

**GEOLOGY OF THE EASTERN NEW IRELAND BASIN, NORTHEASTERN
PAPUA NEW GUINEA**

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ABSTRACT

The eastern part of the arcuate northwest-trending New Ireland Basin is some 600 km long by 150 km wide, and most of it lies offshore northeast of New Hanover and New Ireland. This study integrates onshore geology with offshore reflection seismic profiling and limited sampling to provide a coherent picture of basin geology and petroleum prospects.

Most of the basin is a structurally simple downwarp which formed as a fore-arc basin lying between an Eocene to early Miocene volcanic arc in the southwest and an outer-arc high in the northeast. It contains up to 5 km of sedimentary rocks interpreted as generally consisting of early Miocene and possibly Oligocene volcanoclastics, early to late Miocene shelf carbonates, late Miocene and Pliocene bathyal chalks and volcanoclastics, and Pleistocene to Recent sediments ranging from terrestrial conglomerates to hemipelagic oozes. In the eastern part of the basin Plio-Pleistocene volcanism has formed islands and has greatly disturbed the older strata.

Petroleum prospects offshore appear to be moderate. Early to late Miocene clastic and carbonate source rocks appear to be present, and presumed reefal bodies in a thick and deeply-buried early to late Miocene platform carbonate sequence, similar to the widespread Lelet Limestone of New Ireland itself, could form traps.

INTRODUCTION

This paper integrates onshore and offshore geological and geophysical data in the eastern part of the New Ireland Basin in northeastern Papua New Guinea, in order to better comprehend its regional geology and petroleum prospects. The basin is an arcuate feature extending 900 km northwestward from the Feni islands in the east to Manus Island in the west (Figs 1&2). It is bounded by the 6000 m deep Manus- Kilinailau Trench* in the north, and the 2500 m deep Manus Basin in the south. The eastern part of the basin (Fig. 2) is up to 150 km wide and includes both New Ireland and New Hanover.

The basin has a gentle overall slope to the northeast, with axial water depths increasing from around 1500 m in the northwest to 3000 m in the southeast. It has been truncated on the southwest by a series of major coast-parallel onshore and offshore faults with overall vertical displacement of more than 2000 m (eg. Connelly, 1976); these are related to the Pliocene-Recent formation of the Manus Basin, a spreading marginal basin (Taylor, 1979).

The New Ireland Basin was shown by Exon & Tiffin (1984) to be a relatively simple downwarp with up to 5 km of Oligocene and younger sedimentary fill, which was a forearc basin to the trench to the north in Eocene and Oligocene times. Two outer- arc highs to the north, the Emira-Feni Ridge and the Nuguria Ridge (new names) limit much of the depositional basin. Evidence from Mussau indicates recent uplift of that part of the Emirau-Feni Ridge.

Eocene to early Miocene arc volcanics form basement to the basin, and there were further periods of volcanism in the early Miocene, Pliocene and Pleistocene. The Pliocene and younger volcanics of the Tabar to Feni groups of islands (Wallace et al., 1983) have cut through the southeastern part of the basin, destroying its simple structure.

* Footnote: This paper follows the nomenclature of the latest published bathymetric map (Kroenke, Jouannic & Woodward, 1983).

The presence of a thick sequence of Miocene reefal carbonates onshore (Hohnen, 1978), and possibly offshore (Exon & Tiffin, 1984) has focussed attention on the petroleum prospects of the basin. The Geological Survey of Papua New Guinea is carrying out detailed stratigraphic studies of the sequence on New Ireland, and a multichannel seismic cruise of the R.V. S.P. Lee was carried out in mid 1984 under an Australian, New Zealand and United States of America aid program for the South Pacific region under the auspices of CCOP/SOPAC, Suva.

The present report relies on reflection seismic surveys carried out by CCOP/SOPAC (Exon, 1981; Tiffin, 1981), the IFP-CEPM- ORSTOM group (de Broin, Aubertin & Ravenne, 1977), and Gulf Research and Development Company (1973), and continues the study started by Exon & Tiffin (1984). The bathymetric map (Fig. 2A) was prepared from all available data, but the structure contour and isopach maps (Figs. 2B & C) are based only the Gulf lines, of which there are 25 in the area. The assessment of the petroleum potential makes no use of the S.P. Lee's results.

Because there are no drillholes and few offshore samples in the New Ireland Basin it is difficult to provide adequate control for our seismic interpretation, which therefore relies heavily on the extrapolation of onshore geology offshore and on seismic character. It is apparent that some drilling on New Ireland, such as that proposed by the Working Group on Island Drilling at the late 1984 CCOP/SOPAC-IOC STAR Meeting in Samoa, would resolve many questions related to regional geology, source rocks, and reservoir rocks.

Regional tectonics

The tectonics of the New Ireland Basin have been discussed by several authors, including Taylor (1979), Falvey & Pritchard (1984), Exon & Tiffin (1984) and Kroenke (in press). Palaeomagnetic data (Falvey & Pritchard, 1984), in conjunction with other information, suggest that New Britain, Manus Island, New Hanover and New Ireland were all part of a northwest-facing volcanic arc in the Eocene-early Oligocene. By late Oligocene times the arc had rotated to face northeast, perhaps as the result of the formation of the Solomon Sea back-arc basin. Volcanism related to this arc ceased in the early Miocene. There followed a long period of quiescence, during which limestones were widely deposited on the arc. Following a short period of southwest-facing arc activity, probably involving the New Britain Trench, the development of the Manus Basin started in the mid Pliocene, and this led to the relative movement of New Britain southeastward past New Hanover and New Ireland. A hot and light mantle anomaly associated with the opening of the Manus Basin may

have caused the uplift of the southwestern side of the New Ireland Basin by as much as 2000 m (Johnson et al., 1979).

ONSHORE GEOLOGY

Exon and Tiffin (1984) hypothesized that the offshore sedimentary sequence northeast of New Ireland was laid down in environments similar to those of the succession exposed onshore. Plio-Pleistocene uplift of the present-day onshore area has since greatly changed relative elevations. This section summarizes the stratigraphy of the onshore sequence (Fig.3). The descriptions that follow are based partly on original stratigraphic work by Hohnen (1978) in New Ireland and by Brown (1982) in New Hanover, but also incorporate new data from onshore Stratigraphic studies being carried out by the Geological Survey of Papua New Guinea (Stewart and Sandy, in prep.).

The oldest rocks exposed on New Ireland and New Hanover are the middle Eocene to early Miocene Jaulu Volcanics, typical island arc volcanics estimated to be 2000 m thick (Fig. 3). Similar rocks are present on Mussau and the Tabar Islands (Fig. 2). The dominant lithologies are porphyritic andesite, lapilli tuff and agglomerate. Subordinate welded tuff and amygdaloidal and pillow lava also occur. Lenses and blocks of coralline and tuffaceous limestone are also present within the sequence, but their precise stratigraphic position is unclear. The island arc volcanics presumably built upward from older seafloor, and most were probably extruded in a submarine environment. Local reefs and carbonate banks developed in shallow water areas during periods of

relative quiescence.

Very little direct evidence is available to establish the precise age range of the Jaulu Volcanics. Hohnen (1978) reported a single K-Ar date of 30.7 ± 1.0 m.y. (earliest late Oligocene). Forams of early Oligocene age (Tertiary Letter Stage Tc) have been recovered from one limestone lens, and another yielded forams no younger than late Oligocene (lower Te) in age. More data are available from similar basement rocks (the Tinniwi Volcanics) on the Manus Island, which initially formed as part of the same island arc complex. There, Jaques (1980) reported K-Ar dates ranging from 47.8 ± 5.0 m.y. (middle Eocene) to 20.2 ± 0.8 m.y. (early Miocene, equivalent to planktic foraminiferal zone N5). It is probable that the Jaulu Volcanics have a similar age range.

In central and southern New Ireland, the Jaulu Volcanics are intruded by the Lemau Intrusive Complex, which consists of stocks and dykes of basic, dioritic and granodioritic composition. Three K-Ar dates from this complex have yielded ages ranging from late Oligocene to middle Miocene. The younger phases have therefore probably intruded the basal part of the early Miocene and younger sedimentary cover rocks in some places.

A small inlier of bedded Oligocene calcilutite was found on Ambitle, in the Feni islands, apparently carried up by the Plio-Pleistocene volcanics. It consists largely of planktonic foraminifera identified by D.J. Belford as of middle to late Oligocene age (Wallace et al., 1983).

With the cessation of island arc volcanism, a quiescent period of neritic carbonate and bathyal clastic sedimentation ensued, continuing until the earliest middle Miocene in northwestern New Ireland, and until late middle or late Miocene in the remainder of the island. In deeper water areas, the early to middle Miocene Lossuk River Beds accumulated at upper bathyal depths (150-500m), deposition probably commencing in mid early Miocene time (about N5 or N6). In shallower water areas the Lelet Limestone accumulated contemporaneously as a carbonate shelf. In central and southern New Ireland, the onshore carbonate succession unconformably overlies volcanic basement. In the northwestern part of the island, the Lelet Limestone appears to conformably overlie the Lossuk River Beds in places, reflecting progradation of the carbonate shelf into deeper water (Fig. 3). Similar stratigraphic relationships probably occur of€ the remainder of New Ireland as well.

