Woodlark Basin/D'Entrecasteaux Islands project:

A study of lithospheric extension in an actively deforming area

ew9203 Cruise report

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Objectives

General background

The process(es) by which continental lithosphere accommodates strain prior to and during the initiation of seafloor spreading and the formation of a new divergent plate boundary are presently know primarily from the study of ancient systems - the present passive continental margins bordering rifted continents and/or the exposed record of past continental margins that have been incorporated into the continental record by subsequent convergent tectonics. In both cases extensional tectonics have long ceased and we are required to reconstruct evidence for active tectonic processes from a record that is often highly disrupted. On most continental margins, for instance, breakup occurred many millions of years ago and the structures developed during the final stages of intra-continental extension and the initiation of seafloor spreading are frequently buried beneath hundreds of meters of sediment. In the case of the "classic" Atlantic continental margins the depth of post-breakup cover is several kilometers. The ancient record, such as that of the development of the Ligurian Tethys preserved in mountain belts of southern France, is often highly fragmented and incomplete.

A great deal has also been learnt from study of regions of intra-continental extension such as the Basin and Range Province of the Western United States and the Aegean where extension has occurred recently by comparison with the passive margin examples, but has obviously not proceeded to the point of continental breakup. It has, however, been argued that the mode of extension in the Basin and Range Province is unlike that that can be recognized in any present continental margins and hence that it may represent a "special case", although it is not at all clear what the special conditions are in the Basin and Range that promotes the "uncommon" behavior.

From these and other studies a variety of conjectures has been made concerning the processes attending the whole scale rupture of the continental lithosphere and the beginnings of seafloor spreading. One particularly controversial conjecture involves the role of areally extremely large normal detachment faults that dip at low angles and accommodate very large amounts of strain through simple shear of the entire lithosphere. This conjecture was posed on the basis of studies in the Basin and Range Province (and is one of the reasons some scientists have claimed that region to be non-representative of general rifting processes) and has generated considerable debate among earth scientists. Several investigators have identified structures in passive margin settings that may be detachment faults and re-examination of the ancient record has revealed the likely presence of many such structures.

Activity on normal detachment faults provides at least a heuristic explanation for enigmatic structures known as metamorphic core complexes - large dome-shaped structures bounded by detachment surfaces in extensional terrains which have rocks from the deepest crustal levels as their central core. It has been suggested that these complexes form as a natural consequence large-scale movement on low-angle normal detachment faults which penetrate deep into the crust and will exhume (or unroof) the lower crust given sufficient amounts of extension. The release of vertical load due to unroofing together with associated magmatism is thought to cause the lower crust to be brought rapidly to the surface.

The role of low-angle normal sense detachment faults has been strongly contested both on observational grounds and because motion on these surfaces requires that the fault be extremely weak - almost frictionless - in order to allow horizontal stresses to cause failure on low-angle planes. The growing evidence for a weak fault and strong crust associated with motion on the San Andreas transform fault provides evidence in support of the weak normal detachment fault model, but the mechanism by which friction is effectively reduced on the fault surface is not understood in either setting at present. Nevertheless models abound in the literature in which low-angle detachment faulting is an essential mechanism of large-scale strain accommodation. Many models propose that small degrees of extension that occur early in the history of breakup are accommodated on high-angle fault planes while large amounts of extension are accommodated on low-angle surfaces which, upon final breakup lead to the development of highly asymmetric conjugate continental margins - sometimes describes as upper plate and lower plate margins.

The overall objective of the Woodlark Basin/D'Entrecasteaux Islands study was to make an investigation of continental breakup and the initiation of seafloor spreading in a region where the phenomenon of interest is presently active. Given that rifting and the initiation of seafloor spreading has occurred repeatedly throughout the history of the earth there are surprisingly few present examples of this tectonic situation. Other regions include the politically difficult Aegean Sea, the Red Sea where extensive salt deposits are a major impediment to seismic imaging, and the Gulf of California where the rifting could be considered to be transform-dominated. The present study area, described briefly below, represents one of the simplest settings in which extension is active in a variety of different stages, from intra-continental through to bona fide seafloor spreading within a relatively restricted region. The basic plan was to image the structure using multichannel seismic reflection profiling and collect magnetic and gravity data to use for constructing models of the processes involved in lithospheric extension.

Woodlark Basin/D'Entrecasteaux Islands study

This region was chosen for study because previous investigations have suggested that several important stages in the process of intra-continental extension and the initiation of seafloor spreading are represent in a tectonically contiguous zone. Here the Woodlark Basin spreading center has been propagating westward forming oceanic crust in the Woodlark Basin for about the past 3.5 Ma (Figures 1, 2). Oceanic crust is known with some certainty to be forming westward to 152° E and with considerably less certainly beyond that longitude. By 151°E strain is accommodated by lithospheric deformation of a crust thickened by convergent processes that effected the region over a period of at least 10 Ma prior to the onset of rifting in the Woodlark Basin. We refer to this lithosphere as continental to distinguish it from the oceanic crust of the Woodlark Basin, recognizing that this term may not be wholly appropriate.

West of 151°E lie the D'Entrecasteaux Islands - Goodenough, Fergusson and Normanby - which separate the Trobriand Basin to the north from the Goodenough Basin to south (Figure 2). The structure of Goodenough and Fergusson are dominated by metamorphic core complexes that have been exhumed to the surface as a response to extensional stresses associated with the propagation of the Woodlark spreading center (Figure 3). These islands therefore represent the youngest core complexes known on the earth. The main detachment surface associated with the core complexes dip to the north but major antithetic shear zones dip to the south on both islands and the overall geometry of the detachment surfaces is complex. Goodenough and Fergusson are separated by a major northeast-southwest trending transcurrent fault zone - the Barrier Islands fault zone - which has been active during the motion of the detachments and is probably a major transfer or accommodation zone. Shallow seismicity characterizes the surrounding regions and at least two earthquakes to the east of the islands have focal mechanism solutions that permit motion on low-angle normal faults. The region thus represents one in which evidence for active extension, including the extreme extension associated with formation of metamorphic core complexes, is available from several independent studies, both geological and geophysical.

The basic experimental plan involved operating in five regions that are geographically distinct and may represent distinct tectonic provinces (Figures 2, 5,6,7):

1. Trobriand Basin. In this region north of the D'Entrecasteaux Islands we might anticipate that the detachment faults associated with the core complexes of the islands would be found dipping at low angles northward beneath the basin. The region is heavily covered with reefs which rise from regional water depths of 400 to 50 meters. Seismic data was obtained in the region by Western and GSI for Amoco in the early 1970's and detailed navigation charts were available to guide the vessel. Two wells were drilled as a result of the seismic investigations

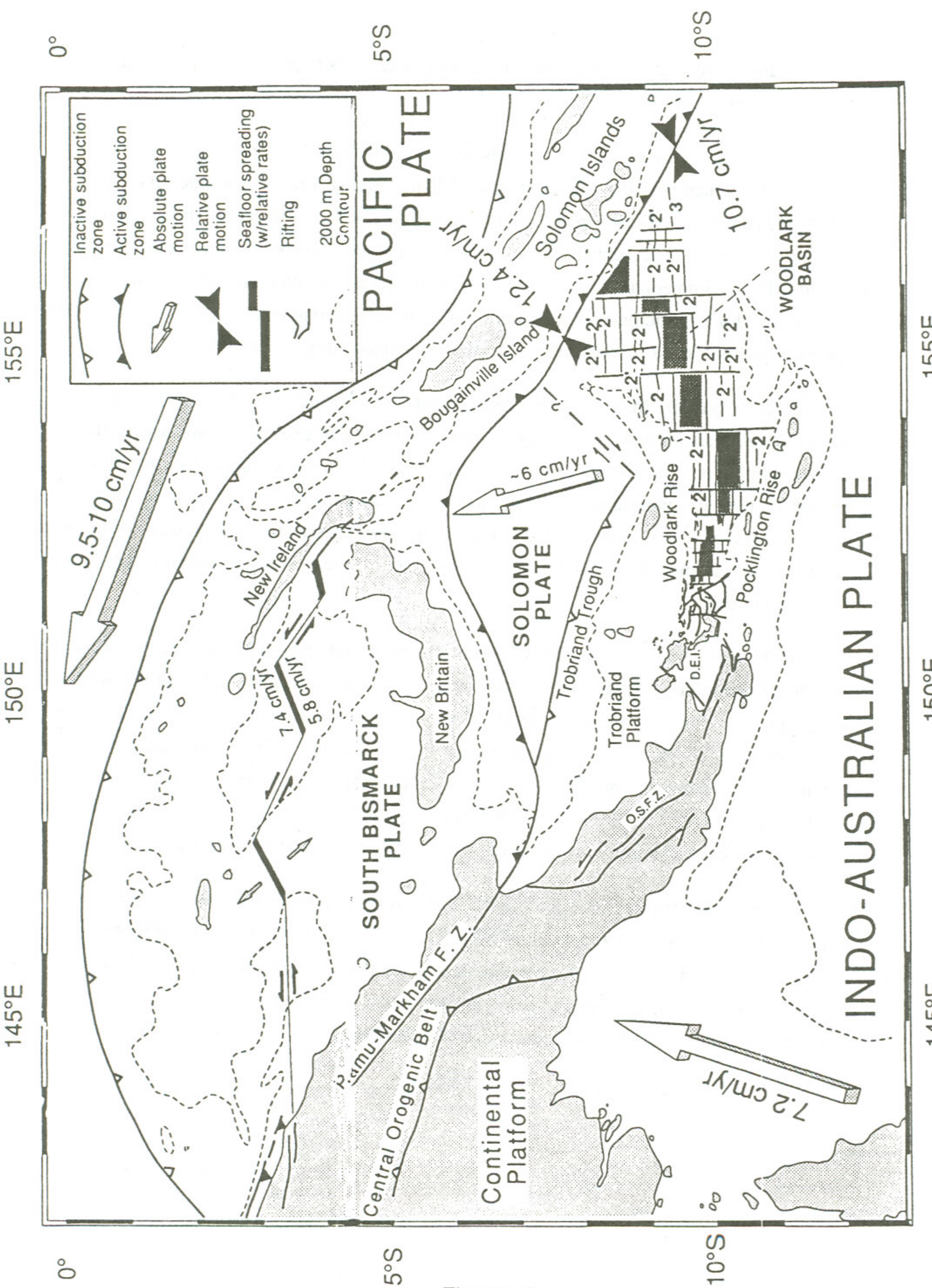
(Figure 4) and one of our aims here was to intersect these wells to provide a stratigraphic tie for our seismic data.

2. Kiribisi/Tufi Basins. These basins are poorly defined and lie west of the core complexes associated with the D'Entrecasteaux Islands. Being furthest from the tip of the propagating center of seafloor spreading they are presumably least effected by lithospheric extension and may be representative of an early stage in intra-continental extension. However, given that they lie immediately adjacent to the core complexes which represent extreme degrees of extension we should anticipate some evidence for diminishing extension across the basin or the presence of a major transfer structure that transfers extension to another region.

3. Goodenough Basin. This is a relatively deep water region to the south of the D'Entrecasteaux Islands and presumably represents the result of extension associated with the core complex formation on the islands, although the nature of the basin is essentially unknown. Tectonically the basin is generally antithetic to the core complexes if indeed the dip of the associated detachments is to the north. The basin, however, occupies almost the same area as the islands themselves and there is no direct evidence to confirm that its development was coeval with the core complexes.

4. Between the D'Entrecasteaux Islands and the Woodlark spreading center. This region is not well defined in the sense that the location of the most westward propagation of the Woodlark spreading center is not completely defined. The PACKLARK Group has suggested that a fairly distinct boundary occurs along a major transform structure at 151°40'E across which strain accommodation changes from a dominantly mechanical process to a dominantly magmatic process. Thus the region west of this longitude should represent the zone where intra-continental extension has proceeded to the maximum degree immediately prior to the first seafloor spreading.

5. Passive margins east of 151°30'E. The Woodlark and Pocklington Rises are the conjugate structures formed as a result of rifting in the Woodlark Basin. Both are submerged except for a series of island that occupy their summit regions (Woodlark, Misima, The Bonvoulior Group, Egum Atol,Togula, Rossel). Little is know about these rises. Presumably they will exhibit structures that represent the final stage of extension.



Inactive subduction zone
Active subduction zone
Absolute plate motion
Relative plate motion
Seafloor spreading (w/relative rates)
Rifting
2000 m Depth Contour
PACIFIC PLATE
SOUTH BISMARCK PLATE
SOLOMON PLATE
INDO-AUSTRALIAN PLATE
WOODLARK BASIN
9.5-10 cm/yr
12.4 cm/yr
10.7 cm/yr
~6 cm/yr
7.4 cm/yr
5.8 cm/yr
7.2 cm/yr
New Ireland
New Britain
Bougainville Island
Solomon Islands
Trobriand Trough
Trobriand Platform
Woodlark Rise
Pocklington Rise
D.E.I.
O.S.F.Z.
Ramu-Markham F. Z.
Central Orogenic Belt
Continental Platform
0°
5°S
10°S
145°E
150°E
155°E

