# SEDIMENTARY ENVIRONMENTS AND GEOLOGICAL HAZARDS ON TARANAKI CONTINENTAL SHELF

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## Abstract

Bathymetric and sediment charts for the Taranaki continental shelf have recently been updated, providing crucial baseline data for petroleum companies operating in the area. In particular, the bathymetric chart shows: the 1-5 m high scarp associated with the Cape Egmont Fault Zone; complicated bottom topography of the South Taranaki Bight; and clear morphologic definition of the Farewell Rise (or Landbridge), an area subaerially exposed at the peak of the last glacial about 20,000 years before present.

The sediment chart indicates five prominent sedimentary regimes: Maui field muds; lahar deposits fringing the Mt Taranaki ringplain; sandy and gravelly substrates found across and east of the Farewell Rise; fine-grained deposits in south Wanganui Bight; and carbonate enrichment of these sediments by bryozoan-molluscan assemblages. A combination of waves and currents, mainly generated by prevailing southwesterly swells and storms, are probably the dominant sediment transport agents operating on the Taranaki shelf at present. Semi-permanent oceanic currents and tidal flows play only a minor role. Variations in sea level through the late Quaternary have significantly affected sediment distribution patterns across the shelf. These effects are evaluated using a computer-generated model to investigate the changes of physical oceanographic conditions over recent geological time. High resolution seismic stratigraphy also provides a means of assessing the impact of sea level fluctuations.

Geological hazards on the Taranaki shelf include: recently active faulting along the Cape Egmont Fault Zone; the presence of highly mobile sandy sediments in the South Taranaki Bight; shallow gas in marine muds; and volcanic and engineering hazards associated with the lahar deposits lying offshore Taranaki Peninsula. Preliminary evaluation of these hazards indicates that little is actually known with regard to the recent activity and timing of such events, therefore, limiting the effectiveness of predictive models for future hazard and risk assessment.

New bathymetric, sediment and seismic information collected and compiled by the N.Z. Oceanographic Institute provide a valuable database for the planning of future offshore developments and for the assessment of geological hazards on the Taranaki continental shelf.

## Introduction

The Taranaki continental shelf forms the broad western approach to the narrow corridor of Cook Strait. Historically, the greater Cook Strait area has played an important role in the development of New Zealand's petroleum industry. This is primarily due to the discovery and exploitation of a large offshore gas resource, the Maui field, by Shell, B.P., & Todd Oil Services Ltd (now, Shell Todd Oil Services Ltd) in the 1950s and 1960s. Other petroleum exploration companies have also exercised considerable interest in the region, conducting extensive exploration programmes over almost all areas of the western shelf, including the drilling of numerous exploratory wells.

In 1989, an ongoing 3-year research programme was initiated at New Zealand Oceanographic Institute (NZOI), D.S.I.R. Marine & Freshwater (now National Institute of Water and Atmospheric Research), to investigate the late Quaternary sedimentary evolution of the Taranaki continental shelf, with a view to establishing seabed conditions and to assess potential geological hazards to future engineering developments in the area.

## New Bathymetry and Sediment Charts

Of particular interest to oil exploration companies operating on the Taranaki continental shelf is the recent revision and update of the PATEA 1:200 000 bathymetry and sediment charts, both of which encompass the shelf area north of 40°10'S to 39°15'S and east of 173°05'E to the Manawatu coast (175°15'E).

### Bathymetry

The original PATEA 1;200 000 bathymetry chart was first published in 1969 by NZOI with 25 m isobaths (Brodie 1969). This scale, however, fails to reveal some of the more important geomorphic variations found on the broad Taranaki continental shelf that result from faulting or sedimentary processes. In contrast, the revised version (Figure 1; Nodder and Baldwin, in press) utilises a 10 m bathymetric contour interval, in accordance with other recent NZOI chart publications. Due to the complete coverage of the area by the original Navy echosounding surveys conducted between 1959-1964 by H.M.N.Z. *Lachlan*, the same database employed in the construction of the 1969 PATEA chart was also used in the recently compiled chart. Additional bathymetric information and cross-checks of the original data set were provided by data from NZOI archives and Shell Todd Oil Services Ltd.