The Lossuk River Beds were originally named by Hohnen (1978). In this paper, the term is restricted to a sequence of massive bedded, medium to dark grey, tuffaceous calcareous siltstone and very fine grained sandstone of earliest middle Miocene (N8) age and older. The sediments contain poorly sorted feldspar, quartz, pyroxene, magnetite, foraminifera and calcite as common constituents, and are highly weathered to form volcanic secondary minerals. They also contain visible carbonaceous and woody material, and have yielded some high values of total organic carbon (M. Glikson, pers. comm.). Neritic limestone olistoliths of probable early Miocene (upper Te) age have been identified within the sequence at one locality. Thin interbeds of

agglomerate appear in the uppermost part of the unit. The overall thickness of the Lossuk River Beds cannot be determined with confidence due to poor exposure and the lack of complete sections. The exposed portion is estimated to be some 100-200m thick, and at least a comparable thickness is believed to be present in the subsurface.

The early to late Miocene Lelet Limestone is a sequence of thick to massive bedded reefal, backreef and forereef limestones, which accumulated under stable conditions on a steadily subsiding substrate. It is apparent that many of the limestones had high primary porosity. Most of the unit appears to have been deposited in an inner to mid-neritic environment (water depths of less than about 50 m), although outer neritic facies have also been identified. Algal-foraminiferal biomicrite is the most common lithology, but in-situ coral and algal biohermal reef material has been identified in places by Hohnen (1978). Common faunal constituents include gastropods, bryozoa, echinoids, pelecypods, encrusting forams, corals, benthic foraminifera, and coralline and calcareous algae. Planktic foraminifera become more common in deeper water facies. Some algal limestones have surprisingly high values of total organic carbon (M. Glikson, pers. comm.).

The overall thickness of the Lelet Limestone cannot be determined with confidence owing to extensive faulting and the absence of complete sections. The limestone was probably deposited on a substrate with considerable relief, and its thickness may vary markedly from one area to the next. In northwestern New Ireland, where carbonate deposition terminated

early, thickness are probably about 400 - 500 m. Thicker sections are present in the Lelet Plateau area and in the northern Hans-Meyer Range, where thicknesses may approach or even exceed 1000 m.

Precise dating of the limestone sequence has proven difficult as very few samples contain age-diagnostic foraminifera. The lowermost part of the succession is of early Miocene (upper Te) age. Specific late early to middle Miocene (lower Tf) age determinations have been made from several stratigraphic levels. Two samples yielded possible late middle to late Miocene (upper Tf) ages, but how near they are stratigraphically to the top of the formation cannot be established.

In northwestern New Ireland, both the Lossuk River Beds and the Lelet Limestone are conformably overlain by an unnamed succession of middle Miocene to early Pliocene pyroclastic and epiclastic rocks, a renewed phase of volcanism commencing in the earliest middle Miocene. The volcanism stopped carbonate deposition in the immediate area, and coincided with a general period of subsidence. The unnamed succession is estimated to be between 550 and 650 thick in outcrop, and is divisible into three distinct units (Fig. 3). The lower unit, of early middle Miocene age (probably about N9), is dominantly tuff with minor interbedded agglomerate, and is about 70 m thick. The middle unit, of middle Miocene age (probably about N10-N12), consists of about 350-450 m of agglomerate, volcanic conglomerate and subordinate tuff. The upper unit, of late middle Miocene to possibly earliest Pliocene age (about N12 to upper N17 or N18), is composed of at

least 150 m of tuff, tuffaceous sandstone and tuffaceous siltstone. Preliminary paleobathymetric determinations by Dr D.W. Haig of the University of Papua New Guinea suggest that the overall sequence was deposited at depths ranging from middle to uppermost bathyal.

In areas of central and southeastern New Ireland removed from this volcanic activity, platform carbonate deposition apparently continued unabated until latest middle Miocene or late Miocene (upper Tf) time. Hohnen (1978) originally mapped two limestone units over this area: the Lelet Limestone in central New Ireland, and the Surker Limestone in southeastern New Ireland. The two units are separated by an area of late Miocene to early Pleistocene bathyal pelagic and volcanoclastic sediments. He hypothesized that late Miocene faulting separated the island into two parts, and that the gap was filled by the younger sediments. The term "Surker Limestone" is now considered redundant by the Geological Survey of PNG, and the name "Lelet Limestone" is being applied to the neritic limestone succession throughout New Ireland.

At least 160 m of southward-dipping limestone, with a maximum elevation of 180 m, rest on volcanics at Simberi, the northernmost of the Tabar Islands. The limestone is typically massive, and contains limestone clasts and the fragmentary remains of corals, algae and molluscs (Wallace et. al., 1983). Foraminiferal identifications on four samples by D.J. Belford (in Wallace et. al., 1983) showed one to be early Miocene, two to be middle to late Miocene, and the last to be Pliocene. Much of this sequence

is inferred to be of forereef origin, indicating the presence of reefs well to the north of New Ireland, and at least partly contemporaneous with the Lelet Limestone. Marine seismic data indicate that the Tabar Islands are horsts, and it is probable that these limestones are upthrown equivalents of the C-D seismic sequence that lies at depths of more than 1000 m below sea level nearby (Fig. 2B).

Furthermore, reconnaissance mapping of Mussau (C.M. Brown, pers. comm.) revealed that it contains early Miocene shelf limestone, pebbles of early Miocene planktonic foraminiferal limestone in a conglomerate, and Pliocene planktonic foraminiferal limestone. Determinations by D.J. Belford and G.C. Chaproniere include upper Te, upper Te or possibly lower Tf, and N19-29-20. A series of raised limestone terraces indicate marked recent uplift on the island.

The next youngest unit exposed in central and southern New Ireland is the late Miocene to early Pliocene Punam Limestone (Fig. 3), which crops out extensively along the east coast of the island in fault contact with the Lelet Limestone. In other areas it conformably underlies volcanoclastics of the Rataman Formation. The Punam Limestone typically consists of soft, foraminiferal biomicrite which accumulated at mid to lower bathyal depths (500-4000 m) as a Globigerina ooze. In central New Ireland, only the upper 20-30 m of the unit are exposed, and this part of the sequence is early Pliocene (N18-low N19/20) in age. Similar rocks which are probably part of the Punam Limestone are extensively exposed at Cape St. George at the southeastern tip of New

Ireland. B. McGowran (in Mitchell and Weiss, 1982) tentatively dated part of this succession as late Miocene (N16) in age. Including these sediments, the Punam Limestone could attain an overall thickness of as much as 150-200 m.

The stratigraphic relationship between the Punam and Lelet Limestones is unclear at present, as the two units have been observed only in fault contact. The offshore seismic sections discussed later in this paper suggest that the offshore equivalents of the Punam Limestone stratigraphically overlie the inferred lateral equivalents of the Lelet Limestone. If so there was very rapid regional subsidence from neritic to at least mid-bathyal depths during the early late Miocene. Field studies of the Cape St. George sequence are planned for early 1985.

The Punam Limestone is sharply but conformably overlain by volcanoclastic sediments of the early Pliocene to early Pleistocene Rataman Formation (Fig. 3), which is exposed in the narrow central part of New Ireland, and in fault-bounded blocks along both coasts southeastward, and on Dyaul Island to the northwest (Fig. 2). The appearance of the Rataman Formation signalled a short-lived phase of volcanism which affected the whole of the New Ireland area and lasted about 2 million years from mid-Pliocene to earliest Pleistocene time (N19/20 to high N21).

The Rataman Formation is largely andesitic and dacitic crystal lithic tuff interbedded with slightly to non-calcareous volcanogenic lutite. Foraminiferal assemblages indicate

deposition in mid-lower bathyal depths, and abundant sedimentary structures indicate deposition by turbidity currents. Tuffaceous units become thinner and less numerous upward, and foraminiferal biomicrites predominate towards the top of the formation reflecting a gradual waning of volcanic activity. Equivalent rocks on Dyaul Island were apparently situated nearer to eruptive centres, as they contain interbedded andesitic lava flows. Thickness estimates of the Rataman Formation are complicated by extensive mesoscale faulting: thickness is probably about 400 m.

In central New Ireland, the Rataman Formation grades upward into an unnamed limestone unit similar in lithology to the Punam Limestone. Only about 15 m are exposed, and foraminiferal assemblages indicate deposition at mid- to lower bathyal depths. Evidence from probable equivalents of this unnamed limestone in southeastern New Ireland suggests a rapid shallowing in depositional environment with time, and a gradational contact with neritic Quaternary carbonates. This would reflect the effects of rapid uplift in early Pleistocene time.

In parts of central and southern New Ireland there are more proximal time equivalents of the Rataman Formation and the upper unnamed limestone, the Uluputur Beds (Fig. 3). The unit is largely well bedded silty sandstone, but up to 10 m of poorly sorted cobble and boulder conglomerate occur in its upper part. In central New Ireland, the conglomerate clasts were derived mainly from the Rataman Formation, whereas in southeastern New Ireland such clasts were derived mainly from the Jaulu Volcanics. Rare limestone clasts apparently derived from the Lelet Limestone

occur in both areas. Foraminiferal assemblages indicate that the Uluputur Beds were deposited mainly at mid- to upper bathyal depths, and that their age ranges from mid-Pliocene to early Pleistocene (N1(19/20-low N22) in age.

