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***Journal of Scientific and Engineering Research*, 2020, 7(5):241-248**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Foraminiferal Biostratigraphy of Middle to Late Miocene sediments in Well X-1, OML 108, Offshore Niger Delta

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Abstract The quest for more recovery of hydrocarbon in the proliferous Cenozoic Niger Delta has led to a paradigm shift in oil exploration to the deep offshore areas of the delta. Thus, exploration business requires a more accurate methods to reduce the uncertainties ofq this siliciclastic setting, hence this study. Fifty (50) ditch cutting rock samples from interval 8,040ft and 11,010ft of Well X-1, OML 108, Offshore Niger Delta, were processed Micropaleontologically, for their foraminiferal content. The aim was to identify the individual species of the foraminiferal assemblage, their abundance and diversity as well as their stratigraphic distribution and use it to establish the foraminiferal biozonation framework for the purpose of delineating the age of the sediments penetrated by the well interval. The samples were subjected to standard foraminiferal sample processing techniques and analysis for the recovery of the foraminifera. The analysis yielded moderately rich and diverse foraminifera consisting twenty- seven (27) planktics, fifty-one (51) calcareous benthic, and twenty-four (24) agglutinated benthic species. Based on First Downhole Occurrences (FDO) and Last Downhole Occurrences (LDO) of the foraminiferal markers, three foraminiferal concurrent range zones were erected and used to characterize the age of the sediments. They are from top to bottom: *Uvigerina subperegrina, Globorotalia acostaensis* and *Globorotalia obesa / Eggerella scabra* concurrent range zones corresponding with N17-N16, N16 and N15-N14, planktic zones of [1] respectively. These zones indicate a Middle to Late Miocene age for the rock succession penetrated by the well interval studied.

Keywords Foraminifera, Age, Zonation, Miocene, Biostratigraphy, Niger Delta

1. Introduction

The Cenozoic Niger Delta is a petroliferous province situated in the West African continental margin. The recent recovery of hydrocarbon in deep offshore areas of the basin has led to a shift in exploration activities to these areas for better output. Foraminifera is an important micropaleontological tool in basin evaluation, contributing in age characterization, correlation, reconstruction of paleoenvironment, paleogeography, as well as recognition of oil and gas horizons. Although there is paucity of published biostratigraphic works by oil companies who treats these data as proprietary, several authors have published on foraminiferal biostratigraphy of the Niger Delta [2-10], among others. Concerted effort is still ongoing by the stratigraphic committee of the Niger Delta for the unification of standard coding system in foraminiferal systematics of shell petroleum development company and other oil industries for easier referencing.

Fifty (50) ditch cutting rock samples from interval 8,040ft and 11,010ft of Well X-1, OML 108, Offshore Niger Delta, (figure 1) were processed for their foraminiferal content. The aim was to identify the individual species of the foraminiferal assemblage, their abundance and diversity as well as their stratigraphic distribution and use it to establish the foraminiferal biozonation framework for the purpose of delineating the age of the sediments penetrated by the well interval. The samples were subjected to standard micropaleontological sample processing techniques and analysis for the recovery of the foraminifera.