Some of the features of the revised bathymetric chart include:

(i) Delineation of a seafloor scarp associated with the Cape Egmont Fault Zone Van der Lingen (1971) previously employed high-resolution bathymetry to reveal a "ridge-and-valley" seafloor system corresponding with the Cape Egmont Fault Zone (CEFZ), 6 km to the east of the Maui-A production platform. This feature is clearly defined on the revised PATEA bathymetry chart. More detailed investigation across the zone indicates that a prominent scarp, 1-5 m in elevation, extends over a distance of 45 km, and is indicative of geologically recent activity on the fault.

(ii) Complex bottom topography of South Taranaki Bight Details of the complex bottom topography in the South Taranaki and Wanganui Bights, including areas of shoaling at water depths as little as 15-20 m, up to 35 km offshore, are revealed. Prominent sand ridges to the west and south of Wanganui are also accentuated by the updated bathymetry (e.g. Lewis 1979).

(iii) Morphologic definition of the Farewell Rise (or Landbridge) An elongated area of shallowing, 70-90 m below present sea level, known as the Farewell Rise, lies 45 km southwest of Opunake. This represents the remnants of a "landbridge" postulated to have been present between the North and South Islands at the time of the last glacial, c. 20 000 years ago (e.g. Fleming 1980; Proctor and Carter 1989). To the immediate east of this feature, a 2 km wide, shallow trough, marking the head of the D'Urville Sea Valley, occurs.

## Sediments

The updated version of the PATEA sediment chart (Fig. 2) is based upon an extensive data base of grain-size determinations and sediment descriptions from surface grab samples collected at up to 250 stations held in NZOI Geology archives, and supplemented by descriptive information provided by Navy charts. Compared with the previous chart (McDougall and Gibbs 1970), the revised chart significantly improves and refines our understanding of the distribution of sediments across the Taranaki shelf, while maintaining compatibility with previous charts for the area.

As depicted on the earlier sediment chart, the new PATEA chart indicates 5 prominent sedimentary regimes present on the Taranaki shelf:

(i) Fine-grained deposits dominate the shelf west of the Farewell Rise and extend to within 11 km of the Taranaki coast. Sub-bottom 3.5 kHz seismic profiles across this area reveal that this mud cover ranges in thickness from 0-20 m, attaining localised maximum thicknesses along the Cape Egmont Fault Zone. The new chart indicates a grading

