NEARSHORE BATHYMETRY AND SEABED MORPHOLOGY, MELE BAY, EFATE, VANUATU

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SUMMARY

Geophysical mapping of the nearshore zone of Mele Bay using seismic and precision echo sounding has revealed a variety of seafloor landforms which appear to indicate a significant amount of instability of bottom sediments on the shelf slopes. Acoustic indicators of this instability are hummocky topography, internally chaotic sub-surface reflections, extensive submarine channeling of the shelf slopes, step faulting and deformed bedding. Factors contributing to this instability are a very narrow shelf with steep shelf slope gradients up to 15 degrees, tropical cyclones and active seismicity. A catastrophic event such as a cyclone can rapidly generate large quantities of unstable sediment, transported by rivers offshore and deposited on the slopes. An absence of natural shoreline protection such as a barrier reef or river delta sand bars to break up large storm waves generated by cyclones, and the loss of sediment from the shelf slope by slumping, are natural events which are believed to contribute to the coastal erosion of Mele Beach.

ACKNOWLEDGEMENTS

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OBJECTIVE

This work was carried out to fulfill the requirements of SOPAC 1990 Work Plan Task 90.VA.6a. Physical and Oceanographic baseline study of Havannah Harbour. The objective of the survey was to map the nearshore bathymetry and seabed morphology and study sedimentation processes at the head of Mele Bay.

INTRODUCTION/BACKGROUND

A SOPAC nearshore geophysical survey, No. VA9001, was conducted in Mele Bay, Efate, Vanuatu between 7th March and 19th March 1990 to map bathymetry, seabed morphology, and establish the sedimentary processes occurring immediately offshore (Figure 1).

In Mele Bay, beach erosion is recognised as a serious problem. Mining beach sands for building aggregate has contributed to the accelerated retreat of the coastline in recent years (Temakon and Harrison, 1988); Rearic, 1990. Other large changes to the shoreline have been attributed to cyclone Uma in 1986 which appears to have obscured the normal picture of sedimentary processes in the area. In the nearshore area of Mele Bay, the little information available on bathymetry and seabed morphology is found in published Admiralty Chart 1494 for Efate, but this information is limited to navigational hazards.

Improved information on Mele Bay's bathymetry, nearshore morphology and sedimentary processes which will assist development of a resource management scheme for future beach mining.

GEOGRAPHICAL AND GEOLOGICAL SETTING

Mele Bay is a large embayment formed in the southwest of Efate Island. The bay is flanked by two headlands, Devil's Point in the west and Pongo in the southeast. The principal drainage into Mele Bay is via the Teae Tepwukoa, La Colle and Tagabe rivers from which, an extensive alluvial fan has formed in the low-lying areas of Mele Bay, rising from a sandy beach to 40 - 50 metres above mean sea level at its highest point.

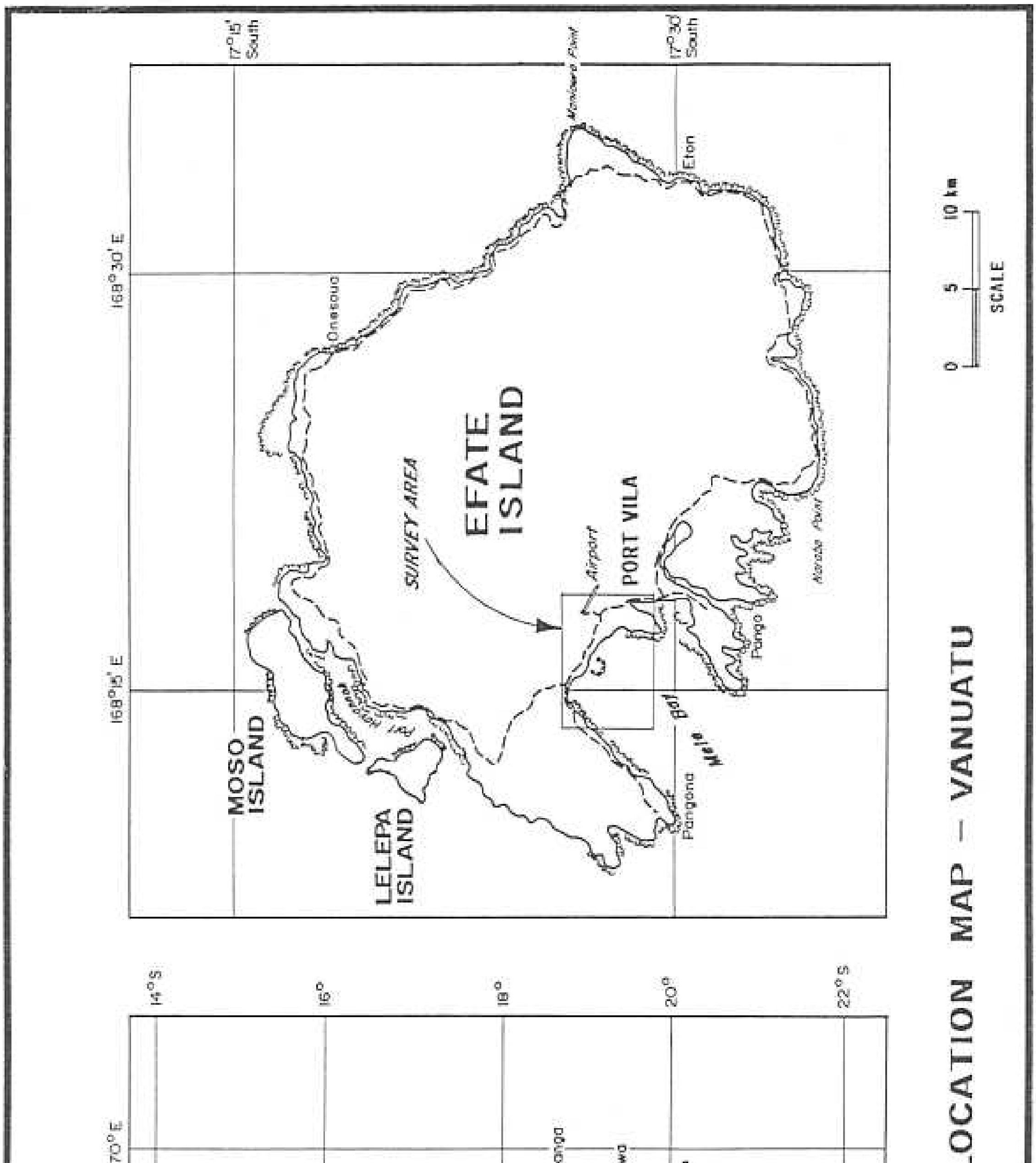

Figure 1. Location map of survey area.

