

RESEARCH ARTICLE

RECONSTRUCTION OF THE PALEO-DEPOSITIONAL SETTINGS OF THE CHATTIAN GH6.2 SAND IN THE ARO FIELD, ONSHORE DEPOBELT, NIGER DELTA BASIN

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ABSTRACT

Delineating the depositional environment is a key factor in oil field characterization because it serves as a key input into property distribution in the 3D model. This study is carried out to reconstruct the paleo-environment of deposition of the GH6.2 reservoir through data integration. A combination of well logs, lithological and mineralogical description of side wall samples and biofacies data were used to reconstruct the paleo-environment of deposition. Gamma ray log signatures were utilised to infer depositional features, discriminate litho-units, and define facies association. Lithological descriptions of Side Wall sample describe a grey sandy clayey, fine to silty with rare to medium and coarse grains sediments across some wells. The mineralogical description on side wall sample denotes the presence of quartz, mica flakes and pyrites. The interpretation of biofacies data located the deposit in the Middle to Outer Neritic environment deposited in the Oligocene in the Chattian age during a rising sea level. The integration of the results from the well logs, side wall samples, mineralogical studies, and biofacies data points that the GH6.2 reservoir is a channelised shoreface deposit, deposited in the Chattian age in a transgressive environment.

KEYWORDS

Paleo environment, Biofacies, Well logs, Side wall sample, channel and Shoreface

1. INTRODUCTION

The first stages of a reservoir's existence are discovery and exploration. Once a finding has been found, the following step is to characterize the reservoir as precisely as possible to estimate the reserves and choose the most effective method of extracting as much petroleum as feasible. Static and dynamic modeling, as well as inferring the depositional environment, are involved. Untangling the primary sediment dispersion mechanism and the unit's depositional evolution across time and space are necessary for reconstructing the depositional history of any ancient siliciclastic unit (Allen, 1970). Facies stacking patterns in various sedimentary packages reflect the depositional processes and environments. In order to properly investigate the paleo-depositional environment, it is essential to recognize and comprehend both the processes and their reactions. By the integration of the data that is already accessible, including well log data, side wall sample lithological and mineralogical descriptions, and biofacies data, this research intends to enhance workflow procedures for reconstructing the reservoir depositional environment.

2. GEOLOGICAL OVERVIEW

The Niger Delta is among the largest and most hydrocarbon-rich deltas in the world (Doust 1990; Haack et al., 2000). According to a study, the Niger Delta system is located between Latitude 4° 49' N and N and Longitude 6° 0' E in the Gulf of Guinea continental edge of West Africa (Doust and Omatsola, 1990). With acreages spanning over 75,000 km, it is rated as the twelfth biggest delta in the world. The Niger Delta is a regressive series with deposits that range in thickness from 30,00 to 40,00 feet. The Niger Delta is estimated to contain 34.5 billion barrels of oil (BBO) and 93.8

trillion cubic feet² of gas (TCFG) (14.9 billion barrels of oil equivalent, BBOE) in cumulative production plus proven reserves.

Pre-Cambrian rift faulting produced the 10 km thick sediments that make up the Nigerian pericratonic basin (Doust and Omatsola, 1989). Deep-seated faults known as the Chain and Charcot fracture zones, which are located along the Benin and Calabar hinge lines, shape the Niger Delta's contours. From the early Cretaceous period, the basin has experienced the deposition of at least three significant sedimentary cycles (Reijers, 2011). The second cycle between Campanian and Paleocene incursions is when the delta started to expand. The creation of the Niger Delta may be attributed to the third sedimentary cycle that took place during the Paleocene.

The majority of the deltaic sequence is made up of shaly marine sediments known as the Akata Formation. These are then covered by paralic sediments, which are composed of mixed continental, brackish water, and marine deposits, called the Agbada Formation, which is then covered by continental sands and gravels (Benin Formation) such deltaic sediments often have an S-shaped temporal stratigraphic unit in cross section (Merki, 1972).

2.1 Geology of the study area

In the Greater Ughelli depobelt in the Niger Delta, the research area is situated in the ARO field, onshore eastern belt. The field has 12 wells. The field is made up of stacks of shales and paralic sequences of sand, the majority of which contain hydrocarbons. The study reservoir has a depth that spans from 8900 to 965000 feet TVDSS.

