International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Microfacies, Diagenesis and Depositional Environment of the Cenomanian – Turonian Gongila Formation, Bornu (Chad) Basin, Northeastern Nigeria

B. Shettima[1], A. M. Kyari[1], M. M. Liman[2], A. J. Musa[3]
[1]Department Geology University of Maiduguri
[2]Ministry of Petroleum Resources, Abuja
[3]Department Environmental Sciences, Federal University of Jigawa

***Abstract*— *The Gongila Formation in the Bornu Basin is represented by a succession of interbeds of shales and limestones, and these limestones facies consist of packstone (pack biomicrite), wackestone (sparse biomicrite), mudstone (micirte) and extraclast biofacies. The packstone and wackestone microfacies may possibly have been formed in an inner to middle shelf environment with relatively low energy conditions while the mudstone biofacies must have formed under quiet water lagoonal environment. The extraclast biofacies may suggest periods of erosion which might have occurred during relative sea level fall that must have exposed the limestone facies subareial conditions. These limestone facies have undergone different phases of diagenesis which include micritization, dissolution, neomorphism and calcitization and this has altered the original fabric of the limestone, leading to the development of moldic and vuggy porosities in some of the limestone facies*.

***Keywords*— *Microfacies, diagenesis, Gongila Formation, Bornu (Chad) basin*.

I. INTRODUCTION

The study area is at Bularafa village which is located in southeastern part of the Chad Basin (Fig. 1a), and the geology of this area is generally defined by Gongila Formation consisting of shales and limestones distribution commonly impregnated by basaltic intrusions (Fig. 1b). This Cenomanian – Turonian formation represents the onset of the global mid – Cretaceous marine transgression in the Bornu Basin (Carter, et al., 1963). Most of the researches being carried out on this formation are generally on organic geochemistry and biostratigraphy (Olugbemiro, 1997; Obaje and Hamza, 1997). Therefore, this current research is going to be centered towards the description of the lithofacies and biofacies of the Gongila Formation, in order to deduce its diagenetic history and paleoenvironment.

II. GEOLOGICAL AND STATIGRAPHIC SETTING

The origin of the Bornu Basin is associated with the separation of the African and South American continents in the early Cretaceous (Burke *et al*., 1972; Nwajide, 2013). An active phase of sea floor spreading in the Atlantic during the mid-Cretaceous resulted in the subsidence of the West African intracratonic basins, leading to the widespread Cenomanian-Turonian marine transgression into the Chad Basin (Carter *et al*., 1963).

Sedimentation in the Bornu Basin began in the Albian with the deposition of a continental, sparsely-fossiliferous medium to the coarse grained feldspathic sandstone with some shale intercalations known as the Bima Sandstone (Fig. 2). This formation rests directly on the Precambrian Basement Complex (Carter *et al.,*1963; Avbovbo *et al.,*1986).

The Bima Sandstone is conformably overlain by the Gongila Formation which is composed of calcareous shale and sandstones, deposited in a shallow marine environment (Popoff *et al.*, 1986) (Fig. 3). The deposition of this formation marks the beginning of marine incursion into the Bornu Basin (Carter *et al.*, 1963). The marine transgression which started in the Albian reveals its peak in the Turonian during which the bluish-black, ammonites-rich open marine Fika Shale was deposited, and this deposition continued into the Santonian (Carter *et al.*, 1963). The Gombe Sandstone which contains intercalation of siltstone, shale, ironstone and sandstone was deposited in the Maastrichtian and it unconformably overlies the Fika Shale.

A phase of extensional deformation occurred in the Bornu Basin in the Late Maastrichtian times and this continued up to the end of Cretaceous. As a result of that, the basin was reconstructed into an elongate NE-SW garben system and the remnant basin that succeeded the deformation formed the site for the deposition of the Kerri-Kerri Formation, which unconformably overlies the Cretaceous sediments (Carter *et al.*, 1963; Dike, 2002).

In the Pleistocene and presumably during the Pliocene, the continental deposits of the Chad Formation were unconformably laid down on top of the Kerri-Kerri Formation (Carter *et al.*, 1963; Shettima, *et al*., 2009). Toward the end of the Tertiary to recent times, widespread volcanic activities occurred in the south and central part of the basin (Burke *et al*, 1972).

III. METHODOLOGY

The sections of the Gongila Formation were established using core samples from boreholes drilled by the Yobe State Government at Bularafa village. Seven boreholes were studied with depths varying from 21 – 39m out of which 12 limestone samples were collected for petrographic analysis using a binocular microscope at a magnification of (x40).

The limestones are described and classified using Dunham (1962) as modified by Embry and Klovan (1972) and Folks

B. Shettima, A. M. Kyari, M. M. Liman, and A. J. Musa, "Microfacies, Diagenesis and Depositional Environment of the Cenomanian – Turonian Gongila Formation, Bornu (Chad) Basin, Northeastern Nigeria," *International Research Journal of Advanced Engineering and Science*, Volume 2, Issue 4, pp. 17-25, 2017.

(1962, 1965) carbonate classification scheme. The thin sections of the limestones were examined to determine the microfacies, textures, diagenetic changes, porosity and depositional environment.

IV. Results

Lithological Descriptions

The Gongila Formation was studied at Bularafa village in Yobe State from seven boreholes (Fig. 1b). Lithologically, the formation consists of interbeds of limestones and shales of which the shales constitute the thickest parts in all the boreholes studied (Figs. 3, 4, 5, 6, 7, 8 and 9) respectively. The shales usually range in colour from light grey to dark grey, with the former being mostly weathered and occurs at the top of the section, while the later occurs towards the base. They are generally fissile and vary in thickness from 2 – 4m. The limestone display light grey or grey colour with thickness ranging from 1.6 – 6.7m. Most of the limestones are generally massive but nodular and fossilferous types are also common. However, the fossil type could not be identified because they occur in form of fragments in the core samples. There are also occurrences of siltstone in some of the boreholes (Figs. 3 and 6) usually associated with limestone – shale sequence and they typically occur at the base of the section.

Microfacies Description:

Packstone (Packed biomicrite)

The packstone (packed biomicrite) microfacies are not frequent in the study area. These facies consist of over 50% allochems and are only identified at borehole 2 (BH2A), borehole 13 (BH13B) and borehole 19 (BH19E) (Figs. 3, 5 and 7) respectively. The units are highly fossilferous and bioturbated. Allochem components include shell fragments of pelecypods, gastropods, bryozoans, echinoid, foraminfera, ostracods (Fig. 10 a, b and c) and skeletal grains. Some the shell fragments have been dissolved and have undergone void filling (Fig. 10c) by sparry calcite. The porosity type developed by diagenetic alteration of the skeletal fragments include moldic and vuggy.

