A MORPHOTECTONIC INTERPRETATION OF SOPACMAPS 1:500 000 CHARTS CENTRAL SOLOMON ISLANDS - SOUTHERN TUVALU

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EXECUTIVE SUMMARY

The SOPACMAPS data, a proprietary geophysical data set which includes 730 000 km of Symrad EM 12 multibeam imagery and swath bathymetry, was collected by the Institut Francaise de Recherche pour l'Exploitation de la Mer (IFREMER) during three 29-day survey cruises on the N/O L'Atalante. These surveys were undertaken by IFREMER, under contract to the South Pacific Applied Geoscience Commission (SOPAC) with European Union funding. The region encompassed by the survey extends from the New Georgia Group in the Solomon Islands to the eastern end of the Vitiaz Trench. The contoured bathymetry and imagery, contained in a series of maps covering nine separate areas, were provided by IFREMER at three different scales, 1:500 000; 1:250 000; and 1:100 000 (the last one being limited to two small detailed surveys in the central Solomon Is). An independent study of the SOPACMAPS data, undertaken by the writer during July and August of 1995 at the SOPAC Secretariat offices in Suva, Fiji, resulted in a preliminary geological interpretation and the preparation of structural overlay maps for seven of the 1:500 000 scale maps. Preliminary findings, which are in good agreement with the shipboard analysis of the data undertaken by IFREMER, are summarized as follows:

Regional Geology

Because of the presence of two opposing subduction zones on either side of the region, i.e., the active San Cristobal/New Hebrides zone on the southern side and the fossil North Solomon/Vitiaz zone on the northern side, geological relationships in the SOPACMAPS survey areas are unusually complicated. In the western survey areas, intense compressional tectonism, characterized by the emplacement of great thrust sheets, predominates. Structural deformation, severest near Malaita, includes nappe formation and anticlinal folding, both probably facilitated by the development of duplex structure. Large-scale slump/landslide activity is also ubiquitous in the western areas. In the eastern survey areas, extensional tectonism, typified by the formation of large rift grabens, predominates. These areas have also been extensively overprinted by rejuvenation of island-arc volcanism. In the transitional central areas, the thrust sheets and adjoining basin floors have also been overprinted by relatively recent development of divergent basin structures, including the formation of synrift volcanic and neovolcanic zones, as well as by rejuvenation of island-arc volcanism.

Mineral Resources

Preliminary findings suggest the potential for ocean-ridge type of hydrothermal mineral deposits both on land and offshore. In the Eastern Solomon Islands the data suggest that the neo-volcanic zone in the middle of a small, but well-developed, rift basin has been overthrust by the Duff Islands Ridge. This probably occurred during a recent phase of thrust faulting, concomitant, perhaps, with rejuvenation of the nearby Vitiaz Arc volcanism that formed the islands of Anuta and Fatutaka. The reported occurrence of warm springs on one of the Duff Islands supports this interpretation as it suggests that hydrothermal solutions, emanating from the neovolcanic zone, may be percolating through the thrust sheet to the island surface. Mineralization could either be occurring at shallow depths beneath the surface of the island, which could be evaluated by shallow drilling, or on the upper flanks of the island, which could more readily be explored using high-resolution swath mapping.

Preliminary findings also suggest the presence of a heretofore unrecognized petroleum potential in large areas of the northern Fiji and southern Tuvalu EEZs. In these areas, fault-bounded depressions (rift grabens) form deep closed basins where anoxic conditions could have prevailed. The basins appear to contain thick sequences of sediment. A favorable thermal history is indicated by evidence of up to four episodes of volcanism within the region. Shallow reef platforms, which lie adjacent to these thickly sedimented basins, could provide suitable reservoirs for any hydrocarbons that might have been generated within these basins. A favorable uplift/subsidence history, as suggested by the sequence of regional tectonic events, could have promoted formation of impermeable caps, facilitating the trapping of any hydrocarbons that may have migrated upslope from the adjoining basins. Follow-up multichannel surveys as well as sniffer/bottom sampling surveys looking for hydrocarbon traces to further investigate this potential are indicated.

Geological Hazards

The acquisition of SOPACMAPS co-registered imagery and swath bathymetry has enabled the recognition of sites of potentially destructive submarine slope failure. Ubiquitous, large-scale landslide/slump scars, evident in the SOPACMAPS imagery, attest to the high degree of slope instability and catastrophic downslope movement, rampant in the region. The obviously recent character of the scars in northern Vanuatu, in particular, as well as in Solomon Islands areas portends the occurrences of potentially disastrous tsunamis in the region. The SOPACMAPS data also confirm the presence of a serious explosive volcanic hazard in northern Vanuatu.

Hazards to Navigation

The SOPACMAPS surveys were navigated using a Geodetic Positioning System (GPS). This is the same system that is widely used to accurately and reliably control aircraft flight paths. In differential dynamic mode this system is accurate to 1-3 meters. In nondifferential mode, however, the system is typically accurate to within 25 meters. In geodetic mode accuracies of 1 cm +/- 2ppm x baseline are achievable. Although geodetic positioning of land and shoal areas was not one of the objectives of the SOPACMAPS surveys, data collected during the course of the surveys indicate numerous hazards to navigation. Mislocated islands in the Eastern Solomon Islands and Vanuatu and mislocated and poorly charted islands and shoals in the EEZs of Fiji and southern Tuvalu have been identified in addition to those mentioned by IFREMER. It should be further emphasised as was stressed by IFREMER, that the relocated positions of the shoals and islands is only an optimal adjustment and should not be used for navigation until the new positions are verified.

Recommendations for Further Work

Shallow-water swathmapping surveys should be conducted over the crest of Duff Island Ridge to identify potential sites of mineralization. Shallow-water swathmapping surveys, supplemented perhaps by multi-channel seismic surveys, should also be conducted over the very shallow and still uncharted crests of the banks mapped during the PBA, ACBA, and STBA surveys to determine the derivation and developmental history of the banks and to target potential hydrocarbon reservoirs. Additional long-range swathmapping should be undertaken in the areas adjacent to the ACBA and STBA surveys, to better define the closed basins and adjoining banks that have been only partially surveyed, as well as the unsurveyed banks, shoal areas, and seamounts reported to lie nearby. Examination of the gravity field derived from Seasat data suggests a potential for the presence of still more uncharted or mislocated shoal areas in the poorly mapped or unexplored reaches of the Vitiaz forearc between 164'E and 173'E. Long-range swathmapping should also be undertaken, therefore, in those areas where additional shallow banks and seamounts might be found.

A bottom sampling program should be undertaken along the Duff Island Ridge in the MAG area to search for indications of the presence of any metalliferous deposits. A bottom sampling program, supplemented perhaps by sniffer surveys, should also be undertaken within the closed basins already mapped and over the adjoining shallow banks in the PBA, ACBA, and STBA areas to search for evidence of any hydrocarbon seepage.

ACKNOWLEDGEMENTS

The writer is indebted to N. Naibitakele and P. Woodward for their admirable cartographic efforts under the somewhat fluid working conditions that accompanied the evolution of the structural interpretations during the course of this study. The writer is also grateful to the other SOPAC management and staff for their encouragement and technical support. In this regard, the efforts of M. Bukarau, D. George and S. Prasad in particular, are acknowledged. Helpful criticisms werte provided by R. Howorth, J. Lum, C. Pratt and R. Smith. This study was funded by the United States Defense Mapping Agency with the concurrence of the United States Department of State.

INTRODUCTION

For almost a decade swath mapping of the seabed has been an important part of the work programme of the South Pacific Applied Geoscience Commission (SOPAC). Thus the prospect of a soon-to-be-conducted swath-mapping cruise in the SOPAC region was greeted with overwhelming support and was vigorously welcomed by the member countries at the 19th Session of SOPAC in Tarawa, Kiribati in 1990 (Sherwood and Bukarau, 1990b). Fiji, PNG, Solomon Is, Tuvalu, and Vanuatu all expressed considerable interest, designating priority areas for the new swath-mapping surveys. By late 1991 plans were being formulated to conduct surveys in the eastern Solomon Islands, central Vanuatu, northern Fiji and southern Tuvalu offshore areas. These plans subsequently laid the groundwork for the SOPACMAPS Project, a long-range seabed swathmapping project, funded by the European Union and designed to survey as much area as possible in the EEZs of Fiji, Solomon Islands, Tuvalu, and Vanuatu.

The SOPACMAPS survey, undertaken in the latter half of 1993 by the Institut Francaise de Recherche pour l'Exploitation de la Mer (IFREMER) during three 29-day cruise legs on the N/O L'Atalante, focussed on the acquistion of swath bathymetry and sidescan sonar imagery, as well as ancillary geophysical data. The region encompassed by the survey extended from the New Georgia Group in the Solomon Islands to the eastern end of the Vitiaz Trench in southern Tuvalu and included ten separate survey areas. The ten areas that were mapped during the SOPACMAPS cruises (Fig. 1), comprising 730 000 km, were actually surveyed in 74 days, excluding transit time, i.e., almost 10 000 km were surveyed per day.

The SOPACMAPS data are a proprietary geophysical data set, which includes Symrad EM 12 multibeam imagery and swath bathymetry, as well as gravity, magnetic, and seismic reflection profiling data, Navigational data were acquired with a Global Positioning System (GPS). This is the same system that is widely used to accurately and reliably control aircraft flight paths. In geodetic mode accuracies of 1 cm +/- 2ppm x baseline are achievable. In differential dynamic mode this system is accurate to 1-3 meters. In nondifferential mode, however, the system is typically accurate to within 25 meters. These data were collected by IFREMER under contract to SOPAC (with European Union funding). The contoured bathymetry and imagery, contained in a series of maps covering the nine separate areas, were provided by IFREMER at three different scales, 1:500 000; 1:250 000; and 1:100 000 (the last one being limited to two small detailed surveys in the central Solomon Is). Final reports for each of the areas were also provided as

SOPAC Technical Reports 192-199 (IFREMER, 1994a-h); the two detailed surveys in the central Solomon Islands were covered by a single report.

The entire SOPACMAPS dataset, in final form, was received at the Secretariat offices in Suva, Fiji, in record time, within five months of the completion of the survey. Due to the excellent quality of the survey data, it was possible to complete an independent study of most of the newly acquired dataset within 3 months of receipt of the data. This study, undertaken by the writer during July and August of 1994 at the SOPAC Secretariat offices in Suva, Fiji, resulted in a preliminary geological interpretation of the primary survey areas and the preparation of structural overlay maps for seven of the 1:500 000 scale maps, complementing the shipboard analysis provided by IFREMER. The study was facilitated and supplemented in part by a previously completed cable route survey (SSI Inc., 1991), commissioned by Telstra, Australia, that was situated between the Malaita and Melanesian Arc Gap surveys. The three-dimensional swath bathymetry along a portion of the cable route survey depicting a simplified version of the structural interpretation based on SCS reflection profiles collected during the Telstra survey is shown in Figure 2.

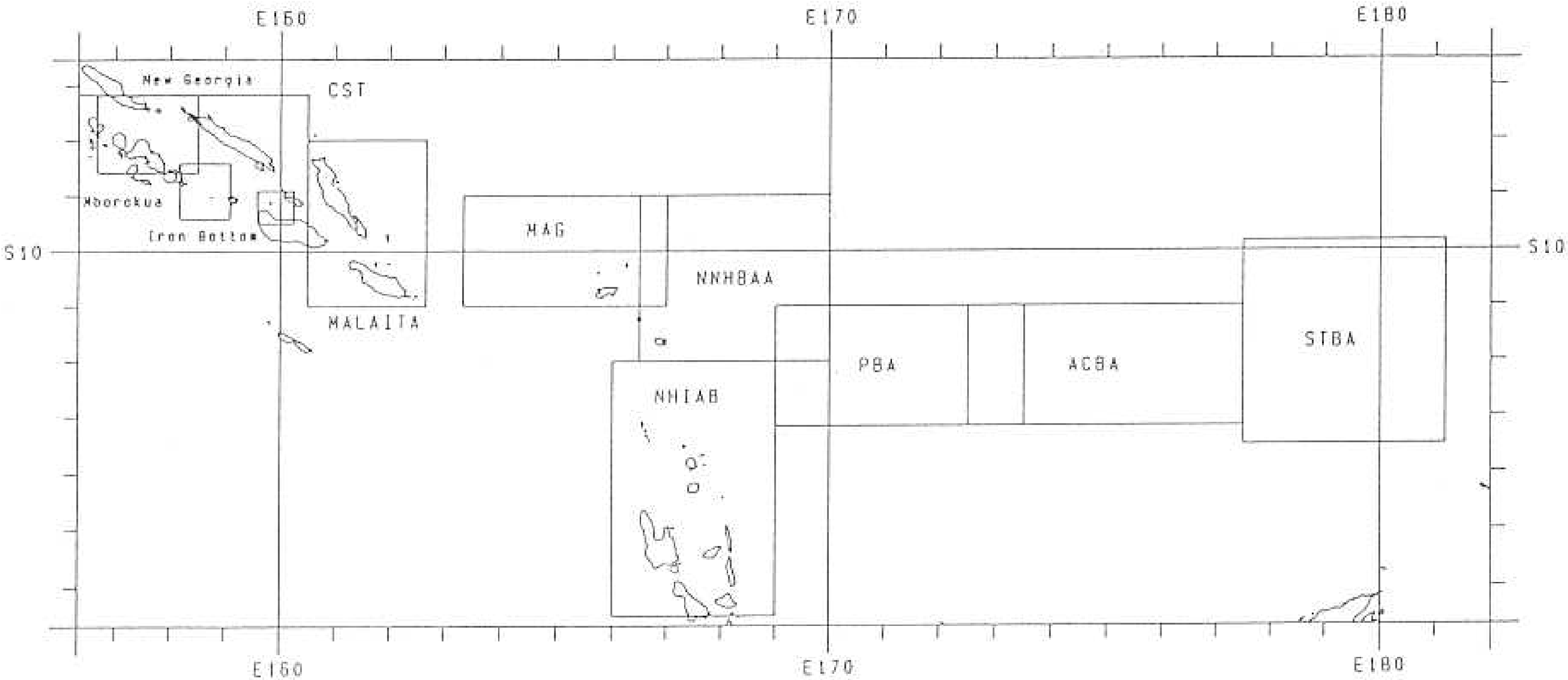


Figure 1. Location of SOPACMAPS 1:500 000 scale maps and detailed survey areas.