Figure 1

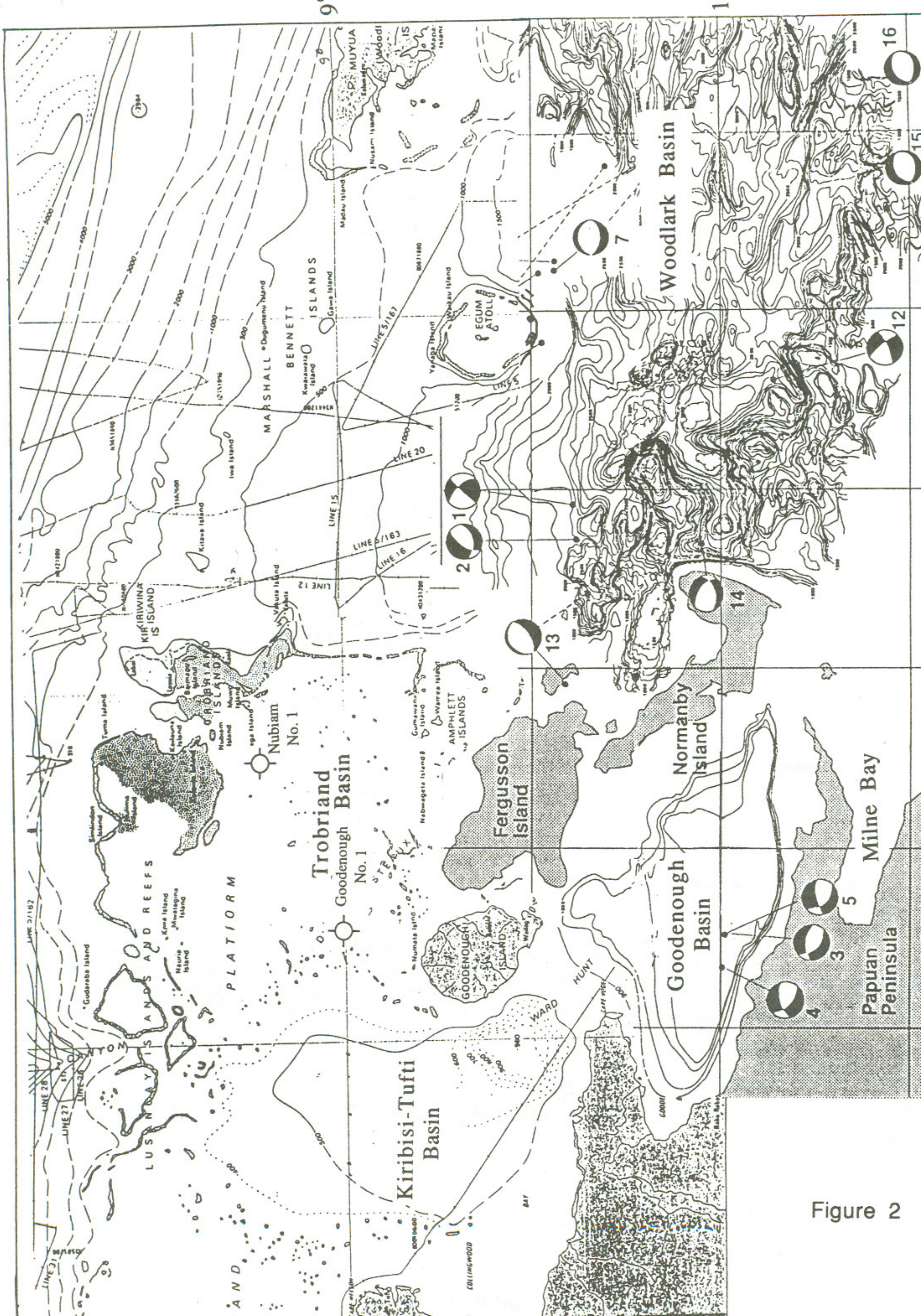
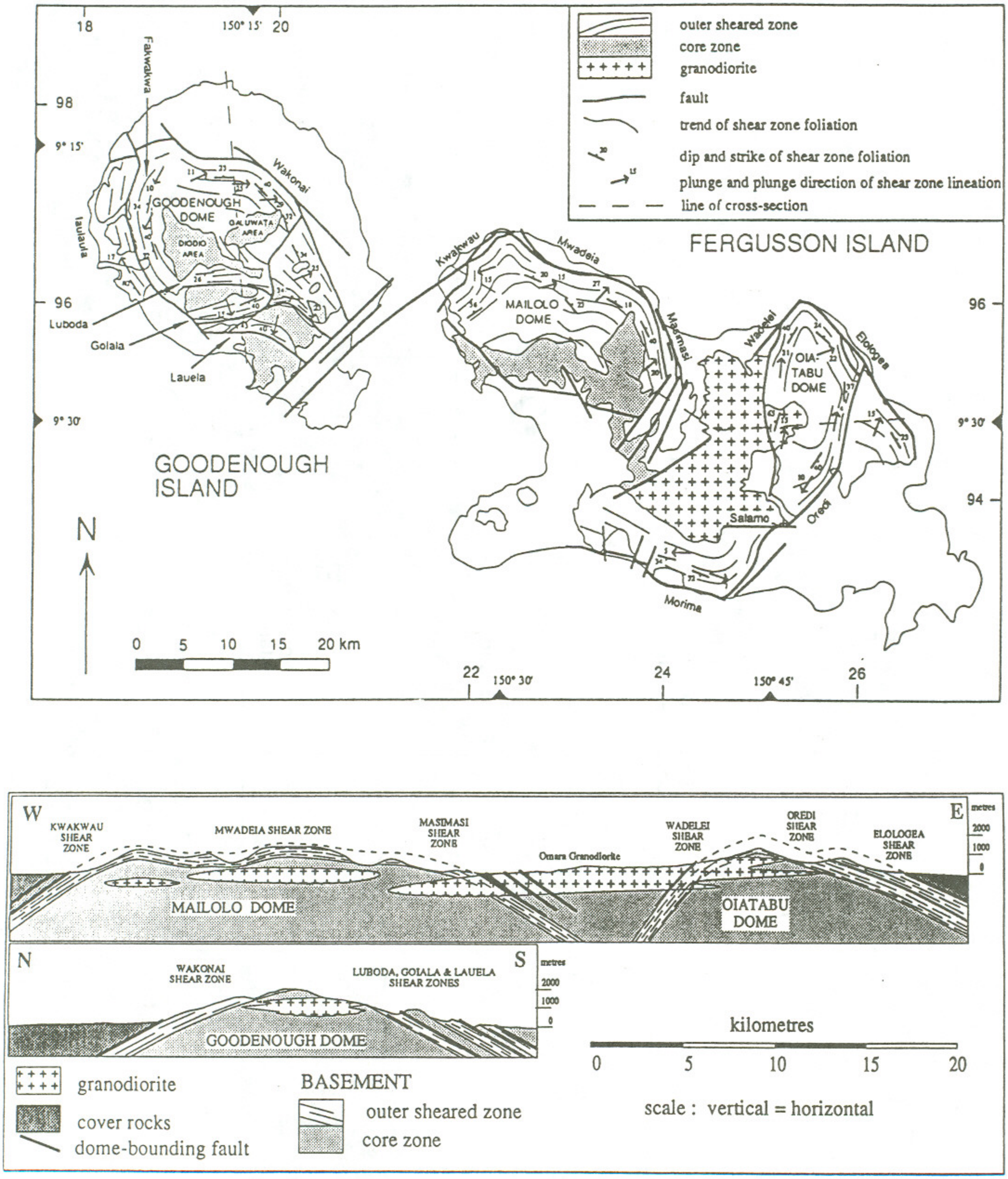
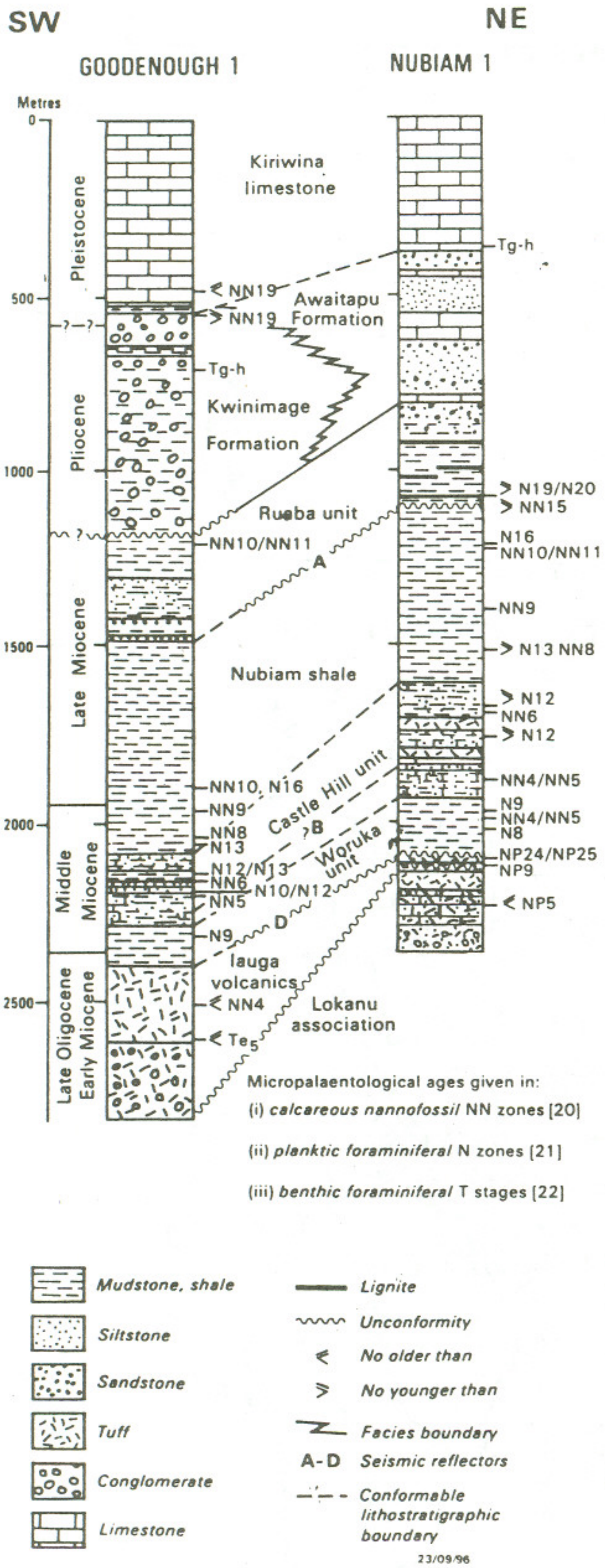

Woodlark Basin
Trobriand Basin
Goodenough Basin
Kiribisi-Tufti Basin
Milne Bay
Papuan Peninsula
Fergusson Island
Normanby Island
GOODENOUGH ISLAND
EGUM ATOLL
MARSHALL BENNETT ISLANDS
AMPHLETT ISLANDS
TROBRIAND ISLANDS
KIRIWINA ISLAND
Nubiam No. 1
Goodenough No. 1
PLATFORM
WARD HUNT
MUYUA
LINE 15
LINE 20
LINE 16
LINE 12
LINE 5/163
LINE 5/167
1
2
3
4
5
7
12
13
14
15
16
150°00'E
150°30'E
151°00'E
151°30'E
152°00'E
152°30'E

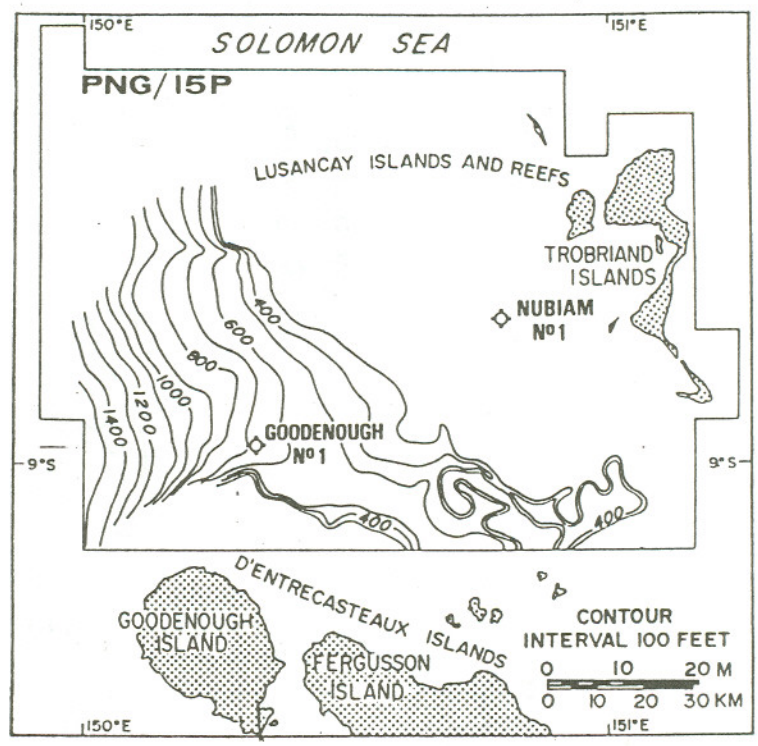
Figure 2



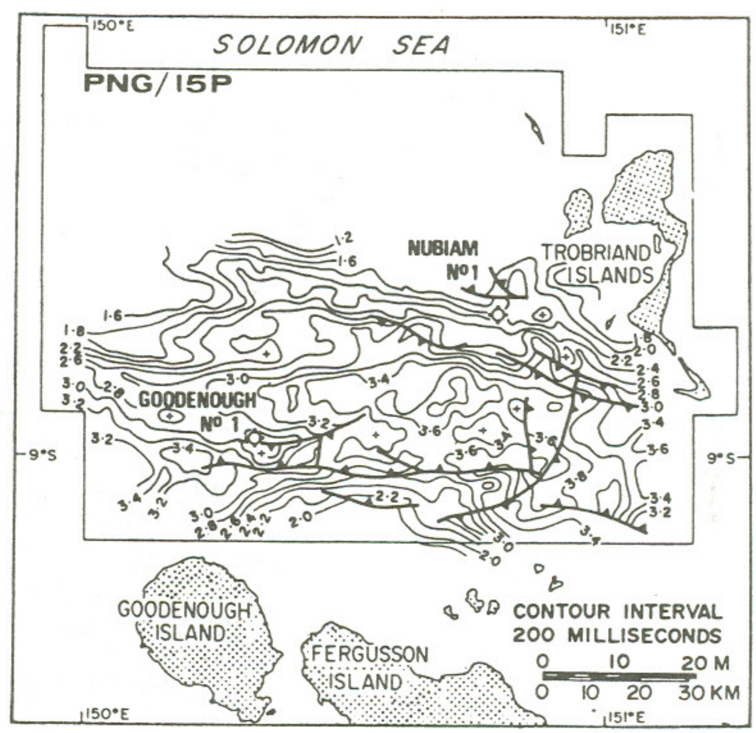
outer sheared zone
core zone
granodiorite
fault
trend of shear zone foliation
dip and strike of shear zone foliation
plunge and plunge direction of shear zone lineation
line of cross-section
18
150° 15'
20
98
9° 15'
96
9° 30'
94
22
150° 30'
24
150° 45'
26
Fakwakwa
Wakonai
GOODENOUGH DOME
GALUWATA AREA
DIODIO AREA
Iaulaula
Luboda
Goiala
Lauela
GOODENOUGH ISLAND
FERGUSSON ISLAND
Kwakwau
Mwadeia
MAILOLO DOME
Masimasi
Wadelei
OIATABU DOME
Elologea
Salamo
Oredi
Morima
N
0 5 10 15 20 km
W
E
KWAKWAU SHEAR ZONE
MWADEIA SHEAR ZONE
MASIMASI SHEAR ZONE
WADELEI SHEAR ZONE
OREDI SHEAR ZONE
ELOLOGEA SHEAR ZONE
Omara Granodiorite
MAILOLO DOME
OIATABU DOME
metres
2000
1000
0
N
S
WAKONAI SHEAR ZONE
LUBODA, GOIALA & LAUELA SHEAR ZONES
GOODENOUGH DOME
granodiorite
cover rocks
dome-bounding fault
BASEMENT
outer sheared zone
core zone
kilometres
0 5 10 15 20
scale : vertical = horizontal

