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Structural Framework and Deep-Marine Depositional Environments of Miocene- Pleistocene Sequence in Western Offshore Myanmar

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Summary

The western Myanmar Rakhine Basin has developed renewed interest in Hydrocarbon exploration after recent giant gas discoveries. The basin lies in an active subduction regime and possesses very complex geological history. The basin has proven petroleum system and most of the significant hydrocarbon discovery lies in stratigraphic traps or strati-structural traps. Thus understanding of the structure and depositional environment is essential to identify prospects for hydrocarbon exploration. This study is aimed to understand the tectonics of the study area and provide a depositional model of the stratigraphic units interpreted from seismic data and attribute analysis.

Introduction

The study area is in the shallow waters near the coast of Sittwe town of West Myanmar. Previous Geoscientific studies had revealed that this area was introduced to multistress mechanism generated due to the converging Indian plate and Myanmar plate. Geological studies being limited in this area, hence an effort is made to understand the Neogene depositional environment of the area so as to have an idea on the small scale regional reservoir distribution within different stratigraphic units.

The aim of the study is:

- To understand the tectonic settings and delineating the major tectonic elements of the area.
- To visualize the structural geology of the stratigraphic units across the study area.
- To understand the surface distribution of the stratigraphic units on map and
- To understand the depositional environment from the seismic data and its evolution through time and space.

Tectonic Settings

The study area falls within the GANGES-BRAHMAPUTRA DELTA GEOLOGICAL PROVINCE [USGS World Petroleum Assessment 2000], and also in the Eastern Fold Belt sub province of Indo-Myanmar subduction zone. Eastern part of the study area is relatively more deformed than western part and the deformation diminishes gradually towards the west.

The area lies in the active ocean-continent convergent plate boundary where Indian Plate is subducting beneath the Myanmar Plate. The motion of subduction is oblique slip convergent (*Sikder et al 2003*). As a result the formations of thrust components are dominantly in East-West direction.

The trench in the fore deep area is hidden beneath the huge pile of sediment supplied from the uplifted Himalayas and also from Chittagong Fold Belt [CFB]. This huge sediment thickness got gradually uplifted as thick accretionary wedge system due to the continuing subduction of the Indian plate and thus developed large scale thrust and fold mountain belts which runs parallel to the subduction zone up to the Himalayan syntaxes. The study area is dominated by the SE extension of CFB (*Alam et al 2003*) and show typical characters of a thrust-fold belt.

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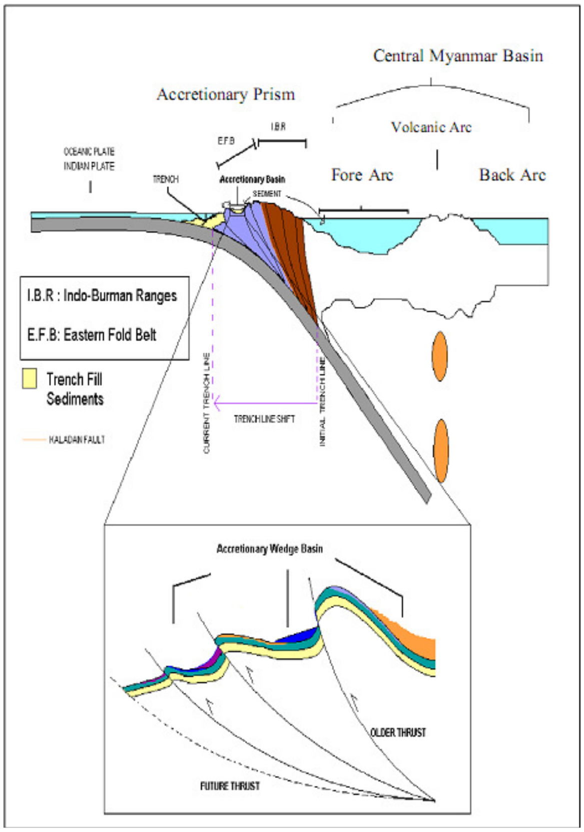

Fig 1: Schematic model of the Indo-Myanmar Subduction zone and inter accretionary wedge basin showing different tectonic elements. Thrust geometry model for an accretionary wedge is shown on inset.