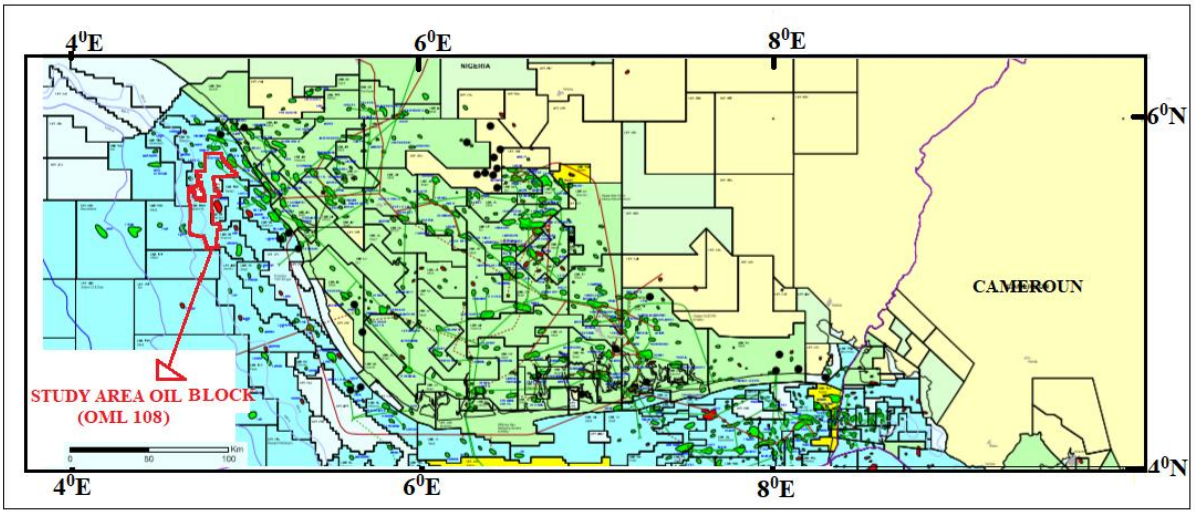

Figure 1: Location of the study area (OML 108) Offshore Niger Delta (Modified from [11])

1:1. Niger Delta stratigraphy

]The stratigraphic setting of the arcuate Cenozoic Niger Delta and the underlying Cretaceous strata has been described in [12-16], among others.

The Niger delta complex is divided into three formations, that are distinguished mostly on the basis of sand-shale ratios. They are the Akata, Agbada and Benin Formations.

Akata Formation

This formation underlies the entire delta and forms the lower most unit. It is a uniform shale unit, consisting of dark grey sandy, silty shale with plant remains at the top. The Akata formation is typically over pressured and believed to have formed during lowstand of sea level when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency [16]. The thickness of this sequence is not known but may be up to 7000m in the central part of the basin [14]. This formation crops out offshore in diapers along the continental slope and onshore in the northeastern part of the delta, where they are known as Imo Shale and ranges in age from Paleocene to Recent. The Akata Formation sources the hydrocarbon in the Niger Delta [17-18].

Agbada Formation

The formation is a sequence of alternating shales and sands/sandstones; it is divisible into two subunits: the upper subunit in which the sands/sandstones constitute the thicker part and the lower subunit where shales form the thicker layers. Agbada Formation is very rich in microfauna which decreases upwards in abundance suggesting an increase in the rate of deposition at the delta front. As with the marine shales, the paralic sequence is present in all depobelts and ranges in age from Eocene-Recent. It is the hydrocarbon-prospective sequence in the basin with its sands serving as the reservoir rocks while the shales are contributory source rocks [19] and seals. Most exploratory wells in the Niger Delta, which reaches a maximum thickness of more than 3000m, have bottoms in this lithofacies and the major hydrocarbon accumulations are found in the several reservoir sands within it at intervals between Eocene and Pliocene.

Benin Formation

The formation, which comprises of over 90% sandstones with shales intercalations, extends from the west across the entire Niger Delta area and southwards beyond the present coast line. The thickness of the formation varies from 0 to 2100m, coarse grained, gravelly, poorly sorted, sub-angular to well-rounded sands that contain lignite streaks and wood fragment. Generally, the formation ranges in age from Oligocene to Recent. Very little hydrocarbon accumulation has been associated with this highly porous and mainly freshwater bearing sands.