Figure 3



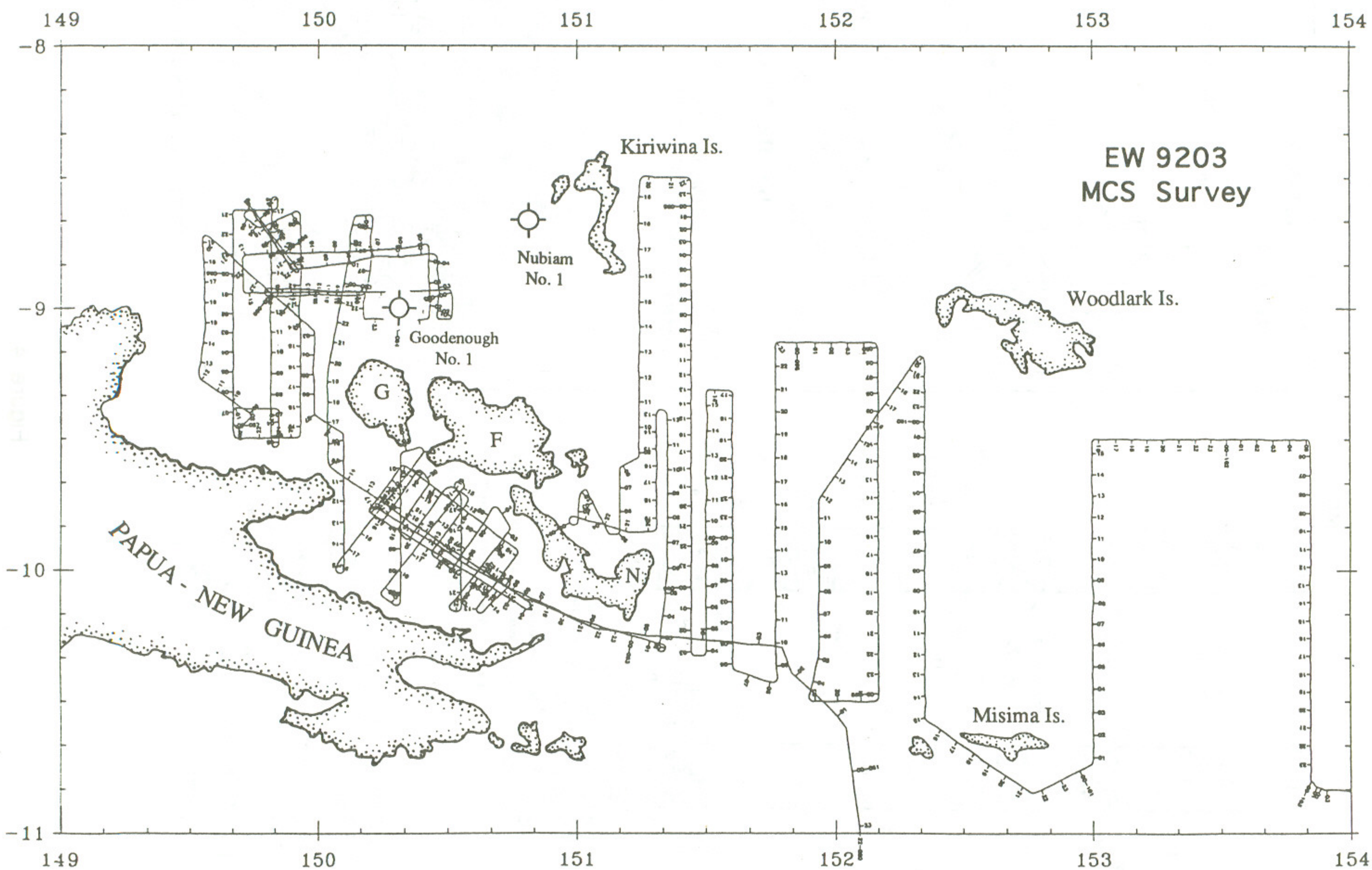


BATHEMETRY



DEPTH TO BASEMENT

Figure 4


EW 9203
MCS Survey
Kiriwina Is.
Woodlark Is.
Misima Is.
Nubiam
No. 1
Goodenough
No. 1
G
F
N
PAPUA - NEW GUINEA
149
150
151
152
153
154
-8
-9
-10
-11

EW9203

Cruise Narrative

March 17th - 21st: transit to work area.

The Maurice Ewing departed Gladstone, Australia (Queensland) at 1330 local time on March 17th and took the passage inside the Great Barrier Reef to Cairns. During the passage approximately the first 1km of the streamer was flaked onto the deck to make repairs and to install and move DTs as appropriate to configure the streamer correctly for 240 channels. Cans # 18 and 19 were changed out together with sections 18 and 19. The streamer had been built by connecting sections and cans on the way from Lyttletown, New Zealand to Gladstone, Australia but few DTs were in place. By working on deck we were able to get DTs in place to Can #24 and had a streamer working to Can#1

At Cairns we picked up an item of baggage for John Mutter containing a number of documents that were important to the conduct of the study and had been lost on the way from the US. These were brought out to the vessel by a small boat arranged by the agent. The vessel then exited the reefs at the Grafton Passage and crossed the Coral Sea to the Jomard Entrance into the Woodlark Basin area and made for the work area. Lab watches began at 1800 on the 18th. The magnetometer was deployed after passing the Australian EEZ and retrieved for the run through the Jomard Entrance due to the narrowness of the passage, shallow water and traffic.

Passed through Goshen Passage at the southeast end of the Goodenough Basin and began deploying the streamer at ~1800 on 21st. During the transit across the Coral Sea the streamer developed a telemetry failure at Can# 13/14. The STIC was put on line and appears to function correctly.

March 22

Streamer and gun deployment went fairly routinely. Streamer towed well. Several guns found to have failed SMDs and it was several hours before all gun firing was registering correctly. Began Line WLK#1 (Figure 7) to the northwest through the center of the Goodenough Basin at ~1500. There was apparently a problem with a buffer in the DSS 240 so we recorded 14 seconds of data at a shot rate of 21 seconds although 15 and 20 is more desirable. We maintained an average speed of 4.7 knots to try to compensate for the slower shooting rate. System initially subject to crashes. Data is being recorded on 3480 cartridge tapes which are considerably easier to manage than the recording of 9-track tape on the Telex drives. Tape labelling is not very satisfactory at present being based on a system that Dale Chayes put together on the previous leg. It does not write on the correct sized labels and requires the smaller of the two labels to be hand written. It is certainly satisfactory but a proper tape labelling system is needed.

Hydrosweep ran well but initially no tape was being made and no plotting was available at any time on the leg.

March 23

Completed Line WLK#2 running north on the western side of Goodenough Island to the northernmost part of the Trobriand Basin. North of Goodenough WLK#2 follows Amoco line 2-3. We then turned east on line 2-216 and south on line 1-108 (Figure 6). On these line the Amoco maps had proven largely very faithful. Where shoals and reefs had been indicated on their maps they could be re-located in essentially correct position from our observations. In general it was possible to identify shoal areas visually by light blue colored water while deeper areas are consistently dark blue/green in color. On line 1-108 we made several close passages by marked reefs and shoals. About four hours after commencing this line the streamer developed extreme noise characteristics from about the middle back as we passed by one of the shoal areas. The shoal was passed by at least 0.2 nm and water depths were more than 100 meters, so it was not immediately suspected that the streamer had contacted the reef - we initially believed that it might have been attacked by fish (sharks!).

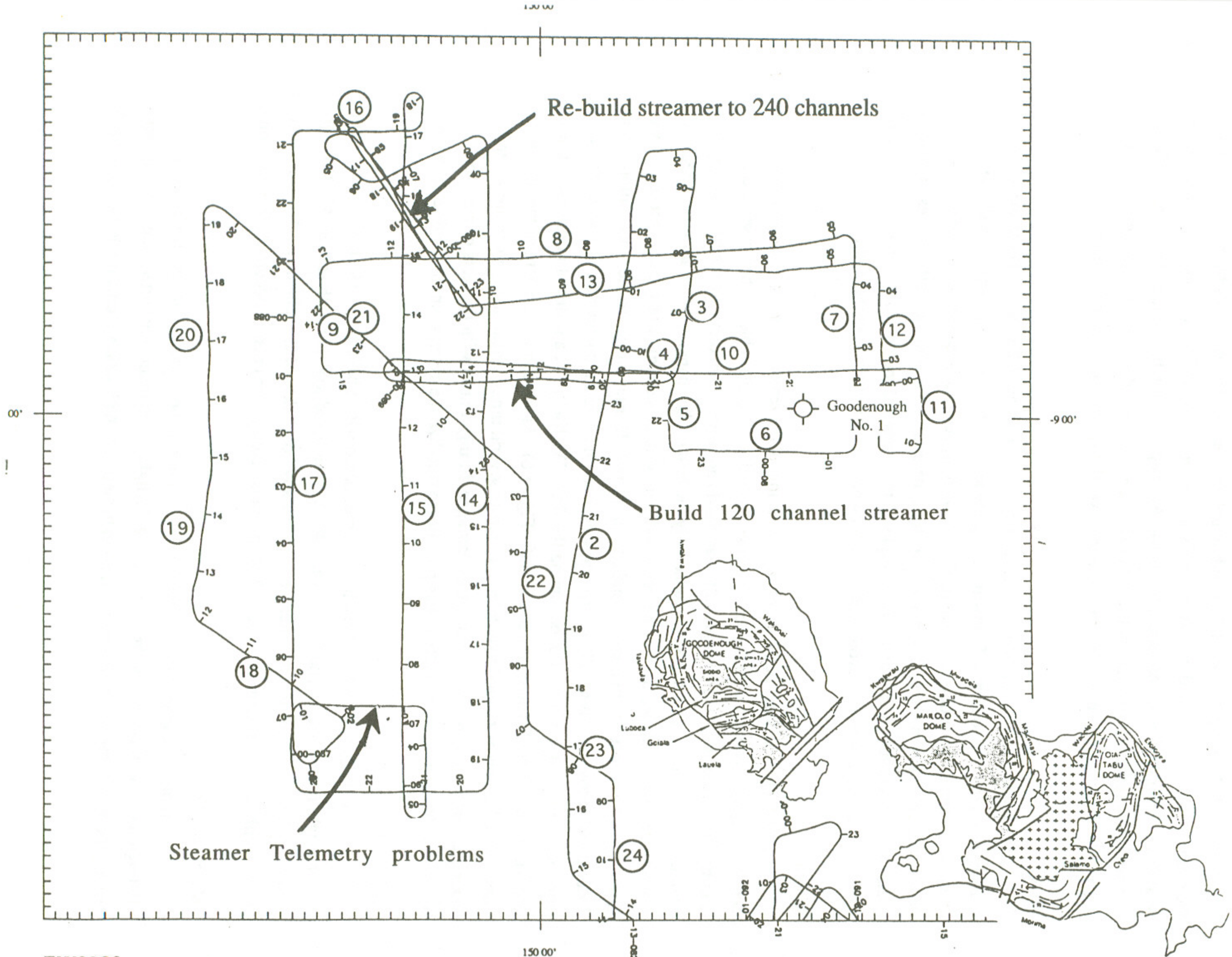
Streamer retrieval to assess the noise problem began about 1800 as the vessel turned west along Amoco line 1-208. It became immediately apparent that the streamer had contacted bottom. From about Can#34 aft many of the sections were severely punctured. In some instances entire sections had a puncture at each of the bulkheads. The last two depth control birds were damaged beyond repair; one broken off its mount at the front end, the other missing completely. Both these birds had had floats attached and these too were missing. The tailbuoy was missing having been broken off at the rope.

Apparently, although we passed a safe distance from reefs and shoals in good water depths there was sufficient set on the streamer due to strong currents to set the streamer into the reef. The mate on watch reported that he was steering more than 15° off the line bearing to maintain the appropriate course made good. Presumable we rubbed most of the back half of the streamer side-ways along the reef.

Given this analysis of the cause of the damage we decided to build a 1.5 km, 120 channel system from the remaining streamer and carried out a truncated program in the reefs of the Trobriand Basin (Figure 6).

March 24

Commenced work with the 120 channel streamer at ~0400, picking up the remainder of line 1-108 south to line 1-204. We then made transits east along 1-24, north along 1-118 and then



150 00'
Re-build streamer to 240 channels
Build 120 channel streamer
Steamer Telemetry problems
Goodenough
No. 1
GOODENOUGH DOME
MAROLO DOME
OIA-TABU DOME
-9 00'

EW9203

west along 1-212 during daylight hours ending up well west of the reef areas by nightfall. During the evening hours we worked west of the reefs in the deep waters of the Kiribisi/Tufi Basins to the west of the Trobriand and Goodenough Basins. Although nominally uncharted this area is shown on several compilations of bathymetric data to be free of reefs and always several hundred meters deep. Work in this region over the subsequent several days showed this to be the case.

March 25

We made a second excursion into the reefs of the Trobriand Basin this day in the same manner as on the previous day, following along tracks already shot by Amoco. The shorter streamer presented no problem for navigating through the restricted reef areas. Minimum water depths were about 20 meters. The magnetometer apparently hit bottom several times as judged by indications of jerking on the cable. We completed the westward transit out of the reefs and started to re-build a longer streamer around 2000. This work continued through the night.

March 26

A 240 channel streamer was constructed using all the remaining good sections that had not been damaged by contact with the reef, together with all spares available on the vessel and a number of sections that had been partially damaged and were repaired during the time we worked with the 120 channel system. We included only the best of the spares at the head of the streamer (fat 50's) to insure that sections in the best condition were in the region of greatest stress, and we placed the oldest sections in poorest condition at the tail. During this work the "lost" tailbuoy was located and recovered essentially in tact and was used on the re-built streamer. We were able to commence work at around 1800, beginning the first - WLK#14 - of a series of north-south lines in the basin west of the D'Entrecasteaux Islands (Figure 6). At the commencement of the first of these lines the streamer failed with telemetry errors several times. Presumably there are several poor areas in the streamer that were either damaged during contact with the reefs or are poor because of there age. Eventually it was possible to stabilize the system running with 200 channels.

March 27

Towards the end of WLK#14 the streamer failed with a hard error at Can 48. The streamer was brought in to this area and Cans 48 and 49 were removed together with section 49. With no spares to work with this left the streamer short of any possibility of 240 channels. We were able to restart with a stable system running at 220 channels. No system crashes occurred after this point.

March 28, 29

Completed a series of north-south oriented lines in the Kiribisi/Tufi Basins including one through the central portion of the basin during daylight hours in an "uncharted" area. Water depths were around 500 meters throughout and an indicated region of shoals seems not to be present. At the beginning of line WLK#18 we began recording 15 second records with 20 second shots as the smaller number of channels recorded could be recorded within the buffer limitations. It was later recognized that the buffer problem was related only to the camera output so had not effected data recording at any time. The MCS Sun workstation failed today, apparently caused by a problem with the video monitor, making it unusable for continued development by John Diebold. Work in the Kiribisi/Tufi Basins was completed with a diagonal run across the basin at an orientation roughly co-linear with the long axis of Goodenough Island then a peg-leg line to the south close to Goodenough and passing through Ward Hunt Straight on a southerly orientation and into the Goodenough Basin.

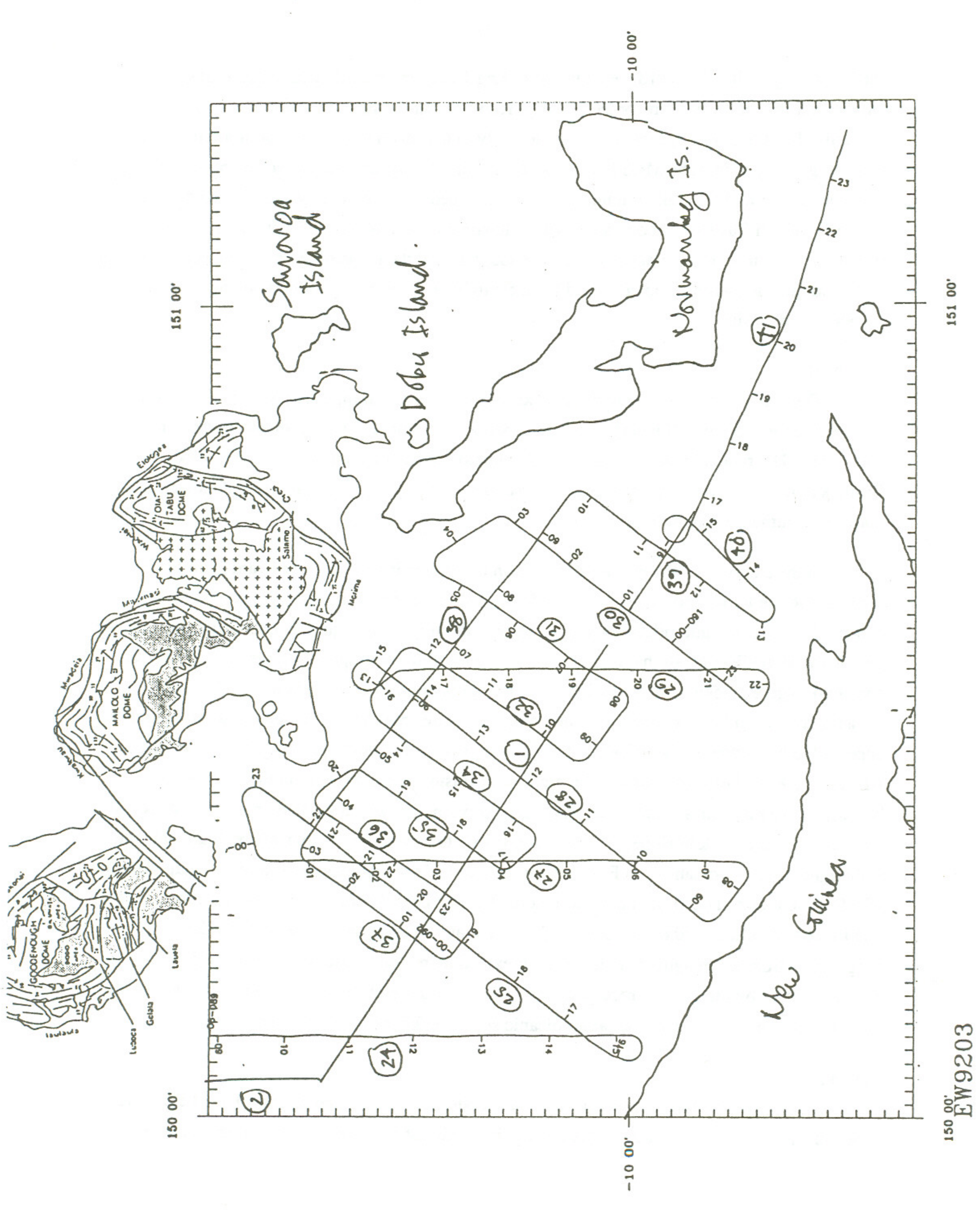
March 30

This day and the beginning of the next were occupied making a series of zig-zag lines through the Goodenough Basin (Figure 7). Lines were oriented north-south and northeast-southwest. The rationale was that the overall direction of seafloor spreading in the Woodlark Basin is north-south while the extensional structures on the D'Entrecasteaux Islands follow a northeast-southwest orientation.

