Sedimentary facies and Penecontemporaneous deformation features in Andaman Flysch at South point, South Andaman Island and their implications for Depositional Environment.

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Abstract

The Andaman island arc, a part of the Burma Java subduction complex, comprises marine sequences ranging from Late Cretaceous to Recent. These rocks are exposed in the Andaman Nicobar Island chain which is an uplifted subduction complex. Within these exposures, a Palaeogene siliciclastic marine sequence, the Andaman Flysch, has drawn attention of Petroleum Geologists and sedimentologists as a good reservoir section for hydrocarbon exploration and because of their intriguing nature of deposition.

The sediments of the Andaman Flysch has been studied bed by bed for their sedimentary structures and described in detail at South point section in South Andaman Islands. The sedimentary structures along with sedimentary facies and geometry, points out deposition in a deep water realm .The ramifications of realising the facies and depositional system of the flysch lies in predicting reservoirs in the Forearc section for hydrocarbon exploration.

Seven sedimentary facies have been recognised in the south point section viz, massive sandstone, sandstone with clasts, contorted sandstone, plane laminated sand shale intercalations, ripple laminated sand shale intercalations, contorted sand shale and contorted shale. Associated sedimentary structures like planar laminae ripple and cross laminae, contorted beds, flame structures, flute marks, prod and groove marks, burrows have aided in identifying gravity flow processes, particularly debris flows in greater part of the section.

Athough cyclicity in form of fining upwards cycles of sand to shale have been observed, yet vertical stacking of clear sand rich and mud rich intervals reveal a channel and levee system for the Andaman flysch at South Point, South Andamans.

Introduction:

The Andaman Islands, represents an uplifted subduction complex in the Sunda arc trench system. The Andaman Island Arc along with the islands came into existence due to anticlockwise rotation of the Indian plate and its subduction beneath the Eurasian plate. The major tectonic elements have been described from West to east as: outer arc, Andaman trench, accretionary prism, trench slope break or structural high, forearc, volcanic arc and back arc with a spreading centre (Roy1982, 1992; Curray, 2005). The Islands are a part of the trench slope break. The sedimentary pile in the Islands and the adjacent fore arc basin comprises marine Late Cretaceous to Recent sediments overlying an Ophiolitic Melange basement (Roy,1992,1993).Within the sedimentary section, the Palaeogene section is clastic prone while the Neogene section is carbonate prone (Roy, 1982).

The upper part of the Paleogene section, the Andaman Flysch, is around 3 km thick on the Islands and in the fore arc (Chakraborty and Pal, 2001; Mukhopadhay et al., 2003). Chakraborty and Pal (2001) in their detailed facies analysis of the Oligocene Andaman Flysch Group in North and South Andaman Islands identified fourteen facies and termed them as inner fan and depositional lobe in the middle fan of a submarine fan system. They used the Bouma divisions to classify the facies. Mukhopadhay et al. (2003), studied similar sections as Ckaraborty and Pal (2001), and looked into facies clustering involving Hurst statistics. They felt that cyclicity was not there in the Andaman Flysch facies associations.

The Andaman Flysch onlaps into the underlying Mithakari Group (conglomerate and coarse clastics) and is overlain by the Tertiary Neogene sediments with an intervening unconformity. In the South Andamans, the Andaman Flysch has been observed directly onlapping into Cretaceous Ophiolitic Melange basement in Corbyns Cove bend, South Andamans. In this exercise, the upper part of the Palaeogene section, the Andaman Flysch, has been subjected to process sedimentology at a 250 m-thick good exposure in South Point section in South Andaman Islands. The sedimentary succession is an overturned section with near-vertical dips as observed from sedimentary structures in the beds. Detailed bed by bed observations have been carried out in conjunction with study of sedimentary structures, bed geometry and sedimentary facies. Detailed observations have led to demarcation of sedimentary facies and the associated structures within them. These observations have been collated to imply the impending depositional environment. Seven sedimentary facies distributed over 250 m in South Point section, have been identified:

i. Massive sandstone
ii. Sandstone with floating clasts
iii. Contorted sand
iv. Plane laminated sand shale intercalations
v. Ripple laminated sand shale intercalations
vi. Contorted sand shale
vii. Contorted shale

Most of the sedimentary structures appear to be products of various subaqueous density flows and processes associated with transport and associated deposition of sediments. A series of primary and secondary sedimentary structures have been observed in the above facies which help in deciphering the depositional environment. The primary sedimentary structures include planer laminae, ripple laminae, convolute laminae, outsized clasts in sand stone, flute marks, prod marks, in wave base, concretions and cross bedding. Secondary sedimentary structures include Dewatering structures like flames and load casts, burrows and discordant beds / dykes cutting pre existing beds.

Sedimentary facies

The seven sedimentary facies distributed over the South point section in South Andaman Island have a distinct pattern in vertical distribution.

Massive sandstone: These are essentially very fine- to fine-grained, occasionally medium-grained, light grey to khaki well-sorted sandstones. They have a thickness range of 30 cm to 6-7 m with an average thickness of 1-2 m. The beds pinch out laterally or show variations in thickness. The grading is normal/reverse. Dish structures and pipes have been observed in few sand units with thin mud concentrations. They have an undulating basal contact with underlying shale. The lower contact is often spread with flute marks (5-10 cms along long axis), groove marks and prod marks. This has been attributed to bottom currents at start of deposition of these sand stone beds. The upper contact usually with sand – shale intercalation is gradational. Some beds have planer laminae. In addition, striations parallel to the bedding plane and impacting the floating clasts is intriguing and could be surmised happening due to the sliding of beds. However, closer examination reveals that they could also be visualised as planer laminae passing through the so called clasts, the latter basically being concretions within the massive sand stone. The bed bases, marked by undulations are due to flute marks and indicative of bottom currents at commencement of deposition of this massive sandstone. Rest of the bed is affected by laminar flow conditions and are inferred to be typically products of sandy debris flow.