Wackestone (sparse biomicrite)

The wackestone (sparse biomicrite) microfacies is the most common microfacies and it has been identified in all the boreholes and samples as represented in [BH1A, (borehole 1), BH2E and BH2F (borehole 2), BH10A and BH10B, (borehole 10), BH12G (borehole 12) and BH18F and BH18D (borehole 18)] (Figs. 3, 4, 5 and 7) respectively. It is mud supported microfacies, the allochems range between 10% – 50% and consists of shell fragments of pelecypods, gastropods, bryozoans, mollusk ostracods and fragments of ammonite (Fig.10e; 11a and b). The bioclasts constitutes about 40% while micrite constitutes 60% of the rock and forms the matrix. Micritization of the outer shell fragment (micrite envelop) and filling of the inner portion with micrite are identified and in some cases sparry calcite fill the inner portion (Fig. 10e;11a and b).

Mudstone (micrite)

The mudstone (micrite) microfacies was only identified at borehole 1 (BH1D, Fig.3). These microfacies units consist of micrite with allochems of up to 1%. The mudstone microfacies (Fig. 11d) are commonly represented by either micrite or microsparite having been affected by aggrading neomorphism.

Extraclast

The extraclast micro biofacies was identified in borehole 12 (BH12G, Fig. 10) and they appear to consist of mixed sub-angular to rounded grain fragments of limestone associated with rounded chert grains (Fig. 11c).

V. Discussion

Paleoenvironment

The limestones classification scheme of Embry and Kolvan (1972) and Folk (1962) indicated that the limestone facies of the Gongila Formation generally consists of packstone (pack biomicrite), wackestone (sparse biomicrite) and mudstone (micrite). Packstone and wackestone microfacies are formed in a relatively low energy environment because of the considerable proportion of carbonate mud in their textural framework (Dunham, 1962), while the mudstone microfacies settles out from suspension under quiet water conditions (Nichols, 2006). The identified extraclast facies in borehole 12 (BH12) may suggest the occurrences of erosion of older limestone facies outside the depositional basin, because they are usually derived from older carbonate platform areas (Pettijohn, *et al.*, 1987; Tucker, 1988). There are no reported older carbonate rocks than the Gongila Formation in the Chad Basin. Therefore, the occurrence of this facies may indicates a relative sea level fall in which some part of the limestone of the Gongila Formations were exposed, thereby leading to erosion and subsequent deposition of the extraclast. The rounded limestone grains in the extraclast may suggest longer distance of travel while the sub-angular grains may suggest shorter distance of travel.

The microfacies contains high diversity, abundant skeletal grains showing bivalves, gastropods, ostracods, ammonite and calcisphere. These fossils dwell in a shallow water marine environment because of their benthonic nature (Tucker, 1991), therefore, this may suggest that the packstone and wackestone biofacies were probably deposited in a shallow open marine environment having moderate to low circulation and agitation conditions.

The alternating proportion of the limestone and shales, and the predominance of wackestone microfacies observed in the sections studied could be attributed to deposition in a relatively unstable carbonate shelf platform, where the clastics deposits, might have been supplied from adjacent highland at low sedimentation rate (Tucker and Wright, 1990). Peter and Dana (2003) indicated that mudstone (micrite) biofacies usually develop under low energy conditions where circulations are highly restricted which are very common in lagoonal settings, while packstone and wackestone develop in a relatively high energy settings usually in an intertidal – subtidal shoal areas. On the basis of this, it may be suggested that the Gongila Formation might have probably formed in shallow epieric seas.

Diagenesis

Diagenetic analysis of the limestone facies of Gongila Formation shows various phases of diagenetic processes and these includes, micritization, compaction, dissolution, neomorphism and dolomitization. Compactions are commonly observed in the packstone biofacies with most of the skeletal grains showing sutured contacts and fragmentation. This phase occurs early in the diagenetic history and commences immediately after deposition due to overburden pressure (Tucker, 1991).

Dissolution generally occurs due to unstable mineralogy (presences of high magnesium calcite and aragonite), cool temperature and low – PH pore waters that are unsaturated with calcium carbonate (Wilson, 1975). This phase of diagenesis appears to have affected mainly the bioclast were unstable minerals (aragonite) are dissolved resulting in moldic and vuggy porosity (Fig. 10, a – d and Fig. 11b).

Neomorphism, which is a transformation occurring in a solid state between a mineral and itself or polymorph(Wilson, 1975; Tucker, 1991), is observed in virtually all the samples studied, however with different degrees of intensities. These transformation or recrystallization in the Gongila Formation is represented by the transformation of microspar to pseudospar, calcitization of originally aragonitic skeletons and recrystallization of micrite to sparite which is the most common. Clay mineral content and magnesium ion (Mg^+) attached to micrite usually inhibits transformation to sparite (Tucker, 1992), the Mg^+ ion ideally 'cage' around the micrite crystal (Folk, 1974). The prevalence of this neomorphic diagenesis is indicative of the fact that the clays in the limestone facies might have been flushed with meteoric water, thereby freeing the surface of the micrite grain for subsequent recrystallization to microspar.

Calcitization of bioclast composed of aragonite are also common diagenetic features but preserved only in very few limestone facies. This usually occurs in the presences of water by means of dissolution of the aragonite grain, leaving behind relicts of the internal structures of the shell (Boggs, 1995).

The occurrence of dolomitization is very rare in the microfacies studied. This selective dolomitization in the Gongila Formation depends on pore water, sediment chemistry and crystal size, therefore, only carbonate grains of favorable mineralogy and suitable chemistry are being recrystallized to dolomite.

VI. Conclusion

The Gongila Formation contains limestone deposits of shallow water origin possibly forming on an inner to middle shelf environment having relatively low energy and under quiet water lagoonal environment as indicated by the packstone (pack biomicrite), wackestone (sparse biomicrite) and mudstone (micirte) biofacies. The extraclast biofacies may indicate periods of sea level fall, erosion and deposition in the overall phase of the main marine transgression that led to the deposition of the Gongila Formation. A suite of diagenetic processes such as micritization, dissolution, neomorphism and calticization have affected the limestone leading to the development of moldic and vuggy porosities in some of the limestone facies.

