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D.C. Mosher and S. Goss

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Shallow Geohazard Assessment, RepsolYPF block30, Demerara Rise, Offshore Suriname, South America

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EXECUTIVE SUMMARY

The 3D seismic volume from Repsol YPF Block 30 of the Suriname continental margin transits from the shelf to slope environments. The region is a passive continental margin and seismicity is rare. A number of features are identified from the shallow, near surface section that represent potential geohazards or constraints to offshore hydrocarbon development.

1) **Shallow faults** break the seafloor producing clear offsets that correlate across the width of the survey area. Faults provide conduits for overpressured gas and fluids and provide planes of weakness for initiation of mass failures. Faults parallel the shelf break and extend laterally for significant distances, suggesting they are related to sediment loading and subsidence, further increasing their potential role in sediment mass failure. A major fault that offsets the seafloor breaks within 2 km of the West Tapir drill site.
2) **Hard substrate:** Variable and high amplitude reflections occur on the shelf. Combined with outcropping reflectors, these features suggest an erosional environment with a hard substrate. Strong currents, therefore, may be present.
3) **Bright spots** (high amplitude anomalies) are common beneath the uppermost slope. These anomalies possibly represent shallow gas or sand bodies (channels). The may be indicative of shallow overpressure, which in turn may pre-condition the sediments to mass failure. In this region also, seafloor slope angles are steepest (~3°) and there is evidence of buried headscarps suggesting mass-failures have occurred.
4) A possible **BSR** (bottom simulating reflector), indicative of the base of gas hydrate, was noted in the upperslope region. Gas hydrate dissociation can lead to formation overpressures and lead to slope failure.
5) **Mass transport deposits** are indicated by bodies of incoherent reflections with irregular contacts and surface renders showing 0.1 s high head scarps, lateral escarpments, and rugose surface patterns fanning out downslope. Although the low angles of the slope in this region suggest static stability, these deposits indicate mass failures have occurred in the past. Trigger mechanisms are unknown, but possibly relate to ground motions due to rare earthquakes. Shallow gas, gas hydrate dissociation and periods of high sediment input may be contributing factors. Recurrence intervals are unknown but presumably are rare because of the combination of events required to initiate failure. The shallowest mass transport deposit is buried by ~0.2 s of parallel, coherent reflections forming the present seafloor. Shallow mass transport deposits can consist of a variety of lithologies of varying strength properties and states of consolidation. They can; therefore, pose drilling difficulties.

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1.0 INTRODUCTION

1.0 Justification:

In 2003, D. Mosher participated in Ocean Drilling Program Leg 207 to the Demerara Rise, offshore Suriname, as a geophysicists and geohazard specialist. As a result of this involvement, RepsolYPF, an exploration company operating in the region, was interested in consulting with him prior to an exploration drilling program. Through this process, RepsolYPF kindly provided a 3D seismic volume, associated 2D seismic data and financial support for a graduate student (S. Goss) research topic. In return, D. Mosher committed to provide a geohazard assessment which would form part of the student's research. This report is the result.

1.1 Purpose:

This preliminary report summarizes results obtained from initial study of 3D seismic data from the Western Demerara Rise in the Repsol YPF block 30. The purpose of this study was to investigate these data for evidence of shallow geohazards and geologic constraints to offshore exploratory drilling and potential hydrocarbon development.

1.2 Location

The study area lies on the shelf and upper slope in ~ 100 to ~1750 m of water depth just west of the Demerara Rise, between latitudes of approximately 7°N and 9°N and longitudes 54° and 56°W (Figs. 1 and 2). The shelf break is indicated by a change in slope gradient from essentially zero (<0.5°) to almost 5°, which corresponds with approximately the 175 m contour (Fig. 2). In gross scale, the region encompasses a generally expressionless seafloor and gently dipping platform without significant regional or large-scale morphological features.

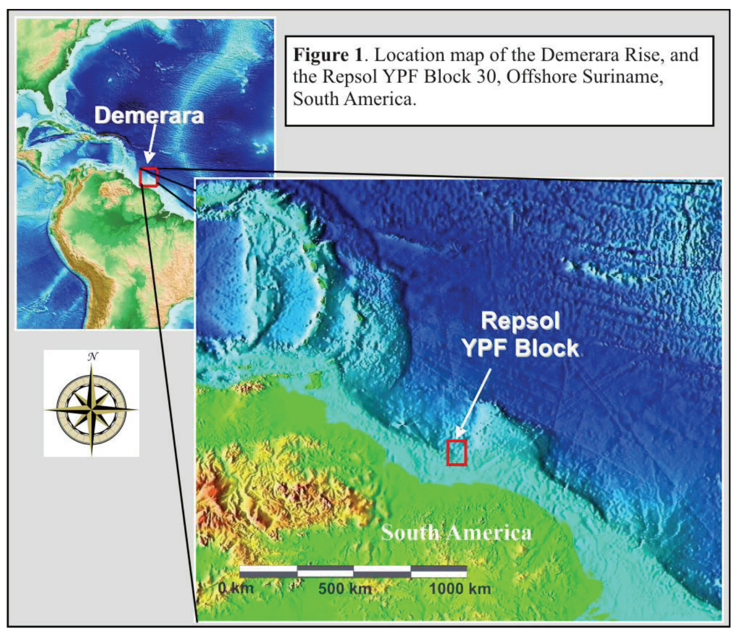

Figure 1. Location map of the Demerara Rise, and the Repsol YPF Block 30, Offshore Suriname, South America.

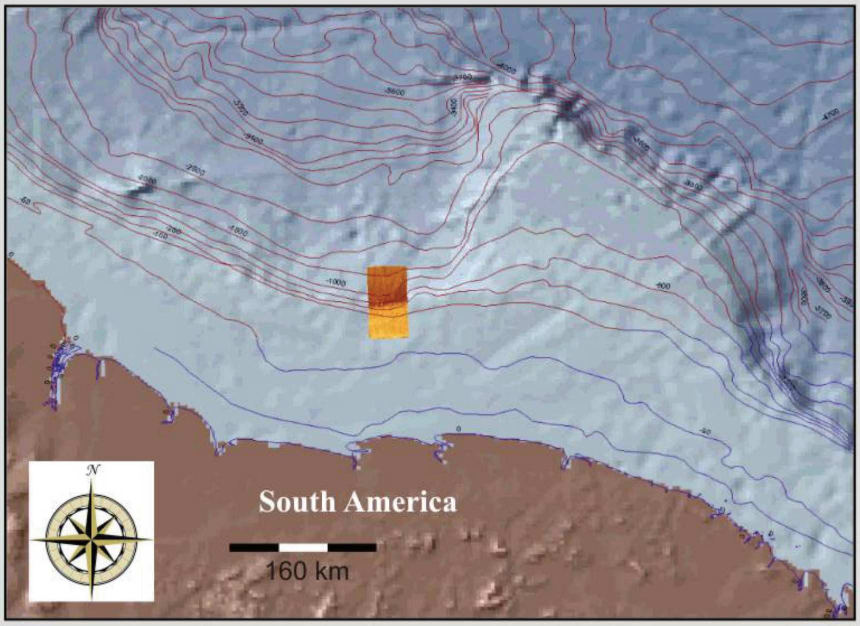

Figure 2. Location diagram of Repsol YPF Block 30 with depth contours.

1.3 Tectonic Setting

The Demerara Rise is built on Precambrian and early Mesozoic aged continental crust. It is believed that the Guinea Plateau (Western Africa) and the Demerara Rise are conjugate margins (Figs. 3 and 4) that formed the southern border of the central Atlantic margin during Jurassic times prior to rifting (Benkhelil et al., 1995; Mosher et al., 2007). At the onset of Middle Jurassic rifting, the Demerara Rise was contiguous with the Guinea Plateau of West Africa, and its composite terrain was contiguous with the SE limit of the continental crust beneath the Grand Banks of the Bahamas. In the central Atlantic, north-south rifting causing east-west extension with a large component of dextral shearing initiated about 180 Ma (Mascle et al., 1988; Mosher et al., 2007). This rifting initiated synsedimentary normal and strike-slip faulting (Mosher et al., 2005, 2007). Complexities caused by plate rotation resulted in a late compressional phase before final rifting. This compression led to en échelon folding and flower structures within the Demerara Rise.

Beneath the Demerara Rise, a Late Aptian and Late Albian double unconformity is reported within the sedimentary section (Benkhelil et at., 1995; Erbacher et al., 2004; Mosher et al., 2005, 2007). The first unconformity may be correlated with the formation of en échelon folds. While the late Albian event resulted from the main compression phase and is recorded by a strikingly prominent unconformity easily distinguishable temporally and spatially across the Demerara and Guinea Plateaus (Benkhelil et at., 1995; Erbacher et al., 2004; Mosher et al., 2005, 2007).

