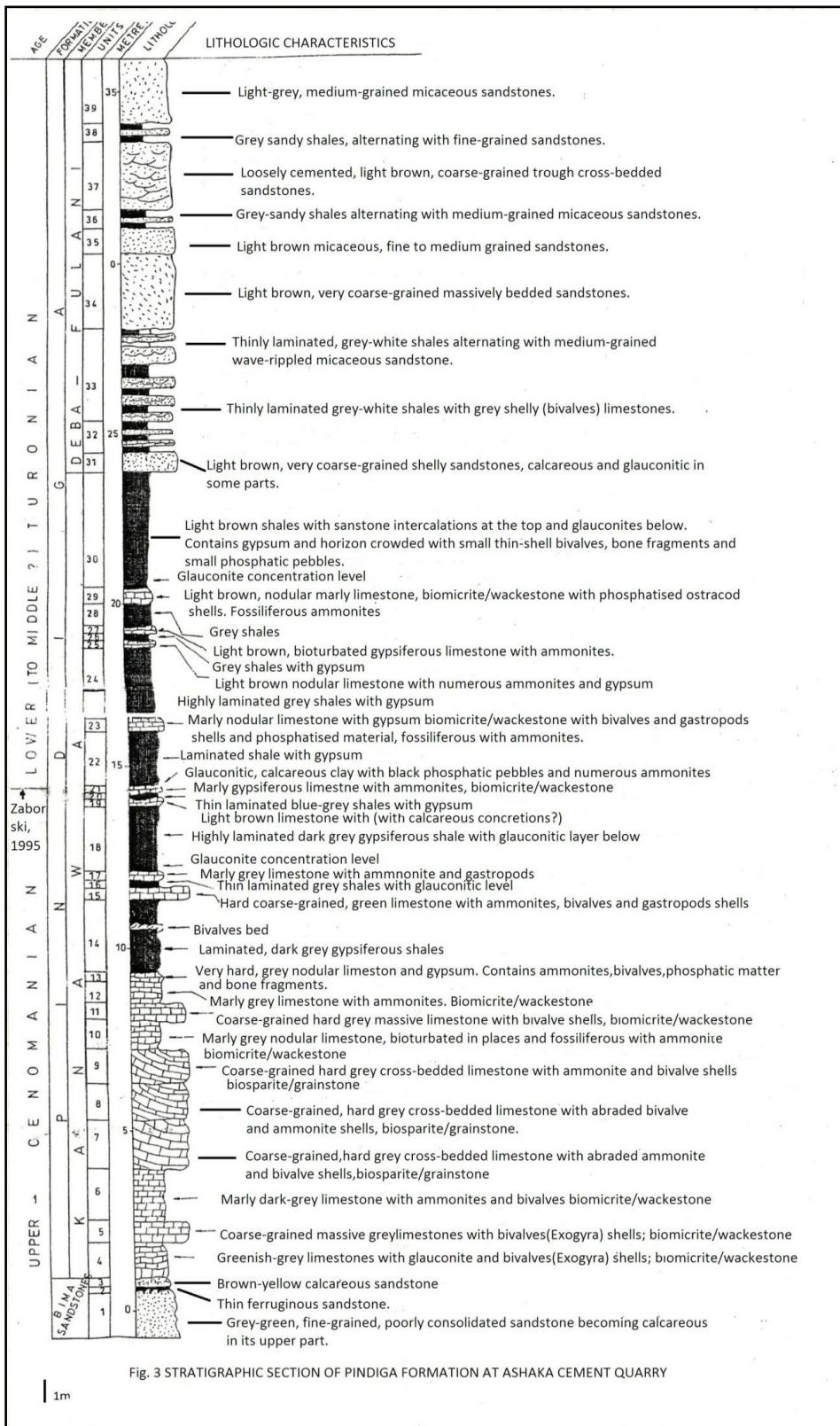
**Figure 2:** Lower Bima Formation (B1) (foreground, overlain by condensed limestone of the Kanawa Member (middle) with an angular unconformity; the limestone is overlain by the Dumbulwa Member (background); at the foot of Dumbulwa Hills, 2 km southwest of Nguzowa village.