Reference

[1] Avbovbo, A.A., Ayoola, E.O and Osahon, G.A. (1986). Depositional and structural styles in Chad Basin of northeastern Nigeria. Bulletin American Association Petroleum Geologists, 70, 1787-1798.

[2] Boggs, S.Jr. (1995). Principle of sedimentology and stratigraphy, 2nd ed: Prentice Hall, New Jersey, 109.

[3] Burke. K.C., Dessauivagie, T. F. and Whiteman, A.J. (1972).Geological History of the Benue valley and adjacement areas. In: African Geology (Edited by Dessuvagie, T.F. J. and Whiteman, A.J.) Pp. 187-205. Ibadan University Press, Ibadan, Nigeria.

[4] Carter, J. D., Barber, W., Tait, E.A and Jones, G.P. (1963). The geology of parts of Adamawa,Bauchi and Borno provinces in north-eastern Nigeria. Bulletin Geological Survey Nigeria. 30, 1-99.

[5] Dike, E.F.C. (2002).Sedimentation and tectonic evolution of the Upper Benue Trough and Bornu Basin, Northeastern Nigeria. Nigerian Mining Geosciences Society 38th Annual and International Conference, Port Harcourt 2002 (NMGS/ELF award wining paper) Abstr. Vol., 45p

[6] Dunham, R.J. (1962). Classification of carbonate rocks according to their depositional texture. Memoir American Association of Petroleum Geologists, 1, 108-127.

[7] Embry, A.F. and Klovan, J.E. (1972). A Late Devonian reef tract on the northeastern Banks, N.W.T. Canadian Petroleum Geologists Bulletin. 19, 730-781.

[8] Folk, R.L. (1962).Spectral subdivisions of limestone types. In: Classification of carbonate (ed W.E. Hams) American Association of Petroleum Geologists Memoir, 1,62-84.

[9] Folk, R.L. (1965). Some aspect of recrystallization in ancient limestones, In L.C. Pray and R.S. Murray (eds), dolomitization and limestone diagenesis. Society of Sedimentary Petrologists, Special Publication, Tulsa, 13, 14-48.

[10] Folk, R.L. (1974).Petrology of sedimentary rocks. Hemphill, Austin, 159p.

[11] Genik, G.J. (1993). Petroleum geology of Cretaceous Tertiary rift basins in Niger, Chad and the Central African Republic. Bull. Amer. Assoc. of Petrol. Geol. 77, 1405 - 1434.

[12] Nichols, G. (2006). Sedimentology and stratigraphy. Blackwell, Oxford, 186p.

[13] Nwajide, C.S. (2013). Geology of Nigeria's sedimentary basins. CCS Bookshop Ltd, Lagos, 86p.

[14] Obaje, N.G. and Hamza, H. (1997). Biostratigraphy and source rock potentials of Cretaceous sediments in the Upper Benue Trough and Chad Basin of Nigeria. Unpubl, Report, DepartmentGeology, ABU Zaria, 134p.

[15] Olugbemiro, O.R. (1997). Hydrocarbon potential, maturation and Paleoevironments of the Cretaceous (Cenomanian-Santonian) series in the Bornu (Chad) Basin, NE Nigeria. Tiibinger Mikropalaontologische Mitteilungen 14, 8-150.

[16] Peter, S.C. and Dana, S.S. (2003). A colour guide to the petrography of carbonate rocks: Grains, textures, porosity, diagenesis. American Association of Petroleum Geologists, Memoir, 77, 341p.

[17] Pettijohn, F. J., Potter, P.E. and Siever, R. (1987). Sand and Sandstones (2nd Ed). Springer- Verlag, 407p.

[18] Popoff, M., Wiedmann, J. and De Klazz, I. (1986).The Upper Cretaceous Gongila and Pindiga Formations, Northeastern Nigeria.Subdivisions, age stratigraphic correlations and paleogeographic implications. Ecologea Geol. Helv.,79, 343-363.

[19] Shettima, B, Kyari, A.M., Goni H. and Usman, L.A. (2009).Facies and facies Architecture, Provenance and depositional environment of the Bama-Maiduguri Ridge Complex, Bornu Basin, northeastern Nigeria. 45th Nigerian Mining and Geosciences Society (NMGS) Annual International Conference Owerri, Abstract Vol, 54p.

[20] Tucker, M.E. (1988). Techniques in sedimentology, Black well, Oxford, 394p.

[21] Tucker, M.E. (1991). Sedimentary petrology. Blackwell, Oxford, 260p.

[22] Tucker, M.E. (1992). Limestone through time: in: understanding the Earth, a new synthesis (eds) G.C Brown, C.J. Hawkesworth and R.C.L. Wilson, Cambridge University Press, Cambridge, 347362.

B. Shettima, A. M. Kyari, M. M. Liman, and A. J. Musa, "Microfacies, Diagenesis and Depositional Environment of the Cenomanian – Turonian Gongila Formation, Bornu (Chad) Basin, Northeastern Nigeria," *International Research Journal of Advanced Engineering and Science*, Volume 2, Issue 4, pp. 17-25, 2017.

[23] Tucker, M.E. and Wright, V.P. (1990). Carbonate Sedimentology. Blackwell, Oxford,482p.
[24] Wilson, J.L. (1975). Carbornate facies in geologic history. Spring-Verlag, New York, 439p.
[25] Zaborski, P., Ugodulunwa, F., Idornigie, A., Nnabo, P. and Ibe, K. (1997). Stratigraphy and Structure of the Cretaceous Gongola Basin, Northeastern Nigeria. Bulletin Centre Research Production Elf Aquitaine, 22, 153-185.