In the extreme northwest part of the basin in the area immediately seaward from the bay between Goodenough and Fergusson Islands we saw evidence on the monitor records for what appeared to be a volcanic ridge that was, in its overall morphology, quite like the ridge we saw last year in the Bransfield Strait that is considered to be an embryonic spreading system. It therefore appeared to give evidence for a possible incipient spreading center in the basin. Subsequent crossing to the southeast showed possible igneous features but did not breach the seafloor and appeared to be located in the footwall of a major normal fault system that roughly paralleled the Islands in the northern side of the D'Entrecasteaux Basin. There location in the footwall was beneath the sloping surface of the normal fault approximately where the hanging wall and footwall meet at a distinct break in slope. This location is structurally similar to that where dilational strain is thought to allow volcanism in East African rifts and where, by analogy, triangular-shaped bodies of reflective material occur in the western north Atlantic oceanic crust. These observations suggest that the region of the northern Goodenough Basin may be presenting an example of the progression from an amagmatic mechanically-extending region to one where extension is accommodated by magmatic processes. On the basis of these observations we planned to double back and conduct a survey of the fault/volcanic structure for approximately one day.

March 31

Completed the long zig-zag lines in the Goodenough Basin and doubled back beginning the series of short lines. These are oriented along the northeast-southwest trend that seems to be



151 00'
150 00'
-10 00'
Sanaroa Island
Dobu Island
Normanby Is.
New Guinea
GOODENOUGH DOME
MAIOLO DOME
OIA TABU DOME
EW9203

Figure 7

appropriate given the position at which we recognized the apparent volcanic structures. Diebold making progress by using the Data Reduction Sun workstation Moray when time is available.

April 1

This day was mainly occupied with shooting a set of seven lines (WLK #30-37, Figure 7), each about 35 km long on a northwest-southeast orientation through the northeastern half of the Goodenough Basin. These lines were tied with a northwest-southeast trending line (WLK#38) along the end of the lines closest to the D'Entrecasteaux Islands. This line complements the central basin line run on the first day of shooting and, if the interpretation suggested by the examination of the monitor records is correct, will provide a tie down the footwall block of the fault system with the earlier line running down the hanging wall block.

April 2

A final zig-zag pair was run in Goodenough Basin at the southeast end and then the ship passed through the Goshen passage and into the western Woodlark Basin where the remainder of the work was carried out. In looking ahead we recognized that the down time experienced during the earlier part of the leg might cause some of the cruise objectives to be compromised so we experimented with increasing the vessels speed and the shot rate. We found that it was not possible for two compressors to keep up with the load at a 19 second repetition rate and that the compressors could barely keep up at 19.5 seconds and we eventually reduced back to 20 seconds with normal ship's speed. It came as something of a surprise to learn that the compressors were so close to their limits as they seem to be able to deal with the load fairly easily at 20 seconds. The remainder of the day we ran a line north just to the west of Normanby Island with the intention of making a turn back to the south at a time appropriate for entering Normanby Bay to survey that region during daylight hours.

April 3

Normanby Bay Survey (Figure 5). Profiling in the Bay began with a roughly east-west oriented line in the southern part of the Bay in a deep trough called the South Valley by the PACKLARK Group. We deployed a sonobuoy in the trough but immediately encountered topography that will likely make the data uninterpretable. We then made a short northward profile in the western end of the valley adjacent to Dobu Seamount and commenced a northeast-oriented track with the intention of starting a southerly line through the center of the Bay from north of a second trough known as North Valley. We were prevented from achieving this as planned when the vessel was required to make a large avoidance manoeuvre to clear an uncharted reef off Sanoroa Island. We diverted to the southern part of the Bay and commenced the central line from there but were required to turn before crossing the southern margin of South Valley. At the end of the day we made north at the extreme western end of the Woodlark Basin toward the Trobriand Island of Kiriwina.

April 4

This day spent running the long line WLK#49 north to Kiriwina.Island and turning south after passing Kitawa Island. On the southward run WLK#50 we encountered strong currents and the vessel's overground speed was reduced to as little as 2.8 knots for several hours. During the last several days the seismic system generally worked very well. System crashes occasionally occur and seem to be related to the times of automatic tape unit switching, although this is not certain. Gun problems have occurred but are essentially routine in nature. No streamer telemetry failures.

April 5

Completed WLK#50 and headed back north on WLK#51 crossing the Moresby Seamount believed to be a large fragment of continental crust isolated as a block during the final stages of rifting. This line was not shot to the same latitude as the lines WLK#49 and 50 as much of the Trobriand Platform sediments seemed largely undeformed and the strong currents on the southward legs of the north-south lines make for very slow progress and a poor investment of time. John Diebold succeeded in making low-fold stacks of the near traces from the streamer and can routinely produce these plots on laser printer output using Moray when Bill Robinson is not using it for data reduction.

April 6 to April 12

The remainder of the leg consisted of running a series of north-south oriented lines across the Woodlark Basin ending at approximately 11° S, 154° E. These lines were run without significant difficulty save for the fact that strong currents were encountered slowing progress on each of the south-going lines and the east-going connecting segments. We made two crossings of the hypocenter location of one of the earthquakes described by Abers as having a solution consistent with low-angle normal faulting. The location is to the southeast of Egum Atol very near to what appears to be the boundary between Trobriand Platform sediments and the oceanic crust of the Woodlark Basin. The monitor records show no structure associated with this earthquake but are not of sufficient quality to make a reasonable judgement.

We completed operations at 1050 in deteriorating weather conditions on April 12. All towed equipment was on board by 1300 when we commenced the transit to Tahiti.

April 12 to April 24

The vessel transmitted to Tahiti in generally poor weather fighting a head wind most of the way requiring that a third engine be used to meet the intended ETA.

In addition we were required to make a diversion to the port of Santos in the New Hebredes to put ashore Anja Pahl who had become ill as soon as the transit began and the weather deteriorated. She had been unable to eat in a satisfactory way and had become very weak, unable to walk unaided. Mirek Benes left the vessel with her to assist in getting her medical treatment and in making travel arrangements. We entered Santos at around 0600 on the 16th, moved to anchorage under pilot at around 0700, disembarked the two members of the science party and left for sea at around 1000. The local customs agents required the vessel to go through customs formalities.

Preliminary Observations

The following general observations are made from examination of low-fold CMP stacks made from a version of JDseis modified for that purpose during the leg. The stack uses only the near traces of the streamer and achieves very little attenuation of multiples, but greatly improved dynamic range and general image quality. We were also able to study along-track plots of center beam bathymetry, FAA gravity and magnetic profiles. The principal findings of the study based on these preliminary data are:

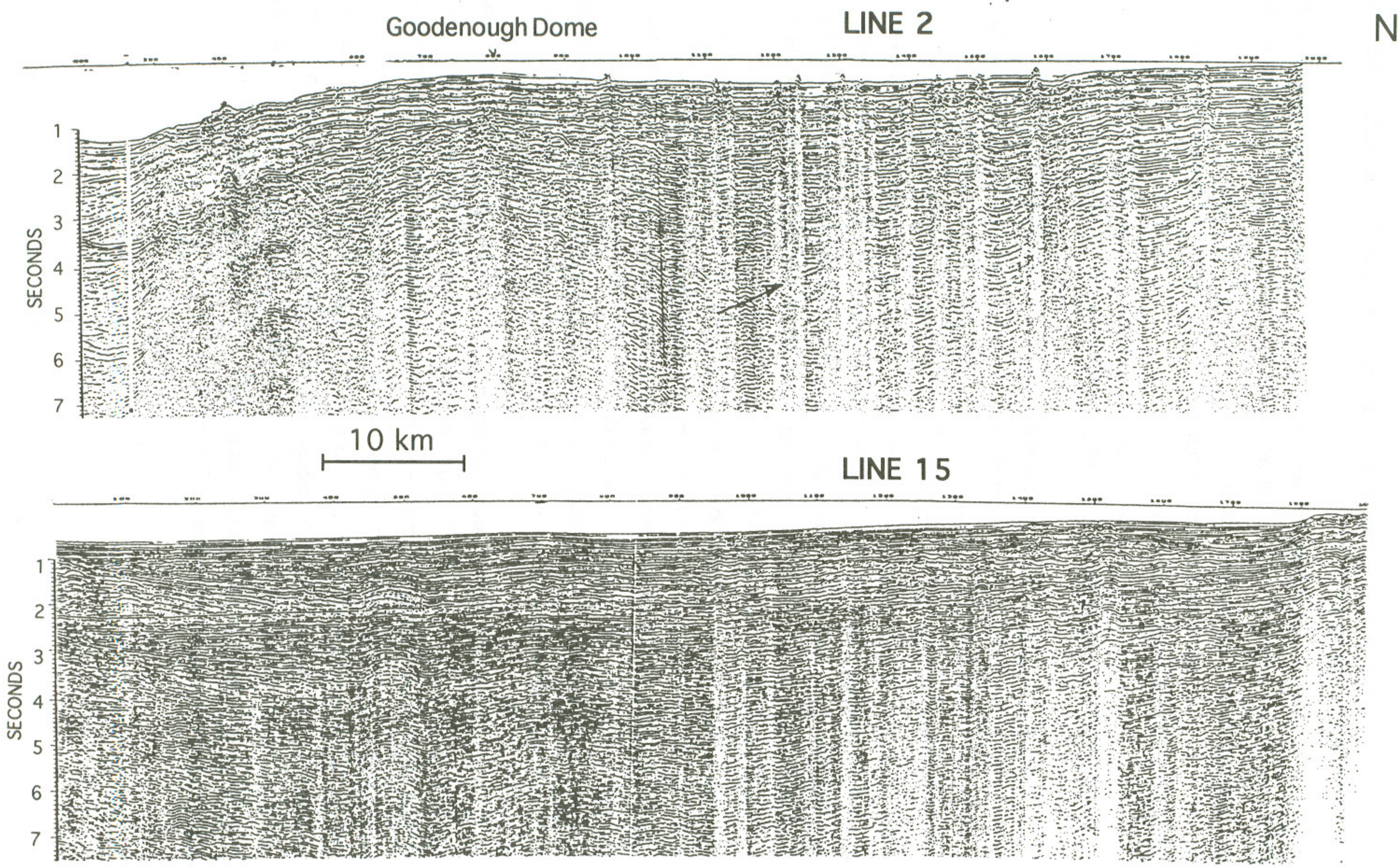
Kiribisi/Tufi Basins and Trobriand Basin

In this region we would anticipate finding structure that represents the earliest stages of intra-continental extension and perhaps features representing proto-domes that are in the beginning stages of becoming core complexes. One immediate result is that the Goodenough dome does **not** create a spectacular structure on the seismic profiles, even on lines shot very close to the island such as WLK#2 (Figures 6 and 8). An arched structure can be recognized but it does not appear to be associated with a major detachment or with strongly deformed "upper plate" rocks, particularly on the northern side of the dome. On the southern side there is evidence for faulting in the section and the sediment-filled bathymetric depression at the southern end of the line may also be formed by faulting. This depression reaches a little more than 1000 meters depth and lies in a position that is antithetic with respect to the geometry of the main normal sense shear zones that define the Goodenough dome. On the northern end of WLK#2 we recognize a strong event dipping to the south for which we have no present explanation but we note that this structure is at least as prominent as the structure associated with the dome itself.

On lines obtained further west in the basin the Goodenough structure is very difficult to recognize. On WLK#15 (Figures 6 and 8) we can easily recognize a strong interface dipping to the north away from the coast of the New Guinea mainland. The hinterland here is the location of the Suckling-Dayman dome, a core complex that is believed to be analogous to those of the D'Entrecasteaux islands. The dipping interface is almost certainly related to the dome but the nature of the structural relationship is not apparent at present. Again we do not see clear evidence for deformation in the upper plate.

Goodenough Basin

In this region the study comprised thirteen lines, most oriented in a northeast-southwest direction, together with two tie lines oriented northwest-southeast (Figure 7). The majority of the lines shot in the region are shown in Figures 10 and 11. These data show four prominent features that characterize the structure of the Basin and are exemplified on Line WLK#29 (Figure 9).


Goodenough Dome
LINE 2
N
SECONDS
1
2
3
4
5
6
7
10 km
LINE 15
SECONDS
1
2
3
4
5
6
7

1. A thick sedimentary sequence that reaches at least 2 sec reflection time occurs throughout much of the basin.

2. A distinct basement ridge - here named Goodridge. It is buried in the southeast but is emergent at the seafloor in the northwest immediately offshore from Moresby Strait - the embayment between Goodenough and Fergusson Islands.