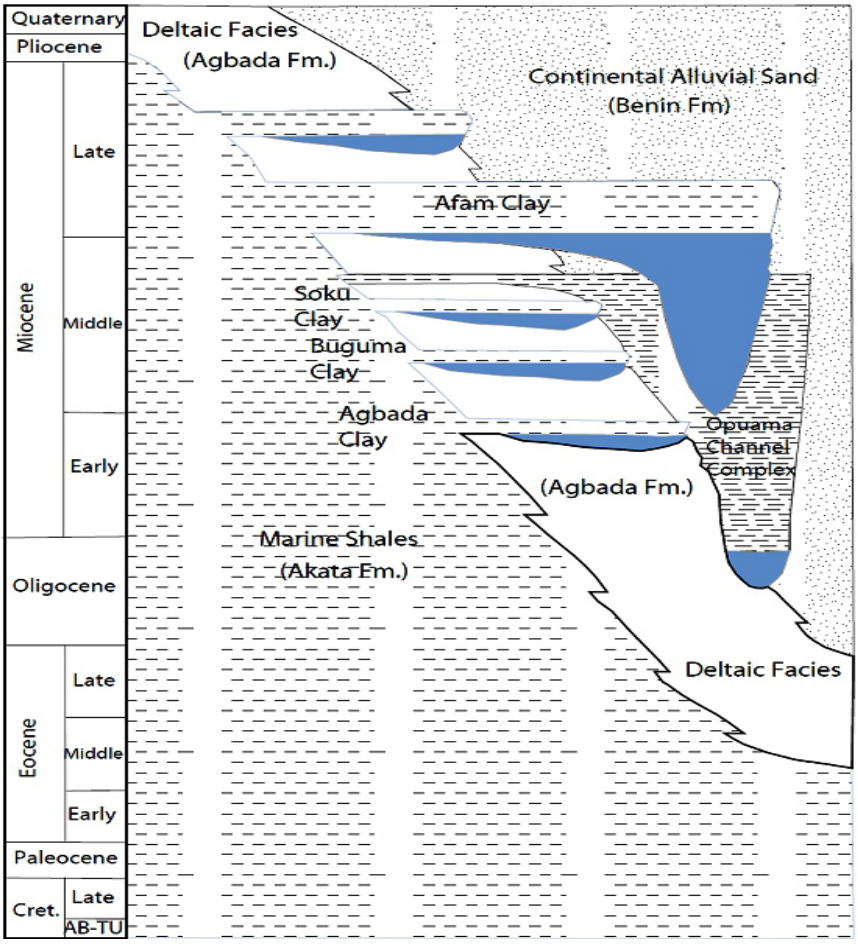

Figure 2: Stratigraphic summary of the Niger Delta (adapted from [14])

2. Method of study

In order to disintegrate the microfaunal components from the rock matrix to facilitate the recovery and subsequent picking, the fifty ditch cutting samples from the well were subjected to the following standard procedure, having observed all safety requirements:

1. 20gm of each sample was weighed (using a Mettler PC 440 digital balance) into sample bowl.
2. Depths on samples were correctly transferred to clean aluminum sample bowls.
3. 30 ml of kerosene was poured into sample to soak for two hours.
4. The kerosene was drained out and sample was soaked in water.
5. Each sample was then washed over a 63 microns sieve with water from a hand directed water jet.
6. The residue collected from the sieve was replaced in the sample bowl and dried on the hot plate.
7. The residue is then sieved over 20- and 80-microns mesh sieves for the coarse and medium fractions while the finest residue in the receiver is treated as fine fraction.
8. The coarse, medium and fine fractions are then stored in properly labeled sample phials for onward transfer to the pickers and analyzers.
9. All the slides were labelled serially according to the labels on the residues.
10. Beginning with the fine fractions of each sample, the residue was scattered on a gridded picking tray and viewed using incident light from stereoscope.
11. Using a fine brush, the visible forams were picked and transferred to a labelled slide.
12. The slide containing the forams was then covered using a glass cover slip.
13. Tragacanth gum was used to attach the specimen to the slides.