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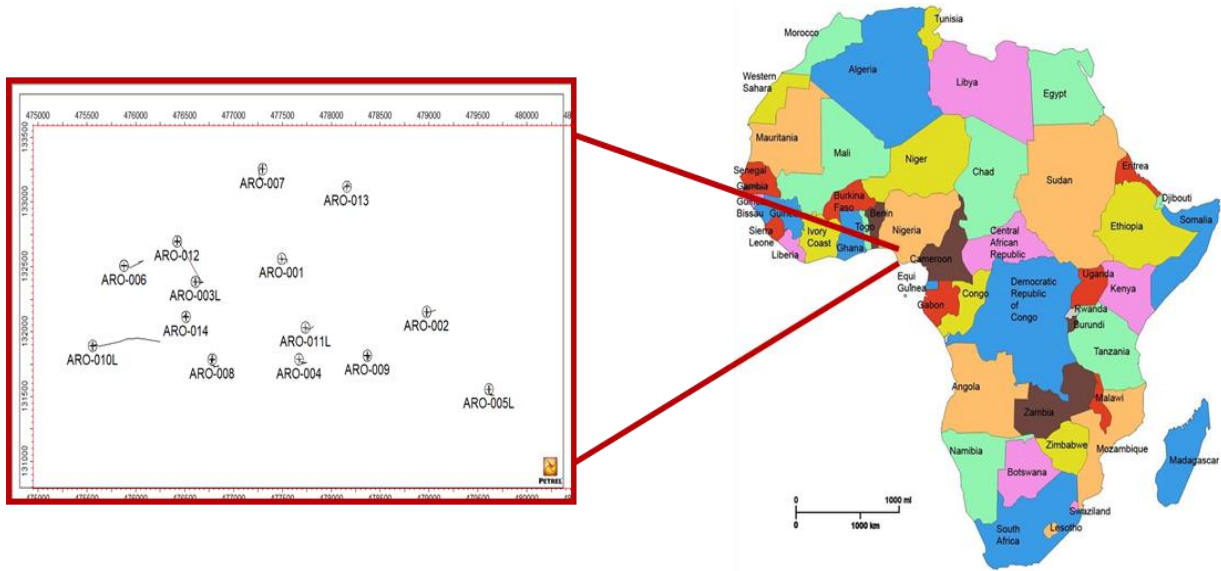


Figure 1: Map Showing the Study Area

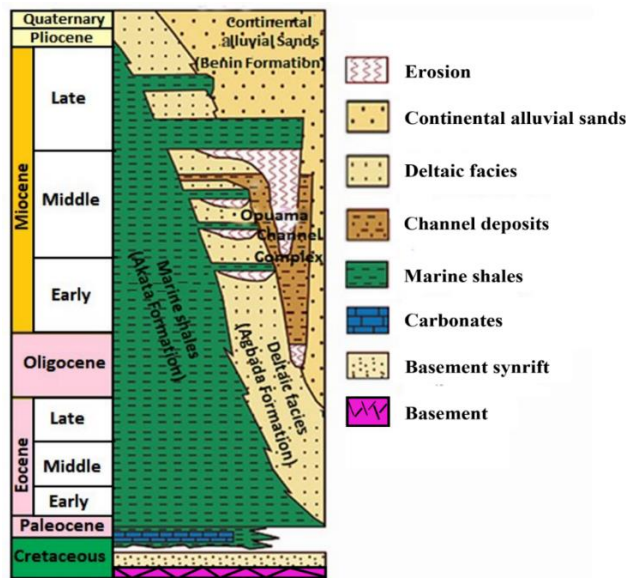


Figure 2: Regional stratigraphic framework highlighting the diachroneity of subsurface lithologic units in the Niger Delta