Low-lying, uplifted Holocene, and older reefs dominate the headlands and a large part of the coastline, leaving only Mele Bay as a sandy beach environment. A fringing reef around the coastline is absent along Mele Beach except for two spurs. The first occurs at Swango Point and is quite large with a mobile, vegetated sand cay (Mele Island) upon it. The other, smaller spur of reef occurs adjacent to Tagabe River and is partially exposed at times of low tide. Figure 2 is a simplified geological map of Mele Bay taken from Ash et al (1978).

EQUIPMENT AND TECHNIQUES

Thirty two geophysical line profiles totalling approximately 50 kilometres were completed and interpreted for this report.

Figure 3 is a track plot of these profiles run in the nearshore of Mele Bay. The base map for navigation control was digitized from the 1:2500 series DOS 065.

Navigation Control

Vessel position was provided by a Del Norte microwave positioning system with all data logged and processed on laptop PC's.

Bathymetry

A Raytheon De719e echo sounder with a digital depth output was recorded by laptop and files created were merged with the navigation data to produce computer generated bathymetry maps. Admiralty published tide tables were used to reduce bathymetry data to a common datum, in this case Lowest Astronomical Tide (LAT).

Seismic Profiling

For the seabed morphology and sub-bottom information, a Data Sonics SBT220 3.5 kHz sub-bottom profiler was used to produce analogue records for interpretation.

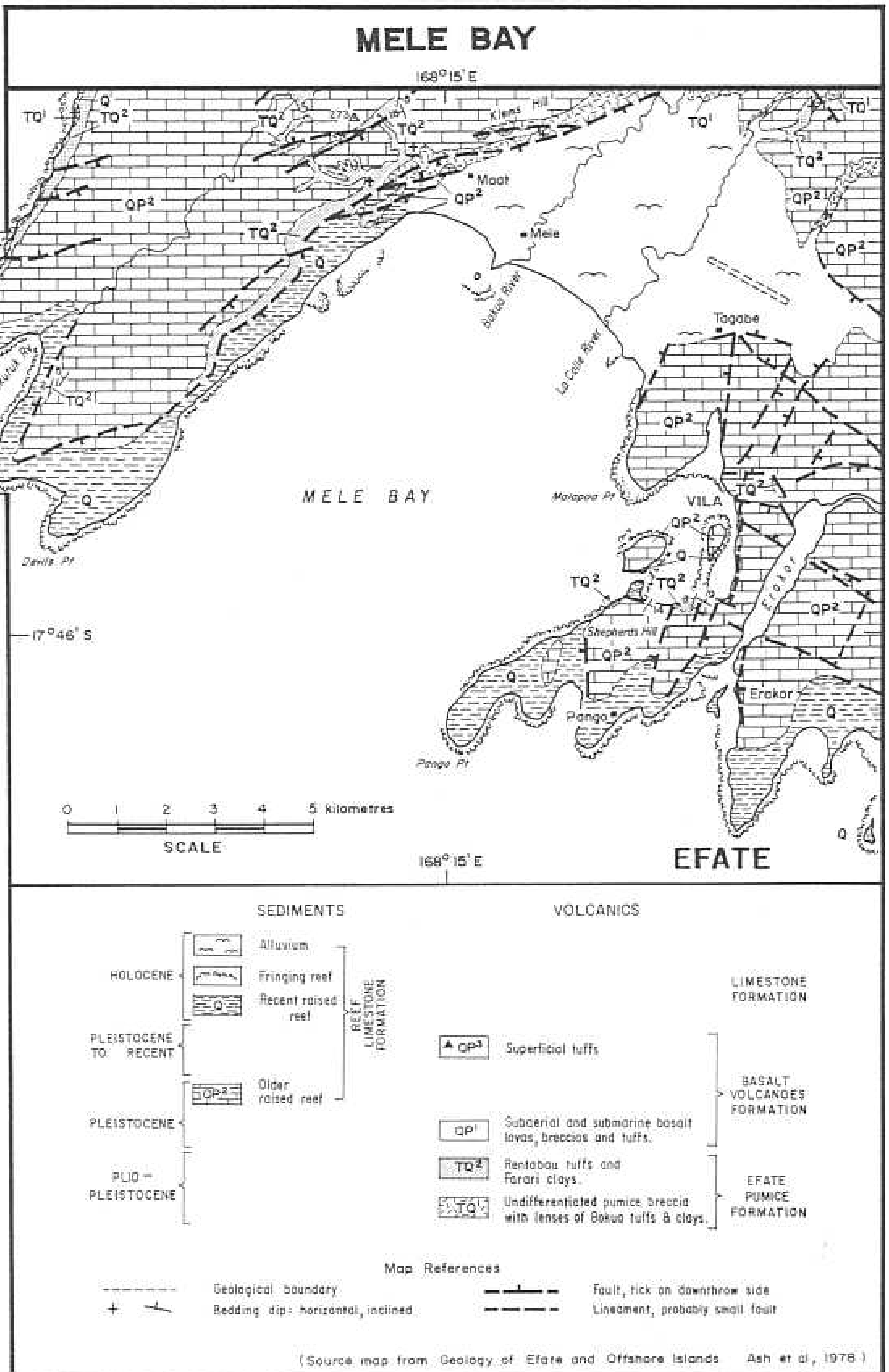

Figure 2. Geology of Mele Bay.