Foraminiferal analysis was carried out by identifying the individual foraminiferal specimen to the specific level and/ or generic level and counting each species to determine its quantity in each sample. The species were also

grouped into benthic and planktic forms. This information culminated in the stratigraphic distribution chart of the foraminiferal species of the interval studied.

3. Results and Discussions

Foraminiferal assemblage over the interval provided for analysis is generally rich and diverse. Species recorded consist of calcareous (benthic and planktic) and arenaceous benthic foraminiferal species. Species recorded include planktic foraminifera *Orbulina universa, Globorotalia obesa, Globigerina venezuelana, Globigerina bulloides, Globigerinoides bolli, Globigerinoides obliquus, Globoquadrina dehiscens, Globigerinoides immaturus and Globoquadrina altispira*. The calcareous benthic species includes *Hanzawaia concentrica, Uvigerina subperegrina, Lenticulina inornata, Siphouvigerina auberiana attenuata, Florilus costiferum, Trifarina angulosa, Ammonia beccarii, Heterolepa pseudoungeriana, Epistominella pacifica, Marginulina costata, Bolivina beyrichi, Cassidulina norcrossi, Cassidulina neocarinata, Hanzawaia mantaensis, Hanzawaia strattonii, Amphycorina scalaris caudata, Bolivina scalprata miocenica, Heterolepa crebbsi, and Gyroidina* soldanii. The associated arenaceous species includes *Haplophragmoides narivaensis, Cyclammina cancellata, Cyclammina minima, Haplophragmoides compressa, Valvulina flexilis, Eggerella scabra, Saccammina complanata, Poritextularia panamensis, Haplophragmoides obliquecarinatus, Ammabaculites strathearnensis, Karreriella subcylindrica, Bathysiphon sp, Karreriella siphonella, Ammodiscus glabratus* and *Ammobaculites agglutinans* (figure 3).