3. METHODOLOGY

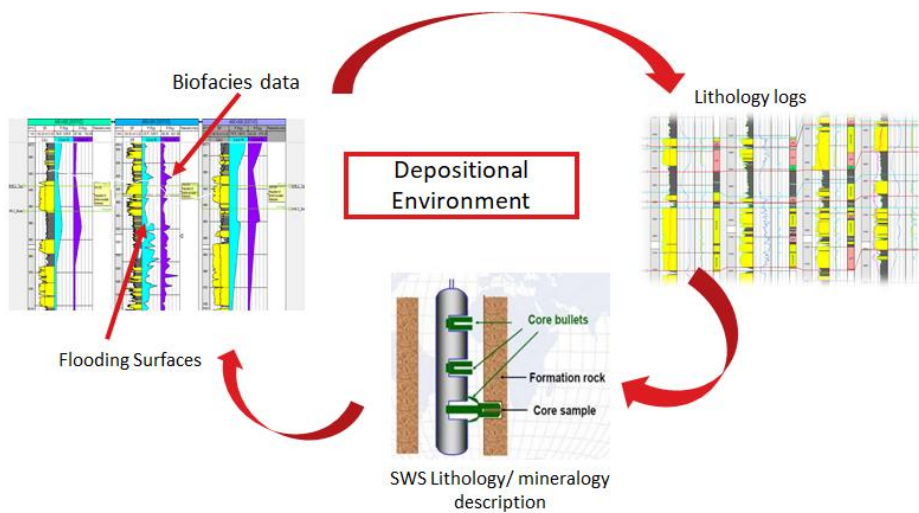


Figure 3: Workflow (Okobiebi and Okobiebi, 2021)

The well logs ASCII were loaded into version 2014 PETREL software and used to generate well log plots. Standard lithofacies patterns recognition pattern was used to infer gross depositional environments of the sand

bodies based on gamma-ray log trends. Intervals with high gamma ray values beyond 80°API indicate shale or very fine grained pelitic sedimentary rocks, whereas the sandy intervals have low gamma ray

values below 80°API. On a field-scale, sand packages were correlated with selected wells (ARO, 006, 012, 001, 002 and 005) in strike directions. This was done to, to infer the lateral continuity of the sands. Correlation was also carried out in dip direction, to tell the depositional story using wells ARO 012, 003 and 008. The lithofacies description was integrated with lithological description and mineralogical description from sidewall samples to reduce uncertainty in characterisation. Biofacies data from Wells ORA-001, ORA-002, ORA-004, ORA-005, ORA-006, and ORA-008 was used to interpret the paleobathymetry by comparing the plankton abundance and foram abundance in the wells. The abundance of foram/planktons was used to define the paleobathymetry, and therefore the different environments of deposition. It was also used for identifying flooding surfaces and maximum flooding surfaces for identifying a timeline of deposition of the reservoir.

3. RESULTS

3.1 Lithofacies description

Sedimentological studies by various researchers have shown that vertical profiles of grain size from a specific environment have certain

characteristics. For instance, prograding deltas and barrier bars deposits display an upward-coarsening grain size profiles, channel deposits tend to have a constant grain size distribution with the channel belt, marine channels also have a reduction in grain size upward as the velocity of flow of the channels reduces (Selley, 1985; Amajor and Agbaire, 1989; Chow et al., 2005). Three prominent trends identified on well logs that helped to delineate the various depositional settings are: coarsening upward trend representing point bar or upper shoreface facies, blocky sand signatures that represent fluvial channels, braided bar or distributary channels and the high gamma ray readings as shales.

Five wells traverse the whole expanse of the field from East to West, namely; ARO, 006, 012, 001, 002 and 005 as shown in Figure 4. Wells ARO 006 and 012 are in the eastern section of the field, and ARO 001 is midway along the strike, whereas ARO 002 and 005 are on the western flank of the field. This covers the lateral extent of the field. Careful observation of facies trends shows shoreface deposits at the western and eastern flank of the field and channel sand in the middle. In the dip direction, the facies had intercalation of shoreface and channel deposits but the thickness of the sand packages reduced down dip as indicated in Figure 5.