The evolution of the area started as deep trench fill, to deep marine shelf-slope system, and deep water shelf conditions followed by structural deformation in the Quaternary. The anticlines are subsequently developed. Most of the anticlines are thrust related anticlines developed due to the compression tectonics. The regional cross section clearly shows the Boronga islands being made up of tight anticlines and the A3 structure as a broad anticline. The synclines tend to be wider in the study area but virtually vanish in the zones of intense deformation i.e. on the Indo Burma Ranges and the CFB.

Tectonic model suggests that the area lies as the inter wedge basin within the accretionary prism and was formed due to the local synclinal depressions created during the thrusting and folding [Fig 1]. These kinds of basin are usually bound by parallel thrust generated anticlines and sediments are deposited within the synclinal part derived from nearby Palaeo-highs and from land through submarine gravity driven debris flow channels. The fine grained sediment thus formed, provide effective hydrocarbon source facies, and gravity driven channel and fan deposit provides coarser reservoir facies for potential hydrocarbon accumulation. Presence of younger clay/ shale is ideal for effective seal and thrust generated anticlines have the ability to provide trapping mechanism for the migrating hydrocarbon. Thus understanding of the depositional condition of the litho facies and its distribution in the context of time- space environment is necessary to proceed for further exploratory work and to delineate the potential prospects.

Methodology

During early stage of this study conflicting information regarding the chronology of the stratigraphic units was found from the available published and unpublished geoscientific reports. To standardize the chrono-stratigraphic paradox, surface outcrop study, subsurface interpretation and well information had been incorporated. Seismic interpretation was done by correlating stratigraphic horizons based on event stratigraphy in conjunction with the available well information in and around the study area. The surface information is drawn from the available geological reports, maps and onshore well data. These data were then integrated to form a surface to subsurface model to visualize the local structural and lithological architecture which was then superimposed on satellite imagery to visualize the spatial distribution of the stratigraphic units [Fig 2]. This model was used to construct an East- West cross section connecting the onshore areas to the offshore area using seismic data**.** The East to West migration of thrust related structures with reducing intensity are evident from the cross-section [Fig 3]**.**

Major seismic sequences are interpreted. The interpreted sequences are divided into thin stratal slices and different attributes i.e. RMS, Variance, Instantaneous Frequency etc were applied to illuminate various geomorphological characters using PETREL 2008 software. RMS attribute stratal slices were found very useful to decipher the sediment deposition patterns on individual stratigraphic units in space and time.