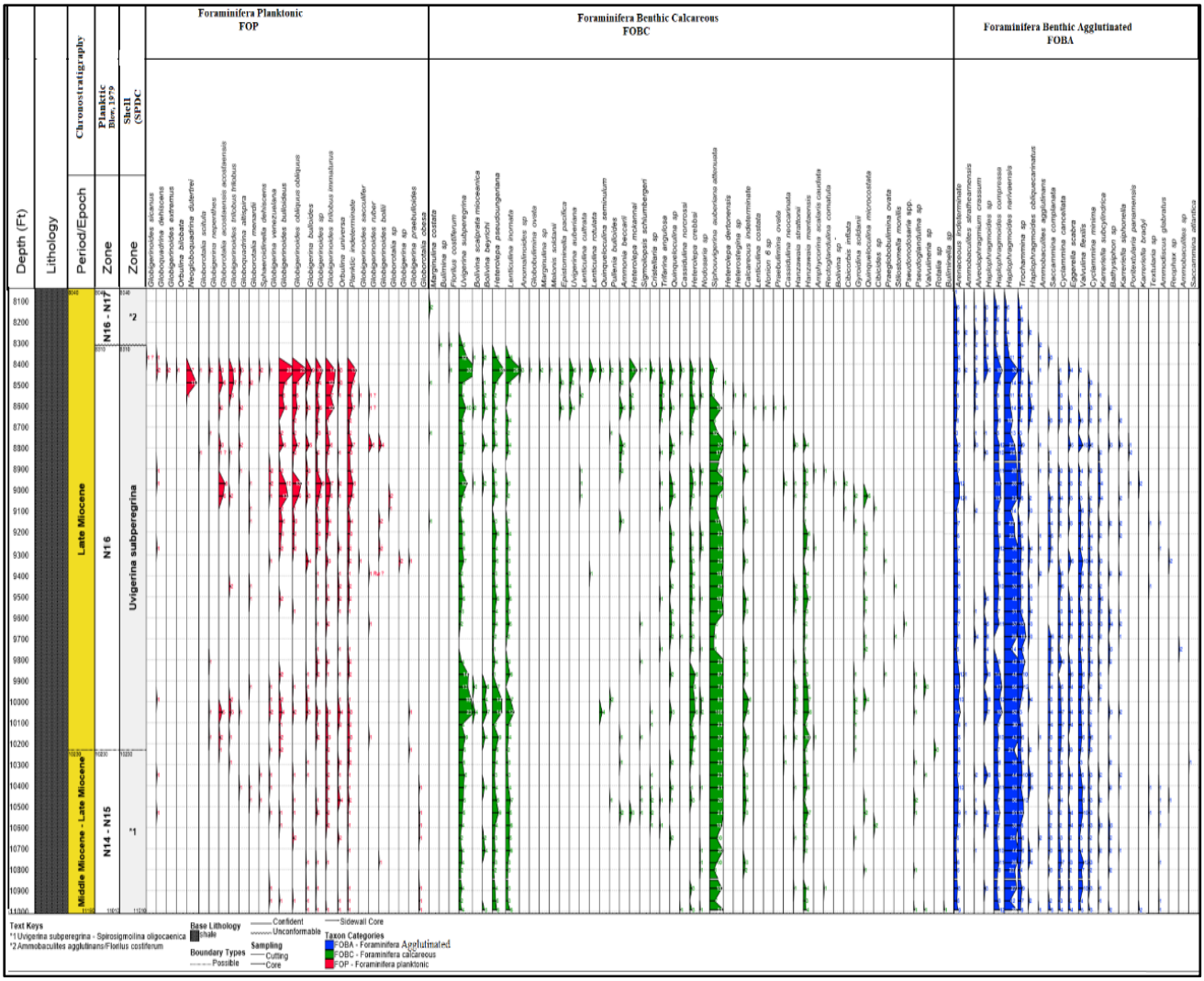

Figure 3: Foraminiferal distribution chart of well X-1

3.1. Foraminiferal Zonation

The foraminiferal zonation of this study was guided by the works of [1]. Due to rarity of planktonic foraminiferal species at some horizons, benthic foraminiferal species whose stratigraphic distributions are well established in the Niger Delta and have been calibrated with planktic foraminiferal species, were also used to assign zonation and age in this Well. Important foraminiferal bio-events considered for the zonation include: foraminiferal abundance and diversity peaks and first downhole occurrence (FDO) and last downhole occurrence (LDO) of chronostratigraphically significant planktic/benthic foraminifera markers.

Interval: 8,040 – 8,310ft**.**
Age: Late Miocene
Planktic Zone: N17 – N16
Zone: *Uvigerina subperegrina* concurrent range zone

Zone: *Uvigerina subperegrina* concurrent range zone

This Interval is characterized by moderate to abundant foraminifera species. Diagnostic foraminiferal species recorded include *Ammobaculites strathearnensis, Saccammina complanata, Alveolophragmium crassum, Haplophragmoides compressa, Haplophragmoides narivaensis, Cyclammina minima, Eggerella scabra, Cyclammina cancellata, Valvulina flexilis,* and *Trochammina sp.*

The First Downhole Occurrence of *Uvigerina subperegrina* at 8,310ft. suggest a Late Miocene age for this interval. Also, the co-occurrence of *Ammobaculites agglutinans* and *Florilus costiferum* at the base of this zone give credence to the Late Miocene age interpreted for this interval.