Kanawa Member is only about 4 m thick made up of dominantly limestone beds but ammonites occurring there demonstrate at least the Paravascoceras cauvini to Pseudotissotia nigeriensis zones that is the age equivalent of the greater part of the unit (Zaborski et al., 1998) as shown in Fig. 3. In the Ashaka quarry section, the Kanawa Member is a condensed section and is only about 27 m thick (Fig. 3). Here, they reported an unconformity between the Kanawa Member and the Dumbulwa Member with the later having a deeply erosional contact with the former. The erosional contact here was a result of local upliftment and subsequent erosion of the Kanawa Member before the Middle Turonian regression that deposited the Dumbulwa Member (Zaborski et al., 1998).

The Dumbulwa Member (equivalent to the beds referred to as the Bima Group) in the Dumbulwa and Bage Hills by Carter et al. (1963) forms the flanks of the Dumbulwa-Bage High. In the southern part of the Dumbulwa-Bage High and the Ashaka Cement Quarry, the Dumbulwa Member passes laterally into the sandstones of the Deba-Fulani Member. These sandy members of the Pindiga Formation are almost always overlain by the Fika Member which is exposed on the northern flank of the Dumbulwa-Bage High. The Fika Member here is equivalent to the “Shale Member” of the Pindiga Formation and Fika Shales of Carter et al. (1963). The Gombe Sandstone is exposed to the west of the Ashaka area.

The Kanawa Member at Ashaka Cement Quarry section is overlain by the Deba-Fulani Member and rest unconformably on the red to light brown, medium-grained sandstone of the Upper Bima Sandstone. Zaborski et al. (1998) recognized a 9 cm thick ferruginous sandstone (unit 2, Fig. 3) horizon separating the sandstone of the Upper Bima Sandstone from the basal Kanawa Member of the Pindiga Formation. The Upper Bima Sandstone also forms the quarry section floor at the northern end of the quarry. The overlying Deba-Fulani Member has a transitional boundary with the Kanawa Member, occurring through a sequence of glauconitic, feldspathic, calcareous sandstone, sandy shelly limestones and shales (Zaborski et al., 1998).

The Kanawa Member as shown in Fig. 3 is a shale-limestone succession about 27 m thick. Unlike in the Pindiga – Gombe sub-basin, the Kanawa in the quarry is made up of directly superposed limestones below and the usual thick shales with limestone intercalations above. The superposed lower limestones are generally grey when fresh but weather to white or cream-brown colours and are often highly fossiliferous. These limestones which are mostly wackestones are made up of 10 individual units with each unit rarely exceeding 1 m in thickness. The contacts between them are usually sharp representing minor intermittent breaks in sedimentation. The units can be persistent but are in some cases discontinuous from the north to the south of the quarry. The units are either hard limestones, marly limestones or limestones with clay seams. Fossils within these units often appear as whole (in the marly limestone units) or broken but recognizable fragments (in the hard limestone units). Ammonites, bivalves and gastropods are the most frequently seen fossils at the outcrop scale in these units. Structures such as cross-bedding are evident within certain of the hard limestones (units 7, 8 and 9, Fig. 3). The upper surfaces of the limestones sometimes show Thalassinoides burrows particularly the marly or nodular limestone units. Above the lower superposed limestones are the thick shales with limestone intercalations which are overburden on the lower exploitable limestones. This upper succession contains 8 limestone units. Calcareous sandstones and shelly (bivalve) limestones occur at the transition with the Deba-Fulani Member. The shales are dark in colour when fresh but show much lighter blue to greenish-grey colours when weathered, while the limestones are grey in colour. Thin layers of gypsum occur frequently within the shales and limestone units. Glauconite occurs as grains at specific horizons (units 15, 18 and 30, Fig. 3). Some of the units contain vertebrate bone fragments, reworked fossils, epifaunas and phosphatic matter which mark discontinuity surfaces or horizons signifying hiatuses.



### III. Methods Of Study

Methods implored in carrying out this research work that established the sequence stratigraphy of the area includes; establishment of detailed stratigraphic relationships and contacts through field-mapping, faunal descriptions, thin-section analysis of rock samples (petrography) and consideration of the general geologic setting of the area.

