HIGH RESOLUTION CALCAREOUS NANNOFOSSILS BIOSTRATIGRAPHY OF THREE WELLS 1, 2 AND 3 IN NORTHWEST OFFSHORE NIGER DELTA, NIGERIA

BY

JANET ADERONKE COLE

B.TECH (Minna), M.Sc (Ibadan)
MATRIC. NO: 102250

A Thesis in the Department of Geology,

Submitted to the Faculty of Science

In partial fulfilment of the requirements for the Degree of

MASTER OF PHILOSOPHY

of the

UNIVERSITY OF IBADAN

APRIL, 2023

CERTIFICATION

I certify that this work was carried out by Mrs J. A. Cole in the Department of Geology, University of Ibadan, Ibadan, Nigeria

……..

Supervisor

O. C. Adeigbe,
B.Sc. (Hons) (Ibadan), M.Sc., Ph.D. (Ibadan)
Senior Lecturer, Department of Geology,
University of Ibadan, Nigeria

DEDICATION

This dissertation is devoted

to the

Almighty God

'*who uses the basket to fetch water in order to disgrace the bucket'*.

ACKNOWLEDGEMENTS

Glory, honor and thanksgiving be to you oh Lord. Without you, it wouldn't have been a reality. To think that I almost gave up on the program, but grace kept me. Thank you Lord.

My sincere appreciation goes to my supervisor, Dr. Christopher Adeigbe, I could not have asked for a better supervisor. Your patience, advice and input went a long way in making this work a reality. Your guidance, constructive criticism and suggestions made my work better. The support and contributions of all my highly respected lecturers is greatly appreciated. The support and understanding shown by all the non-teaching staff of the Department of Geology is also acknowledged.

To my Boss, Mr. Wale Yussuph, I can not thank you enough; you are so easy and accessible. Thanks for all that you do sir. To the entire staff of Earthprobe Nigeria Limited, I say God bless you. Rev. Dr Victor Bamidele Akerele, I will be forever grateful for the encouragement you gave me when I needed it.

To my darling and loving husband, Victor Olakunle Cole, thanks for been there for me always. You are God sent. Your encouraging words and financial support is second to none. God bless you for me. Finally, to my miracle, Victoria Iseoluwa Cole. I am blessed and honored to be enjoying the joy of motherhood through you.

ABSTRACT

Over the years, various biostratigraphic approaches (foraminifera, pollen and spores) have been used for determining age and biozonation which are useful for exploration and production activities in the Niger Delta. However actual age determination and refined zonation of the deep offshore Niger Delta area have not been achieved. Hence the need to determine the litho-stratigraphic sequence, age of the strata and a sequence stratigraphic frame work for the Paleogene – Neogene section of the Niger Delta. This study was therefore designed to establish absolute age using calcareous nannofossils for the sediments penetrated by three Wells 1, 2 and 3 in Northwest offshore Niger Delta.

Five hundred and ninety nine ditch cuttings (599) from three wells (1, 2, 3) offshore Niger Delta were lithologically examined and lithofacies delineated. Slides from the ditch cuttings were prepared using standard procedures and studied using light microscopy. The abundance and diversity of the markers of the calcareous nannofossils were identified using standard procedures and were used for precise zonal delineation and recognition of dated events.

Greyish to brownish shale, silt and mudstone intercalated with coarse to medium and fine-grained sand beds were identified. Forty-one calcareous nannofossil species identified confirmed Early Paleocene to Early Pliocene age (NP3-NN15 zones) for the three wells. Well 1 penetrated Middle Miocene to Early Pliocene (NN7-NN15 zones); Well 2 was restricted to Early to Late Miocene age (NN3-NN11), while Well 3 encountered the Early Paleocene (NP3-NN4 zones). Established on the first and last appearances of the marker species as well as their relative abundances three major zones (NN7-NN8, NN9-NN10, NN10 and Younger) four major zones (NN3-NN4, NN7, NN8-NN10, NN11) and three major zones (NP3-NP6, NP14-NP21, NN4) were identified for well 1, 2 and 3 respectively. The acme events of *Discoaster prepentaradiatus, Catinaster coalithus, Discoaster kugleri, Helicosphaera ampliaperta, Helicosphaera scissura, Pemma basquensis and Chiasmolithus daniscus* were associated with the 8.80, 9.50, 12.18, 14.20, 15.60, 32.47 and 64.75 Ma maximum flooding surfaces, respectively. The correlation of the three wells showed basin-ward younging direction and two zones recognized in wells 1 and 2 (NN7 and NN8) belonging to the Late Miocene age was confirmed.

The established zonation scheme for Wells 1, 2 and 3 subdivided the offshore Niger Delta Paleocene to Pliocene sequence into zones, subzones and lithostratigraphic sequences and hence the absolute age determined.

Keywords: Biostratigraphy, Calcareous nannofossils, Paleocene to Early Pliocene, Maximum Flooding Surfaces.

Word count: 395

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

ABBREVIATION

Lowstand System Tracts	LST
Transgressive System Tract	TST
Highstand System Tract	HST
Low-stand sediments	LST
Gamma ray	GR
Condensed Sections	CS
Maximum Flooding Surface	MFS
Sequence Boundaries	SB
Transgressive Surface	TS
System tract	ST
Last Downhole Occurrence	LDO
Highstand Systems Tract	HST
First Downhole Occurrence	FDO
Total Depth	TD

CHAPTER ONE
INTRODUCTION

1.1 Background to the study

The study of Calcareous Nannofossils has many applications beyond expanding our knowledge on the diversity of life. They are useful in Biostratigraphy, paleoecology, paleobiography, tectonic study and oil exploration. Calcareous nannofossils serve as exceptional assemblage in delivering real time data due to minimal set-up time for their preparation and observation. They are also useful for exploration team in order to confirm and adjust to the drilling program. Calcareous nannofossils are tiny (30 micron) remains of golden brown calcareous algae. They are divided into coccolith and nannolith (Perch-Nielsen, 1985). Calcareous nannofossils are mostly accurate fossil assemblage for age and structural interpretation in the deepwater marine environments. They are exclusively marine fossils which are boosted by their short stratigraphic ranges resulting from the rapid evolutionary trends of many species. This is further aided by the speedy processing procedure that yields quick results for real time age determination. Resolution is thus of tens of thousands of years. Calcareous nannofossils are the most useful assemblage for Jurassic (approx. 210 myrs) to Recent sediments in marine sediments, since their preparation is cheap and the stratigraphic resolution which can be reached with them is high. Seldom sediments can be seeped of calcareous particles, which also removes calcareous nannofossils (for instance in deep sea sediments). Although their use as environmental indicators is limited, while some species are known to be connected with warm or cold water masses. They remain mostly restricted to normal marine environments and have little tolerance for either turbidity or freshwater diluted environments (Hay et al., 1967).

The increasing high demands for hydrocarbon over the years in the world where oil accounts for nearly 35% of the global energy supply has pushed the oil and gas industry to more intensive research for hydrocarbon deposits especially in the extra

deep marine settings. Such efforts including the use of Calcareous Nannofossils for both exploration purposes as well as age dating has become essential.

Calcareous nannofossils are an excellent biostratigraphic tool because of their rapid evolution and geographic dispersal (their entire life cycle is in the photic zone of the ocean) as well as their varied and distinct morphologies. Another important thing is that they can be used to accurately predict overpressured zones in advance of the drill bit. Nannofossil analysis permit precise local, regional, and global time-stratigraphic correlation that help in hydrocarbon prospect and trend delineation, regional stratigraphic/geologic studies, and exploitation evaluations.

They can be examined shortly after being brought to the surface in drill cuttings. Well-site analysis permits immediate identification of stratigraphic levels, drilling objectives and diminishing drilling time. Study of nannofossils helps scientists recognize paleoenvironmental distributions, which in turn helps us interpret sequence stratigraphy and reconstruct the paleogeography and paleoclimate. Relatively little has been published about the paleogeographic distributions of calcareous nannofossils. Less is known about their exact paleoenvironmental preferences, although they have been shown occasionally to penetrate into shallow marine environments. Their main industrial application is their calibration to published time scales and sequence stratigraphic records, especially the association of high abundance with condensed marine sections. They are generally straightforward to study; they occur in a wide range of lithologies. They are typically present at abundance of millions of specimens per gram. The study of calcareous nannofossils represents a foremost instrument made use of by the biostratigrapher in the characterization of the reservoir strata and correlation in well site operation. The calcareous nannoplankton biostratigraphy is important in the accurate reconstruction of time of deposition at the basin scale and plays in the petroleum exploration successful work.

Niger Delta is a major hydrocarbon producing basin in Nigeria where intensive exploration and production activities have been on since early 1960's owing to the discovery of commercial oil at Oloibiri-1 well in 1956. Subsequently, our country has been evaluated as the sixth largest oil producing country in the world. This is with a

proven ultimate reserve of about thirty four billion barrels of oil and two hundred and sixty trillion cubic feet of gas.

Though, about 90% of the twenty six billion barrels recoverable oil reserve previously projected for the Niger Delta are said to have come from the onshore areas of Niger Delta. (Doust and Omatsola 1990).

Serious consideration has currently been focused to the offshore regions and so far, prospects have been encouraging. The advancement in deep-water drilling technology and various exploration techniques have aided this development.

Based on biostratigraphy three (3) key fossil groups are focused, they are pollen and spores, foraminifera and nannofossils. These three have proven very useful. The need for absolute age determination and refined zonation of the deep offshore Niger Delta area has made calcareous nannofossil very useful over other fossils, though they still complement each other. The usage of nannofossils in biostratigraphic studies is becoming increasingly important because of the following:

1) They are planktonic, abundant, short stratigraphic range, develop quickly and largely cosmopolitan.
2) Calcareous nannofossils can be studied from minute rock chips because of their small size.
3) They have fast processing (preparation) procedure that produces fast result especially where real time age determination is required.

1.2 Statement of the Problem

Over the years, various biostratigraphic approaches (foraminifera, pollen and spores) have been used for determining age and biozonation which are useful for exploration and production activities in the Niger Delta. However absolute age determination and refined zonation of the deep offshore Niger Delta area have not been achieved. Hence the need to determine the litho-stratigraphic sequence, age of the strata and a sequence stratigraphic frame work for the Paleogene – Neogene section of the Niger Delta. This study was therefore designed to establish absolute age using calcareous nannofossils for the sediments penetrated by three Wells 1, 2 and 3 in Northwest offshore Niger Delta.

1.3 Aim and Objectives of the Study

The main aims and objectives of the study are:

1) to identify the lithostratigraphic sequence(s) through lithologic description and well log interpretation of wells 1, 2 and 3.

2) to recognize and interpret the abundance of calcareous nannofossils of the sections penetrated by the three wells.

3) establish a biostratigraphic zonation using calcareous nannoffossils recovered from the wells.

4) consruct a sequence stratigraphic framework for the section penetrated by the wells.

5) to identify the age of the various calcareous nannoffossil species recovered from the sediments and carry out correlation of the three wells 1, 2 and 3 based on available information.

1.4 Location of the Study Area

Wells 1, 2 and 3 are situated in the offshore area of the Niger Delta, in the Northwestern Caostal Swamp Depobelt (Figure 1.1). Well 1 and 2 are development wells while Well 3 is exploratory well drilled by one of the International Oil Companies in OML 95. Name and the exact location of the well were not made available for proprietary reasons.

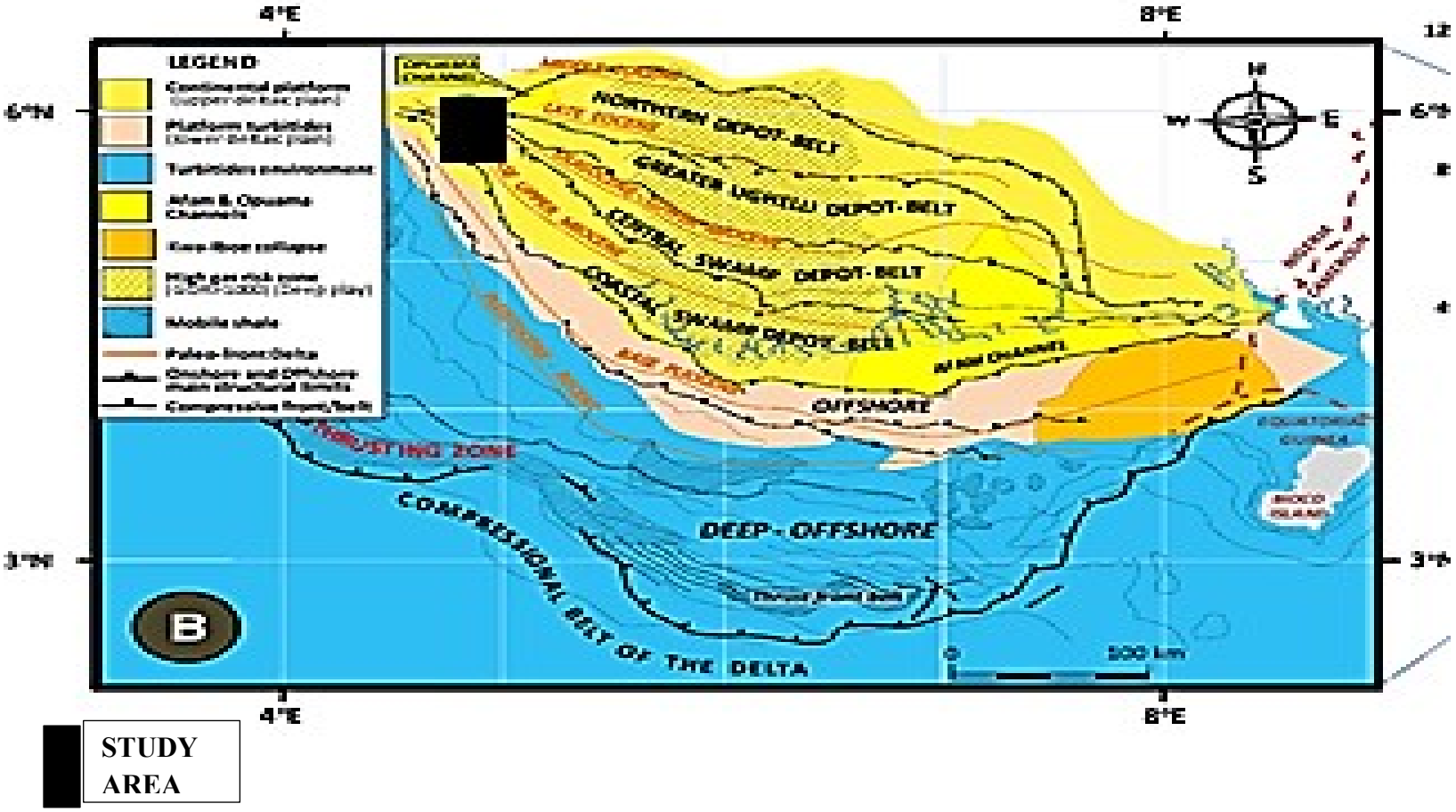


Figure 1.1: Map of Niger Delta area showing location of the study wells.

1.5 Previous Study

Niger Delta, a prolific petroleum province has been sub-divided/dated using various biostratigraphic approaches (foraminifera, pollen and spores). The use of calcareous nannofossils scheme has been limited due to its wide and long range zonation which affect its use for local high resolution biostratigraphy especially in the offshore depobelt. Modern studies on calcareous nannofossils began with the work of Matini and Bramlette (1963). This was carried out on some deep sea samples of Neogene age. The first standard zonation scheme for the Neogene was published by Matini and Worsley (1970). The works of Martini (1971) and Okada and Bukry (1980) remained classical nannofossils zonation schemes which had been applied as a frame work for most nannofossils work worldwide.

Reijers, (2011) wrote on the Stratigraphy and sedimentology of the Niger Delta. He opined that during the Cenozoic, until the Middle Miocene, the Niger Delta grew through pulses of sedimentation over an oceanward-dipping continental basement into the Gulf of Guinea; thereafter progradation took place over a landward-dipping oceanic basement. A 12,000m thick succession of overall regressive, offlapping sediments resulted that is composed of three diachronous siliciclastic units: the deep-marine pro-delta Akata Group, the shallow-marine delta-front Agbada Group and the continental, delta-top Benin Group. Regionally, sediment dispersal was controlled by marine transgressive/regressive cycles related to eustatic sea-level changes with varying duration. Differential subsidence locally influenced sediment accumulation. Collectively, these controls resulted in eleven chronostratigraphically confined delta-wide mega-sequences with considerable internal lithological variation. The various sea-level cycles were in or out of phase with each other and with local subsidence, and interfered with each other and thus influenced the depositional processes. At the high inflection points of the long-term eustatic sea-level curve, floodings took place that resulted in delta-wide shale markers. At the low inflection points, erosional channels were formed that are often associated, downdip, with turbidites in low-stand sediments (Lowstand System Tracts (LSTs).

The megasequences contain regional transgressive claystone units (Transgressive System Tract (TST) followed by a range of heterogeneous fine-to-coarse

progradational or aggradational siliciclastic (para) sequence sets formed during sea-level high-stand (Highstand System Tract (HST). Short and Stauble (1967) presented a detailed work on the subsurface lithostratigraphy of the Niger Delta. They established a threefold lithostratigraphic subdivision in the subsurface of the delta. They are from the oldest to the youngest, Akata Formation which is predominantly composed of marine shales, sandy and silty beds, which are thought to have been laid down as turbidites and continental slope channel fills. This formation has high organic content and it constitutes the major source rock in the Niger Delta. Overlying this formation is the Agbada Formation consisting of interbedded sand with minor shales and lastly the Benin Formation comprising of massive continental sands and gravels, accounting for about 90% of all the lithofacies with a few shale intercalations, which becomes more abundant toward the base. Adeyilola (2017) worked on Intergrated Subsurface Evaluation of 'Doyin' Field, Shallow Offshore Niger Delta, Nigeria. He said Niger Delta basin is ranked among the world's prolific hydrocarbon provinces. The structures, stratigraphy, and traps could be very subtle and complex and are therefore, difficult to map accurately. The degree of reliability and precision of the mapping can be greatly enhanced by integrating seismic data with well logs for hydrocarbon exploration and field development studies. Seismic data and well logs were integrated to delineate the subsurface geometry, stratigraphic framework, and hydrocarbon trapping potential of 'Doyin' Field, offshore Niger Delta, Nigeria.

The objective of this study is to utilize seismic data to image subsurface geology for hydrocarbon exploration and estimate the amount of hydrocarbon resources in place. Seven reservoirs were correlated, mapped, and analyzed for their varying petrophysical parameters using wireline logs. Seismic attribute analysis was used to enhance the quality of interpretation in all reservoirs mapped. Structure contour maps were generated in time and depth domain for the reservoirs and closures were delineated. This study also utilizes the various seismic attributes to investigate structural and stratigraphic elements within the study area to delineate lithology and hydrocarbon.

The trapping mechanism is mainly fault dependent and the accumulations are mainly on the hanging wall of an antithetic fault. Structural style is dominated by two parallel structure-building normal faults trending through the entire field.

Hydrocarbon discovery in this field is estimated at 13.70 BCF for gas and 22.12 MMBO for oil. Obaje, (2014) studied Sequence Stratigraphic Interpretation of Kafe-1 Field, Offshore Western Niger Delta, Nigeria. The principal aim of the paper is to present a sequence stratigraphic interpretation utilizing data sets from biostratigraphic, well logs and seismic. Five (5) wells studied in the area with the following distributions of sequences: Kafe-1-1 well (5 sequences), Kafe-1-2 (6 sequences), while Kafe-1-4, Kafe-1-5 and Kafe-1-6 wells have 4 sequences, respectively. Candidate for maximum flooding surfaces delineated with interpreted gamma ray and resistivity well logs and seismic data were established using biostratigraphic data. Sequence stratigraphic interpretation and correlation of the five wells were performed and the chart produced is useful in further deepening the knowledge of the subsurface geology of the Niger Delta area of Nigeria.

Adegoke, (2002) stressed the value of high resolution biostratigraphy, sequence stratigraphy and 3-D modeling, describing them as indispensable tools for exploration and production activities in the new Millennium. He suggested that the Nigerian oil industry needs to learn from the Gulf Coast experience by subjecting all old well data to re-interpretation so that a chronostratigraphic scheme can be evolved for the entire Niger Delta. He stressed the importance of calcareous nannofossils study which is been currently neglected by most companies noting that it allowed refinement at levels previously unimagined, thus making accurate ties of local sequences to regional and global bio-and chronostratigraphic schemes possible and greatly enhancing correlation. Adegoke et al., (1976) presented a benthonic foraminifera biofacies of the delta. Agagu, (1981), Petters, (1982, 1983), Berggren (1960), Ozumba, (1995) and Okosun and Liebau, (1999) recognized the Danian age for the sediment on the basis of *Globorotalia pseudobulloides, Globigerina triloculinoides, Globigerinoides daubjergensis* assemblages and assigned a lower Paleocene age to it. Avbovbo, (1978) described the stratigraphic and unconformity traps of the Niger Delta, while Ogbe, (1982) established the Paleoecology of the Western Niger Delta using foraminifera. He also identified those regressive phases on the basis of Microfauna and flora in the Niger delta.

Ojo (1996), worked on the biozonation and paleoecology of the Neogene foraminifera of the Central Niger Delta basin. He identified four major biozones within two

temporal epochs. The *Quinqueloculina seminulum Ammonia beccarii* zone was delineated in the late Pliocene and the *Haplophragmoides bradyi Cyclammina cancellata* zone in the early Miocene. The fauna and sedimentological evidences from his work showed that, the environment of deposition varied from a shallow marginal marine environment, (where warm water temperature prevailed in some parts, with varying amount of dissolved oxygen) to outer neritic zone.

Armentrout *et al.* (1990) described the integration of wire line log and paleobathymetric data with microfossil abundance patterns which are useful for locating condensed sections and sequence boundaries and for diagnosing Systems Tracts. He described sequence stratigraphy of the tertiary of the North Central Gulf Coastal Plain: What goes on between the seismic reflectors. He explained seismic stratigraphy and its more generic cousin, sequence stratigraphy, have revolutionalized the study of stratigraphy and depositional environments in the past decade. The concepts neglected or abandoned because they were ahead of their time in a pre-vailian era have been revived to understand better and explain stratigraphic and depositional concepts, while seismic stratigraphy enables a broad view, translating the specific wiggle to a bedding plane contact has been (and remains) a subject of strong controversy.

Adeigbe and Ochigbo, (2017) worked on Biostratigraphy of Ochigbo –1 Well, Offshore Niger Delta; Evidence from Foraminifera, Spores and Pollen. This study involved the palynological and micropalaeontological studies of Ochigbo – 1 well, offshore Niger Delta. The recovered palynomorphs were used in establishing four palynological zones. These are: *Crassoretitriletes vanraadshooveni*/P700 Zone dated middle Miocene; *Magnastriatites howardii*/P600 Zone dated Early Miocene – Late Oligocene; *Retibrevitricolporite obodoensis/protudens*/P500 Zone dated Late – Early Oligocene and *Racemonocolpites hians/*P400 Zone. The recovered foraminferal assemblages revealed the well to have penetrated through the N16-N15 (*Uvigerina subperegrina*) Zone (Late – Middle Miocene), N15-N14 (*Spirosigmolina oligocaenica*) Zone; dated Middle Miocene; N13-N11(*Uvigerina sparsicostata*) Zone; dated Middle Miocene; N5-N4 (*Megastomella africana*) Zone: dated early Miocene; N2 (*Spiroplectammina wrightii*) Zone; dated Late Oligocene; P18-P15 (*Hopkinsinna bononiensis*) Zone; dated Early Oligocene; P14-P12 (*Uvigerina hourqi*) Zone; dated

Late Eocene; P12 (*Uvigerina havanensis*) Zone; dated Late – Middle Eocene; P5-P6/P7 (*Lenticullina pseudomamillegarus*) Zone; dated Early Eocene – Late Palaeocene and ?M18 (*Bolivina afra)* Zone; dated Maastrichtian – Late Campanian. The palaeoclimatic investigation from the recovered palynomorph and foraminifera assemblages revealed dominantly wet climatic environment which ranges from brackish to deep marine environments subjected to trangressive – regressive alternating environment covering Inner Neritic to Upper Bathyal settings. Gallagher (1990) and Farinaciari and Rio, (1996) also presented quantitative stratigraphic studies on calcareous nannofossil of the Tertiary age. Stradner, (1959) first reported the Discoasters of the Tertiary in Austria, the unpublished research works of Oyebamiji (1997),

Fadiya (1999) and Akindipe (2003) comprise systematic calcareous nannofossils Biostratigraphic studies of some Niger Delta wells which were subdivided using the globally recognize zones of Martini and Bramlette (1963) Matini and Worsely (1970) and Matini (1971), Okada and Bukry, (1980) and Berggren et al (1985). Obaje et al, (2014), Ojo et al, (2009) having worked on calcareous nannofossil biostratigraphy of some fields, offshore Niger Delta, reported that the calcareous nannofossil biozones defined indicated various stratigraphic variations in some taxa in the studied wells in comparison to standard biozonation scheme of Martini (1971), Berggren et al, (1985) and Haq et al, (1988). They identified three calcareous nannofossil biozones which are *Calcidiscus premacintyrei* (Zone NN6-NN7), *Catinaster coalitus* (Zone NN8) and *Discoaster hamatus* (Zone NN9). These biozones are indicative of Middle to Late Miocene age for the well depth intervals. Sanuade (2014) studied nannofossil assemblages of Well 'K-2'situated in Deep Offshore Niger Delta, he identified two nannofossils zones (NN19 and NN18) which belong to the Pleistocene and Pliocene ages based on the standard zonation schemes of Martini (1971) and Gartner (1969) respectively. He also postulated two zones based on his study: (1) The *Gephyrocapsa carribeanica* zone and (2) *Gephyrocapsa parallela* zone. The Pleistocene portion of the well section based on this study was characterized by abundant and diverse occurrence of nannofossils.

The Pliocene portion of this interval was characterized by rare and scattered occurrences of nannofossils which preclude a definite zonal and age assignment to the

interval. Sanuade (2014), Fadiya (2008), in their study of the sediments of Wells Deep Offshore Niger Delta, using calcareous nannofossls biostratigraphic studies proposed several new local datums based on nannofossils assemblages for zonal boundary definition with some new zones and subzones erected resulting in the erection of a refined local zonation scheme suitable for use in the Niger Delta and adjoining Gulf of Guinea region. The study also revealed a weak development of calcareous nannofossils in the middle Miocene serravalian age of the deep offshore Niger Delta.

Ajayi et al (2014), reported that the nonappearance of the marker species (*Discoaster calcaris*) in the four wells A, B, C, D Offshore Niger Delta is in agreement with what exists in other previously studied wells in the Niger Delta. The workers adopted proxies for the original marker species at the intervals where marker species had rare or sporadic occurrences. They stated further that biostratigraphic work from the Gulf of Guinea around the coastal region of the Cote d'Ivoire - Ghana margin shows similar reports (Shafik et al 1998). Dairo and Oladiran (2016) work on systematic calcareous nannofossils Biostratigraphic studies of some Niger Delta wells which resulted in subdivision using the globally recognized zones of Martini (1971), Okada and Bukry (1980). Loutit *et al* (1988) worked on condensed sections: Key to age determination of continental margin sequences. He looked at the importance of the condensed section to sequence biostratigraphic. Ojo *et al* (2009), in their work on biozonation and correlation of BDX-1 and BDX-2 wells of deep offshore Niger Delta using calcareous nannofossils reported that certain variations occur in the stratigraphic ranges of some marker taxa in the deep offshore Niger Delta compare to those in the globally used zonation schemes of Matini (1971) and Okada and Burkry (1980). They were able to assign middle Miocene (NN6) – Early pliocene (NN13) to the two wells studied.

Fadiya (2008), reported through his unpublished Ph.d thesis that nannofossils biostratigraphic analysis of eight wells from the deep offshore Niger Delta revealed that abundant and diverse nannofossils occur in the Niger Delta Deepwater environment. He observed that certain variations occur in the stratigraphic ranges of some marker taxa in the deep offshore Niger Delta compared to those in the standard zonation schemes of Matini (1971) and Okada and Bukry (1980). He proposed several new local datums for zonal boundary definition with some new zones and subzones erected resulting in the erection of a refined local zonation scheme suitable for use in

the Niger Delta and adjoining Gulf of Guinea region. The study also revealed a weak development of calcareous nannofossils in the middle Miocene serravalian age of the deep offshore Niger Delta. The zones are *Catinaster coalitus* zone (NN8), *Discoaster hamatus* (NN9), *Discoaster loeblichi* which occupy the base of *Discoaster berggrenii* and the top of *Discoaster bollii* was used to identify the NN10 zone, (The main marker for this zone is *Discoaster calcaris).*

The need for locally refined nannofossils zonation scheme in the offshore Niger Delta becomes important because of the need for precise correlation of reservoirs within a field or basin as well as the basic demand for biostratigraphically aided exploratory drilling of thin channel reservoirs. The present study from the offshore Niger Delta therefore focuses on using high resolution calcareous nannofossils to subdivide the sequence penetrated into zones and subzones

CHAPTER TWO
LITERATURE REVIEW

2.1 Geology of Niger Delta Basin

The Niger Delta Basin is one of the largest Tertiary Delta systems which is believed to have resulted as a failed arm of the rift junction during the separation of the South Atlantic plate and the African plate, as the South Atlantic began to open. The coastal sedimentary basins (southern Nigerian basin) have experienced three main transgressive - regressive depositional cycles from its inception in Early Cretaceous time. This first cycle started during the Cretaceous and was terminated with a brief phase of folding in the Upper Cretaceous. The second included growth of a proto-Niger Delta in the Northern part of the basin and ended in a major Paleocene transgression. Lastly, the third from Eocene to Recent marked the continuous growth of the main Niger Delta.

2.2 Stratigraphy and Sedimentology of the Niger Delta

Throughout the Cenozoic, until the Middle Miocene, the Niger Delta grew through pulses of sedimentation over an oceanward-dipping continental basement into the Gulf of Guinea; thereafter progradation took place over a landward-dipping oceanic basement. A 12,000 m thick succession of overall regressive, offlapping sediments resulted that is composed of three diachronous siliciclastic units: the deep-marine pro-delta Akata Group, the shallow-marine delta-front Agbada Group and the continental, delta-top Benin Group. Locally, sediment dispersal was controlled by marine transgressive/regressive cycles related to eustatic sea-level changes with varying duration. Differential subsidence locally influenced sediment accumulation.

The various sea-level cycles were in or out of phase with each other and with local subsidence, and interfered with each other and thus influenced the depositional

processes. At the high inflection points of the long-term eustatic sea-level curve, flooding took place that resulted in delta-wide shale markers. At the low inflection points, erosional channels were formed that are often associated, downdip, with turbidites in Low-stand sediments (LSTs).

The Nkporo Shale and its adjacent equivalents, the Owelli sandstone and the Enugu shale resulted from the current marine transgression deposite. The marine Nkporo shale ranges from Campanian to Late Maastrichtian West of the Niger, In the East, the Maastrichtian is represented by deltaic deposits- the Manu formation; the Ajali sandstone and the Nsukka formation containing coal seams at several levels which are mined in Enugu area. (Table 2.1). Main stratigraphic unit of Paleocene age is the Imo shale, and it crops out in an arcuate belt from western to eastern Nigeria. The Imo shale is blue-gray, in a fairly sandy and commonly very fossiliferous. In western Nigeria, the Imo shale grades in part, into thick shelly limestone of the Ewekoro formation, which is mined for cement production.

Table 2.1: Table of Sedimentary Formations, Niger Delta Area (after Short and Sttauble 1967)

SUBSURFACE			SURFACE OUTCROPS		
Youngest Known Age		Oldest Known Age	Youngest Known Age		Oldest Known Age
Recent	Benin Formation {Afan Clay Member}	Oligocene	Plio/Pliestocene	Benin Formation	Miocene
Recent	Agbada Formation	Eocene	Miocene Eocene	Ogwashi-Asaba Formation Ameki Formation	Oligocene Eocene
Recent Agbada Formation Eocene			L.Eocene	Imo Shale Formation	Paleocene
			Paleocene	Nsukka Formation	Maestrichtian
EQUIVALENTS NOT KNOWN			Maestrichtian Campanian Campanian/Maestr-ichtian	Ajali Formation Mamu Formation Nkporo Shale	Maestrichtian Campanian Santonian
			Coniacian/Santonian Turonian Albian	Awgu Shale Eze Aku Shale Asu River Group	Turonian Turonian Albian

2.3 Stratigraphy of the Basin Centre

Short and Stauble (1976) and Frankl and Cordy (1967) provided the first information on the subsurface distribution of stratigraphic units in the Delta (Table 2.1). Reyment (1965) and Adegoke (1969) had previously established a stratigraphic distribution of surface outcrops of Tertiary rocks in Southern Nigeria. The Tertiary (Paleogene – Neogene) Niger Delta extends to an area of about 7500 square kilometers and is composed of an overall regressive clastic sequence. This spreads to a maximum thickness of 9,000 – 12,000m (30,000-40,000ft), on which expansion has been based on the balance between frequency of subsidence, the rate of sediment supply and accommodation creation. This balance and resulting sedimentary patterns seem to have been influenced by the structural configuration and tectonics of the basement.

The recent Niger Delta today, appears from sedimentological, faunal, and floral evidence, to have a configuration similar to those of the past. The physiography of the recent Niger Delta is governed by several factors, which influence transport, ultimate deposition of the sediment load and shape and growth of the Delta (Short and Stauble, 1967). Niger Delta may be divided into 3 main sedimentary environments: the continental, transitional and the marine environments.

The continental environment comprises the alluvial environments including the braided stream and meander belt system of the upper deltaic plain. The sediments deposited in this zone are predominantly sandy. Feldspar grains are fairly common and sandy grains commonly are limonite coated. Fine grained sediments (silt and clay) are deposited in the adjacent fresh water back swamps and ox-bow lakes together with large quantities of plant remains.