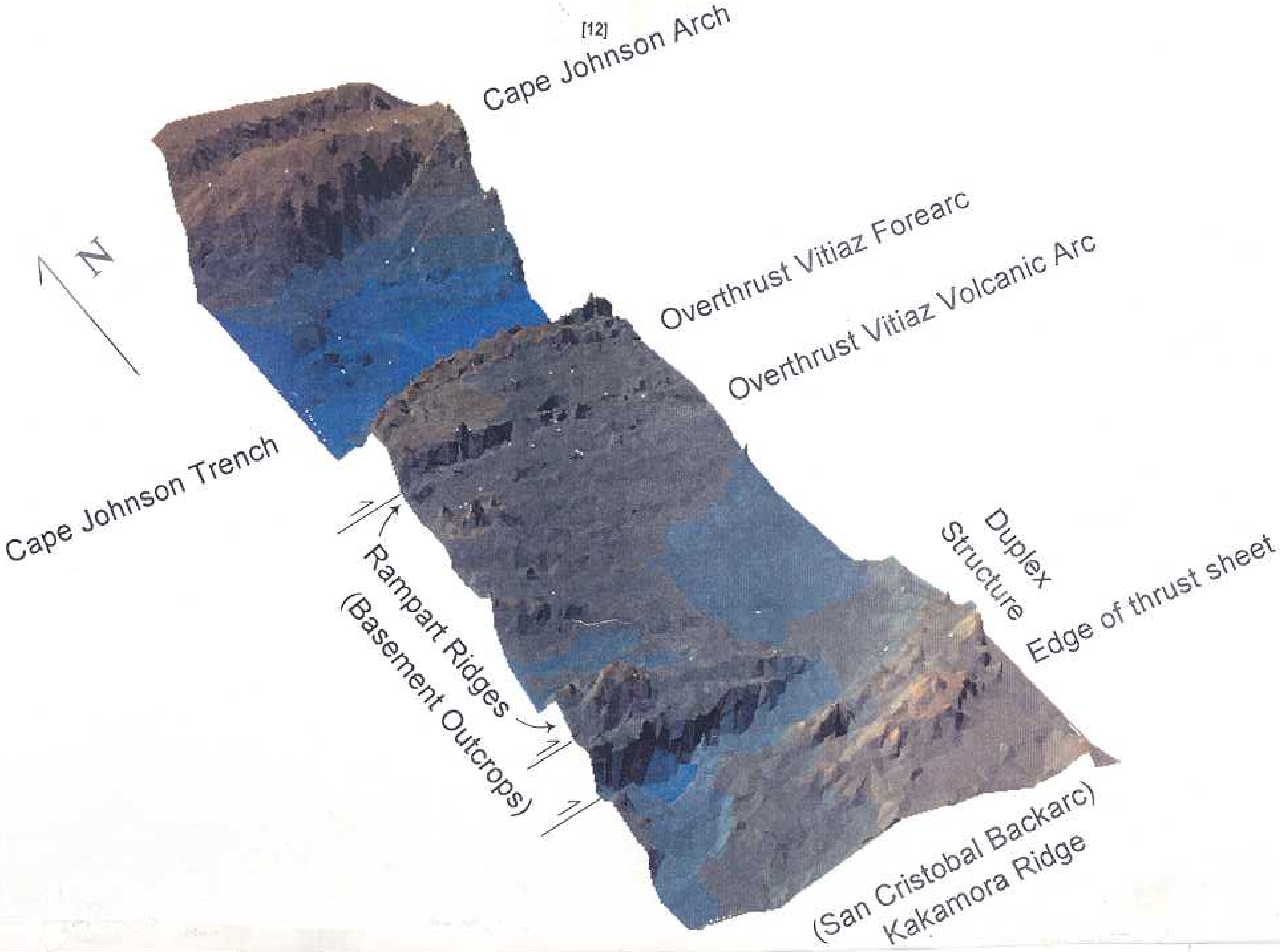


Figure 2. Three-dimensional swath bathymetry from a portion of the Telstra cable route survey in the area between the Malaita and MAG survey areas showing a simplified version of the structural interpretion (from Seafloor Surveys International, Inc., 1991).

The preliminary findings of the independent study of the SOPACMAPS data, together with recommendations for further work, are discussed in the sections that follow. Reduced copies of the structural overlays, as well as small-scale copies of the regional bathymetric maps (from IFREMER, 1994a-h) are included as figures within the appropriate sections.

It should be emphasised that only major structures are shown on the overlays and that structural relationships are poorly constrained, oftentimes inferred based on sparse ancillary geophysical data and extrapolated over large distances.

PRELIMINARY OBSERVATIONS AND INTERPRETATIONS

Malaita

Intense structural deformation is ubiquitous within the Malaita area (Figs 3,4). Thrust faulting, nappe formation, and anticlinal folding predominate. Narrow, elongated, steep-sided ridges, surmounted in some places by islands, commonly mark the leading edges of thrust sheets. Large slumps and submarine landslides are rampant on the back (seaward) sides of the thrust sheets. Duplex structure probably forms the cores of many of the large anticlinal ridges within the thrust sheets.

In the northern part of the Malaita map, the North Solomon trench inner slope adjoining the island of Malaita is formed by two very large rotational slump blocks. Slumping/gravity sliding also appears to be present on the lower outer slope of the trench (with associated slump toe structures near the trench axis).

To the southeast, in the central part of the Malaita map, a series of elongate, narrow, steep-sided ridges, roughly paralleling both the trench axis and the structural grain of Malaita, dominates the trench inner slope. Evidence for extensive downslope sediment transport or mass wasting is widespread on the seaward (northeastern) flanks of the ridges as evidenced by the lack of any appreciable sediment cover. Slumping is also evident to the northeast on the lower outer slope of the trench. The small elongate ridges and depressions present along or near the trench axis here are probably due mostly to the pervasive downslope sediment movement, i.e., sliding/slumping from both sides of the trench. Both the large and small sets of ridges appear to be anticlinal in shape. As deduced from evidence obtained elsewhere, duplex structure probably forms the cores of many of the larger anticlinal ridges. In contrast, many of the smaller antiforms are probably the manifestation of soft sediment deformation at the base, or toes, of slides or slumps. Indeed, the position of the North Solomon Trench axis is controlled almost exclusively by the merging or interfingering of the toes of the large slumps/gravity slides occurring along the northern flank of the Malaita Anticlinorium and the southern flank of the Stewart Arch.

In the southern area, where the North Solomon and San Cristobal trenches converge in the Ulawa Trough or Trench, another elongate, narrow, steep-sided ridge forms the inner trench wall, towering above the trench floor lying more than 6000 m below. This prominent ridge, cresting in the islands of Ulawa and Olu Malau (Three Sisters), is characterized by considerable mass-wasting on its eastern (seaward) side. Major slide/slump scars abound on the flanks of the ridge. Both the Ulawa Trench and the Ulawa-Olu Malau Ridge abut against the shelf along the northern side of Makira (San Cristobal) Is. Overthrust San Cristobal arc volcanoes may form the underpinnings of the small submarine antiforms and islands, such as Uki and Pio, that are aligned along this shelf at the appropriate distance from the San Cristobal Trench to lie above the San Cristobal arc magmatic zone.

The youthful appearance of the structural deformation in this region suggests that compression was active here well after the main docking phase of the Ontong-Java Plateau against the Australian Plate about 25 Ma. The compressive event may have been initiated as recently as 6-5 Ma caused by the entry of buoyant, recently formed, Woodlark Basin lithosphere into the San Cristobal Trench pushing the Solomon Arc to the northeast into the North Solomon Trench. As the compression intensified, the ensuing crustal shortening was absorbed within the North Solomon Trench outer slope; the deformations front progressively moved farther northeastward into the Ontong Java Plateau. Crustal shortening may have proceeded by delamination and detachment of successive layers of the Ontong Java Plateau crust along the trench outer slope with obduction occurring, accompanied perhaps by the formation of duplex structure, as each detached layer or slice was thrust up and over the trench inner slope.

