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Mass-tranport complexes in deep water of Andaman Forearc Basin

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Summary

Mass-transport complexes (MTCs) form a significant component of the stratigraphic record in ancient and modern deep-water basins worldwide. One such basin, is the forearc basin of Andaman, situated along the obliquely converging boundary of the Indian plate and Burmese plate and is characterized by active tectonics and possible migration and sequestration of hydrocarbons. Major structural elements found in the forearc basin include transpressional faults (i.e., Diligient Fault and Eastern Margin fault) and anticlinal structures (result of basin inversion) overlain by extrusive sea-floor mud volcanoes. The interpretation of a 3D seismic survey in the study area enabled mapping of several erosional surfaces that form the boundaries of multiple mass transport complexes. The data show multiple episodes of MTC developments, which are characterized by chaotic, mounded seismic facies and fan like geometry. Their extent and thickness is strongly influenced by the sea floor topography. Individual mass transport deposits (MTDs) show long runout distances from the source area. The depositional architecture identified within these units includes i) large-magnitude lateral erosional edges, ii) linear basal scours and iii) side-wall failures. In the study area of Andaman Forearc, two major MTCs are observed which are separated by finer clastics, deposited in a shallow marine environment and are classified as "Detached MTCs".

Introduction

The Andaman Basin is located in the north eastern Indian Ocean around Andaman-Nicobar chain of islands. This island chain and the basin is a part of large geotectonic unit that extends from Sumatra (Indonesian) Islands in the south to Myanmar (Burma) in the north, associated with converging plate boundaries between Indian Ocean oceanic plate and west Burmese plate. Major geotectonic units from east to west are back arc, volcanic arc, fore arc, Island arc and fore deep. The basin has more than 5000m of thick sediments ranging in age from Cretaceous to Recent. The Andaman basin evolved through a polyphase, multigenetic tectonic history from Early Cenozoic/Late Mesozoic to Recent. The Andaman- Nicobar basin was initiated with northward drift of Indian Plate with respect to Asia. The collision of Indian/Eurasian plates initiated along the irregular boundary and occurred at the same time as the oceanic subduction beneath the southern Eurasia. The so called "soft collision" of the Indian plate with the Burmese plate took place around 59Ma and since then till 55Ma Indian plate underwent anticlockwise rotation of about 20° resulting in complete closure of the suture zone. During this time and till 44Ma Indian plate was indenting the Asian margin and rotating the subduction zone in a clockwise direction. With this rotation the direction of convergence became increasingly more oblique. As subduction progressed, with the consumption of the oceanic plate by under- thrusting along the Bennioff zone, the overlying deep water pelagic sediments and part of Eurasian crust accreted as north-south trending prisms by the process of reverse faulting, thrusting and folding. This resulted into the formation of early arc basin, which accommodated pelagic, turbiditiesand locally generated MTDs forming MTCs due to relative base level changes. These sedimentary successions constitute different major sequences. Paleo bathymetry data shows progressive shallowing of sea during Paleogene and major uplift at the end of Late Oligocene resulting in emergence of Andaman- Nicobar chain of Islands. Further, rise of volcanic arc in east created a fore arc ponded low, which accommodated thick Neogene sediments.

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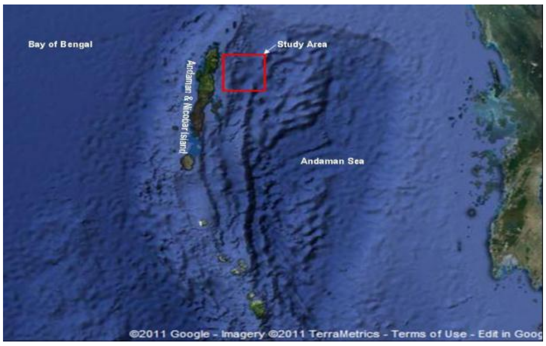

Fig1: Location map and area of study in Andaman- Nicobar Island (from Google Maps).