The transitional environment comprises the brackish water lower deltaic plain (mangrove swamp, flood plain, marshes) and the coastal area with its beaches, barrier bars and lagoons. The sediment in this environment is distinctly finer-grained than in the continental environment. Feldspar is scarce and brackish water faunas may occur.

The marine environment includes part of the delta fringe with its fine sand, silt and clay and the associated marine faunas. The environment grades laterally into the holo marine environments, which is not affected by deltaic activity. (Short and Stauble, 1967)

2.4 Sub-Surface Sedimentary Sequence

The modern Niger delta is underlain by a thick wedge of deltaic deposits of pre-Recent age, which represent the earlier phases (Eocene-Pleistocene) of this regression. In an advancing delta such as that of the River Niger, sediments of the three environments described above become stratigraphically superimposed. The submarine delta fringe will encroach on holo marine sediments and will in turn be covered by younger lower deltaic plain sediments, which subsequently will be overlain by the next younger upper deltaic plain sediments. The same sequence is found in the Niger delta subsurface but is modified by the numerous transgressions, which have occurred from time to time, breaking the continuity of the main overall regression. Thus, three lithographic units are recognized, namely, Akata Formation, Agbada Formation, and the Benin Formation (Fig 2.1 and Fig 2.2).

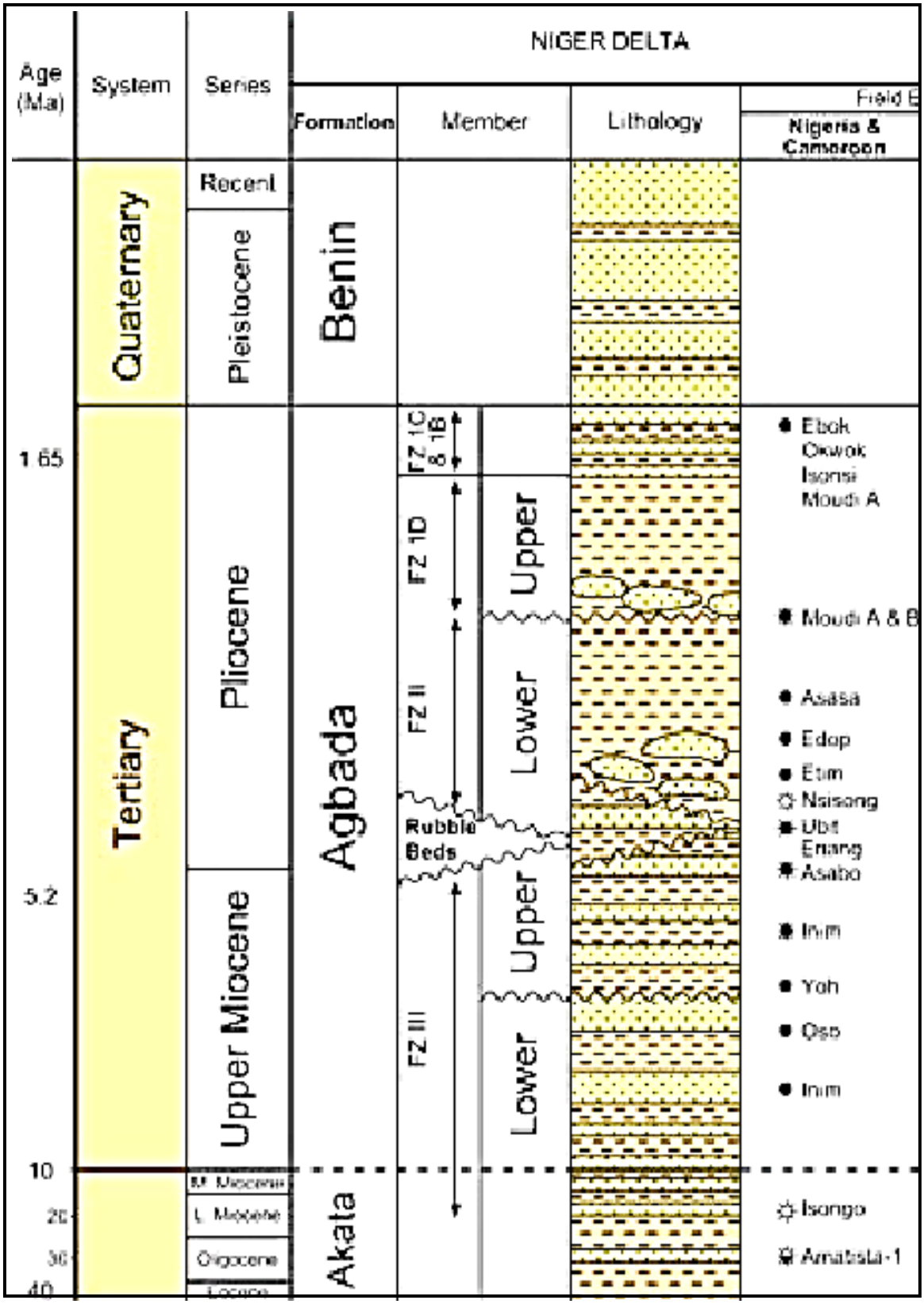


Figure 2.1: The Local Stratigraphy of Regressive cycle of the Niger Delta (Ajakaye et al., 2002)

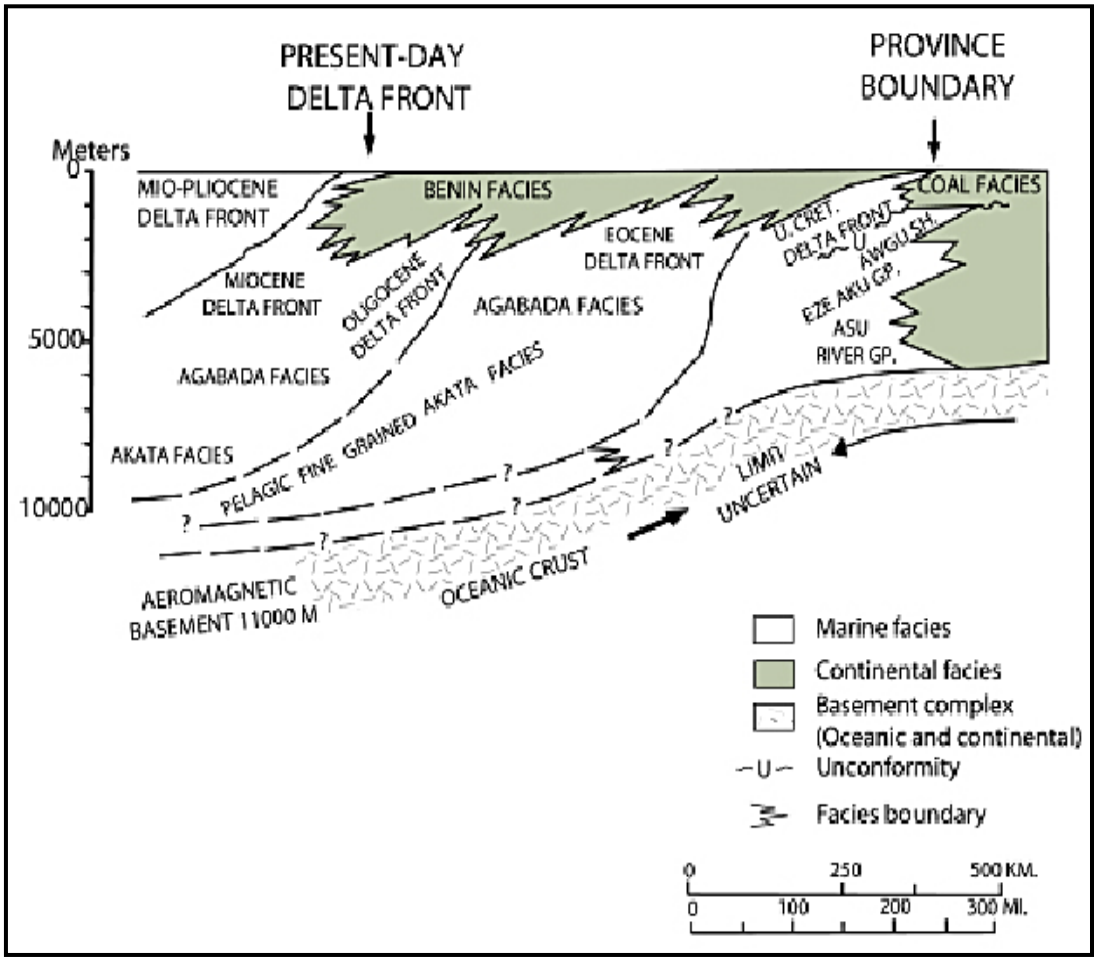


Figure 2.2: Cross Section through the Niger Delta Region. (Modified from Whiteman, 1982)

2.4.1. Akata Formation

This is the basal marine shale, 600 – 6000m (1969 – 19688ft) thick. It is characterized by a uniform shale development as evident in gamma ray (GR) and spontaneous potential (SP) logs. These pro-delta shales are medium to dark gray, moderately hard, at places soft, gumbolike, and sandy or salty. The shales are under-compacted and may contain lenses of abnormally high-pressured siltstone or fine-grained sandstone Short and Stauble (1967). According to Doust and Omatsola (1990), the Akata shales contain a few streaks of sand, possibly turbiditic origin and were deposited in holomarine (delta front to deeper marine) environments. Marine shales form the base of the sequence in each depobelt, and ranges from Paleocene to Holocene in age.

2.4.2. Agbada Formation

The Akata formation is overlain by a paralic sequence of inter-bedded sand and shale, 300 – 4500m (984 – 14766ft) thick, which is termed the Agbada formation (Fig.2.1 and 2.2). The alternating sequence of sandstones and shales of the Agbada formation has been shown by Weber (1971) to be cyclic sequence of marine and fluvial deposits, determined from electric-log patterns, well, cores and dipmeter data. The sandstones are fine to medium grained, fairly clean and locally calcareous, glauconitic, and shelly. They consist dominantly of quartz and potash feldspar with subordinate amounts of plagioclase, Kaolinite, and illite. The shales are medium to dark gray, fairly hard, and silty with local glauconite. The two contain mainly Kaolinite (average value, 75%) with small amounts of mixed layers of illite and montmorillonites. At the central part of the delta, the formation attains a maximum thickness of 3,940m (12,000ft) and thins northward and toward the north western and eastern flanks of the delta (Short and Stauble, 1967; Avbovbo, 1978)

2.4.3. Benin Formation

The shallowest unit of the sequence consists of fluviatile (nonmarine) gravels and sand. It was deposited in alluvial or upper coastal plain environments following a southward shift of deltaic deposition into a new depobelt. The oldest continental sands are probably Oligocene, although they lack fauna and are impossible to date directly. Offshore they become thinner and disappear near the shelf edge. (Fig.2.1 and 2.2). The formation comprises mostly massive, highly porous, fresh water bearing sandstones, with local thin shale inter-beds, which are considered to be of braided stream origin. Mineralogically, the sandstones consist dominantly of quartz and potash feldspar and minor amounts of plagioclase. Short and Stauble, 1967; Weber and Daukoru, 1975.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Materials and Methods

Five hundred and ninety nine (599) samples were obtained at intervals of 30ft (9.1m) each. The well within the intervals of 102-2112m of well 1, 253-1701m of well 2 and 1037-3243m of well 3 were investigated. The samples were packed in small polythene bags which bear the name of the well and sampling depth. The bags were arranged serially in a tray in laboratory for lithologic description and sample processing for calcareous nannofossil analyses. Materials used for this study was ditch cutting samples and well logs from offshore Niger Delta, Nigeria. The wells are code-named as wells 1, 2 and 3. These samples were supplied by Earthprobe Nigeria Limited.

3.2 Lithologic Description of Samples

The lithologic description of the samples was done using a stereo-binocular microscope. A lithostratigraphic description of the ditch cuttings revealed that the bulk of the lithofacies are shale, silt and mudstone which are grey to brown in colour, with intercalations of coarse to medium and fine grained sand beds.

The logs were interpreted for lithology. The lithologic interpretation depends on the API values of the Gamma ray (GR) logs, which range from 0 to 150. The higher the API value, the finer the sediments, and vice versa. High API values represent shale and low API value represents sands. The logs were all interpreted based on the API values discovered. (Detailed lithologic description of the analysed well section is presented as Appendix 2- 4).

A lithostratigraphic column for the well was then constructed and lithostratigraphic units penetrated by the wells delineated based on the lithologic description of the samples.

The three wells were logged and sampled at 9.1m intervals and processed for nannofossil analysis using the standard preparation method. The prepared slides were examined under transmitted light microscope. Detailed identifications were made with the aid of standard literatures. Fossils were recorded in the analysis sheet with other relevant information. The species name and abundance of each species with depths were used as input data into the Stratabug biostratigraphic software (V 2.1). The data were utilized and integrated in the age dating of critical horizons. From this data set, plots of population abundance and species diversity were made using the prepared checklists. (Figure 4.4-4.69) (Enclosures). The coincidence of these peaks guided the selection of the candidate maximum flooding surfaces, the positions of which were subsequently confirmed on the log.

Ages of penetrated sequences were monitored with the aid of calibrated bioevents. The zones were based on the first and last appearances of maker species as well as their relative abundances. In this way, the age of the encountered sequences is gotten. The supplied age from the bioevents provides useful tie points for correlation work. Age dating and biozonation are the basis on which every other biostratigraphic interpretations are based.

Dating is based on the fact that one microfossil group or another constitutes very good index fossils in every part of the Geologic Column. Once sequences are dated and zoned, the relationships of the encountered strata were deduced.

3.3 Sample Preparation and Precautions

Precautions are taken during sample preparation in the laboratory. This is to avoid sample mix-up and protect the workspace and avoid interference from other workers. Calcareous nannofossil biostratigraphy is carried out with utmost care as samples can easily get contaminated with just a drop of water. Disposable pipette is used in nannofossils sample preparation. The steps are summarized below:

1. 10gms of each sample were measured into a porcelain crucible and crushed gently.
2. The samples were put into a test tube
3. The samples were washed to remove drilling mud.
4. A few drops of distilled water were added into the sample in a test tube and mixed thoroughly and vigorously.

5. Sediments were drained out leaving behind as much quantity of grains as possible
6. Samples were mixed thoroughly and two drops were put using a pipette on a cover slip.
6. Samples were spread across cover slip and left to dry.
7. A drop of Norland Adhesive was put on the glass slide and the dried sample on the cover slip was gently and carefully placed.
8. The prepared slide was allowed to dry and ready for analysis.
9. All prepared slides were examined with the Olympus Photomicroscope at 1000X and 1500X magnifications under cross polarized and transmitted light.

CHAPTER FOUR

RESULTS AND DISCUSION

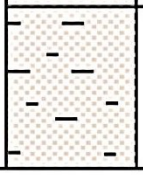
4.1. Lithologic Description of Wells 1, 2 and 3

The results of the Calcareous nannofossils biostratigrahy of wells 1, 2 and 3, OML 95 in the offshore North West Niger Delta are hereby presented below. This study covers an interval of 102-2112m of well 1, 253-1701m of well 2 and 1037-3243m of well 3 comprising 599 samples in all.

The lithology of the wells is described using the log Gamma ray signatures. The Gamma ray log which is one of the lithology logs describes accurately the type of lithology in the sub-surface. The lower the API values of the gamma ray log, the coarser the sediments. The interpretation of the gamma ray in this project assisted in the lithological analysis. The lithological analyses of the three wells are shown in the (Appendix 2 - 4).

4.1.1. Lithostratigraphy of Well 1

Sedimentological criteria including gamma ray log responses and sand/shale ratios indicate that well 1 encountered, within the studied interval, three (3) lithofacies unit of the Agbada Formation. These are the Paralic, Transitional Paralic and Continental Transitional Units as shown below:

Interval(m)	Formation	Lithology	Lithofacies Unit	Diagnostic Criteria
102 - 572	AGBADA		Continental - Transitional	▪Predominantly sand with few and thin shale bodies interbedded ▪Sand/shale ratio is approximately 90:10
572 - 1222			Transitional - Paralic	▪Frequent sand/shale alternations. ▪Sand/shale ratio is approximately 65:35
1222 - 2112			Paralic	▪Frequent sand/shale alternations. ▪Sand/shale ratio is approximately 55:45

LEGEND

Sand

Shale

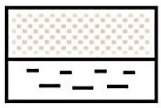


Figure 4.1: Lithostratigraphy of Well 1

Highlights of the lithologic characteristics of the analyzed section within the framework of the identified lithofacies units are as follows:

4.1.1.1 The Paralic Unit (2112 – 1222m)

This unit exhibits frequent sand/shale alternations and a sand/shale ratio of approximately 55:45. The shales are predominantly grey and brown in colour, blocky to flaggy and moderately hard. The sands are predominantly milky white to glassy, predominantly fine-grained, occasionally medium -grained, moderately- to well-sorted and sub-angular. The unit is characterized with rare and sporadic occurrences of mica flakes and shell fragments with scanty and rare occurrences of pyrite. The alternation of sands and shales over this unit is suggestive of frequently interchanging low and high depositional energy regimes which may be associated with the well-known frequent shifting of depositional axes in the Niger Delta. The index accessory minerals suite consisting of mica flakes and pyrite is suggestive of a coastal depositional environment for this unit. The unit exhibits sand bodies that present the hybrid funnel-bell Gamma Ray signature shapes.

4.1.1.2 The Transitional-Paralic Unit (1222– 572m)

This unit is dominantly composed of sands alternating with subordinate proportions of shales. Its sand/shale ratio is approximately 65:35. The sands are generally thicker than the shales. The shale is grey, brown and brownish red in colour. They are predominantly blocky to flaggy and moderately hard. The sands are milky white to glassy, predominantly fine, occasionally medium to coarse grained, moderately- to well-sorted, occasionally poorly sorted, predominantly sub-angular. The index accessories minerals recorded over this unit include rare but regular occurrences of mica flakes, less regular and rare occurrences of shell fragments and sporadic occurrences of pyrite. The alternation of sands and shales over this unit is suggestive of frequently interchanging low and high depositional energy regimes. This may not be unconnected with the well-known frequently shifting depositional axes in the Niger Delta.

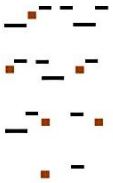
4.1.1.3 The Continental-Transitional Unit (572 – 102m)

This unit is predominantly composed of thick sand bodies which constitute approximately 90% of the unit. The remaining 10% is made up of shales/mudstones which occur as thin interbeds between the sands. The shales are grey, brown and reddish brown. They are predominantly blocky - moderately hard. The sands are whitish to glassy, predominantly fine, occasionally medium to coarse-grained, poorly to moderately sorted, occasionally sub-rounded, fairly regular mica flakes and pyrite as well as sporadic occurrences of ferruginous materials constitute the accessory minerals suite recorded over this unit.

The thin intervening shales/mudstones are probably indicative of short-lived periods of energy abatement. The mica flakes and pyrite recorded over the unit are probably associated with the short-lived low-energy regimes while the ferruginous materials may be related to periods of sub-aerial exposure.

4.1.2 Lithostratigraphy of Well 2

Sedimentological criteria including Gamma Ray log responses and sand/shale ratios indicate that Well 2 encountered, within the studied interval, three broad lithofacies units - the Continental-Transitional, the Marine and the Transitional Units, which are all ascribed to the Agbada Formation as shown below:

Interval (m)	Formation	Lithology	Lithofacies Unit	Diagnostic Criteria
253 - 808	AGBADA		Continental - Transitional	Sand/shale ratio of approximately 90:10. Sporadic occurrences of relatively thin mudstone/shale units.
808 - 1323			Marine	Sand/shale ratio of approximately 5:95 Few relatively thin snad/silt units.
1323 - 1701			Transitional	Sand/shale ratio of approximately 85:15 Thick sand units with relatively thin mudstone/shale bodies.

LEGEND

Sand

Shale

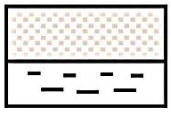


Figure 4.2: Lithostratigraphy of Well 2

Highlights of the lithologic characteristics of the analyzed section within the framework of the identified lithofacies units are as follows:

4.1.2.1 The Transitional Unit (1701 – 1323m)

This unit exhibits a sand/shale ratio of approximately 85/15. The sands are relatively thick while the mudstones/shales are thin and few. Predominantly whitish to glassy sand, occasionally brownish to pinkish, predominantly coarse to very coarse-grained and pebbly, occasionally fine to medium-grained, predominantly well sorted, occasionally poorly sorted (especially over the lower part). The mudstones/shales are greyish to brownish, occasionally reddish brown, predominantly blocky, occasionally platy and hard. The suite of index minerals recorded over the unit comprises fairly regular occurrences of few glauconite pellets and traces of ferruginous materials.

The high sand/shale ratio of 85/15 exhibited by the unit indicates that the unit is a product of high-energy sedimentation.

4.1.2.2 The Marine Unit (1323 – 808m)

This unit is predominantly shaly with few thin sand/silt bodies occurring towards the top. The sand/shale ratio is approximately 5:95. The sands are predominantly whitish whitish to glassy, fine to coarse and occasionally very coarse-grained, dominantly poorly sorted, occasionally well sorted, and sub-angular to sub-rounded. The mudstones/shales are greyish, occasionally reddish brown, predominantly blocky, occasionally flaggy to platy and hard. The interval is characterized by traces of ferruginous materials. The sands are whitish white to glassy, predominantly fine, occasionally medium to coarse-grained, moderately to well-sorted, occasionally poorly sorted, predominantly sub-angular to angular, occasionally sub-rounded.

Fairly regular occurrences of traces of ferruginous materials and shell fragments characterize the unit. In addition, the lower unit presents fairly regular occurrences of pyrite, mica flakes and sporadic occurrences of few to abundant glauconite pellets.

The sand/shale ratio of 5/95 suggests a predominantly low-energy sedimentation for this unit.

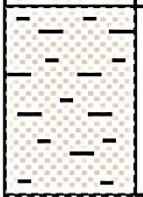
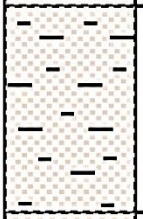
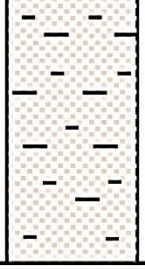
4.1.2.3 Continental-Transitional Unit (808 – 253m)

Ditch cutting descriptions alone provided the sedimentological basis for the lithostratigraphic characterization of this unit. Wireline logs were not available for the unit.

The unit presents primarily sandy character with a sand/shale ratio of approximately 90:10. The sands are predominantly whitish white to glassy, fine to coarse-grained, dominantly poorly sorted, occasionally well-sorted, predominantly sub-angular to sub-rounded, occasionally angular. The mudstones/shales are brownish, blocky and hard. The interval is characterized by traces of ferruginous materials.

4.1.3 Lithostratigraphy of Well 3

Sedimentological criteria including Gamma Ray log responses and sand/shale ratios indicate that the well 3 tested, within the studied interval, two broad lithofacies units - the Marine Paralic and the Marine Units, which are ascribed to the Agbada Formation as shown below:

Interval (m)	Formation	Lithology	Lithofacies Unit	Diagnostic Criteria
1037 - 1341	AGBADA		Upper Paralic	Sand/shale ratio of approximately 45:55 Frequent sand-shale alternations.
1341 - 1868			Marine-Paralic	Sand/shale ratio of approximately 30:70 Relatively thin sand/silt units intercalated with thickermudstone/shale units.
1868 - 2207			Lower Paralic	Sand/shale ratio of approximately 55:45. Frequent alternation of sands and mudstones/shales.
2207 - 3243			Marine	Sand/shale ratio of approximately 20:80. Generally thin sand/silt units intercalated with much ticker mudstone/shale units.

LEGEND

Sand

Shale

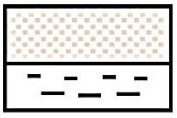


Figure 4.3: Lithostratigraphy of Well 3

Highlights of the lithologic characteristics interpretations of the analyzed section discussed within the framework of the identified lithofacies units are as follows.

4.1.3.1 The Marine Unit (3243 – 2207m)

This unit is predominantly shaly with few intercalated thin sand/silt bodies. It exhibits sand/shale ratio of approximately 20/80. Whitish to glassy sand, largely fine to coarse-grained, ill sorted and sub-angular to sub-rounded. The mudstones/shales are greyish to brownish, occasionally dark grey to black and dark brown, predominantly platy to blocky and moderately hard. The sand/shale ratio of 20/80, together with ubiquitous occurrence of pyrite may suggest that this unit was largely deposited in a low-energy environment, probably below wave base. The few sand bodies observed over the unit may, however, represent short-lived periods of energy burst within the otherwise quiet environment.

4.1.3.2 The Lower Paralic Unit (2207 – 1868m)

This unit exhibits sand/shale ratio of approximately 55/45. The unit shows frequent sand/shale alternations and a general thickening-downward sand profile. The sands are milky white to glassy, predominantly medium to very coarse-grained and pebbly, ill sorted and sub-angular to sub-rounded. The mudstones/shales are greyish to brownish, platy to blocky and moderately hard. The suite of index minerals recorded over the unit comprises regular occurrences of pyrite, iron rich materials, and spotty occurrences of mica flakes, carbonaceous detritus and glauconite pellets. The frequent sand/shale alternations of this unit are probably indicative of the well-known frequent shifting of depositional axis in the Niger Delta.

4.1.3.3 The Marine-Paralic Unit (1868 – 1341m)

This unit is predominantly shaly with few thin sand/silt bodies interbedded. It presents a sand/shale ratio of approximately 30/70. Whitish white to glassy sands, predominantly fine to medium-grained, occasionally coarse-grained, dominantly poorly sorted, occasionally moderately-sorted, and sub-angular to sub-rounded. The mudstones/shales are greyish to brownish, occasionally reddish brown, predominantly blocky, occasionally platy and hard. The accessory minerals suite recorded over the

unit comprises regular occurrence of ferruginous materials, fairly regular occurrences of carbonaceous detritus, shell fragments, mica flakes, and very rare occurrences of pyrite and glauconite pellets.

4.1.3.4 The Upper Paralic Unit (1341 – 1037m)

This unit presents frequent sand/shale alternations and sand/shale ratio of approximately 45/55. Whitish to glassy sands, slightly calcareous, predominantly fine-grained, occasionally medium grained and slightly pebbly, moderately to well sorted, occasionally poorly sorted, and sub-angular to sub-rounded. The mudstones/shales are greyish to brownish to occasionally reddish brown, blocky and hard. The unit is characterized by regular occurrences of ferruginous materials and shell fragments, fairly regular occurrence of mica flakes over the basal section, and sporadic occurrences of pyrite. The frequent sand/shale alternations of this unit are inferred to reflect the well-documented frequent shifting of depositional axis in the Niger Delta.

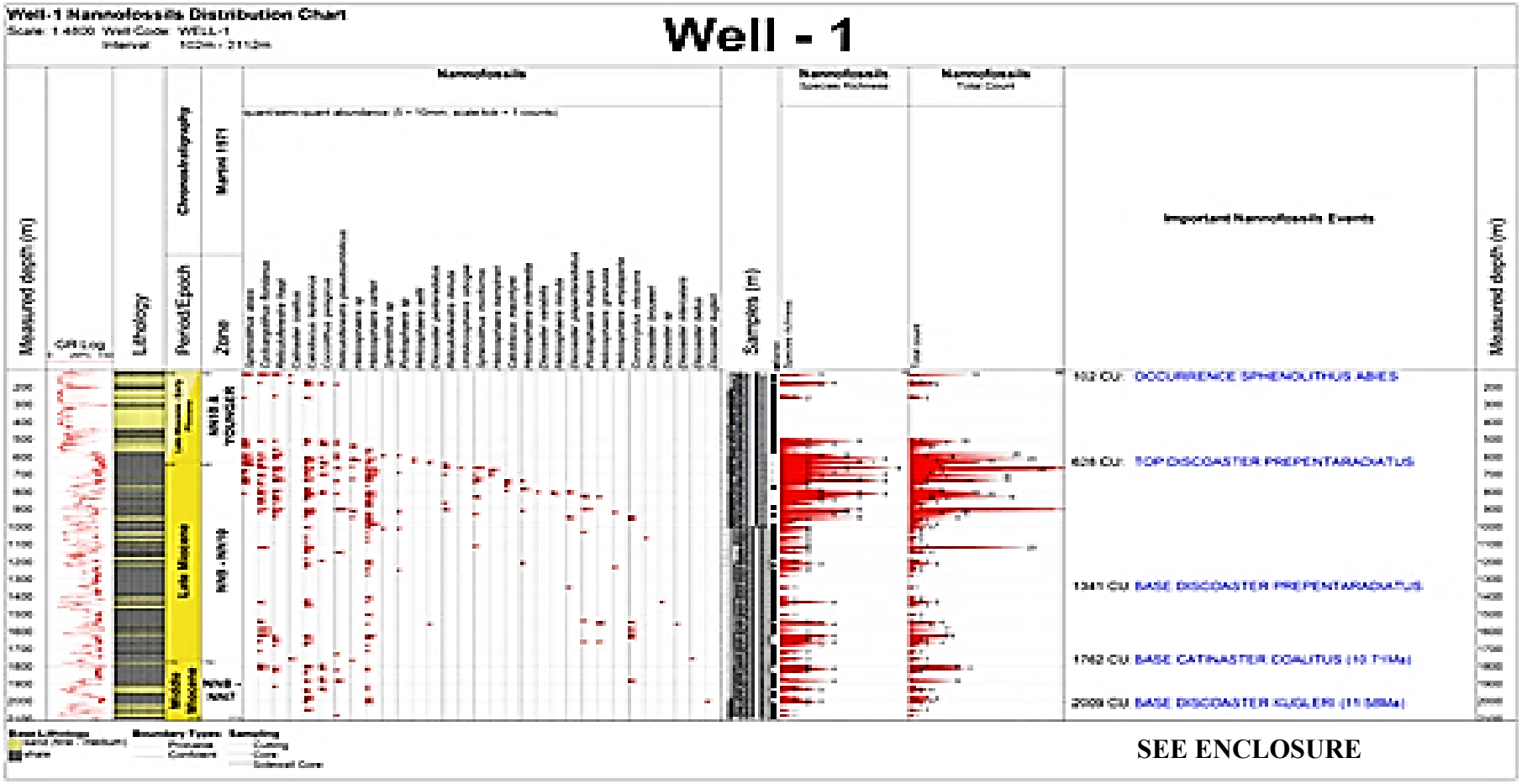


Figure 4.4: Nannofossils Biostratigraphic Disribution Chart of Well 1

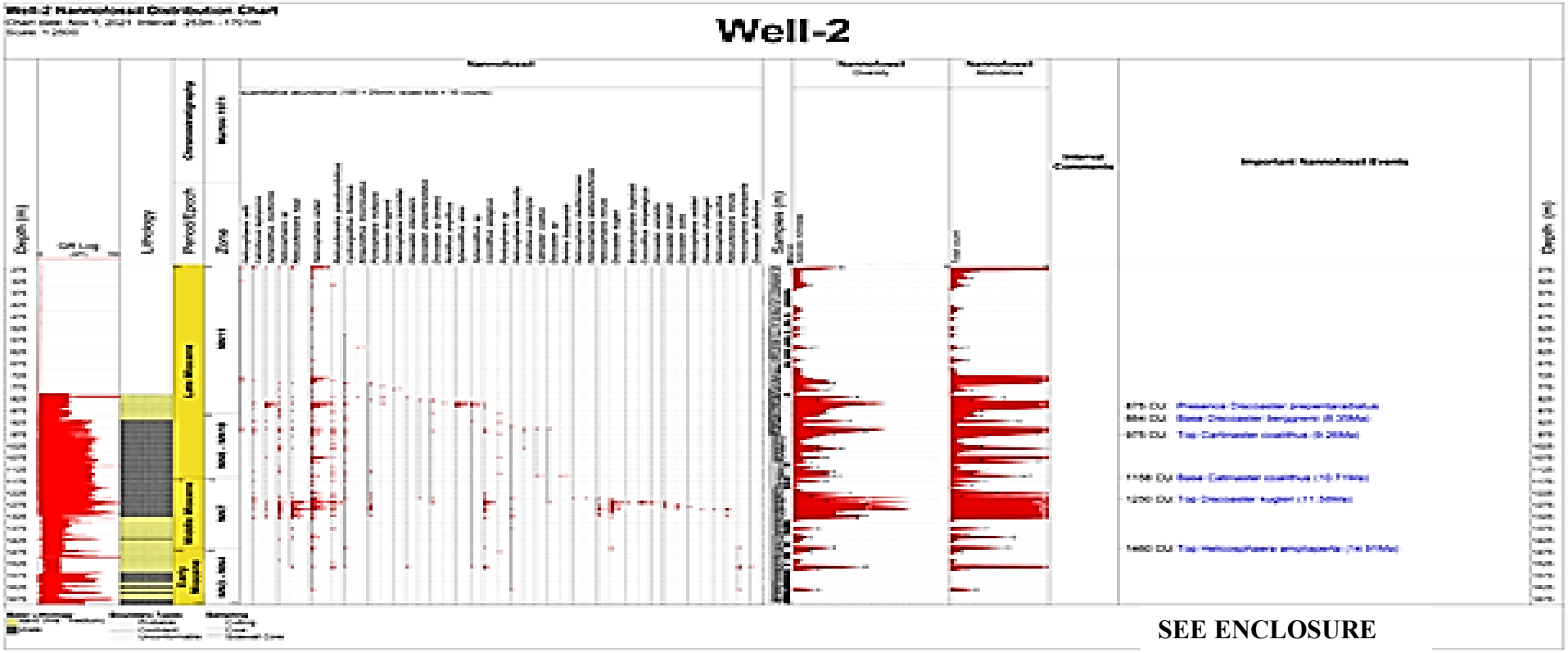


Figure 4.5: Nannofossils Biostratigraphic Disribution Chart of Well 2

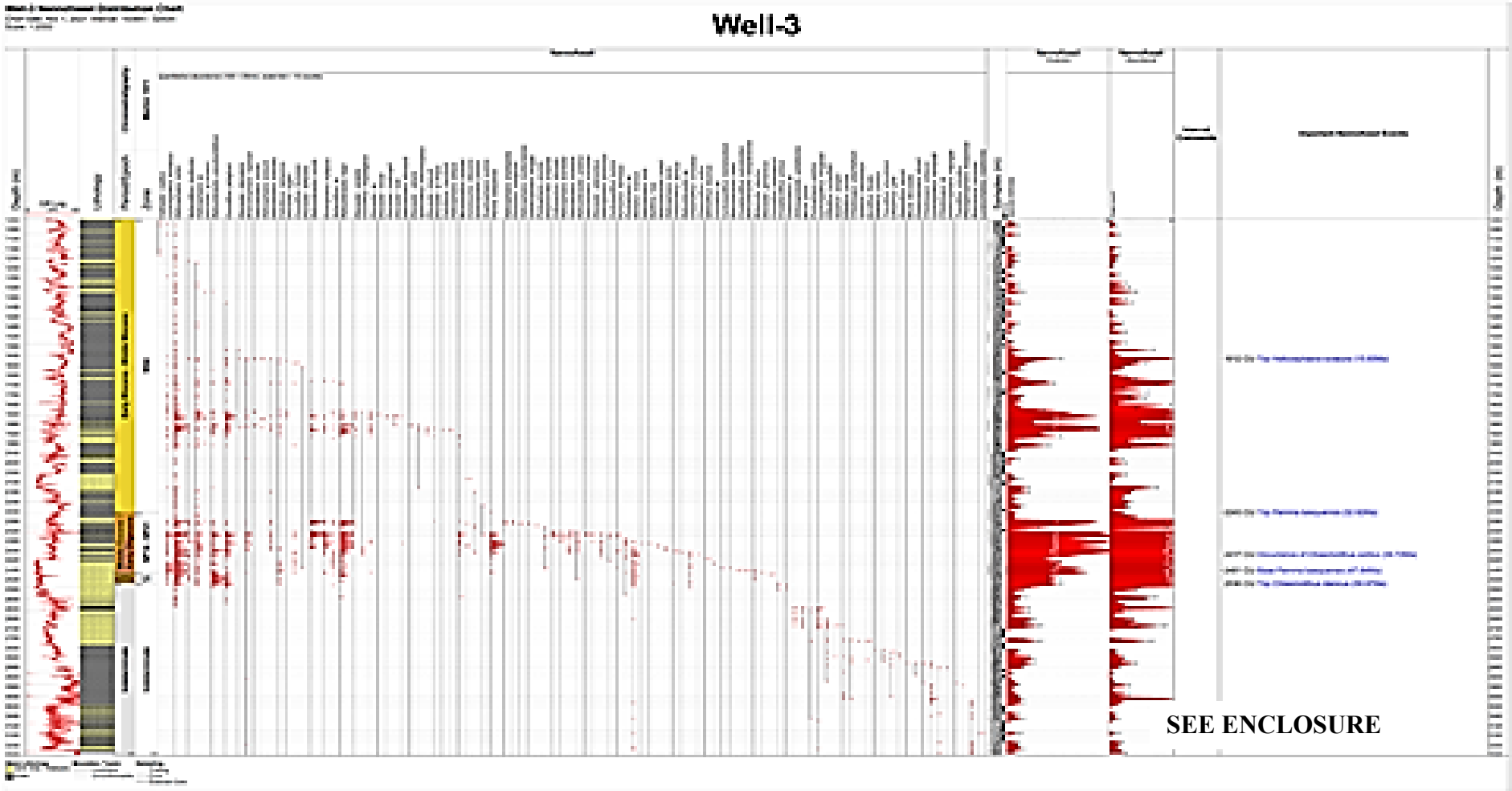


Figure 4.6: Nannofossils Biostratigraphic Distribution Chart of Well 3

4.2 Calcareous Nannofossil Zonation for Well 1

Two hundred and twenty one (221) nannofossil slides prepared from interval 102 – 2112m of well 1 were provided for calcareous nannofossils analysis.