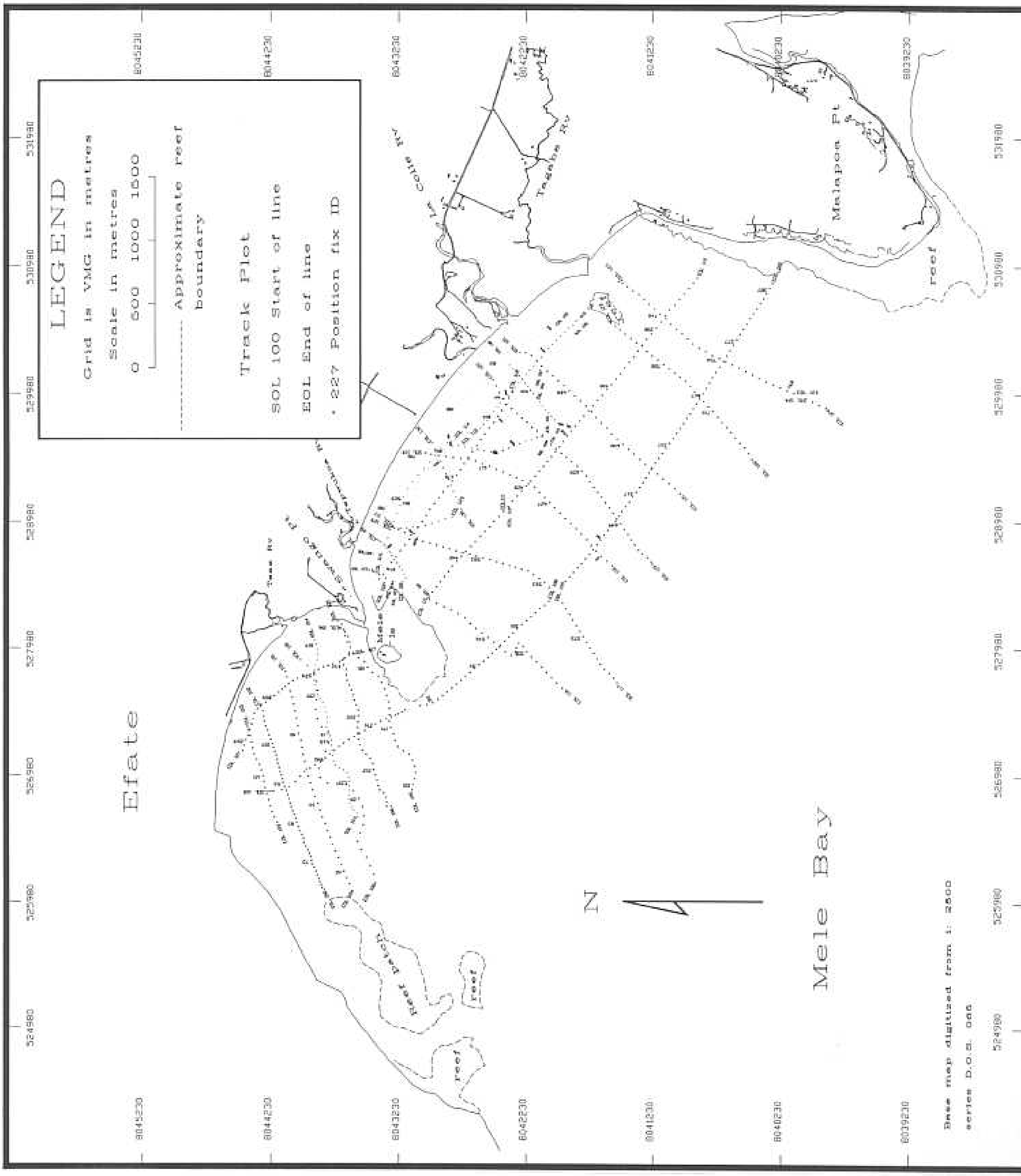

Figure 3. Track plot for bathymetry and 3.5 kHz seismic profiles.

G-Fig 8

A more detailed account of survey techniques and data processing can be found in Smith and Saphore (1990).

RESULTS

Bathymetry

Figure 4 shows the nearshore bathymetry at the head of Mele Bay. This was compiled from the track data shown in Figure 3.

Principal topographic features are a very narrow shelf between the shoreline and shelf break (Figure 5). The average depth of the shelf break is around 10 metres, from which there is a marked increase of slope down into two intraslope basins. Upper slope gradients from the shelf break range from 7 to 15 degrees, with lower slope gradients ranging between 3 and 6 degrees.

The two small intraslope basins are separated by the reef complex of Swango Point on which Mele Island is located. In the northwest, the smaller of the two basins attain depths up to 80 metres; the second basin lying between Swango point and Malapoa Point in the east is in excess of 120 metres deep.

Reef development in the survey area is limited to patch reefs off Swango Point and the Tagabe River and a narrow fringing reef extending from Malapoa Point. On the west side, off Malapoa Point, the precipitous nature of the fore-reef slope suggests, a bathymetric continuation of a northeast-southwest trending normal fault mapped by Ash et al (1978). No natural shoreline protection such as a barrier reef exists for Mele Bay.

Drainage into Mele Bay is via four river systems : the Teae River in the northwest and the Tepwukoa, La Colle and Tagabe rivers in the southeast (Figure 3). Howorth (1983) has shown that the Tagabe and La Colle River delta mouths have changed their positions along a 500 m stretch of the coastline at least three times in the last 50 years. The Tepwukoa River has also changed its position up to 700 m also in this time.

Figure 5 is an interpretation, from seismic and bathymetric data, of the extensive submarine channelling incised in the shelf slope. The black dots represent the location of channels as seen in the seismic profiles.

