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Late Cenozoic Geology of the West Coast Shelf between Karamea and the Waiho River, South Island, New Zealand

by

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ABSTRACT

The structure of the west coast shelf is dominated by a major fault lying close to the shoreline - the Cape Foulwind Fault. This fault extends at least from Kahurangi Point to Jackson Head and may well extend north across the western entrance to Cook Strait and southward to Milford Sound, where it probably merges with the Alpine Fault.

The Cape Foulwind Fault is closely associated with an en echelon series of open folds collectively called the Karamea Bight Anticline. The folds lie immediately east of the fault, which is very steep, but may have reverse slip and an easterly dip. The amount of strike slip, if any, is not known.

Late Pleistocene and Holocene sediments of the Hawera Series rest unconformably on folded and faulted Tertiary and early Pleistocene rocks. The Hawera sediments are generally not faulted or folded, but conceal many fault scarps and erosional features cutting the older rocks below. The Hawera sequence includes many local unconformities, filled gullies, and channels, as well as buried glacial deposits south of Hokitika.

Apart from Hokitika and Cook submarine canyons, the present shelf is everywhere now undergoing sedimentation.

INTRODUCTION

This report describes the stratigraphy, structure, and late Cenozoic history of the continental shelf between Karamea and the mouth of the Waiho River off the west coast of South Island, New Zealand. The sedimentary and structural patterns of the Karamea Bight area north of Cape Foulwind (van der Linden and Norris 1974) are well-known; the inner part of the shelf was cut in Tertiary and lower Quaternary folded strata during mid-Pleistocene low sea levels and subsequently covered by late Pleistocene and Holocene marine sediments. A similar stratigraphic sequence can be recognised in the shelf south of Cape Foulwind. Furthermore, the seismic characteristics of some of the Tertiary units such as the limestones are so distinctive and prominent that they can be recognised in the profiles with some confidence. However, such distinctive stratigraphic horizons are not present in all profiles, and dating beds in such cases remains somewhat speculative owing to incomplete

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stratigraphic and paleontologic data.

The upper Quaternary sediments typically increase in thickness seaward, forming a delta-like plain floored by formations lenticular in cross-section with maximum thicknesses varying from about 40 m to more than 300 m. The smallest maxima occur near Cape Foulwind and the greatest off the glaciated coast in the southern part of the area.

Although very little published information exists on the geology of the west coast shelf south of Cape Foulwind, considerable data have been collected by the New Zealand Oceanographic Institute and by the following companies, Esso Exploration and Production (N.Z.) Ltd, the Marine Mining Corporation, the New Zealand Petroleum Co. Ltd, Shell-BP-Todd Oil Services Ltd, and Magellan Petroleum (N.Z.) Ltd. As most of the proprietary part of this information has recently become available to the general public, it seems useful to publish a summary interpretation of the data collected in order to assist others interested in the geology of the area. The area covered in this study is shown in Fig. 1. The information used comes from a variety of sources, outlined below.

The Marine Mining Corporation obtained a mineral exploration concession on parts of the shelf west and south of South Island in the late 1960s. Their investigation sought to assess the potential of any submerged placer deposits for gold and other heavy minerals. Marine Mining Corporation contracted with Alpine Geophysical Associates to conduct a continuous sparker profile and sampling programme in the concession areas. This report is concerned, in part, with that portion of their concession area lying off the west coast of South Island.

Esso in 1968–69 conducted a seismic profiling using an Aquapulse energy system, to evaluate the petroleum and natural gas potential of the west coast area [Esso Exploration and Production (N.Z.) Ltd, 1968 : Geophysical report P.P.L. 712 (South Greymouth). Unpublished Petroleum Report P.R. 400, N.Z. Geological Survey Library, and 1969 : Final report of marine seismic surveys P.P.L. 711 (Offshore Karamea). Unpublished Petroleum Report P.R. 701, N.Z. Geological Survey Library]. Magellan Petroleum [Magellan Petroleum (N.Z.) Ltd, 1971 : Marine seismic survey, Westland area, review incorporating N.Z. Petroleum Co. data of a 1971 survey, unpublished Petroleum Report P.R. 575, N.Z. Geological Survey Library] obtained about 400 km of reconnaissance sparker profiles in 1969, and in 1970 an additional 160 km of air-gun profiles, in areas they considered to be of greatest interest.