The result of the analysis shows that the analyzed interval is characterized by moderate to sparse nannofossils record. Moderate and diverse nannofossil characterized the middle part of the well, while the top recorded sparse to barren nannofossils species.

Some of the nannofossils that characterized this interval include *Discoaster prepentaradiatus, Reticulofenestra pseudoumbilicus, Catinaster coalithus, Sphenolithus abies, Helicosphaera selli, Sphenolithus moriformis, Discoaster variabilis, Helicosphaera minuta, Discoaster brouweri, Discoaster bellus* and *Discoaster kugleri*. The analyzed section is dated **Middle Miocene – Early Pliocene** based on the presence of some nannofossils species.

The zonation scheme of Martini (1971) was adopted in this study while ages in Ma were based on Berggren *et al.* (1995). Condensed Sections were interpreted with the Global Cycle Chart of Hardenbol *et al,* 1998.

Highlights of the results are summarized by interval below and in Figure 4.7

Stratigraphic Interval: 102 – 628m
Age: Late Miocene – Early Pliocene
Nannofossils Zone: NN10 &YOUNGER
Top: Probably shallower than first sample analysed
Base: Top *Discoaster prepentaradiatus.*

Remarks:
Interval barren of nannofossils.
Rare nannofossils species recorded include Reticulofenestra haqqi, Sphenolithus abies, Calcidiscus leptoporus, and Cyclicargolithus floridanus.

Stratigraphic Interval: 628 – 1762m

Age: Late Miocene

Nannofossils Zone: NN9 – NN10

Top: Top *Discoaster prepentaradiatus*

Base: Base *Catinaster coalithus.*

Remarks:

Interval characterized by moderate and diverse nannofossils species.

Important nannofossil taxa found within this interval include *Sphenolithus abies, Sphenolithus moriformis, Discoaster prepentaradiatus, Discoaster variabilis, Discoaster brouweri, Reticulofenestra pseudoumbilicus, R. haqii, R. minuta, Helicosphaera carteri, Coccolithus pelagicus, and Calcidiscus leptoporus.*

The condensed interval 573-765m is believed to be associated with the 6.0Ma Maximum Flooding Surface with the top of *Discoaster prepentaradiatus* at 628m.

Stratigraphic Interval: 1762 – 2112m

Age: Middle Miocene

Nannofossils Zone: NN7 – NN8

Top: Base *Catinaster coalithus.*

Base: Placed at TD

Remarks:

Characteristic nannofossils include *Helicosphaera cateri, Calcidiscus leptoporus, Reticulofenestrstra haqii, Helicosphaera granulata, Discoaster bellus* and *Coronocyclus nitescens.*

Occurrence of *Discoaster kugleri* at 2009m suggests a middle Miocene NN7 at this depth.

Table 4.1: Summarized chronostratigraphic subdivision of well 1.

Depths (m)	Zones	Age
102 -628	NN10 & YOUNGER	LATE MIOCENE – EARLY PLIOCENE
628 - 1762	NN9 – NN10	LATE MIOCENE
1762 - 2112	NN7 – NN8	MIDDLE MIOCENE

Late Miocene – Early Pliocene

102 – 628m. The age of this interval is based on the following:

- Occurrence *Sphenolithus abies* at 102m
- Top *Discoaster prepentaradiatus* at 628m

Late Miocene

628 – 1762m. The age of this interval is based on the following:

- Top *Discoaster prepentaradiatus* at 628m
- Base *Discoaster prepentaradiatus* at 1341m
- Base *Catinaster coalithus* at 1762m

Middle Miocene

1762 – 2112m. The age of this interval is based on the following:

- Base *Catinaster coalithus* at 1762m
- Base *Discoaster kugleri* at 2009m

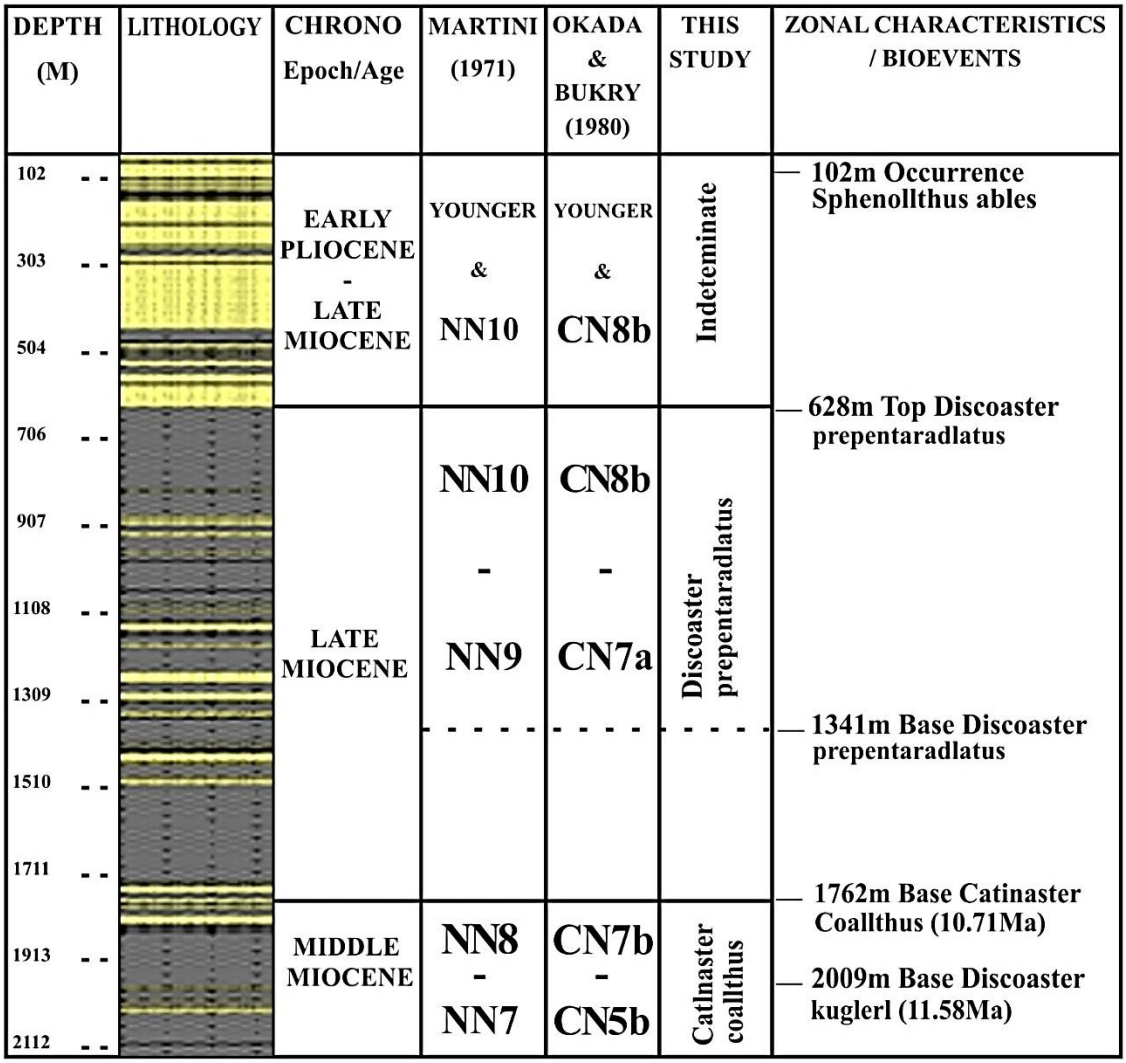


Figure 4.7: Nannofossils Biozonation Distribution in Well 1

4.3 Calcareous Nannofossil Zonation for Well 2

One hundred and thirtysix (136) nannofossil slides prepared from interval 253 -1701m of well 2 were provided for calcareous nannofossils analysis.

The result of the analysis shows that the analyzed interval is made up of rich and diverse nannofossil which enabled the subdivision of the well section into zones.

Important Nannofossil recorded includes *Sphenolithus moriformis, Discoaster berggrenii, Discoaster prepentaradiatus, Sphenolithus abies, Catinaster coalithus, Discoaster kugleri, Helicosphaera cateri, Reticulofenestra haqqi, Cyclicargolithus floridanus and Helicosphaera ampliaperta.*

This barren to near barren nannofossil that characterized this well could be attributable to the preponderance of clastic sediments deposited within the fluvial (Coastal Deltaic), Shallow Inner Neritic and Inner Neritic environments. These environments are unsuitable for the preservation of calcareous nannofossil.

The recorded nannofossils were used in the zonation and age of the study interval. The analyzed section is dated **Late Miocene – Early Miocene** based on the presence of some nannofossil species. The zonation scheme of Martini (1971) was adopted in this study while ages in Ma were based on Berggren *et al.* (1995). Condensed Sections were interpreted with the Global Cycle Chart of Hardenbol et al, (1998).

Highlights of the results are summarized by interval below and in Figure 4.8.

Stratigraphic Interval: 253 – 884m

Age: Late Miocene

Nannofossils Zone: NN11

Top: Probably shallower than first sample analysed

Base: Base *Discoaster berggrenii*.

Remarks:

The upper part of this interval is characterized by paucity of nannofossil species while the lower part recorded fairly abundant of nannofossils.

Nannofossils documented at this zonal interval include *Helicosphaera cateri, Discoaster berggrenii, Reticulofenestra haqqi, Sphenolithus abies and Reticulofenestra pseudoumbilicus.*

Stratigraphic Interval: 884 – 1158m

Age: Late Miocene

Nannofossils Zone: NN8 – NN10

Top: Base *Discoaster berggrenii*

Base: Base *Catinaster coalithus.*

Remarks:

The interval is fairly rich in Calcareous nannofossil with diverse assemblage.

Important nannofossil taxa found within this interval include *Discoaster kugleri, Helicosphaera cateri, Discoaster prepentaradiatus, Catinaster coalithus, Sphenolithus moriformis, Calcidiscus leptoporus, Cyclicargolithus floridanus, and Reticulofenestra pseudoumbilicus.*

Stratigraphic Interval: 1158 – 1460m

Age: Middle Miocene

Nannofossils Zone: NN7

Top: Base *Catinaster coalithus*

Base: Top *Helicosphaera ampliaperta*

Remarks:

Top occurrence of *Discoaster kugleri* at 1250m interval suggests a middle Miocene NN7 at this depth

Interval also characterized by co-occurrence of Cyclicargolithus floridanus. Reticulofenestra pseudoumbilicus, Coccolithus pelagicus, Helicosphaera carteri, Discoaster kegleri, Helicosphaera minuta, Discoaster variabilis and *Discoaster bolli*

Stratigraphic Interval: 1460 – 1701m

Age: Early Miocene

Nannofossils Zone: NN3 – NN4

Top: Top *Helicosphaera ampliaperta.*

Base: Placed at last sample analysed (TD).

Remarks:

Interval generally characterized by rare to barren nannofossil species

The FDO of *Helicosphaera ampliaperta* at 1460m suggests that this zonal interval is not younger than NN4 zone and probably not older than NN3

The upper limit of this zone (1460m) recorded abrupt occurrence of FDO *Helicosphaera ampliaperta* suggesting a fault/unconformity. This could also be responsible for the non recognition of NN6 and NN5 zone

Table 4.2: Summarized chronostratigraphic subdivision of well 2.

Depths (m)	Zones	Age
253 -884	NN11	LATE MIOCENE
884 - 1158	NN8 – NN10	LATE MIOCENE
1158 - 1460	NN7	MIDDLE MIOCENE
1460 - 1701	NN3 – NN4	EARLY MIOCENE

Late Miocene

253 – 884m. The age of this interval is based on the following:

- Base *Discoaster berggrenni* at 884m
- Top *Catinaster coalithus* at 975m
- Base *Catinaster coalithus* at 1158m

Middle Miocene

1158 – 1460m. The age of this interval is based on the following:

- Base *Catinaster coalithus* at 1158m
- Top *Discoaster kugleri* at 1250m
- Top *Helicosphaera ampliaperta* at 1460m

Early Miocene

1460 – 1701m. The age of this interval is based on the following:

- Top *Helicosphaer ampliaperta* at 1460m

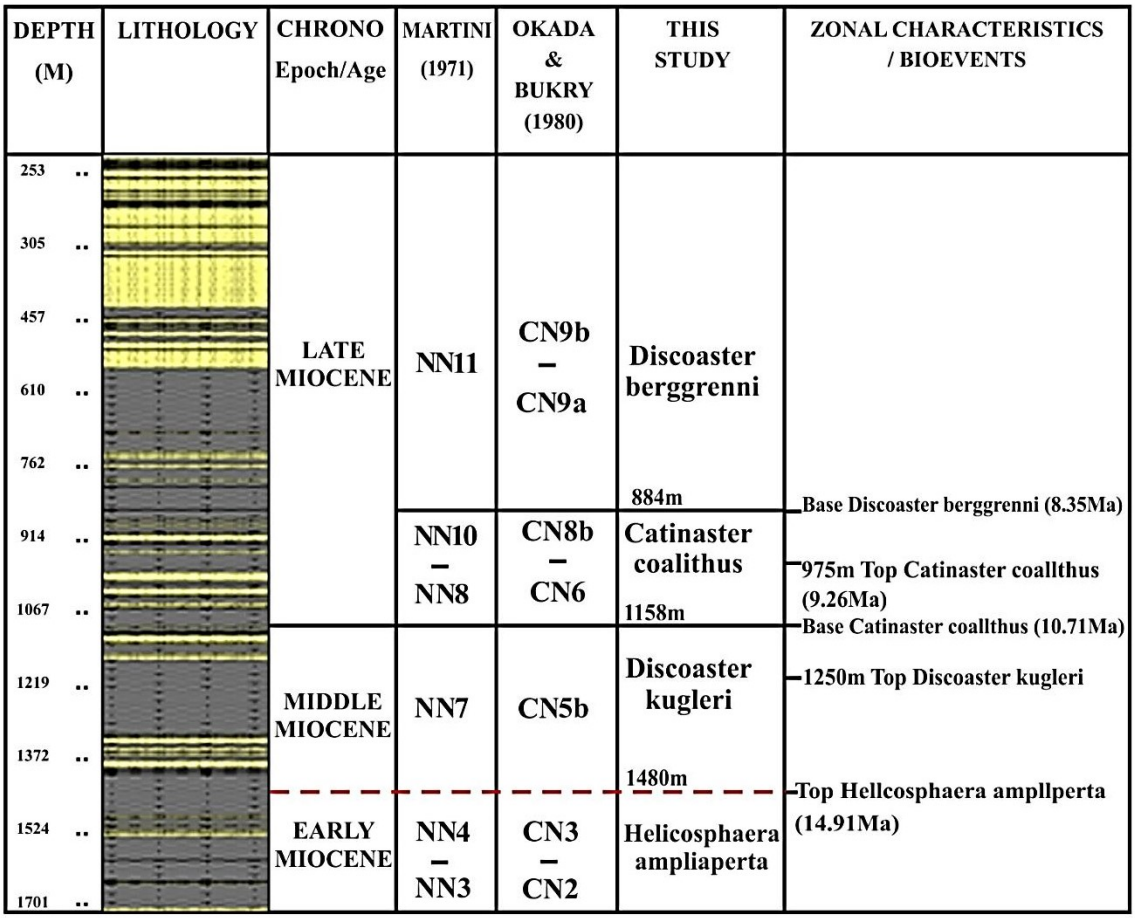


Figure 4.8: Nannofossils Biozonation Distribution in Well 2

4.4 CALCAREOUS NANNOFOSSIL ZONATION FOR Well 3

Two hundred and forty two (242) nannofossil slides prepared from interval 1038 – 3243m of well 3 were provided for calcareous nannofossils analysis.

The result of the analysis shows that the analyzed interval is characterized by rich and diverse nannofossil which enabled the subdivision of the well section into zones.

Some of the important nannofossil recorded includes *Helicosphaera scisura, Chiasmolithus solitus, Pemma basquensis, Reticulofenestra umbilica, Coccolithus formosus, Helicosphaera bramlettei, Helicosphaera seminulum, Chiasmolithus daniscus, Arkhangelskiella cymbiformis, Eiffellithus turriseiffelii* and *Tranolithus phacelosus.*

The recorded nannofossils were used in the zonation and age of the study interval. The analyzed section is dated **Middle Miocene - Early Paleocene** based on the presence of nannofossil species. The zonation scheme of Martini (1971) was adopted in this study while ages in Ma were based on Berggren *et al* (1995). Condensed Sections were interpreted with to the Global Cycle Chart of Hardenbol *et al.,* (1998). Most of the younger aged nannofossils encountered in the well were probably as result of caving.

The highlights of the results are summarized by interval below and in Figure 4.9.

Stratigraphic Interval: 1037 – 2243m
Age: Early - Middle Miocene
Nannofossils Zone: NN4
Top: Probably shallower than first sample analysed
Base: Top *Pemma basquensis*

Remarks:
Interval characterized by diverse nannofossil species.
Top *Helicosphaera scissura* at 1612m, suggests NN4 middle Miocene at this depth.
Important nannofossil taxa that characterized this interval include *Helicosphaera scissura, Calcidiscus leptoporus, Helicosphaera cateri,* and *Cyclicargolithus floridanus*.

The lower limit of this NN4 zone which is usually mark by the top *Sphenolithus belomnos* is not recorded but marked by the abrupt top occurrence of *Pemma basquensis* at 2243m suggesting a fault/unconformity at this depth. This could also be responsible for the non-recognition of NN3 to NN1 zones.

Stratigraphic Interval: 2243 – 2490m
Age: Early Oligocene – Middle Eocene
Nannofossils Zone: NP21 - NP14
Top: Top *Pemma basquensis*
Base: Base *Pemma basquensis*

Remarks:
Interval characterized by abundant and diverse nannofossil species.
Occurrence of *Chiasmolithus solitus* at 2417m suggests a middle Eocene age.
Interval also characterized by occurrence of *Pemma basquensis, Chiasmolithus solitus, Helicosphaera seminulum, Coccolithus formosus, Cyclicargolithus floridanus, Reticulofenestra umbilica, Coccolithus pelagicus, and Helicosphaera bramlettei.*
The lower limit of this zone is placed at the base *Pemma basquensis* at 2481m. The non-recognition of NP7 to NP13 zones below this zonal interval could be attaributed to the presence of a fault/unconformity at this depth.

Stratigraphic Interval: 2490 – 2536m
Age: Early Paleocene
Nannofossils Zone: NP3 - NP6
Top: Base *Pemma basquensis*
Base: Top *Chiasmolithus danicus*

Remarks:
Interval characterized by diverse nannofossil species.
Nannofossils recorded at this zonal interval include *Chiasmolithus danicus*, *Helicosphaera carteri, Coccolithus pelagicus* and *Reticulofenestra pseudoumbilicus.*

Stratigraphic Interval: 2536 –3243m

Age: Indeterminate

Nannofossils Zone: Indeterminate

Top: Top *Chiasmolithus danicus*

Base: Last sample analysed

Remarks:

Interval characterized by fairly abundant nannofossil species.

Interval also characterized by occurrence of *Arkhangelskiella cymbiformis, Eiffelithus turriseifelii, Tranolithus phacelosus* and *Braarudosphaera bigelowii.* The co-occurrences of these species suggest probable ? Maastrichtian age for this interval.

Table 4.3: Summarized chronostratigraphic subdivision of well 3.

Depths (m)	Zones	Age
1037 -2243	NN4	EARLY - MIDDLE MIOCENE
2243 - 2490	NP21 – NP14	EARLY OLIGOCENE - MIDDLE MIOCENE
2490 - 2536	NP3 – NP6	EARLY PALEOCENE
2536 - 3243	INDETERMINATE	INDETERMINATE

Early - Middle Miocene

1037 – 2243m. The age of this interval is based on the following:

- Top *Helicosphaera scissura* at 1612m
- Top *Pemma basquensis* at 2243m

Early Oligocene - Middle Miocene

2243 – 2490m. The age of this interval is based on the following:

- Top *Pemma basquensis* at 2243m
- Base *Pemma basquensis* at 2481m

Early Paleocene

2490 – 2536m. The age of this interval is based on the following:

- Base *Pemma basquensis* at 2481m
- Top *Chiasmolithus daniscus* at 2536

2536 – 3243m Indeterminate

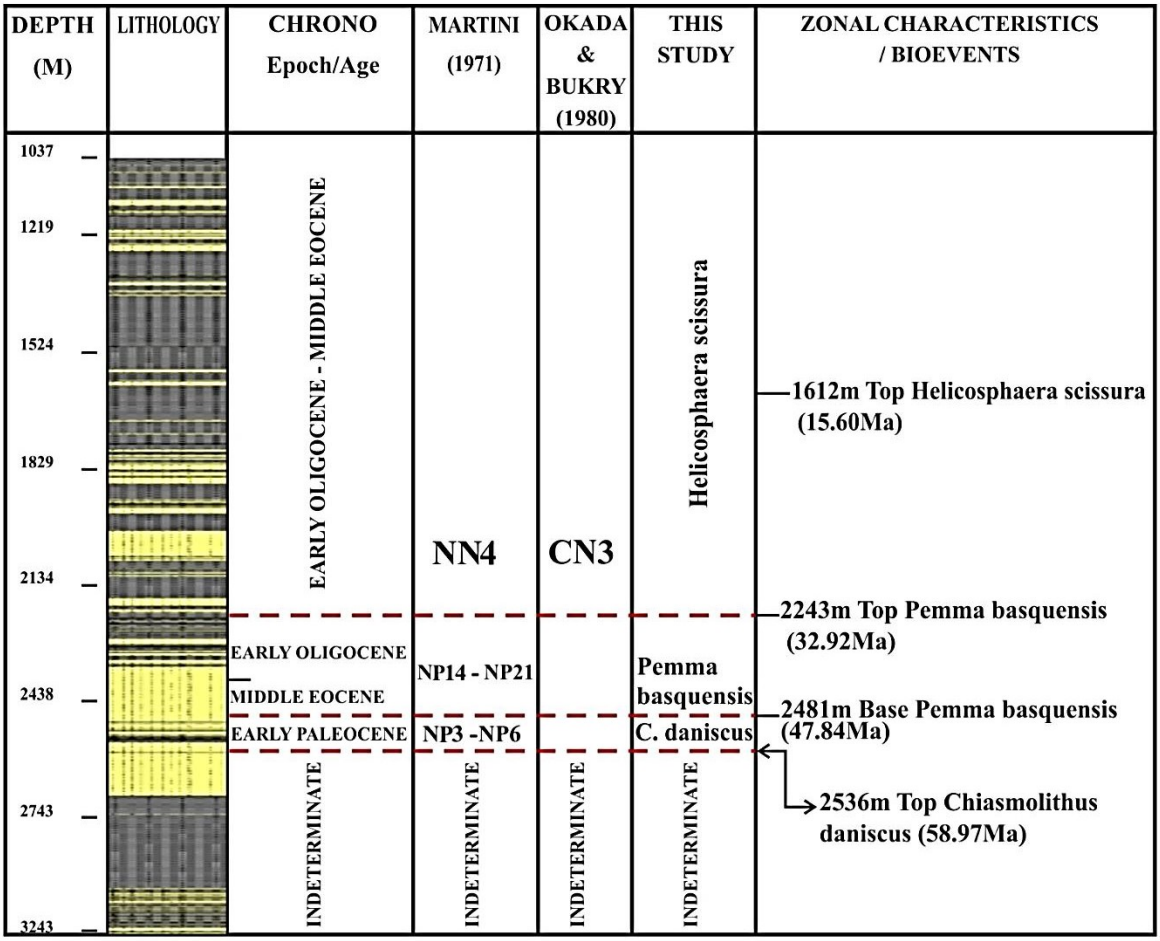


Figure 4.9: Nannofossils Biozonation Distribution in Well 3

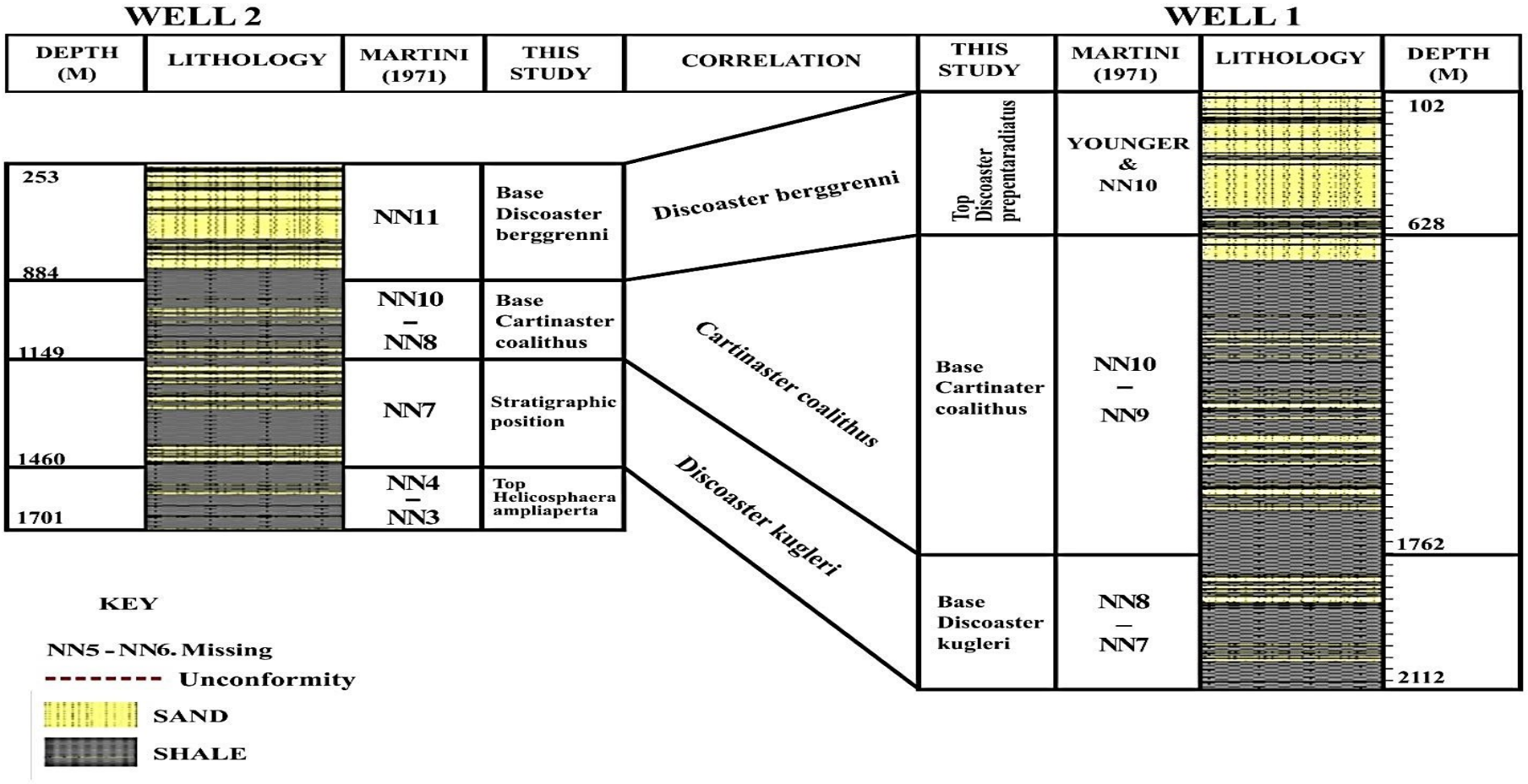


Figure 4.10: Correlation of Calcareous Nannofossils Zones in Wells 2 and 1

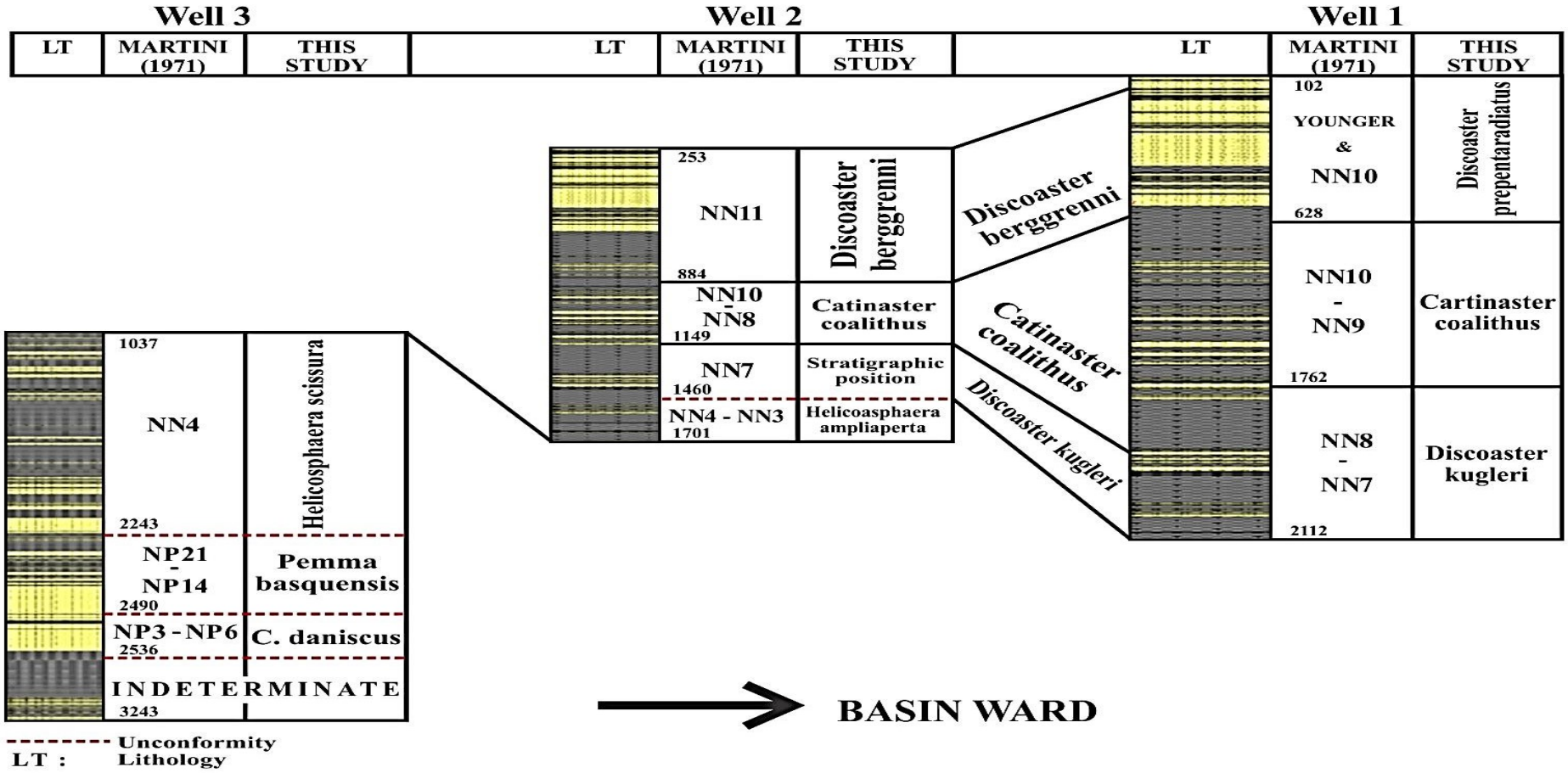


Figure 4.11: Correlation of Calcareous Nannofossils Zones in Wells 3, 2 and 1

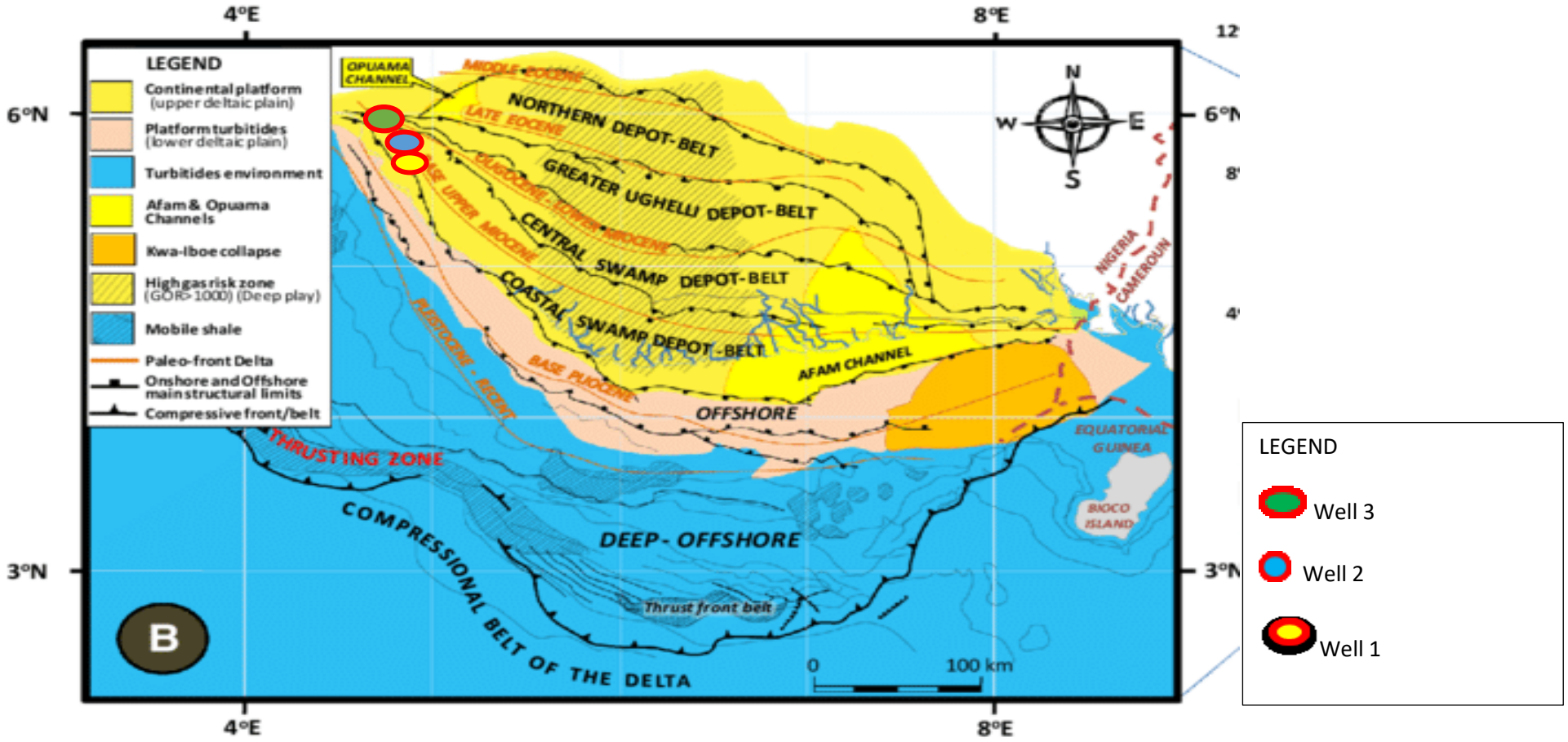


Figure 4.12: Sectional map of the Niger Delta depobelts and structural limits showing the position of Wells 3, 2 and 1. (Redrawn from Doust and Omatsola 1990

4.5 Sequence Stratigraphy:

The idea of depositional sequence first established by Sloss (1963) and later modified by the Exxon School particularly Vail et al (1977), Vail (1987) and Van Wagoner et al (1988) led to the concept of sequence stratigraphy. A depositional sequence is defined as "a stratigraphic unit composed of a relatively conformable succession of genetically related strata bounded at its top and base by unconformities or their relative conformities' (Mitchum et al., 1977).

The depositional sequence is deemed to represent a succession of changing events determined by eustatic changes of a sea level and that an individual sequence represents the rocks deposited between a sea level rise and a sea level drop (Vail et al., 1977). The approach has been found to be of great value to petroleum exploration as some parts of a sequence have been observed to contain reservoir rocks and other parts sealing shales.

The concept of sequence stratigraphy involves the integration of high resolution biostratigraphy and paleobathymetric data and the characteristic well log signature with seismic reflection profiles (Vail and Wornardt, 1990). This methodology permits geologist and geophysicists to divide a rock section into series of lithogenetic units bounded by chronostratigraphic Condensed Sections (CS) and Maximum Flooding Surface (MFS) and Sequence Boundaries (SB). The condensed sections are dated on the bases of biostratigraphy. Each sequence is then sub divided into smaller packages called Systems Tracts on the basis of the characteristic well log pattern.

Condensed sections are defined as "thin marine stratigraphic units consisting of pelagic to hemipelagic sediments characterized by very low sedimentation rates which are most areally extensive at the time of maximum regional transgression" (Loutit et al,.1988). The Maximum Flooding Surface (MFS) is defined as "the surface corresponding to the time of maximum flooding" (Van Wagoner et al., 1988). Sequence Boundaries (SB) refers to erosional bounding depositional sequences above and below while the Transgressive Surface (TS) represent the first significant marine flooding surface within a sequence. A system tract (ST) is a set of linked contemporaneous depositional systems (Brown and Fisher, 1977).

Conventional sequence stratigraphic analysis involves the integration of biostratigraphic data with well log signatures, lithographs from ditch cutting samples, paleoenvironmental data from foraminiferal biostratigraphy, Palynological biostratigraphy as well as seismic reflection profile.

However, only biostratigraphic data from nannofossils, lithology interpreted from ditch cuttings and well logs are available for this work which permits only a tentative seuquence stratigraphy interpretation. This is due to absence of paleoenvironmental data from foraminifera and seismic refection profile. Abundance and diversity patterns are calibrated with chronostratigraphycally important bioevents to date all observed major condensed sections and is correlated with the Global Cycle chart of Hardenbol et al., (1998).

4.5.1 Sequence Stratigraphy of Well 1

The log sequence stratigraphic analysis technique proposed by Vail and Wornardt (1991) has been adopted in this study. The methods of recognizing chronostratigraphic surfaces using patterns of faunal abundance and diversity as proposed by Armentrout *et al.* (1990) were also utilized.

Nannofossil density/diversity minima and maxima were used for defining candidates for sequence boundary and condensed section respectively. Furthermore, identifiable systematic variations in nannofossil abundance and diversity correlated with similar variations in stacking patterns as seen on the available gamma ray log acquired over the analyzed section aided the recognition of systems tracts.

The sequence stratigraphic framework proposed here for well 1 was correlated with the Global Cycle Chart of Hardenbol et al. (1998). The proposed sequence stratigraphic framework for the well is summarized in Table 4.7 and briefly highlighted below:

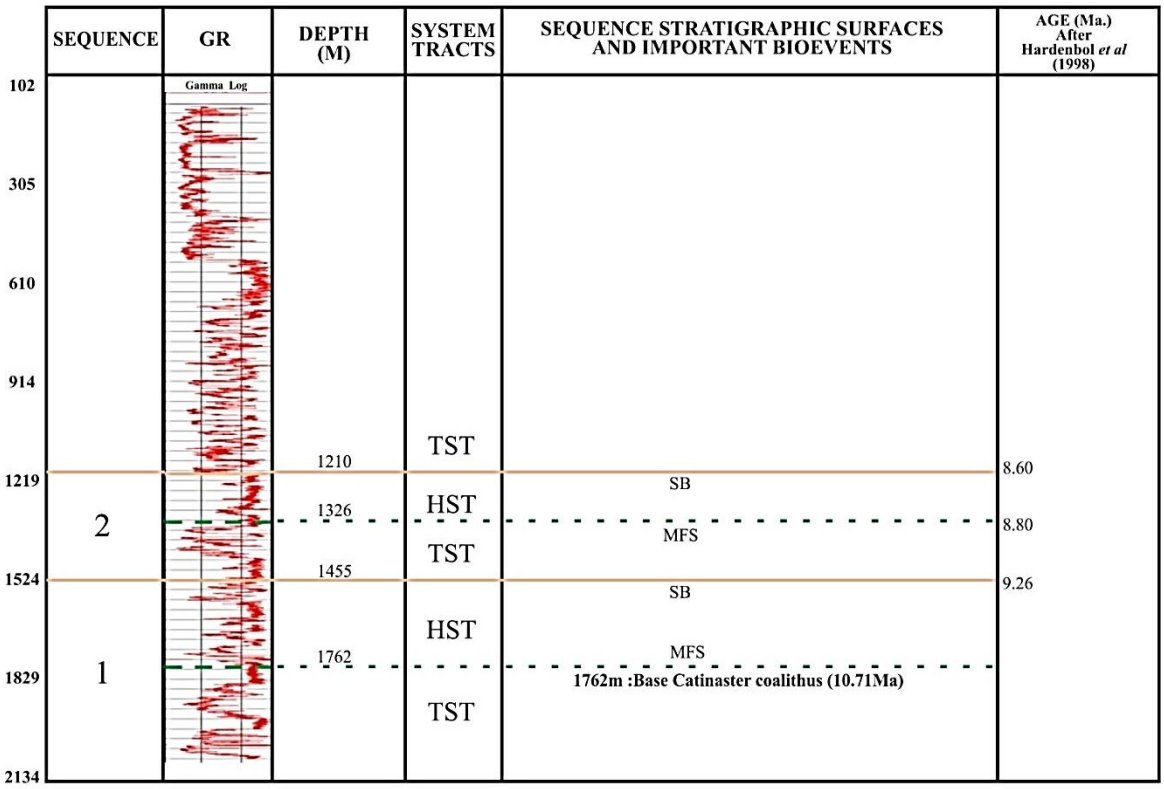


Figure 4.13: Sequence Stratigraphy of Well 1.

4.5.1.1 Sequence 1 (2112 – 1455m)

This depositional sequence began its development with a Transgressive Systems Tract (TST) composed of sediments presenting a regressive profile. The TST terminates at a Maximum Flooding Surface (MFS) marked by a Gamma Ray peak and associated with faunal abundance and diversity peaks at 1762m. This MFS is proposed to be related to the 10.71 Ma MFS of Hardenbol et. al. (1998) based on its association with the Last Downhole Occurrence (LDO) of Catinaster coalithus at 1762m. The progradational unit over the interval 1530 – 1455m is interpreted as a Highstand Systems Tract (HST). The Sequence Boundary (SB) capping the HST is probably related to the 9.26 Ma SB of Hardenbol *et al* (1998). This proposition is based on the stratigraphic position of the SB between the proposed 9.50/10.20 Ma and 8.80 Ma MFS's.

4.5.1.2 Sequence 2 (1455 – 1210m)

This sequence is bounded at the base by the proposed 9.26 Ma SB at 1455m. A fining-upward succession of sediments laid down on the SB over the interval 1455 – 1326m is interpreted as representing a Transgressive Systems Tract (TST). The Gamma Ray positive deflection at 1326m within a Condensed Section is proposed as the MFS capping the TST. This MFS is correlated to the 8.80 Ma MFS of Hardenbol et. al. (1998). The Base occurrence of the calcareous nannofossil species, *Discoaster prepentaradiatus* (dated 8.80 Ma) at 1341m is consistent with the age assigned to this MFS. Above the MFS, a progradational succession of mudstones/shales, capped by a sand body constitutes the HST laid down as the shoreline apparently receded. The SB bounding this sequence at the top has been defined at the point of change-over from a coarsening-upward to a fining-upward profile at 1210m. The SB has been assigned an age of 8.60 Ma based on correlation with the Global Sea Level Cycle Chart of Hardenbol et al. (1998).

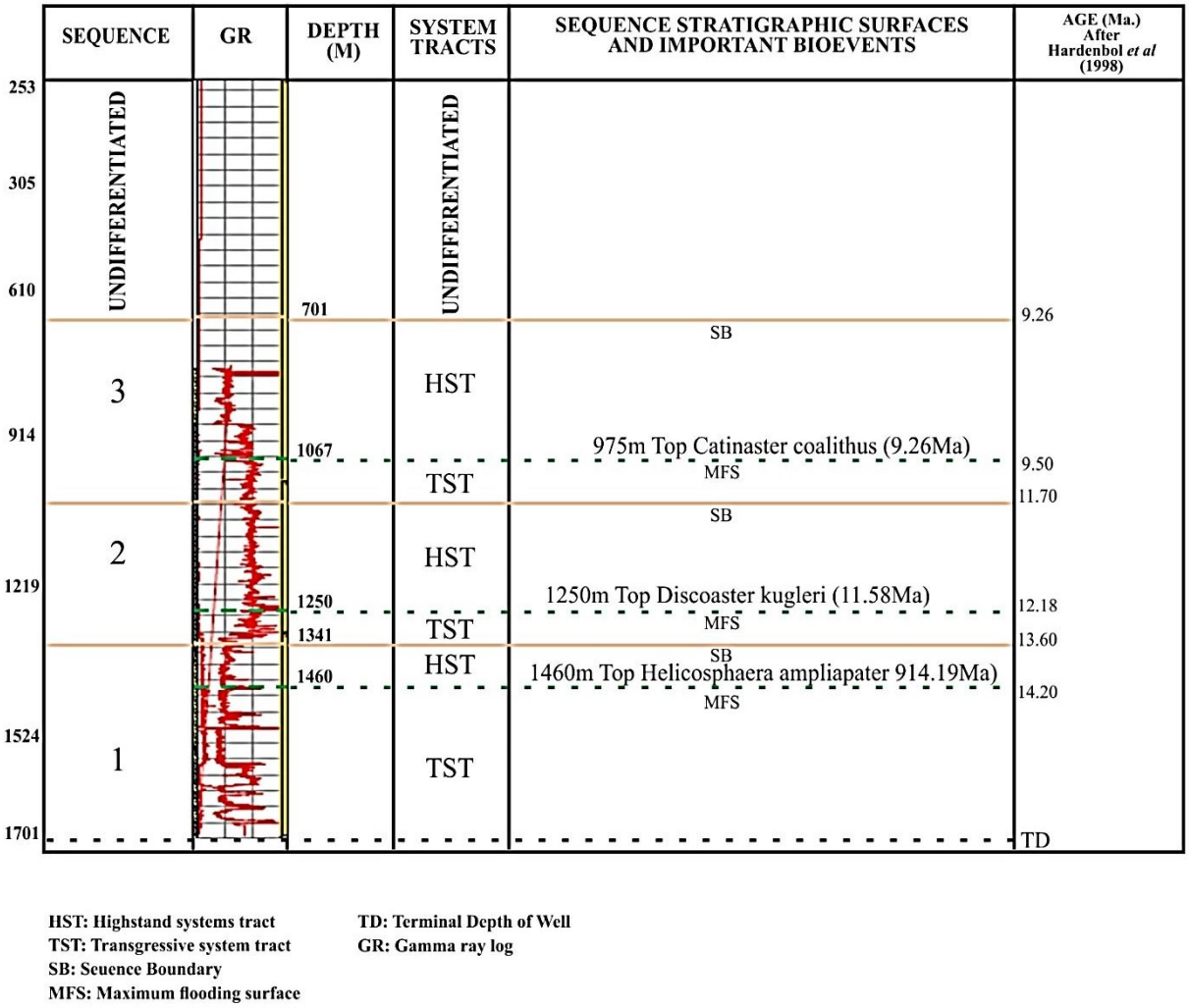
4.5.1.3 Sequence 3 (1210 – 890m)

This sequence is composed of a fining-upward and deepening-upward profile of sediments associated with increasing-upward nannofossils abundance and diversity over the interval 1210 – 902m. This is interpreted as a Transgressive Systems Tract (TST).

4.5.2 Sequence Stratigraphy of Well 2

4.5.2.1 Sequence 1 (1701- 1460m)

The fining-upward sedimentary succession associated with increasing-upward faunal abundances and diversities over the basal interval 1701 – 1460m is interpreted as a Transgressive Systems Tract (TST). The TST is capped by a Maximum Flooding Surface (MFS) marked, within a Condensed Section, by a Gamma Ray positive deflection at 1460m. The age of this MFS is association with the 14.19Ma nannofossils zone NN4. The TST is succeeded by a progradational-aggradational unit characterized by decreasing-upward calcareous nannofossil abundances and diversities over the interval 1591 – 1460m. This is indicative of a Highstand Systems Tract (HST). The Sequence Boundary (SB) at the top of the sequence is defined at 1341m, being the erosional top of a sand body. The age of this SB is 13.60Ma.



HST: Highstand systems tract
TST: Transgressive system tract
SB: Seuence Boundary
MFS: Maximum flooding surface
TD: Terminal Depth of Well
GR: Gamma ray log

Figure 4.14: Sequence Stratigraphy

4.5.2.2 Sequence 2 (1341 – 1067m)

The Transgressive Systems Tract (TST) exhibits a fining-upward profile accompanied by increasing-upward calcareous nannofossil abundance and diversity patterns over the interval 1341 – 1250m. The TST terminates at a Maximum Flooding Surface (MFS) signaled by a Gamma Ray peak within a Condensed Section at 1250m. This MFS is proposed to be related with the 12.18 Ma MFS of Hardenbol et al. (1998). Its association with the top occurrence of the calcareous nannofossil species, *Discoaster kugleri* (dated 11.58Ma) at 1250m informed the assigned age. The Highstand Systems Tract (HST) sitting on the MFS is composed of a progradational succession of predominantly mudstones/shales associated with decreasing-upward calcareous nannofossil abundance and diversity patterns over the interval 1250 – 1067m. The Sequence Boundary (SB) capping this depositional sequence is marked at the abrupt top of a silt/sand body at 1067m. An age of 11.70 Ma is proposed for this SB on the basis of its stratigraphic position between the proposed 12.18 Ma and 9.50 Ma MFS's.

4.5.2.3 Sequence 3 (1067 - 701m)

This sequence is composed of a fining-upward profile of sediments typical of a Transgressive Systems Tract (TST) over the interval 1067 – 975m. The TST terminates at a Maximum Flooding Surface (MFS) marked by a Gamma Ray peak at 975m. The MFS is held to be related with the 9.50 Ma MFS of Hardenbol et. al. (1998). This bioevent is known to be associated with the 9.50 Ma MFS in the Niger Delta. A Highstand Systems Tract (HST) indicated by a progradational sedimentary succession characterized by decreasing-upward faunal and floral abundance and diversity patterns and a shallowing-upward profile occurs over the interval 975 – 701. The position of the Sequence Boundary (SB) capping this depositional sequence is uncertain due to the non-availability of wireline logs over the upper part (808 – 253m) of the well section. The SB is, however, tentatively placed at 701m. This SB has been dated 9.26 Ma based on correlation with the Global Seal Level Cycle Chart of Hardenbol et al. (1998).

2.5.2.4 Undifferentiated Sequences / Systems Tracts (701 – 253m)

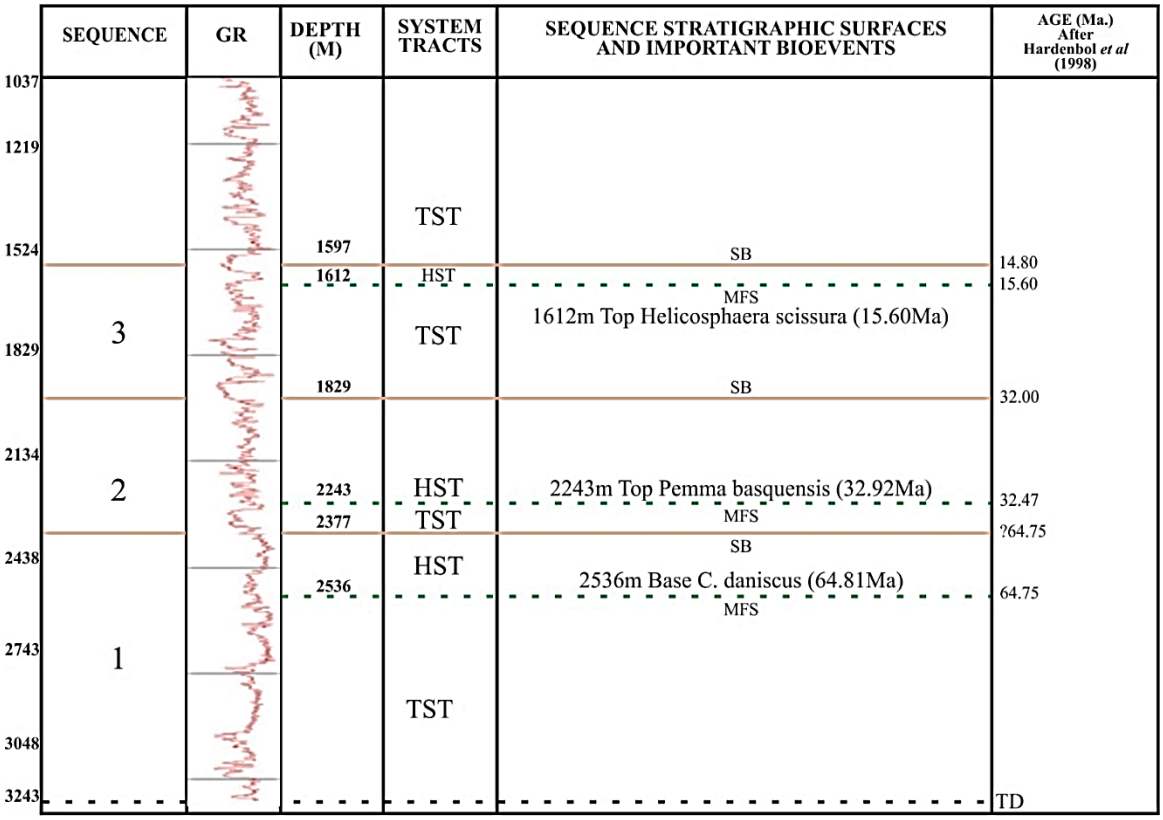
It is difficult to delineate / differentiate the interval 701 – 253m into systems tracts. This is due to the non-availability of wireline logs over the interval and the sandy nature of the interval (~100% sand) with the concomitant poor biostratigraphic control.

4.5.3 Sequence Stratigraphy of Well 3

4.5.3.1 Sequence 1(3243 – 2377m)

This is the oldest depositional sequence encountered by the well 3 over the studied interval. A fining-upward succession of mudstones/shales, interspersed with a few thin units of silts/sands and associated with an increasing-upward nannofossil abundance and diversity and a deepening-upward profile over the interval 3243– 2536m, is proposed as a Transgressive Systems Tract (TST). A Gamma Ray spike at 8,320ft within a Condensed Section is suggested to indicate the Maximum Flooding Surface (MFS) capping the TST. The absolute age of this MFS, which occurs within this definitely Cretaceous depositional sequence, is uncertain (?64.75Ma) as a result of a dearth of datable bioevents around the MFS.

A progradational succession arises from the MFS and terminates at the erosional base of a blocky sand body at 2377m. This is interpreted as a Highstand Systems Tract (HST) capped by a Sequence Boundary (SB) at 2377m. This sequence boundary is probably related to the 64.75 Ma Sequence Boundary of Hardenbol et. al. (1998). This proposition is informed by the last downhole occurrence (LDO) of the calcareous nannofossil species, *Chlasmolithus danicus* (dated 64.81 Ma) at 2536m.



HST: Highstand systems tract
TST: Transgressive system tract
SB: Seuence Boundary
MFS: Maximum flooding surface
TD: Terminal Depth of Well
GR: Gamma ray log

Figure 4.15: Sequence Stratigraphy of Well 3

4.5.3.2 Sequence 2 (2377 – 2012m)

This is indicative of a Transgressive Systems Tract (TST). The TST terminates at a Maximum Flooding Surface (MFS) indicated by a positive Gamma Ray deflection within a condensed section at 2243m. The age of this MFS is suspected to be 32.47Ma based on correlation with the Global Sea Level Cycle Chart of Hardenbol et. al. (1998) and its association with the First Downhole Occurrence (FDO) of Pemma basquensis (dated 32.92Ma) at 2243m. Above the MFS, the Highstand Systems Tract (HST), comprising marine mudstones/shales and shoreface sands, presents a progradational stratal stacking pattern over the interval 2243 – 2012m. The sequence boundary (SB) capping the HST is defined at the erosional base of a blocky sand unit within a zone of faunal abundance and diversity minima at 2012m. The sequence boundary is possibly related to the 32.00 Ma Sequence Boundary of Hardenbol et al. (1998).

4.5.3.3 Sequence 3 (2012 – 1597)

The TST shows a generally retrogradational succession of parasequences over the interval 2012 – 1612m. The Maximum Flooding Surface (MFS) capping the TST is indicated at 1612m by a Gamma Ray peak within a condensed section. The MFS has been correlated to the 15.60Ma MFS of Hardenbol et. al. (1998). The First Downhole Occurrence (FDO) of Helicosphaera scissura dated 15.60 Ma at 1612m is consistent with this proposition. This may indicate that this SB is an unconformity representing a fairly large time interval of about 17,2 Ma. In other words, the 14.80 Ma erosional event probably eroded the older deposits down to about 32.00 Ma. It is also possible, however, that the apparently missing segment of the sedimentary column observed here, may have resulted from a cut-out occasioned by a faulting event.

This is based on the First Downhole Occurrence of Helicosphaera scissura (dated 15.60Ma) at 1612m below the MFS. Above the MFS, a coarsening-upward succession of prodelta mudstones/shales interspersed with a far less significant proportion of delta front sands is observed in association with decreasing-upward calcareous nannofossil abundance and diversity as well as a shallowing-upward profile over the interval 1612m – 1597m. This is suggestive of a Highstand Systems Tract (HST). The sequence boundary (SB) terminating this HST has been defined to coincide with the erosional base of a coastal sand body at 1597m. This SB has been correlated to the 14.80 Ma SB of Hardenbol et al. (1998).

4.5.3.4 Sequence 4 (1597 – 1038m)

This sequence is composed of a fining-upward profile of sediments over the interval 1597 – 1038m. This is interpreted as a Transgressive Systems Tract (TST). The top of this sequence probably lies shallower than the top of the studied section of well 3.

4.6. Calcareous Nannofossil Zonation Discussion for Well 1

On the basis of the recovered chronostratigraphic nannofossils marker species, the entire studied interval (102 – 2112m) for well 1is conclusively dated Middle Miocene (NN7) – Early Pliocene (NN15). (Figure 4.7)

Sedimentological criteria including gamma ray log responses and sand/shale ratios indicate that well 1 encountered, within the studied interval, three (3) lithofacies unit of the Agbada Formation. These are the Paralic, Transitional Paralic and Continental Transitional Units. (Figure 4.1)

The biostratigraphic data acquired over the analyzed interval (102 – 2112m) (Figure 4.7) facilitated the stratigraphic resolution of the well and the recognition of the condensed sections together with their associated Maximum Flooding Surfaces. The availability of wire-line log data for correlation with the biostratigraphic results further enhanced the determination of the positions of the Maximum Flooding Surface for Sequence stratigraphic interpretation. (Figure 4.13) Ages in Ma were based on Berggren et al (1995).

Stratigraphically significant nannofossils assemblages (Figure 4.4) recovered from the well section are referenced to the standard worldwide calcareous nannofossils zonation schemes of Martini (1971)

The sequence stratigraphic framework proposed here for well 1 was correlated with the Global Cycle Chart of Hardenbol et al.(1998).

The analyzed section is dated Middle Miocene – Early Pliocene based on the presence of some nannofossils species.

The depositional sequence is deemed to represent a succession of changing events determined by eustatic changes of a sea level and that an individual sequence represents the rocks deposited between a sea level rise and a sea level drop (Vail et al., 1977). The approach has been found to be of great value to petroleum exploration as some parts of a sequence have been observed to contain reservoir rocks and other parts sealing shales.

The log sequence stratigraphic analysis technique proposed by Vail and Wornardt (1991) has been adopted in this study. The methods of recognizing chronostratigraphic

surfaces using patterns of faunal abundance and diversity as proposed by Armentrout *et al.* (1990) were also utilized.
The proposed sequence stratigraphic framework for the well is summarized in (Figure 4.13)

Well 1 encountered two (2) Maximum Flooding Surfaces (MFS) and two (2) Sequence Boundaries (SB) and age-dated using Hardenbol et al (1998). These MFSs are 8.80Ma (1326m) and 9.50Ma (1737m). The Sequence Boundaries are 8.60Ma (1210m) and 9.26Ma (1455m)

The high sand/shale ratio exhibited by some of the unit indicates that they are product of high-energy sedimentation, while the low sand/shale ratio suggests predominantly low energy sedimentation.

4.7. Calcareous Nannofossil Zonation Discussion for Well 2

On the basis of the recovered chronostratigraphic nannofossils marker species, the entire studied interval (253 – 1701m) for well 2 is conclusively dated Late Miocene (NN11) – Early Miocene (NN3). (Figure 4.8)

Sedimentological criteria including Gamma Ray log responses and sand/shale ratios indicate that Well 2 encountered, within the studied interval, three broad lithofacies units - the Continental-Transitional, the Marine and the Transitional Units, which are all ascribed to the Agbada Formation. (Figure 4.2)

The biostratigraphic data acquired over the analyzed interval (253 – 1701m) (Figure 4.8) facilitated the stratigraphic resolution of the well and the recognition of the condensed sections together with their associated Maximum Flooding Surfaces. The availability of wire-line log data for correlation with the biostratigraphic results further enhanced the determination of the positions of the Maximum Flooding Surface for Sequence stratigraphic interpretation. (Figure 4.14) Ages in Ma were based on Berggren et al (1995).

Stratigraphically significant nannofossils assemblages (Figure 4.5) recovered from the well section are referenced to the standard worldwide calcareous nannofossils zonation schemes of Martini (1971)

The sequence stratigraphic framework proposed here for well 2 was correlated with the Global Cycle Chart of Hardenbol et al.(1998).

The recorded nannofossils were used in the zonation and age of the study interval. The analyzed section is dated Late Miocene – Early Miocene based on the presence of some nannofossil species.

The depositional sequence is deemed to represent a succession of changing events determined by eustatic changes of a sea level and that an individual sequence represents the rocks deposited between a sea level rise and a sea level drop (Vail et al., 1977). The approach has been found to be of great value to petroleum exploration as some parts of a sequence have been observed to contain reservoir rocks and other parts sealing shales.

The log sequence stratigraphic analysis technique proposed by Vail and Wornardt (1991) has been adopted in this study. The methods of recognizing chronostratigraphic

surfaces using patterns of faunal abundance and diversity as proposed by Armentrout *et al.* (1990) were also utilized.
The proposed sequence stratigraphic framework for the well is summarized in (Figure 4.14)

Well 2 encountered three (3) Maximum Flooding Surfaces (MFS) and three (3) Sequence Boundaries (SB) and age-dated using Hardenbol et al (1998). These MFSs are 9.50Ma (975m), 12.18Ma (1250m) and14.20Ma (1460m). The Sequence Boundaries are 9.26Ma (701m), 11.70Ma (1067m) and 13.60Ma (1341m).

The admixtures of zonal markers and missing of some zones observed at some depths (1460m) were most probably due to erosional activities, faulting/unconformity. However, these need to be confirmed or compared with seismic facies.

The high sand/shale ratio exhibited by some of the unit indicates that they are product of high-energy sedimentation, while the low sand/shale ratio suggests predominantly low energy sedimentation.