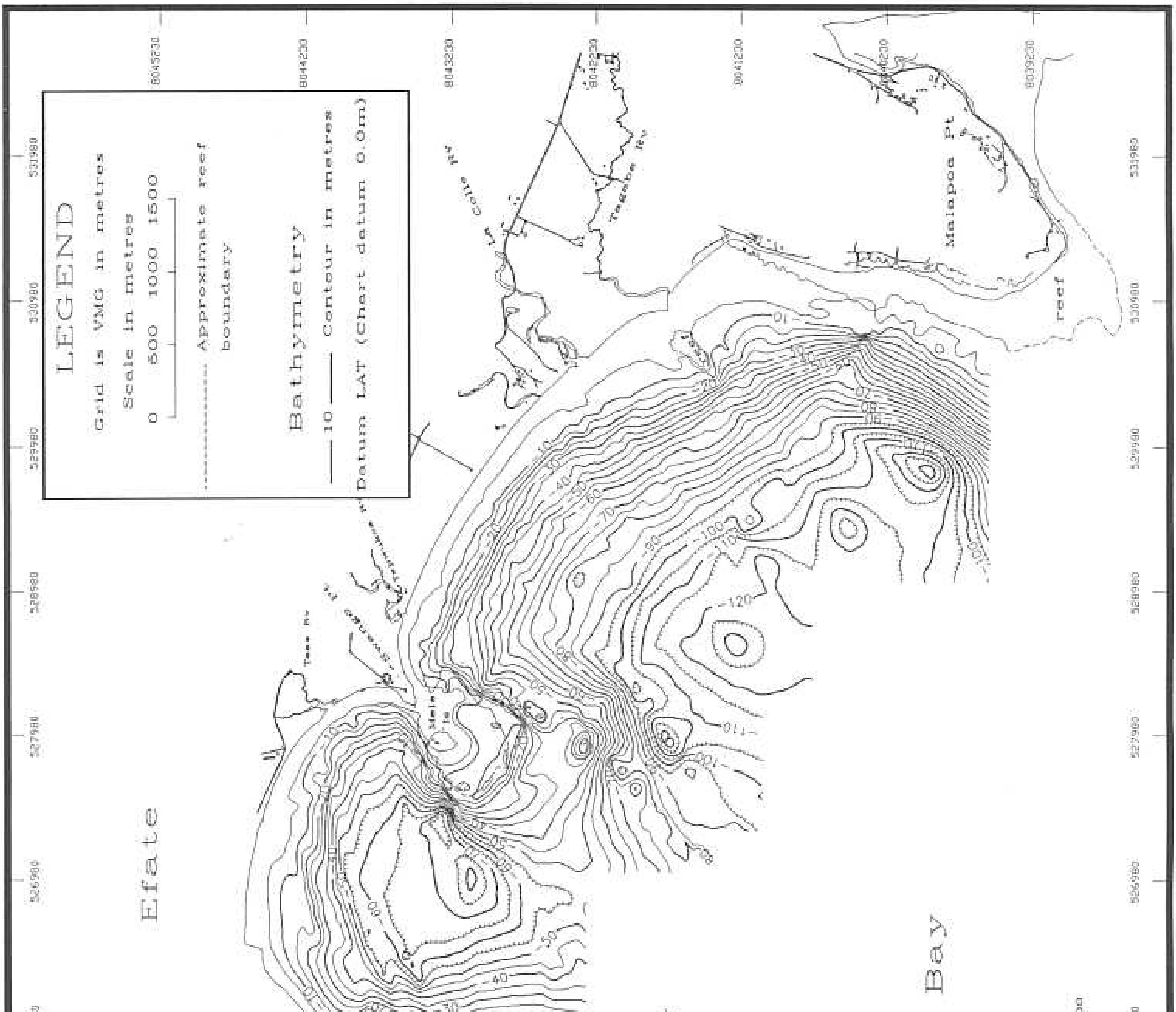

Figure 4. Nearshore bathymetry of Mele Bay.

TB9
G Fig 11

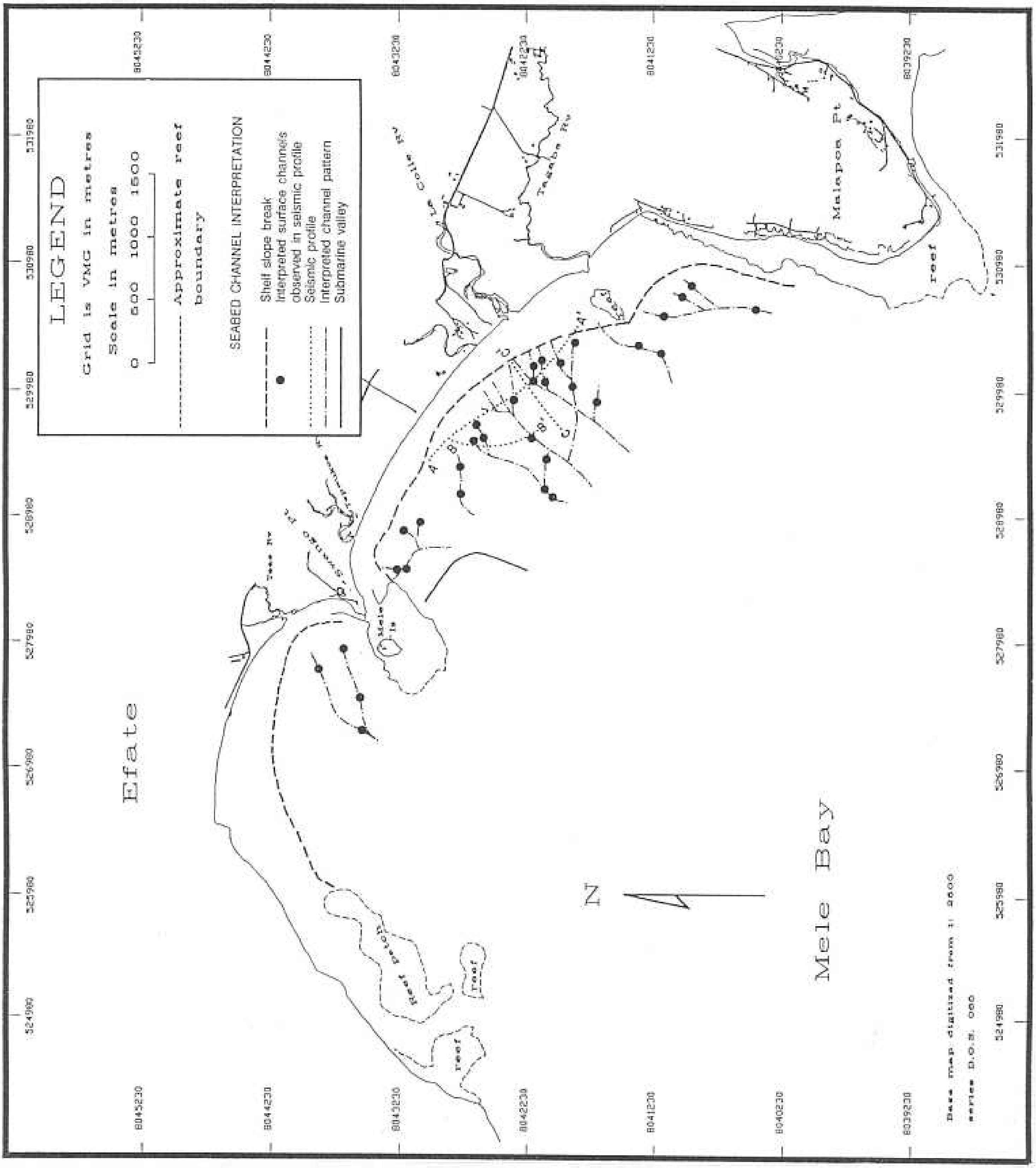

Figure 5. Map illustrating interpreted shelf slope channel distribution.

TB9, G, Fig 12

Figure 6 is a profile (AA' see Figure 5 for location) traversing sub-parallel to the coastline adjacent to the deltas of the LaColle and Tagabe rivers, showing the extensive channel development of the shelf slope.

Pronounced channel development appears to be most prominent in the central portion of Mele Bay adjacent to the LaColle and Tagabe rivers. Evidence of palaeo-channels (Figure 7) being infilled was noted on some profiles, suggesting that these slope channels are quite mobile. A submarine valley originating east of Mele Island, trending eastwards initially before turning to the northeast, is also seen in the bathymetry.

Seismic Interpretation

The analysis of thirty two 3.5 kHz profiles revealed three different seismic zones in the survey area, based on acoustic characteristics. The inferred seismic zone types noted were reef or reef-associated bedrock, stable and unstable sediments (Figure 7).

Reef/reef Bedrock

A strong seabed reflector, with opaque sub-bottom detail. Strong hyperbolic diffracted wave patterns are characteristic. Locations of this type of seabed are shown in Figure 7. In the northwest portion of Mele Bay, buried reef underlies surficial sediments of varying thickness at the end of lines 101, 102 and start of line 100. Reef does outcrop at the seafloor south of the end of these lines.

Other reef/reef associated bedrock seafloor is seen to extend south and southeast of the Mele Island reef platform. Strong seabed reflections with an opaque sub-bottom characterise this area.

Stable Sediments

In stable sediment areas such as the northwest portion of Mele Bay (Figure 7), the shelf slope and basin floor are smooth and linear.