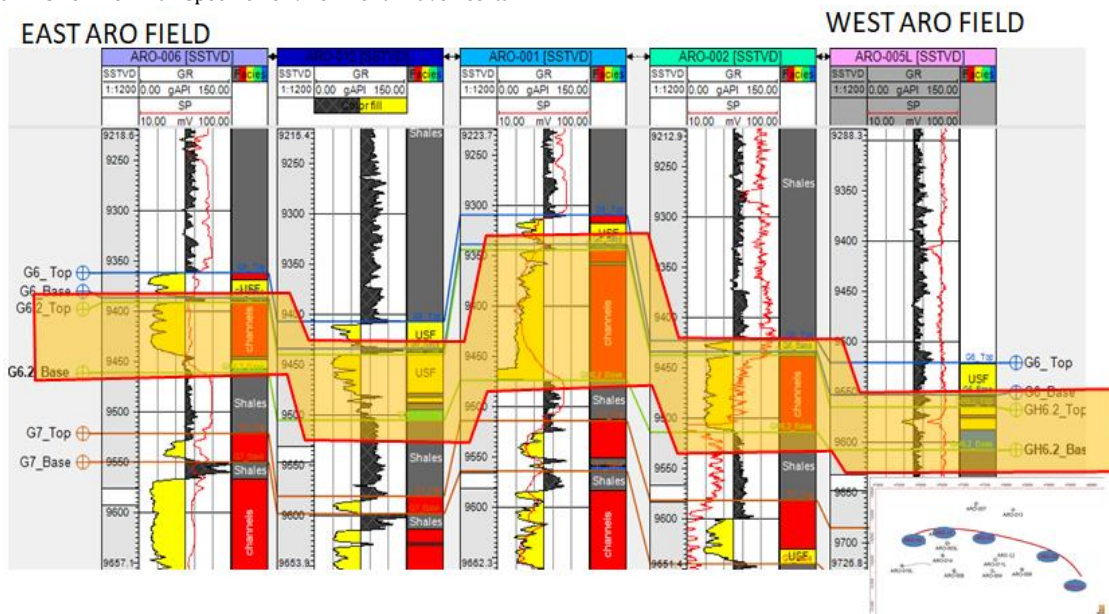


Figure 4: A strike from East to West showing the Litho-correlation of Gh 6.2 sand across the Field

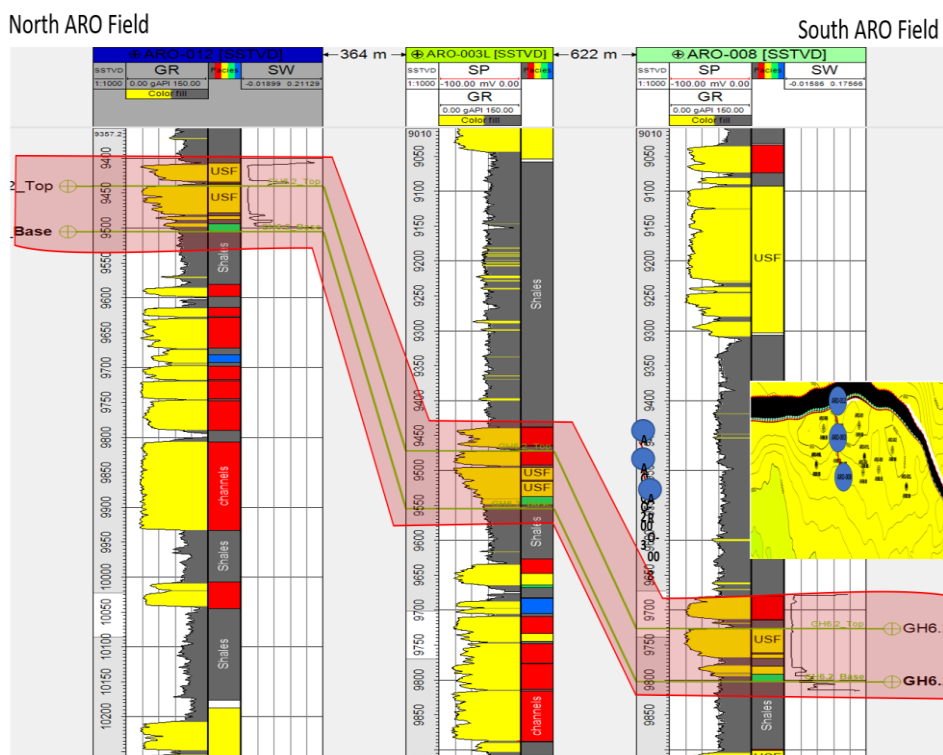


Figure 5: A dip section from north to south showing litho-correlation of the Gh6.2 wells basin ward in the Field

3.2 Side Wall Sample Descriptions

Side wall samples were interpreted for mineralogical and lithological description. The interpretation of the mineralogical composition of the side wall sample using wells ARO 002, 003, 004, 005, 008 and 010 showed the presence of pyrite, micas and quartz and reflects minimal amounts of glauconite and lignite as presented in Table 1. The SWS lithological

description of the reservoir sands reveals grey coarse silts with very rare coarse grains, moderately sorted, and loosely consolidated. Well ARO 004 consists of grey fine silt with rare to medium grains; well sorted and loosely consolidated. In well ARO 008 showed Brownish grey; coarse silt with a few very coarse grains, poorly sorted and unconsolidated. The observations in the other wells all ranged within these descriptions.