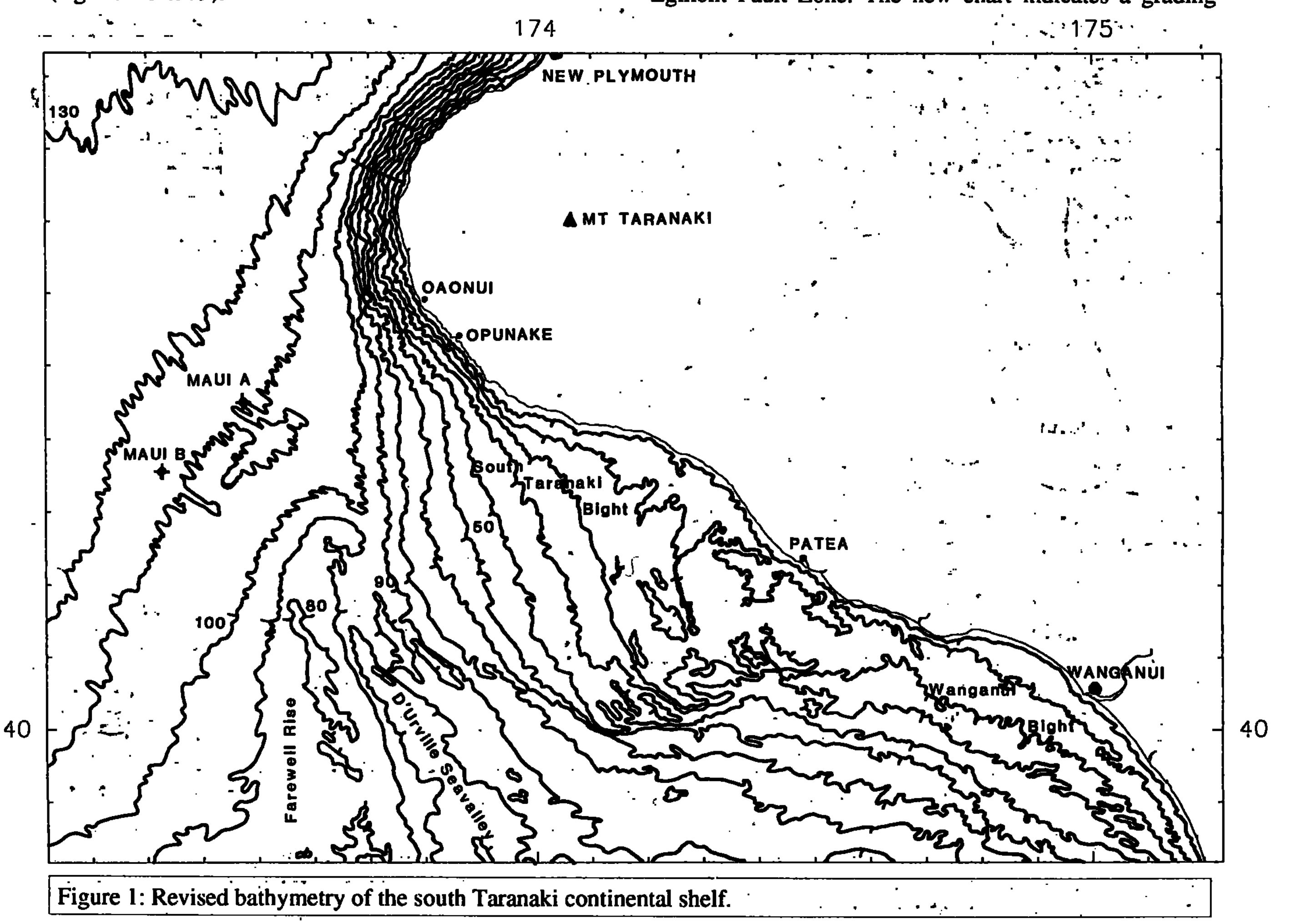


Figure 1: Revised bathymetry of the south Taranaki continental shelf.

offshore from sandy silts to silts and muds. A prominent belt of sandy muds occurs in the northwestern corner of the chart, associated with a localised patch of relict muddy sand. The relict sediment is correlated with 14 000 year old shelly sands encountered at 1-2 m depth in cores to the south.

(ii) Inshore, the muddy sediments lie above bouldery lahar deposits, derived from Mt Taranaki. The lahar deposits presently lie submerged at water depths of 0-90 m around the Taranaki Peninsula. Ages of these offshore lahar deposits is problematic; V.E. Neall (pers comm. 1991) suggests that the apron probably comprises Opua (6-7000 years old) or Pungarehu (23 000 years old) (or older) Formations.

(iii) Silty sands occur on the Farewell Rise, where continuous parallel reflectors on 3.5 kHz records are correlated with a simple core stratigraphy comprising well sorted, fine sands and shelly sands, alternating with silty muds. These sands are post-glacial deposits; $^{14}C$ dates obtained from shelly horizons reveal ages of 10-11 000 years B.P. at sub-bottom depths of 1-2 m.

(iv) To the east of the Farewell Rise, the sediment distribution becomes more complex. Calcareous muddy gravels and sands characterise the surficial sediments found in the southeastern portions of the chart, and an apron of predominantly sandy sediments occurs closer inshore, south of onshore Opunake, across the South Taranaki Bight, to Wanganui. From side-scan sonar records, it is apparent that the predominantly sandy sea floor, in fact, consists of a variety of discontinuous sand and gravel substrates, many of which appear to be highly mobile in storms, as suggested by the occurrence of megaripple bedforms.

(v) Calcareous sands and gravels, currently being studied at University of Waikato, occur south of the nearshore sand salient. Previous work by Keane (1986) on the skeletal carbonate component of these deposits indicates that it is dominated by bryozoans and molluscs (average 50 % and 20 %, respectively, in total sample), with a subdominant foraminiferal fraction (12 %).

**Sedimentary processes**

Studies by Carter and Heath (1975), Lewis (1979), and Kibblewhite *et al.* (1982) have suggested that waves and currents, mainly generated by prevailing southwesterly-westerly storms, are probably the dominant sediment transport agents presently operating on the Taranaki shelf. Once sediment has been suspended into the water column by this activity, material may be moved laterally by a combination of tidal- and storm-induced currents. Circulation patterns in the region are, therefore, dependent upon changing meteorological conditions, associated with the semi-regular passage of weather systems across New Zealand (e.g. Heath 1978; Pickrill and Mitchell 1979; Kibblewhite *et al.* 1982). Obviously, optimum conditions for sediment transport will occur when two or more of the major transporting agents complement each other at any one time. For example, this may occur particularly when tidal flows parallel prevailing wind and wave directions.