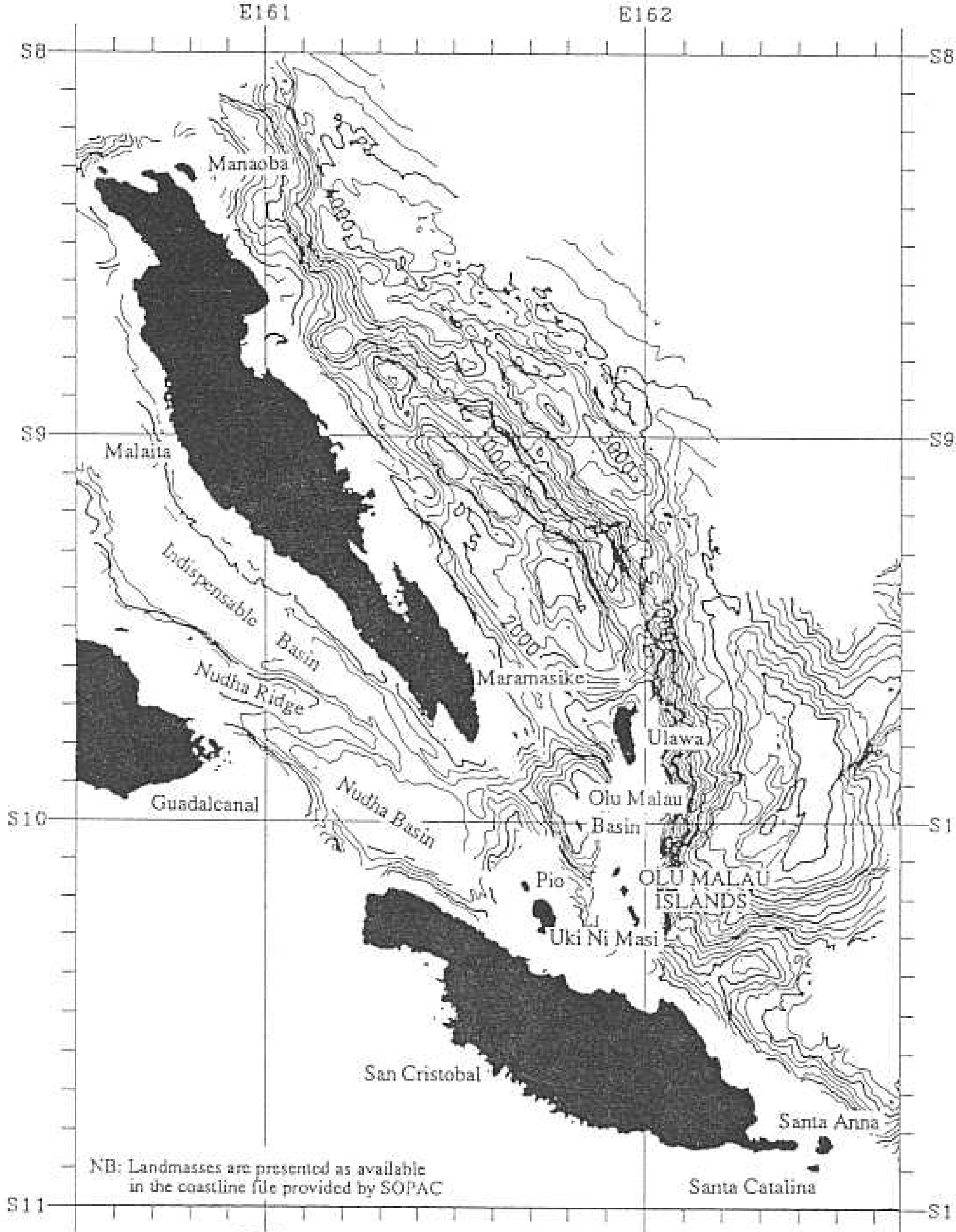
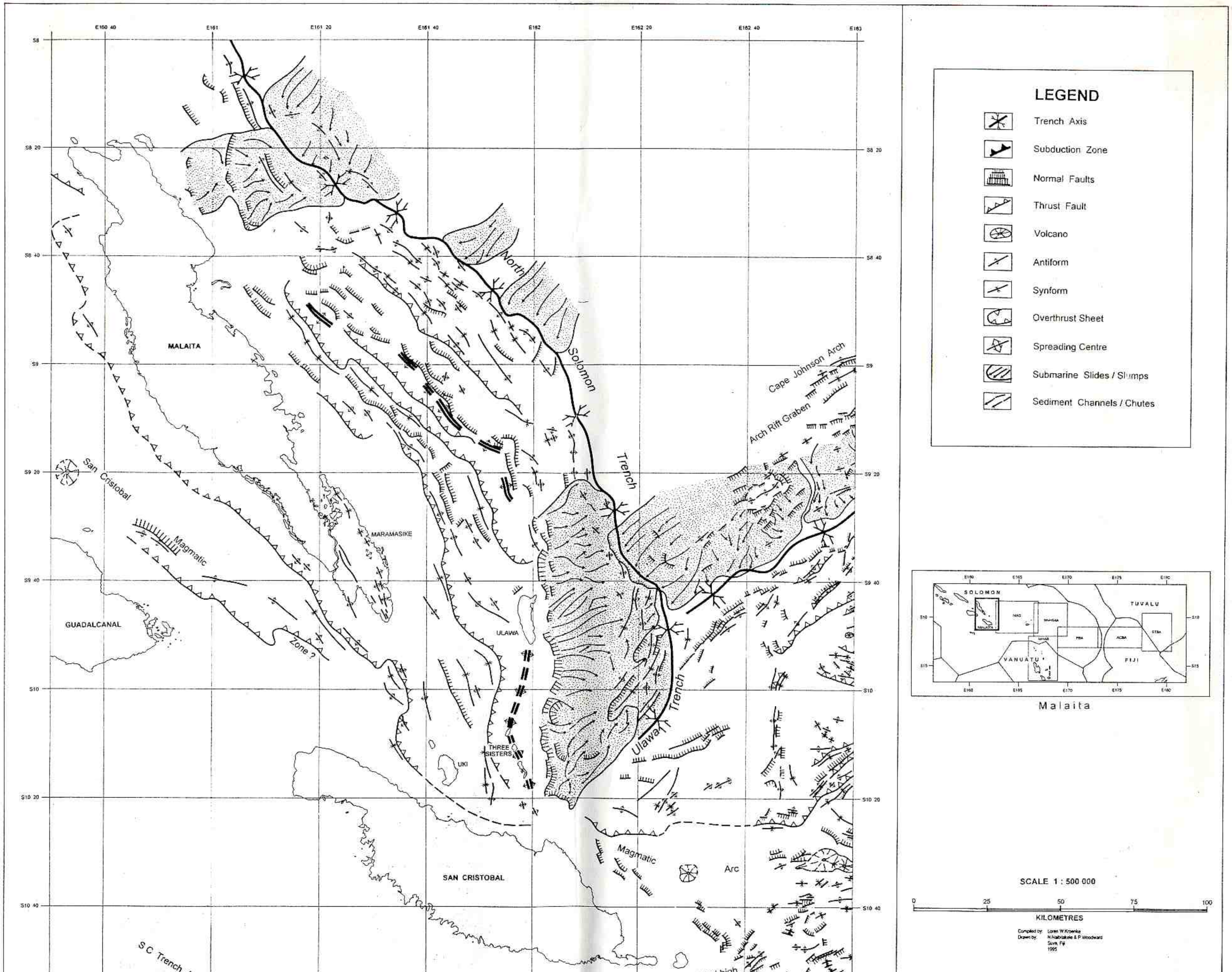


Figure 3. Bathymetry in the Malaita area from IFREMER (1994c).


LEGEND
Trench Axis
Subduction Zone
Normal Faults
Thrust Fault
Volcano
Antiform
Synform
Overthrust Sheet
Spreading Centre
Submarine Slides / Slumps
Sediment Channels / Chutes
North Solomon Trench
Ulawa Trench
Cape Johnson Arch
Arch Rift Graben
MALAITA
MARAMASIKE
ULAWA
THREE SISTERS
UKI
SAN CRISTOBAL
GUADALCANAL
San Cristobal Magmatic Zone ?
Magmatic Arc
S C Trench
SOLOMON
TUVALU
VANUATU
FIJI
Malaita
SCALE 1 : 500 000
KILOMETRES
Compiled by: Loren W Kroenke
Drawn by: N Halbrtakele & P Woodward
Suva, Fiji
1995

Melanesian Arc Gap

A series of high, steep, south-facing escarpments or ramparts, extends eastward across the Melanesian arc gap (MAG) area (Figures 5, 6) and well into the Northern New Hebrides back-arc area (NNHBAA). Shallow depressions, 50-150 m deep, commonly lie immediately to the south of, and near the base of, these escarpments. The steep ramparts are interpreted to constitute the leading edge of a vast overthrust sheet, with the adjoining depressions forming the forerunning thrust basins. The emplacement of this great thrust sheet, which has completely overridden the Vitiaz Trench and arc, has drastically altered the seafloor topography, infilling much of the trench, engulfing the old Vitiaz forearc, obliterating the original Vitiaz volcanic arc, and inundating the intra-arc basins north of the San Cristobal Trench. The overthrusting is believed to have been caused by the collision between the newly formed Woodlark Basin spreading system and the San Cristobal arc that was initiated between 6 and 5 My ago and which displaced the arc northeastward into the OJP.

North of the leading edge of the overthrust sheet, well within the interior of the overthrust sheet, a line of young but inactive volcanic edifices lies parallel to, and at a constant distance from, the Vitiaz Trench (MAG & NNHBAA maps). This volcanic chain is believed to represent a renewed phase of arc volcanism originating from the Vitiaz magmatic zone that was rejuvenated during a second phase of overthrusting. Apparently subduction was reactivated during a change in Pacific plate motion that occurred about 2 My ago. The volcanic chain, therefore, probably defines the former location of the old Vitiaz volcanic arc prior to back-arc rifting and basin formation.

South of the rejuvenated Vitiaz magmatic zone, but still within the thrust sheet, lies a diffuse zone of extensional normal faulting interspersed with small volcanic cones. The volcanic cones, scattered among subparallel normal faults, are interpreted to form a synrift volcanic zone. This zone becomes better organized to the east, evolving into a clearly discernable neovolcanic zone centered within a well developed rift basin. Both the synrift volcanic zone and adjoining rift basin and neovolcanic zone appear to have incised the thrust sheet and thus are probably of fairly recent origin, i.e., postdating the initial phase phase of overthrusting that began about 5 My ago (Yan and Kroenke, 1994), and is probably still active today.

South of the edge of the thrust sheet, a line of active or recently active volcanoes and volcanic cones lies parallel to, and at a constant distance from, the San Cristobal Trench (MAG & NNHBAA maps). This volcanic chain, terminating at its eastern end in Tinakula Is, is believed to define the San Cristobal magmatic arc. Intervening between the San Cristobal arc and the edge of the thrust sheet are arrayed the large edifices/islands representing the displaced remnants of Vitiaz Arc volcanoes rafted southward during an earlier episode of North Fiji Basin opening that occurred between 10 and 6 Ma, i.e., preceding overthrusting and emplacement of the thrust sheet.

East of the eastern end of the San Cristobal arc, on both the MAG & NNHBAA maps, a line of active or recently active volcanoes and volcanic cones, lying parallel to, and at a constant distance from the New Hebrides Trench, extends southward to the edge of both maps. This volcanic chain is believed to define the northern terminus of the New Hebrides magmatic arc. The San Cristobal and the New Hebrides arcs and their respective back-arc areas are separated by what appears to be a roughly east-west trending, right-lateral, transtensional fault zone. This zone apparently has accommodated both the westward migration of the New Hebrides subduction zone and the extension in the New Hebrides backarc, as well as facilitating spreading in the North Fiji Basin.

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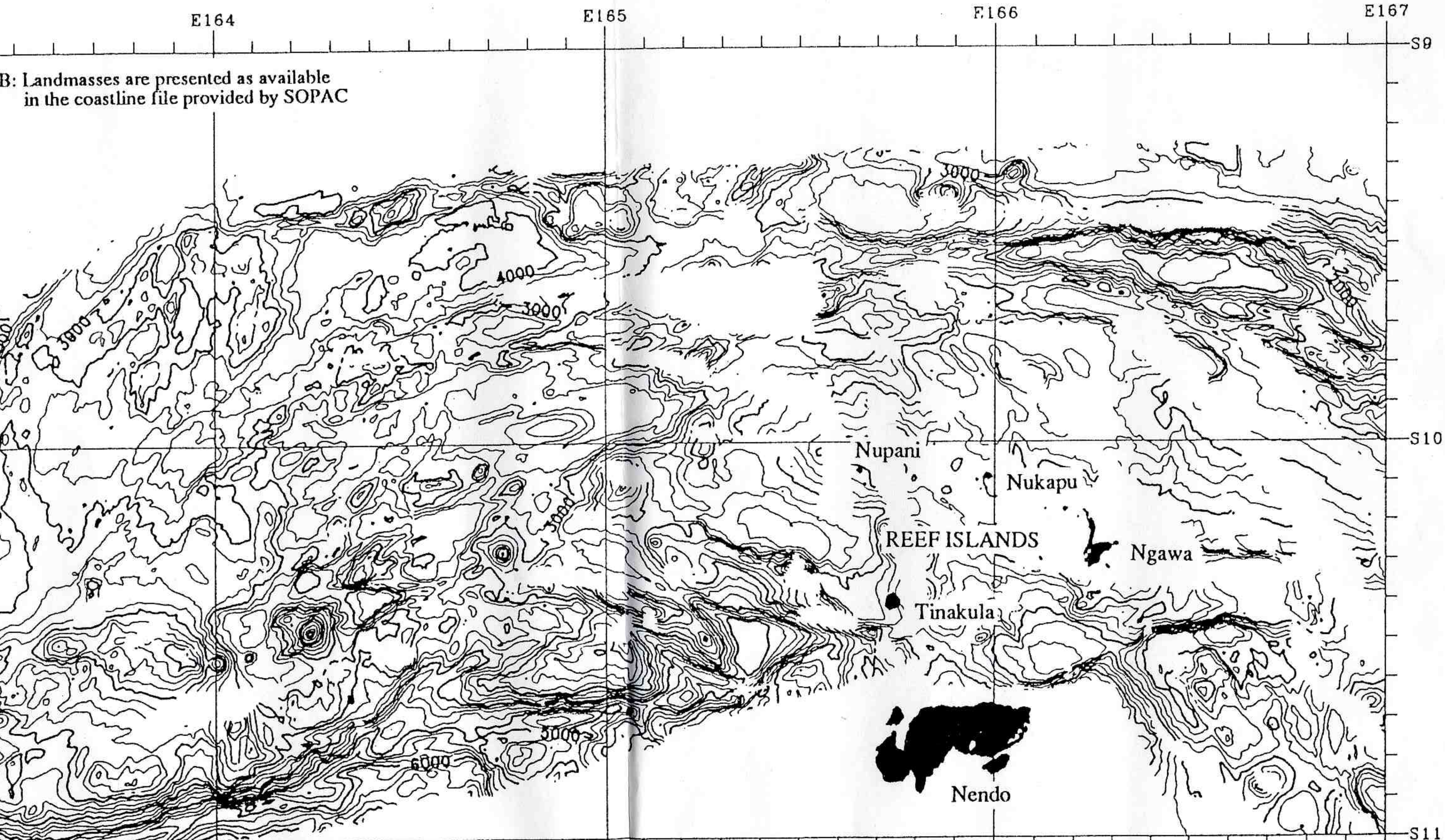
E164
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S9
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B: Landmasses are presented as available in the coastline file provided by SOPAC
4000
3000
3800
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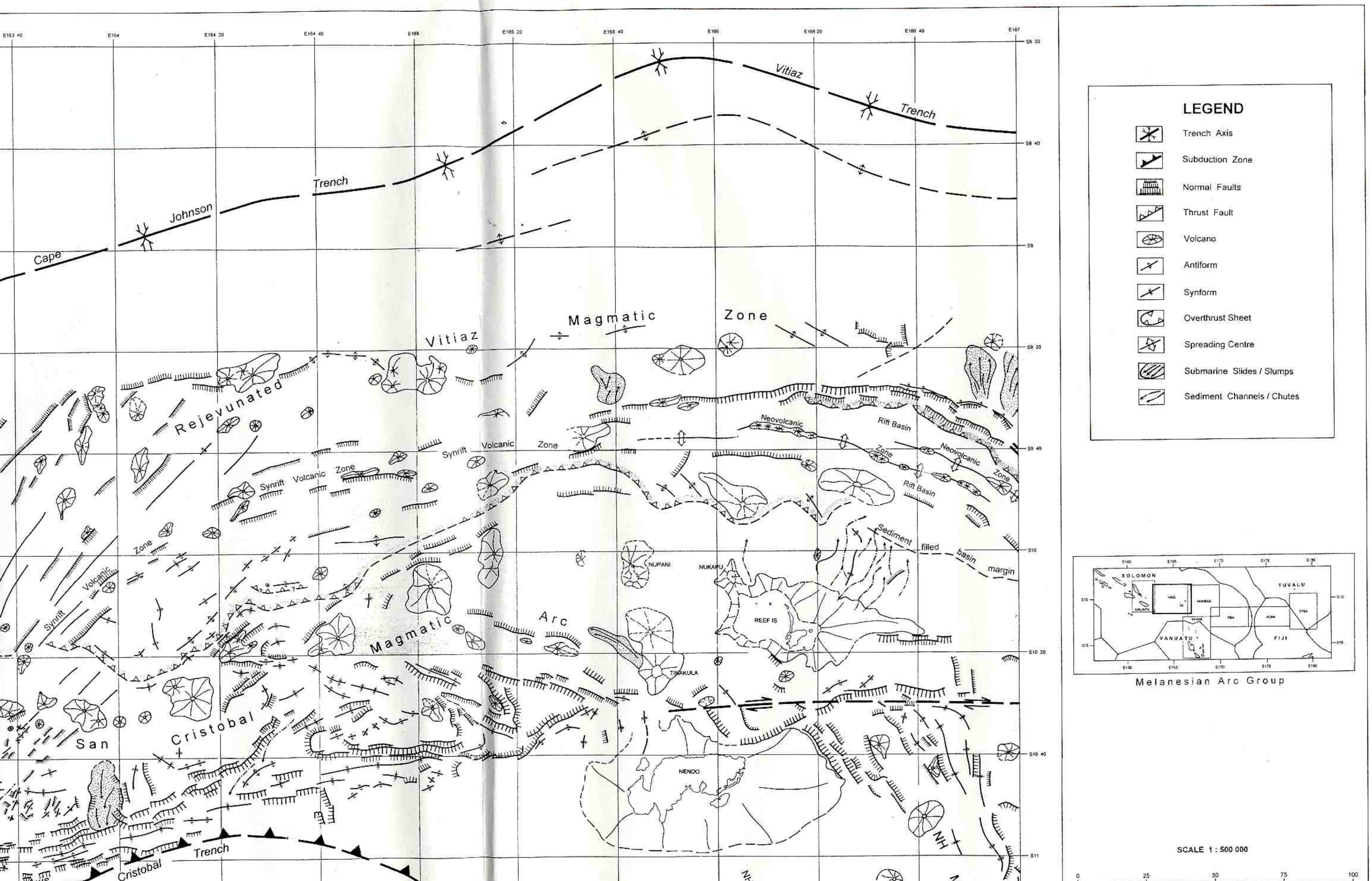
Nupani
Nukapu
REEF ISLANDS
Ngawa
Tinakula
Nendo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Vitiaz Trench
Cape Johnson Trench
Vitiaz Magmatic Zone
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Synrift Volcanic Zone
Neovolcanic
Rift Basin
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Sediment filled basin margin
NUPANI
NUKAPU
REEF IS
TINAKULA
NENDO
Magmatic Arc
San Cristobal
Cristobal Trench
NH
LEGEND
Trench Axis
Subduction Zone
Normal Faults
Thrust Fault
Volcano
Antiform
Synform
Overthrust Sheet
Spreading Centre
Submarine Slides / Slumps
Sediment Channels / Chutes
SOLOMON
TUVALU
VANUATU
FIJI
Melanesian Arc Group
SCALE 1 : 500 000
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Northern New Hebrides Back-Arc Area