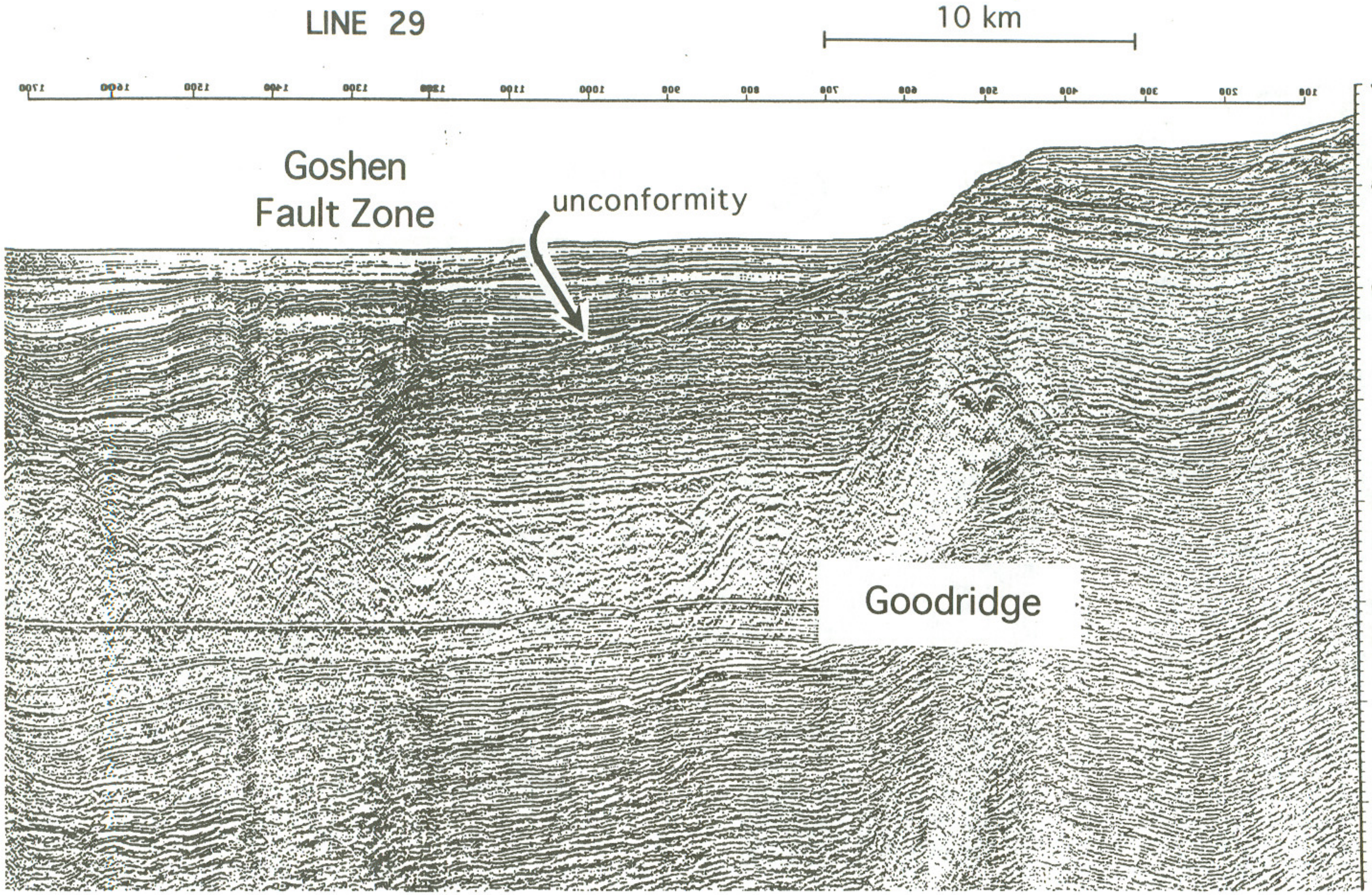
3. A distinct unconformity dipping from northeast to southwest across the sedimentary basin throughout the area.

4. A complex deformation zone occurs in the southwest of the basin and extends into the Goshen Strait south of Normanby Island - here named the Goshen Fault Zone (GFZ).

The age and nature of the basement, and hence of the sedimentary sequences in the Goodenough Basin are not known. If correlation with the parts of the Cape Vogel Basin exposed on the New Guinea mainland is appropriate then the sediments could be as old as late Oligocene with much of the infill comprising deep water clastics of Miocene to Plio-Pliestocene. The sections drilled in the Trobriand Basin are Middle Miocene to Pleistocene marine marls and shales and could also provide analogies for the Goodenough basin sediments. The basin-wide unconformity generally dips to the southwest and separates strata beneath that are essentially horizontal from strata above that are horizontal (in the southeast) to dipping with the sense of dip opposite to that of the unconformity (in the northwest). It is not clear at this stage of analysis whether the unconformity is structural or depositional in origin, or formed by a combination of the two processes. In the southern part of the basin there is evidence for prograding clinoforms in several places beneath the unconformity suggesting that the slope of the unconformity might be due to depositional processes associated with the construction of a basin margin. Here the strata overlying the unconformity are essentially horizontal and the unconformity may have been created by the deposition of sediments from the southern side of the basin which onlap the older margin.

Another interpretation that could explain some aspects of the geometry is that it is erosional in origin. Strata beneath the unconformity in the deeper parts of the basin are, however, roughly horizontal. Hence, if erosion was responsible for the unconformity, and assuming that the erosion cut an approximately horizontal surface, basin sediments would have had to have been rotated through the present dip angle on the unconformity, eroded, then un-rotated by exactly the same amount. Since this seems unlikely we presently favor a tectonic origin. Furthermore, on several profiles sediments in the hanging wall block form a broad arch and dip into the unconformity, and the footwall exhibits a tilt toward the islands in a geometry that resembles hanging wall deformation in well-documented normal fault systems.

LINE 29



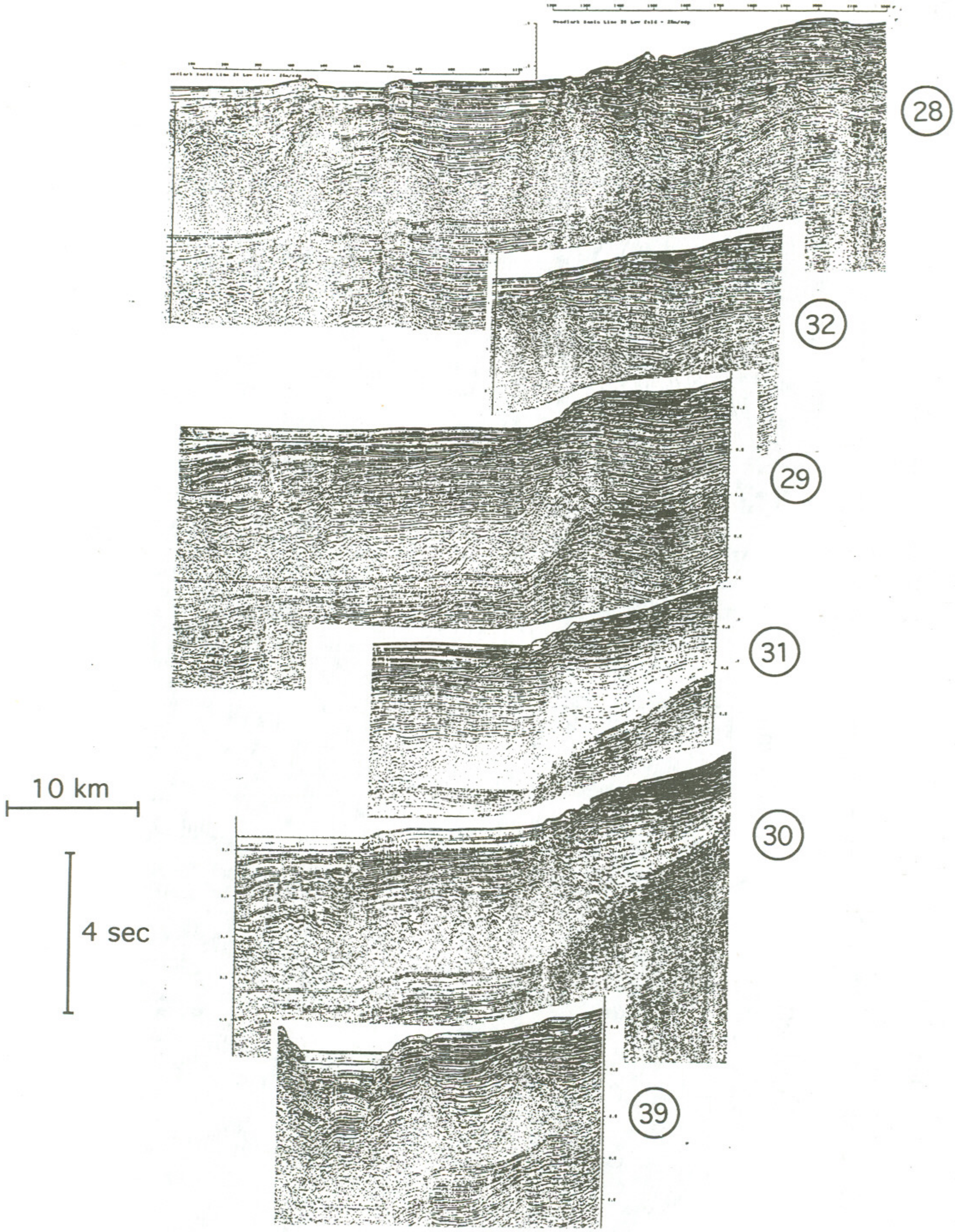


Figure 10

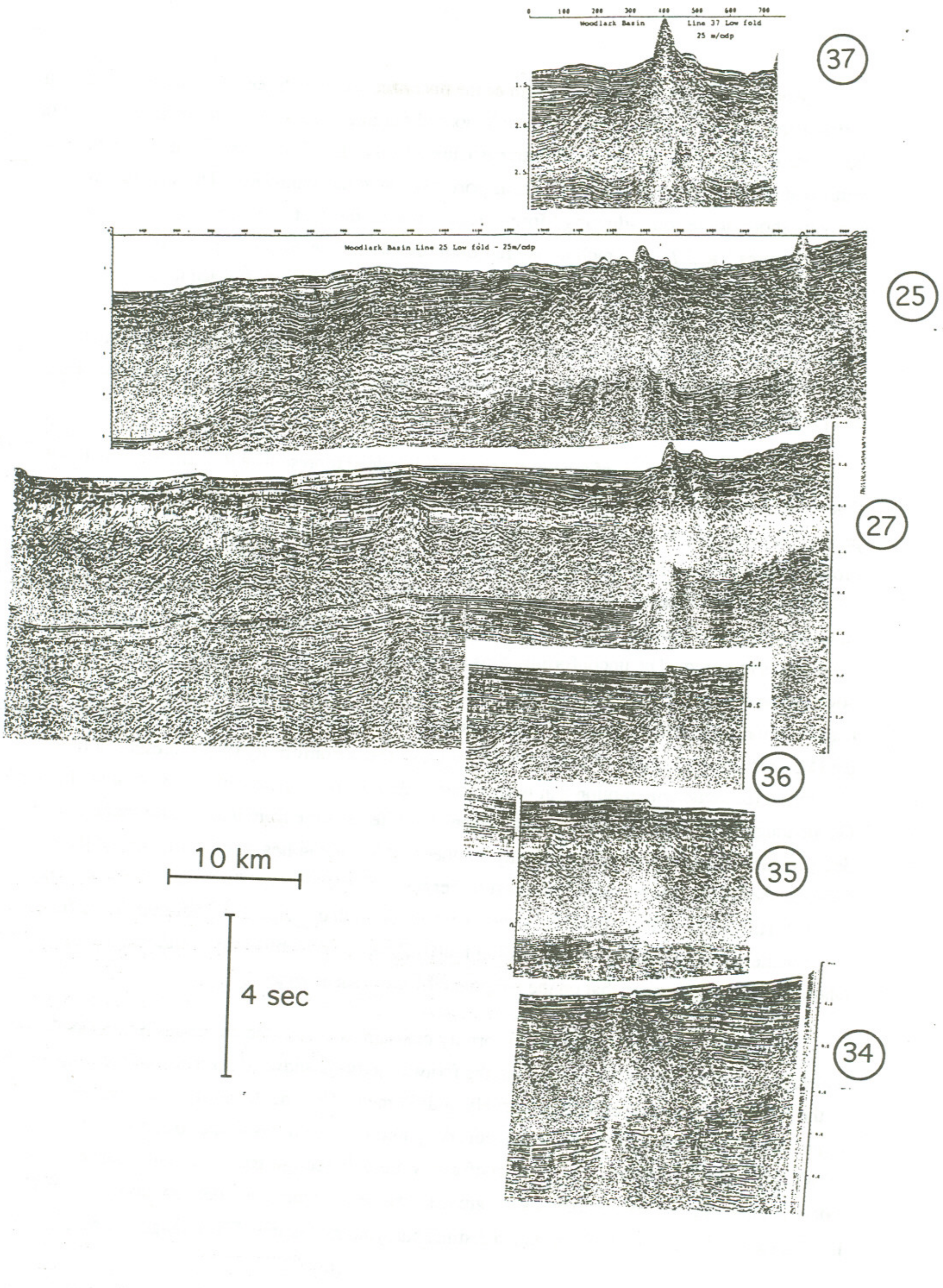

0 100 200 300 400 500 600 700
Woodlark Basin
Line 37 Low fold
25 m/cdp
37
Woodlark Basin Line 25 Low fold - 25m/cdp
25
27
36
35
34
10 km
4 sec

Figure 11

Another interpretation of the origin of the unconformity which seems most applicable to the northwestern part of the basin is by low-angle normal faulting associated with the development of the core complex structures on the D'Entrecasteaux Islands. The Goodenough Basin structure dips southwest and the apparent direction of transport is down to the southwest. The structure lies partly offshore of the south-dipping Morima shear zone on the southwest coast of Fergusson Island (Figures 3 and 7), of which it may represent the offshore extension. In the northern part of the basin strata above the unconformity dip down into the unconformity surface in a manner that recalls the roll-over of the sediments in the hanging wall of a large listric normal fault. Strata beneath the unconformity in the southeast part of the basin have a gentle northeast dip which may represent rotation of a footwall block. One of the aims of data processing is to resolve the origin of this prominent unconformity.

One important aspect of the unconformity if it indeed represents a low-angle normal fault is that it cuts into strata in the deeper part of the basin that are essentially horizontal and this is presumably the attitude at which they were deposited. Thus there is no opportunity for the proposed fault to have formed at a higher angle and have been rotated into its present dip by flexural rotation as recently suggested by Buck and Wernicke and Axen. It may therefore represent an extremely rare example of a low-angle normal fault for which motion at the currently observed dip angle is required. The unconformity dips southwest and the apparent direction of transport is down to the southwest. This motion is in the opposite sense to that reported for motion on the major normal sense shear zones forming the detachment faults surrounding the core complexes on the D'Entrecasteaux Islands. The overall geometry of the unconformity (if it represents a fault) is difficult to reconcile with motion that is antithetic to that on the detachments. It is possible that the Goodenough Basin fault accommodated motion at a different time from that accommodated on the detachments. However, the unconformity southeast of WLK#34 lies largely offshore of the Morima shear zone on the southwest coast of Fergusson which does not bound a core-complex dome. J. Hill has described this shear zone as enigmatic in that it dips to the south and is difficult to reconcile with motion on dome-bounding faults. Thus the unconformity could mark a fault whose motion conforms to that on the enigmatic Morima shear zone.

Southeast of WLK#34 the unconformity cuts across almost the entire basin and Goodridge appears to have acted as a hinge allowing the footwall to tilt islandward northeast of the ridge while to the southwest the footwall appears largely undeformed. The unconformity is always very near to the seafloor northeast of the ridge and cuts deep into the sediments to the southwest. Northwest of WLK#34 basin sediments and the unconformity are only recognized to the southwest of the ridge, the hanging wall block exhibits the greatest degree of arching and deformation.and the ridge itself is exposed at the seafloor forming a distinct bathymetric feature The change in structural style of basin development occurs immediately offshore of the termination of the Morima shear zone where it intersects the transversely-oriented portion of the Masimasi shear zone. Thus the change in offshore basin style occurs at the boundary between the Mailolo Dome on northwest Fergusson and the Omera granodiorites and Oitabu Done of central Fergusson. This association suggests a direct relationship between onshore and offshore structures.