Following the minor recurrence of compressive tectonics, an extensional regime ensued during the Late Cretaceous. This regime is characterized by a general collapse of

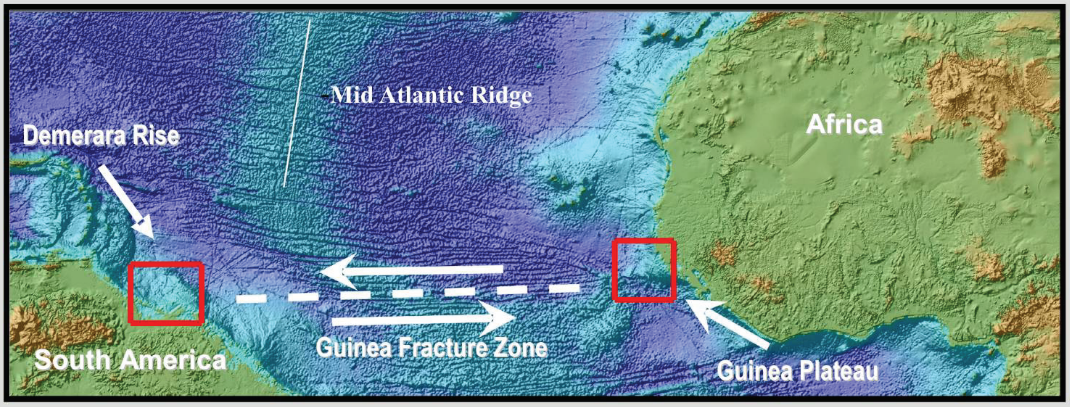

Figure 3. Location of the Demerara Rise and Guinea Plateau conjugate margins separated along the Guinea Fracture Zone (Modifed after Mosher et al, 2007)

the margin, resulting in the final parting between the African and South American continental plates and creation of oceanic crust (Benkhelil et al., 1995). Subsidence was presumably rapid, along with continental synrift sedimentation filling the accommodation space provided by this subsidence (Flicotaux et al., 1988; Mosher et al., 2007). Global sea level continued to rise throughout this period, and reached its highest levels in the Turonina (Haq et al., 1988; Mosher et al., 2007). Tectonic deformation ceased in the Late Cretaceous, followed by normal cooling subsidence as a largely clastic cover was deposited over the previous rift graben on the Demerara Rise (Gouyet et al., 1994).

Today the Suriname margin is a classic “Atlantic Type” passive continental margin. Present equatorial Atlantic spreading rates between South America and West Africa are 28.74 mm/year, thus about half that is accommodated by westward drift of South America. Regional reports for Suriname and French Guyana show little evidence of historical seismicity. The USGS Global Seismic Hazard Assessment Program reports a moderate to severe earthquake generated at 10 km depth, with magnitude 5.2 occurred NNE of Cayenne, French Guiana (1471 miles NE of Paramaribo, Suriname) on March 21, 2007. This event is unique for the Suriname margin in the USGS database. The National Geophysical Data Center lacks historical of seismicity data for Suriname, but Guyana reported a severe earthquake in August, 1774 of unknown magnitude. No further seismological hazard data has been reported for the offshore regions of French Guyana, Guyana, or Suriname. Additionally, gravity data show the region to be in isostatic equilibrium (Lithgow-Bertelloni and Gurnis, 1997).

1.4 Bathymetry

The modern bathymetry offshore Suriname resulted from its tectonic framework overprinted by subsequent Paleogene and Neogene sedimentation and subsidence. The continental shelf lies between the coast and 200 m water depth and is on average 160 km

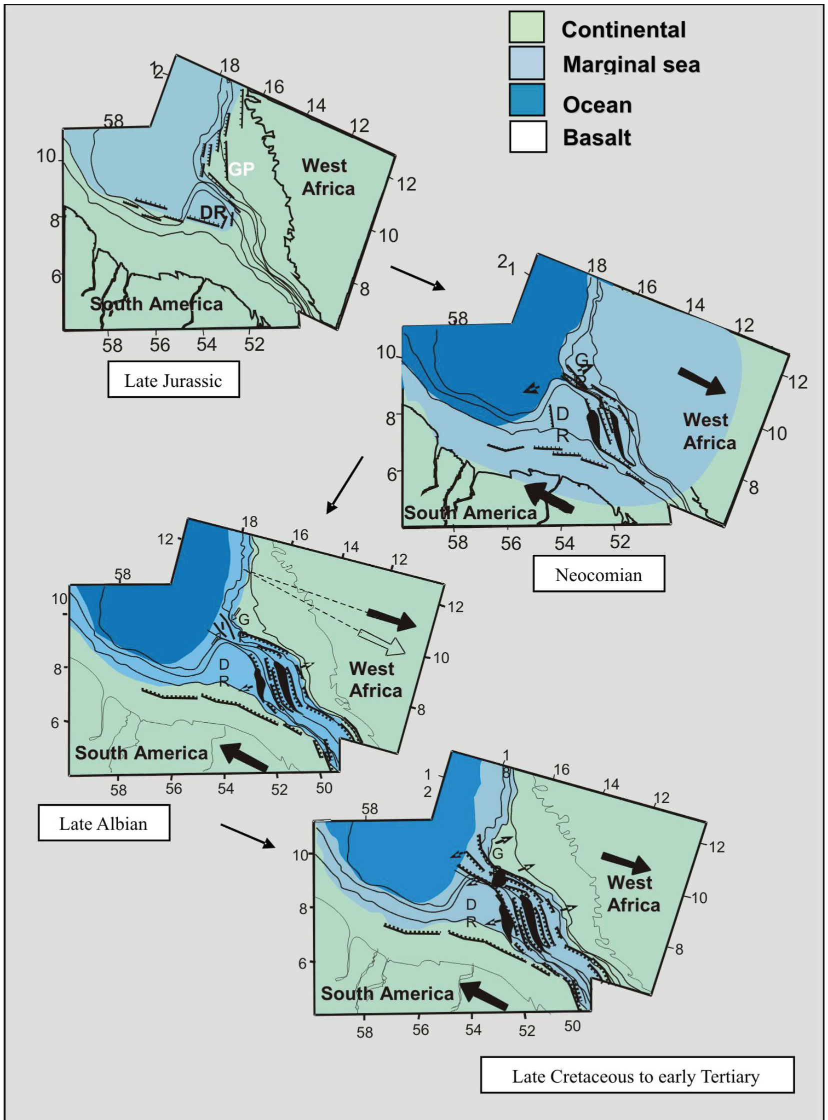

Figure 4. Schematic stages of Mesozoic evolution of the Equatorial Atlantic (Modified after Gouyet et al. 1994, Benkhelil et al., 1995).

wide (Fig. 2). The continental slope lies between the 200 and 3000 m isobath and is about 130 km wide near the study area. Its average slope angle is 1.2°. The Demerara Rise is an anomaly along the margin, protruding some 220 km northward from the shelf into the equatorial Atlantic (Fig. 2). It is a gently dipping ramp to about 1500 m water depth before dropping rapidly to abyssal depths at its easternmost flank. This flank is a remnant transform margin. The Rise forms a plateau that is about 56,000 km^2 in area. The study area is located at the innermost edge of this plateau, just as the contours turn northward along its western flank (Fig. 2).

Bathymetry for the study area derived from the 3D seismic volume is shown in Figure 5. The area encompasses the outer shelf, lying in less than 200 m water depth, and the continental slope down to 3000 m. The focus of the study is the area surrounding the West Tapir drill site, for which there is a reprocessed 3D seismic subset volume. This volume is on the shelf in water depths of 100 to 175 m (Fig. 6).