Shell-BP-Todd [Shell-BP-Todd Oil Services Ltd, 1967 : Marine seismic reconnaissance survey - Greymouth offshore, N.Z. (written by M.H. Fland, *in* unpublished Petroleum Report P.R. 548, N.Z. Geological Survey Library] in 1966 investigated an area of about 3900 km^2 off Greymouth using standard explosive reflection profiling. In addition, N.Z. Oceanographic Institute cruises have produced sub-bottom profiles of parts of the area.

LIMITATIONS OF THE DATA

The interpretations in this paper are tentative because there is only one independent check in the form of a drill hole [Haematite Petroleum (N.Z.) Ltd, 1970 : Haku-1 drill hole, unpublished Petroleum Report P.R. 553, N.Z. Geological Survey Library]. There is no piston coring against which the interpretations may be evaluated. Apart from some shell and wood samples turned over to the N.Z. Geological Survey for carbon-14 dating (S. Nathan, personal communication 1976), the drill samples and descriptions obtained by Alpine Geophysical Associates appear to be lost or destroyed. Furthermore, the seismic profiles are often imperfect, with gaps in critical places, and although they are closely spaced, particularly those made by Alpine Geophysical Associates, minor folds, faults, and channels are difficult to trace from one profile to the next. Moreover, a structural feature shown on a single profile gives no evidence of trend, and its strike can be inferred only by reference to known local or regional trends. For the most part, the structural grain in the west coast area parallels the trend of the coast, and this pattern is assumed to be dominant offshore as well as on shore.

The N.Z. Oceanographic Institute records include only line drawings of the Alpine profiles; none of the original seismic profiles was available. These line drawings and oil company isopach maps of strong reflective horizons and basement contour maps were used in this report. While it may be presumed that both were prepared with skill and care, they involve elements of interpretation which may either emphasise or omit details present in the original records. Time did not permit a re-interpretation of the oil company profiles, and the original Alpine profiles appear to have been destroyed. Unfortunately, the depth of penetration in many of the more recent N.Z. Oceanographic Institute profiles is not great enough to provide an independent check of the Alpine or oil company data. However, the boomer profiles made by the N.Z. Oceanographic Institute and discussed by van der Linden and Norris (1974) tie in reasonably well with the structural features mapped by Alpine and Esso in the area north of Cape Foulwind.

The locations of the seismic profiles on which this report is based are shown in Fig. 2 (in pocket at back).