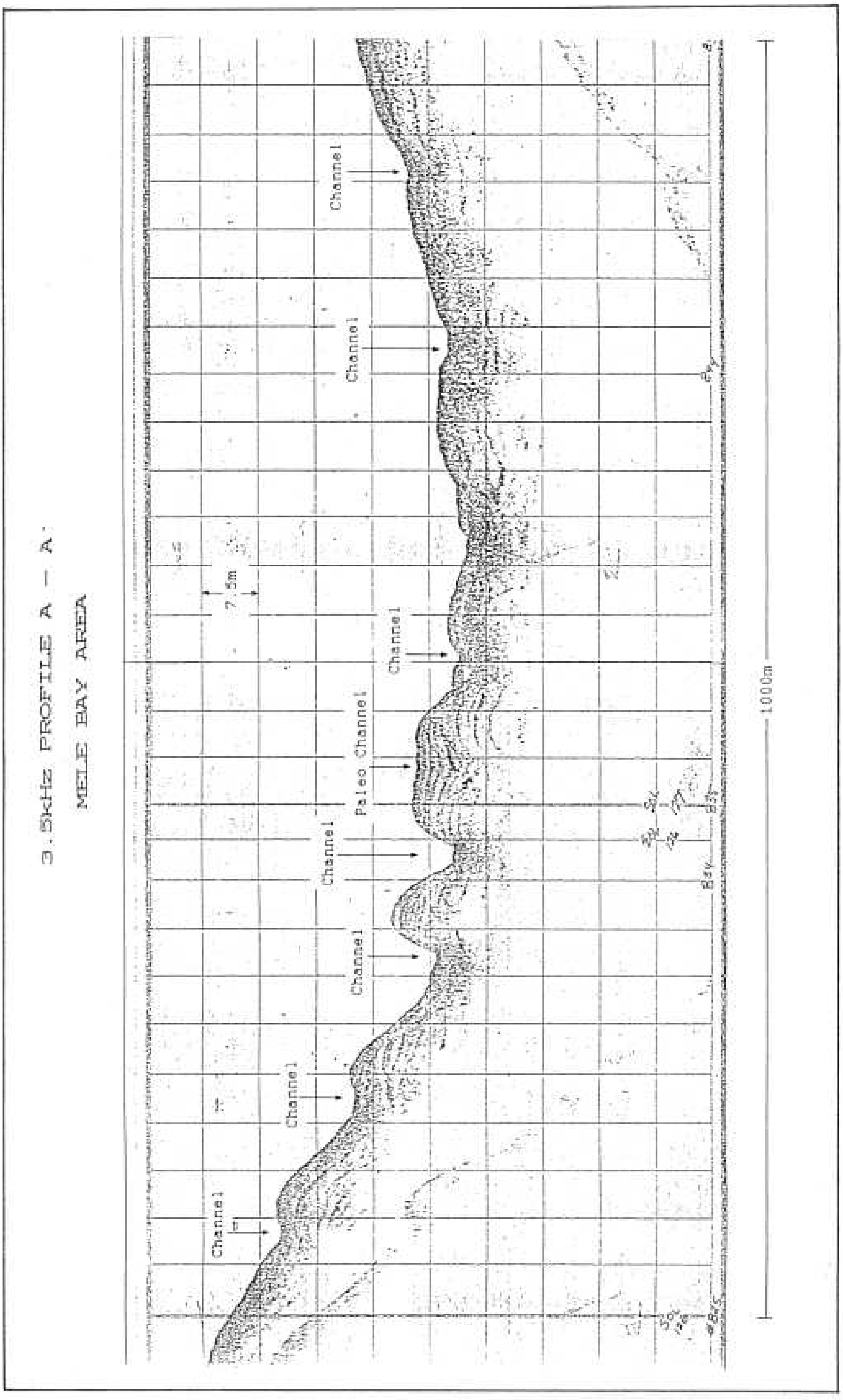

Figure 6. Seismic profile AA' of lines 126, 127 showing extent of channels incised in the self slope.