The greater Cook Strait area is a high energy wave environment, characterised by locally generated storm waves, which have average significant wave heights of 2-3 m and average periods of 6-7 s (Pickrill and Mitchell 1979;

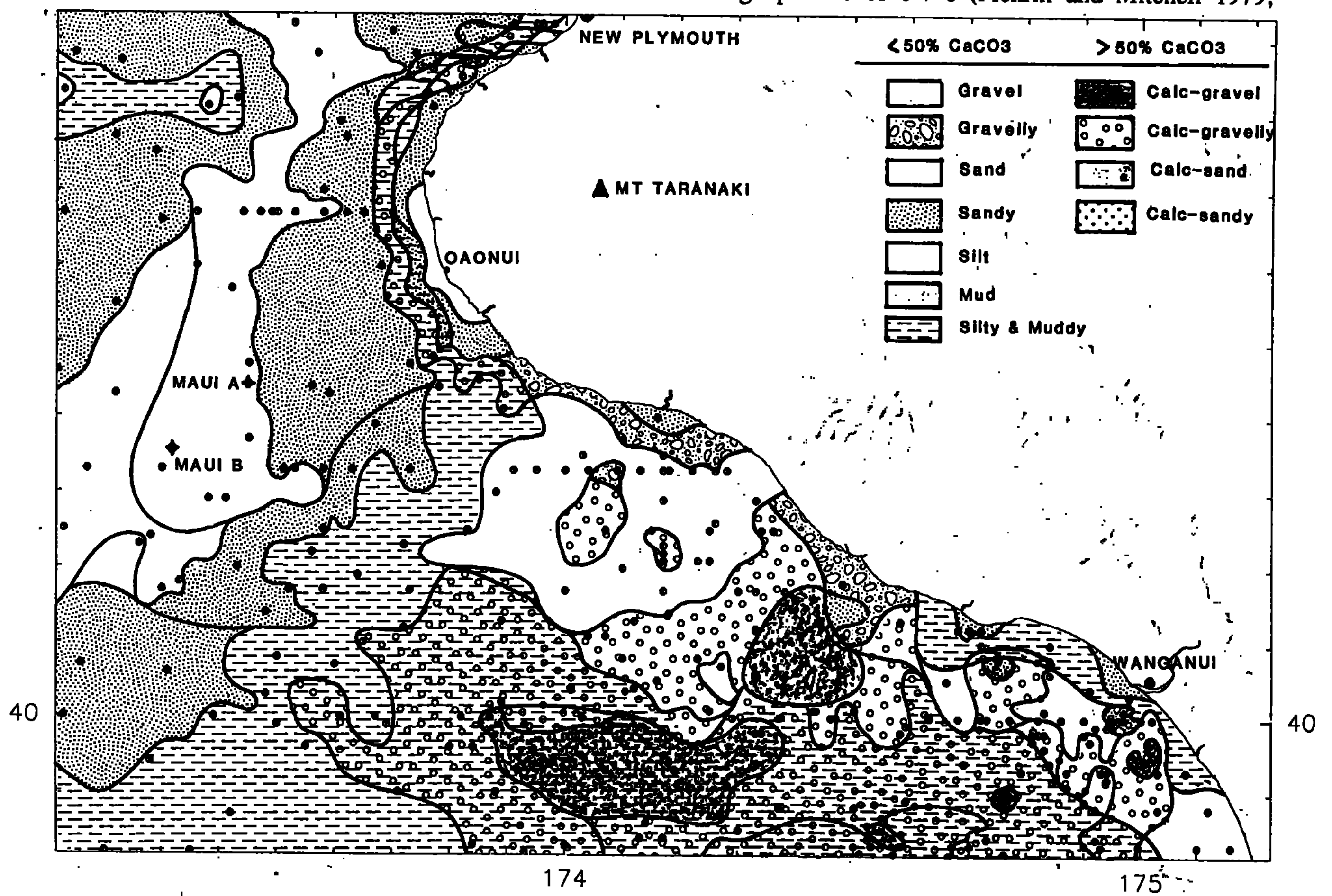


Figure 2 : Sediment distribution across the south Taranaki continental shelf. Surficial grab sample stations used in the compilation of the chart are also shown.