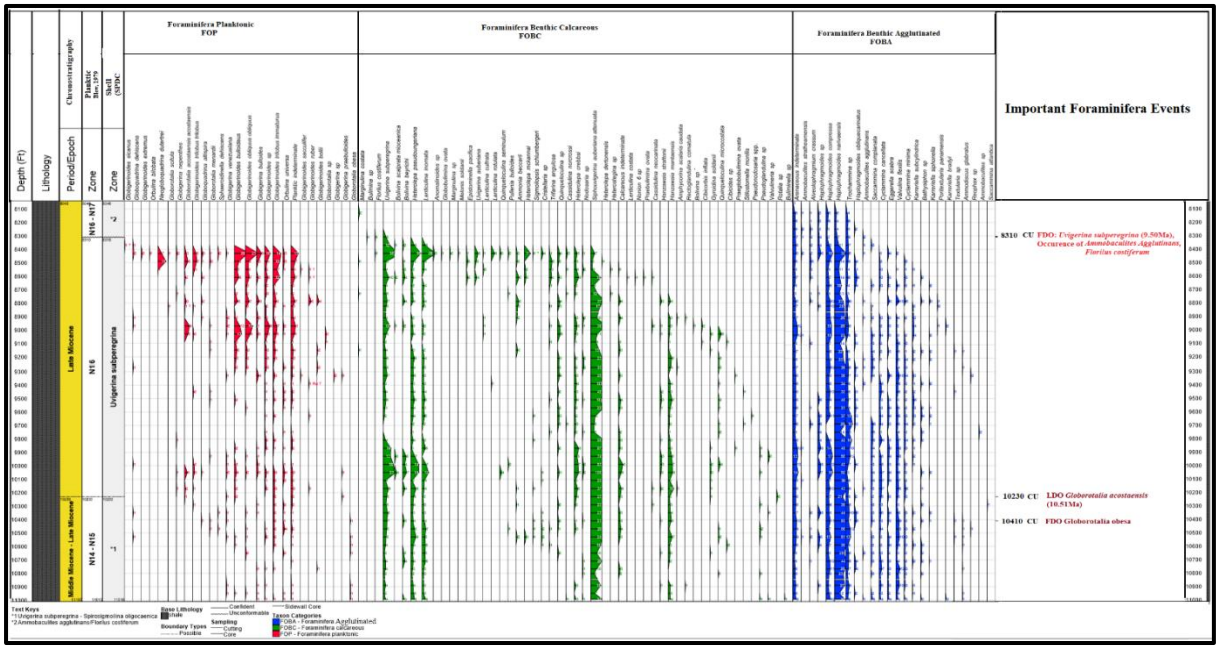

Figure 4: Foraminiferal distribution and foraminiferal zones recognized of well X-1.

Interval: 8,310 – 10,230ft.
Age: Late Miocene
Planktic Zone: N16
Zone: *Globorotalia acostaensis* concurrent range zone

This Interval age is characterized by moderate to abundant foraminifera species. Diagnostic foraminiferal species recorded include diverse planktic and benthic foraminiferal assemblage. However, arenaceous benthic foraminiferal species dominated the entire assemblage over this interval suggesting a Late Miocene age. Recorded planktic species include the followings: *Globoquadrina dehiscens, Globorotalia acostaensis, Neogloboquadrina dutertrei, Orbulina universa, Globigerinoides immaturus, Globigerinoides obliquus, Globigerinoides bulloideus, Globigerinoides trilobus, Globoquadrina altispira, Globigerina bulloides,*

Globorotalia menardii, Globigerina venezuelana, Globigerina praebulloides, Globigerina nepenthes, Globorotalia scitula, Sphaeroidinella dehiscens, Globigerinoides sacculiferus, and *Globigerinoides bolli.*
Calcareous benthic foraminiferal assemblage over this interval includes : *Uvigerina subperegrina, Lenticulina inornata, Siphouvigerina auberiana attenuata, Florilus costiferum, Trifarina angulosa, Ammonia beccarii, Heterolepa pseudoungeriana, Epistominella pacifica, Marginulina costata, Bolivina beyrichi, Cassidulina norcrossi, Cassidulina neocarinata, Hanzawaia mantaensis, Hanzawaia strattonii, Amphycorina scalaris caudata, Bolivina scalprata miocenica, Heterolepa crebbsi, and* Gyroidina soldanii. Associated arenaceous species that characterized this interval include *Haplophragmoides narivaensis, Cyclammina cancellata, Cyclammina minima, Haplophragmoides compressa, Valvulina flexilis, Eggerella scabra, Saccammina complanata, Poritextularia panamensis, Haplophragmoides obliquecarinatus, Ammabaculites strathearnensis, Karreriella subcylindrica, Bathysiphon sp, Karreriella siphonella, Ammodiscus glabratus and Ammobaculites agglutinans.*
The First Downhole Occurrence of *Uvigerina subperegrina* at the top of this zone, confirms a Late Miocene age at this depth, while the Last Downhole Occurrence of *Globorotalia acostaensis* at the base of the zone (10,230ft.) also indicates a Late Miocene age for this zone.