#### **IV. Discussion On The Sequence Stratigraphic Interpretation Of The Study Area**

The Pindiga Formation at Ashaka Cement Quarry section is considered here to comprise a single sequence which is made up of a transgressive systems tract and the highstand systems tract but without the lowstand systems tract and within this sequence parasequences and parasequence sets also occur.

The lower boundary of the sequence is a thin ferruginous crust on top of the Upper Bima Sandstone. The intervening Yolde Formation is not seen at the quarry section; hence it is an unconformity surface marking the onset of the Late Cenomanian–Early Turonian marine incursion that deposited the Kanawa Member. The Late Cenomanian–Early Turonian marine transgression was regional and the most extensive in Nigeria and Niger (Zaborski, 2000). The upper boundary of the sequence is proposed at the base of unit 34 at the quarry which is the correlative conformity of the erosional unconformity seen at the base of the Dumbulwa Member in the Dumbulwa-Bage High area. The erosional contact here was as a result of the erosion of the Kanawa Member at the beginning of the Middle Turonian regression during which the Dumbulwa and Deba-Fulani Members were deposited (Zaborski, 2000).

##### **The Lower Sequence Boundary**

The thin ferruginous crust (unit 2, Fig.4) at the top of the Bima Sandstone at the Ashaka Cement Quarry section is the lower boundary of the sequence. The Yolde Formation is totally absent as a result of uplift of the Dumbulwa-Bage High area during late Early Cretaceous to early Late Cretaceous times. This is therefore an unconformity surface, the ferruginization indicating subaerial exposure. It is also a transgressive surface, since above it is the marine deposits of the Kanawa Member. Because of the subaerial erosion associated with the subaerial exposure, the unconformity (sequence boundary) is a Type 1 unconformity hence the Ashaka Cement Quarry section is a Type 1 sequence.

The basal Kanawa Member (unit 3, Fig. 4) found above the ferruginous crust in the quarry is a calcareous sandstone (Zaborski, 1995) and the basal limestone is quartz- rich. The transgressive surface was marked by marine erosion which recycled sands from the upper parts of the Bima Sandstone and Yolde Formation. Fossils in this unit include hedbergellid foraminifers, *Exogyra columba*, bryozoans and *Nigericeras gadeni*. Gebhardt (1997) reported the existence of non-keeled heterohelicid and hedbergellid foraminifers in the basal limestones of the quarry section. Heterohelicids and globigerinid-shaped hedbergellids are the first to colonize new sea ways and the last survivors, being able to withstand harsh conditions such as shallow and/or dysoxic waters (Eicher and Worstell, 1970; Petters, 1980, 1983).