The age and nature of the basement in the Goodenough Basin is not known, nor is it certain at the present stage of processing whether Goodridge is part of the original basement or was formed as an igneous construction at a later time - it is not possible to determine whether the contacts between the basement ridge and the sedimentary units are depositional or intrusive. The structural relationships between Goodridge, the sediment distribution in the basin and the location of the low-angle normal fault suggest, however, that the ridge was probably an original part of the basement. One reasonable interpretation is that the basement formed by a limited period of seafloor spreading prior to that in the Woodlark Basin. The age of the basement cannot be judged from the magnetic anomalies. Although sediment rates are unknown, and could be quite high given confined nature of the basin and the close proximity of New Guinea and the D'Entrecasteaux Islands, the thickness of the overlying sediments suggests that, if formed by spreading, the period of spreading considerably pre-dates that occurring in the Woodlark Basin.

The youngest structure in Goodenough Basin is the Goshen Fault Zone (GFZ) - a complex zone of deformation that runs the length of the basin on its southwest margin. It is a relatively narrow region which, in the southeast, is developed into a depression in the seafloor approximately 7 km wide which trends directly into Goshen Strait south of Normanby Island. The overall triangular shape of the Goodenough Basin with a deep trough at the southeast end caused by a faulted depression recalls that of the Kiribisi/Tufi Basin. The style of deformation within the GFZ includes fairly tight folding, and the block forming the southwest flank of the GFZ is also complexly folded and tilted by a rotation that is opposite to the sense of rotation of the footwall block associated with the low-angle normal fault. The GFZ therefore appears to include structure indicative of extension forming a narrow trough with footwall to the southwest, but may include a significant component of transform motion giving rise to "flower" structures that include folding. The overall trend of the GFZ appears to roughly parallel the Goodridge but the two converge in the southeastern part of the basin toward Goshen Strait. Individual trends within the deformation zone appear to be more nearly east-west especially in the vicinity of Goshen Strait. One possible interpretation of this feature is that it originated as an antithetic structure integral to the low-angle fault system which developed into a concentrated zone of transtensional motion.

Western Woodlark Basin - rift propagation

Work in this region comprised a brief survey in Normanby Bay in the extreme western end of the Woodlark Basin together with a series of twelve lines oriented north-south crossing the basin from margin to margin, the most easterly at around 154°É (Figure 5). Based on present interpretations of the magnetic anomaly profiles the oldest part of the basin is approximately 2 Ma old at this longitude. The spreading center in the Woodlark Basin is difficult to locate on the seismic data and does not correspond to either a distinct high or an axial depression. This is consistent with spreading at an intermediate rate.

In the region west of about 151°45'E a typical margin-to-margin crossing of the basin (Figure 12) shows no recognizable spreading center but instead the strong juxtaposition of the southward-sloping Trobriand Platform strata with extreme topography formed of very large crustal blocks with relief up to 3km. The northern margin includes a relatively simple post-breakup sedimentary wedge that covers an erosional unconformity beneath which strata dip steeply to the north. These north-dipping sequences may be indicative of fault block rotation but if so the tops of the blocks must have been strongly eroded and there is no simple equivalent of syn-rift strata within the blocks The large-relief crustal blocks rise to much shallower depths than the Woodlark Margin and do not appear to be composed of uplifted and deformed fragments of the Trobriand Platform as they are essentially transparent and do not contain the characteristic stratigraphy of the Platform.

Structural trends in Normanby Bay are strongly developed in an east-west orientation, matching that of the seafloor spreading lineations in the Woodlark Basin. It is generally believed that structure in Normanby Bay reflects the most recent episode of rift propagation although the exact location of the tip of the propagator is uncertain, and it is not clear whether seafloor spreading, senso stricto, is actually taking place in the Bay or if the structure developed there reflects dominantly mechanical extension ahead of the propagating ridge tip.

The northern margin includes the Egum Atol and Woodlark Island. Our survey lines surround Egum Atol and show that the Atol lies atop an uplifted structure in the pre-breakup section that is bound to to northern side by a north-dipping reflector. Woodlark Island is mainly composed of volcanic rocks of Eocene and Miocene age but it is not possible to correlate the geological record from the island with the seismic data. Two sonobuoys shot to the south of the island appear to have recorded basement refractors.

East of about 151°45'E oceanic crust can be recognized and the northern margin retains its relatively simple form. The southern (Pocklington) margin has an arcuate shape with overall trend northwest-southeast and is formed by the boundary between the oceanic crust of the Basin and a

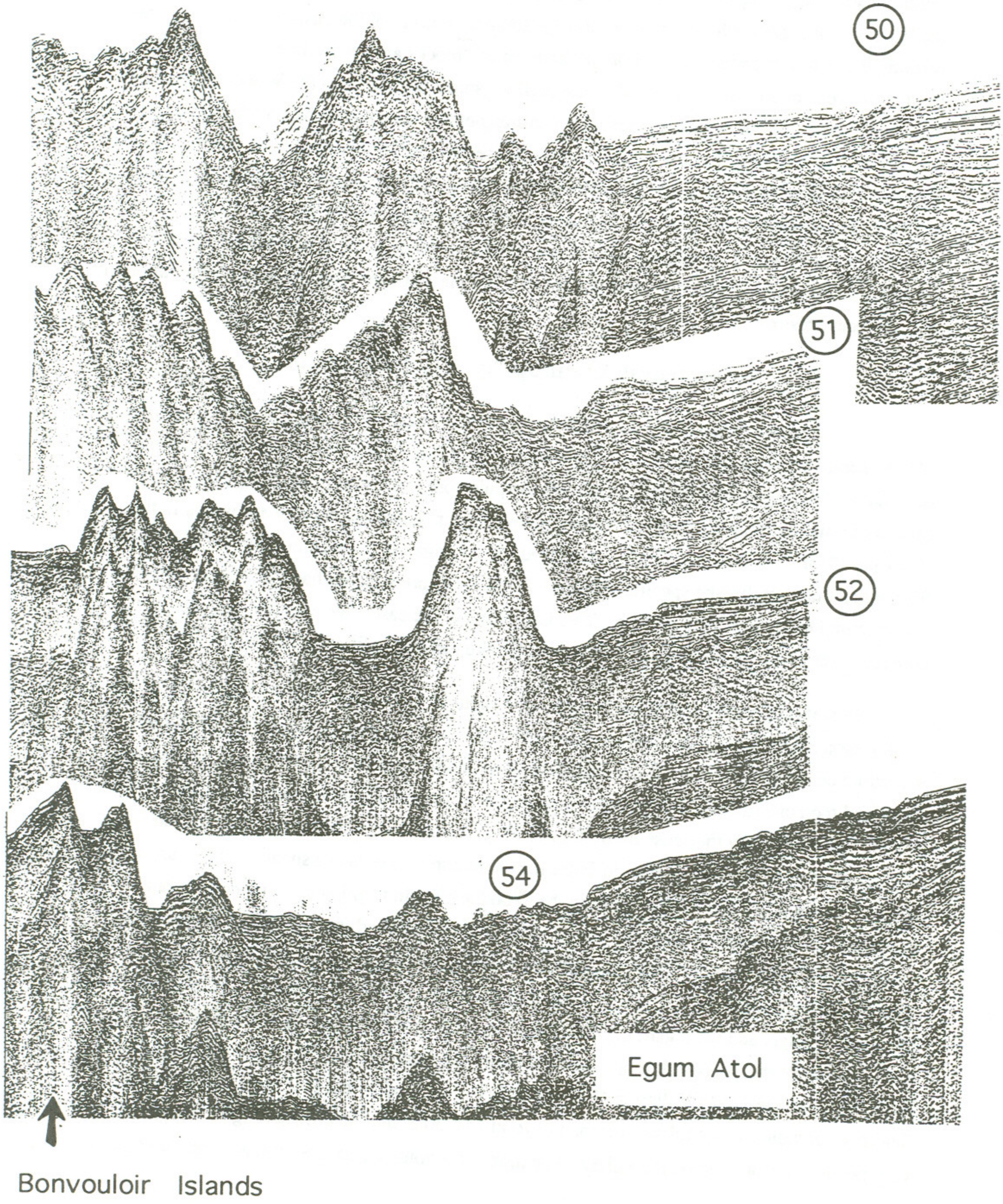


Figure 12

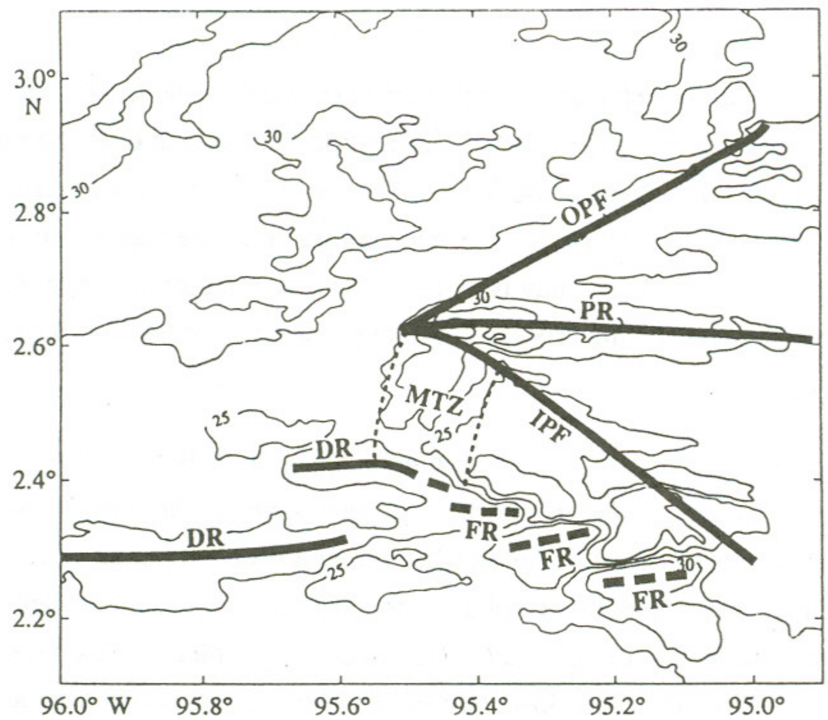
region of very large, high relief crustal blocks. That is, the large blocks that appeared adjacent to the Woodlark margin further west now form the southern margin of the basin with oceanic crust forming the region between. Trends on the large crustal blocks are generally east-northeast to west-southwest, about 30° to the trend of the seafloor spreading center in the Woodlark Basin. The entire zone of large blocks is essentially non-magnetic. Deformation has produced blocks that are typically asymmetric, usually with the steepest face oriented toward the basin. Immediately to the east of Normanby Island there is a distinct series of asymmetric basement structures creating a sawtooth appearance to the seafloor. Further east Misima Island and the Bonvouloir Group are the exposed peaks of two of the largest asymmetric blocks. Absence of reef growth around both islands and terrace structures on the southern side of Misima suggest that uplift has been important in their recent history.

Continental breakup by rift propagation

The objective of the study outlined above was to advance our understanding of the process of continental breakup and the initiation of seafloor spreading with special reference to the role of detachment faulting and the formation of metamorphic core complexes. We recognized that breakup in the region was promoted by the westward propagation of seafloor spreading in the Woodlark Basin. We had, however, considered the propagation to be essentially a driving force for the breakup, but that the specific geometry and style of propagation had little direct influence on the structural evolution of the margin. This is clearly not the case. We examine here the consequences of rift propagation in continental breakup as exemplified in the region.

First it is apparent that the asymmetry of structural development on the Woodlark and Pocklington margins is a direct consequence of the geometry of propagation of the Woodlark spreading center (Figure 13). The arcuately-shaped boundary between the oceanic crust in the basin and the zone of strongly disturbed topography to the southwest is interpreted to be an inner psuedo fault in exactly the sense defined by R. Hey in describing oceanic propagators and we suggest the name Bonvouloir Psuedo-Fault for the feature. The outer psuedo-fault occurs as the northern boundary of the oceanic crust in the Woodlark Basin forming the continent-ocean boundary of the present Woodlark margin. The zone of disturbed topography adjacent to and southwest of the Bonvouloir Psuedo-Fault lies in a position that is the geometric equivalent of the Migrating Extensional Relay Zone, MERZ, as defined by Hey et al for the 95° E propagator on the Galapagos Ridge, and we regard the disturbed zone here as the tectonic equivalent of the MERZ also. The tip of the Woodlark propagator extends west to at least 151°30'E and probably to the western end of the North Valley in Normanby Bay as defined by the PACKLARK Group. Seafloor spreading is not fully developed beyond 151°30'E and the propagating tip must have only very recently formed the North Valley. The inner, Bonvoulior Psuedo-Fault and the outer psuedo-

GALAPAGOS OCEANIC PROPAGATOR



WOODLARK PROPAGATOR

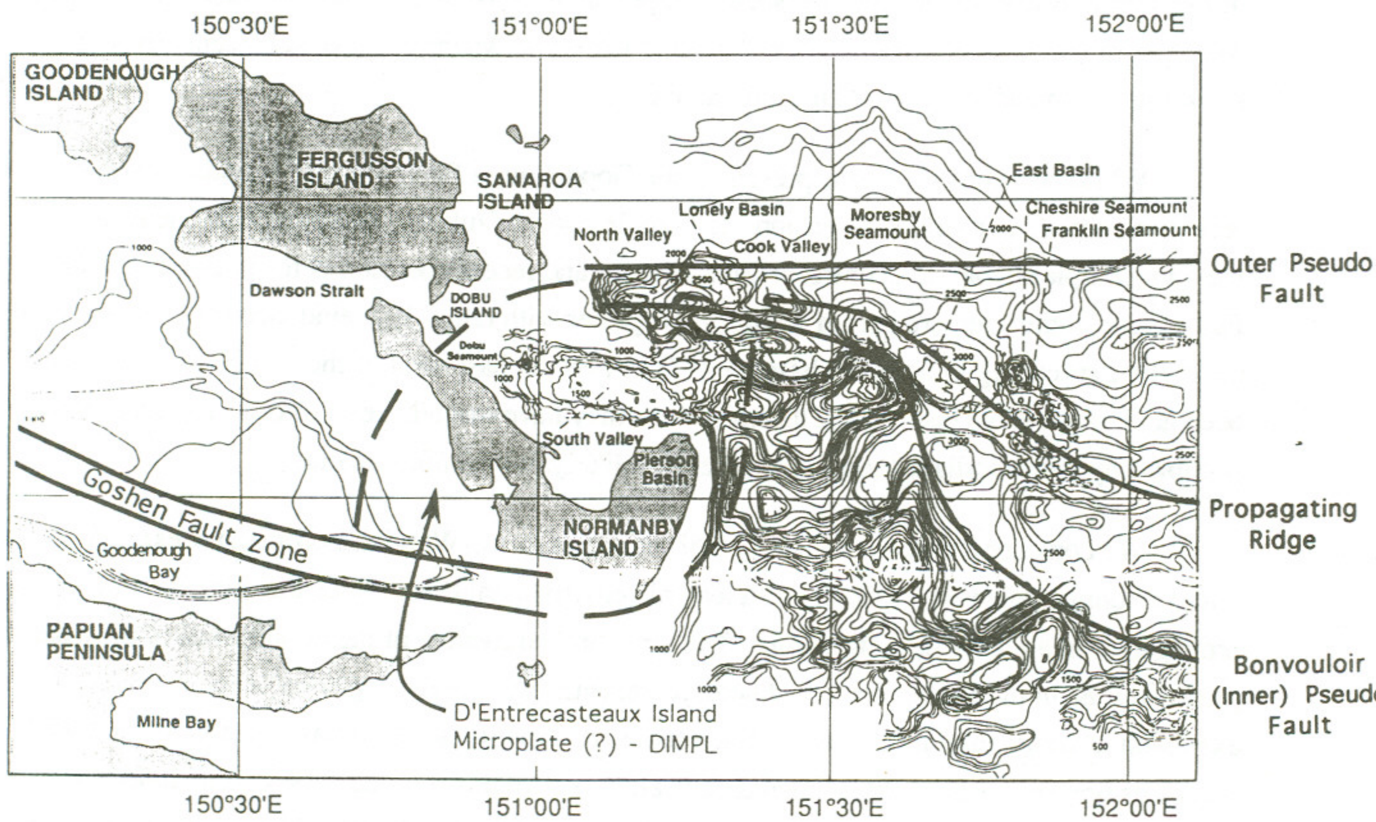


Figure 13

fault form the opposite flanks of North Valley and we consider South Valley to define the youngest part of the MERZ.