 TB9, G, Fig 13

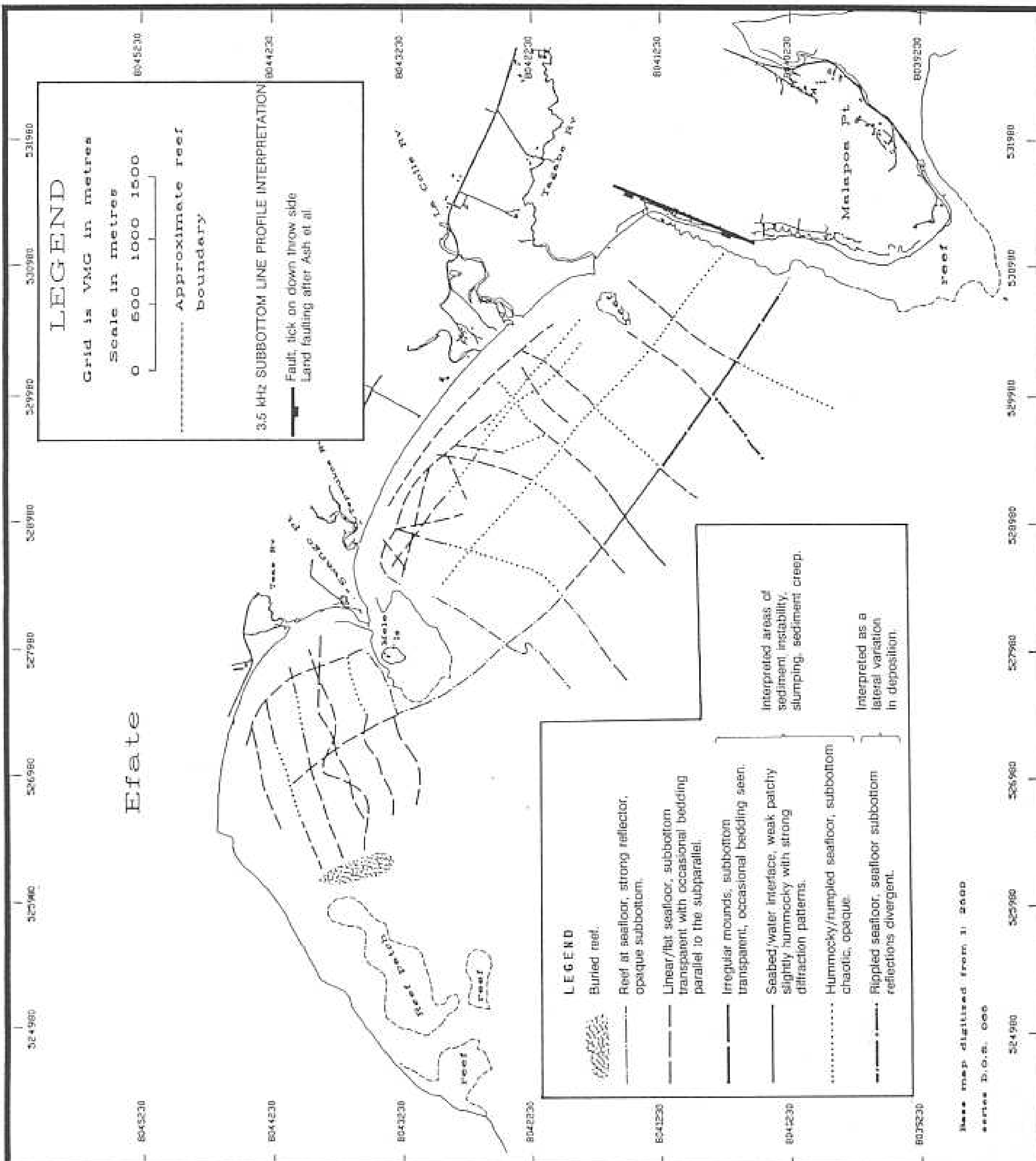

Figure 7. Seismic facies interpretation of seismic line data.

TB9, G, Fig 14

In the subsurface, acoustically-transparent sediments with the occasional burst of high amplitude, but discontinuous, parallel to sub-parallel reflections are characteristic.

Unstable Sediments

Indications of sediment instability in the nearshore of Mele Bay is most evident. Seafloor and subsurface features seen in the 3.5 kHz profiles that indicate sediment instability are hummocky topography, internally chaotic or discontinuous seismic reflections, step faulting and deformed bedding.

Pronounced hummocky seafloor on the lower portion of the shelf slope is most common. In the subsurface, seismic reflections range from transparent with occasional bedding to chaotic and opaque sub-bottom detail. In Figure 8, hummocky topography with a semi opaque internal structure on line 106 is shown. Slope gradient here is 3.5 degrees and above this the upper shelf slopes are as high as 7 degrees between fixes 223-231. Here, individual hummocks are up to three metres high.

In the eastern part of Mele Bay, adjacent to the LaColle and Tagabe rivers, there is extensive slope channelling, slumping and sediment creep. On the shelf slopes off the LaColle River delta, a block slide is interpreted adjacent to profiles 121 and 132 (Figure 9). This slide may be 500 m long on a north-north-west south-south-east axis, 120 metres wide on a north-east south-west axis and 5-10 m in thickness. This mass is estimated to represent anywhere from 90,000 -180,000 cubic metres of sediment removed from the upper shelf slope. Associated hummocky terrain on the lower shelf slope (Figure 10) sometimes in excess of 10 m high, again evidence of past sediment instability in these areas.

Adjacent to the Tagabe River and just west of Malapoa Point in the east, step faulting is interpreted at the shelf break. Figure 11 is of profile 123, illustrating this interpretation. The relief of the step faulting is estimated to be as much as 2 metres. Oblique progradational bedding is evident in the subsurface on the shelf, indicating a high energy depositional regime.

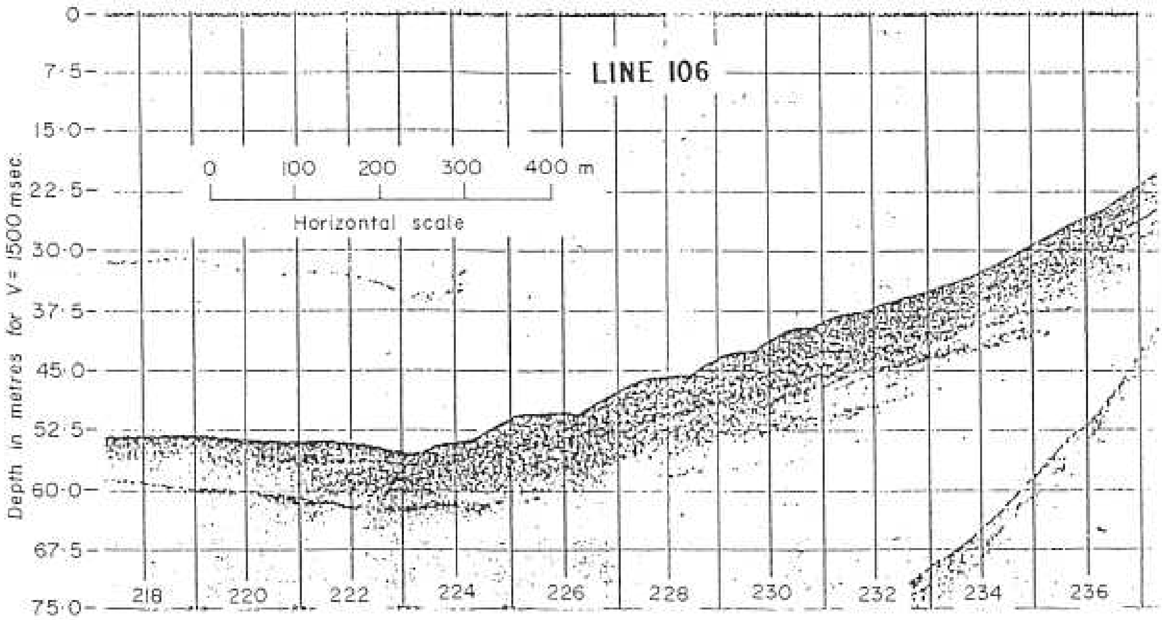

Figure 8. Hummocky topography between fixes 223-231 on the lower shelf slope adjacent to the Teae River indicating past downslope movement of sediment.