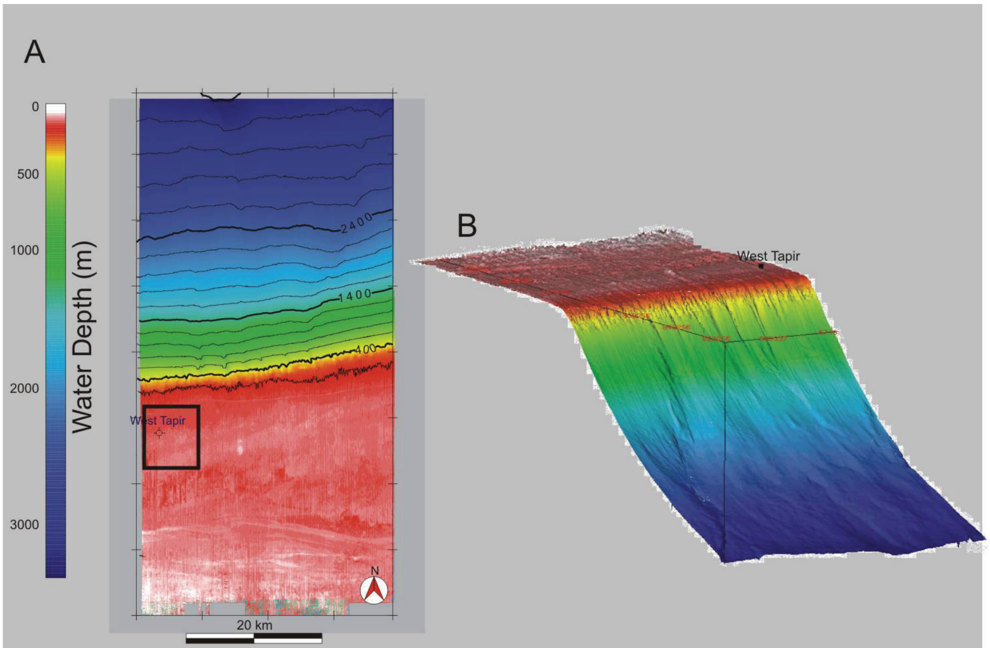

Figure 5. Bathymetry of the Surname Block 30 3D volume. Depths were acquired from the seismic traveltime to the first return signal with a conversion factor of 1500 m/s. A) planview contour map (200 m contour interval) and B) is a perspective view looking to the southwest. The square polygon on the planview map represents the location of the reprocessed 3D volume.

2.0 METHODS

Regional bathymetric data were derived from the ETOPO2 grid, downloaded from the National Geophysical Data Centre and gridded and imaged with ArcMAP. The sole data source for this investigation were 3D seismic data from the RepsolYPF Block 30 survey (Repsol_sur_blk30_final_mig_2x2_grid_final_migration.sgy). Bathymetry data for the survey area were derived from the seafloor first return pick; traveltime converted to water depth assuming a water column velocity of 1500 m/s (Fig. 5). Slope angle data were generated from these surface picked surfaces. The 3D seismic data form a 79.5 x 38.5 km grid of 25 x 25 m bin space (Fig. 5). Maximum horizontal resolution, therefore, is not better than 50 m (assuming Nyquist sampling theorem). Seismic frequencies span from 5 to 70 Hz, with peak energy about 15 Hz. At 70 Hz and assuming a velocity of 1500 m/s (water velocity), the maximum vertical resolution is about 5 m (1/4λ (wavelength) according to the Rayleigh criteria). Resolution deteriorates with depth as velocities increase and higher frequencies attenuate.

Data were loaded into Seismic-Micro Technologies™ Kingdom Suite interpretation software. Seismic stratigraphic horizons, defined by key high amplitude reflectors or noticeable changes in acoustic character, were digitally correlated throughout the data volume. Horizon data were exported to ArcMAP™ for surface rendering and deriving slope angles as well as to integrate with other geographic data.

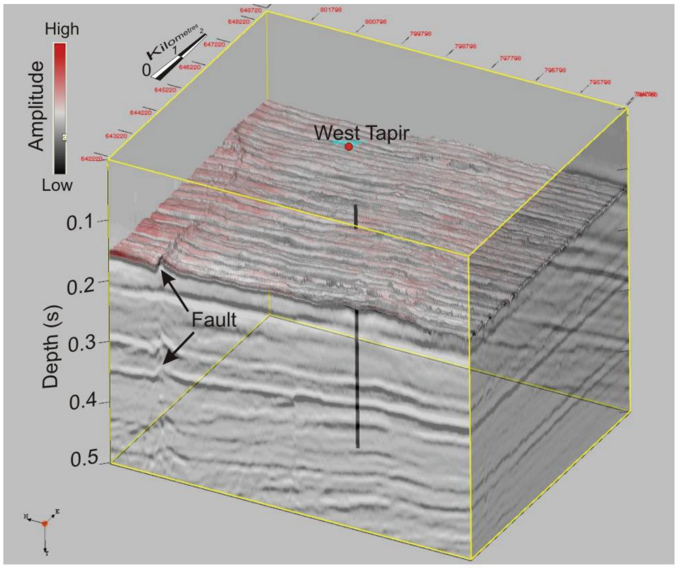

Figure 6. Block diagram of the reprocessed West Tapir 3D seismic subset. The top is the seafloor. The seafloor (top surface) is draped with reflection amplitude, showing amplitude variations across the volume. North-trending lineations are survey artefacts. In profile, subsurface faults are readily apparent, the northernmost one clearly offsets the seafloor.

3.0 RESULTS

3.1 Seismic Stratigraphy

3.1.1 Shelf

Shallow seismic data on the continental shelf from the full 3D seismic volume are of poor quality. This result is likely due to poor static correction, poor data stacking velocity models, multiple interference and high amplitude returns from the seafloor geology. Data quality improves considerable in the reprocessed 50 km^2 volume on the shelf, but survey artefacts in the form of strong linear data trends in the survey inline direction are apparent (Fig. 6). These are possibly related to poor static corrections in the array. The first high amplitude seismic return signal of these data represents the seafloor. A morphological render of this return within the reprocessed volume shows a generally expressionless seafloor (aside from the linear artefacts) (Fig. 7). An amplitude map of this surface shows amplitude variations across the volume, trending in general from high amplitude in the inboard portion to lower amplitudes outboard, despite little change in water depth (Fig. 6). High amplitude variations appear to be real and may indicate the intermittent presence of carbonate hardground or carbonate concretions. The West Tapir well site lies in one of these high amplitude areas.

Numerous listric-normal faults are present beneath the shelf to the southernmost extent of the study area (Figs. 6 to 8). These faults have a general trend of E-W or ESE-WNW, except one major fault that trends ENE-WSW. Seafloor expressions of some of these faults are noted (Figs. 6 to 8) and one of the main faults trends just north of the West Tapir drill site (Fig. 6). The nature of the fault surfaces is concave upward, with dips decreasing with depth (Fig. 8). These faults are responsible for minor offset (<0.03 s) of reflections from the sediment sea-floor interface to depths of 2.75 s twtt.

Below the seafloor of the shelf, reflection amplitudes are generally high with strong lateral coherency (Fig. 9). In dip section, these reflections offlap with dips on the shelf of less than 0.1° and the section thickens northwards (offshore) (Fig. 9 top). Along strike, reflections are largely parallel and laterally extensive (Fig. 9 bottom). Below a strong reflector at 0.6 to 0.8 s, reflections become nearly incoherent with apparent folds and contortion of reflection events. Despite this lateral incoherency along strike, in dip profile the offlap reflection pattern continues. Clearly this seismic facies change represents a lithologic/structural change with probable strong lateral variability in the deeper incoherent section.