The youngest clastic sediments in southwestern New Ireland belong to the Maton Conglomerate, a sequence of poorly sorted cobble and boulder conglomerate, pebbly sandstone and minor coal. This overlies the Lelet Limestone, the Jaulu Volcanics and the Uluputur Beds, and observations by Mitchell and Weiss (1982) show it to occur near several major fault systems. Hohnen (1978) postulated that it was a coalesced series of conglomerate deposits. On the basis of stratigraphic evidence, its age is probably Pleistocene.

The stratigraphic sequence on New Hanover has been described by Brown (1982). There Miocene platform limestones are absent, and the Jaulu Volcanics are overlain by the early Miocene to early Pliocene Lavongai Volcanics, a predominantly pyroclastic succession of agglomerate and lapilli tuff with subordinate porphyritic andesite, basaltic andesite, dacite, lava breccia and bentonitic claystone, probably related to a short lived southwest-facing volcanic arc involving the New Britain Trench. This unit is inferred to be partially laterally equivalent to and partially unconformably overlain by the Matanalaua Formation, up to 400 m of tuffaceous sandstone, siltstone, conglomerate and mudstone together with minor tuff, agglomerate, bentonitic claystone and rare lignite. The Matanalaua Formation is succeeded by calcareous tuffaceous sandstone, siltstone, mudstone and minor

conglomerate of the Pliocene Elsong Formation, estimated to be 200 m thick.

Preliminary re-examination of micropalaeontological samples from the Matanalaua and Elsong Formations by D.W. Haig indicates that both were deposited at least in part at upper bathyal depths. Foraminiferal assemblages from the upper Matanalaua Formation suggest a late Miocene to early Pliocene (upper N17-N18) age, indicating lateral equivalence to the Punam Limestone in northwestern New Ireland. Micropalaeontological control is very sparse, and the formation probably ranges downward in age into the middle Miocene and possibly older (Lelet Limestone equivalent). Samples from the basal Elsong Formation have yielded early to mid-Pliocene (N18-N19/20) ages. Equivalents of this unit are not exposed in northwestern New Ireland, but are the uppermost Punam Limestone in central New Ireland.

Onshore Structural Geology

According to Brown (1982), both New Ireland and New Hanover are dissected by a series of northwesterly trending, northeasterly-tilted fault blocks bounded by high-angle normal faults. This fault pattern is complicated by a "rectilinear pattern of northeasterly, north-northwesterly and easterly trending tensional and conjugate fractures as illustrated by the regular sawtooth pattern of the southern coastline of New Hanover and New Ireland." Brown (1982) concluded that the main fracture sets probably formed during development and uplift of the volcanic arc in the mid-Tertiary, and that differential subsidence of the

fault blocks bounded by these fractures accompanied limestone deposition during the Miocene. Major adjustments were inferred to have occurred during the Pliocene to Recent uplift which formed the present-day islands.

In southeastern New Ireland, Hohnen (1978) mapped two prominent northwest trending fault systems, the Weitin and Sapom Faults (Fig. 2B). Taylor (1979) noted that these faults are probably part of the surface expression of a major transform fault system trending N60'W southwest of New Ireland. According to Johnson (1979), earthquake focal mechanism solutions and the general trend of this feature are consistent with left-lateral strike slip motion.

The onshore geology of New Ireland indicates that extensive uplift has occurred since the various sedimentary sequences were deposited. The presence of early Pleistocene (low N22) sediments of mid-lower bathyal origin (500-4000m water depth) in central and southeastern New Ireland suggests that much of the uplift has occurred in the last 1.5 m.y. The unnamed Pleistocene limestone is now found at elevations as much as 200 m above sea level, and has therefore experienced a minimum vertical displacement of 700m at an average rate of 470m/m.y. Even greater uplift is indicated in the case of fault blocks in southeastern New Ireland, where the Lelet Limestone occurs as much as 1900 m above sea level (see contours in Fig. 2B). This unit was apparently downfaulted to considerable depths during the late Miocene, and was overlain by an unknown thickness of younger sediments. Hence the indicated 1900m of uplift (about 1300m/m.y. assuming uplift started 1.5

m.y. ago) represents only a minimum figure, and the actual figure was probably much greater. Similar calculations involving the sedimentary sequences in central and northwestern New Ireland and New Hanover suggest that the amount and rate of uplift decline in a northwesterly direction.

OFFSHORE GEOLOGY

Seafloor samples from the offshore region have been recovered by Eade (1979), and on Lamont-Doherty Geological Observatory cruises Vema 24, Vema 33 and Robert Conrad 10. Dredge material from the Eade (1979) cruise (Table 2) has been supplied to us by CCOP/SOPAC, and unpublished descriptions of Quaternary (probably Holocene) cores have been provided by Lamont-Doherty Geological Laboratory (Table 3). Dr D.J. Belford of BMR has provided foraminiferal ages varying from late Pliocene (N21) to Recent from a preliminary investigation of the dredge material.

The results from the New Ireland Basin sampling (Tables 2 & 3) suggest that in Quaternary times deposition of foram-rich ooze and chalk may have predominated in shallower water (less than 3000 m), with foram-bearing mud, sand and ash being laid down in deeper water. In Holocene cores from the Manus Basin south of New Ireland, volcanic ash is more abundant. In summary the sampling suggests that hemipelagic sedimentation predominated in the New Ireland Basin in the Quaternary.

The locations of all the seismic lines used in this study are shown in Exxon & Tiffin (1984). For the purposes of this paper,

three seismic lines, NI30-31, NI20 and NI12, are taken as typical (Figs. 2, 4, 5, & 6). Seismic character varies but little in the western part of the basin, which is the area with thicker sediment and apparently greater petroleum prospects. East of the Tabar islands the sequence is not only thinner, but lies in deeper water where it is cut by faulting and by volcanic intrusions and extrusions.

The overall character of the major seismic sequences is shown in Figures 4 & 5, and is summarized in Table 1. The discussion refers largely to the area west of the Tabar islands, where multichannel seismic data are concentrated, and where there is less structural complexity to obscure seismic character. The SB-A sequence, assumed to be Pleistocene - Recent ooze, maintains its character and thickness widely. The A-B and B-C sequences prograde largely northeastward from New Ireland and New Hanover, and hence thin in that direction. These sequences are assumed to consist largely of late Miocene to Pliocene volcanoclastic turbidites, marls and chalks; the A-B sequence may be predominantly volcanoclastics equivalent to the Rataman Formation, and the B-C sequence predominantly chalks and marls equivalent to the Punam Limestone.

The C-D sequence has the overall character and interval velocity of a carbonate platform sequence, and is interpreted to be the equivalent of the early to late Miocene Lelet Limestone of New Ireland. In both NI20 and NI30 (Figs. 4 & 5) buildups, dipping beds and flat-lying strata can be seen, and these are present in places throughout the basin. They could correspond to

reefs, fore-reef rubble and general back-reef and platform deposits. Buildups are more common in this sequence than the others, but can also be seen in both higher and lower sequences in a few areas.

The D-E sequence is the lowest clearly recognizable sedimentary sequence, and probably corresponds in part to the Lossuk River Beds of New Ireland. Its composition is not known with any confidence.

The line drawings of the parallel basin-crossing profiles NI30-31, NI20 and NI12 show the change in basin character along its length (Fig. 6). Profile NI20 was taken by Exon & Tiffin (1984) as typical of the basin. It shows the gentle slope down from New Ireland, and an overall thickening toward the basin axis, followed by overall thinning toward the Emirau-Feni Ridge to the north (located in Fig. 2). The generally prograding nature of the A-B and B-C sequences is clear, as are the buildups in the C-D sequence, especially near the structurally high ends of the lines. Faulting and erosion has removed some of the section near the Emirau-Feni Ridge.

Profile NI30-31 is generally similar to NI20, but shows the southern part of the section which could not be recorded on NI20 because of the existence of the New Ireland landmass. This profile runs just west of New Hanover and illustrates the major fault system on which the southern side of the basin steps down to the young 2000 m-deep Manus Basin (see steep slope on Fig. 2). The oceanic crust of the Manus Basin is shown by reflector V on

the extreme left of the profile. The profile indicates that the fault movements occurred very late in the history of the New Ireland Basin, in line with the onshore geology, and perhaps caused by the seafloor spreading in the Manus Basin which started some 3.5 m.y. ago.

Profile NI12 lies in the eastern part of the basin through which the Plio-Pleistocene volcanics of the Tabar-Feni group of islands have forced their way to the surface. Although correlation is uncertain across the faults bounding Lihir island, it is still clear that there has been a considerable amount of uplift of the older sequences by the intrusive and volcanic activity. This accords well with the presence of upthrown Miocene carbonates in the Tabar islands (see ONSHORE GEOLOGY).

Turning from the seismic profiles to the maps constructed from them and from bathymetric information (Fig. 2), the close interrelationship of all three maps is clear. The structure contour map of the C horizon, the top of the presumed shelf carbonates, shows highs around the islands formed largely of Miocene and older rocks such as Mussau, New Hanover and New Ireland, and around those consisting of younger igneous rocks punched through the older basinal sediments in the Tabar-Feni group. Our interpretation of the seismic profiles (e.g. Fig. 6) indicates that the C structure reflects deeper structure in a general way. The Emirau-Feni Ridge, and older outer-arc high bounding the Manus-Kilinauilau Trench, is quite apparent. The major structural depression between the Emirau-Feni Ridge and the land areas to the south is well defined in the west, but much

disturbed around the volcanic islands in the east.