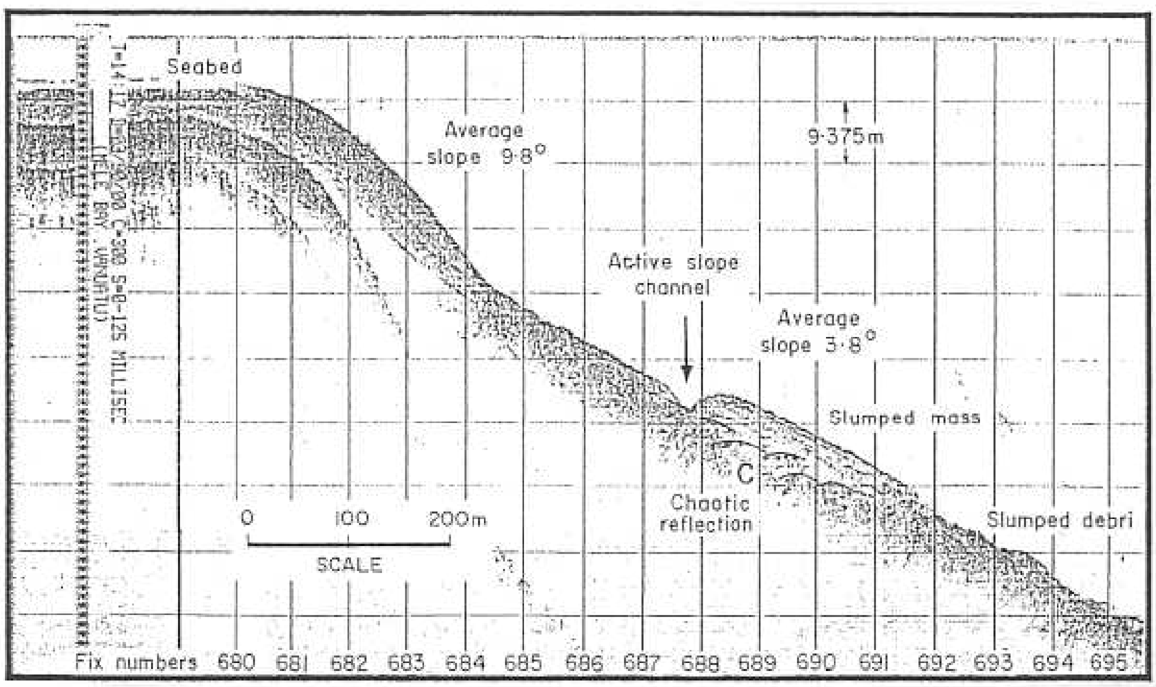

Figure 9. Seismic profile down slope showing on interpreted mud slide between fixes 688-692. Note chaotic reflection below slump-mass, an indication of an older slumping event.

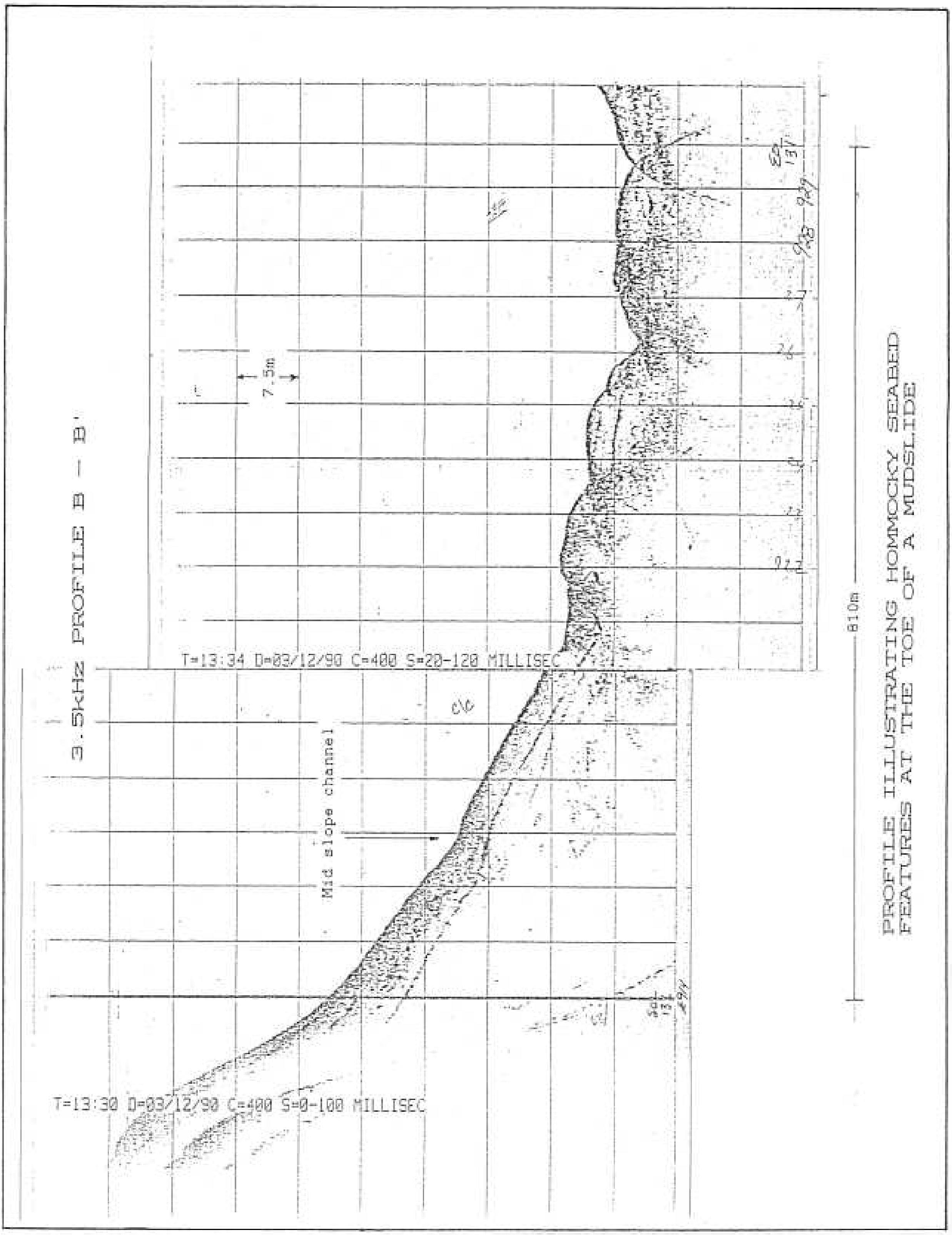

Figure 10. Hummocky seabed a resulting from downslope sediment movements.