The structural asymmetry of the two margins is therefore the result of the significant difference in the tectonics associated with the formation of inner and outer psuedo-faults. The asymmetry is **not** related to asymmetric forms of rifting such as have been frequently discussed in the recent literature, often by invoking large-scale simple shear mechanisms of extension. An important immediate result of the study is that structural asymmetry of continental margins need not be the result of asymmetric rifting processes but may instead be indicative of the action of a propagator during rifting.

In suggesting that the structures bounding the Woodlark Basin are psuedo-faults we are equivalencing them to those found in oceanic settings despite the fact that the rift here is propagating into continental crust. In an oceanic setting the development of an inner and outer psuedo-fault pair requires the existence of a "doomed" ridge which fails in sympathy with the propagation of the extending ridge (Figure 13). Given the geometry of the Woodlark propagator and the associated Bonvoulior Psuedo-Fault we would expect the doomed ridge to lie to the south and west of the propagation tip in roughly the position of the Goshen Strait south of Normanby Island. No ridge has been recognized in that location to date, nor have any tectonic reconstructions of the region lead to suggestion that such a ridge may have been present in the past. Such a ridge would most likely extent west into the Goodenough Basin where we have sufficient coverage to show that no spreading ridge is currently active.

While no doomed ridge is present in the Goodenough Basin there is abundant evidence for recent and active mechanical extension - low-angle normal faulting associated with the formation of the core complexes on the D'Entrecasteaux Islands, and recent complex deformation in the Goshen Fault Zone in the southern part of the basin - together with rather leak evidence for a limited period of seafloor spreading to form the basement. If indeed the basement of the Goodenough Basin is oceanic then the ridge that created the crust there may have extended east into the region presently occupied by the Woodlark Basin. This seems unlikely but cannot rule out.

We consider it much more likely that the action of the Woodlark propagator extending west into the continental crust was to create a tectonic environment that mimics that produced by propagation in a purely oceanic setting. The structural equivalent of the doomed rift of an oceanic propagator is, in the setting described here, represented by an evolving zone of mechanical extension in continental lithosphere. When the tip of the Woodlark propagator was located well east of its present position extensional deformation occurred in a broad zone that included the D'Entrecasteaux Islands and the Goodenough Basin (and may include regions to the west of the islands also) and represents the far-field response to extensional stresses set up by the propagation of the spreading system. Deformation is presently focused in the GFZ in southwest Goodenough Basin, and in the region immediately at the tip of the propagator and represents the direct response to near-field stresses associated with propagation. We suggest that the concentrated zone of recent deformation in the GFZ is acting very much like a plate boundary, with lithosphere of the Indo-Australian Plate to the south and the Solomon Sea Plate to the north. The region identified as a MERZ to the southwest of the Bonvouloir Psuedo-Fault traces out a zone of tectonism that formed by exactly the same mechanism as that involved in oceanic propagators - it is a region where lithosphere of the Solomon Plate is being further deformed, rotated, and transferred to the Indo-Australian Plate as a result of westward propagation of the Woodlark spreading center. The striking similarity of the "continental" MERZ in the Woodlark region to its pure ocean structural equivalent is probably because the continental lithosphere had experienced a period of extensional deformation as a response to far field stresses prior to its involvement in propagation tectonics, and may have resulted in its rheology being modified to be approximately equivalent to that of oceanic lithosphere.

The present plate boundary configuration therefore comprises the propagating Woodlark ridge reaching west to almost 151°E at about 9° 40'S, and the GFZ reaching east, also to almost 151°E, at about 10° 10'S. The GFZ appears to be younger to the east where it gives rise to a pronounced trough in the seafloor. If this can be taken to imply propagation to the east then, combined with the westward propagation of the Woodlark spreading center, a small microplate about 50 km across can be defined that would encompass most of Normanby Island - the name D'Entrecasteaux Islands Micro-Plate seems most appropriate since it has the appealing acronym of DIMPL (Figure 13). The two propagators then represent two distinct plate boundaries - Solomon Sea/DIMPL and DIMPL/Indo-Australia. The structure at the propagating rift tips in the Woodlark area are then analogous to structure at the Endeavor Deep of the Juan Fernandez micro-plate, the Hess Deep of the Galapagos micro-plate, and the Pito Deep of the Easter micro-plate. These areas are known to be associated with high degrees of extensional deformation of existing oceanic lithosphere that has produced very rugged, often strongly asymmetric topography and has lead to the exposure of deep levels of the oceanic crust at the Hess Deep and probably at the other sites also. The style of deformation at the propagating rift tips in the Woodlark area are at least grossly analogous to those associated with ridge propagation in oceanic microplates.

The configuration of plate boundaries also recalls the "roller bearing" model of micro-plate tectonics proposed by H.Schouten to account for plate kinematics of the Easter and Galapagos microplate and recently by Larson et al for the Juan Fernandez micro-plate. Such a model of oceanic plate kinematics cannot be applied in its complete form in the present environment and we would propose that the model be modified in two ways to be appropriate for describing rift propagation associated with continental breakup. First, there is only a single propagating ridge or spreading center - the Woodlark propagator. The roller bearing model requires that the pole of rotation of the major plate with respect to the microplate be located at the tip of the propagator. Spreading rates in the Woodlark Basin decrease to the west suggesting that the pole is located at least near the tip. The opening taking place diametrically opposite the tip of the Woodlark propagator is not occurring by seafloor spreading but by mechanical extension of the lithosphere. Near to the tip of this extending zone the deformation is concentrated in the GFZ, but with distance away from the tip the deformation is distributed over a broad region. The roller bearing model applies if we modify it to treat a large region to the left of the bearing as being involved in deformation, not just the plate boundaries. The second modification is to allow the bearing to be somewhat non-rigid. The region we describe as equivalent to the MERZ of the oceanic propagator is clearly involved in deformation and, translated to the present setting, represents deformation of the DIMPL. One consequence of this deformation is that parts of the bearing may rotate at different rates - the deformation may take up some of the rotation so that the inner parts of the bearing may rotate less rapidly than the outer. Similarly, the deformation may allow one side of the bearing to rotate at a different rate from the other. This type of micro-plate deformation leading to asymmetric rotation may be required if one of the plate-micro plate boundaries is not a fully developed spreading center as is the case here.

What is described above may seem at first glance to be a somewhat exotic form of continental breakup. Most models of final rifting and initiation of seafloor spreading are essentially two-dimensional in nature and concentrate on describing the temporal evolution from intra-continental extension, involving dominantly mechanical deformation of the continental lithosphere, to seafloor spreading which involves a dominantly magmatic process. These aspects of continental breakup are shown here to be integrally woven into the pattern of spatial evolution of a micro-plate system, simultaneously involving mechanical extension and the propagation of seafloor spreading. All that is required for such a tectonic pattern to be developed is that breakup be achieved by a propagation of rifting and that the axis of propagation of spreading is not perfectly aligned with the axis of mechanical extension. Just as overlapping spreading centers on fast spreading ridges migrate along axis leaving their distinct wakes in the diverging plates, the micro-plate associated with the non-alignment of the newly migrating spreading axis and the zone of mechanical extension will migrate along the region of opening of the new ocean basin.leaving behind a strongly asymmetric wake on the conjugate continental margins derived from the structure of the micro-plate and propagator.

The action of a propagator and associated micro-plate tectonics may also help to solve one of the apparent paradoxes of lithospheric deformation - that the forces associated with plate driving stresses are insufficient to cause failure of the lithosphere given the known rheological properties of the continental lithosphere. The problem can be overcome if the plate driving stresses are effectively focused and hence applied over a relatively small region. The action of the propagator achieves this focusing. Stresses are applied to the continental lithosphere to cause rupture in the relatively small plate boundary region surrounding and defining the DIMPL. At any time, while broad regions of the lithosphere may be involved in distributed extension, only a relatively small length of the plate boundary has actually proceeded to the point of failure.

Finally, if we project the propagation of the system described here some small time into the future by assuming relative stability of the current plate boundary configuration the Woodlark propagator would be expected to pass approximately between Fergusson and Normanby Islands and Normanby itself would become involved in the deformation associated with the MERZ. In such a scenario, the core complexes on Fergusson and Goodenough Islands would be rifted, essentially in tact to the north to become part of the Woodlark Margin. It is then reasonable to ask whether previous episodes of propagation of the Woodlark spreading center have isolated core complex domes in this margin. There are two candidates. If the outline of Egum Atol in the Woodlark Margin is compared to that of Goodenough Island a remarkable correspondence in their forms is apparent (Figure 14, upper panel). The general form of Egum Atol is also roughly comparable in shape to that of the western end of Woodlark Island (Figure 14, lower panel). Egum Atol lies atop an elevated basement structure as does Woodlark Island, although neither structure is particularly prominent or clearly analogous to those associated with the Goodenough and Fergusson core complexes. The Woodlark margin structures are, however, associated with FAA gravity anomalies that are comparable to those associated with the offshore extensions of Goodenough and Fergusson. Both the Atol and Woodlark Island are elevated to the north and submerged to the south suggesting that they are subsiding preferentially toward the current spreading axis. Neither of these potential paleo-core complexes are, however, particularly remarkable features in the seismic data at the present level of processing and could easily be overlooked in the seismic record of an ancient continental margin.

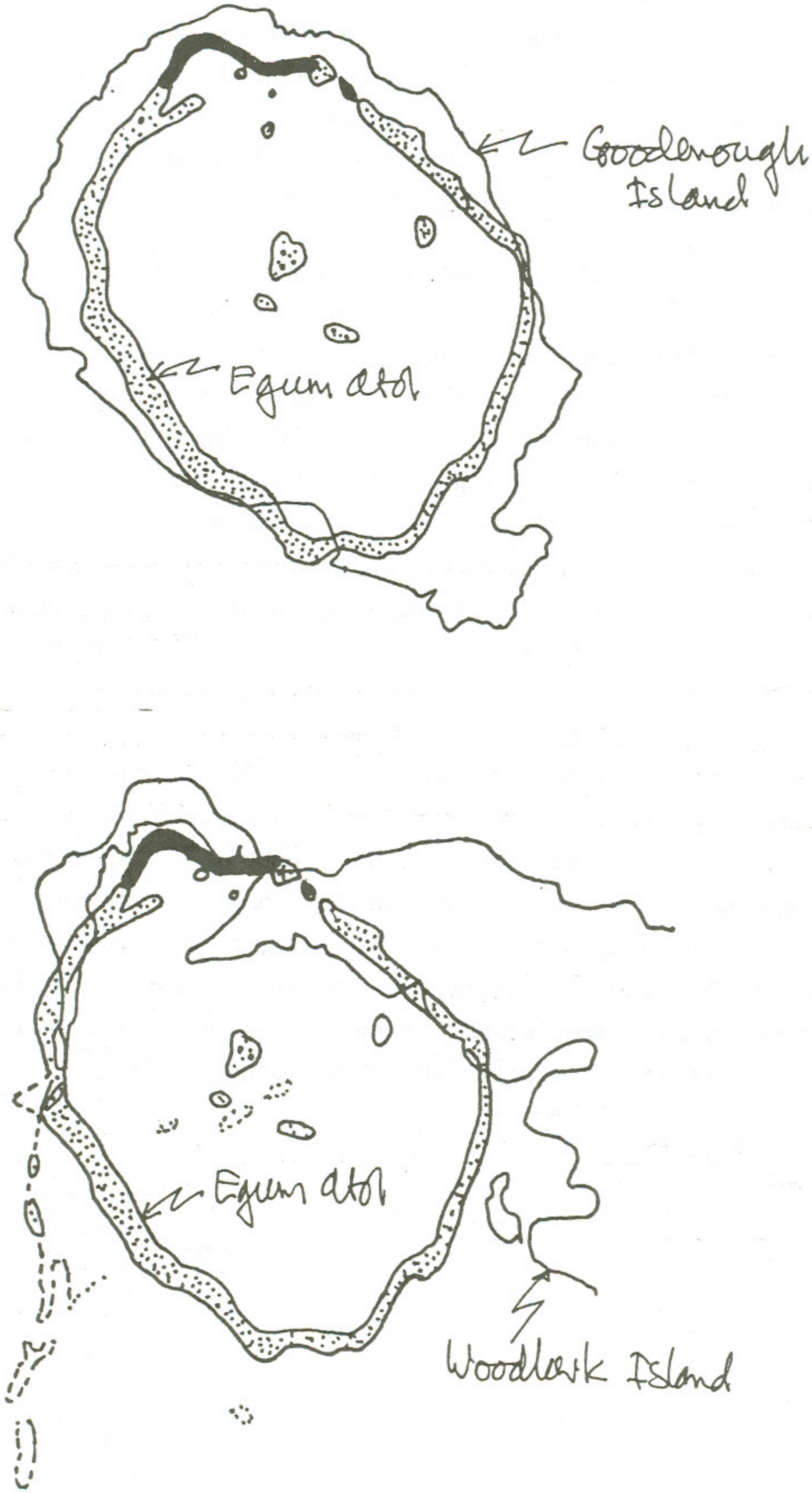


Figure 14

Comments and Recommendations

The investigation described above was a considerable success despite the significant problem that occurred on only the second day of science operations in the reef-covered areas of the Trobriand Basin north of Goodenough Island. The capability to record seismic data of sufficiently high quality to achieve the aims of the investigation were substantially threatened at that time. A major effort was required to re-establish a satisfactory capability and this was achieved through a long, difficult and dedicated effort by the Science Officer, Joe Stennett, and the technical staff whose efforts were critical to the success of the program. Members of the airgun crew also volunteered to assist very willingly and Capt. O'Loughlin released members of the deck department from their normal duties to assist also. On several occasions malfunctions of the pumping system for supplying streamer oil and the hydraulics for the streamer winch malfunctioned and these were quickly attended to by members of the engine department and John Di Bernardo. Everybody seemed to appreciate the gravity of the situation and responded appropriately.

Following the streamer damage and construction of a short streamer we made two day time runs through the same reef-covered areas that had proven hazardous on the second day of science operations. Despite the clear difficulty of making these runs and others into largely unknown waters later in the leg, Capt. O'Loughlin was extremely responsive to the requirements of the science operation. Given the history of problems that occurred early in the leg the Captain could have adopted a position in which he refused to take the vessel into uncharted areas or areas of known reef cover at any time. Instead we modified the program in such a way as to work in these areas in daylight hours with a sailor positioned on the flying bridge as observer to look for lighter colored water as an indication of shallow areas. This procedure worked very well and, given good light, even very small reefs could be seen from a sufficient distance to allow appropriate course alterations for safe passage. Capt. O'Loughlin's willingness to proceed in this manner despite the history of problems was an essential part of the success of the leg.

The compressors and ship's power operated during the study with a minimum of problems. Pressure levels drop on only two or three occasions and never for long enough to require that a line be terminated and re-shot; a significant change from Conrad operations. This improved situation is due in large part to the engine department staff that has stabilized with a group of excellent engineers whose attitude to achieving good performance of all the system for which they are responsible is outstanding.

A number of modifications to lab spaces and accommodations that were Lyttletown have made the vessel a much better place to work and live. In particular the re-routing of the air conditioning in the main lab has achieved the intended objective of cooling the equipment without simultaneously freezing any people in the lab.