The full extent of the Duff Islands Ridge, as well as a portion of the adjoining rift basin and neovolcanic zone, is visible north of the transtensional fault zone in the NNHBAA (Figs 7,8). Within the neovolcanic zone, to the west of the Duff Islands Ridge, the rift basin spreading system is formed by two offset and overlapping spreading ridges. Small discrete volcanic cones, aligned along the spreading axes, demarcate the two spreading centers. These spreading centers abut the Duff Islands Ridge in the vicinity of Taumako Is., in such a fashion to suggest that the neovolcanic zone itself has been overthrust by the Duff Islands Ridge.

The Duff Islands Ridge, rising more than 3500 m above the rift-basin floor, is surmounted by a chain of eight islands. The largest of the islands, Taumako Is., is located in the central part of the chain. The southwestern flank of the Duff Islands Ridge, adjoining the rift basin, is very steep yet the base of the slope appears to be free of any extensive rubble/talus deposit. In contrast, the less steep northeastern flank of the Ridge, as shown on the NNHBAA map, is characterised by widespread and large-scale submarine slumping/landsliding. Based on ridge morphology and tectonic setting, the ridge is interpreted to be the eastward continuation of the leading edge of the large thrust sheet mapped on the adjoining MAG map. This interpretation is supported by the absence of any obvious slump or landslide deposits on the southwest flank of the ridge, which would have been overridden during the overthrusting, and the Duff Islands geology, described as a remnant of a much more-extensive volcanic shield (Hughes, et al., 1981) of island arc origin (Hughes 1978). The reported occurrence of warm springs on Taumako Is (Hughes, *et al.,* 1981) also supports the overthrust interpretation and implies that hydrothermal solutions emanating from the still active neovolcanic zone are percolating up through the thrust sheet to the island surface. The overthrusting of the neovolcanic zone south of the ridge probably occurred fairly recently, perhaps during the second phase of thrusting concomitant with the renewal of Vitiaz arc volcanism that formed Anuta and Fatutaka Is.

Farther to the east on the NNHBAA map lies a roughly E-W aligned volcanic field comprising numerous small volcanic cones that are probably part of another synrift volcanic zone. In juxtaposition with this volcanic field lie several larger volcanic edifices. These large volcanoes are probably rejuvenated Vitiaz arc volcanoes, as they are part of a linear trend of edifices extending to the southeast, parallel to and at the appropriate distance from the Vitiaz Trench to be associated with Vitiaz arc volcanism.

To the south, stretching eastward from the West Tikopia Ridge as far east as Anuta Is (one of the rejuvenated Vitiaz arc volcanos) and possibly beyond, lies the Pandora volcanic zone. This zone, aligned roughly E-W and comprising numerous small volcanic cones, is probably still another synrift volcanic zone. The zone may extend even farther to the east but relationships there are obscured by the intersection with the trend of larger rejuvenated Vitiaz arc volcanoes. The superposition of arc volcanoes within this back-arc basin synrift volcanic zone could easily explain the high TiO_2 content reported for rocks from Anuta and neighboring Fatutaka (Mitre) Is. The volcanism that formed Anuta and Fatutaka dated at 2.2 +- 0.1 Ma, was first attributed to Vitiaz island-arc volcanism by jezek et al. (1977). Thus the location of these arc volcanoes together with the other large submarine volcanic edifices at similar distances from the Vitiaz Trench defines the present position of the Vitiaz magmatic zone and, as such, also serves to define the former location of the much older, Vitiaz arc volcanoes that were displaced during earlier episodes of back-arc rifting and basin formation. The rejuvenation of this magmatic zone may have occurred during a second phase of overthrusting caused by a change in Pacific plate motion that occurred about 2 My ago.

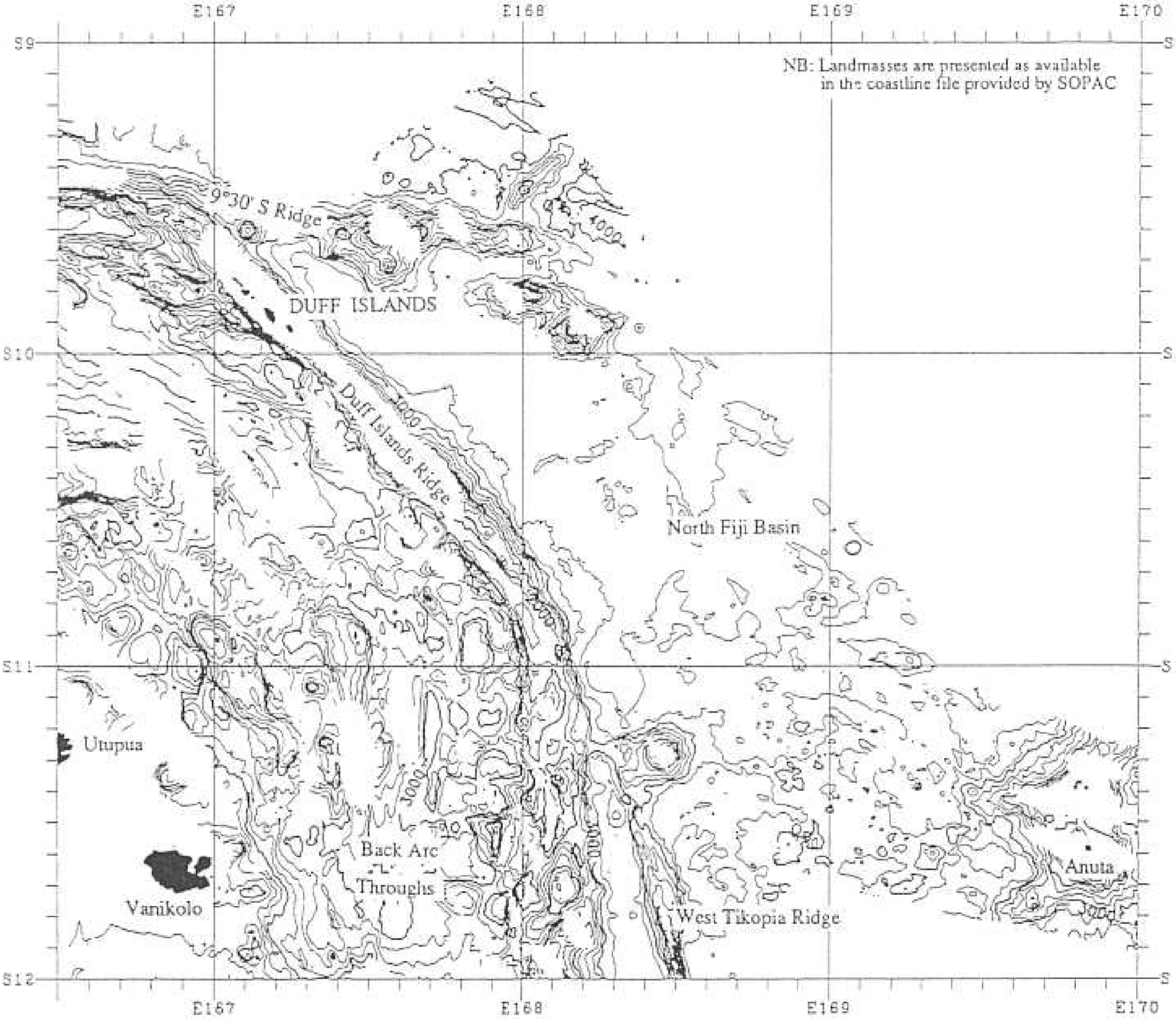
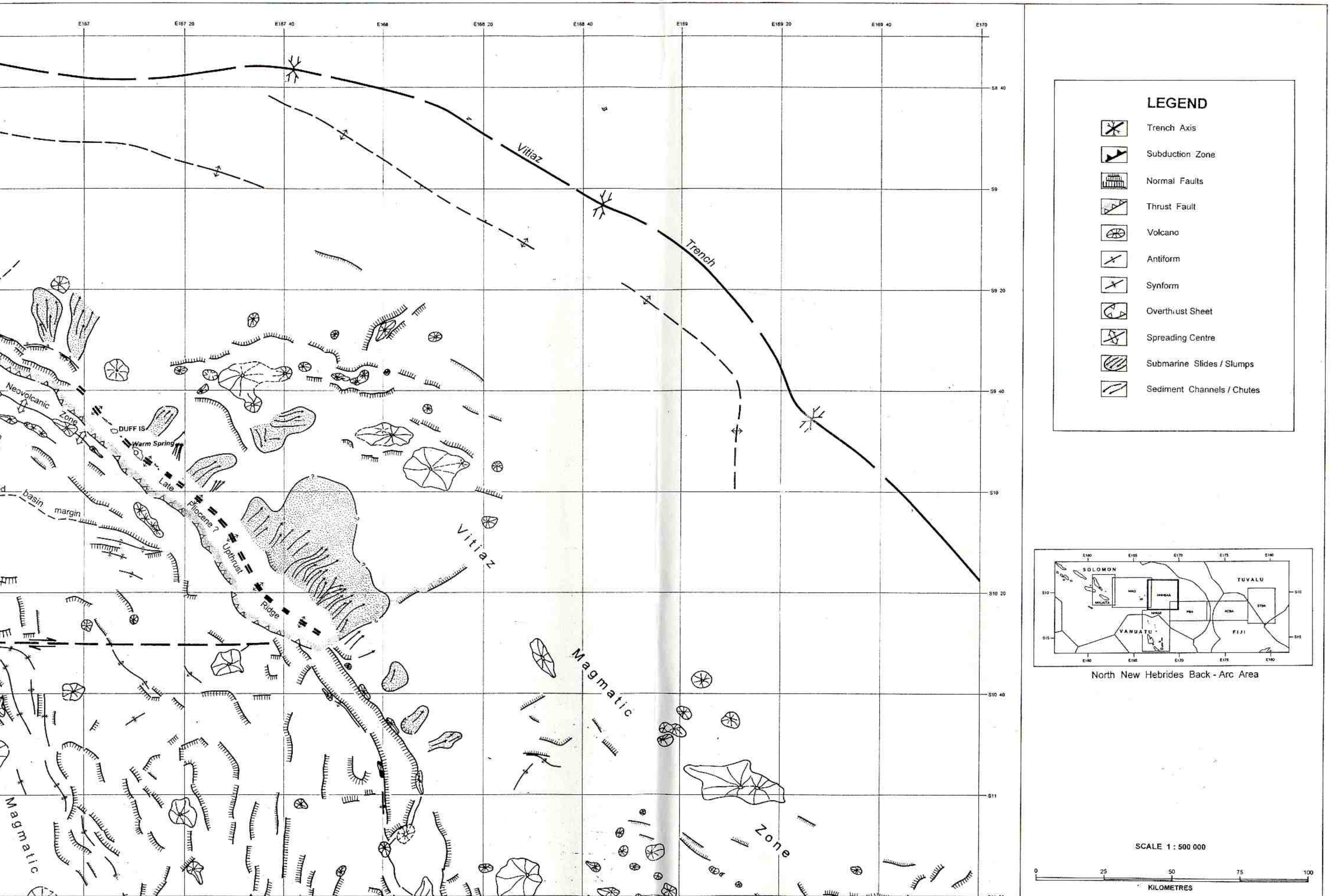