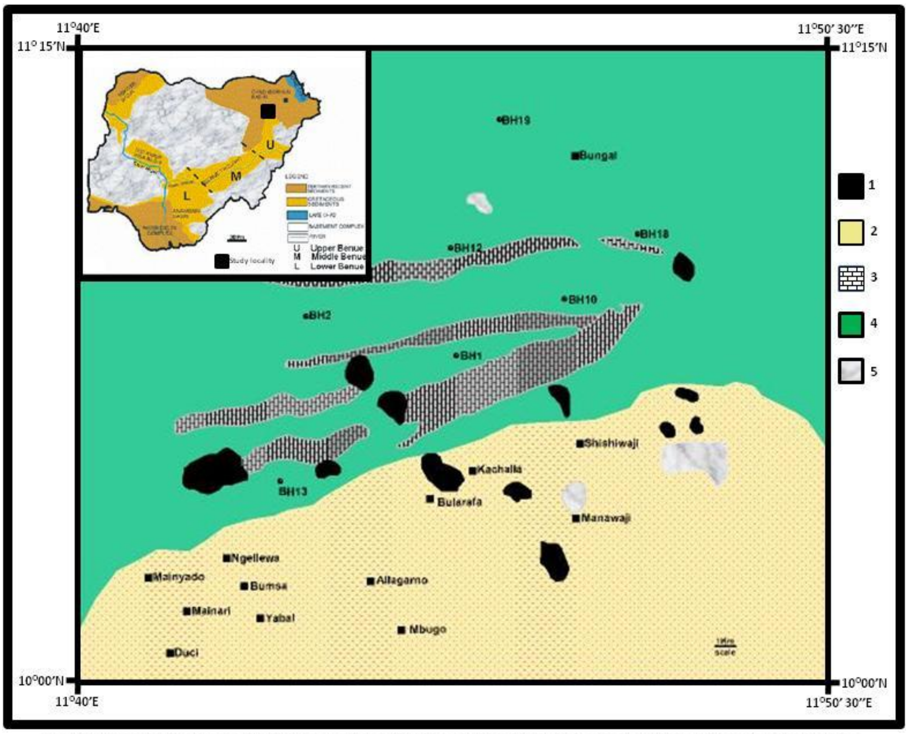

Fig.1(a) Geological map of Nigeria showing study location and (b) geological map of the Bularafa area showing borehole location 1- Basalts , 2- Gulani Sandstone, 3- Gongila Formation limestones, 4- Gongila Formation shales, 5- Basement Complex

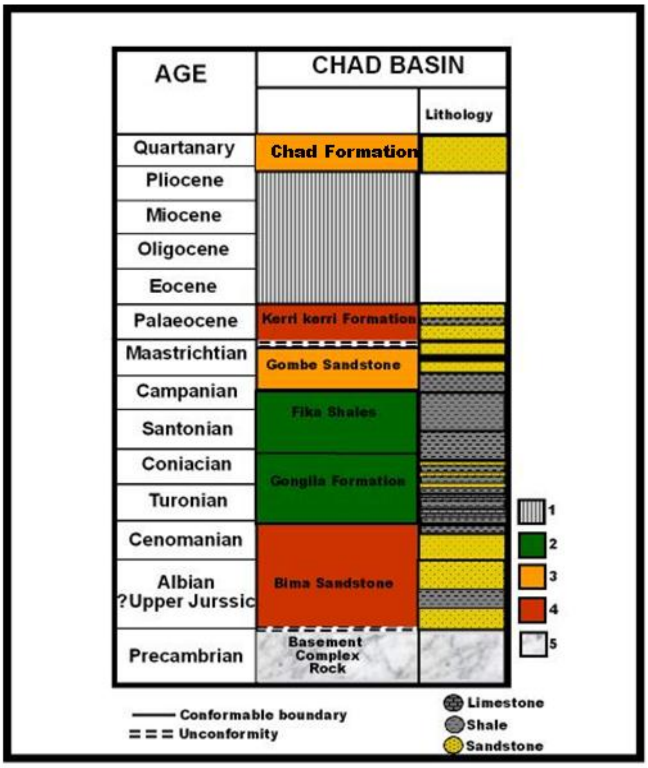

Fig.2 Stratigraphic succession of the Bornu Basin (Carter et al., 1963).