Assuming that the top of the C horizon corresponds to the top of the Lelet Limestone on land, the maximum relief between the structural high of New Ireland and the structural low offshore is some 5000 m west of Tabar (Fig. 2B). In the area near Tanga and Feni the maximum relief is even more at 5500 m. Overall the offshore basin deepens southeastward at the C horizon.

The isopach of the seabed-C interval (Fig. 2C) clearly shows the thick and thin sedimentary sequences that have developed since the early late Miocene. Deposition has been least on the highs on the margins of the structural basin near New Hanover and New Ireland and along the Emirau-Feni and Nuguria Ridges - and also on the slope down into the trench system. A major depocentre extends from west of New Hanover to the Tabar islands, and contains 1500 m to and 2000 m of sediment. It persists eastward from Tabar but sediment thicknesses decrease by at least 500 m. Despite the detrital influx from the volcanic islands, the controlling influence on sedimentation appears to have been sediment eroded from the flanking structural highs. Both these effects were superimposed on the pelagic rain, which must have been approximately the same throughout the offshore area. The displacement of the depocentre south of the structural low (compare Figs. 2B & 2C) shows the importance of material derived from and deposited near the southern landmasses. The relative thinness in the east is probably due to downslope removal of sediment into the structural low south of Feni and into the trench system, especially before the growth of the volcanic islands from

Pliocene times onward accentuated the Emirau-Feni Ridge.

The bathymetry of the area (Fig. 2A) clearly reflects the deep structure, and illustrates the continuing importance of the Emirau-Feni and Nuguria Ridges. The position of the present bathymetric basinal depression, well north of the structural low on the C horizon of Figure 2B, emphasizes the effect of the increased deposition in the south (Fig. 2C) at the sea bed. Both the structural and bathymetric maps suggest that the north to northwest fault trends on land are present offshore as controlling and bounding faults under and near the Tabar, Lihir and Tanga island groups, all of which are elongate northward.

As pointed out by Exon & Tiffin (1984) most offshore faults have formed fairly recently, although some are long-lived growth faults on which movement directions have changed through time. The most spectacular fault system is that which trends northwestward and forms the southern flanks of New Hanover and New Ireland. Onshore this fault system is extensively developed on both islands (Brown, 1982; Hohnen, 1978), perhaps most clearly in the Weitin and Sapom Faults (Figure 2), but also in the high-angle faults, downthrown to the south, on New Hanover (Brown, 1982). Offshore it is clearly shown on Profile NI31 (Fig. 6). This fault system separates the arc crust of the New Ireland Basin from the oceanic crust of the Manus Basin (Taylor, 1979), and is almost certainly a transform fault system (Curtis, 1973; Connelly, 1976) along which New Britain moved southeastward relative to New Ireland (Taylor, 1979; Johnson et al., 1979; Falvey & Pritchard, 1984). Movement on the system has varied from fault to fault with

both transcurrent and vertical movements being important. A lesser parallel set of normal faults occurs further north, offshore and on land. These seem to have formed as simple adjustments to differential loading in the basin and especially to the post-Pliocene tilting of the basin.

SUMMARY OF THE GEOLOGICAL HISTORY

The New Ireland area first came into existence during the Eocene as a northwest-facing volcanic arc, with the oceanic crust to the north being subducted southeastward at the Manus and Kilinailau Trenches. Island arc volcanics built up from older seafloor to form the Jaulu Volcanics in the New Ireland-New Hanover area and its lateral equivalents on Mussau and Manus islands (E-V sequence). By the late Oligocene, the arc had rotated to face northeast due to seafloor spreading in the Solomon Sea (Falvey and Pritchard, 1984). During the early Miocene, subduction and volcanism ceased, but younger phases of the Lemau Intrusive Complex continued to intrude the Jaulu Volcanics and overlying sedimentary cover until at least middle Miocene time.

The main phase of island arc volcanism ceased during the early Miocene, but volcanoclastic sedimentation continued in the forearc basin between the relative highs formed by the Jaulu Volcanics and the Emirau-Feni Ridge. More than one thousand metres of these sediments are present in places (D-E sequence). Lateral equivalents of at least part of this succession are exposed onshore as the turbidites of the Lossuk River Beds. A

carbonate platform developed directly on the volcanic substrate in shallow water areas, and prograded outward over deeper water sediments from early Miocene time to form the Lelet Limestone and its lateral equivalents offshore (C-D sequence). Central and southern New Ireland and adjacent areas offshore were free from Miocene volcanic activity, and carbonate deposition persisted until at least latest middle Miocene or late Miocene time. The resultant, laterally extensive carbonate succession may exceed 2000 m in thickness in parts of the present day offshore area.

Over the equivalent time period, the present-day New Hanover area was apparently the site of persistent volcanism, as represented by the Lavongai Volcanics. Nearby areas, such as northwestern New Ireland and offshore from New Hanover, were not initially affected, and the Lossuk River Beds and the lower Lelet Limestone were laid down during the mid early Miocene to earliest middle Miocene. A subsequent resurgence of volcanism terminated carbonate deposition in the northwest and led to a phase of subsidence and pyroclastic deposition that lasted until the late middle Miocene. Pyroclastic and epiclastic deposition continued there until latest Miocene or early Pliocene time, and carbonate deposition was not re-established. This middle to late Miocene sequence is probably only of local extent, and has not been specifically recognized in the offshore seismic sections.

Elsewhere in the New Ireland Basin, the early late Miocene appears to have been marked by rapid regional subsidence to bathyal depths. This event may have coincided with reversal of the island arc and its transferral to the Pacific Plate, which is

thought by Falvey and Pritchard (1984) to have occurred at about that time. Initially, pelagic deposition prevailed with the accumulation of the chalks and marks of the Punam Limestone and its offshore equivalents (B-C sequence) until early Pliocene time. A resurgence of regional volcanism followed until earliest Pleistocene time, resulting in the deposition of the volcanoclastic turbidites and tuffs of the Rataman Formation and its lateral equivalents offshore (A-B sequence). The volcanism may have been triggered by subduction at the New Britain Trench while New Ireland was still part of the newly formed southwest-facing arc just prior to the opening of the Manus Basin about 3.5 m.y. ago. The volcanic activity was short-lived, lasting only about 2 m.y.

Pelagic carbonate deposition had gradually returned to the area by the early Pleistocene. However New Hanover and New Ireland had already commenced movement to the northwest relative to New Britain along a transform fault system as the Manus Basin opened. Rapid uplift accompanied the strike-slip movement, and over a 1.5 m.y. period present-day New Ireland emerged from the sea. The uplift, which probably exceeded 1900 m in southeastern New Ireland but decreased greatly to the northwest, may have been associated with the thermal anomaly of the spreading centre and heating along the transform faults. Conglomerate deposits of the Maton Conglomerate were subsequently laid down against the newly emergent mountain chain adjacent to the fault scarps, and a variety of terrestrial and shelfal detrital deposits and coastal limestones were laid down elsewhere on New Ireland, and on New Hanover and Mussau. During the same period, subsidence continued

in the offshore areas to the northeast, where pelagic deposition has continued to the present day (SB-A sequence).

Plio-Pleistocene volcanism in the central part of the basin led to the extrusion of alkali volcanics in the Tabar-Feni group of islands. Much of the faulting in these areas appears to be associated with related tectonism.

PETROLEUM POTENTIAL

Elements which must be considered in any petroleum assessment are the thickness of the sediments, the palaeo-heat flow, the existence of potential source rocks, reservoirs and traps, and the geological timing of events. As no wells have been drilled in the area, little control exists over the major part of the basin to assist in the evaluation of these factors. Hence this preliminary assessment of petroleum potential relies heavily on extrapolation of existing onshore outcrop information offshore, on the seismic character of the various sequences identified in the sections, and on comparisons with other basins in similar tectonic settings.

The New Ireland Basin, with about 5km of sedimentary section visible in the seismic sections, is clearly deep enough to have generated hydrocarbons. No data are available, however, to assess palaeo-temperatures or even modern heat flow. Recent studies in the intra-arc New Georgia Basin in the Solomon Islands (Free et al., 1982) have shown that the present heat flow there is rather low, and that petroleum is only likely to have been generated where overburden exceeds 2000 m in thickness. If similar heatflow

is also present in the New Ireland Basin, only the Miocene sequence offshore is likely to contain mature potential source rocks (C-D and D-E sequences in Table 1). This stratigraphic interval is inferred to contain lateral equivalents of the Lelet Limestone and Lossuk River Beds identified onshore.