4.8. Calcareous Nannofossil Zonation Discussion for Well 3

On the basis of the recovered chronostratigraphic nannofossils marker species, the entire studied interval (1038 – 3243m) from well 3 is conclusively dated Middle Miocene (NN4) – Early Paleocene (NP3 - NP6). (Figure 4.9)

Sedimentological criteria including Gamma Ray log responses and sand/shale ratios indicate that the well 3 tested, within the studied interval, two broad lithofacies units - the Marine Paralic and the Marine Units, which are ascribed to the Agbada Formation (Figure 4.3)

The biostratigraphic data acquired over the analyzed interval (1038 – 3243m) (Figure 4.9) facilitated the stratigraphic resolution of the well and the recognition of the condensed sections together with their associated Maximum Flooding Surfaces. The availability of wire-line log data for correlation with the biostratigraphic results further enhanced the determination of the positions of the Maximum Flooding Surface for Sequence stratigraphic interpretation. (Figure 4.15) Ages in Ma were based on Berggren *et al* (1995).

Stratigraphically significant nannofossils assemblages (Figure 4.6) recovered from the well section are referenced to the standard worldwide calcareous nannofossils zonation schemes of Martini (1971)

The sequence stratigraphic framework proposed here for well 3 was correlated with the Global Cycle Chart of Hardenbol et al.(1998).

The recorded nannofossils were used in the zonation and age of the study interval. The analyzed section is dated Middle Miocene - Early Paleocene based on the presence of some nannofossil species.

The depositional sequence is deemed to represent a succession of changing events determined by eustatic changes of a sea level and that an individual sequence represents the rocks deposited between a sea level rise and a sea level drop (Vail et al., 1977). The approach has been found to be of great value to petroleum exploration as some parts of a sequence have been observed to contain reservoir rocks and other parts sealing shales.

The log sequence stratigraphic analysis technique proposed by Vail and Wornardt (1991) has been adopted in this study. The methods of recognizing chronostratigraphic

surfaces using patterns of faunal abundance and diversity as proposed by Armentrout *et al.* (1990) were also utilized.

The proposed sequence stratigraphic framework for the well is summarized in (Figure 4.15)

Well 3 encountered three (3) Maximum Flooding Surfaces (MFS) and three (3) Sequence Boundaries (SB) and age-dated using Hardenbol et al (1998). These MFSs are 15.60Ma (1612m), 32.47Ma (2243m), 64.75Ma (2536m). The Sequence Boundaries are 14.80Ma (1597m), 32.00Ma (2012m.) and ?64.75Ma (2377m).

The admixtures of zonal markers and missing of some zones observed at some depths (2243m, 2481m and 2536m) were most probably due to erosional activities, faulting/unconformity. However, these need to be confirmed or compared with seismic facies.

The high sand/shale ratio exhibited by some of the unit indicates that they are product of high-energy sedimentation, while the low sand/shale ratio suggests predominantly low energy sedimentation.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Calcareous nannofossils biostratigraphic analysis of the three wells 1, 2 and 3 from offshore Niger Delta revealed abundant and diverse nannofossils occurrence in the Niger Delta Deepwater environment. The alternation of Shale, Sand and Sandy Shale within the sequence penetrated by the three wells provides the combination of Source, reservoir and cap rocks necessary for hydrocarbon generation, accumulation and trapping.

The zones encountered in this study range from the Early Paleocene NP3 to Early Pliocene NN15 zones. Well 1 penetrated Middle Miocene to Early Pliocene (NN7-NN15), well 2 is restricted within the Early toLate Miocene age (NN3-NN11) while well 3 encountered Early Paleocene (NP3-NN4) zone.

Three major zones (NN7- NN8, NN9-NN10, NN10 and YOUNGER) for Well 1, four major zones (NN3-NN4, NN7, NN8-NN10, NN11) for Well 2 and three major zones (NP3-NP6, NP14-NP21, NN4) for Well 3 were identified using the first and last appearances of the marker species as well as their relative abundances.

The three Wells encountered Eight (8) Maximum Flooding Surfaces (MFS) and Eight (8) Sequence Boundaries (SB) and age-dated using Hardenbol et al (1998). These MFSs are 8.80Ma (1326m), 9.50Ma (1737m) for Well 1, 9.50Ma (975m), 12.18Ma (1250m), 14.20Ma (1460m) for Well 2, and 15.60Ma (1612m), 32.47Ma (2243m), 64.75Ma (2536m) for Well 3. The Sequence Boundaries are 8.60Ma (1210m), 9.26Ma (1455m) for Well 1, 9.26Ma (701m), 11.70Ma (1067m), 13.60Ma (1341m) for Well 2, 14.80Ma (1597m), 32.00Ma (2012m.) and ?64.75Ma (2377m) for Well 3.

5.2 Conclusion

The correlation of the three wells showed basin-ward younging direction and two zones recognized in wells 1 and 2 (NN7 and NN8) belonging to the Late Miocene age was confirmed. The established zonation scheme for Wells 1, 2 and 3 subdivided the offshore Niger Delta Paleocene to Pliocene sequence into zones, subzones and lithostratigraphic sequences and hence the absolute age determined.

Calcareous Nannofossils Biostrarigraphy studies give us the privilege to document their biostratigraphic distribution, establish biozonation and stratigraphic correlation. Age dating and biozonation are the basis on which every other biostratigraphic interpretations are based. This study has further broadened our knowledge of Calcareous Nannofossils biostratigraphy because it gives absolute ages and refined zonation in the Paleogene - Neogene times. This will also help a great deal in oil exploration activities where well-site biostratigraphers are employed while drilling.

5.3 Recommendation

It is recommended that the study of calcareous nannofossil should be encouraged because of its usefulness in exploration, as well as erecting Calcareous Nannofossil Chronostratigraphic Zonation Scheme for the Niger Delta. More research work on Calcareous Nannofossils is hereby recommended.

The admixtures of zonal markers and missing of some zones observered at some depths in Wells 2 and 3 were most probably due to erosional activities, faulting/unconformity. This however, needs to be confirmed or compared with seismic facies.

Intergration of calcareous nannofossils, foraminifera and pollens and spores for Correlation, Biostratigraphy, Paleoecological interpretations and depositional environments is also recommended.

This similar study is recommended for all other Sedimentary basins in Nigeria.

5.4 Contibution to knowledge

The absolute age of the three wells 1, 2 and 3 offshore Niger Delta were determined dividing the Paleogene-Neogene sequence penetrated into zones and local sub zones, contributing to the geoscience research and data generation activity of the Niger Delta.

REFERENCES

Adegoke, O. S. (2002). High resolution biostratigraphy, sequence stratigraphy and 3-D modeling: indispensable tools for E & P activities in the new millennium. Nigerian Association of Petroleum Explorationists Bulletin, Nigeria, 16 (1): 46-65.

Adegoke, O. S. (1980): Basin of West Africa and Its Implications on the Opening of the North and South Atlantic. Proc. Of 26th Inter. Geol. Cong.,Paris. 268p.

Adegoke, O. S. (1969). Eocene stratigraphy of Southern Nigeria. Mem. Bur. Rech. Geol. mins., 69, pp. 3- 48.

Adegoke, O. S, Omatsola, M. E. and Salami, M. B. (1976). Benthiconic foraminifera biofacies of the Niger Delta. Maritime Sediments Special Publications, U.S.A., 1::279-292.

Adeigbe, O. C., Ochigbo, E. A. (2017). Biostratigraphy of Ochigbo-1 Well, Offshore Niger Delta. Evidence from Foraminifera, Spores and Pollen. BJAST, 19(5): 1-25, 2017.Article no BJAST. 31998.

Adeigbe, O. C., Adebowale, M., Ola Buraimo, A. O., Bankole, S. A., Ayinla, H. A. (2014). Calcareous Nannofossils and Foraminifera Studies: An Integrated Approach to the Depositional Environmental Study and Biostratigraphy of Deb-1 well offshore Eastern Dahomey Basin, Southwestern Nigeria. British Journal of Applied Science & Technology; 1/11/2014, Vol. 4 Issue 2, p319

Adeyilola, A. (2017): Intergrated Sub-surface Evaluation of Doyin Fields, Shallow Offshore Niger Delta. Search and Discovery Article #20399.

Ajayi E. O., Okosun E. A. (2014), Calcareous Nannofossil Biostratigraphy of A, B, C, D Wells, Offshore Niger Delta, Nigeria. Earth Science Research; Vol. 3, No. 1; 2014.

Ajakaye, D. E., Bally, A.W. (2002). Course manual and atlas of structural styles on reflection profiles from the Niger Delta. American Association of Petroleum Geologists, 2002

Akindipe, A. O. (2003). Calcareous nannofossils biostratigraphy of well XX, Niger Delta, Unpub. B.Sc. Thesis, Department of Geology, Obafemi Awolowo University, Ile-Ife, 52p.

Armentrout, J. M, Echols, R. J. and Lee, T. H. (1990): Patterns of foraminiferal abundance and diversity: Implications for sequence stratigraphic analysis. In: Sequence Stratigraphy as an Exploration Tool: Concepts and Practices in the Gulf Coast. Gulf Coast Section SEPM Foundation Eleventh Annual Research Conference Program and Abstracts, 21:53-58

Avbovbo A. A., (1978). Tertiary lithostratigraphy of Niger Delta. American Association of Petroleum Geologists Bulletin. 1978; 62:295-300.

Berggren, W. A., Kent, D. V. and Avan Couvering, J. A., (1995). In: Snelling, N. J. (Ed) The chronology of Geological Record. The Neogene, Part 2, Neogene geochronology and chronostratigraphy. Geological society Memoir, 10: 211-260.

Berggren, W. A. (1960). Paleocene biostratigraphy and planktonic foraminifera of Nigeria (West Africa). Reports of 21st International Geologists Congress, Copenhagen, Denmark, 6, 41-55.

Boboye O. A, Ademola O.J. (2013). Late miocene foraminiferal and palynologic events of Oborduka-1 well, deep offshore, Niger Delta, Nigerian. Middle-East Journal of Scientific Research. 2013;13(7).

Brown, L. F and Fisher, W. L. (1977). Seismic stratigraphic interpretation of depositional systems: Examples from Brazil rift and pull-apart basins. In Payton, C. E. (ed), Seismic Stratigraphy Application to Hydrocarbon Exploration. American Association of Petroleum Geologists Memoir, U. S. A., 26, 213-246

Dairo, V. A., Oladiran, M.O. (2016). Biozonation and Correlation of two Wells in Niger Delta using Calcareous Nannofossils. ACTA Palaeontologica Romaniae (2016) v.12(1),p.43-52

Doust, H. and Omatsola, E., (1990). Niger Delta. In: Edwards, J.D. & Santogrossi, P.A (Eds.) Divergent/ passive margin basins. American Association of Petroleum Geologists Memoir 48: 201-239.

Fadiya, S. L., (2008). Calcareous Nannofossil Biozonation Scheme for the Deep Offshore Niger Delta. Unpublished Ph.D. Thesis, Department of Geology, Obafemi Awolowo University, Ile-Ife, Nigeria, pp. 244.

Fadiya S. L. (1999). Foraminifera and Calcareous Nannofossil biostratigraphy and well log sequence stratigraphic analysis of Opolo-5 and Opolo-9 wells, Niger Delta. Unpub. M.Sc. Thesis, Department of Geology, Obafemi Awolowo University, Ile-Ife, Abstract Published–American Association of Petroleum Geologists Bulletin. 1999;149: 82(11):2162.

Farinaciari, E. and Rio, D. (1996). Latest Oligocene to early Middle Miocene quantitative calcareous nannofossil biostratigraphy in the Meditteranean region. Micropaleontology, 42, 1-37.

Frankl, E. J and Cordy, E. A. (1967). The Niger Delta oil province recent development onshore and offshore: 7th World Petroleum Congress Proceedings, Mexico City, IB: 195-209.

Gallagher L. T. (1990). Calcareous Nannofossil Biozonation of the Tertiary of the North Sea Basin. Newsletters on Stratigraphy. 1989; 22:21-44.

Gartner, S. (1969). Correlation of Neogene planktonic foraminifera and calcarrreous nannofossils zones. Transaction of the Gulf Coast Association of Geological Societies. 19, 585-599.

Haq, B. U, Hardenbol, J,. Vail, P. R, Wright,. R. C, Stover., L. E, Posamentier, H. (1988). Chronology of Fluctuating Sea Levels since the Triassic. Science, 235, 1156 - 1166.

Hardenbol J, Thierry J, Farley M. B, et al. Charts. (1998). In: Mesozoic and Cenozoic Sequence Stratigraphy of European Basins (P-C. De Graciansky et al., eds). Spec. Publ. Soc. Sed. Geol. 1998;60.

Hay, W. W., Mohler, H. P., Roth, P. H., Schmidt, R. R. and Boudreaux, J. E. (1967). Calcareous nannoplanktics zonation of the Cenozoic of the Gulf Coast and transoceanic correlation. Transactions of the Gulf Caost Associations of Geological Societies. 17, 428-480.

Loutit, T. S., Hardenbol, J., Vail, P. R. and Baum, G. R. (1988). Condenced Sections, the key to age determinations and correlation of continental margin sequences. Society of Economic Palaeontologists and Mineralogists special publications, 42: 183-213.

Martini, E., (1971). Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci, A. (Ed.) Proceedings of the Second Nannoplankton Conference, Roma, 1970, Edizioni Technoscienza, Rome, 2, pp. 739-785.

Martini, E. and Bramlette, M.N., (1963). Calcareous nannoplankton from the experimental Mohole drilling. Journal of Paleoecology, 37

Martini, E. & Worsely, T., (1970). Standard Neogene calcareous nannoplankton zonation. Nature, 225: 289-290.

Mitchum Jr., R. M., Vail P. R. and Thompson III, S. (1977). The depositional units as a basic unit for stratigraphic analysis. In Payton, C. E. (ed), Seismic stratigraphy: Application to hydrocarbon exploration, American Association of Petroleum Geologist Memoir, U.S.A., 26, 54-62.

Morley, R. J. (1996). Biostratigraphic characterization of systems tracts in the offshore Niger Delta. Apaper presented at the 14th Annual Conference of the Nigeria Association of Petroleum Explorationists, Lagos. Book of Abstract p.48.

Nton, M. E. (2001): Aspect of Rock Evaluation Studies of the Maastrichtian-Eocene Sediments. J. Min and Geol., Vol.13 (2) Pp 33-39

Obaje, S. O, E. A Okosun, P. I. Olasehinde, (2014). Calcareous Nannofossils Biostratigraphy of XY-1 Field, Offshore Western Niger Delta, Nigeria. International Journal of Science and Technology 3 (5), 2014

Ogbe, F. G. A., (1982). The biostratigraphy of the Niger Delta, Nigeria. Journal of Mining and Geology; 18(2) ; 545 – 582.

Ojo A (1996) Studies on biozonztion and paleoecology Neogene foraminifera of central Niger delta. Unpublished PhD thesis, Obafemi Awolowo University, Ile-Ife, Nigeria.

Ojo, E. A., Fadiya, L. S. and Ehinola, O. A. (2009). Biozonation and correlation of BDX-1 and BDX-2 wells of deep offshore Niger Delta using calcareous nannofossils. Search and Discovery Article (AAPG), no. 50192, 8 pp.

Okada, H. and Bukry, D., (1980). Supplementary modification and introduction of code numbers to the low latitude coccolith biostratigraphic zonation (Bukry, 1973, 1975). Marine Micropaleontology, 5 (3): 321-325.

Oyebamiji, S. A. (1997). Calcareous nannofossil biostratigraphy of a well in the Niger Delta, Nigeria. Unpub.M.Sc. Thesis, University College, London, 83p.

Perch-Nielsen, K., (1985). Cenozoic calcareous nannofossil, *in* Bolli, H.M., J.B. Saunders, and K. Perch-Nielsen, (Eds.), Plankton Stratigraphy, Cambridge Earth Sciences Series, Cambridge University Press: p. 427-554.

Reijers T. J. A. (2011). Selected chapters on Geology: Sedimentary geology and sequence stratigraphy in Nigeria and three case studies and a field guide. Shell Petroleum Company of Nigeria, Corporate Repographic Services, Warri. 1996;197.

Reyment R. A, (1965). Aspect of the geology of Nigeria-the stratigraphy of the cretaceous and sedimentary resource system. Springer 316pp.

Sanuade O. A. (2014), Calcareous Nannofossils Biostratigraphic Analysis of Well K-2, Deep Offshore Niger Delta, Nigeria. Advanced in Research 2(12): 696-711.

Shafik, S., Watkins, D. K., & Shin, I. C. (1998). Upper Cenozoic Calcareous Nannofossil Biostratigraphy Côte d'Ivoire-Ghana Margin, Eastern Equatorial Atlantic.

Short, K. C. and Stauble, A. J., 1967. Outline of geology of Niger Delta. American Association of Petroleum Geologists Bulletin 5 (51): 761-779.

Sloss L. L. (1963). Sequence in the Cratonic interior of North America. Geological Society of America Bulletin, 100, 16661-1665.

Stradner, H. (1959). First report on the discoasters of the Tertiary of Austria and their stratigraphic use. Proceedings of the 5th World Petroleum Congress., 1:1081-1095.

Vail, P. R. and Wornardt, W. W. (1990): An integrated approach to exploration and development in the 90s: Well log-seismic sequence stratigraphic analysis. Transactions - Govt. Coast Associations of Geological Sciences, XII: 630 - 650.

Vail P. R, Mitchum R. M, Todd R. G, Widmier J. M, Thompson S, Sangree J. B, Bubb J. N, Hakleid W. G. (1977). Seismic Stratigraphy and global changes of sea level. Part 3. In: Seismic Stratigraphy-Application to Hydrocarbon explorationm (ed. By C. E. Payton). American Association of Petroleum Geologists, Tulsa, Memoir. 1977; 26:49-62.

Vail P. R (1987). Seismic stratigraphy interpretation using sequence stratigraphy. Part I : Seismic stratigraphy interpretation procedure in Bally, A.W. (ed.). Atlas of Seismic Stratigraphy, I, American Association of Petroleum Geologists Studies in Geology, 27, 6-10.

Van Wagoner, J. C., Posamentier, H. W., Mitchum Jr. R. M., Vail, P. R., Sarg, J. F., Loutit, T. S. and Hardenbol, J. (1988). An overview of sequence stratigraphy. In : Wilgus, C. K., Hastings, B.S., Posamentier, H and Kendall, C. G. Sea level changes : An Integrated Approach. Society of Ecconomic Paleontologists and Mineralogists. Special Publication, 42, 39-45.

Weber, K. J and Daukoru, E.M., 1975. Petroleum Geology of the Niger Delta. Proceedinds of the World Petroleum Congress, Tokyo, 2, pp. 202-222.

Weber, K. J. (1971): Sedimentological aspects of oil fields in the Niger Delta. Geologie en Mijnbow, 171.

APPENDIX I

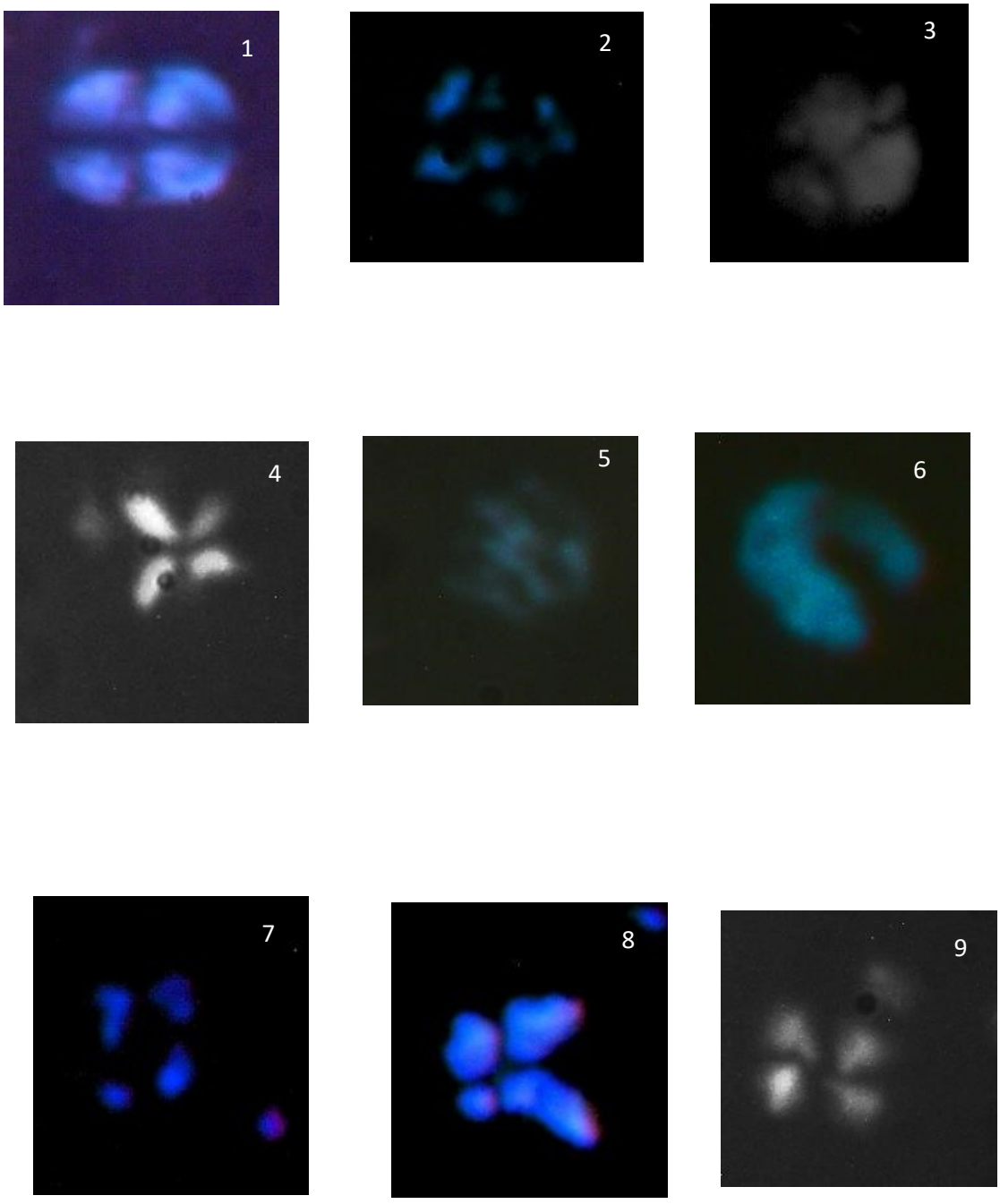


PLATE 1: Well 1 Calcareous Nannofossils photomicrograph images

1. CALCIDISCUS LEPTOPORUS 1000X (2150-2180FT.)

2. DISCOASTER PREPENTARADIATUS 1000X (2030-2060FT.)

3. HELICOSPHAERA CARTERI 1000X (2180-2210FT.)

4. SPHENOLITHUS ABIES 1000X (2150-2180FT.)

5. CATINASTER COALITUS 1000X (2860-2890FT.)

6. AMAUROLITHUS DELICATUS 1000X (335-350FT.)

7. RETICULOFENESTRA HAQII 1000X (2360-2390FT.)

8. SPHENOLITHUS NEOABIES 1000X (1610-1640FT)

9. CYCLICARGOLITHUS FLORIDANUS 1000X (2150-2180FT)

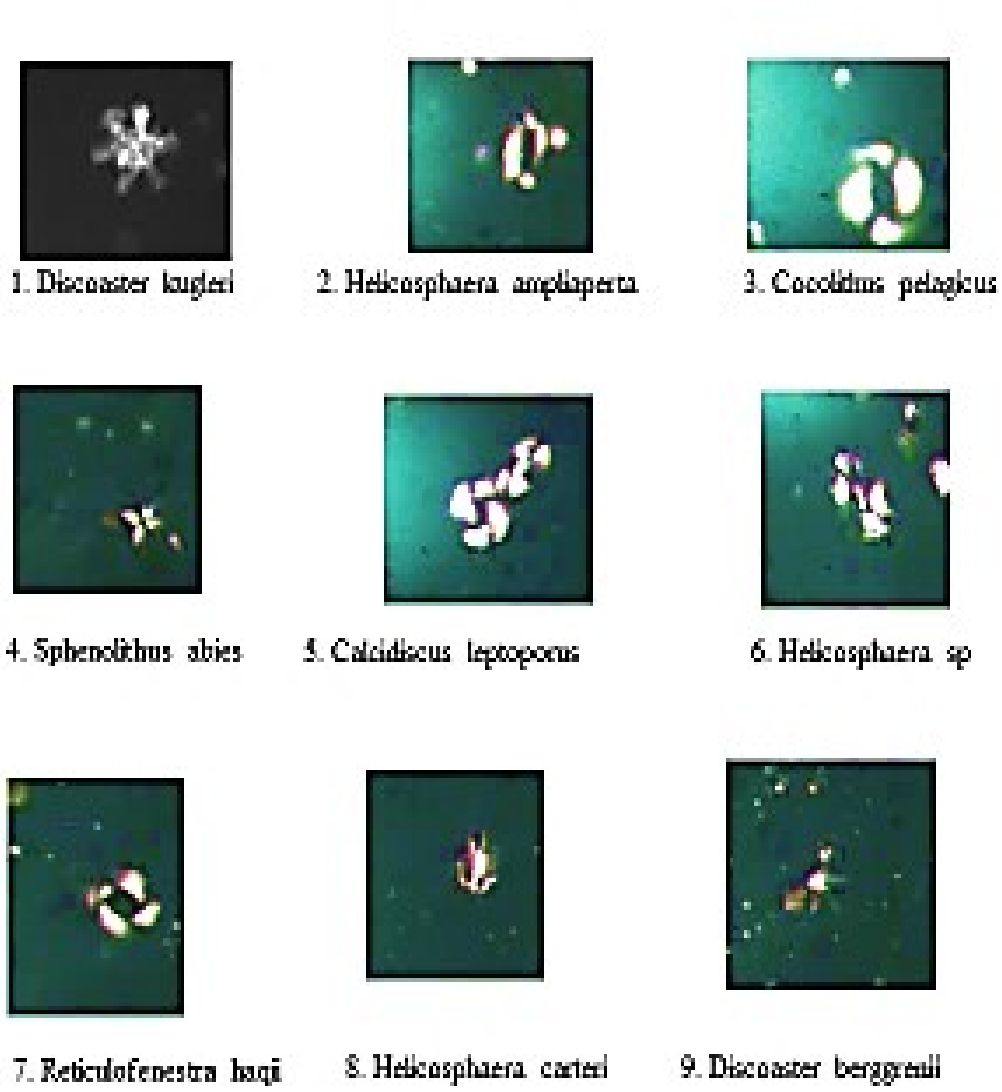


PLATE 2: Well 2 Calcareous Nannofossils photomicropraph images. (1000X)

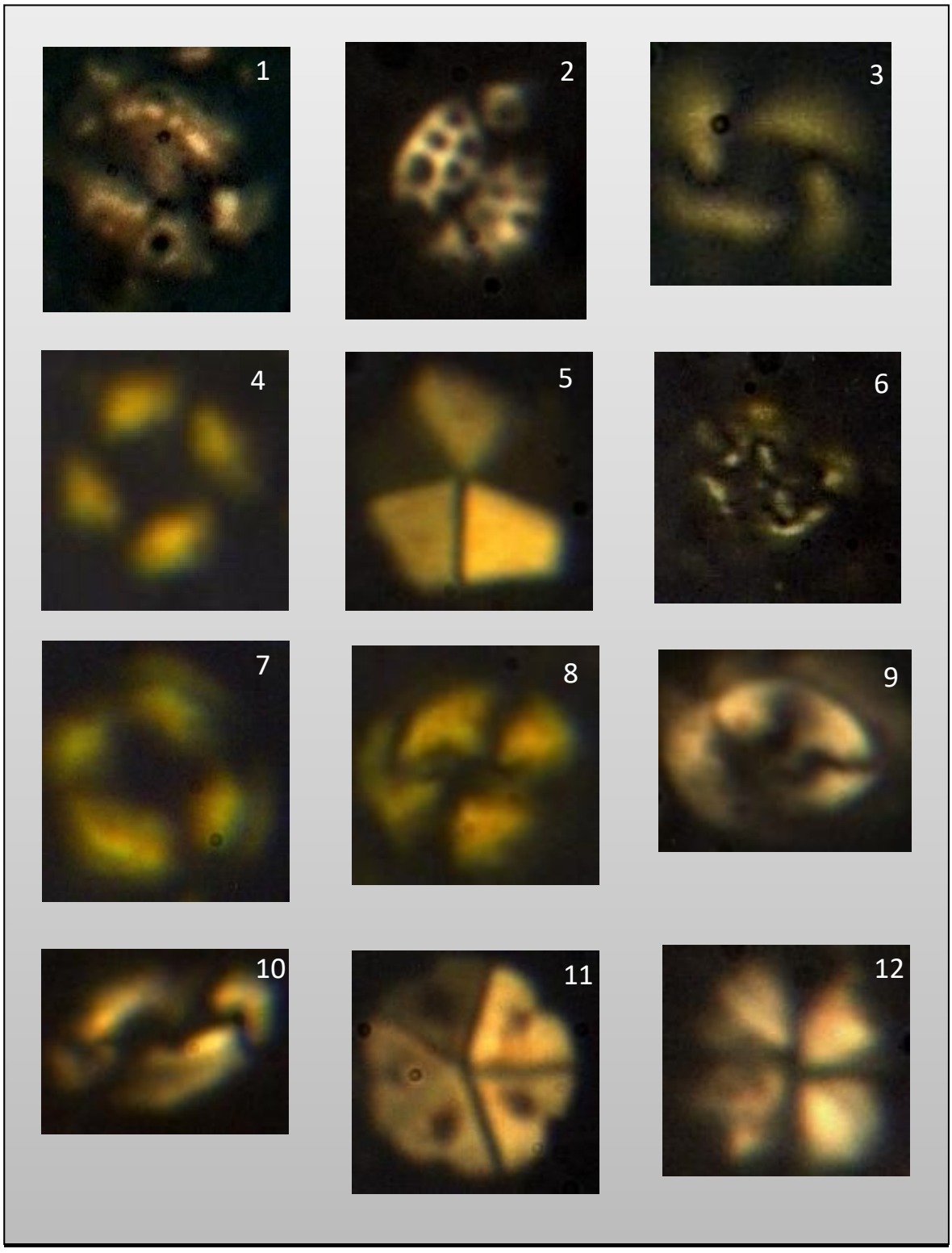


PLATE 3 : Well 3 Calcareous Nannofossils photomicrograph images

1. *Helicosphaera seminulum 1000X (7630-7660ft.)*

2. *Pontosphaera multipora 1000X (6040-6070ft.)*

3. *Reticulofenestra haqii 1000X (7870-7900ft.)*

4. *Markalius inversus1000X (7900-7930ft.)*

5. *Braarudosphaera bigelowii 1000X (7630-7660ft.)*

6. *Chiasmolithus sp 1000X (8290-8320ft.)*

7. *Coccolithus formusus1000X (8140-8170ft.)*

8. *Cyclicargolithus floridanus 1000X (7720-7750ft.)*

9. *Helicosphaera compacta 1000X (7600-7630ft.)*

10. *Helicosphaera scissura 1000X (5260-5290ft.)*

11. *Pemma basquensis 1000X (7600-7630ft.)*

12. *Sphenolithus moriformis 1000X (5260-5290ft.)*

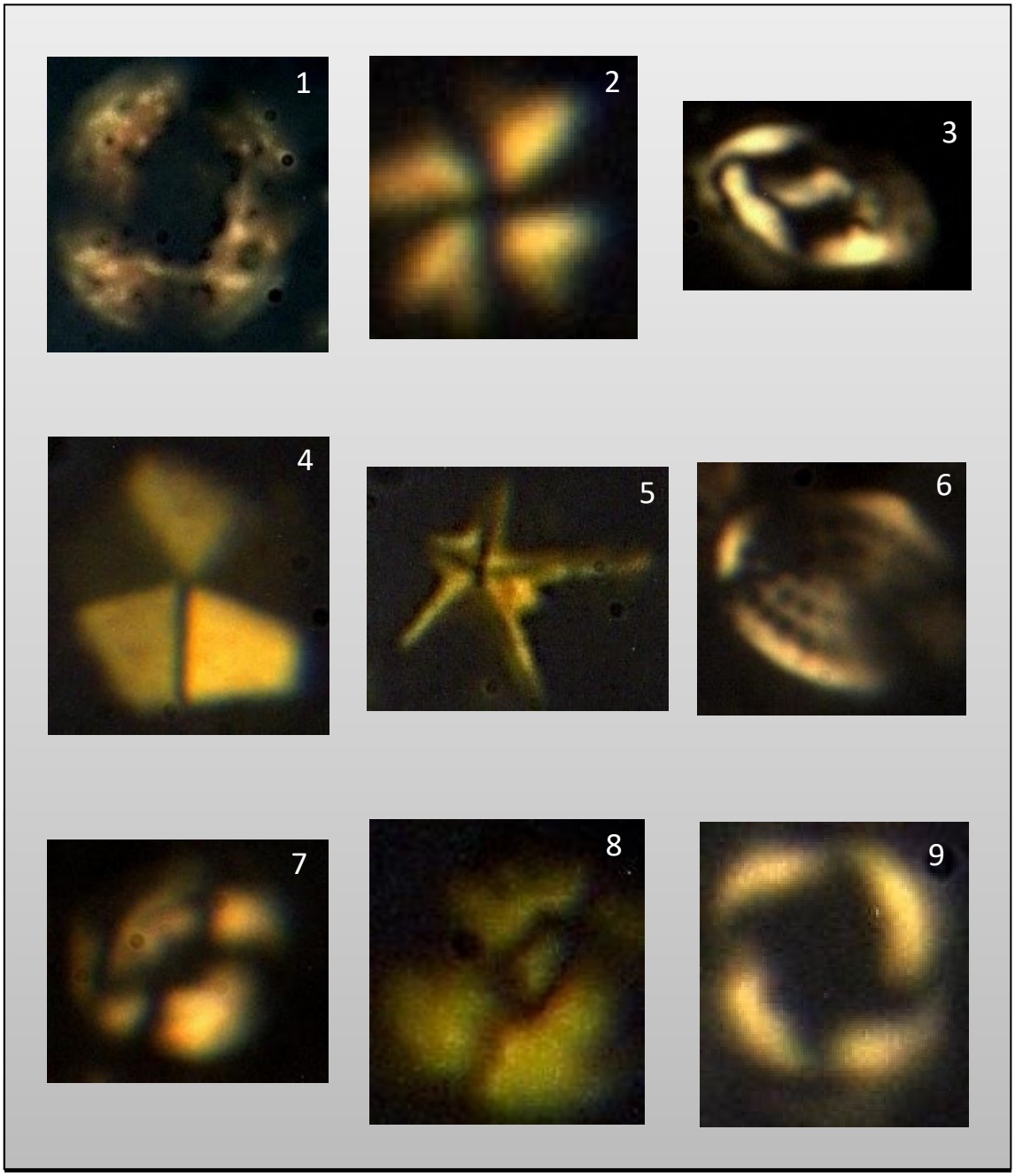


PLATE 4: Well 3 Calcareous Nannofossils photomicrograph images

1. *Reticulofenestra umbilica 1000X (7720-7750ft.)*

2. *Sphenolithus moriformis1000X (6160-6190ft.)*

3. *Helicosphaera compacta 1000X (7600-7630ft.)*

4. *Braarudosphaera bigelowii 1000X (6160-6190ft.)*

5. *Micrantholithus entaster1000X (7720-7750ft.)*

6. *Pontosphaera multipora 1000X (6220-6250ft.)*

7. *Coccolithus pelagicus 1000X (7780-7810ft.)*

8. *Helicosphaera sp 1000X (6040-6090ft.)*

9. *Reticulofenesttra pseuddoumbiliicus 1000X (7540-7570 ft.)*

APPENDIX 2

LITHOLOGICAL DESCRIPTION OF WELL 1

DEPTH (METERS)	LITHOLOGY	DESCRIPTION
102 - 107	SAND	**Sand (100%):** Whitish white to glassy, fine to coarse, subangular to subrounded, fairly well sorted, calcareous. **Accessory Minerals:** Mica flakes, calcites, pyrite, ferruginous, pyrite present.
107 - 116	SAND	**Sand (100%):** Whitish white to glassy, fine to coarse, subangular to subrounded, fairly well sorted, calcareous. **Accessory Minerals:** Mica flakes, calcites, pyrite, ferruginous, pyrite present.
116 - 125	SAND	**Sand (100%):** Whitish white to glassy, fine to coarse, subangular to subrounded, fairly well sorted, calcareous. **Accessory Minerals:** Mica flakes, calcites, pyrite present.
125 - 143	SAND	**Sand (100%):** Whitish to glassy, fine to coarse, subangular to subrounded, fairly well sorted, calcareous. **Accessory Minerals:** Mica flakes, calcites, pyrite present.
143 - 152	SAND	**Sand (100%):** Whitish to glassy, fine to coarse, subangular to subrounded, fairly well sorted, calcareous. **Accessory Minerals:** Mica flakes, calcites, pyrite present.
152 - 162	SAND	**Sand (100%):** Creamy white to glassy, fine grain – coarse grain, sub-angular to sub-rounded, fairly well sorted sands. **Accessory Minerals:** None.
162 - 171	SAND	**Sand (100%):** Cloudy white to glassy, fine grain – coarse grain, subangular to subrounded, fairly well sorted, calcareous. **Accessory Minerals:** None.
171 - 180	SAND	**Sand (100%):** Whitish white to glassy, fine to medium, subangular to subrounded fairly sorted sand grains. **Accessory Minerals:** None.
180 – 189	SAND	**Sand (100%):** Whitish to glassy, fine to medium, subangular to subrounded fairly sorted sand grains. **Accessory Minerals:** None.
189 – 198	SAND	**Sand (100%):** Whitish to glassy, fine to middle to coarse, subangular to subrounded fairly well sorted grains. **Accessory Minerals:** None.