Table 1: Foraminiferal zones of this study in comparison with planktic zones of Blow (1969)

Depth (ft)	Epoch/Period	Age (Ma)	Planktic Zones (Blow 1969)	Zones (this study)	Significant Foraminiferal datums
8,040			First sample analyzed		
8,040 -8,310	Late Miocene	6.0 – 9.5	N17 – N16	*Uvigerina subperegrina*	Interval characterized by the occurrence of benthic marker species of *Ammobaculites agglutinans, Florilus costiferum* and FDO *Uvigerina subperegrina.* This suggests a Late Miocene age
8,310 – 10,230		9.5 – 10.51	N16	*Globorotalia acostaensis*	Interval characterized by FDO *Uvigerina subperegrina* and LDO *Globorotalia acostaensis*
10,230 – 11,010	Late Miocene - Middle Miocene	>10.51	N15 – N14	*Globorotalia obesa*	Interval characterized by Planktic specie LDO *Globorotalia acostaensis* and FDO *Globorotalia obesa*
11,010			Last sample analysed		

Interval: 10,230 – 11,010ft**.**
Age: Late – Middle Miocene
Planktic Zone: N15 – N14
Zone: *Globorotalia obesa / Eggerella scabra* concurrent range zone
Interval age was based on Last Downhole Occurrence of *Globorotalia acostaensis* at 10,230ft. and the First Downhole Occurrence of *Globorotalia obesa* at 10,410ft
Planktic assemblage recorded over this interval include: *Orbulina universa, Globorotalia obesa, Globigerina venezuelana, Globigerina bulloides, Globigerinoides bolli, Globigerinoides obliquus, Globoquadrina dehiscens, Globigerinoides immaturus and Globoquadrina altispira.* Associated Benthic assemblage over this interval includes: *Cyclammina cancellata, Cyclammina minima, Saccammina complanata, Haplophragmoides narivaensis, Haplophragmoides compressa, Haplophragmoides obliquecarinatus, Eggerella scabra, Valvulina*

flexilis, Siphouvigerina auberiana attenuata, Ammodiscus glabratus, Heterolepa pseudoungeriana, Hanzawaia mantaensis, Uvigerina subperegrina, Karreriella subcylindrica and *Heterolepa crebbsi.* First Downhole Occurrences of *Globorotalia obesa* at 10,410ft. suggests N15 –N14 zone at this depth.

The continuous occurrence of *Eggerella scabra* at 11,010ft suggests an age not older than Middle Miocene at this depth. The lower boundary of this zone is tentatively placed at the last sample analyzed (11,010ft, Terminal Depth).

4. Conclusion

Abundant and well preserved planktic and benthic foraminiferal species were recovered and used to establish three foraminiferal concurrent range zones were recognized and compared with planktic zones of [1], for age characterization. They are from top to bottom: *Uvigerina subperegrina*, *Globorotalia acostaensis* and *Globorotalia obesa / Eggerella scabra* concurrent range zones corresponding with N17-N16, N16 and N15-N14 respectively. These zones were used to constrain the age from Middle to Late Miocene epoch. Therefore, the studied interval (8040-11010) ft. of well X-1 range from Middle to Late Miocene age.