A comprehensive onshore study of New Ireland source rocks is currently being carried out by M. Glikson of Australian National University, but only preliminary results were available at the time of writing. Volcaniclastic sediments in general contain only small quantities of organic carbon, as has been shown by recent onshore and offshore studies in Tonga, Vanuatu, Fiji and the Solomon Islands (Buchbinder & Halley, in press; Exon and Herzer, in press; Exon et. al., in press). In the case of the Lossuk River Beds, abundant plant remains and high values of total organic carbon are known to be present (M. Glikson, pers. comm.). However, the organic particles have low hydrogen indices and the rocks themselves are at a thermally immature stage for hydrocarbon generation. These onshore exposures may not be representative of the equivalent sequence offshore. In more distal parts of the forearc basin, organic matter of marine origin might be more prevalent. Also, the seismic sections suggest much deeper burial in the offshore area than is indicated for the Lossuk River Beds exposed onshore. The possibility exists, therefore, that better quality and mature source rocks might be present in the D-E seismic sequence offshore.

In southeastern New Ireland, highly carbonaceous shale of probable lagoonal origin has been found in the Lelet Limestone

atone locality. Due to poor exposure and structural complications, its stratigraphic position and vertical extent are unknown. Initial geochemical results indicate the presence of material similar to cannel coal (M. Glikson, pers. comm.). Such material could be highly productive for hydrocarbon generation under the right burial conditions.

Onshore exposures of the Lelet Limestone are known to contain abundant algal material in some facies. Concentrations of relatively fresh, translucent, brown algal organic matter have been identified in thin section, and total organic carbon values are high in some cases (M. Glikson, pers. comm.). This suggests that the inferred offshore equivalent of the Lelet Limestone, the C-D sequence, could contain petroleum source rocks similar to those documented by Hatley and Harry (1980) in the Miocene carbonate succession off Palawan in the Philippines. The C-D sequence appears to be buried by up to 2000 m of overburden in places, and may itself be up to 2500 m thick, suggesting that sufficient burial has probably taken place to induce hydrocarbon generation.

The most attractive reservoir rocks in the New Ireland Basin are inferred reef and reef-related carbonate sediments in the offshore C-D seismic sequence. Probably similar sediments examined onshore in the Lelet Plateau area display up to 25% moldic, intraparticle, shelter and fenestral primary porosity (terminology as used by Choquette and Dray, 1970). It is not known whether primary porosity is preserved at depth, or secondary porosity is developed.

Younger volcanigenic sediments such as the Rataman Formation are unlikely to contain thick, good quality reservoirs, except in cases where reworking has enhanced porosity and permeability. In general, the offshore equivalents of this unit and the underlying Punam Limestone (B-C and A-B sequences) are more likely to act as seals above the C-D sequence.

Both structural and stratigraphic traps are possible in the New Ireland Basin. Structural traps are most likely to occur where there has been extensive fault movement, such as on the basin margins in the southwest (Profile NI31), or on the Emirau-Feni Ridge in the northeast (Profile NI20; see Fig. 6). Structural traps around the volcanic Tabar-Feni islands are also geometrically possible. Stratigraphic traps on the other hand probably exist over a wider area in the C-D sequence in the form of porous and permeable reef or forereef carbonates. These would be sealed laterally by impermeable carbonates, and vertically by impermeable carbonates or volcanoclastic sediments. Such traps are common in the Miocene sequences of Irian Jaya and Palawan. Traps in the C-D sequence would have been little affected by the Plio-Pleistocene tilting of the basin.

In summary, the New Ireland Basin does have petroleum potential, with the prime reservoir target being reefs in the C-D sequence. Organic-rich shale, siltstone and limestone within and below this sequence would provide potential source rocks. Trapping would be most likely stratigraphic, but structural traps could also be present near the basin margins. The most prospective areas in water shallower than 1000 m lie north and

west of New Hanover and northwestern New Ireland, where a thick sedimentary section and stratigraphic trap may exist, and perhaps on the Emirau-Feni Ridge between Mussau and Emirau Islands, where structural targets may be found. Other prospective areas lie in deeper water.

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Table 1 : Seismic sequences

Sequence Velocity* Thickness	Character	Interpretation
SB-A 1800 m/s 200-300 m	Semi-transparent well-bedded sequence. Conformably overlies high frequency reflector (A) which is unconformable on underlying sequence in places	Pleistocene to Recent hemipelagic oozes
A-B 2000 m/s 500-1000 m	Well bedded sequence with interbedding of strong reflectors and semi-transparent intervals. Progrades northeastward. Conformably overlies shallowest continuous low-frequency reflector (B) which is conformable on underlying sequence	Pliocene volcanoclastic turbidites resulting from volcanism possibly triggered by subduction at the New Britain Trench just prior to and during the initial opening of the Manus Basin, interbedded with marls and chalks. Equivalent to the Rataman Formation on New Ireland.
B-C 2300 m/s 200-500 m	Well-bedded sequence like A-B. Progrades northeastward and is unconformable on regular underlying low-frequency reflector (C)	Late Miocene to earliest Pliocene chalks and marls which accumulated as <i>Globigerina</i> oozes, interbedded with volcanoclastic turbidites. Equivalent to Punam Limestone on New Ireland.
C-D 3600 m/s 1000-2500 m	Mixed seismic character. Weak to strong parallel reflectors, dipping reflectors, and build-ups. Unconformably overlies continuous low frequency reflector (D) which is generally conformable on underlying sequence	Early to late Miocene platform and upper slope limestones equivalent to thick Lelet Limestone of New Ireland. Potential petroleum source and reservoir rocks.
D-E 3000 m/s 1000 m	Well-bedded variably reflecting sequence, locally containing dipping reflectors, channels and build-ups. Unconformably overlies strong low-frequency reflector (E)	Early Miocene outer shelf and slope sediments, largely volcanoclastic, with some channels and possible carbonate banks. Equivalent to Lossuk River Beds on New Ireland; potential petroleum source rocks.
E-V velocity unknown 1000 m	Well-bedded variably reflecting, poorly-defined sequence at limit of acoustic penetration. Unconformably overlies strong, diffracting irregular surface	Probably Eocene to early Miocene volcanics and volcanoclastics equivalent to Jaulu Volcanics on islands. Diffracting surface beneath may either be oceanic basement or lie within Jaulu Volcanics.

* Footnote: "Velocity" is average seismic interval velocity for Gulf line NI20, derived from the normal moveout velocities used for stacking.

Table 2: Dredge hauls from New Ireland region (Eade, 1979)

Station	Location	Latitude	Longitude	Water depth (m)	Description
14	E.Emirau	1'40.0'S	150'27.0'E	537-830	Pleistocene-Recent white chalk, gravel, pebbles
15	W. New Hanover	2'21.2'S	149'49.7'E	483-492	Altered volcanics, pumice
16	E.Emirau	1'44.7'S	150'24.3'E	825	Late Pliocene-early Pleistocene (N21) white chalk; quartz vein rock, pumice
17	NW. Tabar	2'32.9'S	141'50.7'E	344-1084	Limestone
22	NE. Lihir	2'43.6'S	152'50.8'E	1000-1100	Late Pliocene-early Pleistocene (N21) foram-bearing limestone, sandstone, siltstone; foramsand.

Table 3 : Cores from New Ireland region (Lamont-Doherty Geological Laboratory)

Station	Location	Latitude	Longitude	Depth (m)	Recovery (cm)	Description
V24-152	NE. Tanga	3°18'S	153°32'E	2410	343	Foram chalk
V24-153	S. Feni	4°30'S	153°28'E	4103	198	Foram-bearing clay, inter-bedded ash
V33-116	Manus Basin	2°54.5'S	148°35'E	2363	309	Foram-rich mud and sand; some ash
V33-117	Manus Basin	3°47'S	151°0'E	2340	10	Volcanic ash
RC10-138	E. Feni	4°05'S	154°34'E	3563	523	Pelagic mud, interbedded foram-rich sand.

Figure Captions

1. Location of eastern New Ireland Basin. Boxed area is that studied.
2. Three maps of eastern New Ireland Basin.
 - A. Bathymetric map showing 500 m contours, derived from all available bathymetric and seismic profiles. Triangles are dredge samples from "Machias" cruise PN-79(1) (Eade, 1979 & Table 3). Circles are cores from "Vema" cruise 24 (Table 4).
 - B. Structure contour map on the top of the C horizon, which is believed to correspond to the top of the Miocene carbonate sequence. Offshore contours (500 m intervals) derived from 25 Gulf profiles only; onshore contours on top of Miocene limestones after Hohnen (1978). Key profiles NI12, NI20 & NI30-31 are illustrated in Figs. 4, 5 & 6. Velocities assumed to be 1500 m/second in water and 2000 m/second in sedimentary section.
 - C. Isopach map of the seabed - C sequence assuming a velocity of 2000 m/second.
3. Generalized stratigraphic columns on land after Brown (1982) and recent Papua New Guinea Geological Survey stratigraphic studies in New Ireland.
4. Part of multichannel Gulf seismic profile NI20 showing interpretation. Profile location shown in Fig. 2, and location within profile in Fig. 6. Sequence nomenclature in Table 1. Note especially the complex character of sequence C-D, believed to consist of shelf carbonates including reefs.

5. Part of multichannel Gulf seismic profile NI30 showing interpretation. Profile location shown in Fig. 2, and location within profile in Fig. 6. Sequence nomenclature in Table 1. Note the complex character of sequence C-D, and the fault extending throughout the column, with normal movement apparent at depth and reverse movement near the surface. Should the C-D sequence just to the right of the fault be a reef, the apparently large normal movement on D would be an artifact of "velocity pull-up".
6. Line drawings of Gulf seismic profiles NI30-31, NI20 and NI12. Parts of NI30 and NI20 are shown in Figs 4 & 5. Sequence nomenclature in Table 1. Note the overall thickening into the basin, the prograding nature of the A-B and B-C sequences in NI30-31 and NI20, the youth of the faults, and the upthrowing of the older sequences in NI12 on the Lihir Island horst probably caused by the eruption of the Plio-Pleistocene volcanics.