Regional Tectonic Setup and Basin Evolution

Among the major tectonic elements of the Andaman Basin, the ***ForeArc Basin (Ponded fill)*** is an important tectonic element which lies between the Outer High in the west and Volcanic Arc in the east. The western margin of the Forearc basin is down faulted with a large vertical throw against a major fault traceable all along the eastern margin of the high and mapped as Eastern Margin Fault (EMF) indicating this margin as steeper and may have been the source of most sediments (EMF; Roy 1983). However, the dividing line between the outer arc ridge and the Forearc Basin is the Diligent fault (DF) in the central and the northern parts of the basin (Curray, 2005). Invisible bank is another important geo-tectonic feature that lies at the eastern part of the basin. Earlier studies have shown that EMF and DF (Diligent Fault) exhibit normal faulting and also some dextral strike- slip motion at places, in the past as well as in the present. A pronounced unconformity at the Paleogene- Neogene boundary is seen on seismic data all over the Forearc region. In the Forearc Basin, sediments in the Paleogene and Neogene section show extreme variations. The Forearc Basin is composed of various compartments and, sediments in these compartments have been deposited under different environments due to relative base level changes and underwent different tectonic deformational regimes. Since, the present study area falls within the Forearc part of Andaman Basin, it is important to investigate the nature and type of basement and the overlying sedimentary fill.

During the subduction, the Burmese plate was over riding the Indian oceanic plate and the so called accretionary prism phase (Upper Cretaceous to Oligocene) initiated in the area and in the process thin crust of oceanic and /or transitional character got trapped between the arc and the trench/ subduction complex. This phase is characterized by thrusting towards the trench side and bit of extensional faulting (not very conspicuous on seismic) towards volcanic front side which eventually led to formation of outer arc close to Oligocene. The thick sediments between Basement and Oligocene top are mainly clastics of Late Cretaceous to Paleogene age and may also contain offshore ophiolites. Going by the forearc basins classification of Dickinson etal; 1979 (based on the nature of the substratum beneath the basin) and the basement features observed in the study area, the Andaman Forearc basin can be classified mainly as "residual basin", with some features that resemble constructed basin too. However, as observed in nature and also in Andaman region, having a broad Forearc basin is indicative of the fact that this basin is a composite of the above mentioned two basin types. In Andaman, the Forearc basin initiated as residual basin and evolved into a broad composite basin with younger sediments onlapping the arc massif (Invisible bank part) on one flank and the subduction complex on the other (Fig2).

In the forearc phase, most of the sediments were trapped in the arc-trench gap. This phase has been divided into two stages, i.e., ponded fill stage (Miocene) and sag fill stage (Post-Miocene) based on the existence of a major unconformity at top of Miocene. Ponded fill stage is characterized by basin inversion tectonic events during Early Miocene and it dominantly consists of sediments derived from MTDs and mudflows forming multiple MTCs that took place due to frequent base level changes in the area. This was followed by aquiescent period when sedimentation in shallow water had taken place. The Compressional event continued till the close of Miocene leading to the formation of inverted structure at the middle of the study area. The post lower middle Miocene sediments are mainly clastics. Post Miocene the area had undergone passive filling in Sag fill stage (2 to 3 episodes), depositing mainly Pelagites.

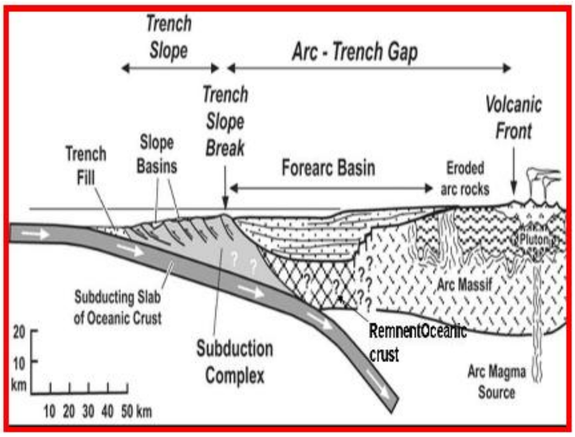

Fig2: Generalized Forearc model.