3.1.2 Shelf break

The shelf break occurs in about 200 m water depth (Fig. 5), marking a change

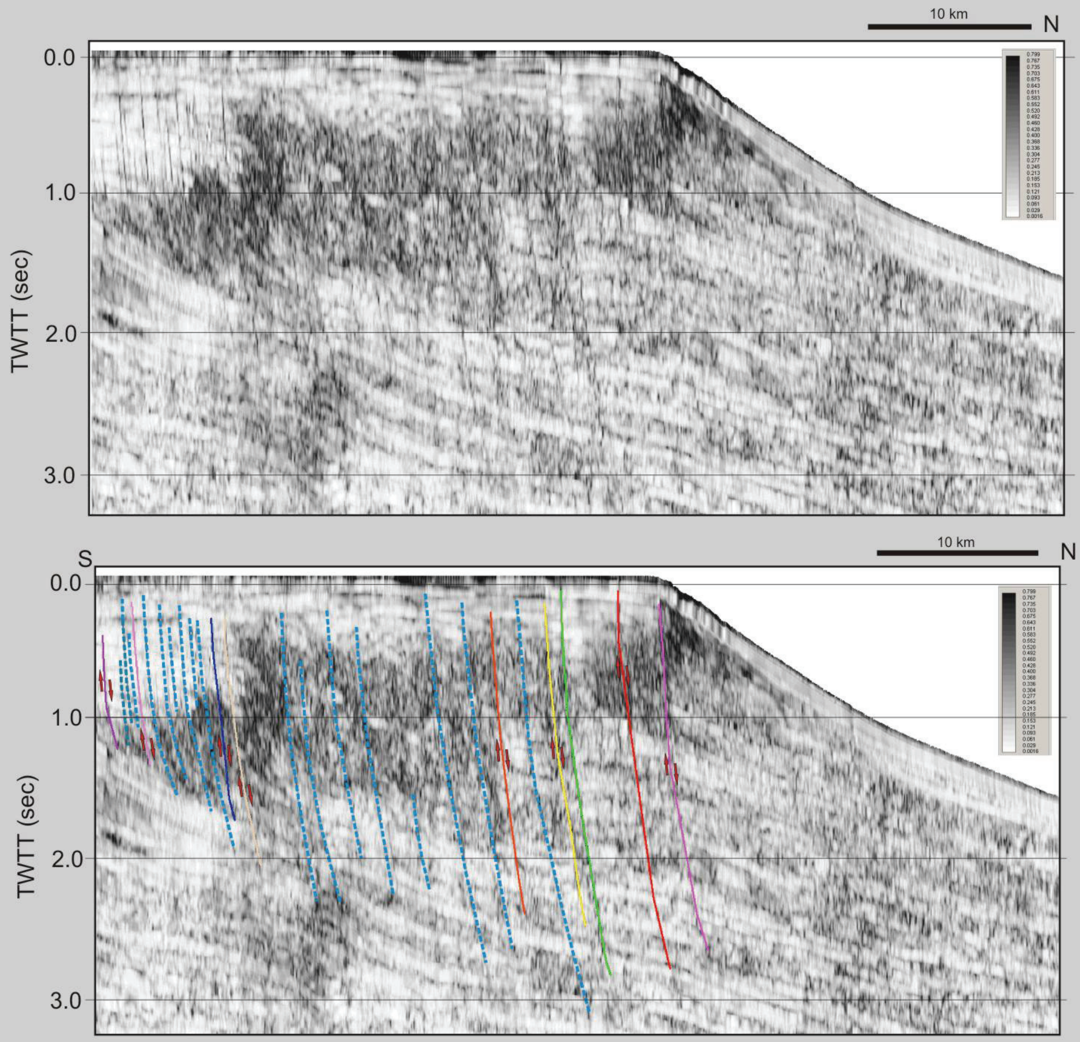

Figure 7. Seismic variance profile of inline 10970. Seismic variance (coherence) enhances detection of faults and other discontinuities. The top profile is uninterpreted and the lower one is the same profile with faults interpreted. Note the abundance of shallow faults within the southern section and deeper rooted

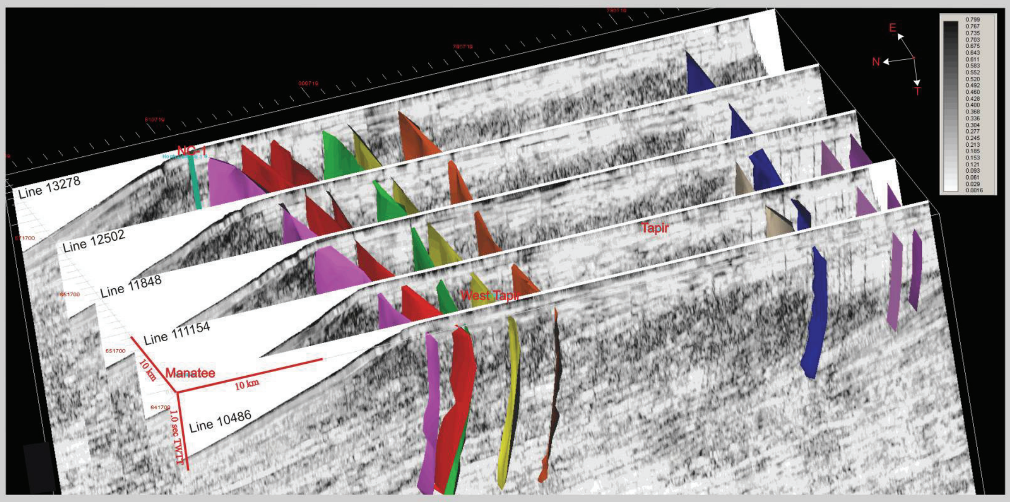

Figure 8. Selected fault planes interpreted from the 3D seismic volume and superimposed within selected variance profiles. This figure illustrates the steep listric nature of the faults parallelling the margin, as well as their lateral continuity. The West Tapir well location is indicated.

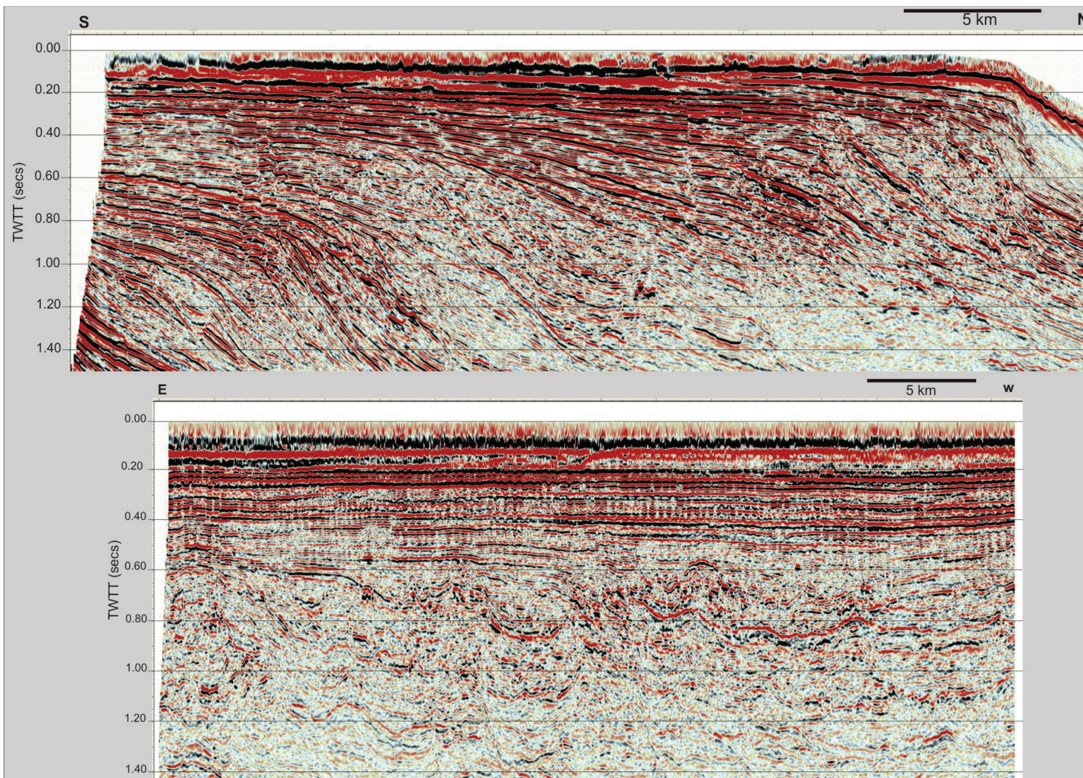

Figure 9. Top: Dip oriented seismic profile across the shelf (inline 10970), illustrating off-lapping reflections underlying the shelf. **Bottom:** Seismic profile (crossline 6084) at the 100 m isobath illustrating high amplitude and strong lateral coherency of reflections in the top 0.5 s of the section under the shelf. It also clearly demonstrates the seismic facies change at about 0.6 s TWTT.

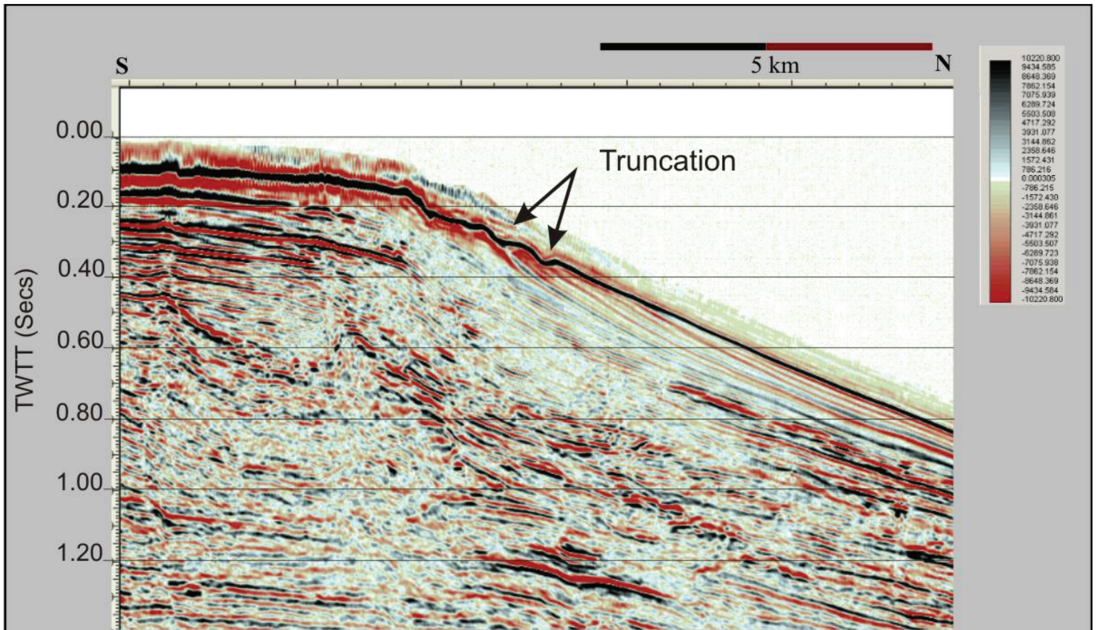

Figure 10. Seismic profile (dipline 10970) at the shelf break illustrating parallel continuous reflections that unconformably overlie chaotic high amplitude reflections. Note truncation of reflectors at the seafloor in the uppermost slope region.