Fig 1

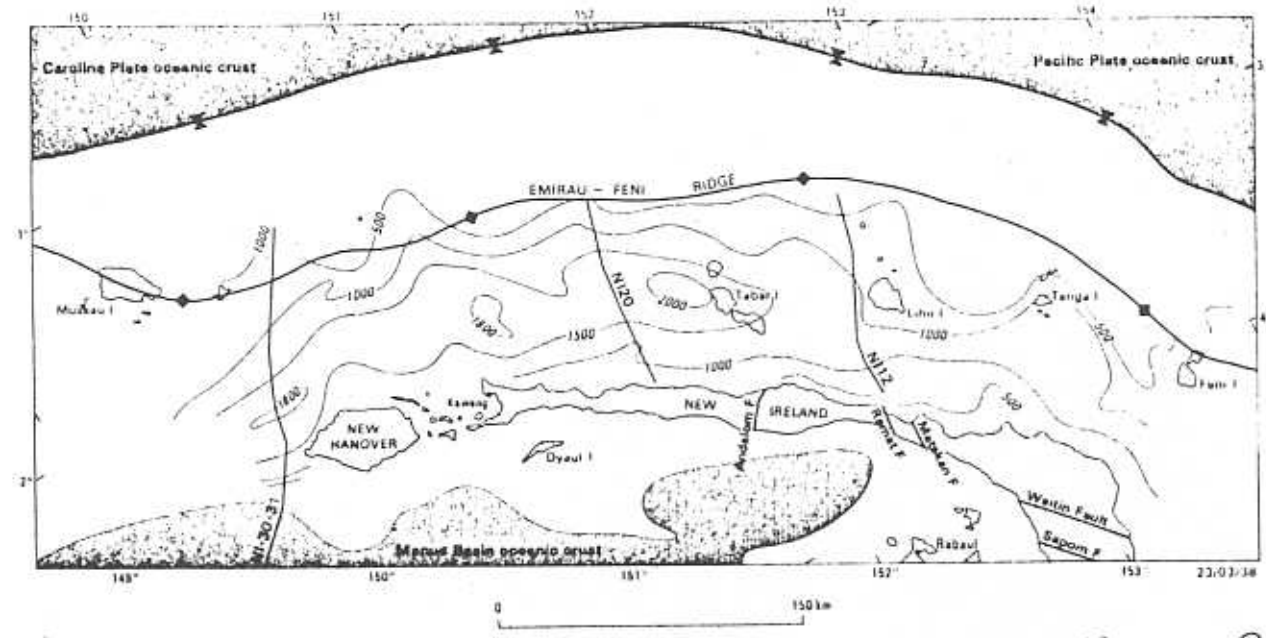
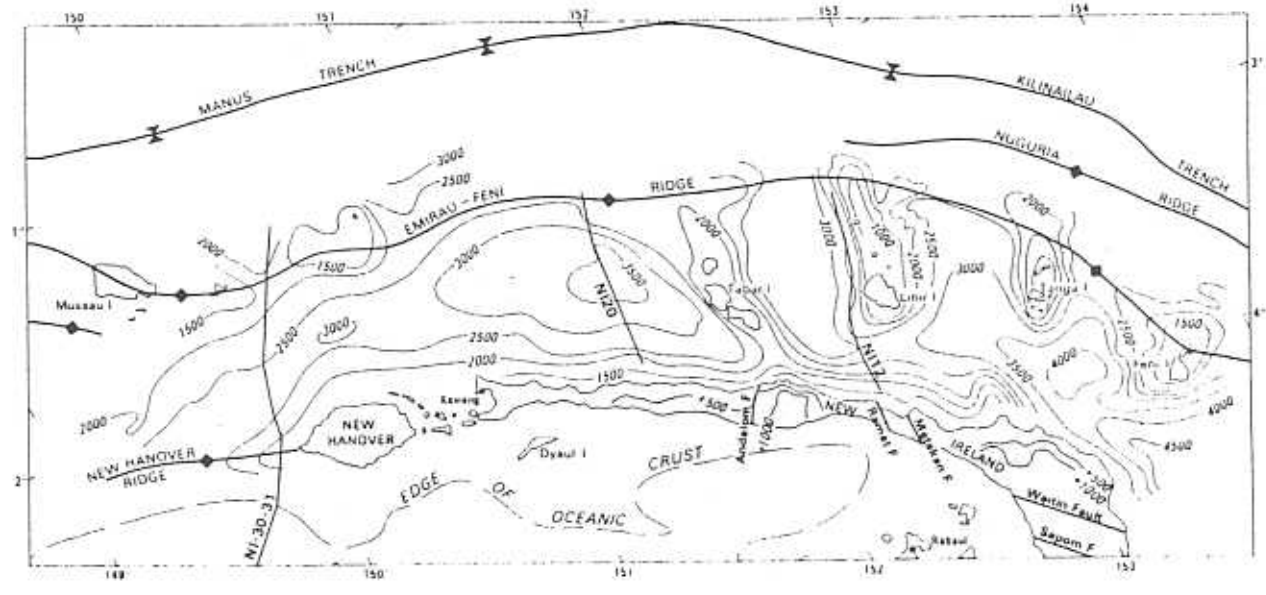
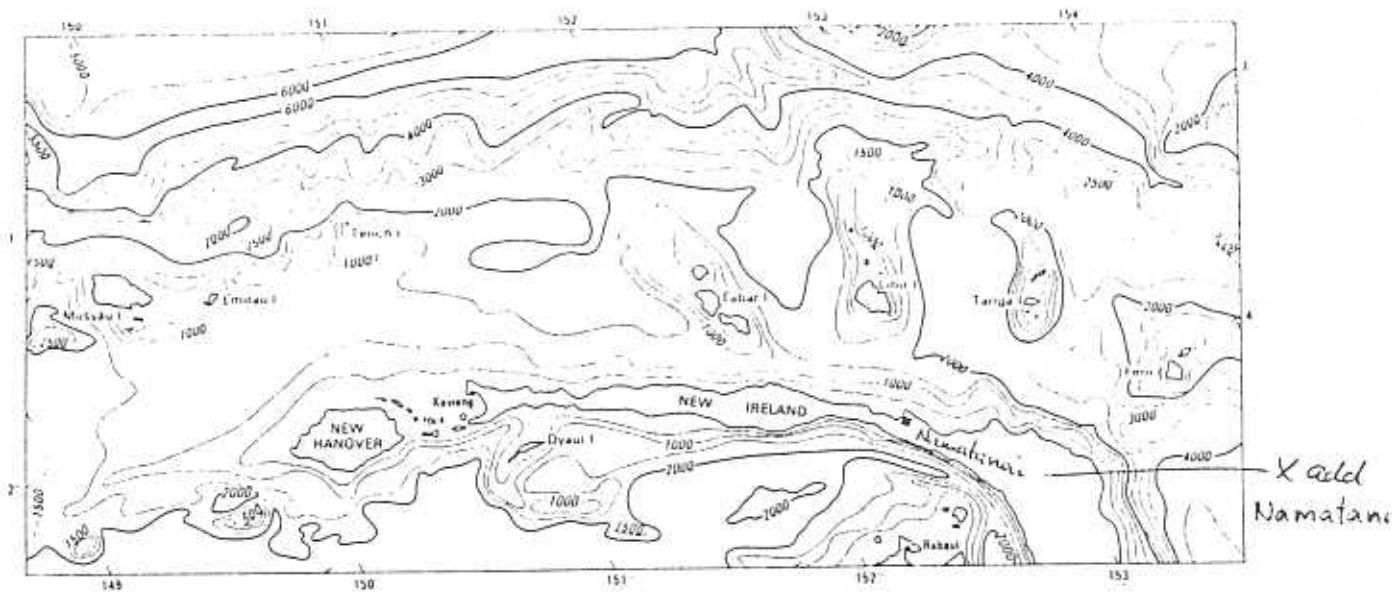