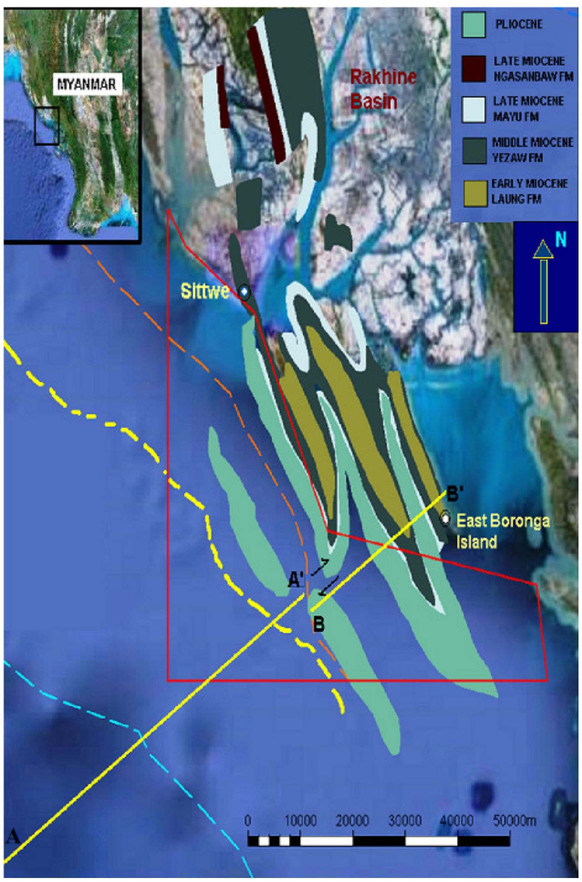

Fig 2: Outcrop map overlain on satellite image showing the Lithology distribution interpreted from seismic and outcrop information. Map shows folded structure displaced by strike slip faults and its outcrop at sub-sea. Dotted line shows recent shelf edge [Light Blue] and Pliocene shelf edge [yellow] and Miocene shelf position [Red]. *[Satellite Image Source: http://wikimapia.org]*

Depositional Environment

The depositional environment of the study area is worked out for the Middle Miocene to Pleistocene Sequences. These stratigraphic units show deep marine depositional condition as inferred from the seismic sequence stratigraphy. The interpretation is well supported by geological interpretation carried out by earlier workers. The deep marine depositional environment varies along time and space as the basin is evolved to the current shallow water shelf environment. The depositional analysis is divided into three parts depending on the age of the strata.

Miocene

Middle Miocene sequence shows presence of deep marine channel levee complex [Fig 4] with clearly defined meandering channels features. The sinuosity of the channels indicates gentle slope of the drainage area. The majority of the channels flow from NE to SW, emerging from the shelf.

Late Miocene sequence exhibits increased sediment supply characterized by turbidity fan system [Fig 5], with overlying channels filled up with fine clastics represented by low seismic amplitudes. These sediments slumped to the basin floor from the shelf regions to develop slump geometry within the basin floor fan.

Outcrop studies from the adjacent onshore areas shows presence of thick sandstones with intercalating clay/shale in Middle and Early Miocene. Palaeo- Rivers flowing through these terrains are most likely to carry these reservoir sands towards the sea to the current study areas where sediment fans are interpreted to be formed at the base of the slopes. Small scale channels flowed over these fans resulting in low seismic amplitude channel fills.

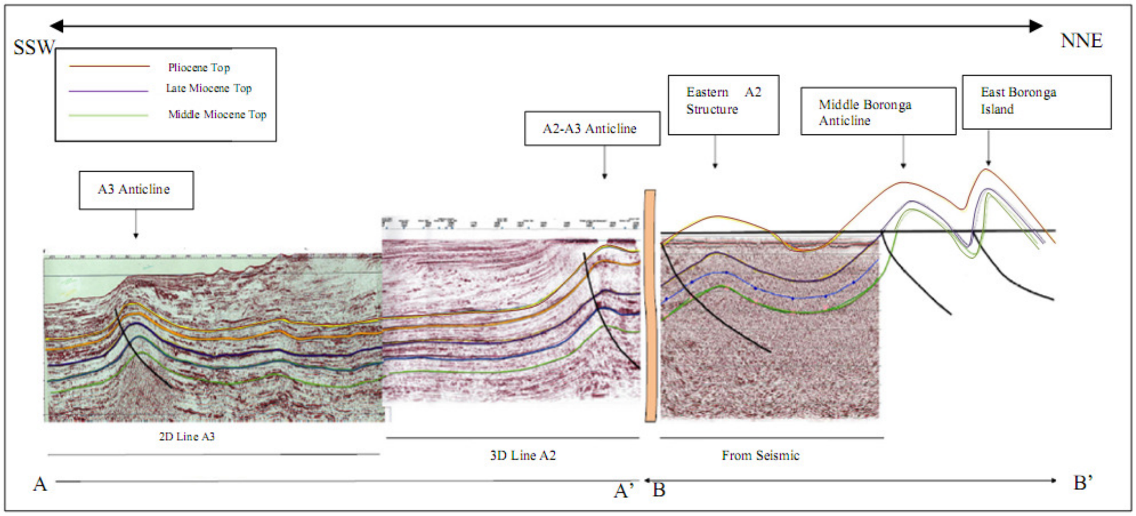

Fig 3: Surface to subsurface correlation showing reducing structural Deformation as indicated by gentler anticline and wider synclines towards SSW direction.