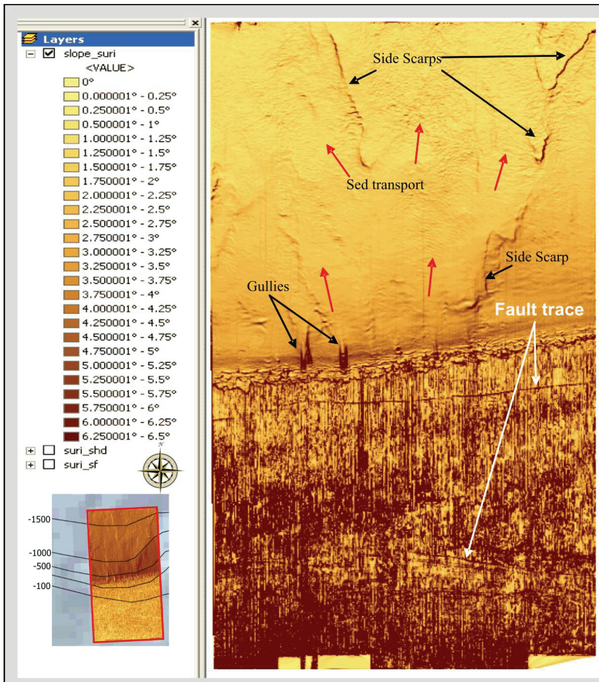

Figure 11. Slope angle map created from the seafloor horizon. Note outcropping of faults on the shelf and a particularly coherent one adjacent to the break in slope. As well, note the change in slope at about the 200 m isobath, and the presence of gullies at this position. Dark colours representing steep slopes on the shelf are a result of data noise. Despite this noise, the coherency of the fault traces shows through.

from <0.5° to 3.0° in slope angle (Figs. 10 and 11). Shallow reflection data under the position of the shelf break are of low amplitude (Fig. 10). The section beneath the shelf break and uppermost slope becomes incoherent below 0.2 to 0.4 s subbottom. Generally, reflections offlap the shelf edge, leading to a progradational wedge of nearly parallel reflections on the slope. The seafloor in this region is marked by many small indentations giving a ridge and gully morphology (Figs. 10 and 11). In addition, the shallowest reflections from the slope clearly truncate against the seafloor in this uppermost slope region (Fig. 10). This truncation and gully morphology suggests erosive off-shelf flow and possible sediment transport is occurring in the modern environment.

3.1.3 Slope

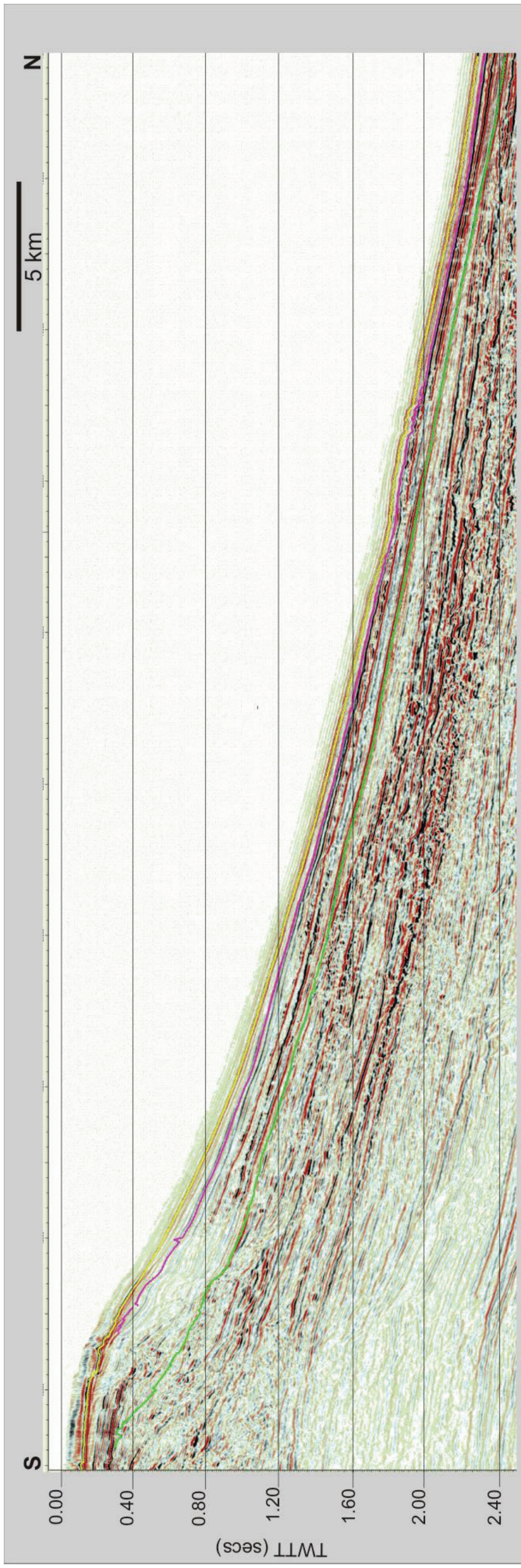

Figure 12. Seismic slope profile (dip line 10970) illustrating seismic characteristics of the slope. Picked horizons (Yellow, Magenta and Green) are illustrated.

The low amplitude reflections beneath the shelf break increase in amplitude downslope and in general there is a thinning of the sediment section distal from the margin (i.e. basinwards) (Fig. 12). A morphologic render of the seafloor horizon shows a relatively featureless slope, with the exception of the aforementioned gullies at the break in slope and a single channel that extends the length of the slope within the limits of the study area (Fig. 13). Below 1200 m water depth, the seafloor is overprinted with escarpments and a rugose morphology that is somewhat subdued, suggesting it is draped with sediment. Slope angles are low, ranging from about 3° in the uppermost slope/shelf break region to 1.5° on the lower slope (Fig. 11). Steep slope angles occur only locally on the edges of gully's and escarpments.

In the seismic section of the slope, there are discrete seismic facies including largely strong amplitude and coherent events that dip to the north at approximately 1.7° and pinch out in the downslope direction (Fig. 14). These are intercalated with packages of incoherent reflections that form wedge-shaped units within this succession (Fig. 14). These patterns of reflections are

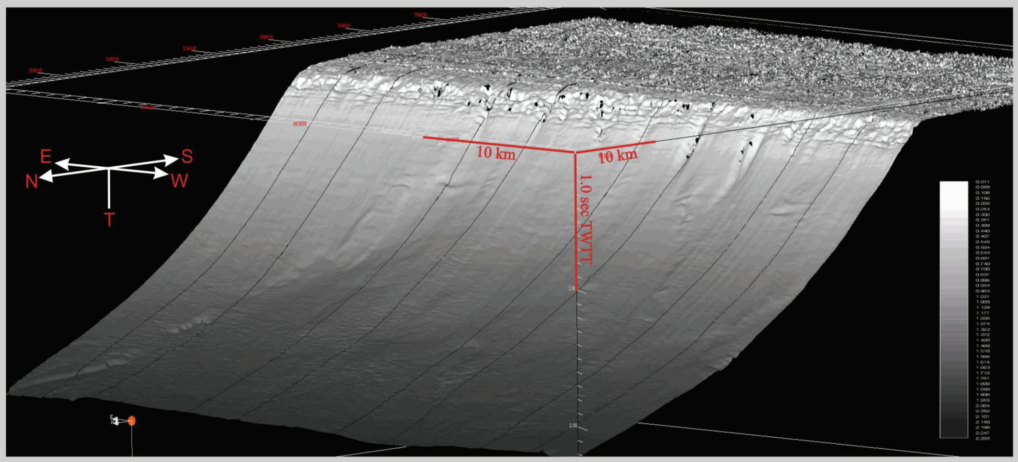

Figure 13. Perspective view of a rendering of the seafloor in the study area looking SE and showing the morphology of the slope.

interpreted as probable mass transport deposits (MTD) interbedded with turbidites and probable hemipelagic material (Fig. 14). Morphologic renders of some the subsurface reflection horizons reveal the complexity of these MTD's and erosional sediment transport processes (Fig. 15). These data clearly reveal a history of at least minor slope failure.