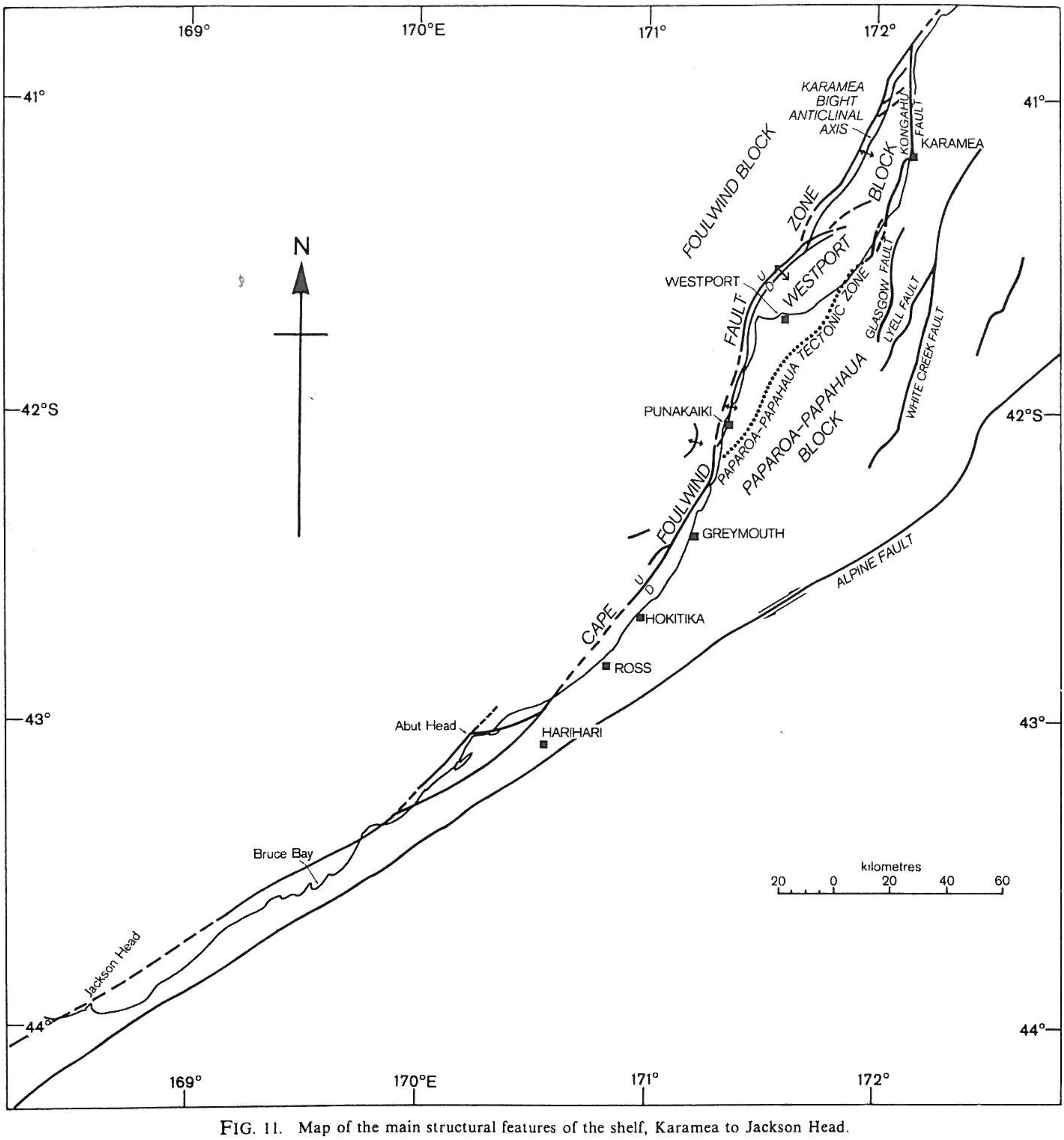

FIG. 11. Map of the main structural features of the shelf, Karamea to Jackson Head.

rather a series or chain of en echelon folds lying along the eastern side of the Cape Foulwind Fault.

Offshore from Punakaiki another minor anticlinal fold is evident in the pre-Hawera rocks as well as in the basement surface. This fold lies about 8 km offshore and follows an arcuate curve with its convex side towards shore (Fig. 11).

A number of Alpine profiles show other folds in the pre-Hawera rocks, but none is traceable for more than about 12 km. The majority appear on only one of the sparker profiles and cannot be matched with features shown in the basement topography. Where traceable, most of the offshore fold axes strike between 10 and 25 degrees east of north. Moreover, it is clear that the block west of the Cape Foulwind Fault is much less deformed than the block to the east of it.

Freund (1971) in his investigation of the Hope Fault in northern South Island, calls attention to the association of obliquely trending synclinal folds with the Hope Fault. Grant-Taylor (1967) notes a similar association of folding and faulting in the Wellington area. Although Freund agrees that there is some evidence that faulting occurred first and that the folds are secondary structures, he thinks it more likely that both folds and faults are different consequences of the same underlying cause. While the Karamea Bight Anticline and the Cape Foulwind Fault zone are almost parallel, their relationship seems generally analogous to the association of folds and faults mentioned above.