Kibblewhite *et al.* 1982). Superimposed upon these waves are persistent, long period (12 s), 1-3 m high, southwest-west swell waves. Waves capable of suspending fine sand at 30 m and 50 m water depths occur 67 % and 20 % of the time, respectively. At the water depths encountered in the Maui field (100-120 m), sediment will only be stirred by wave activity during the maximum 25-year storm when bottom speeds of >35 cm $s^{-1}$ may be possible (Carter and Heath 1975; BTW-NZOI Towroute report 1989).

Tides and wind-driven ocean circulation are considered weak on the Taranaki shelf, with current speeds typically less than 25 cm $s^{-1}$ (Proctor and Carter 1989), except in the vicinity of Cook Strait, where geographic constrictions and large tidal phase differences on either side of the strait enhance tidal flows.

Coast-parallel longshore currents generated by storm set-up and prevailing winds and waves are important in near-shore environments, particularly south of Cape Egmont in the South Taranaki and Wanganui Bights, where mobile sandy sediments predominate (e.g. Heath 1979; Lewis 1979; Kibblewhite *et al.* 1982). Preliminary interpretations of megaripple crest orientation in sands and gravels in the South Taranaki Bight, imaged using side-scan sonar, suggest derivation by bottom currents operating from the southwest-west quadrant, and, therefore, in accordance with previous studies (e.g. Lewis 1979).

Numerical modelling of tidal constituents, and the predicted generation of frictional bottom stresses associated with such flows (Kibblewhite *et al.* 1982; Proctor and Carter 1989) closely mimic actual sediment distribution. High stress values are typically allied with coarse sediments and sea floor erosion, while fine-grained substrates are more commonly associated with areas of predicted low stress.

**Quaternary sea level changes: control on substrate conditions**

Bathymetric information indicates that at the time of the last major sea level lowstand (-113 m) associated with the peak of the last glacial, c. 20 000 years B.P., most of the Taranaki shelf would have been subaerially exposed. Proctor and Carter (1989) have modelled the sedimentological response to the post-glacial transgression suggesting that the area of land connecting the South and North Islands was finally breached and Cook Strait formed about 15 000 years ago.

Preliminary assessment of new high-resolution, single-channel airgun and 3.5 kHz seismic reflection profiles across the Landbridge indicate that the sequence stratigraphic models developed by workers at Exxon (e.g. Vail *et al.* 1977; Wilgus *et al.* 1988), and applied to Pliocene-Pleistocene onshore sequences at Wanganui (Abbott and Carter 1990), may prove useful in interpreting the offshore seismic record. The new airgun profiles reveal a seismic stratigraphy characterised by two main seismic facies that are repeated vertically through the stratigraphic column:

(i) a facies comprising low amplitude, near-parallel reflectors that is tentatively correlated with interglacial climatic conditions and corresponding relatively high sea level conditions; and

(ii) a sequence of high amplitude, discontinuous reflectors, generally with an irregular channelised lower contact, reflecting basal erosion under lowstand glacial environments and subsequent sea level rise.

A third distinctive seismic facies, occurring only in the upper 100 m of the profiles, comprises moderate amplitude, inclined (typically <5°) reflectors, which were probably deposited by intensified tidal or storm currents when the Landbridge was breached about 15 000 years B.P. (e.g. Proctor and Carter 1989). This facies forms most of the preserved remnants of the Landbridge.

## Geological Hazards

Despite the large base of geological information collected from the Taranaki shelf by the petroleum industry since the 1950s, a fully integrated appreciation of potential geological hazards in the region has not yet been made. Such an approach requires detailed investigations using high resolution seismic data, side-scan sonar, and seabed samples, so as to define the physical attributes, anticipated return periods, and likely effects the identified hazard may have on the siting of any engineering structures.

Potential geological hazards on the Taranaki shelf are discussed below.

**Recently active faulting, particularly on the Cape Egmont Fault Zone**

The CEFZ is a major seismogenic structural boundary in the Taranaki Basin, separating the downfaulted Taranaki Graben from the tectonically stable Western Platform (e.g. Pilaar and Wakefield 1978; Knox 1982; Thrasher 1990). Historical seismicity data highlight the active nature of the zone and the very important role the CEFZ plays in accommodating strain in offshore Taranaki (Robinson *et al.* 1976; Smith and Berryman 1983). Although a portion of the CEFZ, 6 km east of the Maui-A production platform, has been previously recognised as "active" on the basis of it having sea floor expression (University of Auckland 1974), only limited knowledge of the Quaternary evolution of the fault zone exists. Work in progress at NZOI is revealing the complexities of late Quaternary structural style, segmentation, and activity of the entire fault zone.