Beneath the slope, particularly in the upper slope region, are patches of high amplitude, phase reversed reflections, or bright spots (Fig. 16). Phase reversal infers a velocity inversion (although possibly density) and the strong amplitude infers a significant velocity contrast. Strong velocity reversals are most typically caused by free gas in formation, so in all likelihood these bright spots reflect pockets of shallow gas.

A potential bottom simulating reflector (BSR) was identified in the lower slope region of the study area (Fig 17). It is located between strike lines 8646 and 10636, and dip lines 11728 and 10636. This anomalous seismic reflection event covers an area of 258 km^2 and dips at ~0.018°. It is identified by its relatively high-amplitude and phase reversed nature and it parallels the seafloor, cross-cutting other reflections. A BSR represents the base of the gas hydrate stability field, where free gas is trapped beneath solid hydrate. It parallels the seafloor because the hydrate stability field is temperature and pressure dependent. Beneath the seafloor, the temperature gradient is typically relatively stable, thus temperature is the dominant controlling factor governing the base of the stability field and explains why the BSR parallels the seafloor. The depth of this BSR is about 0.4 s below seafloor.

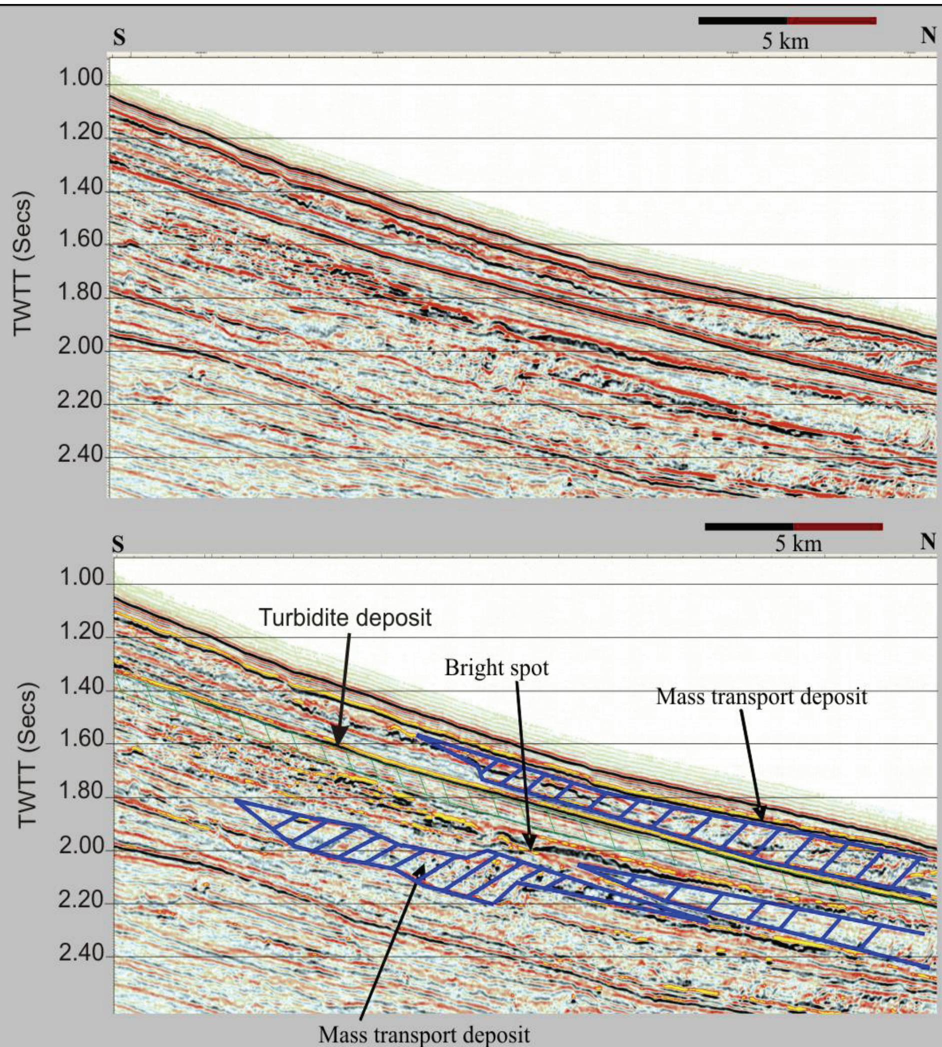

Figure 14. Top: Un-interpreted dip profile (inline 10970). **Bottom:** Interpreted dip profile (inline 10970).

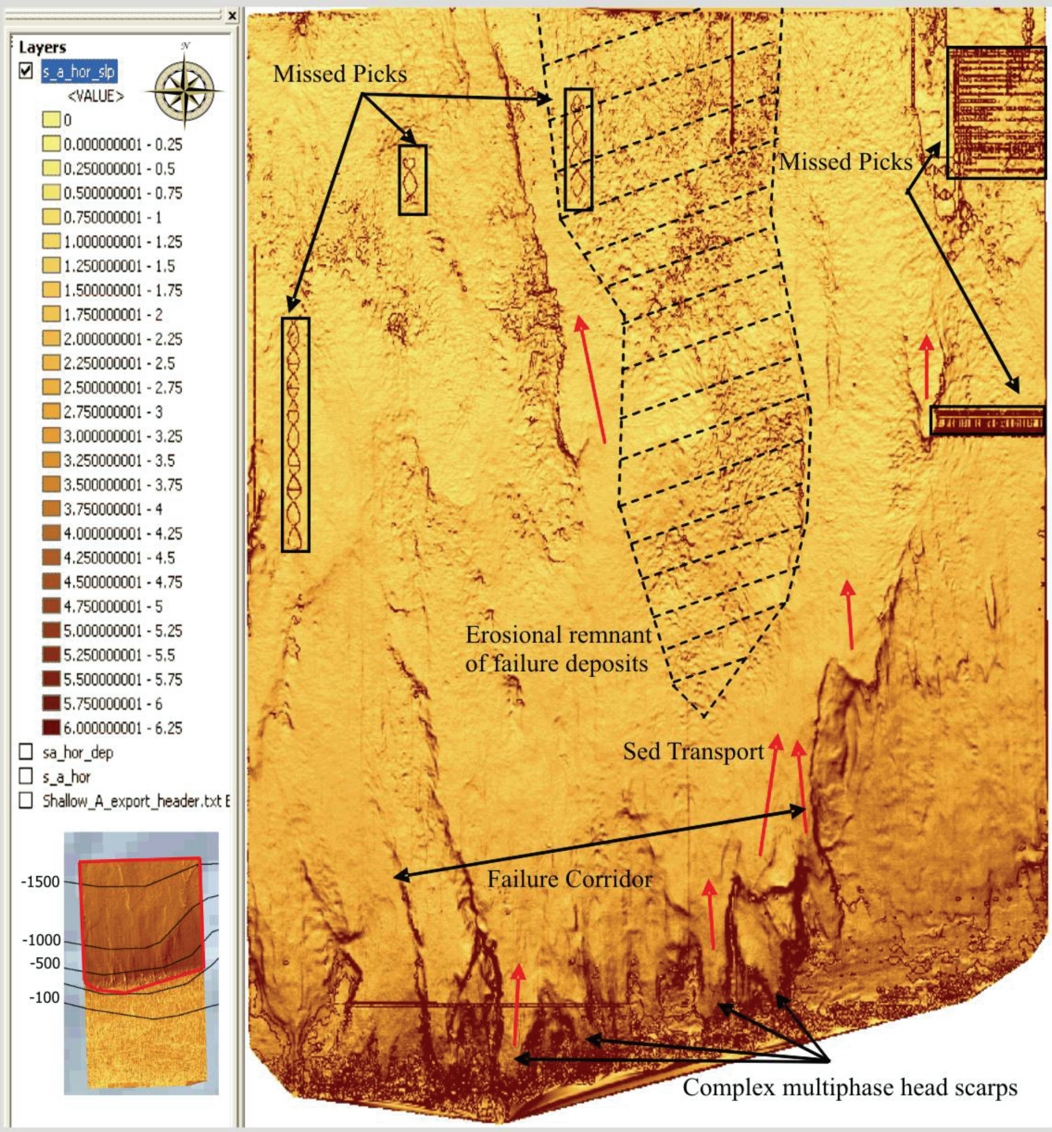

Figure 15. Slope angle map created from rendered magenta horizon on the slope. The lower left corner indicates location of rendered area (red) within the block. Not the complexity of the surface with mass transport deposits and erosional gullies and scars.

