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Influence of Mass Transport Deposits over Paleo-Topography and Sediment Dispersal Pattern: A Case Stuydy Using Shallow Seismic Data, Offshore Krishna-Godavari Basin

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Summary

Few Mass transport deposits (MTDs) or Mass transport complexes (MTCs) are identified in the deepwater, Krishna-godavari basin using near surface 3D seismic data set. The study aims at identifying mass transport complexes and their influence of paleo-topography. The area has been divided to into three regions namely, proximal, central and distal part. An effort to characterize the MTC in all the above three regions is being tried out in the study. Various features like striations, scour marks identified on the basal surface of the MTD suggests the highly erosional activity. This erosion leads to formation of various erosional remnants which can act as isolated reservoirs. The top surface of MTD is characterized by presence of set of normal as well as low angle imbricate thrust faults. These thrust faults resulted due to freezing of MTDs cause irregular topographic features on the top surface. Any sediment deposition on the top surface is controlled by this irregular topography. Sediment dispersal pattern identified from rms amplitude shows that the sediment fills the topography lows generated due to thrust faulting.

Introduction

Mass transport deposits (MTDs) or Mass transport complexes (MTCs) are reported to form a large portion of deepwater deposits (Beaubouef and Friedmann, 2000; Winker and Booth, 2000; Anderson et al., 2003; Armentrout, 2003). These include sediment deposits by slides, slumps, debris flows. A significant mass transport deposit, characterized by transparent to chaotic seismic reflectors lying below the water bottom is interpreted in the deep water region of Krishna-Godavari basin. The study area lies on the outer slope to abyssal plain with the bathymetry varying from 200 to 3100 m. This study aims at describing various aspects of sediment dispersal pattern which are controlled by mass movement. A seismic section passing through the three defined zones i.e. proximal, central and distal part is shown in figure 39. A mass transport complex lying below the water bottom is studied in the following section to understand the sedimentation pattern in affected by mass movement. The profile runs from NW to SE direction. a number of mud flow or mass transport complexes are seen in the section , but the thickest one is described in the study.

This feature could be seen through out the 3D seismic data set and is having a large area of extent. Closely spaced 3D seismic data set are used for the study. Integration of three 3D seismic surveys is done so that we can have the picture of a MTC from point of origin to deeper waters (Fig.1).A representative seismic section connecting the shallow to deep bathymetry is shown in figure 2. The above transparent section is bound by two surfaces present on top and bottom. These horizons namely top and base are interpreted throughout the area .Time structure maps and different attribute maps are calculated along these surfaces for analysis. Only a few RMS amplitude maps are produced in this article for discussion.

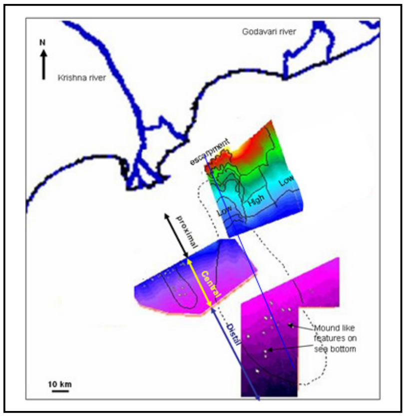

Figure 1: Location map with bathymetry maps .interpreted from 3D seismic data set .Black dotted line indicates extent of mass transport deposit interprered from 2D seismic. Blue line represents the regional sesismic section used in the figure 2.Red-low value,Black-high value

Movement of Mass transport complexes affect topography of both the base and top surface. While prominent erosion activity occurs at the basal surface, the top surface is characterized by presence of numerous faults (which may be normal or thrust).These faulting activity actually controls the geometry of the top surface. The authors would like to divide mtc features identified into three zones namely proximal, central and distal (Fig.1).As can be seen from the figure the proximal zone refers to the initial part characterized by a number of canyons, while the central part is having flat bathymetry with no significant featres, lastly the distal part comprises of a rouged sea bottom with a number of low relief topographic high features.

Bathymetry Analysis:

Detail analyses of bathymetry map of the three regions are presented in figure 3a. 3D visualization of bathymetry map for the individual region gives imprints of mass movement in the area.