Possible hazards of active faulting include ground shaking, liquefaction of buried sands, pipeline rupture, and structural failure of engineering works. Since the CEFZ is recognised as the design structure for the offshore Taranaki region it is important that the paleoseismic history of the zone is well documented and understood.

**Storm-generated sediment mobility**

Side-scan sonar records reveal bedforms in the sandy and gravelly substrates that indicate the periodic movement of material on the bottom at water depths less than 50 m, probably under the influence of storm-generated east-northeast directed currents. Drifter experiments by Kibblewhite *et al.* (1982) suggest that surface currents in the South Taranaki Bight generally operate parallel to the coast under the influence of local winds. Drifter speeds of 3-23 cm $s^{-1}$ were encountered. Long-term bottom current measurements or temporal studies have not been attempted in the area, but would prove beneficial to the petroleum industry.

Mobile sea floor substrates will have impacts on the stability of seabed structures; for example, extensive scour may occur around the bases of structural supports, and pipelines may become buried.

**Shallow gas**

BTW Associates (1984; formerly Buxton Tuder & Waugh Associates) report the occurrence of shallow hydrocarbon gas in the vicinity of Moki-2 well, approximately 45 km south of the Maui-A site. The proposed Maui-B site has also recently been surveyed using multichannel seismic equipment, while in the North Taranaki Bight, recent seismic trials by NZOI were able to trace subsurface gas using single channel seismic reflection techniques. However, determination of the nature, origin, and distribution of shallow gas on the Taranaki shelf has not been attempted at present.

The presence of shallow gas presents a potential hazard to the long-term stability of drilling rigs and to the safety of personnel and property during drilling operations.

**Volcanic hazards associated with Mt Taranaki**

It is recognised that the greatest volcanic hazard associated with Mt Taranaki lies in the threat of lahars or landslides (Grant-Taylor 1964). In particular, it is apparent that the western flank of Mt Taranaki is most vulnerable to collapse, therefore posing an immediate threat to the onshore Oaonui Production Station, where the gas and condensate pipelines from the Maui field are landed. Although there is very limited information currently available regarding Mt Taranaki lahar flow properties and their Quaternary chronology, lahars with volumes in the order of $10^7$ $m^3$ are likely to have recurrence intervals of 100-200 years (J.H. Latter pers comm. 1990).

Lahars are a significant hazard to the pipelines associated with the Maui field development. These pipelines presently cross an extensive area of late Quaternary submerged laharic deposits, which extend over 11 km offshore.

**Wind and wave stresses on exploration structures**

The Taranaki shelf is well known for its harsh weather and sea regimes due to exposure to swell and storm waves, and the vulnerability of the entire New Zealand region to the rapid lateral movement of weather systems.

The longevity of structures depends upon adequate engineering design criteria being used to account for such harsh environmental conditions. Many engineering structures are designed to have a lifespan of between 30-50 years, but must be capable of withstanding large storms on the Taranaki shelf with return periods of 25 years or less.

## Conclusions

New baseline data has been provided by the revision of the PATEA 1:200 000 bathymetry and sediment charts. This data will be valuable for planning offshore development, such as positioning pipelines or the targeting offshore aggregate resources. Geological hazards occur within the region. These include active faulting, particularly within the Cape Egmont Fault Zone, mobile seafloor substrates, and volcanic hazards associated with onshore Mt Taranaki. To date, assessment of the risks associated with these hazards has not been of sufficient detail to develop appropriately accurate predictive models. New high-resolution seismic reflection, side-scan sonar, and seabed sample information, together with the updated bathymetry and sediment charts, provide an important base for such assessments.

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## Acknowledgements

I wish to thank Philip Barnes, NZOI, for editing a draft manuscript of this paper and would like to acknowledge the assistance of co-authors Ruth Baldwin, Nicola Edwards, and Martin Burrows in the completion of the two revised charts. Some of the data presented here has been reproduced with the kind permission of Shell Todd Oil Services Ltd.

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