Sandstone with floating clasts: The description of this unit is very similar to that of massive sandstone with the additional component of having clasts of various shapes, sizes, orientations and mud balls. The clasts are either rounded or platy. The rounded clasts range in sizes from cm to 30 by 50 cms.The elongated clasts are usually oriented parallel to the bedding plane and are often a few to 30 cm along the long axis. The clasts are made of sandstone as well with a bias of ultra mafic or dark constituents and are extremely hard. The clasts are fine- to medium-grained and moderately sorted. The rounded clasts show a random to oriented disposition along the bedding plane. Their concentration within a sandstone bed varies from a few scattered ones to moderate distribution. The planer clasts are few cms in width and occur in several ways. It could either occur as parallel clasts close to the base or top of the bed, or at top and base of bed, or at three rows at top, centre and bottom of bed or as two closely spaced parallel rows at centre of the bed. Striations passing over the clasts parallel to the bedding plane are note worthy. The sand stone beds have planer laminations. In addition, striations parallel to the bedding plane impacting the tops of floating clasts is intriguing and is surmised to be due to sliding of the beds. The variety in shapes and sizes of sand clasts are indicative of a flow having a strength or capacity to maintain it during transportation and deposition, in spite of having similar density as the bed rock. The clast orientation with long axis oriented parallel to the bedding plane can be used to infer laminar flow conditions, a common condition of debris flow.

Contorted sand: Only a few beds have been observed in the entire South Point section. Sigmoidal imbricate slices or duplex structures occur in the unit. The bed sizes are usually less than one metre. The sand shale alternation unit just above and adjacent to these units have opposite imbricate slices with respect to the contorted sand and have dips of 25-40degrees.This has been attributed to sedimentary slumping.

Plane Laminated and Rippled Sand/Shale: Cross-stratifications and moving ripple laminae alternating with plane laminations, characterize this unit. Each unit comprise alternate silt (light coloured) and shale (dark coloured) layers, which exhibits all variations from plane parallel to gentle ripple laminated to pronounced wave ripple laminated. Each shale unit is 5-10 cms in thickness and each silt unit varies from 8-20 cms. Several amalgamated units comprise the facies. This unit shows a gradational relationship with the overlying shale and underlying sandstone unit. Some ripples are draped with mud layers with fluctuating energy conditions. Bottom current reworking is observed in a few beds. Many of the units particularly in the lower part of the exposure are mildly to heavily bioturbated with both vertical and horizontal burrows.

Contorted sand shale intercalations: Some of the fine grained sand to silt and shale alterations exhibits slump structures with sand being contorted and floating as clasts in shale and vice versa. Flame structures, distorted and contorted are also commonly observed. Each shale or silt unit varies between 5-20cms in thickness, 8cms being the average. An amalgamation of several sand silt make up one facies unit. There is agradational contact with the overlying shale and underlying sandstone unit. Dish and pillar structures are common. So is load casts. Duplex structures attributed to tectonic deformation of lithified units of this facies and the underlying massive sandstone facies is observed in some places.The origin of this facies is attributed to sedimentary slumping. Heterolithic slumps in the muddy system are conspicuous.

Contorted Shale: Dark laminated shales, sometimes carrying floating clasts of sandstones, due to liquefaction is observed. Each contortion of the bed with a degree of acute flames to contorted bedding is suggestive of syn-sedimentary deformation. This facies represents “true debrites”. Such debrites with large clasts are termed as Olistostromes (Sanmugam, 2005). The size of the beds varies from few cms to 1 metre.

Laminated Shale: Black plane laminated shales, with occasional floating clasts are attributed to true debrites happening due to suspension settling. The shale as are pelagic to hemipelagic with thickness ranging from 10cms -2.5 metres. The maximum thicknesses of the shales are of the order of 6-8 metres.

Sedimentary Cycles and discussion: First and foremost, it has been observed in the South Point section, there is a clear cyclicity of fining upwards Sandstone, sandstone shale intercalations and shale cycles. Most cases however, involve the first two, and the cycles ranges from 50cms to usually 2.5 metres. However thick sand beds of 2m - 8 metres often vertically stacked together have also been observed. The second aspect is the facies association identified in this paper, clearly is involving sub aqueous density and gravity flows, suggestive of sandy debrites and classic debrites in shale. Oriented clasts in sandstone suggesting laminar flow, typical of debris flows and bottom current reworking at the base of sandstone beds are characteristic. Some highly contorted beds overlain and underlain by beds with no contortions is suggestive of tectonic overprinting in the former beds through earthquakes or tsunamis. No Bouma sequence could be identified in the South point section. Application of Bouma sequence to Andaman Flysch would mean a forced effort to call beds as Bouma units.

The south point section is sand prone in the upper and lower parts and is more shaly in the central part of the section. The lower sandstone units are clast prone while the upper ones have massive sandstone beds suggestive of stronger gravity flow processes in the former.

Striations parallel to the bedding plane in sand beds could imply slides. However, some clasts within the sand stones, parallel to bedding planes having planer laminae passing through them be termed as iron concretions. Major 6m shale in the section has been used in correlating beds in the area.

Conclusions:

The south point section of Andaman flysch is clearly a product of gravity flows. Seven sedimentary facies with associated sedimentary structures promote a case of subaqueous flows with strong indications of debris flows. Vertical stacking of sand rich and clay rich intervals in the section with associated facies and fining upward cycles is suggestive of channel and levee deposits in a deep water realm.

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