Proximal part: The shallower section or the initial part shows well developed canyons. The area is present on the upper slope regime .a number of slump scars can be identified from the bathymetry map. Figure 3a shows a detailed bathymetry of the proximal part of the mass transport deposit. Bathymetry in this region vary from 250m to 2200 m. a number of slope canyons are identified which act as the conduits for sediment dispersal into the deep water. It can be seen from the figure that there are two prominent lows present on the flanks of a topographic high. All the erosional activities and slump failures are constrained to these lows. As can be seen from the regional seismic section (Fig.2) all the faults in the initial part are normal faults .So these are faults are actually related to the slumping activity.

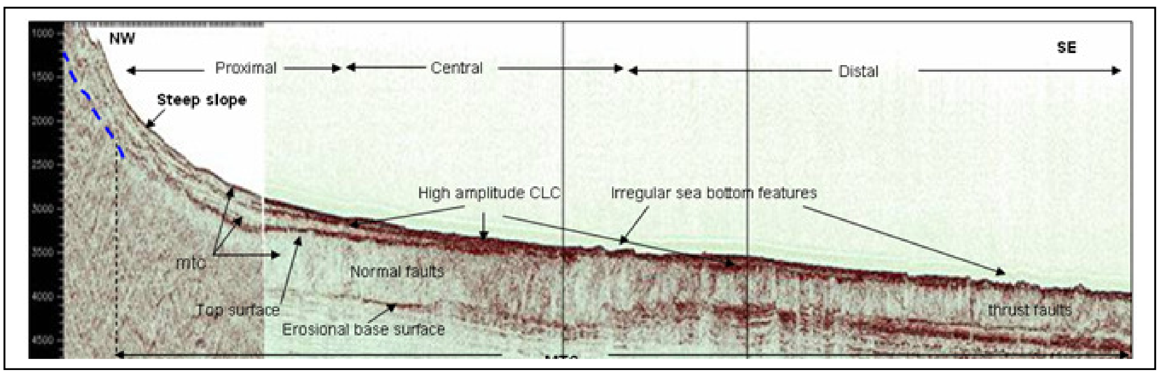

Figure 2: An arbitrary seismic section connecting the shallow to deep water .Presence of thick MTC can be seen through out the area. On the SE part the MTC is seen to affect present day water bottom.

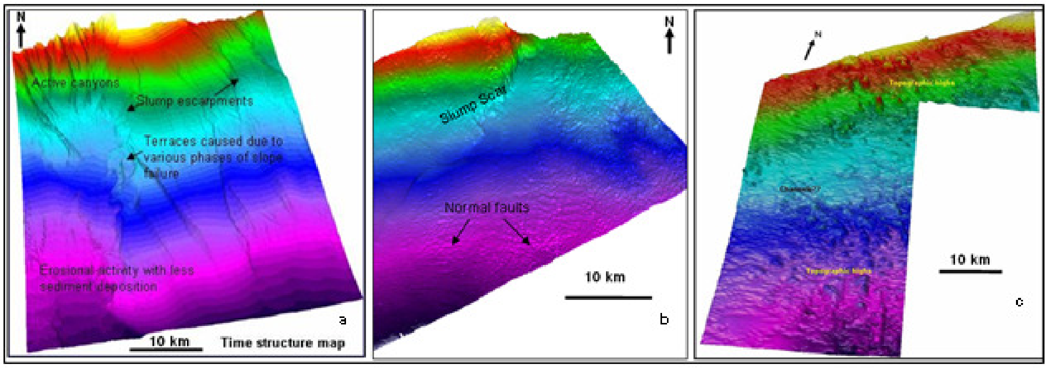

Figure3: Detailed bathymetry map for the Proximal (a),central (b) and distal part (c).Active erosional features can be seen on the proximal and distal part while distal part is characterized by topographic highs generated due to low angle thrust faults. Color scales are different for all the maps where Red represents low values,black represents high values.

Central Part: The central part of the flow also shown in the map shows more of erosional activity and distortion (Fig.3b).No definite fault trends could be identified in the region. Water depth in the region varies from 2200 to 2600m

Distal Part: A detailed 3D visualization of the present day bathymetry map of the distal area is shown in figure 3c.The Map shows almost a flat bathymetry (2600 to 2800 m) with no active canyon or erosional features. But a set of interesting features could be seen in on the map. These are a number of mounds like features standing out of the bathymetry map. These features characterized by high amplitude seismic reflectors and are having varying area of extent. Some of these features are quite small with area of 0.1 sq km while some are having area of one sq km.Height of the features also ranges from few meters to 100 m. Only a few of these features area having height near to 100 m otherwise the average height is near to 10 to 20 m.These features show a distinct alignment.