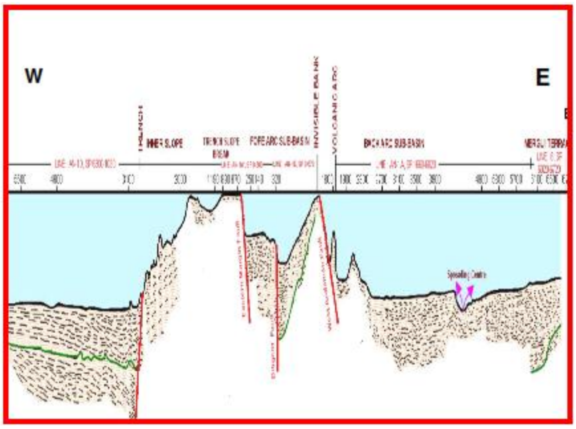

Fig3: A Geological Section across the Andaman-Nicobar Basin (E-W direction)(Source: DGH website)

Present Study

The present study aims to bring out in detail the observed character and architecture of the multiple MTDs that form the depositional sequence of MTCs vis-à-vis the processes involved in their deposition in deep water of Andaman forearc basin. The primary tool for study of the deep water deposits in Andaman offshore is 3D seismic data through a range of visualization and attribute analysis technique, that helps in identifying the internal architecture of the MTCs. MTCs (slides, slumps and debris flow) together constitute quite a significant component of the deep water sediments of Andaman Fore arc.

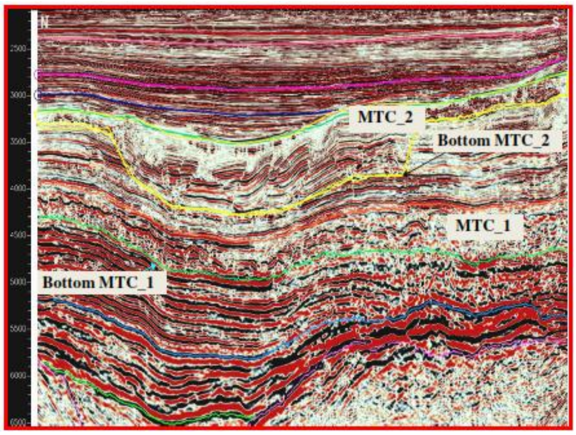

Fig4: N-S seismic line showing presence of two big MTC sequence within the study area separated by finer clastics deposit.

In the study area two distinct MTC sequences (MTC_1and MTC_2) are present that are separated by deep water finer clastics (Fig4). In seismic sections, MTCs are recognizable by the presence of seismic facies that show low- amplitude, semitransparent, chaotic reflections (Posamentier & Kolla, 2003). However, the internal architecture may consist of regions of semi-deformed mixtures of low and high amplitude reflections indicative of syndepositional thrust and imbricate geometries (Moscardelli etal., 2006) (Fig4 and Fig5). Here, the upper and lower boundaries marked by high amplitude seismic

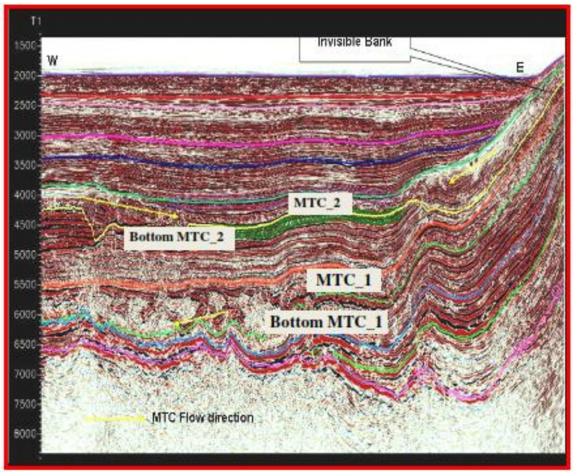

Fig5: E-W line showing two MTC sequence and their flow direction (yellow arrow).

reflections (Fig5). The lower boundary often shows a variety of erosional surfaces of which the larger ones are referred to as megascours (Moscardelli etal., 2006) as they are quite deep and have wide aereal extent, often in terms of kms. The MTC_2 is made up of slump and debris flow while the MTC_1 is mainly of debris flow, as evident from their internal architecture. Both the MTCs show megascours at their base as well as syndepositional thrusts at the terminal end of the slump/debris lobe indicative of compressional regime associated with deceleration of the flow. The RMS amplitude extracted from different seismic time intervals within the sequences suggest that these flows are dominantly sourced from Invisible bank side of the forearc basin but a significant amount is also contributed from the accretionary prism side due to tectonic movement along the DF and EMF fault planes (Fig6).