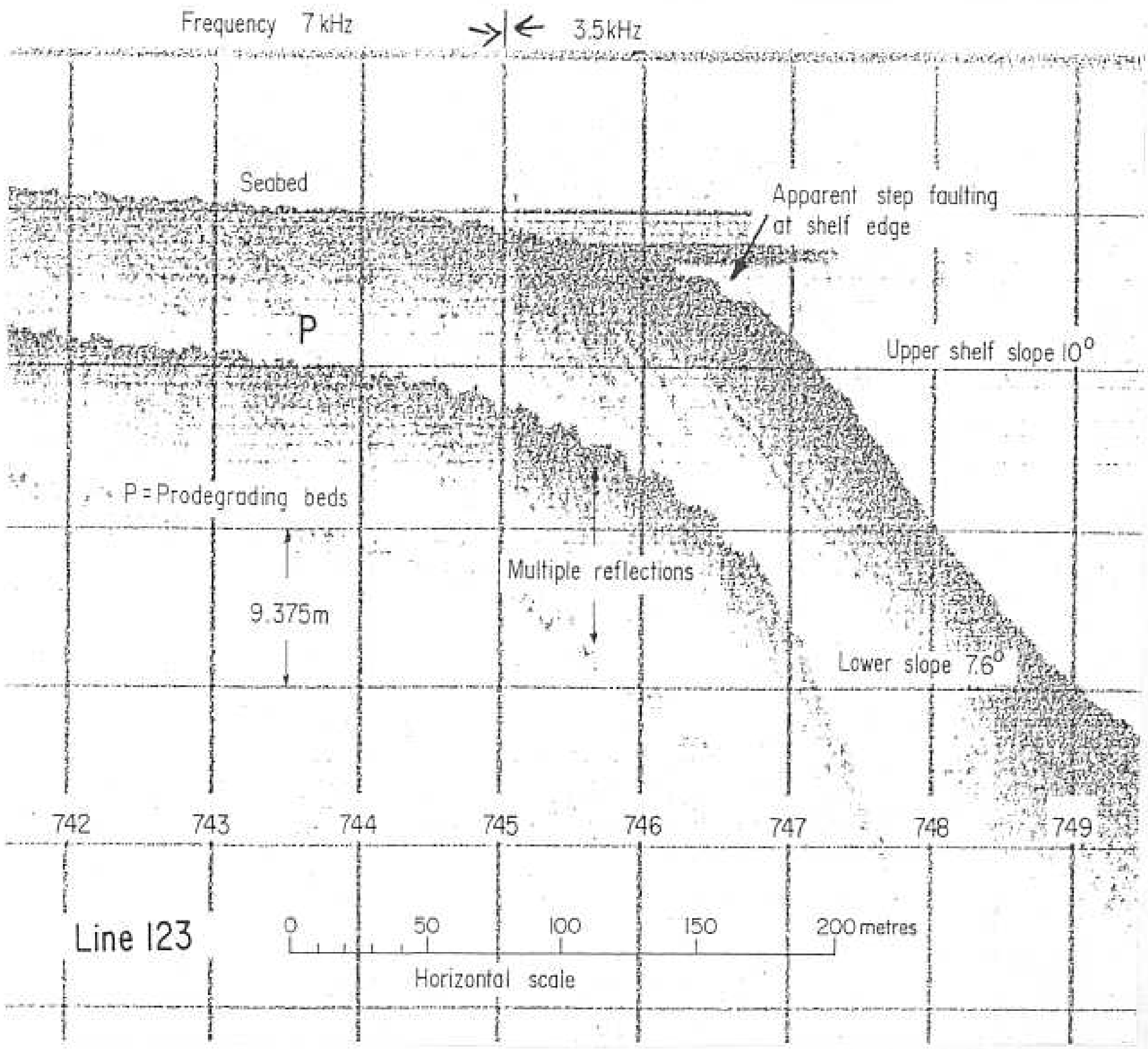

Figure 11. Seismic profile illustrating interpreted step faulting at shelf edge west of Malapoa Point.

DISCUSSION

Sediment instability is evident in the nearshore area of Mele Bay. Factors contributing to this instability are a steeply sloping bottom, accumulation of thick sediments, large storm waves, rapid sedimentation, and active seismicity.

Results of the nearshore survey in Mele Bay show the existence of a very narrow shelf below the littoral zone. Beyond the shelf-break, sea-bed slope range from 3 degrees up to 15 degrees. A slope of much less than 1 degree can be sufficient to cause sliding or slumping when a high sediment accumulation rate has resulted in under-consolidation and high pore pressure.

The mud slide off the La Colle and Tagabe deltas has no internal deformation. This type of slide can occur when a high sediment accumulation rate prevents proper dewatering so that the sediments remain unconsolidated. A slide can occur when normal or over-consolidated sediments are interbedded with one or more underconsolidated layers which then may act as slide zones (Bouma, 1981).

The effects of large storm waves can either directly influence the bottom sediment or cause severe vibrations which can be propagated to the sediment below. Mele Bay has no natural barriers that would help dissipate the effects of storm waves on the beach, which combined with a very narrow shelf below the littoral zone, means that large quantities of sediment can be moved offshore and lost to the beach system.

The active seismicity of the region is another source of energy which could initiate a mudslide. Localised Tsunami affecting the Mele Plain could be generated by such sediment slumping.

Implications of Sediment Instability

Sediment instability in the nearshore has implications for coastal erosion on Mele Beach. Any sediment lost on the upper slopes must be replaced to maintain a form of equilibrium. An event such as a mudslide removes large volumes of sediment from the nearshore zone. To replace this sediment it must therefore come from either the rivers or the shoreline or a combination of both. Recent studies (Rearic 1990) indicate that the only source of sediment replenishment is from the rivers draining Mele Plain and under present conditions, sediment input is unable to keep pace with the total amount being removed from the beach sediment system, including that being removed by beach mining.

If sediment is removed from the shelf by slumping of unstable sediments, a period of intense coastal erosion must occur to replace sediment lost by shelf slope instability, followed by a period of coastal stability or even beach deposition for a time until slope failure occurs again to repeat the cycle.

Because nearshore sediment instability is a naturally occurring problem, the implications are that significant coastal erosion may take place in cycles directly influenced by the effects of slumping and sediment creep on the shelf slope which in turn are influenced by natural events as cyclones and earthquakes. Present data are insufficient to predict the time span of these cycles.

CONCLUSIONS

1. The nearshore zone of Mele Beach is characterised by a very narrow shelf, steep shelf slopes into two intraslope basins at 80 and 120 metres depth.

2. Severe sediment instability is evident adjacent to the LaColle and Tagabe rivers and to a lesser extent adjacent to the Teae River in the northwest of the bay.

3. An extensive channel network has developed on the shelf slope, providing conduits for the rapid transportation of the sediment offshore which is consequently lost to the nearshore system, requiring replenishment by river-transported sediments or by beach erosion.

4. Sources of energy that could trigger mudslides are large storm waves and earthquakes, both frequent events in the area.

5. Localised tsunami generation in Mele Bay could be triggered as a result of slumping on the shelf slopes.

6. As there is no shoreline protection in the form of a barrier reef or deltaic sand bars for Mele Bay, the effects of large storm waves on the beach can be quite catastrophic.

7. During cyclones, rapid accumulation of sediment offshore could result in improper dewatering of the sediments forming a sediment pile that is prone to instability.

8. In dealing with such dynamic processes as are evident in Mele Bay, studies of several years duration may be necessary to understand and monitor the changes that result and to predict future events.

RECOMMENDATIONS

1. As large storms can influence the bottom sediments and the shoreline, data should be obtained on the height, period and direction of the largest predictable waves.

2. Under-consolidation is the normal result of rapid deposition of fine-grained sediments, resulting in sediment instability. Such sediments will have a high water content and low shear strength. Routine geotechnical measurements would provide data about nearshore sediment strength and slope stability.

3. Sidescan sonar of the nearshore area would improve the interpretation of sea-bed channelling, and the aerial extent of the sediment instability of the area.

4. In dealing with such dynamic processes as evident in Mele Bay, studies of several years duration may be required.

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