Mass transport complex affecting older Sediments

Base surface of a mass transport complex is always characterized by extensive erosion (Moscardelli 2006, Posamentier & Kolla 2003). Base surface marked in the area was analyzed to discuss distribution of sediments along the surface. Amplitude extracted along the base of the MTC is presented in the figure 4.

Proximal part: The proximal part shows presence of a number of slump scars running in NW-SE direction. well developed slump scour marks could be identified (Fig. 4a).These huge scour marks dominates this region. A set of normal faults could be seen in the region.

The amplitude map shows slump scars running in the same NW-SE direction This part also shows more erosional features like scar marks.

Central part: Amplitude map shows well defined slump scars referring to major slump failures (Fig 4b). Slide scour marks are also interpreted which suggest erosion due to mass movement in the region. A few high amplitude packs are seen on the map which may be representing the uneroded sediments. It can be summarized that o the region is mostly affected by erosion

Distal part: As can be seen from the amplitude map of the bottom surface a number of striations could be interpreted (Fig 4c).There are a set of striations running in NW-SE direction and seem to fan out into the deep water. These sour marks are characterization features of mass movements. During movements these sediments rich in slump and slide blocks erodes the base causing the marks. In between the striations a number of high amplitude linear bodies are seen , these represents the uneroded or the erosinal remnants. Some of the firm

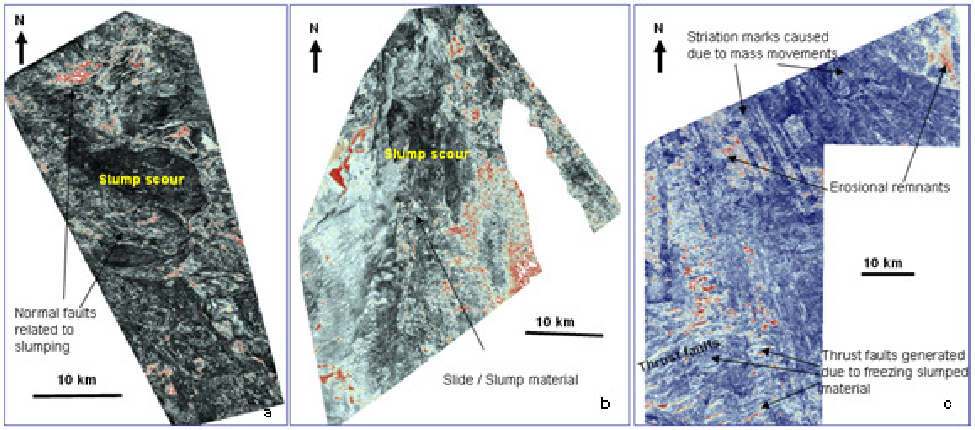

Figure 4: RMS amplitude extracted along the base of the MTC showing erosional imprints. a) Proximal, b) central, c)distal part

lithologies could not be eroded and hence stands out. The mass transport complex moves over these bodies. In the zoom section of the northern area a number of slump bodies could be seen. A close investigation of the southern area shows presence of linear ridge like features running in SW-NE direction.thse are related to the imbricate thrust faults present inside the mud flow. As the mtc moves down the slope at some point of time it freezes and looses its strength to move. Hence at that point the preceding sediments rides over the freezed sediment body causing formation of the thrust faults. Thse faults are one of the most important characters to identify the mass transport complexes and are formed mostly at the distal part of the complex. In the distal part the amplitude map shows well developed striation marks associated with the base of the mtc.These shows the direction of movement of the mtc a set of thrust faults could be identified which refers to the freezing of the sediments.So this zone is characterized by erosion and sediment deposition. Zone wise geomorphic features are summarized below:

Proximal part: slump escarpments, mostly erosion activity, normal faults, less erosional remnants .older sediments are eroded

Central part: slump scars, distotred slump bodies, no defined striation marks, must be a bypass zone for sedimentation. Older sediments are eroded

Distal Part: Straiation marks related to erosion due to mass movement, a set of erosional remnants which represents the older sediments which could not be eroded

Mass transport complex controlling younger Sediment dispersal pattern

One significant interpretation made in the above 3D seismic data set is the sedimentation pattern overlying the mass transport complex. It has been suggested that in a sequence stratigarphic model a mud flow or a mass transport deposit is overlained with channel levee complex (Emery & Myers, 1996, Octavian 2006).