FAULTING

Faulting is indicated on the Alpine profiles by abrupt changes in dip or by a sharp break in the continuity of beds (reflectors). On the oil company basement maps faulting is also indicated by abrupt changes in depth to basement. Some features mapped as faults locally pass into sharp monoclinal folds and others are closely associated with buried sea cliffs or shoreline angles. If the feature in question is marked by a discontinuity of bedding that can be traced from profile to profile but varies in depth, then a fault origin is more likely than an erosional origin. Sea cliffs and shoreline angles should maintain a similar elevation from profile to profile.

The most important fault shown by the Alpine and oil company profiles is the Cape Foulwind Fault (Fig. 11) which may extend as much as 560 km from near Kahurangi Point southward to beyond Jackson Head. It could also be described as a fault zone; the oil company basement maps suggest that it is composed of a number of closely spaced but en echelon segments north of Greymouth at least, and S. Nathan (personal communication, 1976) points out that detailed mapping in south Westland suggests that it becomes a very wide fault zone there.

Mutch and McKellar's mapping (1964) suggests that segments of this fault are exposed on land at Tititira Head and on either side of the Moeraki River mouth. South of the Moeraki River the fault zone appears to strike out to sea, passing close to the Open Bay Islands and joining a fault zone extending south from Jackson Head for about 11 km, also mapped by Mutch and McKellar (1964). However, S. Nathan (personal communication, 1976) questions the existence of faulting near Jackson Head. Although this seafloor segment has not been established by any profiles, its existence seems possible. There is some likelihood that this large fault zone continues south close to shore, eventually merging with the Alpine Fault zone near the entrance to Milford Sound, although there is, at present, little firm evidence that the Cape Foulwind Fault extends south of Haast. It nevertheless seems probable that the Cape Foulwind Fault zone extends as much as 560 km along the west coast of South Island, and there is a possibility that it may continue northward across the western entrance of Cook Strait to join either the Cape Egmont Fault (van der Linden 1971) or a parallel fault.

Immediately west of the Cape Foulwind Fault, the depth from sea level to basement varies from less than 1950 m off Cape Foulwind to more than 2250 m off the mouth of the Little Wanganui River about 50 km to the north. Southward, off Punakaiki, it lies 2200 m below sea level. Still farther south, in the vicinity of the Cook River mouth, the basement surface on the seaward side of the fault descends to as much as 4500 m below sea level. In contrast, on the east side of the fault, the basement surface is very close to or at the surface from Cape Foulwind south to near Greymouth; Bowen (1964) shows land exposures at several places near the shoreline. In addition, various types of basement — Foulwind granitic rocks and Greenland Group greywackes and argillites — are exposed close to the fault on its east side at the Mikonui River, between the Waitaha and Wanganui Rivers, near the mouth of the Waiho River, and at several other places as far south as Jackson Bay. Though the surface of the basement is much higher on the eastern side of the Cape Foulwind Fault zone than on the western side, it is quite irregular and in some places is quite deeply buried. For example, the basement surface on the landward side of the fault lies about 900 m below sea level off the mouth of the Mokihinui River, descending to near 1900 m off Karamea. These values are summarised in Table 3. These data show that the basement surface is vertically separated by as much as 4000–5000 m in some places, but at other places, often only a few kilometres away, the apparent offset is much less. This marked variation appears to be due to differential uplift of the pre-Tertiary basement and folding of the overlying Tertiary succession, and possibly to an unknown amount of strike-slip movement on the fault. Some of the variation may be due also to the initial relief on the basement before the overlying sedimentary blanket was deposited. In short, although there is insufficient information at hand to allow an accurate determination of either the vertical or horizontal offset on the Cape Foulwind Fault, it is clear that the west side is relatively depressed. Whether the fault is dextral or sinistral, or even has any transcurrent movement, is unknown. Most nearby faults on land with similar strike have a reverse offset and a sinistral pattern of movement.

It seems likely that the Cape Foulwind Fault has a reverse slip and conforms generally to the pattern seen on many other faults in northern South Island including the Awatere, Clarence, Alpine, and Jollies Pass (Bowen 1964). The White Creek Fault, usually credited with causing the 1929 Murchison earthquake, and the Inangahua Fault, along which the 1968 Inangahua quake originated (Adams *et al.* 1968), both show sinistral as well as reverse offset — both earthquakes were accompanied by prominent ground shortening. Similarly, the Paparoa Tectonic Zone which extends along the coast from about Greymouth to Westport, is nearly everywhere a high-angle thrust (Laird 1968).