Figure 2

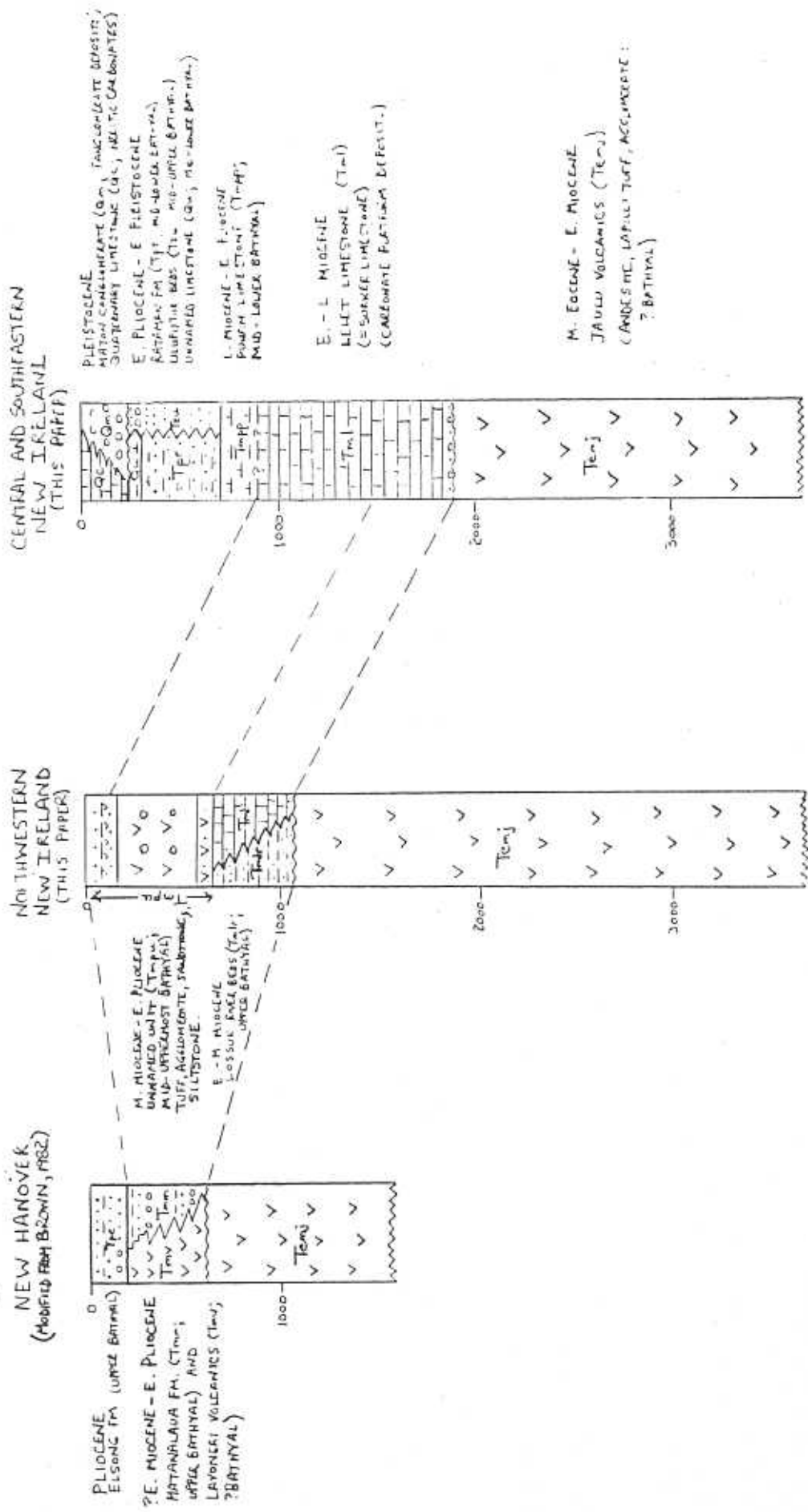


FIGURE 3

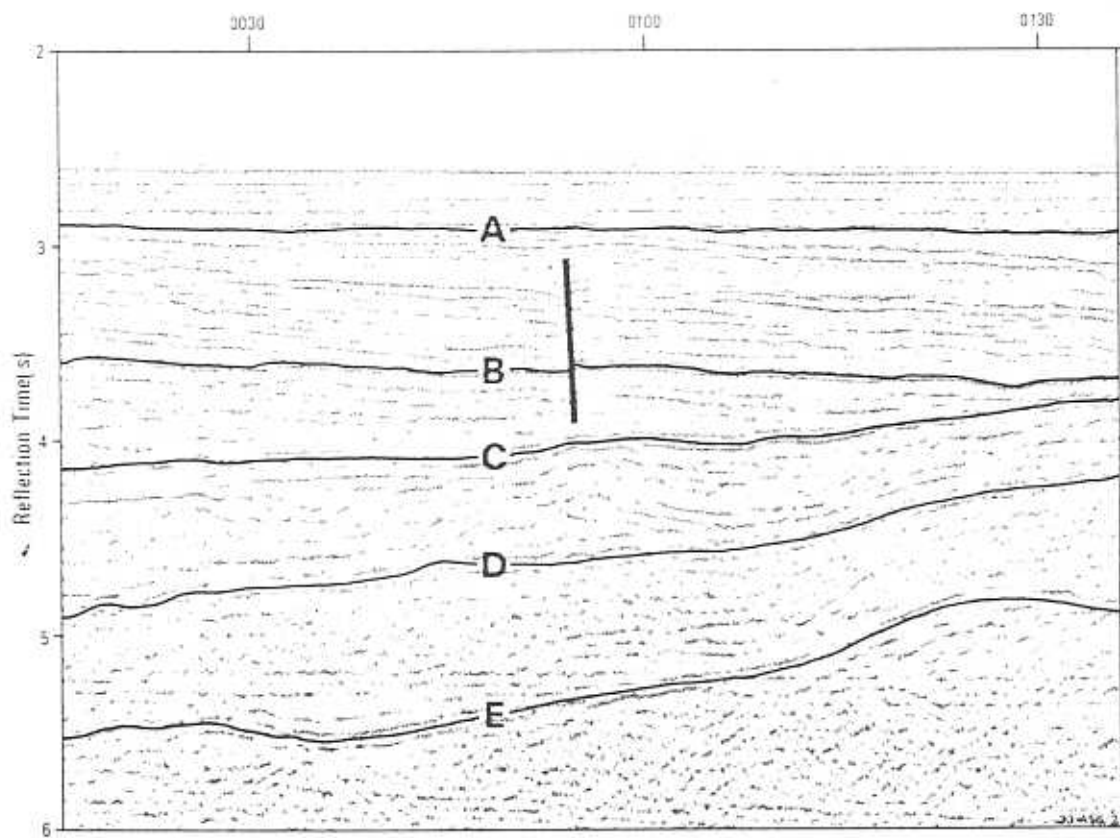
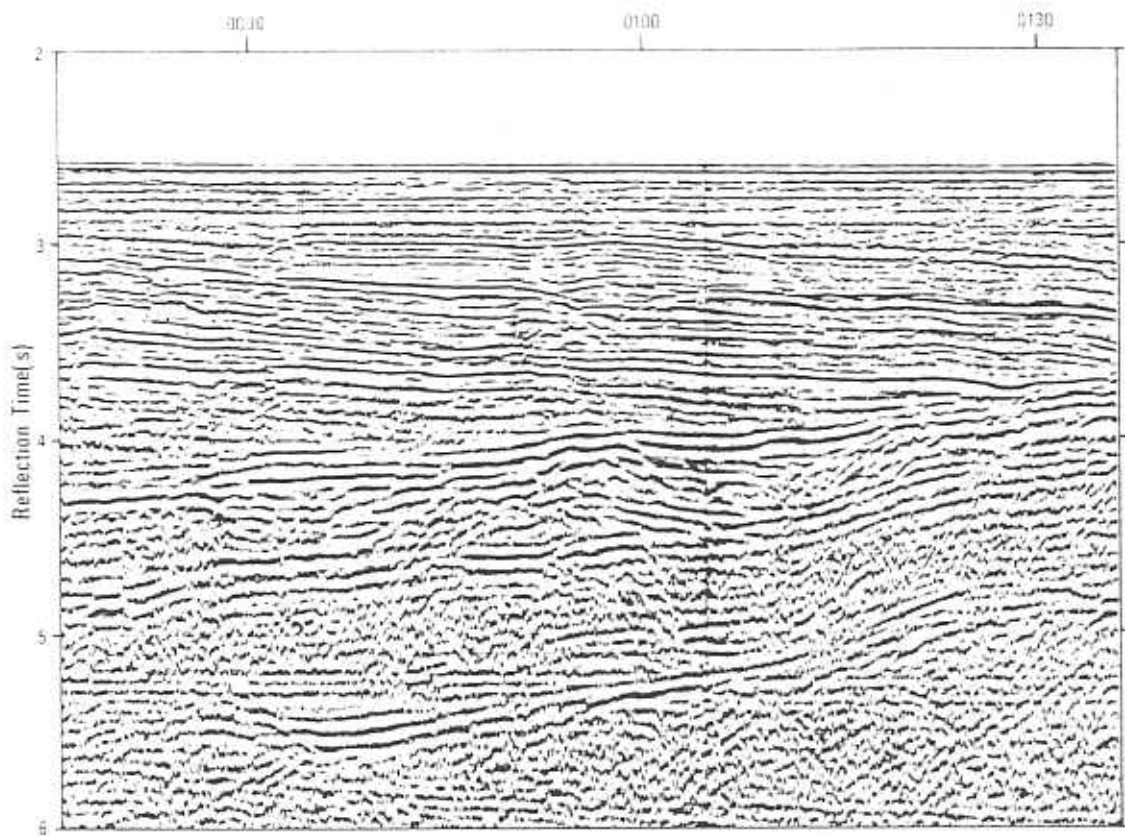