While mass transport deposits are characterized by chaotic, transparent seismic reflectors, the overlying channel levee complexes shows high amplitude reflectors. This relation between mtc and channel levee complex could well be seen in the present study area. It can be seen from the seismic section (Fig. 2), that the zone between the top of mtc and water bottom is filled with high amplitude seismic reflectors. These represent sediments which fill the small basin like structures formed by the fault movements. The upper surface morphology is affected by internal deformation of MTC (Dykstra et al., 2003,Dykstra& Kneller 2002).

Amplitude map on top surface of mtc:

RMS amplitude was extracted between the water bottom and the top of mtc (Fig. 5).This amplitude map represents channel like elements identified from the area. The prominent set of channel like features is seen on the southern portion of the area. A comparison of these three maps brings out the deposition pattern of the channels.

Proximal part: Amplitude extracted along the top surface of the 3D in the proximal part shows impression

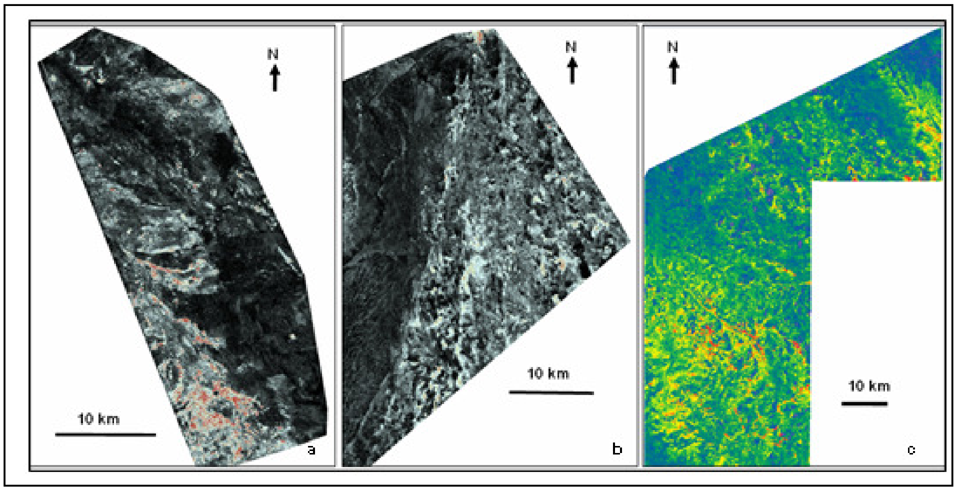

Figure 5: RMS amplitude extracted along top of MTC showing interpreted depositional elements.(red-high amplitude)

of sediment flow from the NW to SE direction (Fig.5a).A set of impressions of normal faults can be seen .Structural lows could be seen between two consecutive faults from the seismic section (Fig. 2). These lows act as mini basins receiving sediments.Hence any channel levee deposits above the mtc will fill these basins generating some isolated deposits. The proximal part is characterized by steep slope; hence sediment bypass is very much active here.

Hence the thicker sediment deposition will be restricted to the lows while other area will receive little sediments.

Central Part: Amplitude map on the central part shows no definite sedimentation pattern (Fig.5b). A number of small scale lows and highs related to normal faults are seen here. If these lows are of much small in relief; isolation of sediment deposition here may not take place. In this figure no definite high amplitude pattern could be idendified.As the central part is present on the toe of the slope region ,ponding of sediment may occur.

Distal part: Amplitude map on top surface for the distal part shows a better picture of sediment dispersal pattern in the younger age (Fig.5c).There present a thick high amplitude pack between the top of the mtc and present day water bottom which relates to the channel levee complex. Amplitude map shows a well defined channel like feature. Figure 6 shows zoomed maps of the distal part.from the seismic section presented here it can be understood how the channels are more confined to the lows .These lows which are having area of extent more than one sq km can behave as separate mini basins.