The following recommendations are intended to build on the solid foundation of performance presently achieved to gain even better results.

1. Streamer, recording system, and data processing.

a) The encounter the streamer made with the reef in the Trobriand Basin resulted from lack of knowledge of the extent to which the streamer had been set off the track by lateral currents. While some notion of this could have been guessed from the heading the ship had to take to make good the intended course, no direct knowledge of streamer position is available from the system at present. Had this information been available at the time we may have been been able to make the decision to shorten the streamer before entering the reefs rather than having to wait until it was proven necessary. Presently we have available a number of compass sections which can be inserted in the streamer and from which the streamer position can be reconstructed after the fact. Digicon, along with the rest of the seismic industry, has largely moved away from this system to the use of "Digicourse" depth control birds that include compasses. Systems can be obtained with displays that give a graphical representation of the streamer position that could be installed in the main lab and on the bridge. These birds also contain Depth Transducers and have an advanced system of streamer depth control in which the bird seeks the desired depth by constantly adjusting the attitude of the wings, referencing the depth from its own DT. Apart from the likelihood that the accident with the streamer might have been avoided had direct knowledge of the streamer been available at the time on-line knowledge of streamer position is essential for 3D seismic work which we hope to do in the future. The time involved in installing and/moving and/or exchanging DTs would also be eliminated and greatly improved depth control of the streamer would be achieved.

• We recommend that we assess the costs and most effective way to acquire a set of Digicourse birds and the associated displays.

b) A considerable amount of time was spent in tracking down streamer failures - attempting to locate the nature and position of problem areas. In general the system diagnostics presently available are imprecise in that most problems are indicated as Telemetry Failures whether this is indeed the problem or not, and the position of the failed component in the streamer is poorly specified. We also continue to experience system crashes in which the entire system fails and can only be re-started by powering down the streamer and re-building the system. The problem is intermittent and although it has been with us for more than a year we are no closer to understanding its origin or how to deal with it.

We currently lose a considerable amount of time to tracking problems that, once found, seem that they could have been diagnosed with a better QC system. It seems that a lot of the QC that Digicon does relies heavily on a great deal of operating experience they have with the system. We call on that experience by making phone calls from the ship when we run into a problem that we cannot solve.

• It is recommend that we either arrange to have a Digicon field technician sail on the Ewing during a seismic investigation or for Joe Stennett to sail on a Digicon vessel on one of their jobs. Digicon has also developed a considerably upgraded ship-board monitoring system that includes considerably improved diagnostics, data acquisition, quality control and some on-line data processing based around Sun workstations that replace the present CAI computer. It is a field version of the TANGO processing system they use in-house for seismic data processing. It would be very desirable if we could acquire this improved system, especially if it could come as a system upgrade without significant cost to Lamont.

c) It seems like I get to grumble about this every time I go to sea. The deck lighting on the fantail is inadequate to conduct operations on the streamer at night in a way that does not risk mistakes such as failure to recognize water in streamer sections, damage to the streamer components by dragging them over the deck or poor level-winding, and injury to personnel. Night operations are also slower for simple reasons like loosing tools in the dark.

• The fantail lighting needs to be thoroughly revised and substantially improved. Presumably this would be to the benefit of all operations that need to be performed at night.

e) The 3480 cartridge tape recording system worked extremely well with the exception of the tape labelling system which was put together by Dale Chayes on the previous leg. Although satisfactory for the present it does not print on the large square labels and does not write at all on the smaller labels. There were a number of instances when the tapes were incorrectly by watchstanders even though what was required of them was truly minimal. Presumably it is not difficult to improve the labelling and this is desirable not just for the convenience but because of the need to avoid incorrect labelling by the watch.

• We recommend that an adequate tape labelling system be implemented before the next Shipley's MCS program in September.

e) The availability of 3480 tapes also facilitated the production of simple low-fold CMP stacks which were available from a modification to JDseis made on the cruise. This produced a simple low-fold stack of the near traces of the streamer using and assumed shot geometry and velocity function. Letter-sized laser printer output was used to produce sections that gave a small degree of multiple attenuation but greatly improved dynamic range and display quality. We are very close to having the capability to produce processed output of this type routinely and essentially on-line. This could be achieved one or two tapes behind real time if a Sun workstation was available to do the task in parallel with the acquisition of the data. To make this worth while a much better plotting system is required that would allow the production of continuous plots and a Sun workstation would have to be dedicated to the task.

• We recommend that the hardware resources be acquired to implement an on-line seismic data processing system for the vessel. This mainly consists of a Sun workstation, plotter and 3480 drives.

2. Compressors and gun system

a) Airgun failure rate was higher than normally experienced. Repeated problems occurred with particular guns, others operated the entire leg with no failures at all. Most problems were routine in nature - O rings, SMDs, solenoids, and firing lines - but two top housings were also broken on old guns that came from the Bernier. In addition there were repeated electrical problems with the gun fire detection system so that guns that were firing correctly would register as not firing. On all but the shortest lines guns either failed or the gun fire detection system failed. This level of performance is presently below that which we would like to achieve and has been creeping up on us for some time now

• It seems that many components of the airgun system are starting to show signs of age.and it may be time that a thorough review of the status of the system is appropriate, and we recommend that it be undertaken as soon as possible.

b) The compressors performed well but there has been considerable concern raised about the status of the Fisher valve. Although this situation may be in the process of being remedied the current status is that there are no spares on board the vessel, no manuals and no-one trained in how to repair the valve. Failure of the valve would certainly terminate the operation on an MCS leg because system crashes and operator mistakes at EOL and SOL often result in missed fire commands causing pressure to build up very quickly to dangerous levels which could not be reliably and safely released by manual operations.

• A complete set of spares and associated manuals for the Fisher valve should be available on the vessel and it is desirable that at least one member of the engine department take a training course with Fisher to learn how to properly maintain the valve.

3 Small stuff

How come the Science Library is being set up in the Chief Scientists room? Under normal circumstances there are two chief scientists who rotate there hours such that one is up at all times. This implies that the chief scientists room is normally occupied by a sleeping scientist. So when does anyone get access to the science library? The present set-up is the equivalent of putting all the technical manuals in the science officer's room. The science library should be accessible to any member of the science party at any time - nobody should have to sneak into the chief scientists room to get a book.

• At least one, and preferably two of the bookcases presently installed in the chief scientists room should be moved to a commonly accessible area like the Science Office. The ATS set could be moved to the area presently occupied by the seldom-used Compaq computer to make space.

CREW LIST PAGE TWO

R/V MAURICE EWING

DEPARTURE- GLADSTONE, AUSTRALIA DATE - 17 March, 1992

SCIENTISTS AND TECHNICIANS

#	NAME	POSITION	NATIONALITY/PP#	D.O.B.
23.	Mutter, John C.	Ch/Scient.	Aust J1947868	01 May 48
24.	Alverez, Carlos A.	Technician	USA 091679683	22 Feb 71
25.	Benes, Vladimer	Scientist	Can HA937486	21 June 60
26.	Di Bernardo, John G	Technician	USA J221959	09 May 58
27	Diebold, John B.	Scientist	USA G452722	22 Mar 44
28	Gutierrez, Carlos D.	Technician	Col AD072741	09 Jan 48
29	Kawalge, Simon	Scientist	PNG O67874	17 Apr 65
30.	Koczynski, William J.	Technician	USA 040558668	09 May 48
31	Maiwiriwiri, Ropate	Technician	Fiji 187094	10 Apr 41
32.	Pahl, Anja-Karina	Scientist	Aust J0972467	22 Jun 68
33.	Robinson, William J.	Technician	USA F1268080	08 Sep 49
34.	Stennet, Joseph N.	Science Off.	USA H308435	08 Jun 36
35.	Xu, Liqing	Scientist	CHINA 1524535	13 Mar 62
36.				
37.				
38.				
39				
40.				

TOTAL CREW INCLUDING MASTER 35

JAMES E. O'LOUGHLIN, MASTER

MCS Line log ew9203

LINE	TIME	Latitude S	Longitude E	TAPE #s	# CHANNELS
WLK#1	082:0505	10° 05'	150° 46'	1	240
	082:1455	09° 36'	150° 02.5'	27	
WLK#2	082:1538	09° 32'	150° 02.5'	28	240
	083:0320	09° 32'	150° 09'	59	
WLK#3	083:0451	08° 41'	150° 13'	60	240
	083:0730	08° 54'	150° 12'	68	
WLK#4	083:1954	08° 56'	150° 05'	69	120
	083:2107	08° 57'	150° 10'	71	
WLK#5	083:2126	08° 57'	150° 10'	71	120
	083:2230	09° 02'	150° 10'	72	
WLK#6	083:2334	09° 04'	150° 10'	72	120
	084:0115	09° 05'	150° 25'	76	
WLK#7	084:0133	09° 05'	150° 25'	76	120
	084:0430	08° 46'	150° 25'	81	
WLK#8	084:0537	08° 46'	150° 21'	82	120
	084:1257	08° 58'	149° 43'	92	
WLK#9	084:1320	08° 49'	149° 42'	93	120
	084:1432	08° 56	149° 42	94	
WLK#10	084:1520	08° 56'	149° 46'	95	120
	084:2347	08° 56'	150° 30'	107	
WLK#11	085:0015	08° 58'	150° 31'	108	120
	085:0057	09° 02'	150° 31'	108	
WLK#12	085:0150	09° 02'	150° 28'	110	120
	085:0408	08° 48'	150° 27	113	
WLK#13	085:0439	08° 47'	150° 25'	114	120
	085:1003	08° 51'	149° 56'	121	
WLK#14	086:0914	08° 40'	154° 55'	122	200
	086:1855	09° 30'	154° 55'	142	
WLK#15	087:0615	09° 28'	149° 49'	143	220
	087:1740	08° 35'	149° 49'	171	
WLK#16	087:1908	08° 38'	149°47'	172	220
				175	
WLK#17	087:2115	08° 40'	149° 40'	176	220
	088:0733	09° 27'	149° 40'	201	
WLK#18	088:0922	09° 23'	149° 41'	202	220
	088:1158	09° 17'	149° 33'	209	
WLK#19	088:1225	09° 14.5'	149° 33'	210	220
	088:1446	09° 05'	149° 34'	216	
WLK#20	088:1448	09° 05'	149° 34'	217	220
	088:1909	08° 44'	149° 33'	226	
WLK#21	088:2003	08° 45'	149° 36'	227	220
	089:0245	09° 05'	149° 59'	246	
WLK#22	089:0317	09° 08'	149° 59'	247	220
	089:0653	09° 24'	149° 59'	256	
WLK#23	089:0705	09° 25'	150° 00'	257	220

	089:0830	09° 29'	150° 05'	261	
WLK#24	089:0850	09° 30'	150° 06'	262	220
	089:1515	10° 01'	150° 05'	280	
WLK#25	089:1636	10° 01'	150° 05'	281	220
	089:2254	09° 33'	150° 23'	298	
WLK#26	089:2330	09° 32'	150° 22	299	220
	090:0008	09° 33'	150° 20'	300	
WLK#27	090:0030	09° 34'	150° 19'	301	220
	090:0728	10° 08'	150° 19'	320	
WLK#28	090:0905	10° 04'	150° 34'	321	220
	090:1500	09° 41'	150° 34'	337	
WLK#29	090:1640	09° 41"	150° 34'	338	220
	090:2141	10° 09'	150° 33'	352	
WLK#30	090:2245	10° 07'	150° 31	353	220
	091:0305	09° 51'	150° 44'	365	
WLK#31	091:0500	09° 47'	150° 38'	366	220
	091:0751	09° 59'	150° 31'	373	
WLK#32	091:0942	09° 55'	150° 27'	374	220
	091:1207	09° 44'	150° 34'	381	
WLK#33	091:1240	09° 43"	150° 33'	382	220
	091:1310	09° 41'	150° 31'	383	
WLK#34	091:1345	09° 42'	150° 29'	384	220
	091:1615	09° 53'	150° 21'	390	
WLK#35	091:1730	09° 50'	150° 19'	391	220
	091:1936	09° 42	150° 25'	396	
WLK#36	091:2057	09° 39'	150° 22'	397	220
	091:2315	09° 49'	150° 15'	403	
WLK#37	092:0045	09° 45'	150° 13'	404	220
	092:0245	09° 37'	150° 21'	410	
WLK#38	092:0324	09° 37'	150° 22'	411	220
	092:0937	09° 56'	150° 46'	428	
WLK#39	092:1010	09° 58'	150° 45'	429	220
	092:1254	10° 08'	150° 37'	436	
WLK#40	092:1340	10° 09'	150° 39'	437	220
	092:1520	10° 03'	150° 44'	441	
WLK#41	092:1637	10° 04'	150° 44'	442	220
	093:0146	10° 17'	150° 20'	467	
WLK#42	093:0306	10° 16'	151° 20'	468	220
	093:1210	09° 25'	151° 21'	492	
WLK#43	093:1300	09° 25'	151° 19'	493	220
	093:1933	09° 51'	151° 18	511	
WLK#44	093:2017	09° 52'	151° 15'	512	220
	093:2332	09° 48'	151° 00'	520	
WLK#45	094:0035	09° 48'	151° 00'	521	220
	094:0152	09° 43'	151° 01'	524	
WLK#46	094:0155	09° 43'	151° 01'	525	220

	094:0239	09° 44'	151° 03'	526	
WLK#47	094:0239	09° 44'	151° 04'	527	220
	094:0400	09° 52'	151° 07'	532	
WLK#48	094:0532	09° 50'	151° 10'	533	220
	094:1930	08° 31'	151° 15'	571	
WLK#49	094:2011	08° 31'	151° 17	572	220
	094:2134	08° 30'	151° 25'	575	
WLK#50	094:2220	08° 31'	151° 27'	576	220
	096:0303	10° 19'	151° 25'	654	
WLK#51	096:0409	10° 18'	151° 30'	655	220
	096;1528	09° 22'	151° 30'	686	
WLK#52	096:1713	09° 20'	151° 35'	687	220
	097:0608	10° 22'	151° 36'	722	
WLK#53	097:0645	10° 24'	151° 37'	723	220
	097:0741	10° 25'	151° 43'	727	
WLK#54	097:0843	10° 23'	151° 46	728	220
	097:2250	09°09'	151° 46'	766	
WLK#55	097:2315	09° 08'	151° 48'	767	220
	098:0435	09° 08'	152° 09'	781	
WLK#56	098:0515	09° 10'	152° 10'	782	220
	099:0010	10° 29'	152° 10'	833	
WLK#57	099:0029	10° 30'	152° 09'	834	220
	099:0300	10° 30'	151° 55'	840	
WLK#58	099:0344	10° 28'	151° 53'	841	220
	099:1141	09° 46'	151° 54'	862	
WLK#59	099:1200	09° 45'	151° 54'	863	220
	099:1940	09° 11'	152° 19	884	
WLK#60	099:2035	09° 12'	152° 20'	885	220
	100:1500	10° 34'	152° 21'	935	
WLK#61A	100:1522	10° 35'	152° 22'	936	220
	100:2127	10° 51'	152° 56'	952	
WLK#61B	100:2152	10° 50'	152° 47'	953	220
	101:0036	10° 45'	152° 59'	960	
WLK#62	101:0101	10° 43'	153° 00'	961	220
	101:1532	09° 31'	153° 01'	1001	
WLK#63	101:1601	09° 31'	153° 01'	1002	220
	102:0515	09° 31"	153° 50'	1038	
WLK#64	102:0533	09° 32'	153° 51'	1039	220
	102:2355	10° 48'	153° 51'	1089	