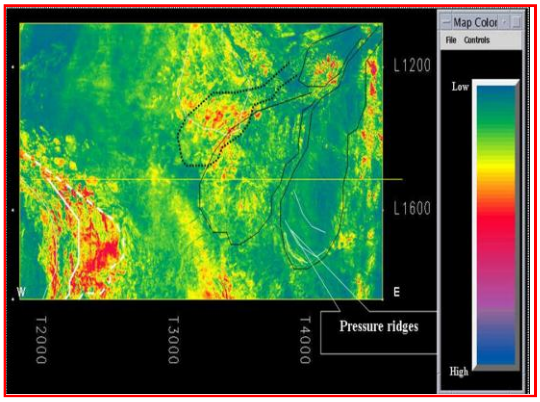

Fig6: RMS attribute map showing flow direction and multiple episode of flow of MTC and associated pressure ridges.

Features like pressure ridges, erosional edges, side wall failures and episodic flow of MTCs are also evident from the RMS amplitude maps. The attribute map also suggests that MTCs are of finer clastics (muddy in nature??) though presence of some volcano-clastics derived from the Invisible bank at eastern margin of the basin is not ruled out.

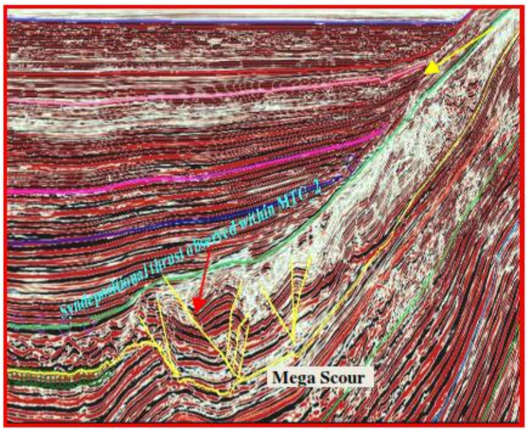

Fig7: The slump, part of the MTC shows compressive syndepositional thrust feature and mega scour at the bottom.

Based on the observations from seismic data and amplitude maps, a conceptual depositional model for these MTCs is proposed here (Fig8).

It is envisaged that these two MTCs were composed of different MTDs that had their origin in the eastern margin of the basin, most likely derived from the Invisible Bank part though few had their origin in the western side too. Since, Invisible bank had an episodic upliftment history with steepening slope dipping towards west; it was easy for the slump and debris flow to originate with change in slope and fluctuation in sea level. Also, this logic holds true for the western side of the basin, in addition to the structural disturbances that have happened along the two major faults EMF and DF. These two MTCs also have a good aereal extent.

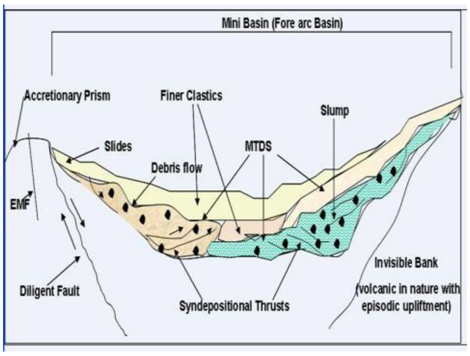

Fig8: Conceptual model for deposition of MTCs in deep water of Andaman Forearc Basin. The model indicates a detached MTC whose genesis is associated with over steepening of one of the margin of the mini basin.

Conclusions

Two major MTCs observed in the study area are separated by finer clastics deposited in a shallow marine environment. Based upon the criterion of new classification of MTCs proposed by Moscardelli etal.,(2007) the MTCs in Forearc basin of Andaman fall in the group of " Detached MTCs" . The causal mechanisms for these MTCs are unstable margins of this forearc basin, collapsed flanks/ gravitational instability of the flanks and over-steepening of one of the margin of the basin (Invisible Bank). These MTCs are smaller; they occupy tens of square kilometres area and their source is confined within the margins of the forearc basin. In this basin these systems are triggered mainly by local gravitational instabilities associated with seismicity, volcano reactivation, and over- steepening of slopes.

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