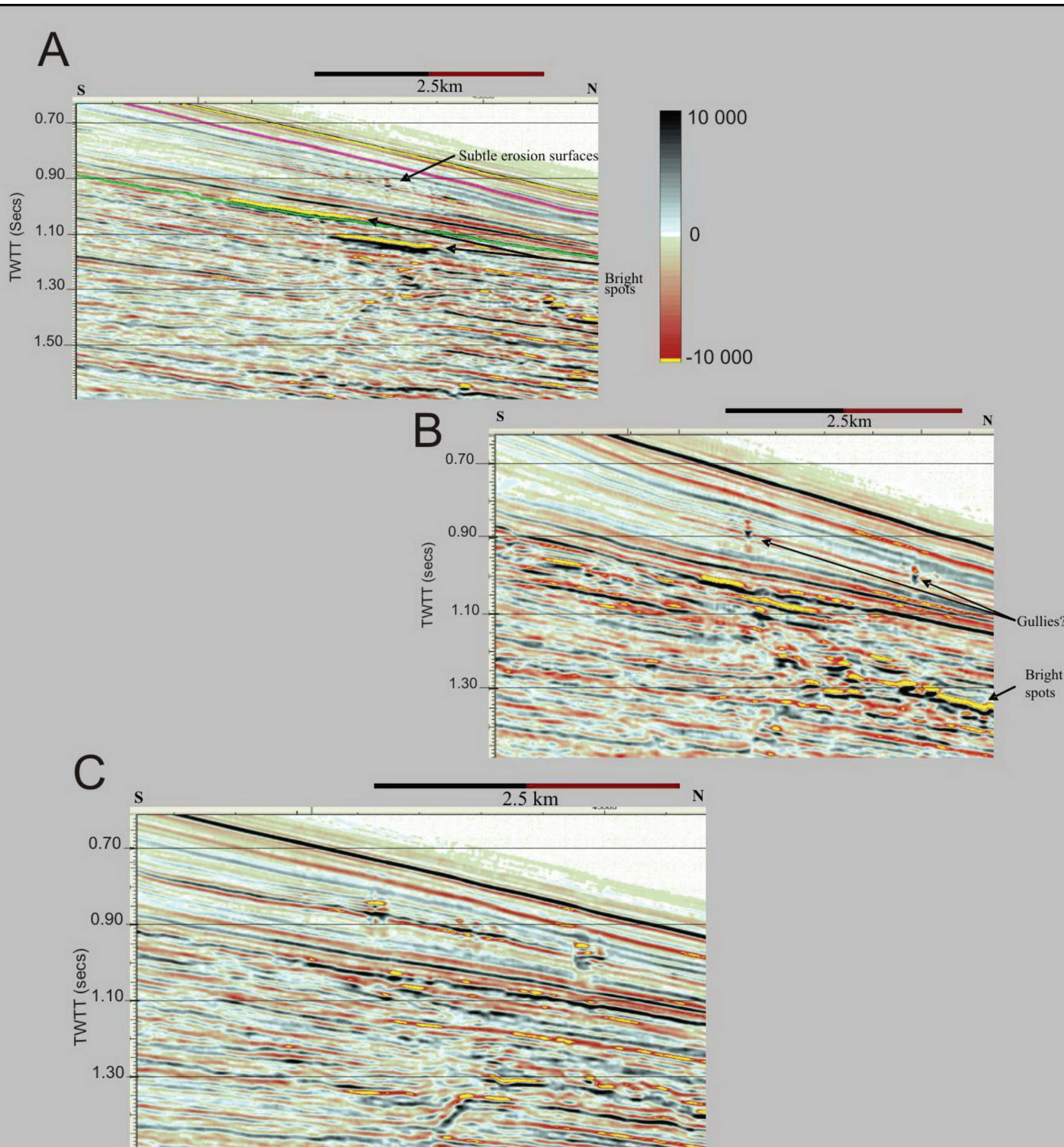

Figure 16. Phase inverted flat bright spots (displayed as yellow) located below the upper slope. A) inline 11938; B) inline 11958, and C) inline 11898.

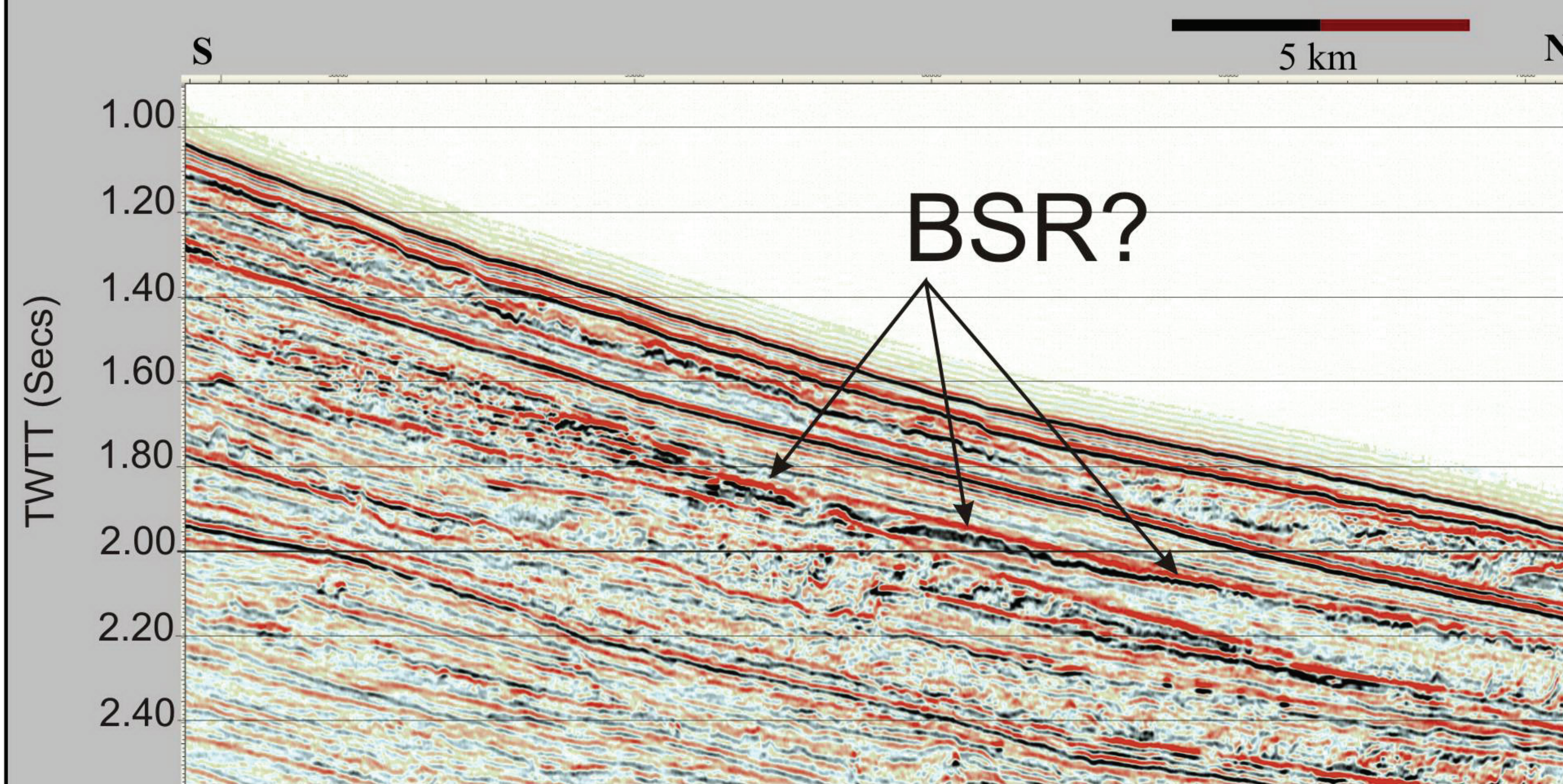

Figure 17. Inline 10970 showing a possible bottom simulating reflector (BSR), recognized by its strong negative phase that does not conform to stratigraphic relationships but rather parallels the seafloor.

4.0 POTENTIAL GEOHAZARDS

For the purposes of this investigation, features identified as representing potential geohazards or constraints to exploratory drilling and hydrocarbon development are presented. Specifically, such features within this data set include 1) shallow faults, 2) hard substrate, erosional scour and seafloor slopes, 3) mass transport processes, and 4) suspicious amplitude anomalies and BSR's.