198 – 207	SAND	**Sand (100%):** Milky white to glassy, fine to intermediate to coarse, subangular to subrounded fairly well sorted grains. **Accessory Minerals:** None.
207 – 216	SAND	**Sand (100%):** Cloudy white to glassy, fine to middle to coarse, subangular to subrounded fairly well sorted grains. **Accessory Minerals:** None.
216 – 226	SAND	**Sand (100%):** Whitish to glassy, occasionally grayish, fine to medium, subangular to subrounded, poorly sorted sand grains. **Accessory Minerals:** None.
226 – 235	SAND	**Sand (100%):** Cloudy white to glassy, medium to coarse to quartzose, subangular to subrounded fairly well sorted sand grains. **Accessory Minerals:** None.
235 – 244	SAND	**Sand (100%):** Cloudy white to glassy, medium to coarse to quartzose, subangular to subrounded fairly well sorted sand grains. **Accessory Minerals:** None.
244 – 253	SAND	**Sand (100%): W**hitish to glassy, occasionally pinkish, fine-medium-occasionally coarse, subangular to subrounded poorly sorted sand grains. **Accessory Minerals:** None.
253 - 262	SAND	**Sand (100%):** Cloudy white to glassy, occasionally pinkish, fine-medium-occasionally coarse subangular to subrounded poorly sorted sand grains. **Accessory Minerals:** None.
262 – 272	SAND	**Sand (100%):** Whitish to glassy, medium - coarse - very coarse, subangular to subrounded, poorly sorted sand grains. **Accessory Minerals:** None.
272 – 280	SAND	**Sand (100%):** Whitish to glassy, intermediate to coarse to very coarse, subangular to subrounded, poorly sorted sand grains. **Accessory Minerals:** None.
280 – 290	SAND	**Sand (100%):** Creamy white to glassy, fine to intermediate to coarse, subangular to subrounded, poorly sorted sand grains. **Accessory Minerals:** None.
290 - 299	SAND	**Sand (100%):** Cloudy white to glassy, fine to middle to coarse, subangular to subrounded, poorly sorted sand grains. **Accessory Minerals:** None.

299 – 308	SILICA RICH SHALE	**Sand (40%):** Whitish to glassy, very fine to fine to occasionally coarse, subangular to subrounded, fairly well sorted, slightly calcareous sand grains. **Shale (60%):** Brownish to reddish brown, blocky, moderately hard shale. **Accessory Minerals:** None.
308 – 317	SHALY SAND	**Sand (60%):** Whitish to glassy, very fine to fine to occasionally coarse, subangular to subrounded, fairly well sorted, slightly calcareous sand grains. **Shale (40%):** Brownish to reddish brown, blocky, moderately hard shale. **Accessory Minerals:** None.
317 – 326	SAND	**Sand (100%): W**hitish to glassy, fine to medium, subangular to subrounded fairly well sorted sand grains. **Accessory Minerals:** Pyrite.
326 - 335	SAND	**Sand (100%):** Whitish to glassy, fine to medium, subangular to subrounded fairly well sorted sand grains. **Accessory Minerals:** Pyrite.
335 – 344	SAND	**Sand (100%):** Whitish to glassy, fine to medium, subangular to subrounded fairly well sorted sand grains. **Accessory Minerals:** Pyrite.
344 – 354	SAND	**Sand (100%):** Whitish to glassy, fine to medium, subangular to subrounded fairly well sorted sand grains. **Accessory Minerals:** Pyrite.
354 – 263	SAND	**Sand (100%):** Cloudy white to glassy, to occasionally pinkish, fine to medium, subangular to subrounded fairly well sorted sand grains. **Accessory Minerals:** Mica flakes, crystals of calcite.
263 – 372	SAND	**Sand (100%):** Cloudy white to glassy, to occasionally pinkish, fine to medium, subangular to subrounded fairly well sorted sand grains. **Accessory Minerals:** Mica flakes, crystals of calcite.
372 – 381	SAND	**Sand (100%):** Whitish to glassy, fine to medium, rarely coarse, subangular to subrounded, fairly well sorted sand grains. **Accessory Minerals:** Few mica flakes
381 – 390	SAND	**Sand (100%):** Whitish white to glassy, fine to medium, rarely coarse, subangular to subrounded, fairly well sorted sand grains. **Accessory Minerals:** Few mica flakes.
390 – 399	SAND	**Sand (100%):** Whitish white to glassy, fine to medium, rarely coarse, subangular fairly well sorted sand grains. **Accessory Minerals:** Few mica flakes.

399 – 408	SAND	**Sand (100%):** Whitish white to glassy, fine to medium, occasionally coarse subangular fairly well sorted sand grains. **Accessory Minerals:** Few mica flakes.
408 – 416	SAND	**Sand (100%):** Whitish to glassy, fine to medium, occasionally coarse, subangular fairly well sorted sand grains. **Accessory Minerals:** None.
416 – 426	SHALY SAND	**Sand (95%):** Cloudy white to glassy, fine to medium, occasionally coarse subangular fairly well sorted sand grains. **Shale (5%):** Greyish to brownish, blocky, moderately hard shale **Accessory Minerals:** None.
426 – 436	SHALY SAND	**Sand (95%):** Whitish to glassy, middle - coarse, subangular - subrounded, well sorted slightly calcareous sand grains. **Shale (5%):** Greyish to brownish, blocky shale. **Accessory Minerals:** carbonaceous detritus, mica flakes, pyrite.
436 – 445	SANDY SHALE	**Sand (45%):** Cloudy white to glassy, middle - coarse, subangular - subrounded, well sorted slightly calcareous sand grains. **Shale (55%):** Greyish to brownish, blocky, discreetly hard shale. **Accessory Minerals:** Carbonaceous detritus, mica flakes, pyrite.
445 – 454	SANDY SHALE	**Sand (45%):** Cloudy white to glassy, fine - medium - occasionally coarse, subangular - subrounded, poorly sorted sand grains. **Shale (55%):** Greyish to brownish shale. **Accessory Minerals:** None.
454 – 463	SHALY SAND	**Sand (70%):** Cloudy white to glassy, fine to middle - occasionally coarse, subangular - subrounded, poorly sorted sand grains. **Shale (20%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** None.
463 – 472	SHALY SAND	**Sand (80%):** Cloudy white to glassy, fine to medium, fairly well sorted slightly calcareous sand grains. **Shale (20%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Pyrite.
472 – 482	SHALY SAND	**Sand (80%):** Whitish to glassy, fine to medium, fairly well sorted slightly calcareous sand grains. **Shale (20%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Pyrite.

482 – 491	SHALY SAND	**Sand (70%):** Cloudy white to glassy, fine to medium, occasionally coarse fairly well sorted, angular to subangular to subrounded sand grains. **Shale (30%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Mica flakes.
491 – 500	SHALY SAND	**Sand (70%):** Creamy white to glassy, fine to medium, rarely coarse fairly well sorted, angular to subangular to subrounded sand grains. **Shale (30%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Mica flakes.
500 – 509	SHALY SAND	**Sand (70%):** Creamy white to glassy, fine to medium, rarely coarse fairly well sorted, angular to subangular to subrounded sand grains. **Shale (30%):** Greyish to brownish, discreetly hard shale. **Accessory Minerals:** Mica flakes.
509 – 518	SHALY SAND	**Sand (70%):** Creamy white to glassy, fine to medium, rarely coarse fairly well sorted, subangular - subrounded sand grains. **Shale (30%):** Greyish - brownish, blocky, moderately hard shale. **Accessory Minerals:** Mica flakes.
518 – 527	SHALY SAND	**Sand (70%):** Creamy white to glassy, fine to medium, occasionally coarse fairly well sorted, angular to subangular to subrounded sand grains. **Shale (30%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Mica flakes.
527 – 536	SHALY SAND	**Sand (70%):** Creamy white to glassy, fine to medium, occasionally coarse fairly well sorted, angular to subangular to subrounded sand grains. **Shale (30%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Mica flakes.
536 - 546	SHALY SAND	**Sand (70%):** Cloudy white to glassy, fine to medium, occasionally coarse fairly well sorted, angular to subangular to subrounded sand grains. **Shale (30%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Mica flakes.
546 - 556	SHALY SAND	**Sand (70%):** Cloudy white to glassy, fine to medium, occasionally coarse fairly well sorted, angular to subangular to subrounded sand grains. **Shale (30%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Mica flakes.

555 – 564	SANDY SHALE	**Sand (40%):** Cloudy white to glassy, occasionally greyish, fine to medium, to coarse poorly sorted sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Mica flakes.
564 – 573	SANDY SHALE	**Sand (40%):** Cloudy white to glassy, occasionally greyish, fine to medium, to coarse poorly sorted sand grains. **Shale (60%):** Greyish to brownish, blocky, discreetly hard shale. **Accessory Minerals:** Mica flakes.
673 – 582	SILICA RICH SHALE	**Sand (40%): W**hitish to glassy, chiefly fine, but occasionally medium - coarse fairly well sorted sand grains. **Shale (60%):** Greyish to brownish, blocky, slightly hard shale. **Accessory Minerals:** Few mica flakes.
582 – 591	SANDY SHALE	**Sand (40%): M**ainly fine, but occasionally medium to coarse fairly well sorted, milky white to glassy sand grains. **Shale (60%):** Greyish to brownish, blocky, soberly hard shale. **Accessory Minerals:** Few mica flakes.
591 – 600	SILICA RICH SHALE	**Sand (40%): M**ostly fine, but occasionally medium, to coarse fairly well sorted, milky white to glassy sand grains. **Shale (60%):** Greyish to brownish, blocky, temperately hard shale. **Accessory Minerals:** Few mica flakes.
600 – 610	SANDY SHALE	**Sand (40%): L**argely fine, but occasionally medium, to coarse fairly well sorted, milky white to glass sand grains. **Shale (60%):** Greyish to brownish, blocky, temperately hard shale. **Accessory Minerals:** Few mica flakes.
610 – 618	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionally coarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
618 – 628	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionally coarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.

628 – 637	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionallycoarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
637 – 646	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionally coarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
646 – 655	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionally coarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
655 – 664	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionally coarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
664 – 674	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionally coarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
674 – 683	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionally coarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
683 – 692	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionally coarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
692 – 701	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, with occasionally coarse, subangular to subrounded, well sorted, sand grains. **Shale (60%):** Greyish to brownish, blocky, moderately hard shale. **Accessory Minerals:** Traces of mica flakes.

701 – 710	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular, well sorted sand grains. **Sand (55%):** Reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, pyrite.
710 – 719	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular, well sorted sand grains. **Sand (55%):** Reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, pyrite.
719 – 728	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, occasionally coarse, subangular to subrounded slightly calcareous, well sorted, sand grains. **Shale (40%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
728 – 738	SANDY SHALE	**Sand (30%):** Milky white to glassy, very fine, occasionally coarse, subangular to subrounded slightly calcareous, well sorted, sand grains. **Shale (70%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
738 – 746	SANDY SHALE	**Sand (30%):** Milky white to glassy, very fine, occasionally coarse, subangular to subrounded slightly calcareous, well sorted, sand grains. **Shale (70%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes and pyrites
746 – 756	SHALY SAND	**Sand (55%):** Milky white to glassy, very fine, occasionally coarse, subangular to subrounded slightly calcareous, well sorted, sand grains. **Shale (45%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, pyrite.
756 – 765	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, occasionally coarse, subangular to subrounded slightly calcareous, well sorted, sand grains. **Shale (40%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
765 – 774	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, occasionally coarse, subangular to subrounded slightly calcareous, well sorted, sand grains. **Shale (40%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.

774 - 783	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular to subrounded well sorted, sand grains. **Shale (60%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes with lots of shell fragments.
783 – 792	SANDY SHALE	**Sand (40%):** Whitish to glassy, very fine, subangular to subrounded well sorted, sand grains. **Shale (60%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes with lots of shell fragments.
792 – 802	SANDY SHALE	**Sand (40%):** Whitish to glassy, very fine, subangular to subrounded well sorted, sand grains. **Shale (60%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes with lots of shell fragments.
802 – 811	SANDY SHALE	**Sand (40%):** Whitish to glassy, very fine, subangular to subrounded well sorted, sand grains. **Shale (60%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes with lots of shell fragments.
811 – 820	SANDY SHALE	**Sand (45%):** Whitish to glassy, very fine, subangular to subrounded well sorted, sand grains. **Shale (55%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes with lots of shell fragments.
820 - 829	SHALY SAND	**Sand (55%):** Whitish to glassy, very fine, subangular to subrounded well sorted, sand grains. **Shale (45%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
829 – 838	SANDY SHALE	**Sand (45%):** White to glassy, very fine, subangular to subrounded well sorted, slightly calcareous sand grains. **Shale (55%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
838 – 847	SANDY SHALE	**Sand (45%):** White to glassy, very fine, subangular to subrounded well sorted, slightly calcareous sand grains. **Shale (55%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.

847 – 856	SHALY SAND	**Sand (55%):** White to glassy, very fine, subangular to subrounded well sorted, sand grains. **Shale (45%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
856 – 866	SHALY SAND	**Sand (60%):** White to glassy, very fine, subangular to subrounded well sorted, sand grains. **Shale (40%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
866 – 875	SHALY SAND	**Sand (65%):** White to glassy, very fine, subangular to subrounded well sorted, sand grains. **Shale (35%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
875 – 884	SANDY SHALE	**Sand (45%):** White to glassy, very fine, subangular to subrounded well sorted, slightly calcareous sand grains. **Shale (55%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
884 – 893	SANDY SHALE	**Sand (45%):** White to glassy, very fine, subangular to subrounded well sorted, slightly calcareous sand grains. **Shale (55%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
893 – 902	SHALY SAND	**Sand (55%):** White to glassy, very fine, subangular to subrounded well sorted, slightly calcareous sand grains. **Shale (45%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
902 – 911	SANDY SHALE	**Sand (45%):** White to glassy, very fine, subangular to subrounded well sorted, slightly calcareous sand grains. **Shale (55%):** Greyish to reddish brown, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
911 – 920	SANDY SHALE	**Sand (30%):** White to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (70%):** Greyish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.

920 – 930	SHALY SAND	**Sand (60%):** White to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (40%):** Greyish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
930 – 939	SANDY SHALE	**Sand (55%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (40%):** Greyish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
939 – 948	SHALY SAND	**Sand (70%):** Milky white to glassy, very fine, well sorted, slightly calcareous sand grains. **Shale (30%):** Greyish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
948 – 957	SHALY SAND	**Sand (70%):** Milky white to glassy, very fine, well sorted, slightly calcareous sand grains. **Shale (30%):** Greyish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
957 - 966	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
966 – 975	SANDY SHALE	**Sand (55%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (45%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
975 – 985	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains, with lots of wood shavings. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
985 – 994	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains, with lots of wood shavings. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.

994 – 1003	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, well sorted, slightly calcareous sand grains, with lots of wood shavings. **Shale (55%):** Greyish to brownish, pellets to blocky moderatelyhard shale. **Accessory Minerals:** Traces of mica flakes.
1003 – 1012	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains, with lots of wood shavings. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
1012 – 1021	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1021 – 1030	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1030 – 1039	SHALY SAND	**Sand (70%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (30%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1039 - 1049	SHALY SAND	**Sand (70%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (30%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1049 – 1058	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.

1058 – 1067	SHALY SAND	**Sand (55%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (45%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1067 – 1076	SHALY SAND	**Sand (90%):** Milky white to glassy, very fine, subangular well sorted, rarely calcareous sand grains. **Shale (10%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, with few shell fragments.
1076 - 1085	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular well sorted, rarely calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, with few shell fragments.
1085 – 1094	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular well sorted, rarely calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, with few shell fragments.
1094 – 1103	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular well sorted, rarely calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, with few shell fragments.
1103 – 1113	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (4%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1113 – 1122	SANDY SHAL	**Sand (40%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.

1122 – 1131	SHALY SAND	**Sand (65%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (35%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1131 – 1140	SANDY SHALE	**Sand (35%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (75%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1140 – 1149	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular poorly sorted, slightly calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1149 – 1158	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular poorly sorted, slightly calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes, shell fragments.
1158 - 1167	SHALYSAND	**Sand (60%):** Milky white to glassy, very fine, subangular poorly sorted, rarely calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale **Accessory Minerals:** Traces of mica flakes, shell fragments.
1167 – 1177	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular poorly sorted, rarely calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale **Accessory Minerals:** Traces of mica flakes, shell fragments.
1177 – 1186	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular poorly sorted, rarely calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale **Accessory Minerals:** Traces of mica flakes, shell fragments.

1186 – 1195	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular poorly sorted, rarely calcareous sand grains. **Shale (55%):** Greyish to brownish, pellets to blocky moderately hard shale **Accessory Minerals:** Traces of mica flakes, shell fragments.
1195 - 1204	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular poorly sorted, rarely calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale **Accessory Minerals:** Traces of mica flakes, shell fragments.
1204 – 1213	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular poorly sorted, rarely calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale **Accessory Minerals:** Traces of mica flakes, shell fragments.
1213 – 1222	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular poorly sorted, slightly calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale **Accessory Minerals:** Traces of mica flakes, shell fragments.
1222 – 1231	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular poorly sorted, slightly calcareous sand grains. **Shale (55%):** Greyish to brownish, pellets to blocky moderately hard shale **Accessory Minerals:** Traces of mica flakes, shell fragments.
1231 – 1241	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (55%):** Greyish to brownish, pellets to blocky slightly hard shale **Accessory Minerals:** Very few mica flakes.
1241 – 1250	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (55%):** Greyish to brownish, pellets to slightly hard shale **Accessory Minerals:** Very few mica flakes.
1250 – 1259	SHALY SAND	**Sand (55%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (45%):** Greyish to brownish, pellets to moderately hard shale **Accessory Minerals:** Very few mica flakes.

1259 – 1268	SHALY SAND	**Sand (55%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (45%):** Greyish to brownish, blocky hard shale **Accessory Minerals:** Very few mica flakes.
1268 – 1277	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Very few mica flakes, shell fragments.
1277 – 1286	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Very few mica flakes, shell fragments.
1286 – 1294	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Very few mica flakes, shell fragments.
1294 – 1305	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Very few mica flakes, shell fragments.
1305 – 1314	SHALY SAND	**Sand (55%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (45%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1314 – 1323	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1323 - 1332	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (55%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.

1332 – 1341	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (55%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1341 – 1350	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (40%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1350 – 1359	SHALY SAND	**Sand (55%):** Milky white to glassy, very fine, subangular poorly sorted, highly calcareous sand grains. **Shale (45%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1359 – 1369	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None
1369 – 1378	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1378 – 1387	SANDY SHALE	**Sand (40%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1387 – 1396	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1396 – 1405	SHALY SAND	**Sand (70%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (30%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.

1405 – 1414	SHALY SAND	**Sand (75%):** Milky white to glassy, very fine, subangular well sorted, slightly calcareous sand grains. **Shale (25%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1414 – 1423	SANDY SHALE	**Sand (40%):** Milky white to glassy, fine - medium, angular - subangular fairly well sorted, slightly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Mica flakes present.
1423 – 1433	SHALY SAND	**Sand (40%):** Milky white to glassy, fine - medium, angular - subangular fairly well sorted, slightly calcareous sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Mica flakes present.
1433 – 1442	SHALY SAND	**Sand (65%):** Milky white to glassy, very fine, subangular, well sorted, slightly calcareous sand grains. **Shale (35%):** Greyish to brownish, moderately hard, pellets to blocky shale. **Accessory Minerals:** Few shell fragments and mica flakes present.
1442 – 1451	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular, well sorted, slightly calcareous sand grains. **Shale (40%):** Greyish to brownish, pellets to block shale. **Accessory Minerals:** Few shell fragments and mica flakes present
1451 – 1460	SHALY SAND	**Sand (75%):** Milky white to glassy, very fine, subangular, well sorted sand grains. **Shale (25%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None
1460 – 1469	SHALY SAND	**Sand (70%):** Milky white to glassy, very fine, subangular, well sorted sand grains. **Shale (30%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None
1469 – 1478	SHALY SAND	**Sand (60%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Few shell fragments.
1478 – 1487	SHALY SAND	**Sand (60%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Few shell fragments.

1487 – 1497	SANDY SHALE	**Sand (40%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Few pyrites present.
1497 – 1506	SANDY SHALE	**Sand (40%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Few pyrites present..
1506 – 1515	SHALY SAND	**Sand (55%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (45%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1515 – 1524	SHALY SAND	**Sand (60%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (40%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1524 – 1533	SANDY SHALE	**Sand (45%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (55%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1533 – 1542	SANDY SHALE	**Sand (45%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (55%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1542 - 1551	SANDY SHALE	**Sand (45%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (55%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1551 – 1561	SANDY SHALE	**Sand (45%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (55%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None
1561 – 1570	SHALY SAND	**Sand (55%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (45%):** Brownish, moderately hard, pellets to blocky shale. **Accessory Minerals:** Few mica flakes present.
1570 – 1579	SHALY SAND	**Sand (55%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (45%):** Brownish, pellets to blocky slightly hard shale. **Accessory Minerals:** Few mica flakes present.

1579 – 1588	SANDY SHALE	**Sand (60%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (40%):** Brownish, moderately hard, pellets to blocky shale. **Accessory Minerals:** Few mica flakes present.
1588 – 1597	SHALY SAND	**Sand (55%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (45%):** Brownish, pellets to moderately hard shale. **Accessory Minerals:** Few mica flakes present.
1597 – 1606	SHALY SAND	**Sand (55%):** Milky white to glassy, fine, subangular, well sorted sand grains. **Shale (45%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1606 – 1615	SHALY SAND	**Sand (60%):** Milky white to glassy, fine - occasionally medium, subangular to subrounded, fairly well sorted sand grains **Shale (40%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1615 – 1625	SHALY SAND	**Sand (60%):** Milky white to glassy, fine - occasionally medium, subangular to subrounded, fairly well sorted sand grains **Shale (40%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1625 - 1634	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular, fairly well sorted sand grains. **Shale (55%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1634 – 1643	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular, fairly well sorted sand grains. **Shale (55%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1643 – 1652	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular, fairly well sorted sand grains. **Shale (55%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1652 – 1661	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular, fairly well sorted sand grains. **Shale (55%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1661 – 1670	SANDY SHALE	**Sand (45%):** Milky white to glassy, very fine, subangular, fairly well sorted sand grains. **Shale (55%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.

1670 - 1679	SHALY SAND	**Sand (55%):** Milky white to glassy, very fine, subangular, well sorted sand grains. **Shale (45%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1679 – 1689	SHALY SAND	**Sand (60%):** Milky white to glassy, very fine, subangular, well sorted sand grains. **Shale (40%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1689 - 1698	SHALY SAND	**Sand (65%):** Milky white to glassy, fine - medium, subangular - subrounded, fairly sorted sand grains. **Shale (35%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1698 – 1707	SANDY SHALE	**Sand (40%):** Milky white to glassy, fine - medium, subangular - subrounded, fairly sorted sand grains. **Shale (60%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1707 – 1716	SANDY SHALE	**Sand (40%):** Milky white to glassy, fine - medium, subangular - subrounded, fairly sorted grains. **Shale (60%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None
1716 – 1725	SHALY SAND	**Sand (60%):** Milky white to glassy, fine - medium, subangular - subrounded, fairly sorted grains. **Shale (40%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** None.
1725 – 1734	SANDY SHALE	**Sand (55%):** Milky white to glassy, fine - medium, subangular - subrounded, fairly sorted grains. **Shale (45%):** Brownish, pellets to blocky moderately hard shale **Accessory Minerals:** Presence of few mica flakes and pyrite.
1734 – 1743	SANDY SHALE	**Sand (60%):** Milky white to glassy, fine to medium, subangular, fairly well sorted sand grains. **Shale (40%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of few mica flakes and pyrite.

1743 – 1753	SANDY SHALE	**Sand (30%):** Milky white to glassy, fine to medium, subangular, fairly well sorted sand grains. **Shale (70%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of few mica flakes.
1753 – 1762	SHALY SAND	**Sand (60%):** Milky white to glassy, fine to medium, subangular, fairly well sorted sand grains. **Shale (40%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of few mica flakes.
1762 – 1771	SHALY SAND	**Sand (60%):** Milky white to glassy, fine to medium, subangular, fairly well sorted sand grains. **Shale (40%):** Brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of few mica flakes.
1771 - 1780	SHALY SAND	**Sand (70%):** Milky white to glassy, fine to medium, subangular, fairly well sorted sand grains. **Shale (30%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1780 – 1789	SHALY SAND	**Sand (70%):** Milky white to glassy, fine to medium, subangular, fairly well sorted sand grains. **Shale (30%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1789 – 1798	SHALY SAND	**Sand (65%):** Milky white to glassy, fine to medium, subangular, fairly well sorted sand grains. **Shale (35%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1798 – 1807	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine to medium, subangular, fairly well sorted sand grains. **Shale (55%):** Grey to brownish, white occasionally reddish brown pellets to blocky moderately hard shale. **Accessory Minerals:** None.
1807 – 1817	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine to medium, subangular, fairly well sorted sand grains. **Shale (60%):** Grey to brownish, white occasionally reddish brown pellets to blocky moderately hard shale. **Accessory Minerals:** None.

1817 - 1826	SANDY SHALE	**Sand (40):** White to glassy, fine to medium, subangular, poorly well sorted sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of pyrite and traces of mica.
1826 – 1835	SANDY SHALE	**Sand (40):** Milky white to glassy, fine to medium, subangular, poorly well sorted sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of pyrite and traces of mica.
1835 – 1840	SANDY SHALE	**Sand (40):** Milky white to glassy, fine to medium, subangular, poorly well sorted sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of pyrite and traces of mica.
1840 – 1853	SANDY SHALE	**Sand (40):** Milky white to glassy, fine to medium, subangular, poorly well sorted sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of pyrite.
1853 – 1862	SANDY SHALE	**Sand (40):** Milky white to glassy, fine to medium, subangular, poorly well sorted sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of pyrite.
1862 – 1871	SANDY SHALE	**Sand (40):** Milky white to glassy, fine to medium, subangular, poorly well sorted sand grains. **Shale (60%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of pyrite.
1871 – 1881	SHALY SAND	**Sand (60%):** Milky white to glassy, fine, subangular well sorted sand grains, rarely calcareous. **Shale (40%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of pyrite, with few mica flakes.
1881 – 1890	SHALY SAND	**Sand (65%):** Milky white to glassy, fine, subangular well sorted sand grains, rarely calcareous. **Shale (35%):** Greyish to brownish, pellets to blocky moderately hard shale. **Accessory Minerals:** Presence of pyrite, with few mica flakes.
1890 – 1899	SHALY SAND	**Sand (60%):** Milky white to glassy, fine, subangular well sorted sand grains, rarely calcareous. **Shale (40%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.

1899 – 1908	SANDY SHALE	**Sand (45%):** Milky white to glassy, fine, subangular well sorted sand grains, rarely calcareous. **Shale (55%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** Traces of mica flakes.
1908 – 1917	SHALY SAND	**Sand (55%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (45%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** None.
1917 – 1926	SHALY SAND	**Sand (60%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (40%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** None.
1926 – 1935	SHALY SAND	**Same as described above**
1935 – 1945	SHALY SAND	**Sand (70%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (30%):** Greyish to occasionally brownish, blocky moderately hard shale. **Accessory Minerals:** None.
1945 – 1958	SHALY SAND	**Sand (70%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (30%):** Greyish to occasionally brownish, blocky moderately hard shale. **Accessory Minerals:** None.
1958 – 1963	SHALY SAND	**Sand (70%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (30%):** Greyish to occasionally brownish, blocky moderately hard shale. **Accessory Minerals:** None.
1963 – 1972	SHALY SAND	**Sand (60%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (40%):** Greyish to occasionally brownish, blocky moderately hard shale. **Accessory Minerals:** None.
1972 – 1981	SHALY SAND	**Sand (55%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (45%):** Greyish to occasionally brownish, blocky moderately hard shale. **Accessory Minerals:** None.
1981 – 1990	SANDY SHALE	**Sand (35%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (65%):** Greyish to occasionally brownish, blocky moderately hard shale. **Accessory Minerals:** None.

1990 – 1999	SANDY SHALE	**Sand (35%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (65%):** Greyish to occasionally brownish, blocky moderately hard shale. **Accessory Minerals:** None.
1999 – 2009	SANDY SHALLE	**Sand (35%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (65%):** Greyish to occasionally brownish, blocky moderately hard shale. **Accessory Minerals:** None.
2009 – 2018	SHALY SAND	**Sand (60%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (40%):** Brownish, blocky moderately hard shale. **Accessory Minerals:** None.
2018 – 2027	SHALY SAND	**Sand (65%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (35%):** Brownish, blocky moderately hard shale. **Accessory Minerals:** None.
2027 – 2036	SHALY SAND	**Sand (65%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (35%):** Brownish, blocky moderately hard shale. **Accessory Minerals:** None.
2036 – 2045	SHALY SAND	**Sand (70%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (30%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** None.
2045 – 2054	SHALY SAND	**Sand (60%):** Milky white to glassy, fine, subangular well sorted sand grains. **Shale (40%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** None.
2054 – 2063	SHALY SAND	**Sand (55%):** Milky white to glassy, fine - middle, subangular - subrounded, fairly sorted grains. **Shale (45%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** Few mica flakes.
2063 – 2073	SHALY SAND	**Sand (70%):** Milky white to glassy, fine - middle, subangular - subrounded, fairly sorted grains. **Shale (30%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** Few mica flakes.
2073 – 2082	SHALY SAND	**Sand (70%):** Milky white to glassy, fine - middle, subangular - subrounded, fairly sorted grains. **Shale (30%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** Few mica flakes.