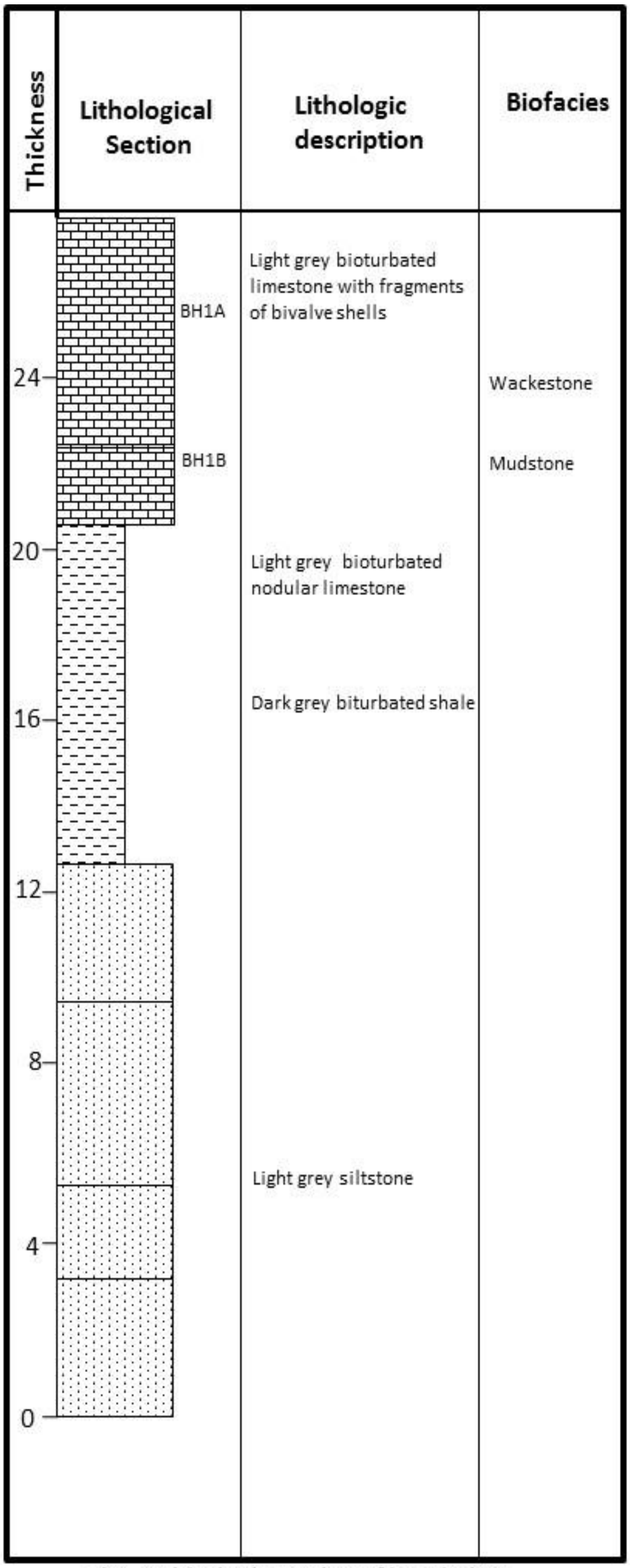

Fig . 3 Lithologic section of borehole 1

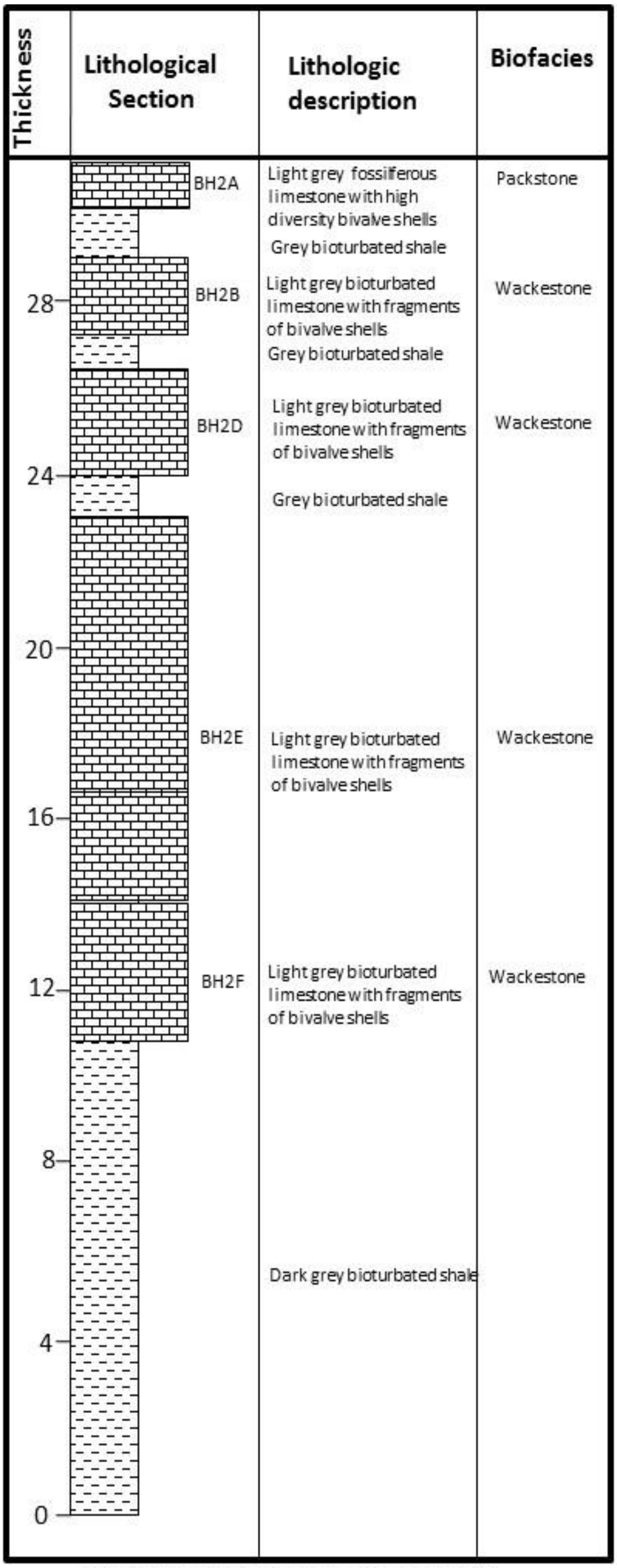

Fig.4 Lithologic section of borehole 2

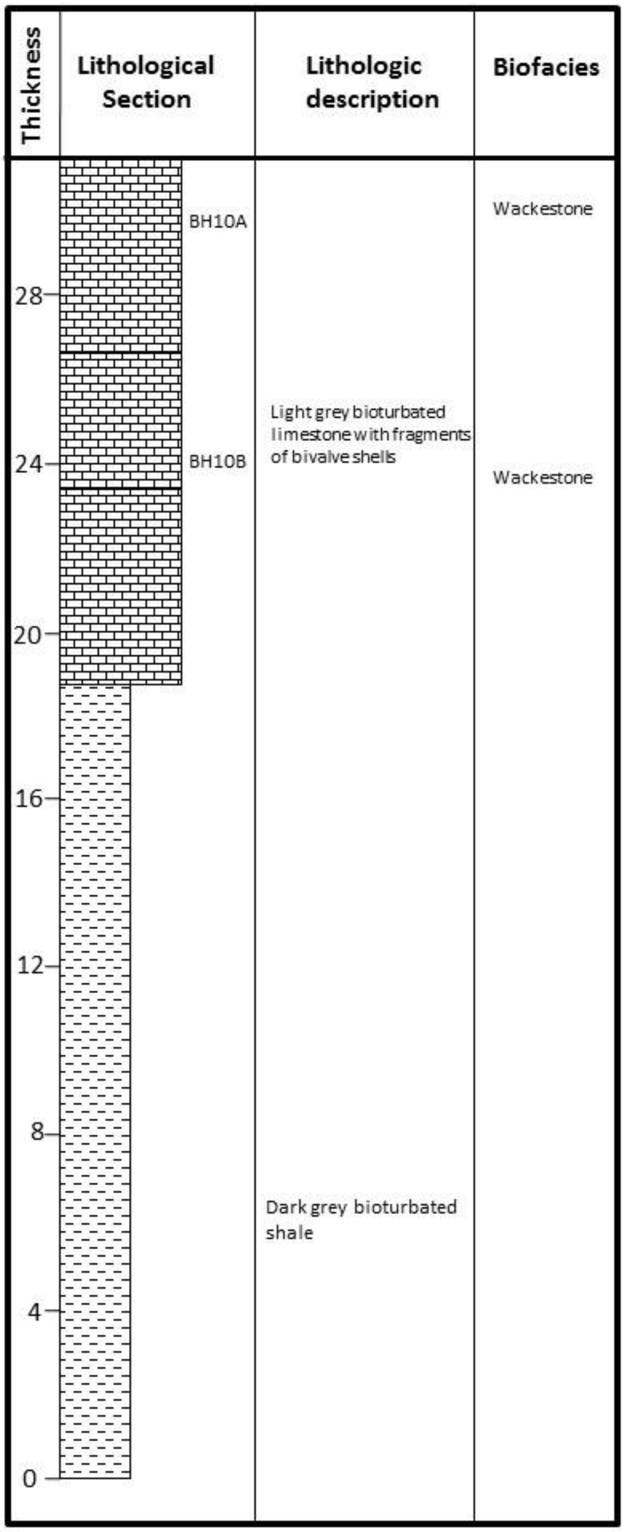

Fig. 5 Lithologic section of borehole 10

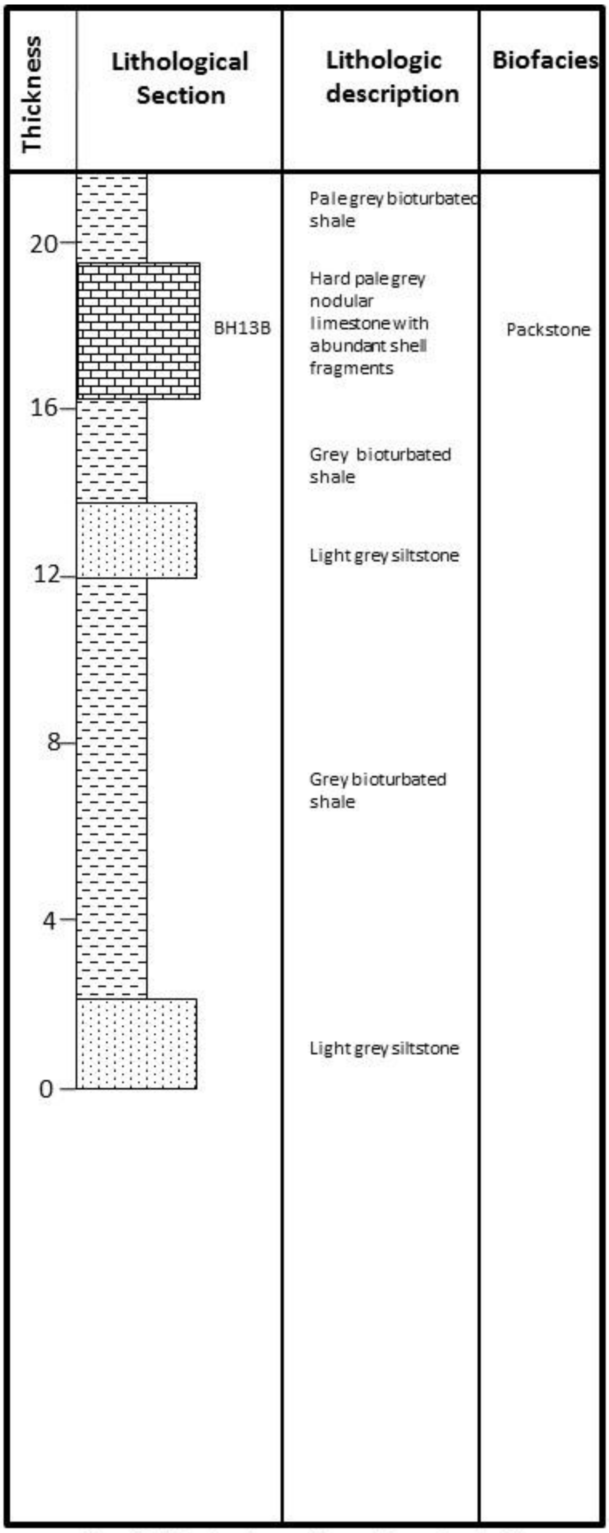

Fig. 6 Lithologic section of borehole 13

B. Shettima, A. M. Kyari, M. M. Liman, and A. J. Musa, "Microfacies, Diagenesis and Depositional Environment of the Cenomanian – Turonian Gongila Formation, Bornu (Chad) Basin, Northeastern Nigeria," *International Research Journal of Advanced Engineering and Science*, Volume 2, Issue 4, pp. 17-25, 2017.