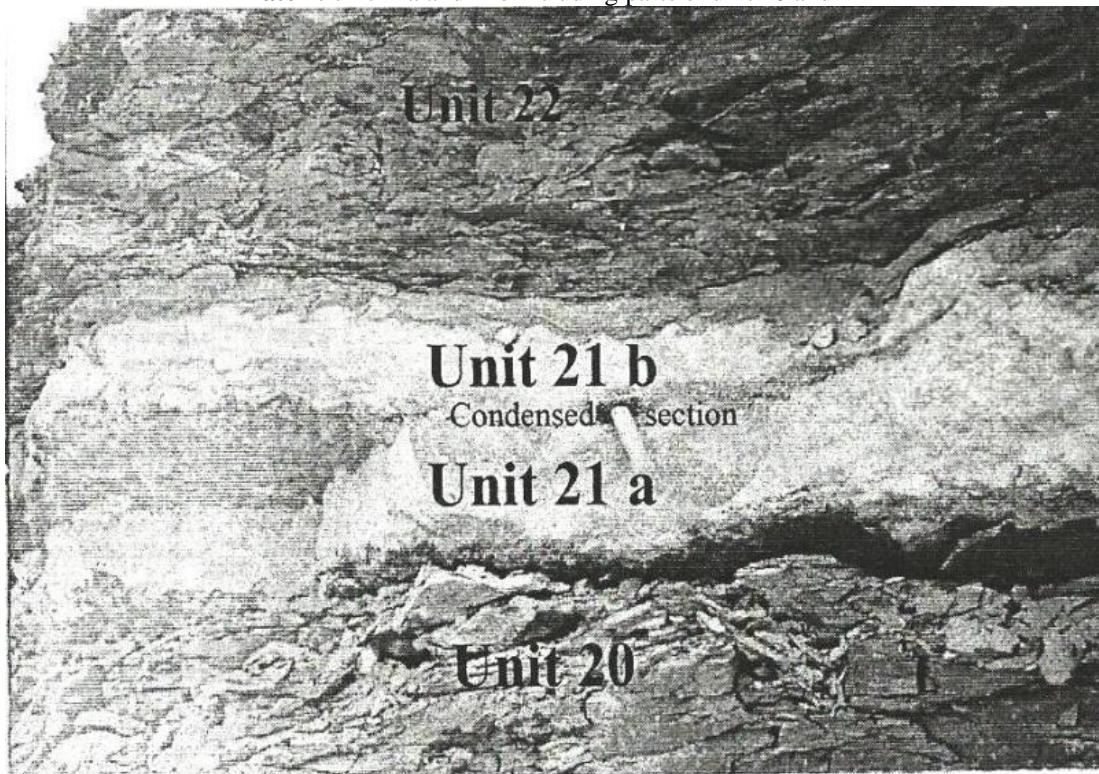
##### **The Upper Sequence Boundary**

Regionally the Type 1 unconformity between the Kanawa Member and the Dumbulwa Member in the Dumbulwa-Bage High area may be taken as the next sequence boundary. However, at the quarry section, this major unconformity is missing. The point which is here regarded as the upper sequence boundary is the base of unit 34 (Fig. 4) within the Deba-Fulani Member. This point is regarded here as the correlative conformity of the regional unconformity between the Kanawa Member and the Deba-Fulani Member. Above this point, the units became dominantly arenaceous and characteristically continental in nature. The sequence boundary here does not coincide with the boundary between the Kanawa Member and the Deba-Fulani Member (taken at the first appearance of sandstone) because the lowermost units of the Deba-Fulani Member are characteristically marine. The sandstones contain bivalves and are wave rippled. These are probably deposits formed during the early stages of relative sea level fall and belong within the highstand systems tract.

##### **Maximum Flooding Surface**

The maximum flooding surface is a surface that marks the change from a retrogradational to an aggradational parasequence set and is commonly indicated by condensed section. Condensed sections are beds which are product of low rates of sediment accumulation. They occur largely within the transgressive and distal highstand systems tracts (Van Wagoner et al., 1987). They also often contain reworked fossils, phosphatic matter; phosphatised fossils bone fragments and glauconite. The maximum flooding surface (MFS) of the quarry sequence is found within unit 21 (Fig. 4). This unit is in two parts with a minor hiatus in-between as shown in Plate 1. The lower part is rather hard limestone with *Pseudotissotia nigeriensis*. The upper part is condensed. It is a gypsumiferous, glauconitic marl with black phosphatic nodules. Its ammonite fauna includes *Vascoceras propium propium*, *Pseudospidoceras flexuosum*, *Watinoceras aff. coloradoense*, *Vascoceras obscurum*, *Thomasites gogilensis*, *Pseudotissotia nigeriensis*, *Wrightoceras munieri* and *Bageites bakui* Zaborski. This is the most exotic (deepest water?) fauna in the Ashaka Cement Quarry section. Gebhardt (1997) also reported the existence of some species of foraminifers here to include; *Guembeliria cenomana*, *Heterohelix fayose*, *Heterohelix reussi* and *Ammobaculites bauchensis*.

Plate 1: unit 21a and 21b including parts of unit 20 and 22



Photograph of the maximum flooding surface of Ashaka cement quarry section

There is no evidence of a lowstand systems tract preceding the transgressive systems tract in the quarry sequence since the lower sequence boundary (LSB) corresponds with the transgressive surface (TS). However, in the Gongola Basin generally there is no evidence of an unconformity between the Kanawa Member and the underlying Yolde Formation. Here the lower sequence boundary is located within the Yolde Formation. The lower sandstone/mudstone part of the transitional Yolde Formation makes up the lowstand systems tract of the sequence regionally. In the same vein, the transgressive surface also lies within the Yolde Formation above which are the limestones, calcareous sandstones and shales of the upper part of the Yolde Formation which belong to the transgressive systems tract here.