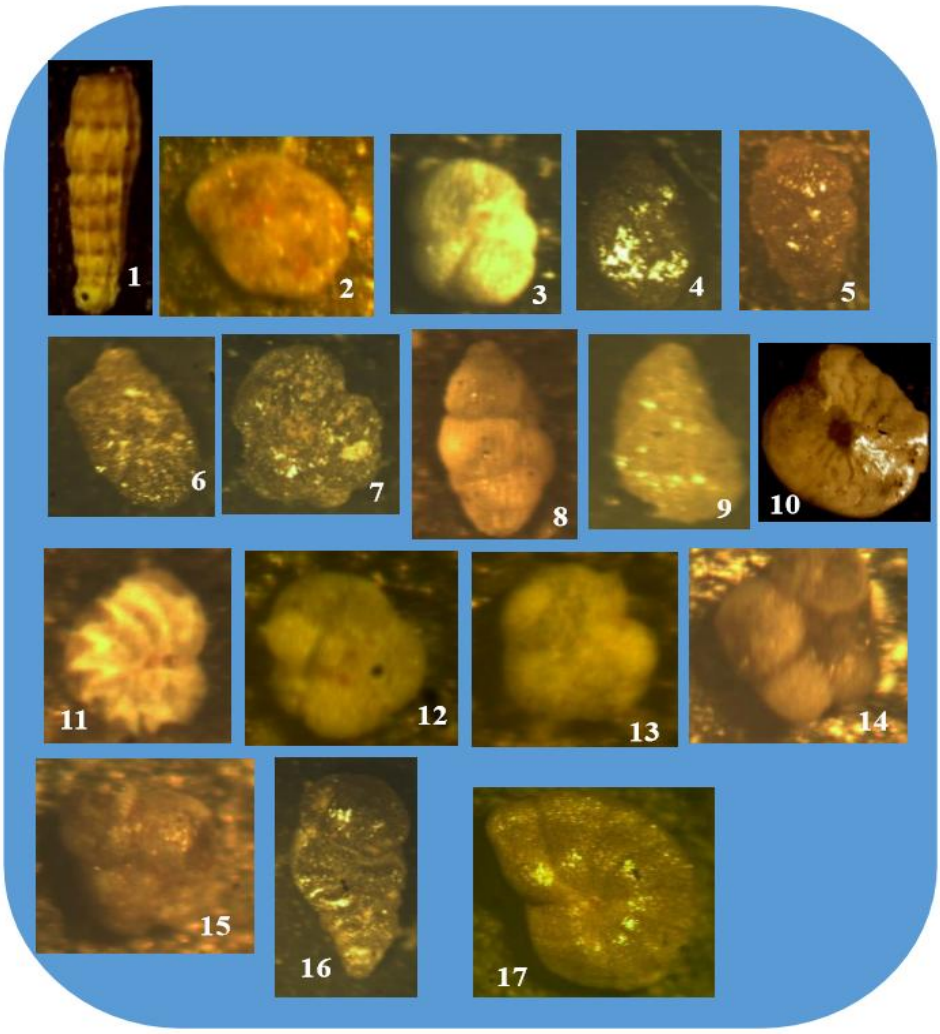

Plate 1: photomicrographs of some recovered foraminifera in well X-1

1. *Marginulina costata* 2. *Haplophragmoides compressa* 3. *Globigerina nepenthes* 4. *Cyclammina minima* 5. *Eggerella scabra* 6. *Ammobaculites strathearnensis* 7. *Haplophragmoides narivaensis* 8. *Uvigerina subperegrina* 9. *Ammobaculites agglutinans 10. Amphistegina lessonii* 11. *Florilus costiferum* 12. *Globorotalia acostaensis* 13. *Globorotalia acostaensis* 14. *Globorotalia obesa* 15. *Globorotalia obesa* 16. *Valvulina flexilis* and 17. *Cyclammina cancellate.*

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