Figure 7. Bathymetry in the Northern New Hebrides Back Arc Area (NNHBAA) from IFREMER (1994e).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S11
Vitiaz
Trench
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Magmatic
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Magmatic
Neovolcanic
Zone
DUFF IS
Warm Spring
Late
Pliocene ?
Upthrust
Ridge
basin
margin
LEGEND
Trench Axis
Subduction Zone
Normal Faults
Thrust Fault
Volcano
Antiform
Synform
Overthrust Sheet
Spreading Centre
Submarine Slides / Slumps
Sediment Channels / Chutes
SOLOMON
TUVALU
VANUATU
FIJI
North New Hebrides Back - Arc Area
SCALE 1 : 500 000
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KILOMETRES

New Hebrides Intra-Arc Basin Area

Skirting the eastern flank of Vanikolo in the Eastern Solomon Islands, a line of active volcanic islands, submarine volcanoes, and volcanic cones spans the length of the New Hebrides Intra Arc Basin (NHIAB) area from north to south (Figures 9,10). This active volcanic line, the manifestation of the New Hebrides magmatic arc in northern Vanuatu, trends slightly east of south across the map and includes the islands of Vanua Lava and Gauna (Santa Maria) in the Banks Island Group, and Aoba. Surrounding these islands are the intra-arc basins of the northern New Hebrides, i.e., the Vanikolo, Banks, and North and South Aoba basins in the northern, central, and southern sectors of the NHIBA map, respectively.

The presence of numerous geological hazards in northern offshore Vanuatu, including explosive submarine volcanic eruptions, submarine slumps/landslides, and tsunamis, has already been well documented by Wong and Greene (1988). The SOPACMAPS data bolster the conclusions of Wong and Greene, highlighting the potential for both submarine slumps/landslides and explosive submarine volcanism.

The fact that considerable submarine landslide activity has occurred within the confines of the North and South Aoba basins (Central Basin) is clearly discernible in both the NHIAB imagery and bathymetry. Indeed, the areal extent of the slides is much more extensive than that previously mapped by Greene et al. (1988). The location of this basin in juxtaposition with the d'Entrecasteaux-New Hebrides Forearc collision zone serves to elevate the already high level of seismic risk that is normally associated with the subduction processes that occur in island arc tectonic settings. This high seismic risk coupled with the presence of extensive unstable marine slope deposits, mapped by Grene *et a/. (1988),* as well as the obvious slope instability evidenced by the visible presence of numerous large recent submarine landslides in the NHIABA imagery heightens the concern for the initiation of catastrophic submarine landslides and, more importantly perhaps, the ensuing generation of potentially damaging tsunamis.

Continuing island-arc style, explosive volcanic activity along the New Hebrides arc magmatic line, as was noted by Wong and Greene (1988), also poses an extant and serious geological hazard. The presence of numerous active or recently active submarine volcaniform features that are clearly discernible in both the NHIABA imagery and bathymetry further serves to highlight the serious nature of this hazard.

Although the focus of the SOPACMAPS survey in Northern Vanuatu was on the basins surrounding the presently active arc volcanoes, it is important to remember that allocthonous terrains exist on the western sides of the basins and in the adjoining frontal arc, which are remnants of the much-older Vitiaz arc (Kroenke, 1984). Displaced southwestward as the New Hebrides arc rotated clockwise, accommodating, in turn, the opening of the North Fiji Basin, these Vitiaz arc fragments may have carried with them portions of adjoining rift basins that were formed prior to the inception of North Fiji Basin spreading. The presence of older basinal sedimentary deposits coupled to a subsequent favorable thermal history may have produced an environment conducive to the maturation of hydrocarbons in similar fashion, perhaps, to that suggested described below for the SOPACMAPS survey areas to the east. Indeed the petroleum potential of northern Vanuatu is currently the focus of a promotional campaign being conducted jointly by the Australian Geological Survey Organisation (AGSO) and the Vanuatu Government (Vanuatu Dept. of Geol., Mines, and Water Res., AGSO, 1995) with the sponsorship of the Australian Agency for International Development (AusAID).

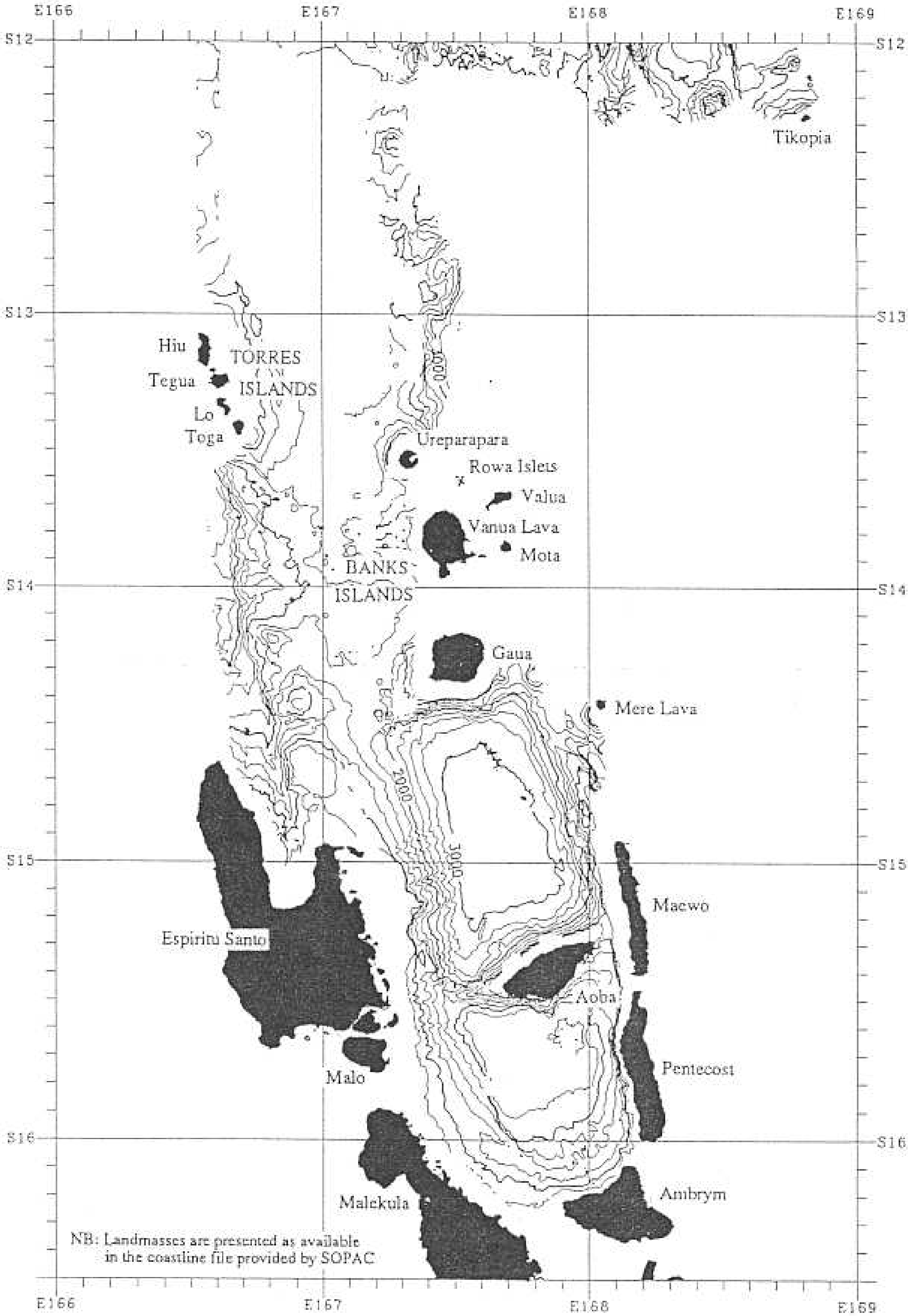
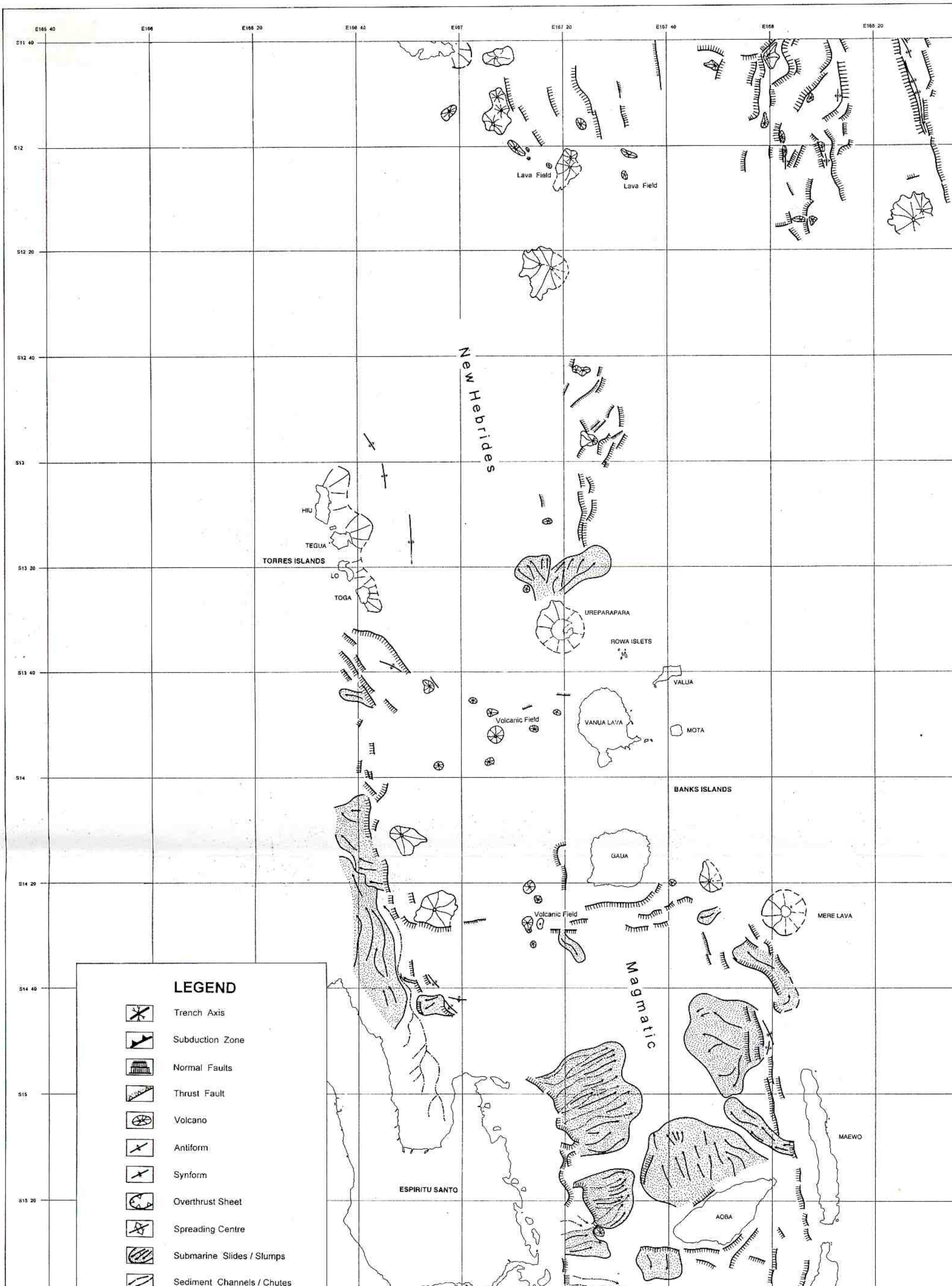


Figure 9. Bathymetry in the New Hebrides Intra-Arc Basin (NHIAB) area from IFREMER (1994b).