Therefore, in the Ashaka Cement Quarry section, the transgressive systems tract comprises units 3 to 21a (Fig. 4). The highstand systems tract includes units 21b to 33 (Fig. 4). The beds of the Deba-Fulani Member above unit 33 are characteristically continental in nature showing a return to regressive conditions and the beginning of a new sequence. The differences between the composition of the sequence at the Ashaka Cement Quarry section and the nature of the sequence boundaries compared to the regional conditions are due to local tectonic factors, namely the uplift that affected the Dumbulwa-Bage High during the mid-Cretaceous.

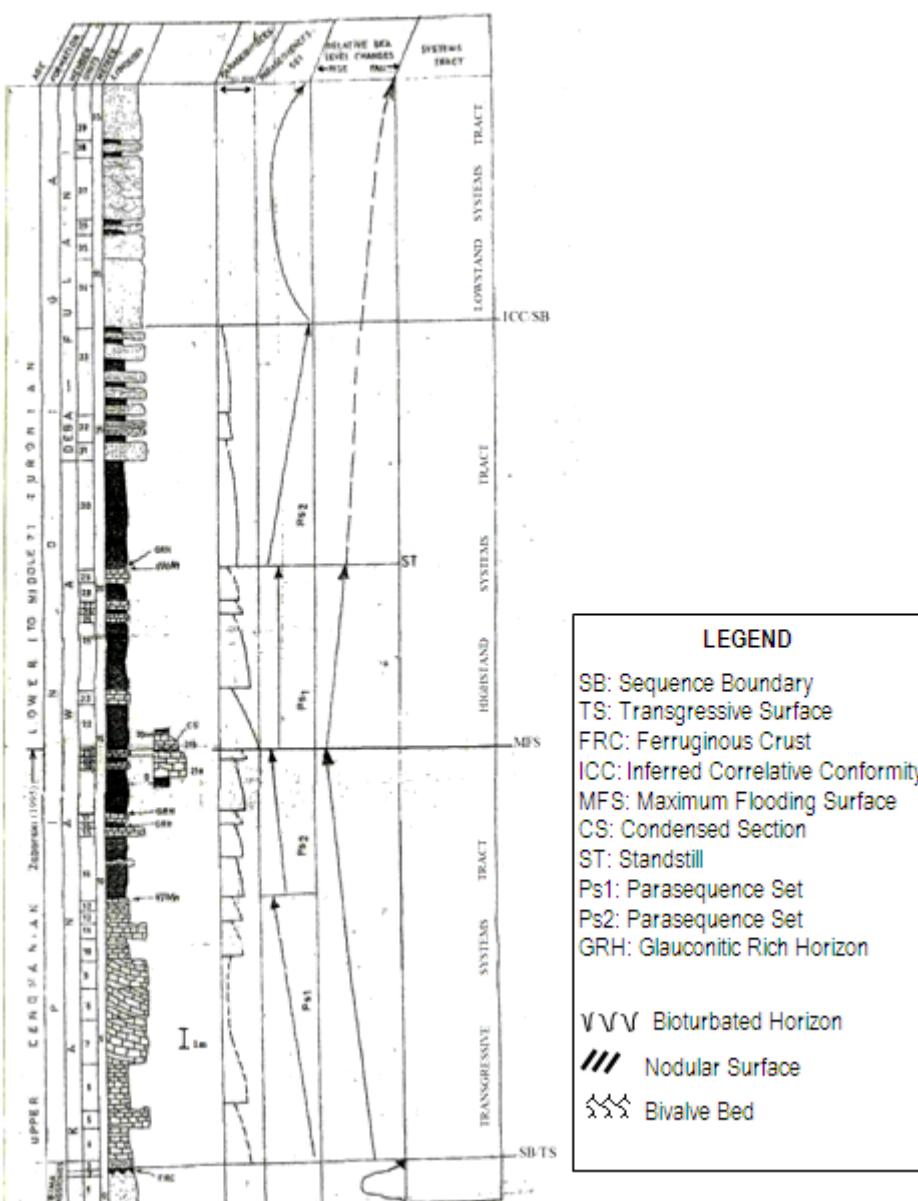
#### Parasequences within the quarry sequence