2082 - 2091	SHALY SAND	**Sand (70%):** Milky white to glassy, fine - middle, subangular - subrounded, fairly sorted grains. **Shale (30%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** Few mica flakes.
2091 – 2100	SHALY SAND	**Sand (60%):** Milky white to glassy, fine - medium, subangular - subrounded, fairly sorted grains. **Shale (40%):** Greyish to brownish, moderately hard blocky shale. **Accessory Minerals:** Few mica flakes.
2100 – 2109	SHALY SAND	**Sand (55%):** Milky white to glassy, fine - medium, subangular - subrounded, fairly sorted grains. **Shale (45%):** Greyish to brownish, blocky shale. **Accessory Minerals:** Few mica flakes.
2109 - 2112	SANDY SHALE	**Sand (45%):** Milky white to glassy, fine - medium, subangular - subrounded, fairly sorted grains. **Shale (55%):** Greyish to brownish, blocky moderately hard shale. **Accessory Minerals:** Few mica flakes.

APPENDIX 3

LITHOLOGICAL DESCRIPTIONS OF WELL 2

DEPTH (METERS)	LITHOLOGY	DESCRIPTION
253 – 262	SAND	**Sand (100%):** Whitish to glassy, fine - medium - coarse, angular - subangular - subrounded, poorly sorted sands. **Accessory Minerals:** None.
262 – 271	SAND	**Sand (100%):** Whitish to glassy, fine - medium - coarse, angular - subangular - subrounded, poorly sorted sands. **Accessory Minerals:** None.
271 – 280	SAND	**Sand (100%):** Whitish to glassy, fine - medium - coarse, angular to subangular - subrounded, poorly sorted, with rod-like sand grains. **Accessory Minerals:** Traces of ferruginous materials.
280 – 290	SAND	**Sand (100%):** Whitish to glassy, fine - medium - coarse, angular - subangular - subrounded, poorly sorted, with rod-like sand grains. **Accessory Minerals:** Traces of ferruginous materials.
290 – 299	SAND	**Sand (100%):** Whitish to glassy, fine - medium - coarse, angular - subangular - subrounded, poorly sorted, with rod-like, very coarse sand grains. **Accessory Minerals:** None
299 - 381	**MISSING SAMPLE**	
381 – 390	SAND	**Sand (100%):** Whitish to glassy, medium to coarse, angular to subangular to subrounded, fairly sorted, sand grains. **Accessory Minerals:** None.
390 – 399	SAND	**Sand (100%):** White to glassy, medium to coarse, angular to subangular to subrounded, fairly sorted, sand grains. **Accessory Minerals:** None.
399 – 408	SAND	**Sand (99%):** Whitish to glassy, medium, angular to subangular to subrounded, well sorted, slightly calcareous sand grains. **Shale (1%):** Brownish blocky hard shale. **Accessory Minerals:** None.

408 – 418	SAND	**Sand (99%):** Milky white to glassy, medium, angular to subangular to subrounded, well sorted, slightly calcareous sand grains. **Shale (1%):** Brownish blocky hard shale. **Accessory Minerals:** None.
418 – 427	SAND	**Sand (100%): W**hitish to glassy, fine to middle - coarse - very coarse, poorly sorted sand grains. **Accessory Minerals:** None.
427 – 436	SAND	**Sand (100%):** Whitish to glassy, fine to intermediate – coarse - very coarse, poorly sorted sand grains. **Accessory Minerals:** None.
436 - 445	MISSING SAMPLE	
445 – 527	SAND	**Sand (100%):** Whitish to glassy, intermediate - occasionally coarse, subangular - subrounded, well sorted sand grains. **Accessory Minerals:** Few ferruginous materials.
527 – 536	SAND	**Sand (100%):** Whitish to glassy, fine to intermediate – coarse - very coarse, poorly sorted sand grains. **Accessory Minerals:** None.
536 – 546	SAND	**Sand (100%):** Cloudy white to glassy, fine to middle - coarse - very coarse, poorly sorted sand grains. **Accessory Minerals:** None.
546 - 555	SAND	**Sand (100%):** Cloudy white to glassy, to occasionally brownish, subangular to subrounded, to occasionally rounded well sorted sand grains. **Accessory Minerals:** Traces of ferruginous materials
555 – 564	SAND	**Sand (100%): W**hitish to glassy, to occasionally brownish, subangular to subrounded, to occasionally rounded well sorted sand grains. **Accessory Minerals:** Traces of ferruginous materials.

564 – 573	SAND	**Sand (100%):** Chalky white to glassy, medium, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
573 - 582	MISSING SAMPLE	
582 – 591	SAND	**Sand (100%):** Chalky white to glassy, to occasionally reddish brown, coarse, angular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
591 – 600	MISSING SAMPLE	
600 – 610	SAND	**Sand (100%):** Chalky white to glassy, medium, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
610 – 619	SAND	**Sand (100%):** Cloudy white to glassy, medium, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
619 – 628	SAND	**Sand (100%):** Chalky white to glassy, medium, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
628 – 637	SAND	**Sand (100%):** Cloudy white to glassy, medium, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
637 – 646	SAND	**Sand (100%): W**hitish to glassy, medium, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
646 - 655	SAND	**Sand (100%):** Chalky white to glassy, medium, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
655 – 664	SAND	**Sand (100%):** Chalky white to glassy, medium, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.

664 – 674	SAND	**Sand (100%):** Cloudy white to glassy, medium, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
674 – 683	SAND	**Sand (100%):** Chalky white to glassy, coarse, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
683 – 692	SAND	**Sand (100%): W**hitish to glassy, coarse, subangular to subrounded, well sorted sand grains. **Accessory Minerals:** None.
692 – 701	SAND	**Sand (100%):** Whitish to glassy, coarse, subangular to subrounded, well sorted, slightly calcareous sand grains. **Accessory Minerals:** None.
701 – 710	SAND	**Sand (100%):** Cloudy white to glassy, coarse, subangular to subrounded, well sorted, slightly calcareous sand grains. **Accessory Minerals:** None.
710 – 719	SAND	**Sand (99%):** Whitish to glassy, fine to intermediate - coarse, subangular - subrounded, poorly sorted, slightly calcareous grains. **Shale (1%):** Brownish blocky hard shale. **Accessory Minerals:** None.
719 – 728	SAND	**Sand (98%):** Cloudy white to glassy, fine - medium - coarse, subangular - subrounded, poorly sorted, slightly calcareous grains. **Shale (2%):** Brownish blocky hard shale. **Accessory Minerals:** None.
728 – 738	SAND	**Sand (98%): W**hitish to glassy, fine to medium - coarse, subangular - subrounded, poorly sorted, slightly calcareous sand grains. **Shale (2%):** Greyish to brownish blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
738 – 747	SAND	**Sand (98%):** Whitish to glassy, fine to middle - coarse, subangular - subrounded, poorly sorted, slightly calcareous sand grains. **Shale (2%):** Greyish to brownish blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.

747 – 756	SAND	**Sand (98%):** Milky white to glassy, fine - coarse, subangular - subrounded to rod-like, poorly sorted, slightly calcareous grains. **Shale (2%):** Brownish, platy to blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
756 – 765	SAND	**Sand (98%):** Milky white to glassy, fine - coarse, subangular - subrounded - rod-like, poorly sorted, slightly calcareous grains. **Shale (2%):** Brownish, platy to blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
765 – 774	SAND	**Sand (98%):** Milky white to glassy, fine - coarse, subangular - subrounded - rod-like, poorly sorted, slightly calcareous grains. **Shale (2%):** Brownish, platy to blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
774 – 783	SAND	**Sand (99%):** Milky white to glassy, fine - coarse, subangular - subrounded - rod-like, poorly sorted, slightly calcareous grains. **Shale (1%):** Brownish, platy to blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
783 – 838	SAND	**Sand (98%):** Milky white to glassy to occasionally brownish, coarse, subangular to subrounded, well sorted, slightly calcareous sand grains. **Shale (2%):** Greyish to brownish, platy to blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
838 – 847	SAND	**Sand (98%): W**hitish - glassy, medium - coarse - very coarse, subangular - subrounded, well sorted, slightly calcareous sand grains. **Shale (2%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** None.
847 – 856	SAND	**Sand (98%):** Whitish **-** glassy, medium - coarse - very coarse, subangular - subrounded, well sorted, slightly calcareous sand grains. **Shale (2%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** None.

856 – 866	SHALY SAND	**Sand (75%):** Whitish - glassy, medium - coarse - very coarse, subangular - subrounded, well sorted, slightly calcareous sand grains. **Shale (25%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** None.
866 – 875	SHALY SAND	**Sand (75%):** Whitish - glassy, medium - coarse - very coarse, subangular - subrounded, well sorted, slightly calcareous sand grains. **Shale (25%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** None.
875 – 884	SHALY SAND	**Sand (60%):** Whitish - glassy, medium - coarse - very coarse, subangular - subrounded, poorly sorted, highly calcareous grains. **Shale (40%):** Greyish to brownish to occasionally reddish brown, blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials and shell fragments, with fish tooth.
884 – 893	SHALY SAND	**Sand (60%):** Whitish - glassy, medium - coarse - very coarse, subangular - subrounded, poorly sorted, highly calcareous sand grains. **Shale (40%):** Greyish to brownish to occasionally reddish brown, blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials and shell fragments, with fish tooth.
893 – 902	SHALY SAND	**Sand (55%): W**hite - glassy, medium - coarse - very coarse, subangular - subrounded, poorly sorted, highly calcareous grains. **Shale (45%):** Greyish to brownish to occasionally reddish brown, blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials and shell fragments, with fish tooth.

902 – 911 911 – 920	SHALY SAND SANDY SHALE	**Sand (55%):** Whitish - glassy, medium to coarse to very coarse, subangular to subrounded, poorly sorted sands, highly calcareous sand grains. **Shale (45%):** Greyish to brownish to occasionally reddish brown, blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials and shell fragments, with fish tooth.
920 – 930	SILICA RICH SHALE	**Sand (31%):** Milky white to glassy, fine - coarse - very coarse, subangular - subrounded to elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (69%):** Brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Shell fragments and traces of ferruginous materials.
930 – 939	SANDY SHALE	**Sand (15%):** Milky white to glassy, fine - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (85%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.
939 – 948	SANDY SHALE	**Sand (10%):** Milky white to glassy, fine - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (90%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.
948 – 957	SANDY SHALE	**Sand (10%):** Milky white to glassy, fine - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (90%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.

957 – 966	SANDY SHALE	**Sand (15%):** Milky white to glassy, fine – intermediate - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (85%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.
966 – 975	SANDY SHALE	**Sand (20%):** Milky white to glassy, fine - middle - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (80%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.
975 – 985	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine - medium - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (80%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.
985 – 994	SILICA RICH SHALE	**Sand (31%):** Whitish to glassy, fine - coarse - very coarse, subangular - subrounded elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (69%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.
994 – 1003	SANDY SHALE	**Sand (35%):** Milky white to glassy, fine – intermediate - coarse - very coarse, subangular to subrounded to elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (65%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.

1003 – 1012	SILICA RICH SHALE	**Sand (31%): W**hitish to glassy, fine - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (69%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.
1012 – 1021	SILICA RICH SHALE	**Sand (35%): W**hitish to glassy, fine - medium to coarse - very coarse, subangular to subrounded - elongated, rod-like poorly sorted sands, slightly calcareous sand grains. **Shale (65%):** Greyish to occasionally brownish blocky hard shale. **Accessory Minerals:** Shell fragments present.
1021 – 1030	SANDY SHALE	**Sand (35%):** Milky white to glassy, fine - medium - coarse - very coarse, subangular to subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (65%):** Brownish, pellets to blocky hard shale. **Accessory Minerals:** Pyrites, shell fragments, traces of ferruginous materials present.
1030 – 1039	SILICA RICH SHALE	**Sand (31%): W**hitish to glassy, fine - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (69%):** Brownish, pellets to blocky hard shale. **Accessory Minerals:** Pyrites, shell fragments, traces of ferruginous materials present.
1039 – 1049	SILICA RICH SHALE	**Sand (31%): W**hitish to glassy, medium - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (69%):** Brownish, pellets to blocky hard shale. **Accessory Minerals:** Pyrites, shell fragments, traces of ferruginous materials present.
1049 – 1058	SILICA RICH SHALE	**Sand (32%): W**hitish to glassy, fine - medium - coarse - very coarse, subangular - subrounded - elongated, rod-like poorly sorted, slightly calcareous sand grains. **Shale (68%):** Brownish, pellets to blocky hard shale. **Accessory Minerals:** Pyrites, shell fragments, traces of ferruginous materials present.

1058 – 1067	SANDY SHALE	**Sand (30%):** Whitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (70%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Presence of fish tooth and shell fragments.
1037 – 1076	SANDY SHALE	**Sand (30%):** Whitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (70%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Presence of fish tooth and shell fragments.
1076 – 1085	SANDY SHALE	**Sand (30%):** White to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (70%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Presence of fish tooth and shell fragments.
1085 – 1094	SANDY SHALE	**Sand (30%):** Whitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (70%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Presence of fish tooth and shell fragments.
1094 – 1103	SANDY SHALE	**Sand (25%):** Whitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (75%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
1103 – 1112	SANDY SHALE	**Sand (25%): W**hitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (70%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
1112 – 1122	SANDY SHALE	**Sand (20%):** Whitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (80%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of pyrite.

1122 – 1131	SANDY SHALE	**Sand (20%):** Whitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (80%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of pyrite.
1131 – 1140	SILICA RICH SHALE	**Sand (16%): W**hitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (84%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of pyrite.
1140 – 1149	SILICA RICH SHALE	**Sand (17%): W**hitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted sands. **Shale (83%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of pyrite.
1149 – 1158	SANDY SHALE	**Sand (20%):** Whitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted, slightly calcareous sands. **Shale (80%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of pyrite.
1158 – 1167	SILICA RICH SHALE	**Sand (15%): W**hitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted, slightly calcareous sands. **Shale (85%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of pyrite.
1167 – 1177	SILICA RICH SHALE	**Sand (15%): W**hitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted, highly calcareous sands. **Shale (85%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of pyrite with shell fragments.

1177 – 1186	SILICA RICH SHALE	**Sand (15%): W**hitish to glassy, medium to fine to coarse, angular, elongated, flat, subangular to subrounded poorly sorted, highly calcareous sands. **Shale (85%):** Greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Traces of pyrite with shell fragments.
1186 – 1195	SANDY SHALE	**Sand (15%): W**hitish to glassy, very fine, sub-angular - sub-rounded, well sorted, highly calcareous sands. **Shale (85%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Traces of pyrite with shell fragments and fish tooth.
1195 – 1204	SANDY SHALE	**Sand (15%):** Whitish to glassy, very fine, sub-angular - sub-rounded, well sorted, highly calcareous sands. **Shale (85%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Traces of pyrite with shell fragments and fish tooth.
1204 – 1213	SANDY SHALE	**Sand (10%):** Whitish to glassy, very fine, sub-angular - sub-rounded, well sorted, highly calcareous sands. **Shale (90%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Traces of pyrite with shell fragments.
1212 – 1222	SANDY SHALE	**Sand (10%):** Whitish to glassy, very fine, sub-angular - sub-rounded, well sorted, highly calcareous sands. **Shale (90%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Traces of pyrite with shell fragments.
1222 – 1231	SANDY SHALE	**Sand (10%):** Whitish to glassy, very fine, sub-angular - sub-rounded, well sorted, highly calcareous sands. **Shale (90%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Few mica flakes present.

1231 – 1241	SANDY SHALE	**Sand (20%):** Whitish to glassy, very fine, sub-angular - sub-rounded, well sorted, highly calcareous sands. **Shale (80%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Few mica flakes present.
1241 – 1250	SANDY SHALE	**Sand (20%):** Whitish to glassy, very fine, sub-angular - sub-rounded, well sorted, highly calcareous sands. **Shale (80%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Few mica flakes present.
1250 – 1259	SANDY SHALE	**Sand (20%):** Whitish to glassy, very fine, sub-angular - sub-rounded, well sorted, highly calcareous sands. **Shale (80%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Few mica flakes present.
1259 – 1268	SANDY SHALE	**Sand (30%):** Whitish to glassy, very fine, sub-angular - sub-rounded, well sorted, highly calcareous sands. **Shale (70%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Few mica flakes present.
1268 – 1286	SANDY SHALE	**Sand (25%):** Whitish to glassy, fine to medium to coarse, elongated quartz grains, poorly sorted slightly calcareous sands. **Shale (75%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials present.
1286 – 1294	SANDY SHALE	**Sand (25%):** Whitish to glassy, fine to medium to coarse, elongated quartz grains, poorly sorted slightly calcareous sands. **Shale (75%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials present.
1294 – 1305	SANDY SHALE	**Sand (25%):** Whitish to glassy, fine to medium to occasionally coarse, poorly sorted slightly calcareous sands. **Shale (75%):** Reddish brown to occasionally greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Presence of pyrite and ferruginous materials, with abundant of glauconite.

1305 – 1314	SILICA RICH SHALE	**Sand (32%): W**hitish to glassy, fine to medium to occasionally coarse, poorly sorted slightly calcareous sands. **Shale (68%):** Reddish brown to occasionally greyish to brownish, pellets to blocky hard shale. **Accessory Minerals:** Presence of pyrite and ferruginous materials, with abundant of glauconite.
1314 – 1323	SHALY SAND	**Sand (70%):** Whitish to glassy, coarse, sub-angular - sub-rounded well sorted sands. **Shale (30%):** Reddish brown to occasionally greyish blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
1323 – 1332	SHALY SAND	**Sand (70%):** Whitish to glassy, coarse, sub-angular - sub-rounded well sorted sands. **Shale (30%):** Reddish brown to occasionally greyish blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
1332 – 1341	SHALY SAND	**Sand (70%):** Whitish to glassy, coarse, sub-angular - sub-round well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
1341 – 1350	SHALY SAND	**Sand (70%):** Whitish to glassy, coarse, sub-angular - sub-rounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials.
1350 – 1359	SHALY SAND	**Sand (70%):** Whitish to glassy, coarse, sub-angular - sub-rounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials, with pyrite and few glauconite pellets.
1359 – 1369	SHALY SAND	**Sand (70%):** Whitish to glassy, coarse, sub-angular - sub-rounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** Traces of ferruginous materials, with pyrite and few glauconite pellets.

1369 – 1378	SHALY SAND	**Sand (70%):** Milky white to glassy, coarse, sub-angular to sub-rounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** None.
1378 – 1387	SHALY SAND	**Sand (70%):** Milky white to glassy, coarse, subangular - subrounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** None.
1387 – 1396	SHALY SAND	**Sand (70%):** Milky white to glassy, coarse, sub-angular - subrounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** Few glauconite pellets.
1396 – 1405	SHALY SAND	**Sand (70%):** Milky white to glassy, coarse, sub-angular - subrounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** Few glauconite pellets.
1405 – 1414	SHALY SAND	**Sand (%):** Milky white to glassy, coarse, sub-angular - subrounded well sorted sands. **Shale (%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** None.
1414 – 1423	SHALY SAND	**Sand (70%):** Milky white to glassy, coarse, sub-angular - subrounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** None.
1423 – 1433	SHALY SAND	**Sand (70%):** Milky white to glassy, coarse, sub-angular - subrounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** None.
1433 – 1442	SHALY SAND	**Sand (70%):** Milky white to glassy, coarse, subangular - sub-rounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** None.

1442 – 1451	SHALY SAND	**Sand (70%):** Milky white to glassy, coarse, sub-angular - subrounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** None.
1451 – 1460	SHALY SAND	**Sand (70%):** Milky white to glassy, coarse, sub-angular - subrounded well sorted sands. **Shale (30%):** Greyish to occasionally reddish brown blocky hard shale. **Accessory Minerals:** None.
1460 – 1469	SHALY SAND	**Sand (80%):** Milky white to glassy, bristly - very coarse to pebbly, sub-angular - subrounded poorly sorted sands. **Shale (20%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** None.
1469 – 1478	SHALY SAND	**Sand (80%):** Milky white to glassy, very coarse to pebbly, sub-angular - subrounded poorly sorted sands. **Shale (20%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** None.
1478 – 1484	SANDY SHALE	**Sand (35%):** Milky white to glassy, medium - coarse to pebbly to elongated, sub-angular - subrounded poorly sorted sands. **Shale (65%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** Pellets of glauconite.
1484 – 1494	SANDY SHALE	**Sand (35%):** Whitish to glassy, fine - medium - coarse to pebbly to elongated, sub-angular - su-rounded poorly sorted sands. **Shale (65%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** Pellets of glauconite.
1494 – 1503	SHALY SAND	**Sand (75%): W**hitish to glassy, medium - coarse to pebbly, sub-angular - subrounded poorly sorted sands. **Shale (25%):** Greyish to brownish, blocky hard shale. **Accessory Minerals:** Pellets of glauconite.
1503 – 1512	SHALY SAND	**Sand (75%):** Milky white to glassy, fine - medium - coarse - pebbly, sub-angular - subrounded poorly sorted sands. **Shale (25%):** Grey to brownish, blocky hard shale. **Accessory Minerals:** Pellets of glauconite.

1512 –1521	SHALY SAND	**Sand (55%):** Whitish to glassy, coarse to occasionally pebbly, sub-angular - subrounded fairly sorted sands. **Shale (45%):** Greyish to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Pellets of glauconite, with traces of ferruginous materials.
1521 – 1530	SHALY SAND	**Sand (55%):** Milky white to glassy, coarse to occasionally pebbly, sub-angular to sub-rounded fairly sorted sands. **Shale (45%):** Greyish to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Pellets of glauconite, with traces of ferruginous materials.
1530 – 1539	SHALY SAND	**Sand (75%):** Whitish to glassy, coarse, sub-angular – subrounded well arrange sands. **Shale (25%):** Greyish blocky hard shale. **Accessory Minerals:** None.
1539 – 1548	SHALY SAND	**Sand (75%):** Whitish to glassy, coarse, sub-angular - subrounded well arrange sands. **Shale (25%):** Greyish blocky hard shale. **Accessory Minerals:** None
1548 – 1558	SHALY SAND	**Sand (80%):** Whitish to glassy to pinkish to brownish, medium, subangular - sub-rounded well sorted sands. **Shale (20%):** Greyish to brownish to occasionally reddish brown, platy to blocky hard shale. **Accessory Minerals:** Traces of ferrugineous materials.
1558 – 5140	SHALY SAND	**Sand (80%): W**hitish to glassy to pinkish to brownish, medium, subangular - sub-rounded well sorted sands. **Shale (20%):** Grey to brownish to occasionally reddish brown, platy to blocky hard shale. **Accessory Minerals:** Traces of ferrugineous materials.
5140 – 1576	SANDY SHALE	**Sand (45%):** Whitish to glassy to brownish, very fine to fine to medium - coarse, subangular - sub-rounded to elongated, poorly sorted sands. **Shale (55%):** Grey to brownish to reddish brown, blocky hard shale. **Accessory Minerals:** Traces of ferrugineous materials.

1576 – 1585	SANDY SHALE	**Sand (45%):** Whitish to glassy to brownish, very fine to fine to intermediate - coarse, subangular - subrounded to elongated, poorly sorted sand. **Shale (55%):** Grey to brownish to reddish brown blocky hard shale. **Accessory Minerals:** Few glauconite pellets.
1585 – 1588	SANDY SHALE	**Sand (10%):** Whitish to glassy to brownish, very fine to fine to middle - coarse subangular - subrounded to elongated, poorly sorted sand grains. **Shale (90%):** Grey to brownish to reddish brown blocky hard shale. **Accessory Minerals:** Few glauconite pellets
1588 – 1615	SANDY SHALE	**Sand (20%):** Whitish to glassy to brownish, to occasionally pinkish, fine to medium - coarse, subangular - subrounded to elongated, poorly sorted sand grains. **Shale (90%):** Grey to brownish to reddish brown blocky hard shale. **Accessory Minerals:** Few glauconite pellets.
1615 – 1625	SANDY SHALE	**Sand (30%):** Whitish to glassy to brownish, to occasionally pinkish, fine to medium - coarse, subangular - subrounded to elongated, poorly sorted sand. **Shale (70%):** Grey to brownish to reddish brown platy to blocky hard shale. **Accessory Minerals:** None.
1625 – 1634	SANDY SHALE	**Sand (30%):** Whitish to glassy to brownish, to occasionally pinkish, fine to medium - coarse, subangular - subrounded to elongated, poorly sorted sand. **Shale (70%):** Grey to brownish to reddish brown platy to blocky hard shale. **Accessory Minerals:** None.
1634 – 1643	SHALY SAND	**Sand (55%):** Whitish to glassy to brownish, to occasionally pinkish, coarse, subangular to subrounded to elongated, well sorted sand grains. **Shale (45%):** Grey to brownish to reddish brown platy to blocky hard shale. **Accessory Minerals:** None.

1643 – 1652	SHALY SAND	**Sand (55%):** Whitish to glassy to brownish, to occasionally pinkish, coarse, subangular to subrounded to elongated, well sorted sand grains. **Shale (45%):** Grey to brownish to reddish brown platy to blocky hard shale. **Accessory Minerals:** None.
1652 – 1661	SHALY SAND	**Sand (55%):** Whitish to glassy to brownish, fine to medium - coarse, subangular - subrounded, poorly sorted grains. **Shale (45%):** Grey to brownish, platy to blocky hard shale. **Accessory Minerals:** Few glauconite pellets.
1661 – 1670	SHALY SAND	**Sand (55%):** Milky white to glassy to brownish, intermediate - coarse, subangular - subrounded, poorly sorted sand grains. **Shale (45%):** Greyish to brownish, platy to blocky hard shale. **Accessory Minerals:** Few glauconite pellets.
1670 – 1679	SANDY SHALE	**Sand (35%):** Whitish to glassy to brownish, fine to intermediate - coarse - pebbly, subangular - subrounded - elongated, poorly sorted sand grains. **Shale (65%):** Greyish to brownish, platy to blocky hard shale. **Accessory Minerals:** Few glauconite pellets.
1679 – 1689	SANDY SHALE	**Sand (35%):** Whitish to glassy to brownish, medium to coarse, to pebbly, subangular - subrounded to elongated, poorly sorted sand grains. **Shale (65%):** Greyish to brownish, platy to blocky hard shale. **Accessory Minerals:** Few glauconite pellets.
1689 – 1701	SANDY SHALE	**Sand (25%):** Whitish to glassy to brownish, medium - coarse, to pebbly, subangular - subrounded to elongated, poorly sorted sand grains. **Shale (75%):** Greyish to brownish, platy to blocky hard shale. **Accessory Minerals:** Few glauconite pellets.

APPENDIX 4

LITHOLOGICAL DESCRIPTIONS OF WELL 3

DEPTH(METERS)	LITHOLOGY	DESCRIPTION
1038 – 1045	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine to occasionally pebbly, subangular to subrounded, fairly sorted sands. slightly calcareous. **Shale (70%):** Dark to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments.
1045 – 1055	SANDY SHALE	**Sand (25%):** Whitish to glassy, fine to occasionally pebbly, subangular to subrounded, fairly sorted sands. slightly calcareous. **Shale (75%):** Dark to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments.
1055 – 1064	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine to occasionally pebbly, subangular to subrounded, fairly sorted sands. highly calcareous. **Shale (60%):** Dark to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments
1064 – 1073	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine to occasionally pebbly, subangular to subrounded, fairly sorted sands. highly calcareous. **Shale (55%):** Dark to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments.
1073 – 1082	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. highly calcareous. **Shale (70%):Dark** to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments.

1082 – 1091	SHALY SAND	**Sand (55%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. highly calcareous. **Shale (45%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments.
1091 – 1100	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. slightly calcareous. **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Ferruginous materials.
1100 – 1109	SANDY SHALE	**Sand (35%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. slightly calcareous. **Shale (65%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Ferruginous materials.
1109 – 1119	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, but occasionally coarse, subangular to subrounded, fairly sorted sands. slightly calcareous. **Shale (65%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Iron rich materials and shell fragments
1119 – 1128	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, but occasionally coarse, subangular to subrounded, fairly sorted sands. slightly calcareous. **Shale (65%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Iron rich materials and shell fragments
1128 – 1137	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. highly calcareous. **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments, ferruginous materials, mica flakes.

1137 – 1146	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. highly calcareous. **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments, ferruginous materials, mica flakes.
1146 – 1155	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. highly calcareous. **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments, ferruginous materials.
1155 – 1164	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. highly calcareous. **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Shell fragments, ferruginous materials
1164 – 1173	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. highly calcareous. **Shale (55%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** Mica flakes, Shell fragments, ferruginous materials
1173 – 1183	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. highly calcareous. **Shale (55%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** mica flakes, shell fragments and ferruginous materials
1183 – 1192	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands. rarely calcareous. **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** None

1192 – 1201	SANDY SHALE	**Sand (40%):** White to glassy, fine, subangular to subrounded, well sorted sands. rarely calcareous. **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories: None**
1201 – 1210	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** mica flakes, shell fragments and ferruginous materials
1210 – 1219	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** mica flakes, shell fragments and ferruginous materials
1219 – 1228	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** mica flakes, pyrites and ferruginous materials
1231 – 1238	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (55%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** mica flakes, pyrites and ferruginous materials
1237 – 1247	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (55%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** mica flakes and ferruginous materials
1247 – 1256	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (55%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** mica flakes and ferruginous materials

1256 – 1265	SANDY SHALE	**Sand (35%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (65%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** few mica flakes and abundant ferruginous materials
1265 – 1274	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (70%):** Grey to brownish to occasionally reddish brown, blocky hard shale **Accessories:** few mica flakes and abundant ferruginous materials
1274 – 1283	SANDY SHALE	**Sand (40%):** Whitish to glassy, intermediate - coarse, subangular - subrounded, poorly sorted, slightly calcareous sands **Shale (60%):** Grey to brownish to reddish brown, blocky, hard shale **Accessories:** Iron rich materials and few mica flakes.
1283 – 1292	SILICA RICH SHALE	**Sand (45%):** Whitish to glassy, subangular - subrounded, poorly sorted, slightly calcareous sands **Shale (55%):** Grey to brownish to reddish brown, blocky, hard shale **Accessories:** Iron rich materials and few mica flakes.
1292 – 1301	SILICA RICH SHALE	**Sand (46%):** Whitish to glassy, fine to middle to coarse, subangular to subrounded, poorly sorted, slightly calcareous sands **Shale (54%):** Grey to brownish to reddish brown, blocky, hard shale **Accessories:** Iron rich materials abundant and few mica flakes.
1301 – 1311	SILICA RICH SHALE	**Sand (45%):** Whitish to glassy, smooth - coarse, subangular - subrounded, poorly sorted, slightly calcareous sands **Shale (55%):** Grey to brownish to reddish brown, blocky, hard shale **Accessories:** **F**erruginous materials abundant and few mica flakes.
1311 – 1329	SHALY SAND	**Sand (55%):** Whitish to glassy, smooth - coarse, subangular - subrounded, poorly sorted, slightly calcareous sands **Shale (45%):** Grey to brownish to reddish brown, blocky, hard shale **Accessories:** Iron rich materials abundant and few mica flakes.