Table 1: Showing the lithological and Mineralogical description from side wall samples collected at different depth

Wells	Depths (MD)	Lithology	Lithological desc.	Mineralogical desc.
ARO-002	9554	Sand	Grey, coarse to silt, with rare very coarse grains, moderately sorted, loosely consolidated.	Pyrite common.
	9618	Clay with irregular Sand streaks: CLAY (50%), SAND (50%)	CLAY: Grey, slightly sandy with grains ranging from very fine to silt, slightly calcareous. SAND: Grey, loosely cemented by calcareous matter, very fine to silt, well sorted, loosely consolidated.	CLAY: Little pyrite, rare glauconite and carbonaceous matter. SAND: Little pyrite and rare glauconite.
	9620	Sand	Grey, very coarse to silt, with rare granules, poorly sorted, unconsolidated.	Rare pyrite.
ARO-003	9590	Sand	Grey; slightly clayey; fine to silt with rare medium and coarse grains; moderately sorted; loosely consolidated.	Abundant pyrite; plant remains common; rare mica flakes; glauconite and lignite.
	9600	Sand	Grey; coarse to silt with a few very coarse grains; moderately sorted; loosely consolidated.	Rare feldspars and a few grains show pyrite coating and inclusion.
	9620	Sand	Grey; very coarse to silt; poorly sorted; loosely consolidated.	Grains showing pyrite coating and inclusion common.
	9640	sand	Grey; locally cemented by calcareous matter; fine to silt with rare medium; well sorted; loosely consolidated.	A few pyrite and rare mica flakes.
	9660	Sand with streaks of Carbonaceous matter.	Grey; very fine to silt with a few fine grains; well sorted; loosely consolidated.	A few carbonaceous matter; rare pyrite and glauconite.
	9670	Sand with Clay streaks: SAND (70%); CLAY (30%).	SAND: Grey; very fine to silt; well sorted; loosely consolidated. CLAY: Dark grey; slightly silky; frangible.	SAND: Rare glauconite. CLAY: Plant remains common; a few pyrite and rare lignite.
ARO-004	9744	Sand	Grey; fine to silt with rare medium grains; well sorted; loosely consolidated.	A few mica flakes and rare pyrite inclusion.
	9784	Sand with streaks of brownish/ dark grey Clay: Sand (80%).	Grey; fine to silt; well sorted; loosely consolidated.	Abundant lignite and plant remains; rare mica flakes.
	9794	Sand with Lignite streaks	Grey; fine to silt; well sorted; loosely consolidated.	Abundant lignite; a few carbonaceous matter and pyrite.
	9802	Sand with Lignite streaks	Grey; very fine to silt; well sorted; loosely consolidated.	Lignite common; a few pyrite; mica flakes and plant remains.
ARO-005	9822	Sand	Grey; coarse to silt with a few very coarse grains; moderately sorted; loosely consolidated.	Pyrite common.
ARO-008	9840	Mud/Sand	Brownish grey; very fine to silt. Well sorted and muddy.	
	9857	Sand	Brownish grey; coarse to silt with a few very coarse grains. Poorly sorted and unconsolidated.	A few grains show pyrite coating and inclusion.
	9870	Sand	Grey. coarse to silt with rare very coarse grains. poorly sorted and unconsolidated.	Grains with pyrite coating and inclusion common
ARO-010	10132	Sand	Light yellowish grey; fL to crsL; slightly gravelly; poorly sorted; loosely consolidated.	Fairly common pyrite coatings and inclusions in quartz; rare mica flakes and heavy minerals.
	10136	Sand	Light yellowish grey; fL to crsL; moderately sorted; loosely consolidated.	Few pyrite coatings and inclusions in quartz; rare heavy minerals.
	10141	Sand	Grey; fU to fU; well sorted; slightly clayey; loosely consolidated.	Few pyrite; rare mica flakes and heavy minerals.
	10160	Sand	Grey; fU to fU; slightly silty; very well sorted; slightly clayey; loosely consolidated.	Rare pyrite; mica flakes and heavy minerals.
	10165	Sand	Light yellowish grey; fU to fU; very well sorted; slightly clayey; loosely consolidated.	Fairly common heavy minerals; rare pyrite and mica flakes.
	10170	Sand	Yellowish grey; fU to fU; well sorted; slightly clayey and calcareous; loosely consolidated.	Few mica flakes and pyrite.
	10175	Sand with lignite streaks	Sand (90%): Grey; fU to fU; slightly silty; well sorted; slightly clayey; loosely consolidated.	Fairly common mica flakes and pyrite; rare weathered glauconite.