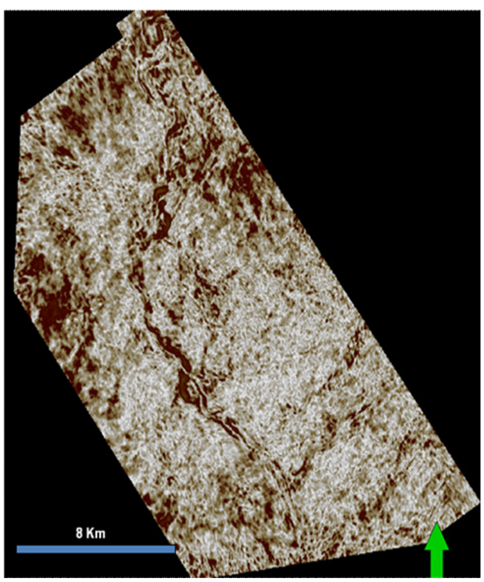

Fig 4**:** RMS Attribute showing Deep Marine Channel levee Complex during Middle Miocene

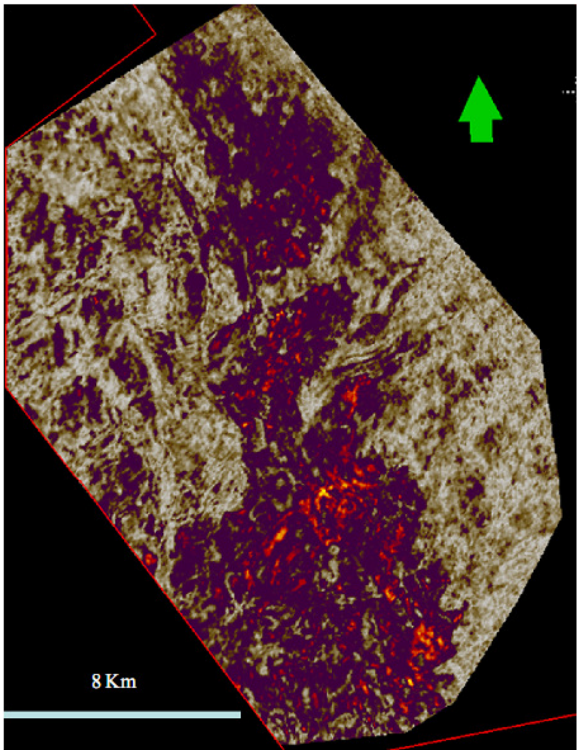

Fig 5: RMS Stratal Slice showing Deep Marine turbidity fan deposits during Late Miocene

Pliocene:

Pliocene sequence deposits show deep marine channel complex with meandering channels with high sinuosity and ox-bow features. The predominant direction of sediment influx is from NNE-SSW. Numerous channels are present often amalgamating into each other. The channels often terminate into elongated fan lobes.

Most of the Early Pliocene is dominated by turbidity fans, with less sinuous channels [Fig 6], which depicts the higher slope which assisted the high energy gravity condition. Apart from fan deposit, Early Pliocene usually consists of fine clastic, which were deposited after a turbidity event or during the times when water was relatively calm to allow fine sediments to settle down.

Middle Pliocene strata dominantly exhibits laterally amalgamated channel features [Fig 6 &7]. These channels form a broad sheet like geometry from where signatures of any individual flows are very difficult to resolve from seismic. They represent moderate slope gradient where sudden gravity flow is difficult but the slope gradient is enough to allow gravity streams to flow with coarse clastic. Middle Miocene channel features also indicate equilibrated system between slope and channels and hence no aggradations features are likely to be developed.

During Late Pliocene, the system became still more gently sloped and gravity affects are reduced, resulting in formation of numerous meandering channel features [Fig 6] which are clearly visible on seismic stratal slices. These channels have well defined geometry with high seismic amplitude clastic deposits and are highly sinuous. Some channels terminate into small fan lobes while others move further towards deeper basinal part.