Although the Cape Foulwind Fault is obviously a young feature, cutting beds of late Tertiary and early Quaternary age, evidence for late Quaternary activity is much less obvious. As far as the Alpine sparker profiles and the N.Z. Oceanographic Institute 3.5 kHz acoustic records go, they contain very little evidence of continued offset, as upper Quaternary beds seem to continue undisturbed across the fault nearly everywhere. There are a few profiles, however, in which there is a slight suggestion of continued vertical offset (Fig. 12). Strike-slip is much more difficult to recognise on the profiles and, if such movement has been significant during the later history of the fault, it could easily go undetected on the profiles.

Between 1940 and 1964, about 15 shallow-focus earthquakes of Richter magnitude 4.0 and over have had epicentres on the seafloor between Kahurangi Point and Greymouth (Eiby 1970). Perhaps half to two-thirds of these show a crudely linear pattern corresponding roughly to the trace of the Cape Foulwind Fault. This shows only that recent tectonic activity is occurring in the vicinity of the fault, and it may be premature to suggest that these earthquakes provide clear evidence of continuing activity on the Cape Foulwind Fault.

CRUSTAL BLOCKS

The seafloor between Westport and Kahurangi Point is divided into three crustal blocks bounded by zones of folding and faulting (Fig. 13). The easternmost block lies almost entirely on land and includes the Paparoa Range between Greymouth and the Buller River and the Papahaua Range north of the Buller. The western margin of this block has long been regarded as a fault, mainly on physiographic evidence. However, a study by Laird and Hope (1968) recognises faulting only north of the Ngakawau River — The Kongahu Fault. They suggest instead that the western boundary of the range is mainly an overfold. Laird (1968) suggests that the overfold north of the Buller River may be traced into the Paparoa Tectonic Zone south of that river.

The Esso maps of offshore basement structure show that the crustal block lying between the Paparoa-Papahaua block and the Cape Foulwind Fault is an eastward tilted slab bounded on both sides by faults or sharp folds. This is here referred to as the Westport block and although folding is evident along both its margins, it is most evident on its western edge. These western folds comprise the series of anticlines which collectively have been called the Karamea Bight Anticline by van der Linden and Norris (1974).

Esso basement maps also extend some distance to the west of the Cape Foulwind Fault and show that the seaward slab — here referred to as the Foulwind block (Fig. 13) — is likewise depressed and moderately folded along its eastern edge where it is in contact with the Cape Foulwind Fault. The surveys do not extend far enough west to reveal either the location or nature of the western boundary of the Foulwind block. If the pattern seen in the Westport block is similar to that in the Paparoa-Papahaua block to the east, the Papahaua-Paparoa Tectonic Zone may prove to be a series of tight folds lying landward of a zone of en echelon or overlapping faults, much like the association between the Karamea Bight Anticline and the Cape Foulwind Fault.

TABLE 3. Depths in metres to basement surface from sea level, along east-west lines across the Paparoa Tectonic Zone and Cape Foulwind Fault.

East-west line through	East side Paparoa Tectonic Zone	West side Paparoa Tectonic Zone	East side Cape Foulwind Fault	West side Cape Foulwind Fault	at Longitude 171°E
Karamea River mouth	—	2350	1890	2500	1740
Little Wanganui River mouth	1680	2440	1840	2260	1770
Mokihinui River mouth	negligible	2350	920	1890	2070
Waimangaroa River mouth	negligible	1710	0	1950	2070
Belfast Creek mouth (42° S lat.)	negligible	?	0	2170	1890
Canoe Creek mouth (42° 12'30"S lat.)	—	?	negligible	1560	1980
Point Elizabeth	—	?	?	1830	2110
Gillespie Point			shallow	4150	
Heretaniwha Point (43° 35'S lat.)			shallow	4570	
Tokakoriri Creek mouth (43° 42'S lat.)			negligible	4400	