ISSN (Online): 2455-9024

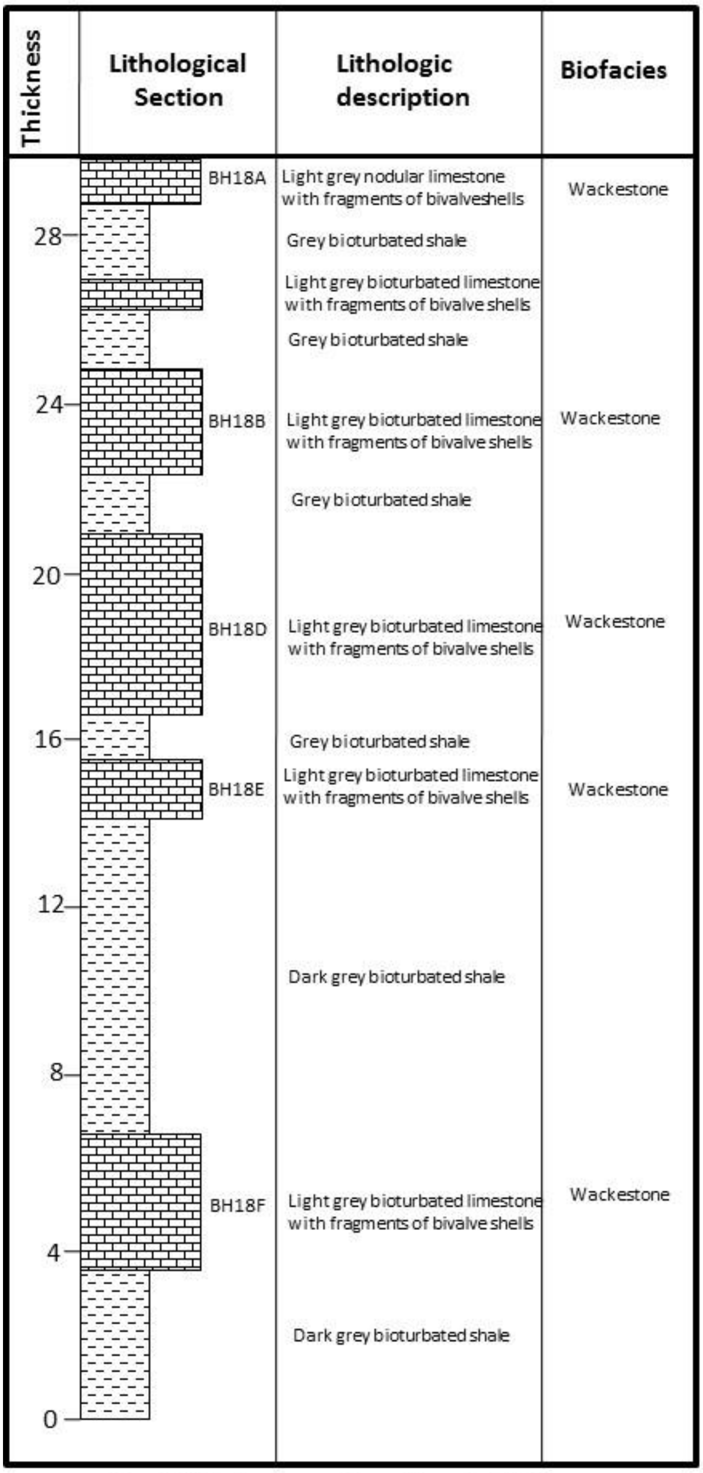

Fig. 7 Lithologic section of borehole 18

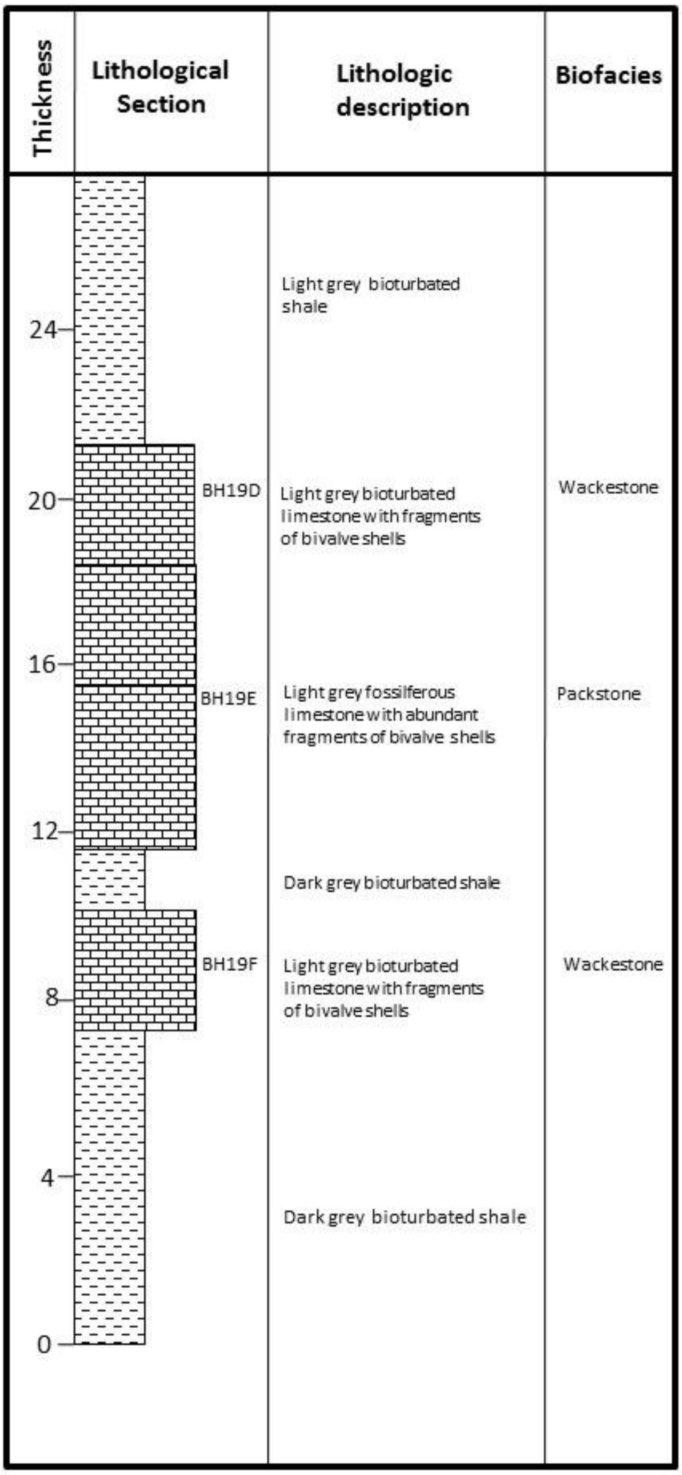

Fig. 8 Lithologic section of borehole 19

B. Shettima, A. M. Kyari, M. M. Liman, and A. J. Musa, “Microfacies, Diagenesis and Depositional Environment of the Cenomanian – Turonian Gongila Formation, Bornu (Chad) Basin, Northeastern Nigeria,” *International Research Journal of Advanced Engineering and Science*, Volume 2, Issue 4, pp. 17-25, 2017.