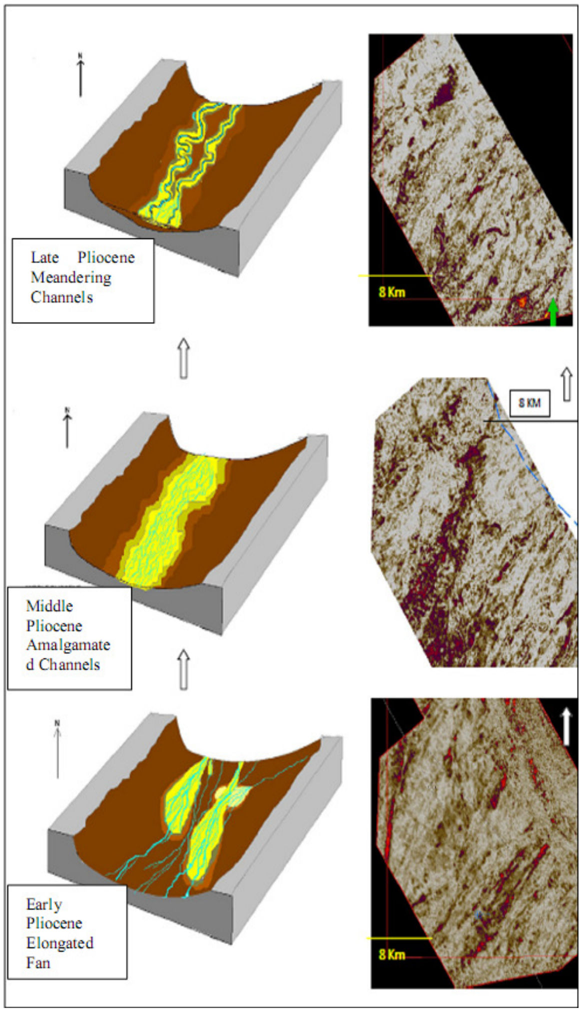

Fig 6: Conceptual model of depositional environment of the Pliocene and supporting seismic attribute maps show the evolution of depositional process of Pliocene sequence from high gradient straight channel flow through amalgamated channels to meandering flow indicating lesser slope gradient.

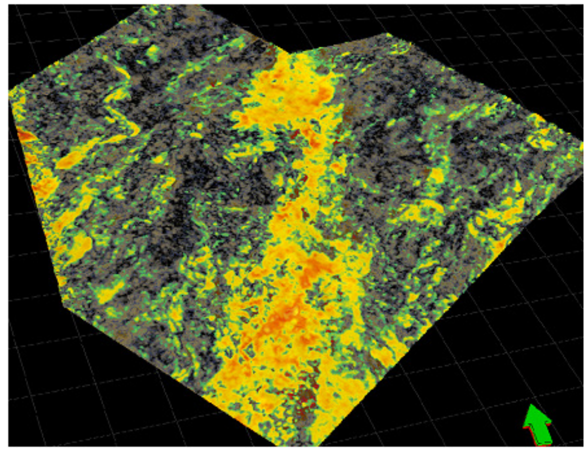

Fig 7: Amalgamated/ Braided channel in Middle Pliocene

Pleistocene

Early Pleistocene in the study area shows typical deep marine depositional environment. Huge sediment influx coupled with relative base level fall caused deep gorges and Incised Valley Fills (IVF) in the shelf with some of them extending to the deep basinal part. Sediments carried by fluvial channels on the shelf moved through these canyons to deep basinal part. High flow condition within these canyons causes them to be devoid of coarser sediments. However at early stages of development of these canyons a few channels were mapped which are expected to hold coarser clastics [Fig 9a]. These canyons were later filled up with fine clastics deposited as a result of high tides. This was followed by sea level rise showing transgression with shoreline again moving NE (Fig: 8). Finally the last set of progradation is evident which continues and defines the present day shoreline. During these times another set of deep sea canyons were developed.