E165 40
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S11 40
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S14
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S14 40
S15
S15 20
Lava Field
Lava Field
New Hebrides
HIU
TEGUA
TORRES ISLANDS
LO
TOGA
UREPARAPARA
ROWA ISLETS
VALUA
Volcanic Field
VANUA LAVA
MOTA
BANKS ISLANDS
GAUA
Volcanic Field
MERE LAVA
Magmatic
MAEWO
ESPIRITU SANTO
AOBA
LEGEND
Trench Axis
Subduction Zone
Normal Faults
Thrust Fault
Volcano
Antiform
Synform
Overthrust Sheet
Spreading Centre
Submarine Slides / Slumps
Sediment Channels / Chutes

Pandora Bank Area

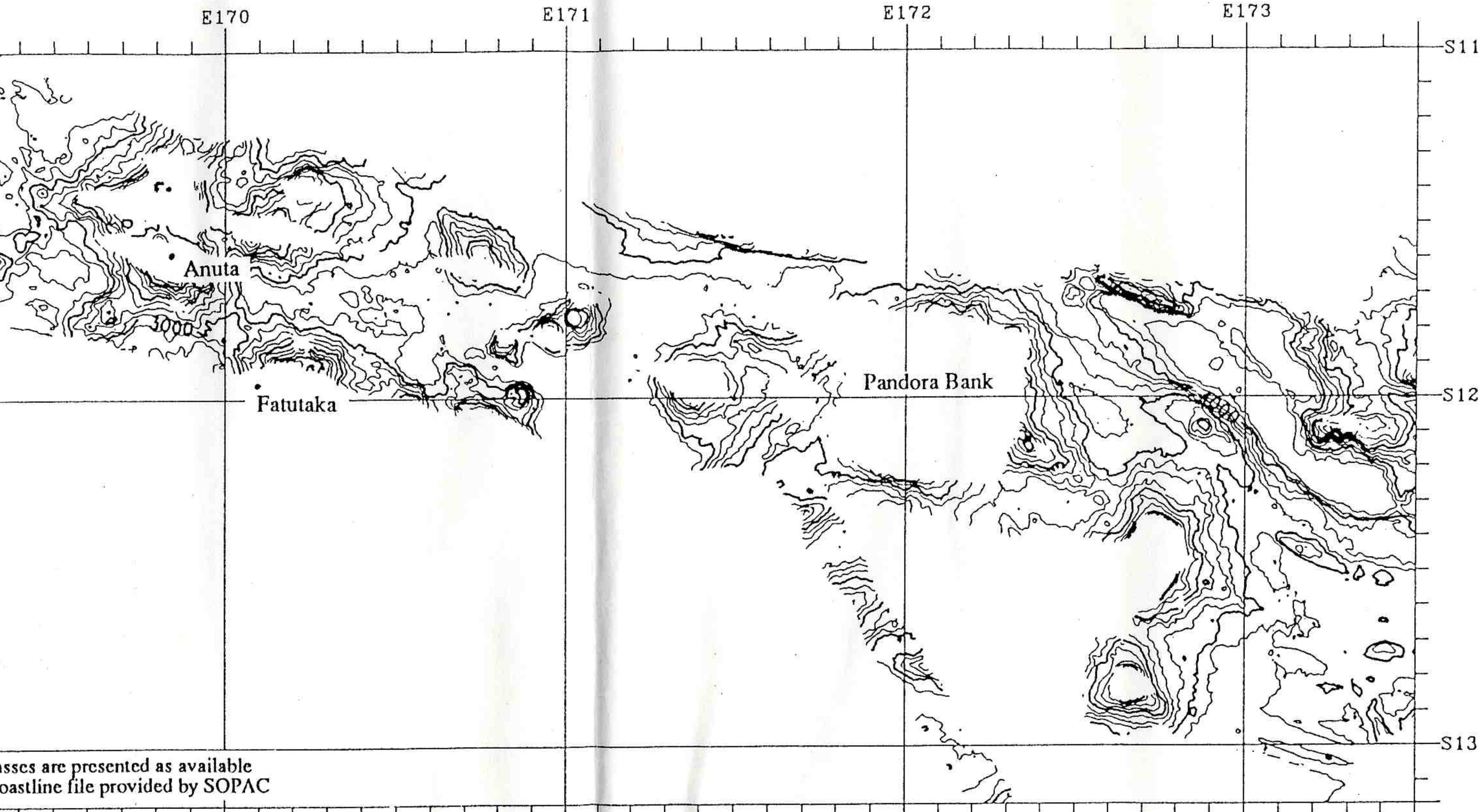
The islands of Anuta and Fatutaka, shown on the lefthand side of the Pandora Bank Area (PBA) (Figs 11,12) are definitely island-arc volcanoes according to Jezek *et al.* (1977) and P. Fryer (Pers. comm. 1995). A line of large seamounts, extending to the east-southeast of Anuta and Fatutaka and passing south of Pandora Bank, again lies at a fixed distance from the Vitiaz Trench, appropriate to lie over the Vitiaz magmatic zone. This tectonic setting is similar to that of the southward trending line of large volcanoes lying north of Anuta on the MAG & NNHBAA maps. The ESE trending line of PBA seamounts is, in all probability, also the product of the same renewed phase of island-arc volcanism originating from the Vitiaz magmatic zone that formed Anuta and Fatutaka and also those Seamounts occurring in a similar tectonic setting on the MAG & NNHBAA maps, about 2 My ago. It should be noted here that the locations of both Fatutaka and Pandora Bank as shown on the PBA map have been roughly repositioned using the SOPACMAPS data.

Pandora Trough, shaded gray on the PBA map, lies east of Pandora Bank and west of Charlotte Bank, as shown on the adjoining Alexa/Charlotte Banks Area (ACBA) map. The trough is deep, steep sided, and flat-floored, and contains a thick sequence of flat-lying sediment. The perimeter of the trough is closed, continuously encircled by 4000 to 4500 m isobaths. The trough is also marked by a very large, negative gravity anomaly. Morphologically resembling a graben, the Pandora Trough does not appear to be the eastward continuation of the Vitiaz Trench, as has been suggested by others (e.g., Brocher, 1985). Rather the Vitiaz Trench is postulated to pass north of the surveyed area, as suggested by Seasat-derived gravity data, and the Pandora Trough is proposed herein to be one of a series of large rift grabens (shown in more entirety on the adjoining ACBA map) that developed during the formation of either the Vitiaz or New Hebrides subduction zones, probably during a period of extensional tectonism similar to that proposed to accompany the formation of the Mariana Trench (see Stern and Bloomer, 1992).

Alexa/Charlotte Banks Area

In the Alexa/Charlotte Banks area, as shown on the ACBA map, the shapes and positions of both Alexa and Charlotte banks, based on SOPACMAPS data, differ considerably from their previously charted locations, as do the shapes and positions of Pandora, Charlotte, and Alexa Troughs (Figs 13,14). The geophysical attributes of both Charlotte and Alexa troughs are similar to that of

Pandora Trough, in that they are also deep, steep sided and flat-floored and contain a thick sequence of flat-lying sediment. Again the perimeters of the troughs are closed, continuously encircled by the 4000-4500 m isobaths. Both Charlotte and Alexa troughs are also marked by large, negative gravity anomalies as are similar troughs on the adjoining South Tuvalu Banks Area (STBA) map. These large gravity lows may have misled investigators into believing that the troughs formed the eastward extension of the Vitiaz Trench. In some places, however, rejuvenated Vitiaz arc volcanism appears to occur within the confines of these troughs or to lie north of them, which would strongly argue against this interpretation. Instead, the interpretation preferred by the writer is that these troughs comprise a series of large rift grabens that developed during a period of extensional rifting that accompanied the formation of either the Vitiaz or New Hebrides subduction zones. These deep grabens could have developed then, either as early as the initiation of Vitiaz subduction (−43Ma) oras late as the inception of New Hebrides subduction (−12 Ma) and thus, in either event, would predate the initiation of both New Hebrides arc volcanism (−10Ma) and North Fiji Basin rifting/spreading.



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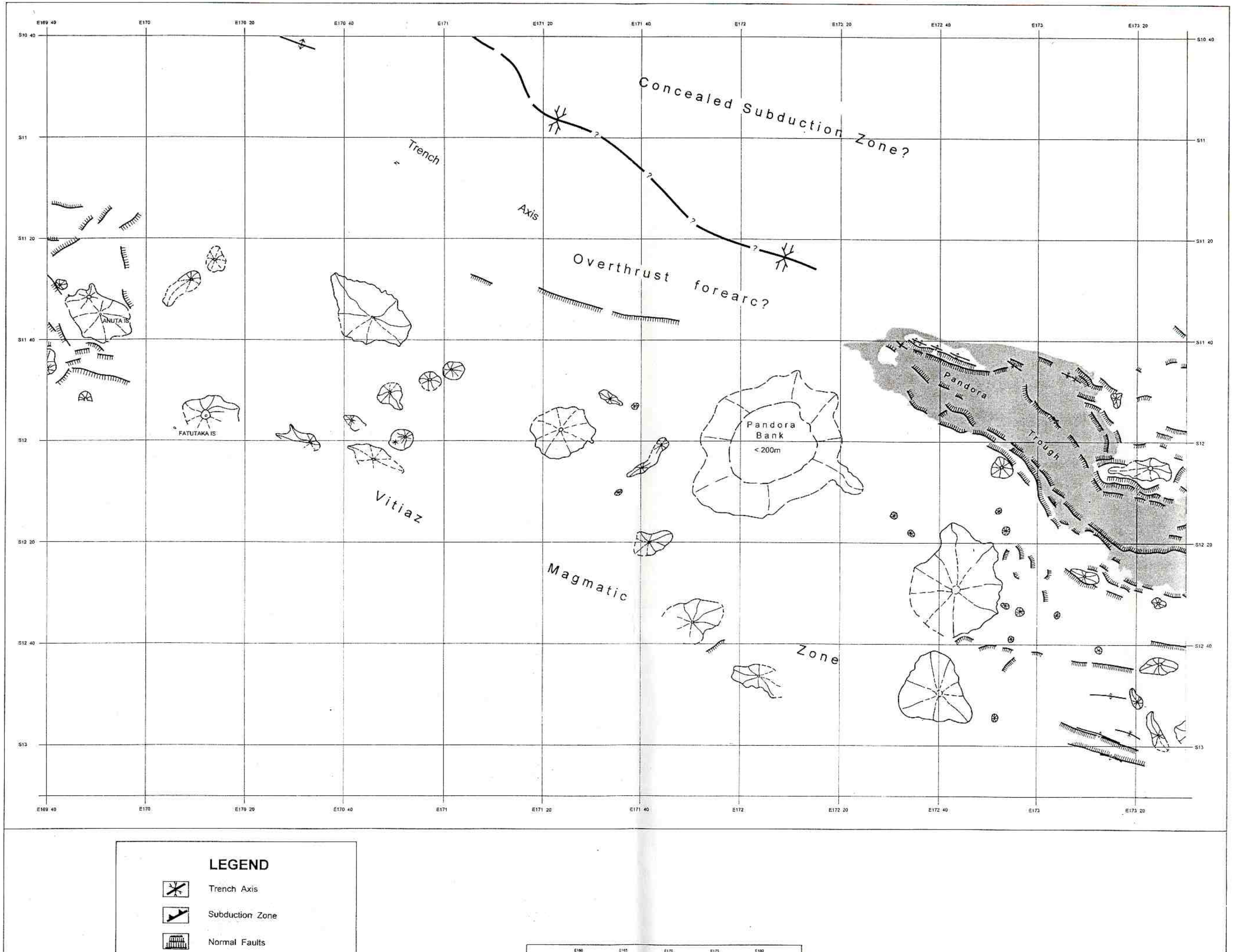
Concealed Subduction Zone?
Trench Axis
Overthrust forearc?
Vitiaz Magmatic Zone
Pandora Trough
Pandora Bank
< 200m
ANUTA IS
FATUTAKA IS
E169 40
E170
E170 20
E170 40
E171
E171 20
E171 40
E172
E172 20
E172 40
E173
E173 20
S10 40
S11
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S11 40
S12
S12 20
S12 40
S13
LEGEND
Trench Axis
Subduction Zone
Normal Faults