3.3 Biofacies description

Biofacies data from Wells ORA-001, ORA-002, ORA-004, ORA-005, ORA-006, ORA-007, and ORA-008 were used to constrain the paleobathymetry of the depositional environment. The Paleo bathymetry data analysed

indicate that the amount of foram exceeded planktons suggesting a shelf deposit within the middle neritic to outer neritic environment. The populations and diversity of the forams in wells ARO 002 and 006 were utilised to pick the regional markers (maximum flooding surfaces) and used for relative dating, as illustrated in Figure 6.

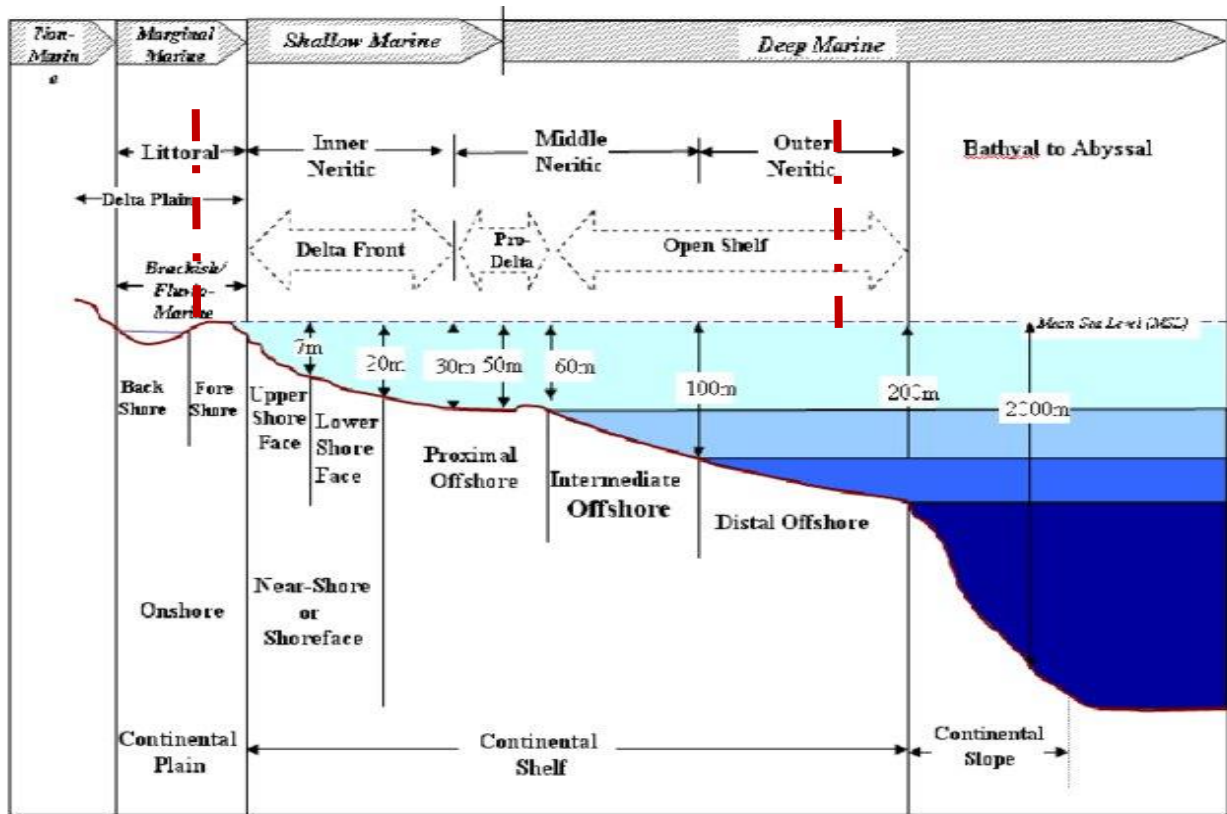


Figure 6: Depositional Environments and Bathymetric Ranges the red lines showing our depositional environment (Allen, 1965; Allen, 1970)