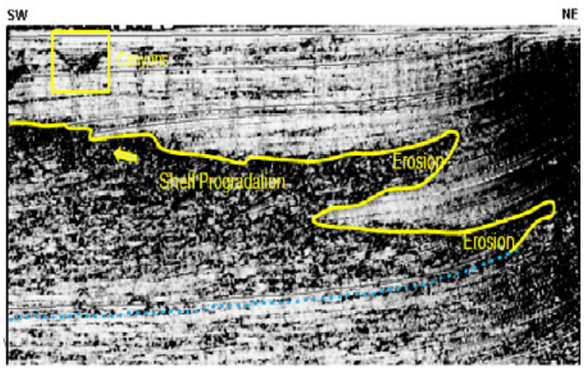

Fig 8: Cyclic transgression and regression of Pleistocene shelf.

Late Pleistocene shelf is wide having gentle slope, consisting of meandering channels, and lobate delta [Fig 9b]. Channels mapped are sub parallel to the self break. Progradation of prodelta facies during regressive cycle brought sediments to canyon mouth which then bypassed through the feeder canyons to deep basinal part. Paralic environment during late Pleistocene [*Reynolds 2005*] was established by occurrence of coal with coarser clastics found during drilling campaign.

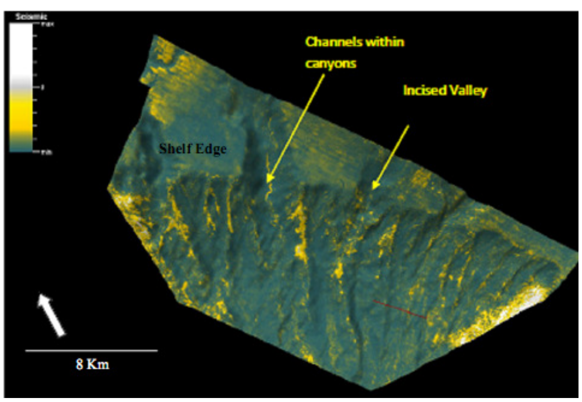

Fig 9a: Early Pleistocene IVF with meandering channels. These deep gorges developed due to extensive down-cutting by sediment laden gravity flows.

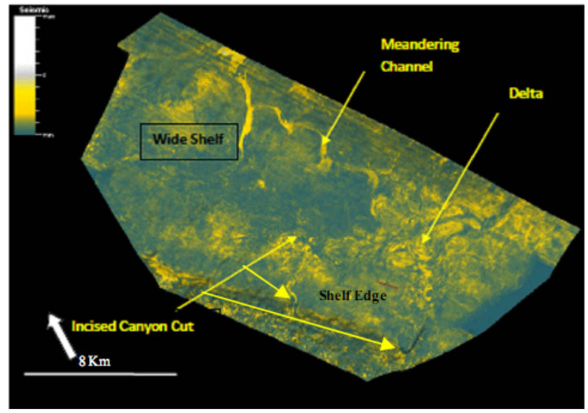

Fig 9b: Late Pleistocene shelf with delta system and meandering channels. Pro-delta region is breached and sediment had flowed through small IVF towards basinal side.

Conclusion

The tectonic and depositional environment study was carried out to have an idea on the facies distribution and also to have an understanding of the geological evolution of the area. Although further work is necessary, this work provides important exploration inputs and provides a base for future exploration. The conclusion that follows is important for hydrocarbon prospect analysis.

The study area lies on active accretionary prism as an interwedge basin. Though the basin was affected by massive thrusting and folding, the study area lies in relatively less deformed part. Structural deformations of the study area were started during Late Pleistocene with formation of a series of thrust related anticlines.

Sediment supply in the area was largely guided and controlled by shelf geometry and also by anticlinal/ synclinal structures. Current study reveals that during Miocene to Recent time, shelf edge in the study area generally experienced continuous progradation from East to west and from North East to South West. Only during a part of the Pleistocene, transgression of sea towards land is interpreted wherein a few incised valleys on the shelf area are interpreted. The sediment deposition during Miocene-Pliocene is dominated by presence of numerous meandering deep water channel levee fan complex. The deep water gravity driven channels are generally filled with sediment transported from nearby uplifted highs and land areas. Out crop studies and existing well data in the study area suggest presence of good quality reservoir facies.

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