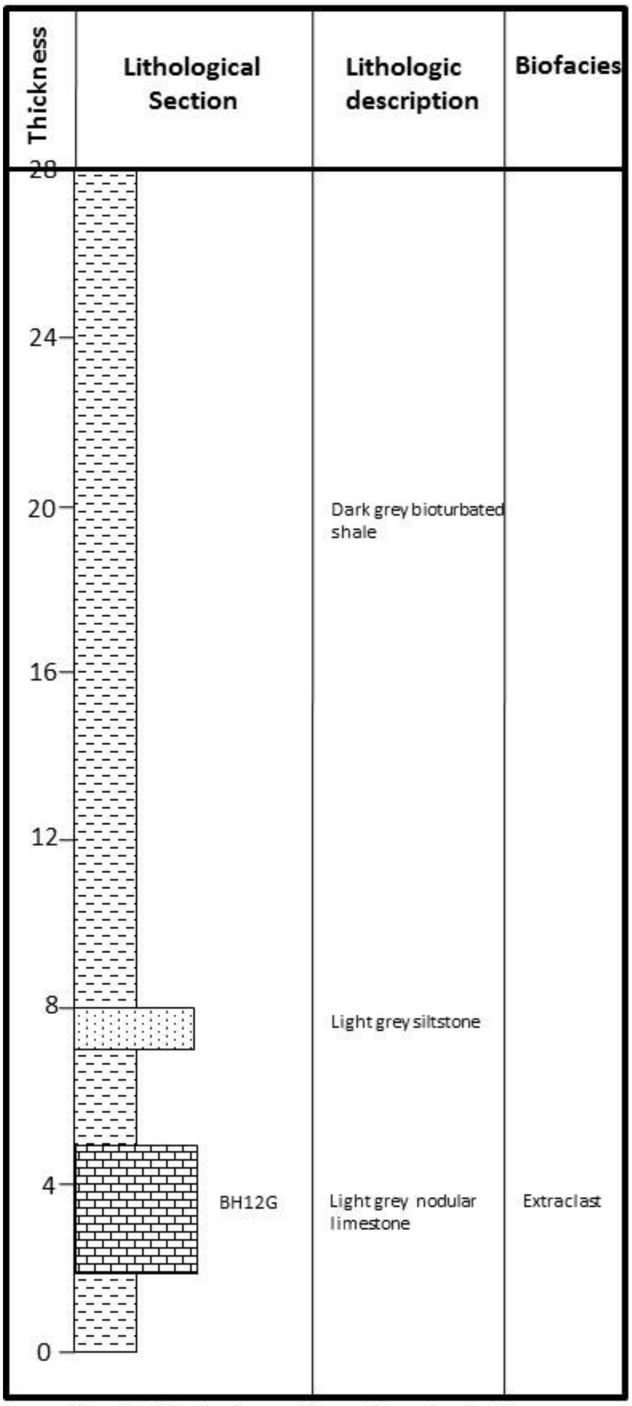

Fig. 9 Lithologic section of borehole 12

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

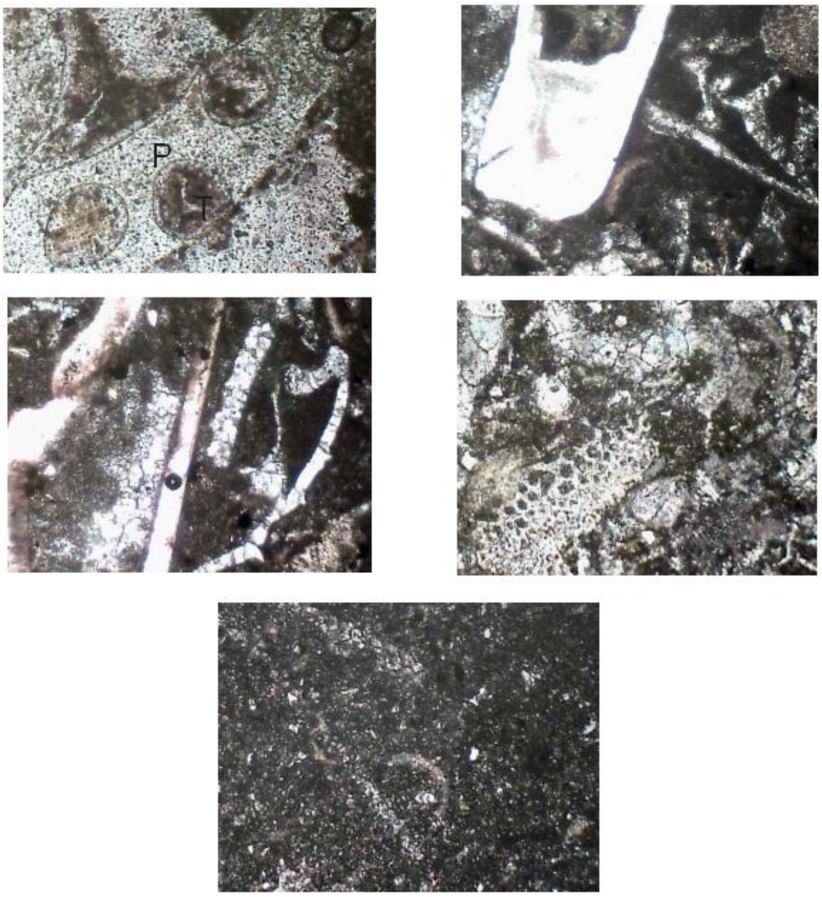

Fig. 10 a) Packstone showing pelecypod(P) and trilete spores(T), sample BH13B: b) Packstone showingpelecypod and ostracods, sample BH19E: c) Packstone showing pelecypod and algae, sample BH2AI: d) Packstone showing pelecypod, echiniod and algae, sample BH2II: e) Wackestone showing pelecypod sample Bh10 [Mag. x40]

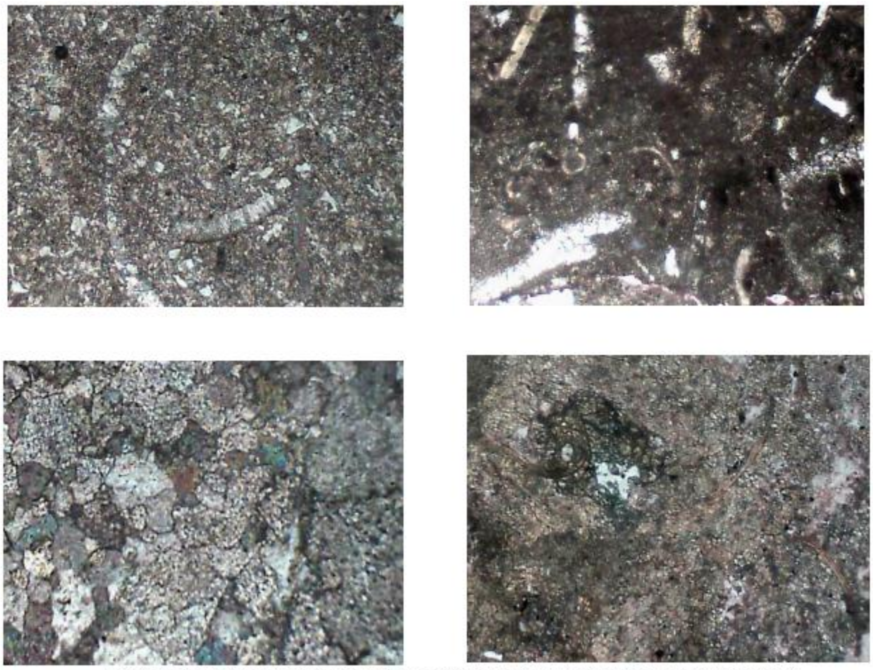

Fig.11a) Wackestone showing brachiopod, sample BH2E: b) Wackestone showing pelecypod, ostracods and forams, sample BH19E: c) showing limestone composed of extraclast, sample BH12G: d) showing limestone composed of carbonate mud(micrite), sample BH1B [Mag. x40]