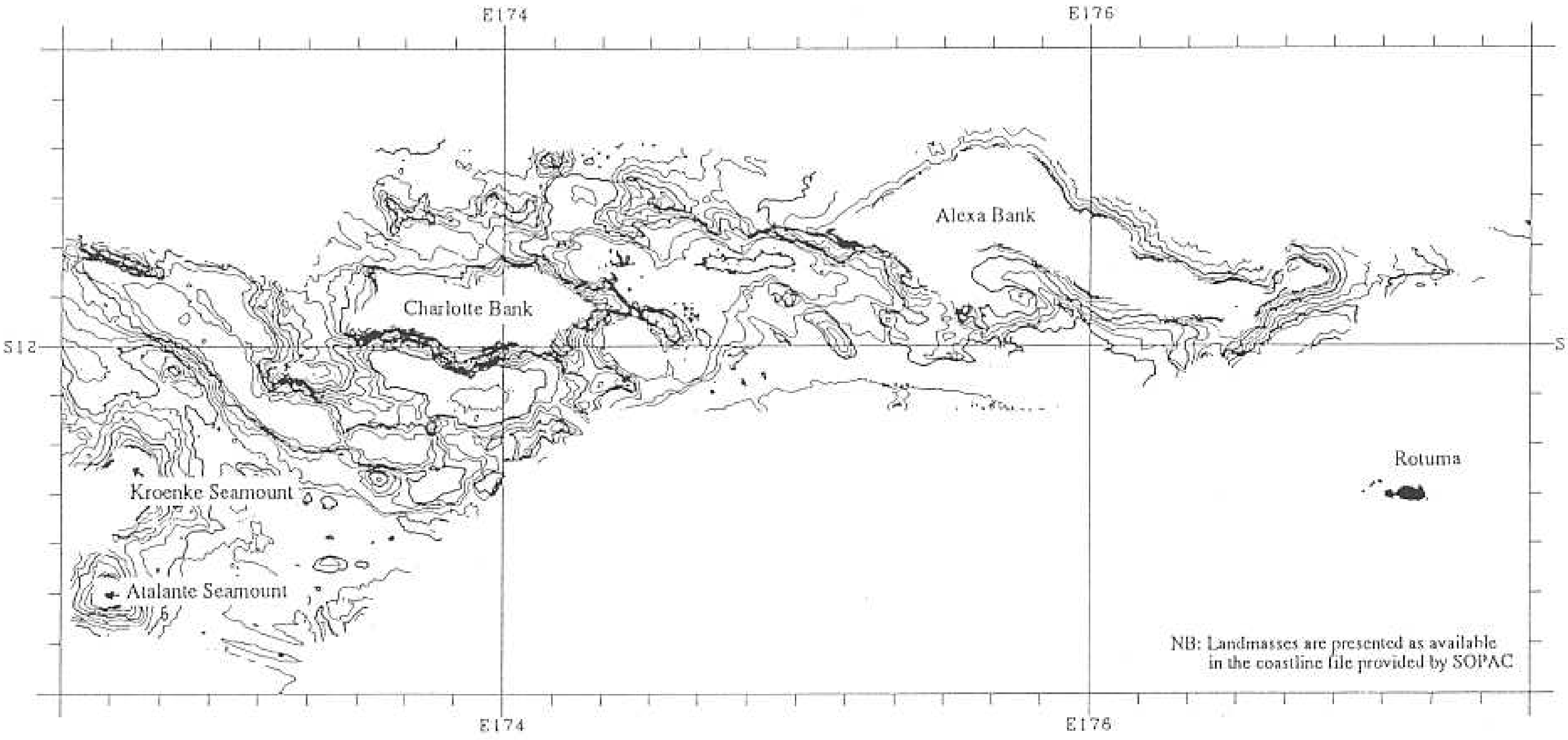
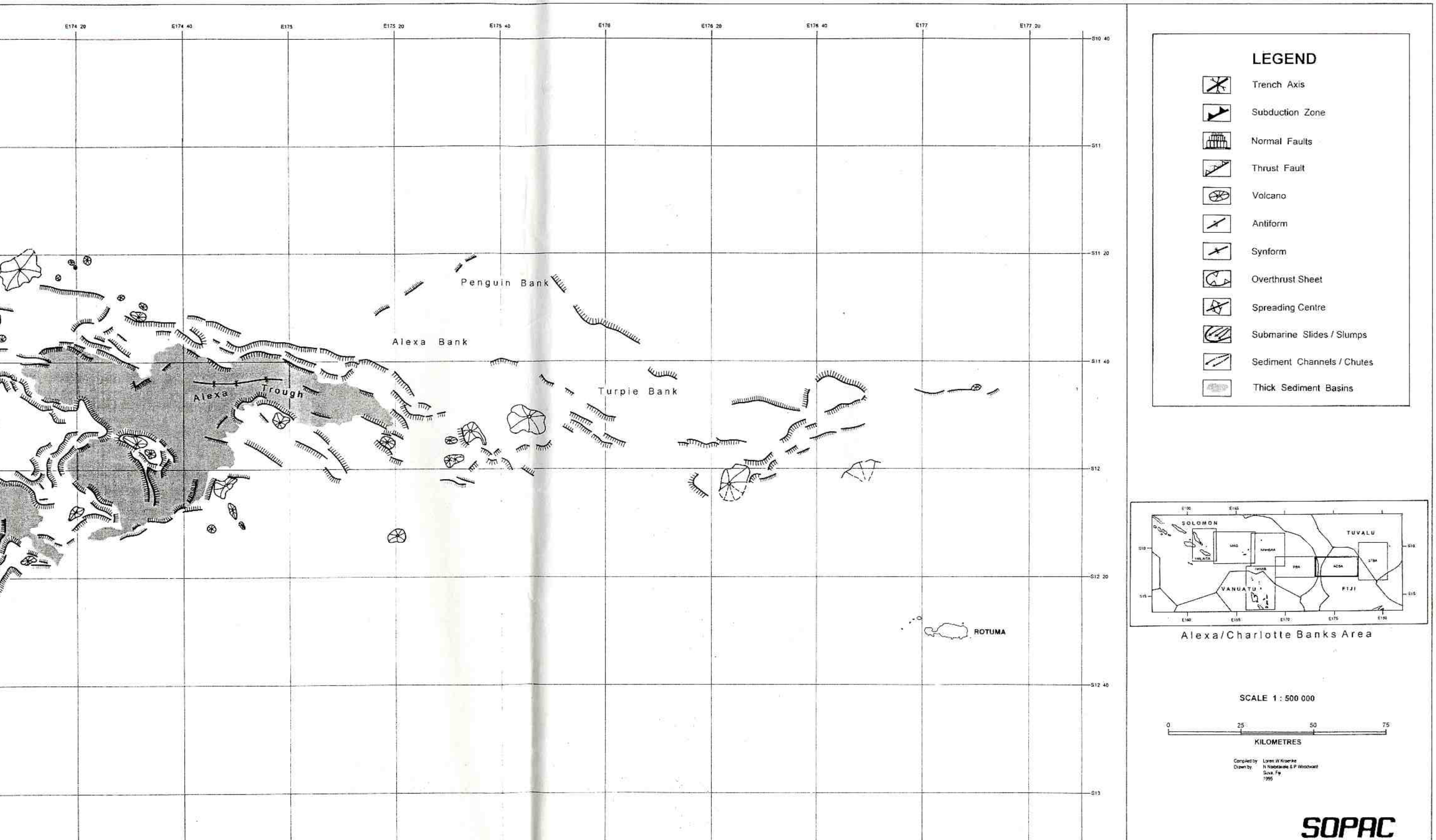


Figure 13. Bathymetry in the Alexa/Charlotte Banks Area (ACBA) from IFREMER (1994g).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E174 40
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S10 40
S11
S11 20
S11 40
S12
S12 20
S12 40
S13
Penguin Bank
Alexa Bank
Turpie Bank
Alexa Trough
ROTUMA
LEGEND
Trench Axis
Subduction Zone
Normal Faults
Thrust Fault
Volcano
Antiform
Synform
Overthrust Sheet
Spreading Centre
Submarine Slides / Slumps
Sediment Channels / Chutes
Thick Sediment Basins
SOLOMON
TUVALU
VANUATU
FIJI
Alexa/Charlotte Banks Area
SCALE 1 : 500 000
0
25
50
75
KILOMETRES
Compiled by Loren W Kroenke
Drawn by N Nasbawala & P Woodward
Suva, Fiji
1995
SOPAC

These grabens form closed basins, where anoxic conditions could have prevailed, and contain thick sequences of sediment. A favorable thermal history, conducive perhaps to the maturation of hydrocarbons, is indicated by evidence for the presence of up to four episodes of volcanism within the region (i.e., Samoan hotspot, New Hebrides Arc, NFB rifting/spreading, & rejuvenated Vitiaz arc volcanism). Shallow reef platforms forming the banks that lie adjacent to these thickly sedimented basins could provide suitable reservoirs for any hydrocarbons that might have been generated within the basins. A favorable uplift/subsidence history, suggested by the regional tectonic development, could have facilitated formation of impermeable caps, enabling trapping of any hydrocarbons that might have migrated upslope from the adjoining basins.

South Tuvalu Banks Area

The geology of the South Tuvalu Banks Area is similar to that described for the Pandora Banks and Alexa/Charlotte Banks areas, but the sediment-filled rift basins between Eaglestone Plateau and Hera-Bayonnaise Bank in the South Tuvalu Banks Area (Figs 15,16), shaded grey on the STBA map, are not as deep as those in the Pandora Bank and Alexa Charlotte Bank areas. This shallowing could be the result of basin foreshortening and uplift that may have occurred during the brief reactivations of Vitiaz subduction that happened about 5 and again at 2 Ma. The ensuing collision with the shoal areas north of the subduction zone also appears to have severely narrowed and constricted the Vitiaz Trench. The reactivation of subduction and the resulting rejuvenation of Vitiaz arc volcanism is evidenced by the line of volcanic edifices trending southeastward across the rift basins. Manatu seamount, located in the lower righthand corner of the STBA Map, lies along this trend. The analysis of rocks dredged from Manatu Seamount, showing island arc tholeiitic affinity (Sinton et al., 1985), gives credence to this interpretation.

South of the grabens on the STBA map lies a prominent sequence of elongate rotational fault blocks that is probably the rift fabric associated with the initial stages of North Fiji Basin development. The Vitiaz Trench itself, now partially infilled and obliterated in some places and considerably constricted in others by the last overthrusting event, is believed to lie north of Charlotte and Alexa (Turpei) banks, passing just south of Niulakita and north of Hera-Bayonnaise Banks.