Parasequences are smaller scale rock units produced by relative sea level changes on a shorter time-frame (10,000–100,000 years) Tucker (1993). In some cases these are bundled into packets to produce parasequence sets. A parasequence is a relatively conformable succession of genetically related beds or bedsets bounded by marine flooding surfaces and their correlative surfaces. A marine flooding surface is a surface that separates younger from older strata across which there is evidence of an abrupt increase in water depth (Van Wagoner et al., 1987). This deepening is commonly accompanied by minor submarine erosion and non-deposition and a minor hiatus may be indicated.

Both the transgressive and highstand systems tracts of the quarry sequence are made up of parasequences and parasequence sets. In the transgressive systems tract of the quarry parasequences commonly separated by marine flooding surfaces marked by encrustations, bioturbations and nodular surfaces can be recognized. These are bundled into two to form two parasequence sets. The first parasequence set is composed of the lower directly superposed limestones (units 4 – 13, Fig. 4). The lower sequence boundary is the lower limit of this parasequence set and the heavily bioturbated surface on top of unit 13 is its upper limit. This parasequence set is almost wholly limestones, indicating the earliest and well oxygenated (preponderance of marine fauna, particularly the benthics) part of the transgressive systems tract. The second parasequence set within the

transgressive systems tract has the nodular surface at the base of unit 14 as the flooding surface and its lower boundary. Its upper limit is the maximum flooding surface (MFS) within limestone unit 21. Therefore this parasequence set comprise units 14 – 21a (Fig. 4) within the transgressive systems tract. The alternating shale-limestone units in the quarry sequence have been attributed to episodes of alternating normal marine oxic conditions (limestones) and dyoxic/anoxic, sometimes brackish, bottom water (shales) that prevailed in the area (Gebhardt, 1997; Zaborski, 1998; Zaborski et al., 1998). Rebelle (1990) attributed the deposition of grey to black shales, very poor in benthic fauna, to water deepening in the area.

Within the highstand systems tract of the quarry sequence, two parasequence sets can also be identified. The first parasequence set has the maximum flooding surface (MFS) as its lower limit and the heavily bioturbated and glauconite rich level on top of limestone unit 29 (representing standstill condition) as its upper limit. This parasequence set has similar characteristics with the last parasequence set of the transgressive systems tract (Fig. 4). It represents the late part of the relative rise in sea level to a standstill condition within the highstand systems tract. The second parasequence set of this systems tract comprises of units from the bioturbated surface on top of unit 29 to the upper sequence boundary at the base of unit 34. The thicker sandstone beds above are regarded as the first probable fluvial/channelized deposits. The second parasequence set therefore marks the late highstand systems tract.



**Fig. 4:** Sequence Stratigraphic Interpretation Of Pindiga Formation (Kanawa Member) At The Ashaka Cement Quarry

### **Depositional environment of the Kanawa Member at the quarry section**

The rich marine macrofossils/microfossils of the Pindiga Formation (Kanawa Member) at the Ashaka Cement Quarry section are indication of marine environment of deposition. However, the possible submarine environments of deposition could only be deduced by considering other parameters. The dominantly limestone part (units 3 – 13, Fig. 3) of the quarry section is an indication of well oxygenated shallow marine environment for this part. The ammonites are vascoceratid dominated. They are known to be shallow water dwellers and thrive in oxic environments. The benthonics; bivalves, gastropods, bryozoans, dasyclads (green algae) and echinoderms, also occur in this part, indicating oxygenated bottom conditions as do the frequent bioturbation on the upper surfaces of some of the limestone units. Hedbergellid and non-keeled planktonic foraminifers were observed here, also pointing to deposition under fairly oxygenated condition. Detrital quartz and feldspars are common towards the base. Oti (1990) indicated that these might have been transported into this area but are here regarded as mostly the result of local submarine erosion of pre-existing sands. Some of the limestone units are cross-bedded without ammonites, packstones/grainstones formed under shallow well agitated water conditions. However, most are marly limestones (wackestones) generally with ammonites attributable to low energy, slightly deeper waters. This part of the section was deposited under normal open marine, sometimes agitated water conditions typical of a marine shelf. Gebhardt (1997) in his tripartite division of the quarry section assigned this part to a lagoon-shelf environment with normal marine salinity and a non-stratified water body.