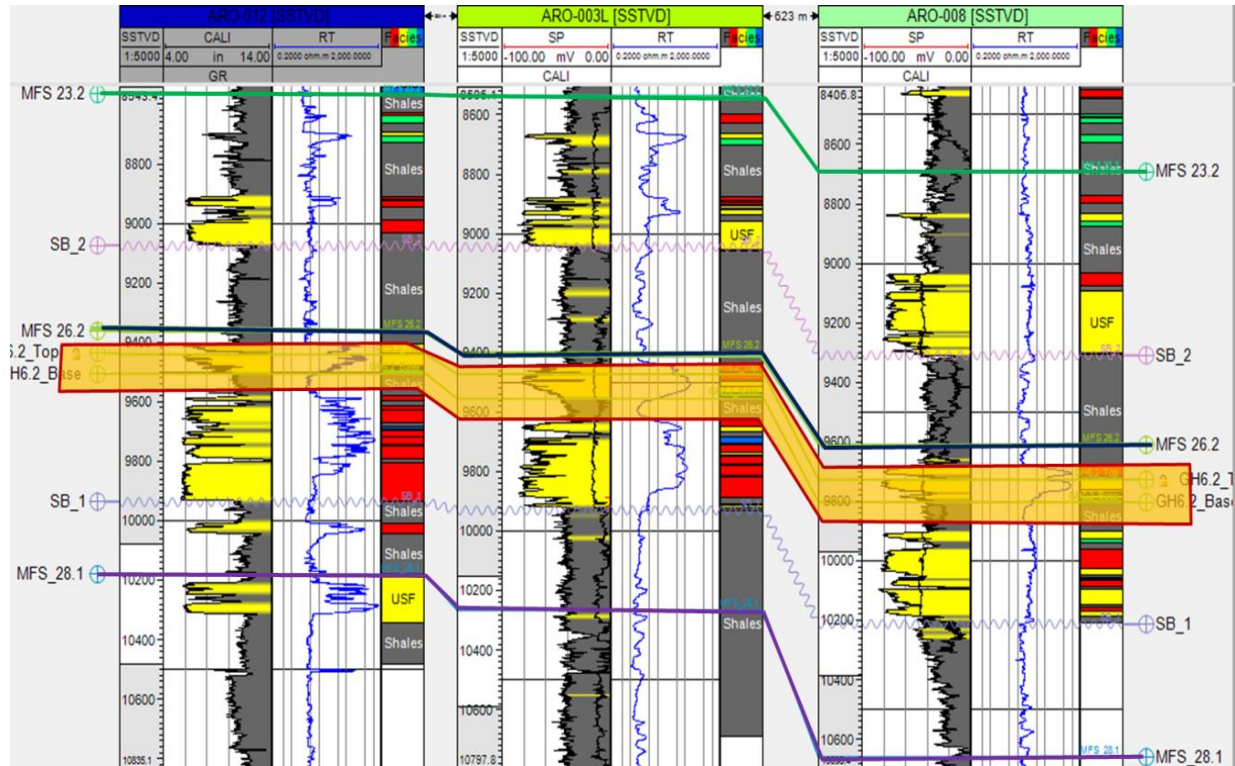


Figure 7: Showing the Maximum Flooding surfaces for dating the reservoirs

4. DISCUSSION

4.1 Paleo-Depositional settings

In the ARO field, shoreface and channel deposits may be found in the lithofacies characterized using the logs motif. A shoreface, subsea, or

mouth bar deposit in a deltaic context is suggested by the gamma ray log's coarsening upward signals, which are an indicator of the increase in particle size from bottoms up. The blocky characteristics seen in ARO-002 are suggestive of a uniform grain size maintained from the bottoms up suggesting a distributary channel, braided fluvial, or a submerged canyon deposit. A silty, fine to coarse sand that is weakly to moderately sorted,

loosely consolidated, and integrating the lithological description of the side wall samples that defines the Gh6.2 reservoir is an excellent reservoir and suggestive of a shelf deposit (Omoboriowo et al., 2012). The uncertainty was further minimized by data integration utilizing hints from side wall sample mineralogical descriptions.