Figure 4

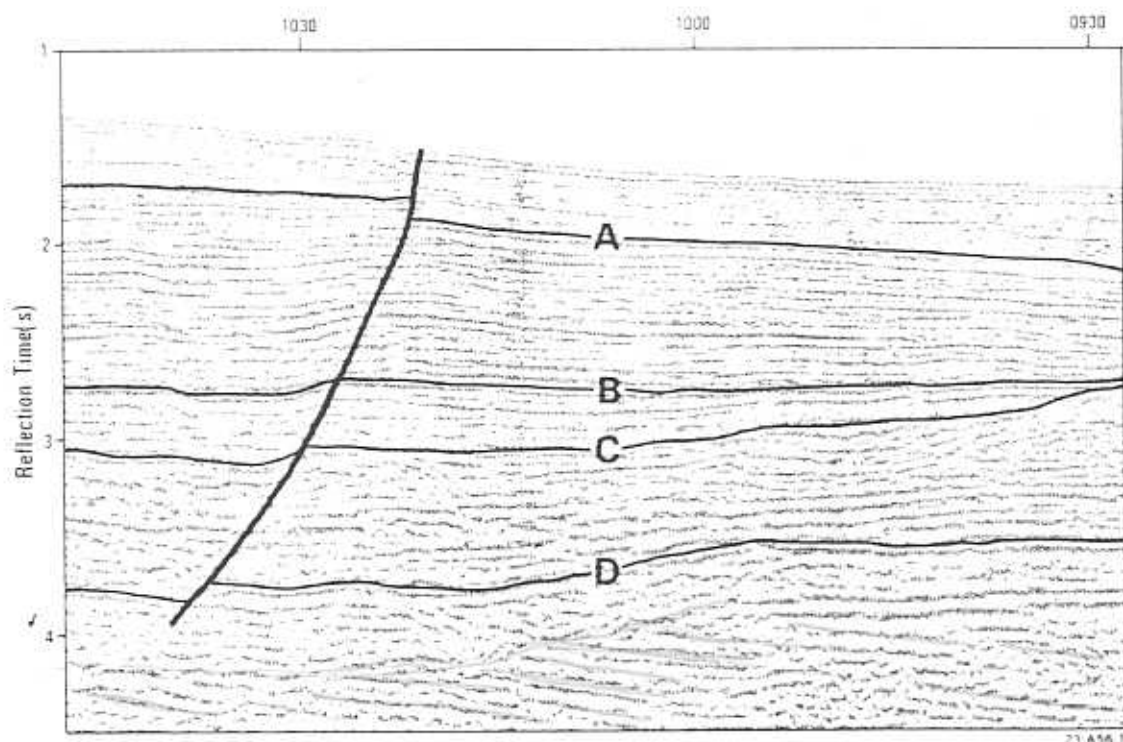
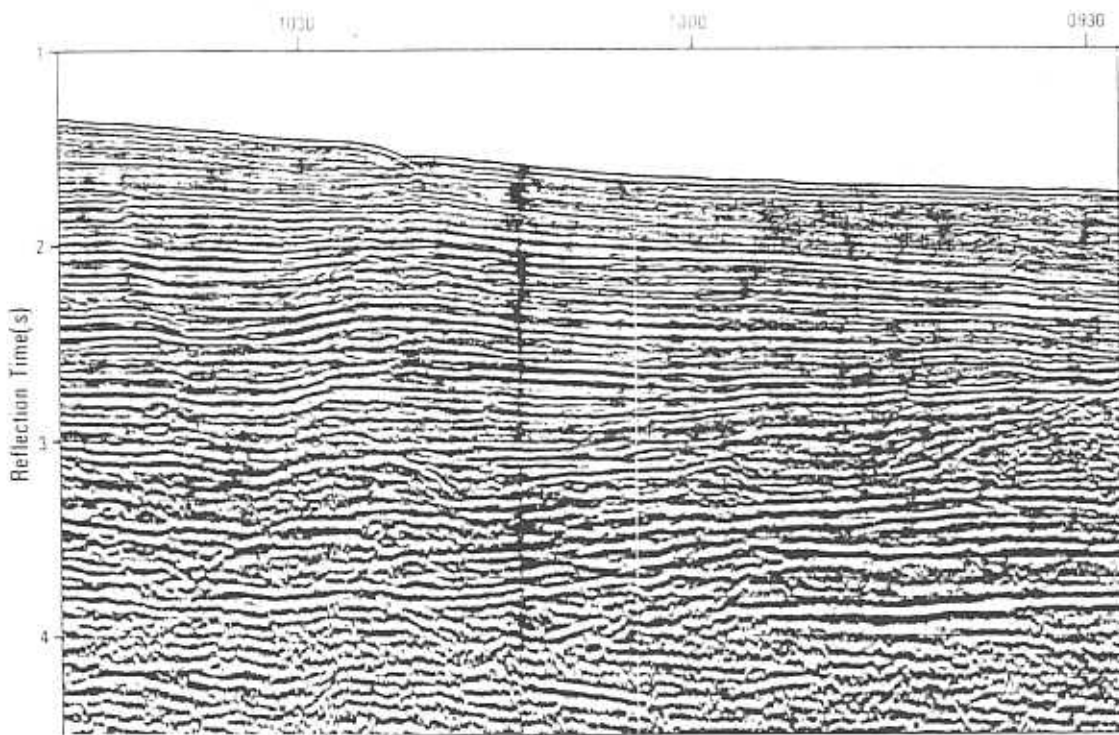


Figure 5

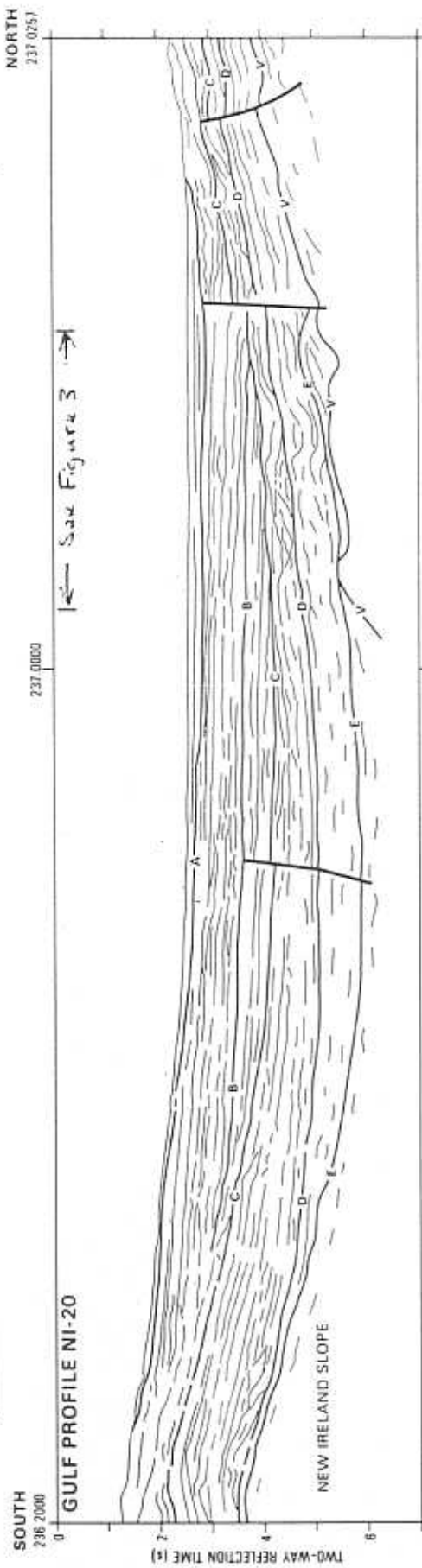
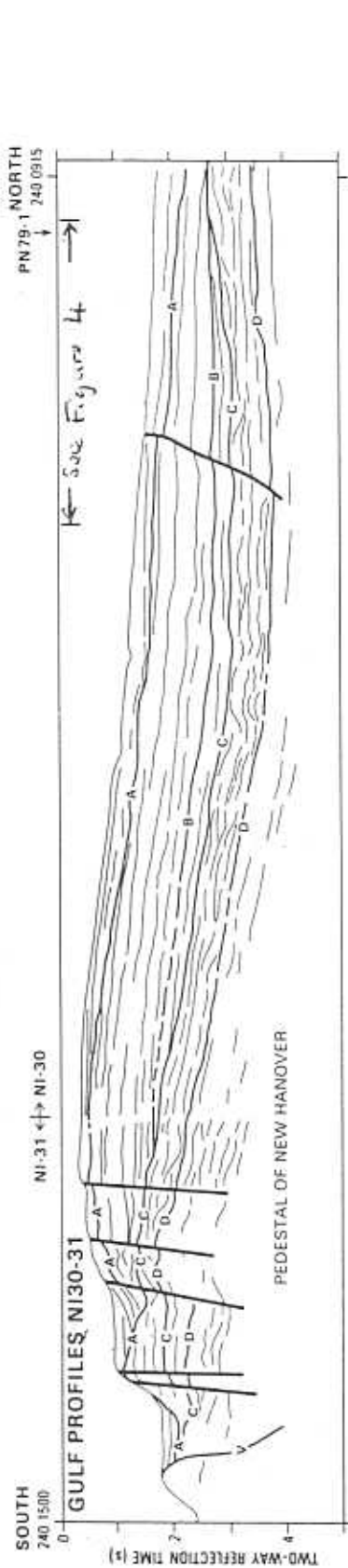


Figure 6