The marine environment becomes progressively quieter and deeper passing up the quarry section (units 14 -33, Fig. 3). This is indicated by the laminated shales with lesser limestone intercalations. Here the benthonic faunas are mainly restricted to the limestones. Gebhardt (1997) also reported an increasing content of planktonic foraminifers here. Glauconite-rich horizons marking water deepening are observed (units 16, 17 and 29, Fig. 3) as is generally increasing glauconite content. The detrital quartz and feldspars disappear.

The typical limestone/shale alternation here shows alternating normal marine oxic (limestones) and sometimes brackish bottom water (shales). This can be attributed to stratification resulting from fresh water influx. In his tripartite division Gebhardt (1997) assigned this part of the section to a shelf environment. Reduced salinities and low oxygen levels may have caused mass mortalities at quarry section (Gebhardt, 1997) and not hypersaline conditions. Therefore, the gypsum lenses were not formed as a result of hypersalinity. These are secondary in origin and have been attributed to late oxidation of sulphides by circulating groundwater (Rebelle, 1990).

According to this study therefore, the Ashaka Cement Quarry section is assigned to a shelf/lagoon environment with fluctuating salinities and oxygen levels.

Microfacies analysis has also revealed more post-depositional characteristics of the Kanawa Member in the quarry section. It is evident that the original sediments were mainly bioclastic lime-muds. Overburden pressure has sometimes caused the development of stylolites and fragmentation of some of the bioclasts. There was dissolution of bioclastic materials with the more aragonitic shells being completely dissolved while the calcitic varieties were retained. The muds originally forming the rock fabric were mostly recrystallised during aggrading neomorphism to microsparite. Voids were filled by drusy sparite. This sparite may have originated from fresh water circulation in the emergent carbonate platform deposits during a subsequent fall of sea level (Rebelle, 1990).

### **V. Conclusion**

It is evident from the various deductions according to this study, that the limestones of the Kanawa Member of the Pindiga Formation at the Ashaka Cement Quarry section are dominantly neomorphosed biomictites or wackestones. Depositional environments of the Kanawa Member and the basal Deba-Fulani Member was generally shallow marine and in most cases low energy, with few instances of agitated conditions (units 7, 8 and 9, Fig. 3). Marine fauna (mollusk dominated) indicated fairly well oxygenated bottom conditions at least for the lower limestones. This however was succeeded by alternating normal marine oxic and dysoxic/anoxic conditions (limestones/shale alternations) attributed to stratification resulting from freshwater influx. This has also caused fluctuating salinities and reduced oxygen levels that killed the rich marine fauna. This stage has also shown the basin to experience calm and water deepening conditions marked by the glauconite-rich horizons. The basin also experienced terrigenous influx at the earliest stage.

The Kanawa Member together with the basal Deba-Fulani Member of Pindiga Formation forms a single Type 1 sequence. The ferruginous crust at the top of the Bima Sandstone forms the lower sequence boundary while an inferred correlative conformity at the base of unit 34 (Fig. 4) within the Deba-Fulani Member is the upper sequence boundary. In the quarry section, the lowstand systems tract preceding the transgressive systems tract is lacking. This, points to the shallow water marginal position of the depositional basin.

### Acknowledgements

The authors wish to thank the department of Geology, Ahmadu Bello University Zaria then under the leadership of Professor Ibrahim Garba. The department provided logistic support particularly during our first fieldtrip to Ashaka quarry as the departmental vehicle was released to us for three days in the month of April of 2001. We were also allowed the used of the departmental equipments such as measuring tapes, GPS and compass/clinometres. Technological staff of the department are also not left in this regard. Mr. Samuel Adegbio and Mr. Robert Lamja assisted in the preparations of Thin-sections of the samples brought from the field. Mr. Emmanuel Animashaua aided in the sedimentological laboratory work while Mr. Linus produced the photographs of the faunas.

The authors also wish to express gratitude to Professor N. G Obaje then of ATBU Bauchi for offering a lot of useful suggestions.

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