4.1 Shallow Faults

It is considered that the most significant geohazard identified from the Surinamme Block 30, including within the immediate area of the West Tapir well site, is the presence of abundant shallow faults (Fig. 6 to 8). These faults are largely listric-normal and are responsible for offsetting reflections on the order of tens of metres. They are restricted to areas beneath the shelf and shelf break. Some are constrained within the near-surface but others clearly extend to depth. One particular fault trace, with a seafloor expression demonstrated in Figures 6 to 8 and 13, parallels the shelf break for the full extent of the survey and comes within two kilometres of the West Tapir well site. It is not known whether these faults represent splays of a master fault system or represent gravitational extension of the shallow margin due to subsidence and gravitational collapse. Faults such as this represent hazards in several senses: 1) they may act as conduits for overpressure fluids or gas from depth, and 2) they form a plane of weakness, which in this particular case is adjacent to a free slope and subsequently there is a risk of detachment and mass failure.

4.2 Seafloor and Seafloor Slope

Acoustic characteristics of the seafloor on the shelf, indicated by varying high amplitude first return reflections (Fig. 6), suggest a hard substrate (carbonate), which may have engineering implications for rig and well head foundation conditions. Increased amplitudes toward the shelf break and truncated reflections at the shelf edge and uppermost slope along with prominent gully formation suggest an erosive environment, probably due to off-shelf flow and possible sediment transport. If they indicate bottom water flow, then these currents may well exist near the West Tapir well site.

Slope angles within Block 30 are generally low, being about 3° at the shelf break and less than 2° over the remainder of the slope. In most marine environments with such low slopes, the risk of static failure (no external trigger mechanisms) is low. In other words, the internal shear strength of surficial sediment is great enough to withstand the gravitational force acting on the sediment column on a slope. External factors, such as seismic ground-shaking or generation of elevated pore pressures by gas or fluid is required to initiate failure. Generation of high pore pressures reduces the shear strength of the sediment. The West Tapir well site is on the shelf and no significant slope angles exist within the immediate area.

4.3 Mass Transport Deposits

Although slope angles are low and subsequently risk of landsliding is low, as indicated above, there is abundant evidence on the slope of mass transport deposits that demonstrate a history of sediment mass-failure on this margin. Packages of incoherent reflections on the slope are interpreted to represent mass transport deposits, such as debris flows or rotational failure. They form approximately 30% of the upper sediment column (upper 2 s below seafloor) (Fig. 14). As shown on seafloor morphologic renders, the slope shows escarpments and a rugose pattern suggestive of near-surface mass transport deposits (Posamentier, 2004). Close inspection shows that these features are buried by a sequence of parallel reflections several 10's of ms thick, but their expression still is visible at the seafloor. Two subsurface horizons, representing shallow mass transport deposit surfaces were picked.

A shallow reflection horizon (within 0.1 s of the seafloor), named Magenta, was picked from the shelf break to the most northern extent of the block (Fig. 15). The morphologic render and associated slope angle map show numerous gullies and headscarps. A failure corridor is lined with steep walls and side scarps from 400 to 1000 m water depth, the inter-corridor ridges are commonly less sharp. In deeper water, corridors coalesce and the inter-corridor ridges are much flatter, with various low scarps. The mid-slope (1000 m) to the north extent of the study area presents a rugose hummocky morphology, with minor sediment lobes (Fig. 15), typical of mass-transport deposit surface morphologies (Posamentier, 2004, Posamentier and Kolla, 2003). The nature of these areas tends to fan and broaden with depth away from the corridor head scarps.

Although not a specific geohazard, mass-transport deposits substantiate a history of submarine landsliding. It is a common process on most continental margins, although trigger mechanisms are not well understood. With age control, estimates of recurrence rates can be derived. In general, risk of landsliding during exploratory drilling is low due to the infrequent occurrence of such events. The risk to development infrastructure is slightly higher because of the longer duration of the facility on the seafloor. Steps to mitigate initiation of landsliding by drilling or development disturbance should be considered. For the West Tapir drill site, mass failure is not an issue because of low slope and dip angles. Significant slope failure retrogression (> 10 km) would have to occur in order to impact the drill site area.

4.4 Subsurface Amplitude Anomalies

High seismic reflection amplitude anomalies (bright spots) represent potential free gas within a rock formation. In many cases, these anomalies are clearly phase-reversed, as expected from a free gas anomaly where velocities are inverted. Typically, theses features are seen north of the shelf break in ~350 m water depth, between 0.8 and 1.2 s twtt (Fig. 16). No evidence of pockmarks or gas escape features (chimneys, vents) within seismic profile or morphologic surface render are apparent, however. Free gas represents a hazard in that it may cause an overpressured zone leading to reduced sediment shear strength or higher than expected formation pressures.

A possible bottom simulating reflector (BSR) was noted spanning cross lines 5000 to 6500 and 1.45-2.25 s twtt (Figs. 31, and 32). BSR's are believed to represent the base of the gas hydrate stability zone, where free gas is trapped beneath solid-phase hydrate, causing a velocity inversion. Because the stability field for hydrates is dictated by pressure and temperature conditions, the lower surface may simulate the seafloor and not necessarily correspond with geological structure. In fact, BSR's are most easily recognized if they cross stratigraphy.

Gas hydrate represents a possible geohazard in that dissociation of the hydrate to free gas can cause formation overpressures; volume expansion during dissociation is significant (164:1). Formation overpressure leads to weakening of sediment shear strength and thus a higher susceptibility to landsliding. Dissociation may be caused by drilling activity and resource extraction (formation heating). Hydrate formation can also be a significant drilling constraint by blocking pipes and other conduits. Within the immediate area of the West Tapir drill site, no BSR's were detected.

5.0 CONCLUSIONS

The 3D seismic volume from the RepsolYPF Block 30 of the Suriname continental margin transits from the shelf to slope environments. The region is a passive continental margin and earthquake seismicity is rare. In large scale, these 3D reflection data show a classic progradational margin down to several seconds travel time below the seafloor. A number of features were identified from the shallow, near surface geologic section that represent potential geohazards or constraints to offshore hydrocarbon development.

The shelf section encompassed by the volume ranges from 60 to 230 m water depth, with shallow dipping (<0.5°), high amplitude reflectors underlying a rather rugose seafloor. Shallow data are of poor quality in this area but high amplitudes and rugose morphology, combined with outcropping reflectors suggest an erosional environment with a hard substrate. Strong currents, therefore, may be present, such as the northward flowing Guyana Current. Shallow faults which break the seafloor are the predominate geohazard in this environment. These fault traces produce clear seafloor offsets that correlate for the width of the survey. Faults can provide conduits for overpressured gas and fluids and provide planes of weakness for initiation of mass failures.

Faults extend to the shelf break as well. The shelf break appears to be the most dynamic environment. The seafloor over the entire width of the survey is dominated by gully cutting, potentially the result of off-shelf transport. Beneath the shelf break, amplitude anomalies are common, possibly representing shallow gas or sand bodies (channels). In this region also, seafloor slope angles are steepest (~3°). Infinite slope stability analysis indicate that these angles are still statically stable for most sediment types but evidence of buried headscarps suggest mass-failures have occurred in the past.

The top several seconds of the continental slope is a progradational wedge created by shelf edge deltas, with sediment offlapping the shelf and thinning in the downslope direction. Seismic characteristics indicate that probable turbidites intercalated with mass transport deposits dominate the sedimentary succession. Surface renders of these features show head scarps, lateral escarpments, and rugose surface patterns fanning out in the downslope direction; typical characteristics recognized of mass transport deposits. Although the low angles of the slope in this region suggest static stability, these deposits indicate mass failures have occurred in the past. Trigger mechanisms are unknown, but possibly relate to ground motions due to rare earthquakes. Shallow gas, gas hydrate dissociation and periods of high sediment input may be contributing factors. Recurrence intervals of these mass transport events are unknown due to present poor age control. Probably these events are rare because of the combination of events required to initiate failure. The shallowest mass transport deposit is buried by ~0.2 s of parallel, coherent reflections forming the present seafloor.

6.0 RECOMMENDATIONS

The following recommendations are provided to enable a more thorough assessment of shallow geohazards and drilling conditions in the Repsol YPF Block 30.

1) Reprocessing of the 3D seismic cube with near-offset traces and modified processing flow to improve vertical and lateral resolution for the shallow sediment section. Attribute analysis of these cubes may assist interpretations.
2) Conduct ultra-high resolution geophysical surveys of proposed drill areas. These techniques include multibeam bathymetry, sidescan sonar and ultra high resolution seismic reflection, as examples.
3) Acquire sediment piston cores, with physical property measurements, and assess well logs from previously drilled sites in the area to provide data for a quantitative geotechnical assessment (foundation conditions and slope stability analysis), age control and seismic-lithologic groundtruth.

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