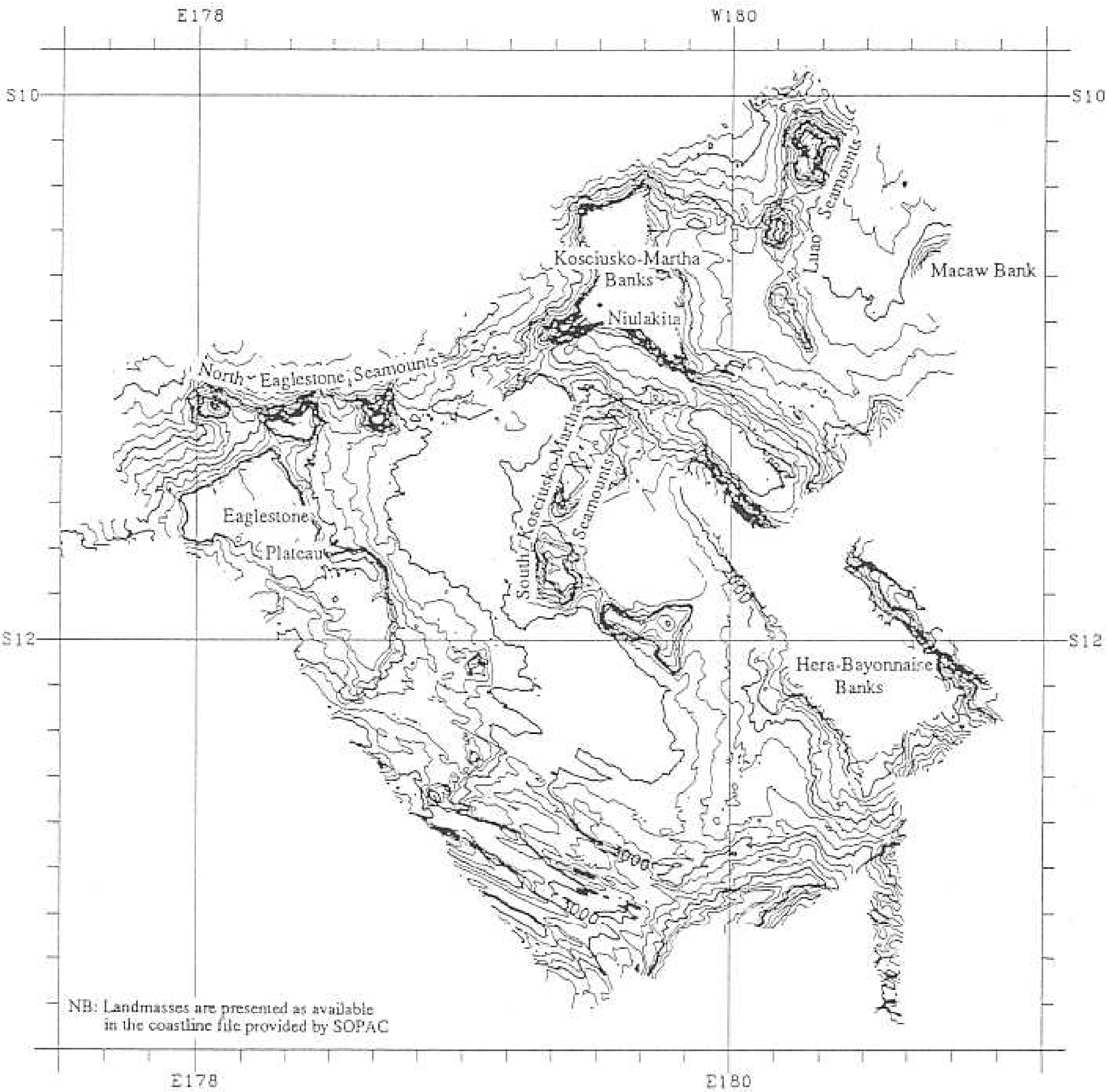
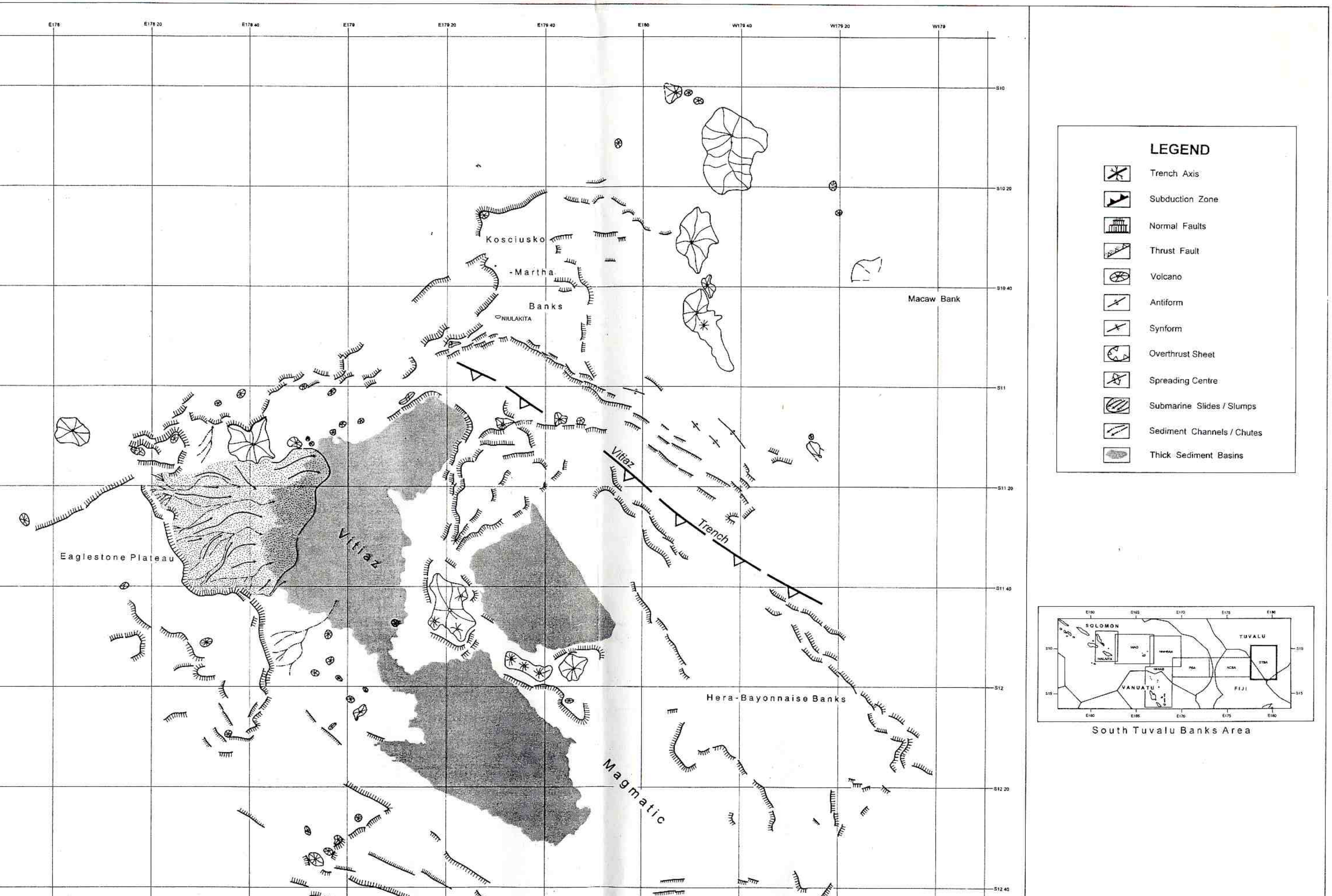


Figure 15. Bathymetry in the South Tuvalu Banks Area (STBA) from IFREMER (1994h).


LEGEND
Trench Axis
Subduction Zone
Normal Faults
Thrust Fault
Volcano
Antiform
Synform
Overthrust Sheet
Spreading Centre
Submarine Slides / Slumps
Sediment Channels / Chutes
Thick Sediment Basins
Kosciusko
-Martha
Banks
NIULAKITA
Macaw Bank
Vitiaz
Trench
Vitiaz
Eaglestone Plateau
Hera-Bayonnaise Banks
Magmatic
SOLOMON
TUVALU
VANUATU
FIJI
South Tuvalu Banks Area

RECOMMENDATIONS FOR FURTHER WORK

The need for confirmation of the techtonic setting of the Duff Islands Ridge, where the structural interpretations of the NNHBAA data in this study indicates that onland or shallow offshore hydrothermal mineralization might be present in the Eastern Solomon Islands, provides a strong argument for conducting additional field studies here. Moreover, the recognition of geological structures that suggest the presence of a previously unrecognised hydrocarbon potential in the PBA, ACBA and STBA survey data definitely underscores the need for further offshore surveys in these areas. It is strongly recommended, therefore, that additional surveys be undertaken as follows:

Additional Swathmapping Surveys:

1. Shallow-water swathmapping surveys should be conducted over the very shallow and still-unsurveyed crest of the Duff Islands Ridge mapped in the NNHBAA surveys to search for evidence of suitable structures for, and build-ups of, hydrothermal deposits.

2. Shallow-water swathmapping surveys should be conducted over the very shallow and still-unsurveyed crests of the banks mapped during the PBA, ACBA and STBA surveys to determine the derivation and developmental history and to target potential reservoirs.

3. Long-range swathmapping surveys should be conducted of areas adjacent to the ACBA and STBA surveys to better define the closed rift basins and adjoining banks that are only partially surveyed, as well as the unsurveyed banks, shoal areas and seamounts reported to lie nearby.

4. Long-range swathmapping surveys should be conducted in Vitiaz fore-arc areas lying to the north of the SOPACMAPS MAG, NNHBAA and PBA surveys south of the Vitiaz Trench, between 164'E and 173'E where additional shallow banks and unts might be found. Anomalously high gravity values, derived from Seasat data (Fig.17) suggest that many more of these shallow features, similar, perhaps, to those encountered in the ACBA and STBA surveys, could also be present in this region.

New Geophysical Surveys:

1. Multichannel seismis (MCS) profiling should be undertaken over the shallow banks (to search for suitable reservoir structures) as well as the adjoining deep basins (to test the depth of, and sedimentary thickness in these basins and to search for “bright” reflectors and “free gas” structures that might indicate the presence of hydrocarbons).

2. Towed geochemical/sniffer surveys should be conducted, in the same areas mentioned above to search for any evidence of hydrocarbon seepage or gas discharge.

Bottom sampling:

1. A bottom sampling program should be undertaken along the Duff Island Ridge in the MAG area to search for indications of the presence of any metalliferous deposits.

2. A bottom sampling program should also be undertaken within the closed basins already mapped and over the adjoining shallow banks in the PBA, ACBA and STBA areas to search for evidence of any hydrocarbon production.

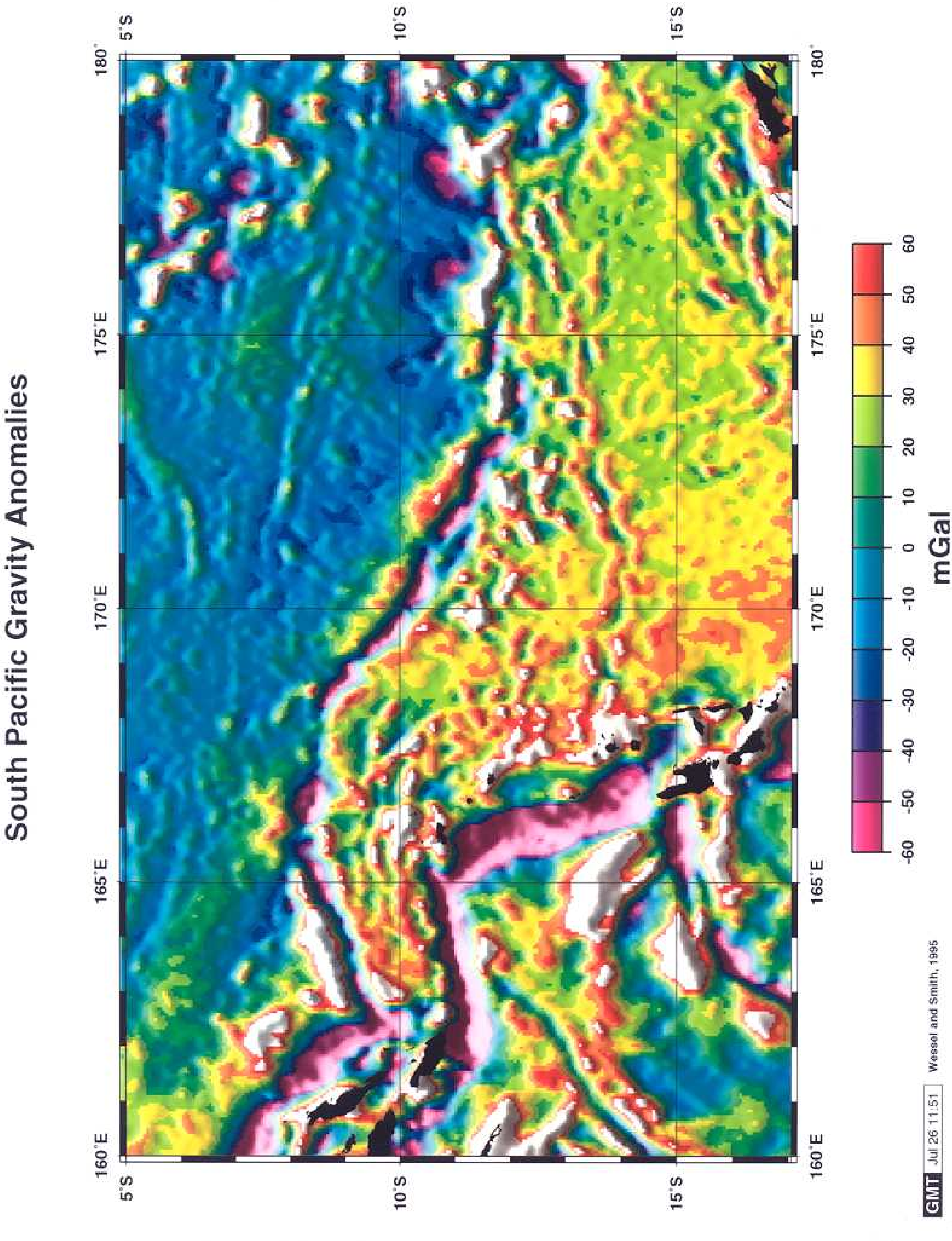


Figure 17. Regional gravity field, derived from ERS-1, Geosat, and Seasat data (Sandwell and Smith, 1992) in the vicinity of the SOPACMAPS survey areas.

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