Indicative of a shallow marine environment with shales in the delta front to an open shelf environment is the presence of lignite and glauconite. The mouth bar and braided bar are no longer available as continental alternatives. The overall foram abundance and diversity are greater than the total plankton abundance and diversity, which suggests a deltaic or marine context, according to the interpretation of the biofacies data at the reservoir level. Because the logs clearly show the effect of the channels

cutting into the base shoreface deposits, it is known as inner neritic to outer neritic (Figure 6).

Maximum flooding surfaces that were dated and correlated over the whole field were constructed using the greatest number and variety of forams. According to Chattian age, the reservoir Gh6.2 was most likely formed between MFS 26.2 Alabamina-1 and MFS 28.1 Bolivia 27. A depositional model was constructed by integrating every observational finding, well placement throughout the field, and the facies at specific well locations. As illustrated in Figure 8, the depositional model indicates a channelized shoreface environment on the shelf incised by two channels, with the broader channel on the eastern half of the field and the smaller one on the western side.

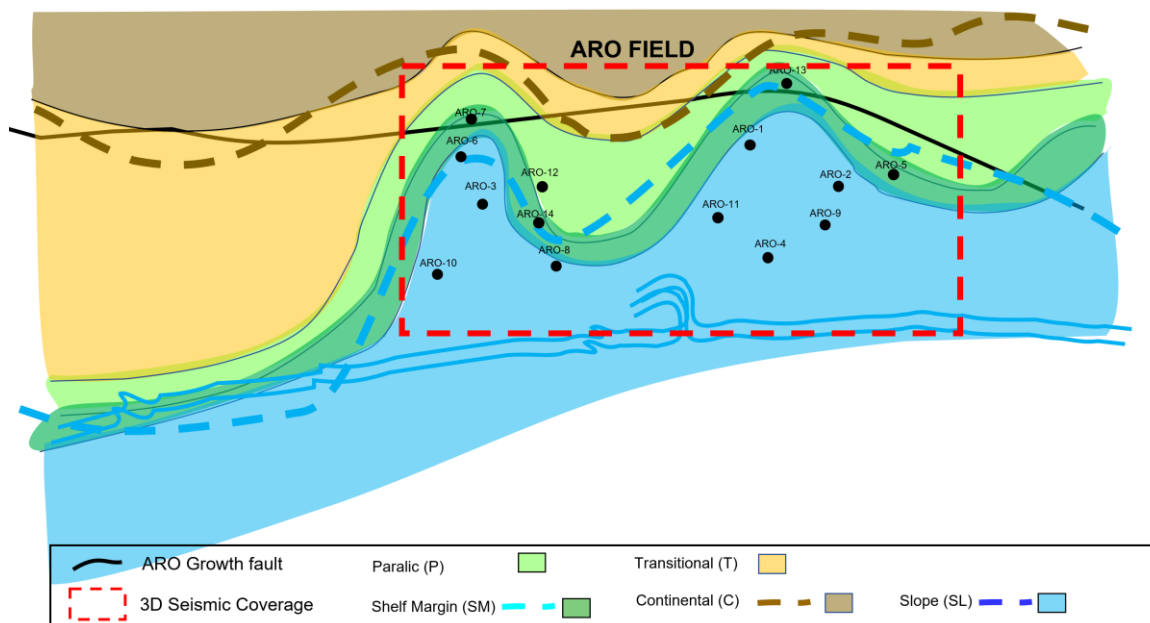


Figure 8: Showing the reservoir level depositional environment of a shelf deposit incised by two channels

5. CONCLUSION

The workflow enumerates the steps that can be used to delineate paleodepositiona environment on a reservoir level. After applying the modified workflow, the following conclusions were made. The depositional environment is predominantly shallow marine deltaic sequence, strongly influenced by two channels depositing clastic sediments. The water depth fluctuated between the inner and outer neritic environments. The regional markers MFS 26.2 Alabamina-2 and MFS 28.1 Bolivia 27 places the time of deposition of the Gh6.2 in the Chattian age of marine transgression.

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