The topographic lows act as barrier or divider generating a number of isolated depocenters. From the above amplitude map it can be seen that due to presence of these low and high features it is difficult to properly image the channel form. This complexity in the sediment dispersal can be ascribed to the series of thrust faults related to mass movements. Figure 44 presents the isopach map and an amplitude map extracted between the water bottom and top of mtc.In the isopach map the red colour represents thinner sediments while blue and dark pink refers to ticker sediments. From the map a prominent sediment fairway running from NW to SE could be interpreted. On the northern side of the map another fairway is also seen. On this map the impression of circular mound like features (as seen on the bathymetry map) can also be identified. This channelised area corresponds to the zone of thick sediment accumulation shown in isopach map. The channellised systems actually flow in the lows flanking around the topographic highs.

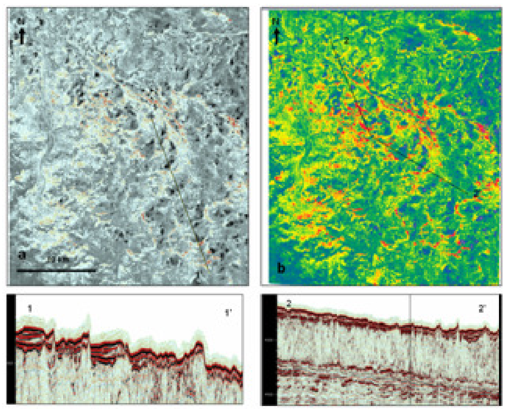

Figure 6: Well defined channel pattern can be seen in the RMS amplitude map (extracted along top surface of MTC).Seismic sections show high amplitude reflectors above on the MTC.

Proximal part: Sediment deposition along the structural lows formed by normal faulting forming few isolated deposits

Central part: Structural lows and high with low relief formed by normal faults.

Distal Part: well defined channels filling up the lows present at the flanks of the topographic highs caused due to thrust faults.

Conclusion:

Emplacement of a mss transport complex affects both the base and top surface. As seen from the study the MTCs are highly erosive in nature. Presence of deep groves suggests the intensity of erosion .In some cases hundreds meters of older sediments are actually eroded. Erosional remnants are surrounded by non reservoirs (sediment transported by MTCs), which can act as seals. So in these cases the remnants may be good prospects to deal with. On the other hand the MTCs may also erode away the previous channel levee deposits which could have acted as good reservoirs. So MTC movement can affect the older sediments to a larger extent. Again the faulting activity associated with the MTC controls the younger sedimentation pattern. From the study it is seen that the faulting (both normal and thrust) creates small lows which can behave as isolated basins. Deposition in the basin will create disconnected isolated reservoir deposits.

The channlelised pattern corresponding to the higher amplitude reflectors lying above MTC follow the path created by alignment of topographic high and low features (generated by thrusting).Some of these lows are hundred meter deep, hence sediment fill in these lows can create isolated reservoir pools. From the study it can be summarized that movement of mass transport complexes affect the already deposit older sediments (by erosion activity) and control deposition of younger sediments (by modifying the top surface topography by normal / thrust faulting).

Acknowledgement

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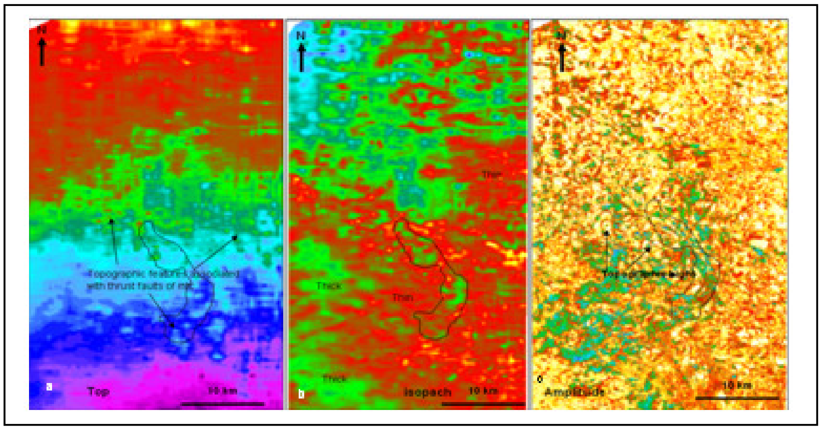

Figure 7: a) Time structure map on MTC top ,b)isopach between MTC top and water bottom,c)RMS amplitude extracted along top surface showing well developed channel pattern (in all the maps :Yellow-low values, magenta-high values)

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