1329 – 1338	SHALY SAND	**Sand (60%):** Whitish to glassy, fine to middle to coarse, subangular to subrounded, poorly sorted, slightly calcareous sands **Shale (40%):** Grey to brownish to reddish brown, blocky, hard shale **Accessories:** **F**erruginous materials abundant and few mica flakes
1338 – 1347	SHALY SAND	**Sand (55%):** Whitish to glassy, fine to middle to coarse, subangular to subrounded, poorly sorted, slightly calcareous sands **Shale (45%):** Grey to brownish to reddish brown, blocky, hard shale **Accessories:** Abundant ferruginous materials.
1347 – 1356	SHALY SAND	**Sand (45%):** Whitish to glassy, fine to middle to coarse, subangular to subrounded, poorly sorted, slightly calcareous sands **Shale (55%):** Grey to brownish to reddish brown, blocky, hard shale **Accessories:** ferruginous materials and few mica flakes
1356 – 1366	SHALY SAND	**Sand (45%):** Whitish to glassy, smooth - medium to coarse, subangular - subrounded, fairly sorted, slightly calcareous sands **Shale (55%):** Brownish, blocky, hard shale **Accessories:** ferruginous materials and few mica flakes
1366 – 1375	SHALY SAND	**Sand (40%):** milky white to glassy, smooth - occasionally coarse, subangular - subrounded, poorly sorted, slightly calcareous sands **Shale (60%):** Brownish, blocky, hard shale **Accessories:** **F**ew mica flakes, shell fragments, and ferruginous materials.
1375 – 1384	SHALY SAND	**Sand (35%):** milky white to glassy, smooth -occasionally coarse, subangular - subrounded, poorly sorted, slightly calcareous sands **Shale (65%):** Brownish, blocky, hard shale **Accessories:** Shell fragments, ferruginous materials and few mica flakes
1384 – 1393	SHALY SAND	**Sand (40%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** few shell fragments, traces of ferruginous materials and few mica flakes

1393 – 1402	SHALY SAND	**Sand (40%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** few shell fragments, traces of ferruginous materials and few mica flakes
1402 – 1411	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Traces of pyrites and ferruginous materials
1411 – 1420	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, well sorted sands **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Traces of pyrites and ferruginous materials
1420 – 1430	SHALY SAND	**Sand (55%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (45%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Pyrites
1430 – 1439	SHALY SAND	**Sand (55%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (45%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Pyrites
1439 – 1448	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (60%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Traces of pyrites
1448 – 1457	SHALY SAND	**Sand (60%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (40%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Traces of pyrites

1457 – 1166	SHALY SAND	**Sand (55%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (45%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Traces of pyrites and few mica flakes
1466 – 1475	SANDY SHALE	**Sand (35%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (65%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Traces of pyrites and few mica flakes
1475 – 1484	SANDY SHALE	**Sand (25%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (75%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Traces of pyrites and few mica flakes
1484 – 1494	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (70%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Few mica flakes with traces ferruginous materials
1494 – 1503	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (70%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Few mica flakes with traces ferruginous materials
1503 – 1512	SANDY SHALE	**Sand (35%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (65%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Few mica flakes with traces ferruginous materials

1512 – 1521	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (70%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Few mica flakes with traces ferruginous materials
1521 – 1530	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted sands **Shale (70%):** Grey to brownish to occasionally reddish brown, blocky, moderately hard shale **Accessories:** Few mica flakes with traces ferruginous materials
1530 – 1539	SILICA RICH SHALE	**Sand (29%): W**hite to glassy, fine - intermediate - rarely coarse, subangular - subrounded, platy, poorly sorted sands **Shale (71%):** Greyish to brownish to reddish brown, blocky, moderately hard shale **Accessories: F**ew mica flakes and with traces of ferruginous materials
1539 – 1548	SANDY SHALE	**Sand (25%):** Smooth - medium - occasionally coarse, subangular - subrounded, platy, poorly sorted, milky white to glassy, sands **Shale (75%):** Greyish to brownish to reddish brown, blocky, moderately hard shale **Accessories:** Few traces of ferruginous materials and few mica flakes
1548 – 1558	SANDY SHALE	**Sand (25%):** Smooth - medium, - occasionally coarse, subangular - subrounded, platy, poorly sorted, milky white to glassy sands **Shale (75%):** Grey to brownish to reddish brown, blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials
1558 – 1567	SANDY SHALE	**Sand (25%):** Whitish to glassy, smooth - medium - occasionally coarse, subangular - subrounded, platy, poorly sorted sands **Shale (75%):** Grey to brownish to reddish brown, blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials

1567 – 1576	SILICA RICH SHALE	**Sand (25%): W**hite to glassy, smooth - medium - occasionally coarse, subangular - subrounded, platy, poorly sorted sands **Shale (75%):** Greyish to brownish to reddish brown, slightly hard shale **Accessories:** Ferruginous materials and pyrites
1576 – 1585	SILICA RICH SHALE	**Sand (20%): W**hitish to glassy, smooth - medium - occasionally coarse, subangular - subrounded, platy, poorly sorted sands **Shale (80%):** Grey to brownish to reddish brown, platy to blocky, moderately hard shale **Accessories:** Ferruginous materials and pyrites
1585 – 1594	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine, subangular to subrounded, platy, well sorted sands **Shale (70%):** Greyish to brownish to reddish brown, platy to blocky, moderately hard shale **Accessories:** Ferruginous materials
1594 – 1603	SANDY SHALE	**Sand (40%):** Whitish to glassy, fine, subangular to subrounded, platy sands **Shale (60%): R**eddish brown, Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Ferruginous materials
1603 – 1612	SILICA RICH SHALE	**Sand (32%):** milky white to glassy, fine, subangular to subrounded, platy, well sorted sands **Shale (68%):** Greyish to brownish, moderately hard shale **Accessories:** Iron rich materials
1612 – 1622	SILICA RICH SHALE	**Sand (30%):** milky white to glassy, fine, subangular to subrounded, platy, well sorted sands **Shale (70%):** Greyish to brownish, moderately hard shale **Accessories:** Iron rich materials
1622 – 1631	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine, subangular to subrounded, platy, well sorted sands **Shale (70%):** Grey to brownish to reddish brown, platy to blocky, moderately hard shale **Accessories:** Ferruginous materials and pyrites

1631 – 1640	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine, subangular to subrounded, platy, well sorted sands **Shale (70%):** Grey to brownish to reddish brown, platy to blocky, moderately hard shale **Accessories:** Ferruginous materials and pyrites
1640 – 1649	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine, subangular to subrounded, platy, well sorted sands **Shale (70%):** Greyish to brownish to reddish brown, platy to blocky, moderately hard shale **Accessories:** Ferruginous materials and pyrites
1649 – 1658	SHALY SAND	**Sand (55%):** Whiteish to glassy, fine, subangular to subrounded, platy, well sorted sands **Shale (45%):** Greyish to reddish brown, platy to blocky, moderately hard shale **Accessories:** Few iron rich materials and pyrites
1658 – 1668	SHALY SAND	**Sand (65%):** milky white to glassy, smooth -occasionally coarse, subangular - subrounded, platy, fairly sorted, slightly calcareous grains. **Shale (35%): B**rownish, platy to blocky, hard shale **Accessories:** Ferruginous materials
1668 – 1676	SHALY SAND	**Sand (55%):** milky white to glassy, smooth - occasionally coarse, subangular - subrounded, platy, fairly sorted, slightly calcareous sands **Shale (45%): B**rownish, platy to blocky, hard shale **Accessories:** Ferruginous materials
1676 – 1686	SHALY SAND	**Sand (60%):** milky white to glassy, very fine, subangular to subrounded, platy, well sorted, slightly calcareous sands **Shale (40%): B**rownish, pellets to blocky, hard shale **Accessories:** Traces of ferruginous materials
1686 – 1695	SHALY SAND	**Sand (70%):** milky white to glassy, smooth - occasionally coarse, subangular - subrounded, platy, fairly sorted sands **Shale (30%): B**rownish, pellets to blocky, hard shale **Accessories:** Traces of ferruginous materials

1695 – 1704	SHALY SAND	**Sand (60%):** milky white to glassy, smooth - occasionally coarse, subangular - subrounded, platy, fairly sorted, slightly calcareous grains **Shale (40%):** Greyish to brownish to reddish brown, platy to blocky, moderately hard shale **Accessories:** Shell fragments
1704 – 1713	SANDY SHALE	**Sand (45%):** milky white to glassy, smooth - occasionally coarse, subangular - subrounded, platy, fairly sorted, slightly calcareous sands **Shale (55%):** Greyish to brownish to reddish brown, platy to blocky, moderately hard shale **Accessories:** Shell fragments
1713 – 1722	SANDY SHALE	**Sand (45%):** milky white to glassy, smooth - medium - occasionally coarse, subangular - subrounded, platy, poorly sorted, slightly calcareous sands **Shale (55%):** Greyish to brownish, platy to pellets to blocky, moderately hard shale **Accessories:** very few shell fragments
1722 – 1731	SILICA RICH SHALE	**Sand (30%):** milky white to glassy, smooth - medium - occasionally coarse, subangular - subrounded, platy, poorly sorted, slightly calcareous sands **Shale (70%):** Greyish to brownish, platy to pellets to blocky, moderately hard shale **Accessories:** few shell fragments
1731 – 1740	SILICA RICH SHALE	**Sand (30%):** milky white to glassy, smooth – medium- occasionally coarse, subangular to subrounded, platy, poorly sorted, slightly calcareous sands **Shale (70%):** Greyish to brownish, platy to pellets to blocky, moderately hard shale **Accessories:** few shell fragments
1740 – 1750	SILICA RICH SHALE	**Sand (30%):** milky white to glassy, smooth - medium - occasionally coarse, subangular - subrounded, platy, poorly sorted, slightly calcareous sands **Shale (70%):** Greyish to brownish, platy to pellets to blocky, moderately hard shale **Accessories:** few shell fragments
1750 – 1759	SILICA RICH SHALE	**Sand (30%):** milky white to glassy, smooth - medium - occasionally coarse, subangular - subrounded, platy, poorly sorted, fairly calcareous sands **Shale (70%):** Greyish to brownish, platy to pellets, moderately hard shale **Accessories:** ferruginous materials

1579 – 1768	SANDY SHALE	**Sand (45%):** Smooth - medium - occasionally coarse, subangular - subrounded, platy, poorly sorted, milky white to glassy, fairly calcareous sands **Shale (55%):** Greyish to brownish, platy to pellets to blocky, moderately hard shale **Accessories:** ferruginous materials
1768 – 1777	SANDY SHALE	**Sand (5%):** milky white to glassy, fine, subangular to subrounded, platy, well sorted sands with wood shavings **Shale (95%):** Greyish - brownish, platy to occasionally blocky, moderately hard shale **Accessories:** carbonaceous detritus
1777 – 1786	SANDY SHALE	**Sand (2%):** milky white to glassy, fine, subangular to subrounded, platy, well sorted sands with wood shavings **Shale (98%):** Greyish - brownish, platy - occasionally blocky, moderately hard shale **Accessories:** carbonaceous detritus
1786 – 1795	SANDY SHALE	**Shale (100%):** Greyish - brownish, platy - occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus and traces of ferruginous materials
1795 – 1804	SANDY SHALE	**Shale (100%):** Greyish - brownish, platy to occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus and traces of ferruginous materials
1804 – 1814	SANDY SHALE	**Shale (100%):** Greyish - brownish, platy to occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus and traces of ferruginous materials
1814 – 1823	SANDY SHALE	**Shale (100%):** Greyish - brownish, platy to occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus and traces of ferruginous materials
1823 – 1831	SANDY SHALE	**Shale (100%):** Greyish - brownish, platy to occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus and traces of ferruginous materials
1831 – 1841	SANDY SHALE	**Shale (100%):** Greyish - brownish, platy to occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus and traces of ferruginous materials

1841 – 1850	SANDY SHALE	**Shale (100%):** Greyish - brownish, platy - occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus and traces of ferruginous materials
1850 – 1859	SANDY SHALE	**Shale (100%):** Greyish - brownish, platy to occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus and traces of ferruginous materials
1859 – 1868	SANDY SHALE	**Sand (5%):** milky white to glassy, fine, subangular to subrounded, platy, well sorted sands **Shale (95%):** Greyish - brownish, platy to occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus, traces of ferruginous materials and glauconite pellets
1868 – 1876	SHALY SAND	**Sand (60%):** milky white to glassy, fine, subangular to subrounded, platy, well sorted sands **Shale (40%):** Greyish - brownish, platy to occasionally blocky, moderately hard shale with wood **Accessories:** carbonaceous detritus, traces of glauconite pellets and ferruginous materials.
1876 – 1887	SHALY SAND	**Sand (55%):** milky white to glassy, subangular to subrounded, poorly sorted sands **Shale (45%):** Greyish to brownish, blocky, moderately hard shale **Accessories:** Pyrites, ferruginous materials and glauconite pellets
1887 – 1896	SHALY SAND	**Sand (60%):** milky white to glassy, fine - middle - coarse, subangular - subrounded, poorly sorted sands **Shale (40%):** Greyish to brownish, blocky, moderately hard shale **Accessories:** Pyrites, ferruginous materials and glauconite pellets
1896 – 1905	SHALY SAND	**Sand (55%):** Whitish - glassy, intermediate - coarse - very coarse, subangular to subrounded, poorly sorted feldsparthic sands **Shale (45%):** Greyish to brownish, blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials

1905 – 1914	SHALY SAND	**Sand (80%):** Whitish - glassy, intermediate – coarse - very coarse, subangular - subrounded, poorly sorted feldsparthic sands **Shale (20%):** Greyish to brownish, blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
1914 – 1923	SHALY SAND	**Sand (80%):** Whitish - glassy, middle - coarse - very coarse, subangular - subrounded, poorly sorted feldsparthic sands **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
1923 – 1932	SHALY SAND	**Sand (80%):** Whitish - glassy, intermediate - coarse - very coarse, subangular - subrounded, poorly sorted feldsparthic sands **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
1932 – 1942	SHALY SAND	**Sand (80%):** Whitish - glassy, middle - coarse - very coarse, subangular - subrounded, poorly sorted feldsparthic sands **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
1942 – 1951	SHALY SAND	**Sand (80%):** Whitish - glassy, middle - coarse - very coarse, subangular - subrounded, poorly sorted feldsparthic sands **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
1951 – 1960	SHALY SAND	**Sand (80%):** Whitish - glassy, intermediate – coarse - very coarse, subangular - subrounded, poorly sorted feldsparthic sands **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
1960 – 1969	SHALY SAND	**Sand (55%):** Whitish - glassy, middle - coarse - very coarse, subangular - subrounded, poorly sorted feldsparthic sands **Shale (45%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials

1969 – 1978	SANDY SHALE	**Sand (45%):** Whitish - glassy, middle - coarse - very coarse, subangular - subrounded, poorly sorted **Shale (55%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
1978 – 1987	SANDY SHALE	**Sand (45%):** Whitish - glassy, intermediate – coarse - very coarse, subangular - subrounded, poorly sorted **Shale (55%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
19871– 1996	SHALY SAND	**Sand (55%):** Whitish - glassy, middle - coarse - very coarse, subangular - subrounded, poorly sorted **Shale (45%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
1996 – 2006	SHALY SAND	**Sand (60%):** Whitish - glassy, middle – coarse - very coarse, subangular - subrounded, poorly sorted **Shale (40%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2006 – 2015	SHALY SAND	**Sand (70%):** Whitish - glassy, coarse - very coarse, subangular - subrounded, poorly sorted **Shale (30%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2015 – 2024	SHALY SAND	**Sand (65%):** Whitish - glassy, medium - coarse, to very coarse, subangular to subrounded, poorly sorted **Shale (35%):** Greyish - brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2024 – 2033	SHALY SAND	**Sand (90%):** Whitish - glassy, medium – coarse - very coarse, subangular - subrounded, poorly sorted **Shale (10%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials

2033 – 2042	SHALY SAND	**Sand (80%):** Whitish - glassy, medium – coarse - very coarse, subangular - subrounded, poorly sorted **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2042 – 2051	SANDY SHALE	**Sand (40%):** Whitish - glassy, middle - coarse - very coarse, subangular - subrounded, poorly sorted **Shale (60%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2051 – 2060	SANDY SHALE	**Sand (45%):** Whitish - glassy, medium – coarse - very coarse, subangular - subrounded, poorly sorted **Shale (55%):** Greyish - brownish, platy - blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2060 – 2070	SANDY SHALE	**Sand (45%):** milky white to glassy, subangular to subrounded, poorly sorted **Shale (55%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites, mica flakes, ferruginous materials
2070 – 2079	SANDY SHALE	**Sand (45%):** milky white to glassy, middle to coarse, subangular to subrounded, poorly sorted **Shale (55%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites, carbonic detritus, ferruginous materials and mica flakes
2079 – 2088	SHALY SAND	**Sand (73%):** milky white to glassy, middle - coarse, subangular - subrounded, poorly sorted **Shale (27%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites, carbonaceous detritus and ferruginous materials
2088 – 2079	SHALY SAND	**Sand (80%):** milky white to glassy, intermediate - coarse, subangular - subrounded, poorly sorted **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites, mica flakes, carbonaceous detritus and ferruginous materials

2079 – 2106	SHALY SAND	**Sand (80%):** milky white to glassy, medium to coarse to pebbly, subangular to subrounded, fairly sorted **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2106 – 2115	SHALY SAND	**Sand (80%):** milky white to glassy, medium to coarse to pebbly, subangular to subrounded, fairly sorted **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2115 – 2124	SHALY SAND	**Sand (80%):** milky white to glassy, medium to coarse to pebbly, subangular to subrounded, fairly sorted **Shale (20%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2124 – 2134	SHALY SAND	**Sand (70%):** milky white to glassy, medium to coarse to pebbly, subangular to subrounded, fairly sorted **Shale (30%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2134 – 2143	SHALY SAND	**Sand (70%):** milky white to glassy, medium to coarse to pebbly, subangular to subrounded, fairly sorted **Shale (30%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2143 – 2152	SHALY SAND	**Sand (70%):** milky white to glassy, medium to coarse to pebbly, subangular to subrounded, fairly sorted **Shale (30%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2152 – 2161	SHALY SAND	**Sand (60%):** milky white to glassy, subangular to subrounded, poorly sorted **Shale (40%):** Greyish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials

2161 – 2170	SHALY SAND	**Sand (60%):** milky white to glassy, subangular to subrounded, poorly sorted **Shale (40%):** Greyish, platy to blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials
2170 – 2179	SHALY SAND	**Sand (45%):** milky white to glassy, subangular to subrounded, poorly sorted **Shale (55%):** Greyish, platy to blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials
2179 – 2188	SHALY SAND	**Sand (55%):** milky white to glassy, smooth - coarse to pebbly, sub-angular - subrounded, poorly sorted **Shale (45%):** Greyish, platy to blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials
2188 – 2198	SHALY SAND	**Sand (55%):** milky white to glassy, middle to coarse to pebbly, subangular to subrounded, poorly sorted **Shale (45%):** Greyish, platy to blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials
2178 – 2207	SHALY SAND	**Sand (55%):** milky white to glassy, middle to coarse to pebbly, subangular to subrounded, poorly sorted **Shale (45%):** Greyish, platy to blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials
2207 – 2216	SANDY SHALE	**Sand (35%):** milky white to glassy, smooth - coarse to pebbly, sub-angular - subrounded, poorly sorted **Shale (65%):** Greyish, platy to blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials
2216 – 2225	SANDY SHALE	**Sand (35%):** milky white to glassy, intermediate - coarse - pebbly, subangular - subrounded, poorly sorted **Shale (65%):** Greyish, platy to blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials

2225 – 2234	SANDY SHALE	**Sand (35%):** milky white to glassy, middle to coarse to pebbly, subangular to subrounded, poorly sorted **Shale (65%):** Greyish, platy to blocky, moderately hard shale **Accessories:** Pyrites and traces of ferruginous materials
2234 – 2243	SANDY SHALE	**Sand (35%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (65%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Traces of ferruginous materials and few glauconite pellets
2243 – 2252	SANDY SHALE	**Sand (35%):** milky white to glassy, fine to intermediate - coarse, subangular - subrounded, poorly sorted **Shale (65%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Traces of ferruginous materials and few glauconite pellets
2252 – 2262	SILICA RICH SHALE	**Sand (30%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (70%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Traces of ferruginous materials and few glauconite pellets
2262 – 2271	SANDY SHALE	**Sand (85%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (15%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2271 – 2280	SANDY SHALE	**Sand (20%):** milky white to glassy, fine coarse, subangular to subrounded, poorly sorted **Shale (80%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2280 – 2289	SANDY SHALE	**Sand (20%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (80%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials

2289 – 2298	SILICA RICH SHALE	**Sand (30%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (70%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2298 – 2307	SILICA RICH SHALE	**Sand (30%):** milky white to glassy, fine - coarse, subangular to subrounded, poorly sorted **Shale (70%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2307 – 2316	SANDY SHALE	**Sand (20%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (80%):** Greyish to brownish, platy to blocky, moderately hard shale **Accessories:** Pyrites and ferruginous materials
2316 – 2356	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2356 – 2335	SANDY SHALE	**Sand (20%):** Whit to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2335 – 2344	SANDY SHALE	**Sand (25%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (75%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2344 – 2353	SANDY SHALE	**Sand (25%):** milky white to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (75%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2353 – 2362	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2362 – 2371	SANDY SHALE	**Sand (20%):** milky white to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites

2371 – 2380	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (70%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2380 – 2390	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (70%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2390 – 2399	SANDY SHALE	**Sand (25%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (75%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2399 – 2408	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2408 – 2417	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2417 – 2426	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (70%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2426 – 2444	SANDY SHALE	**Sand (30%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (70%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2444 – 2454	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites

2454 – 2463	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, blocky moderately hard shale **Accessories:** Pyrites
2463 – 2472	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials
2472 – 2481	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials
2481 – 2490	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials
2490 – 2499	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials
2499 – 2509	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials
2509 – 2518	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials
2518 – 2527	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials

2527 – 2536	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials
2536 – 2545	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials
2545 – 2554	SANDY SHALE	**Sand (20%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (80%):** Greyish to brownish, platy to blocky moderately hard shale **Accessories:** Traces of ferruginous materials
2554 – 2563	SILICA RICH SHALE	**Sand (20%):** Whitish to glassy, smooth - medium, subangular - subrounded, poorly sorted **Shale (80%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Pyrites
2563 – 2573	SILICA RICH SHALE	**Sand (20%):** Whitish to glassy, smooth - medium, subangular - subrounded, poorly sorted **Shale (80%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Pyrites
2573 – 2582	SILICA RICH SHALE	**Sand (20%):** milky white to glassy, smooth - medium, subangular - subrounded, poorly sorted **Shale (80%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Pyrites and ferruginous materials
2582 – 2591	SILICA RICH SHALE	**Sand (20%):** milky white to glassy, smooth - medium, subangular - subrounded, poorly sorted **Shale (80%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Pyrites and ferruginous materials
2591 – 2600	SILICA RICH SHALE	**Sand (20%):** milky white to glassy, very smooth - smooth - medium, subangular - subrounded, poorly sorted **Shale (80%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Pyrites and ferruginous materials

2600 – 2609	SILICA RICH SHALE	**Sand (19%):** milky white to glassy, smooth - medium, subangular - subrounded, poorly sorted **Shale (%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Pyrites and ferruginous materials
2609 – 2618	SILICA RICH SHALE	**Sand (20%):** milky white to glassy, smooth - medium, subangular - subrounded, poorly sorted **Shale (80%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Ferruginous materials
2618 – 2627	SILICA RICH SHALE	**Sand (20%):** milky white to glassy, smooth - medium, subangular - subrounded, poorly sorted **Shale (80%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Ferruginous materials
2627 – 2637	SHALY SAND	**Sand (55%):** Whitish to glassy, fine to medium, subangular to subrounded, poorly sorted **Shale (45%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2637 – 2646	SHALY SAND	**Sand (55%):** Whitish to glassy, fine to medium, subangular to subrounded, poorly sorted **Shale (45%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2646 – 2655	SHALY SAND	**Sand (55%):** Whitish to glassy, fine to medium, subangular to subrounded, poorly sorted **Shale (45%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2655 – 2664	SHALY SAND	**Sand (60%):** Whitish to glassy, fine to medium, subangular to subrounded, poorly sorted **Shale (40%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites

2664 – 2673	SHALY SAND	**Sand (60%):** Whitish to glassy, fine to medium, subangular to subrounded, poorly sorted **Shale (40%):** Greyish black to dark brownish, blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2673 – 2682	SHALY SAND	**Sand (60%):** Whitish to glassy, fine to medium, subangular to subrounded, poorly sorted **Shale (40%):** Greyish, black to dark brownish, blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2682 – 2691	SANDY SHALE	**Sand (5%):** Whitish to glassy, fine to middle, to coarse, subangular to subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, pellets to platy to blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2691 – 2701	SANDY SHALE	**Sand (5%):** Whitish to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, pellets to platy to blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2701 – 2710	SANDY SHALE	**Sand (5%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, pellets to platy to blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2710 – 2719	SANDY SHALE	**Sand (5%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, pellets to platy to blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites

2719 – 2728	SANDY SHALE	**Sand (5%):** milky white to glassy, fine to middle - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2728 – 2737	SANDY SHALE	**Sand (5%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2737 – 2746	SANDY SHALE	**Sand (5%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2746 – 2755	SANDY SHALE	**Sand (5%):** milky white to glassy, fine to middle - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials and pyrites
2755 – 2765	SANDY SHALE	**Sand (5%):** Whitish to glassy, fine to middle, to coarse, subangular to subrounded, poorly sorted **Shale (90):** Grey to dark brownish, blocky to moderately hard shale **Accessories:** Iron rich materials, carbonaceous detritus and pyrites
2765 – 2774	SANDY SHALE	**Sand (5%):** Whitish to glassy, fine to middle - coarse, subangular - subrounded, poorly sorted **Shale (90):** Grey to dark brownish, blocky to moderately hard shale **Accessories:** Ferruginous materials, carbonaceous detritus and pyrites
2774 – 2783	SANDY SHALE	**Sand (5%):** Whitish to glassy, fine to intermediate - coarse, subangular - subrounded, poorly sorted **Shale (90):** Grey to dark brownish, blocky to moderately hard shale **Accessories:** Ferruginous materials, carbonaceous detritus and pyrites

2783 – 2792	SANDY SHALE	**Sand (5%):** Whitish to glassy, fine – intermediate - coarse, subangular subrounded, poorly sorted **Shale (90):** Grey to dark brownish blocky to moderately hard shale **Accessories:** Carbonaceous detritus, abundant ferruginous materials and pyrites
2792 – 2801	SANDY SHALE	**Sand (5%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, blocky to moderately hard shale **Accessories:** Carbonaceous detritus, abundant ferruginous materials and pyrites
2801 – 2810	SANDY SHALE	**Sand (5%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, platy to blocky moderately hard shale **Accessories:** Carbonaceous detritus, abundant ferruginous materials and pyrites
2810 – 2819	SANDY SHALE	**Sand (5%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, platy moderately hard shale **Accessories:** Carbonaceous detritus, abundant ferruginous materials and pyrites
2819 – 2829	SANDY SHALE	**Sand (5%):** Whitish to glassy, coarse to subangular to subrounded, fine to medium, poorly sorted sand **Shale (90):** Greyish to dark brownish, platy moderately hard shale **Accessories:** Carbonaceous detritus, abundant ferruginous materials and pyrites
2829 – 2838	SANDY SHALE	**Sand (5%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Greyish to dark brownish, platy moderately hard shale **Accessories:** Carbonaceous detritus, abundant ferruginous materials and pyrites
2838 – 2847	SANDY SHALE	**Sand (5%):** Whitish to glassy, fine to middle, to coarse, subangular to subrounded, poorly sorted **Shale (90):** Dark brownish, platy moderately hard shale **Accessories:** Carbonaceous detritus, ferruginous materials and pyrites

2847 – 2856	SANDY SHALE	**Sand (5%):** milky white to glassy, fine to middle, to coarse, subangular to subrounded, poorly sorted **Shale (90):** Dark brownish, platy moderately hard shale **Accessories:** Carbonaceous detritus, ferruginous materials and pyrites
2856 – 2865	SANDY SHALE	**Sand (5%):** Whitish to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Dark brownish, platy moderately hard shale **Accessories:** Carbonaceous detritus, ferruginous materials and pyrites
2865 – 2874	SANDY SHALE	**Sand (5%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (90):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Carbonaceous detritus, ferruginous materials and pyrites
2874 – 2883	SANDY SHALE	**Sand (5%):** milky white to glassy, fineto coarse, subangular to subrounded, poorly sorted **Shale (90):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Carbonaceous detritus, ferruginous materials and pyrites
2883 – 2892	SANDY SHALE	**Sand (15%):** milky white to glassy, smooth - coarse, subangular - subrounded, poorly sorted **Shale (75%):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Carbonaceous detritus, ferruginous materials and pyrites
2892 – 2902	SANDY SHALE	**Sand (15%):** Whitish to glassy, fine to middle, to coarse, subangular to subrounded, poorly sorted **Shale (75%):** greyish - dark, platy - blocky moderately hard shale **Accessories:** Carbonaceous detritus, Iron rich materials and pyrites
2902 – 2911	SHALY SAND	**Sand (55%):** milky white to glassy, fine to coarse, subangular to subrounded, poorly sorted **Shale (45%):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus

2911 – 2920	SHALY SAND	**Sand (55%):** Whitish to glassy, smooth - coarse, subangular to subrounded, poorly sorted **Shale (45%):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus
2920 – 2929	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (55%):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus
2929 – 2938	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (55%):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus
2928 – 2947	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (55%):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus
2947 – 2956	SANDY SHALE	**Sand (40%):** Whiish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (60%):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus
2956 – 2966	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (55%):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus
2966 – 2975	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (55%):** Light grey to dark, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus

2975 – 2984	SANDY SHALE	**Sand (45%):** Whiteish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (55%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus
2984 – 2993	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (55%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and abundant carbonaceous detritus
2993 – 3002	SANDY SHALE	**Sand (45%):** Whitish to glassy, fine to medium, subangular to subrounded, fairly sorted **Shale (55%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and few mica flakes
3002 – 3011	SANDY SHALE	**Sand (45%):** Whitish to glassy - occasionally greenish, fine - middle – coarse, subangular - subrounded, poorly sorted **Shale (55%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites and few mica flakes
3011 – 3021	SANDY SHALE	**Sand (45%):** Whitish to glassy, to occasionally greenish fine to intermediate - coarse, subangular - subrounded, poorly sorted **Shale (55%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites, mica flakes and few carbonaceous detritus
3021 – 3030	SANDY SHALE	**Sand (45%):** Whitish to glassy, to occasionally greenish, fine - middle - coarse, subangular - subrounded, poorly sorted **Shale (55%):** Dark greyish, blocky moderately hard shale **Accessories:** Iron rich materials, pyrites, mica flakes and few carbonaceous detritus
3030 – 3039	SHALY SAND	**Sand (70%):** milky white to glassy, yellowish medium to coarse, subangular to subrounded, fairly sorted **Shale (30%):** Dark greyish, blocky moderately hard shale **Accessories:** Pyrites, mica flakes and ferruginous materials

3039 – 3048	SHALY SAND	**Sand (70%):** milky white to glassy, yellowish fine to middle - coarse, subangular - subrounded, poorly sorted **Shale (30%):** Dark greyish, blocky moderately hard shale **Accessories:** Ferruginous materials, pyrites, mica flakes
3048 – 3057	SHALE RICH IN SILICA	**Sand (81%):** milky white to glassy, smooth - medium - coarse - very coarse, subangular - subrounded, poorly sorted **Shale (19%):** Dark greyish, blocky, moderately hard shale **Accessories:** Ferruginous materials and pyrites
3057 – 3066	SHALE RICH IN SILICA	**Sand (80%):** milky white to glassy, smooth - medium to coarse - very coarse, subangular to subrounded, poorly sorted **Shale (20%):** Dark greyish, blocky, moderately hard shale **Accessories:** Ferruginous materials and pyrites
3066 – 3075	SHALE RICH IN SILICA	**Sand (80%):** milky white to glassy, fine - intermediate - coarse, subangular - subrounded, poorly sorted **Shale (20%):** Dark greyish, blocky, moderately hard shale **Accessories:** Mica flakes and pyrites and abundant ferruginous materials
3075 – 3085	SHALE RICH IN SILICA	**Sand (80%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (20%):** Dark greyish, blocky, moderately hard shale **Accessories:** Mica flakes and pyrites and abundant ferruginous materials
3085 – 3094	SHALE RICH IN SILICA	**Sand (80%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (20%):** Dark greyish, blocky, moderately hard shale **Accessories:** Ferruginous materials and traces of Pyrites
3094 – 3103	SHALE RICH IN SILICA	**Sand (80%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (20%):** Dark greyish, blocky, moderately hard shale **Accessories:** Ferruginous materials and traces of Pyrites

3103 – 3112	SHALE RICH IN SILICA	**Sand (80%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (20%):** Dark greyish, blocky, moderately hard shale **Accessories:** Ferruginous materials and traces of Pyrites
3112 – 3121	SHALE RICH IN SILICA	**Sand (80%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (20%):** Dark greyish, blocky, moderately hard shale **Accessories:** Ferruginous materials and traces of Pyrites
3121 – 3131	SHALE RICH IN SILICA	**Sand (80%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (20%):** Dark greyish, blocky, moderately hard shale **Accessories:** Ferruginous materials and traces of Pyrites
3131 – 3139	SHALY SAND	**Sand (85%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (15%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials and traces of Pyrites
3139 – 3149	SHALY SAND	**Sand (85%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (15%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials and traces of Pyrites
3149 – 3158	SHALY SAND	**Sand (85%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (15%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials and traces of Pyrites
3158 – 3167	SHALY SAND	**Sand (85%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (15%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, mica flakes

3167 – 3176	SHALY SAND	**Sand (90%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (10%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, mica flakes
3176 – 3185	SHALY SAND	**Sand (90%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (10%):** Dark greyish, platy to blocky moderately hard shale **Accessories:** Ferruginous materials, mica flakes and traces of Pyrites
3185 – 3194	SHALY SAND	**Sand (90%):** milky white to glassy, fine - coarse, subangular - subrounded, poorly sorted **Shale (10%):** Dark greyish, blocky moderately hard shale **Accessories:** Ferruginous materials, mica flakes and traces of Pyrites
3194 – 3203	SHALY SAND	**Sand (90%):** milky white to glassy, fine - coarse, subangular subrounded, poorly sorted **Shale (10%):** Dark greyish, blocky moderately hard shale **Accessories:** Ferruginous materials, mica flakes and traces of Pyrites
3203 – 3213	SHALY SAND	**Sand (90%):** Whitish - glassy, medium - coarse - very coarse, subangular - subrounded, poorly sorted **Shale (10%):** Dark greyish, moderately hard shale **Accessories:** Ferruginous materials, mica flakes and traces of Pyrites
3213 – 3222	SHALY SAND	**Sand (90%):** Whitish - glassy, medium - coarse - very coarse, subangular - subrounded, poorly sorted **Shale (10%):** Dark greyish, platy, moderately hard shale **Accessories:** Ferruginous materials, abundant mica flakes and Pyrites
3222 – 3231	SHALY SAND	**Sand (95%):** Whitish - glassy, medium - coarse - very coarse, subangular - subrounded, poorly sorted **Shale (5%):** Dark greyish, platy, moderately hard shale **Accessories:** Ferruginous materials, abundant mica flakes and Pyrites

3231 – 3240	SHALY SAND	**Sand (95%):** milky white to glassy, middle - coarse - very coarse, subangular - subrounded, poorly sorted **Shale (5%):** Dark greyish, platy, moderately hard shale **Accessories:** Iron rich materials, abundant mica flakes and Pyrites
3240 – 3243	SHALY SAND	**Sand (95%):** milky white to glassy, smooth - medium – coarse, subangular - subrounded, poorly sorted **Shale (5%):** Dark greyish, blocky, moderately hard shale **Accessories:** Iron rich materials, abundant mica flakes and Pyrites