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South Pacific Traverse RP-7-SU-71
Pago Pago to Callao to Seattle

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BOULDER, COLO.
January 1972

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PLATES

SOUTH PACIFIC TRAVERSE RP-7-SU-71

PAGO PAGO TO CALLAO TO SEATTLE

William H. Lucas

Profiles of bathymetry, free-air and Bouguer anomalies, and magnetic anomalies across the Tonga Trench and Melanesian region, South Pacific at 30°S, Peru-Chile trench and the Nasca and Pacific plates are presented and discussed. Approximately 13,200 n mi of trackline were run with control by satellite navigation. Additional topographic and tectonic features crossed include the Austral Seamount Chain, the East Pacific Rise, the Galapagos Rift and the Clipperton, Clarion, Molokai, Murray, Pioneer and Mendocino Fracture Zones.

1. INTRODUCTION

1.1 Purpose

The purpose of this cruise was to acquire geophysical data (1) in the Melanesian region across the Tonga Island arc system into the South Fiji Basin, (2) across the South Pacific along Latitude 30°S, and (3) northward across the East Pacific fracture zones. The ship's track is shown in figure 1.

The NOAA Ship SURVEYOR with scientists B. H. Erickson and W. H. Lucas aboard departed from Pago Pago on April 15, 1971. The return of stowaways, discovered a day and a half out of port resulted in data from along three parallel tracklines spaced 30 n mi apart extending from Samoa across the Tonga trench and arch and the Lau basin to the southwestern margin of the Lau ridge. The track extended into the South Fiji Basin

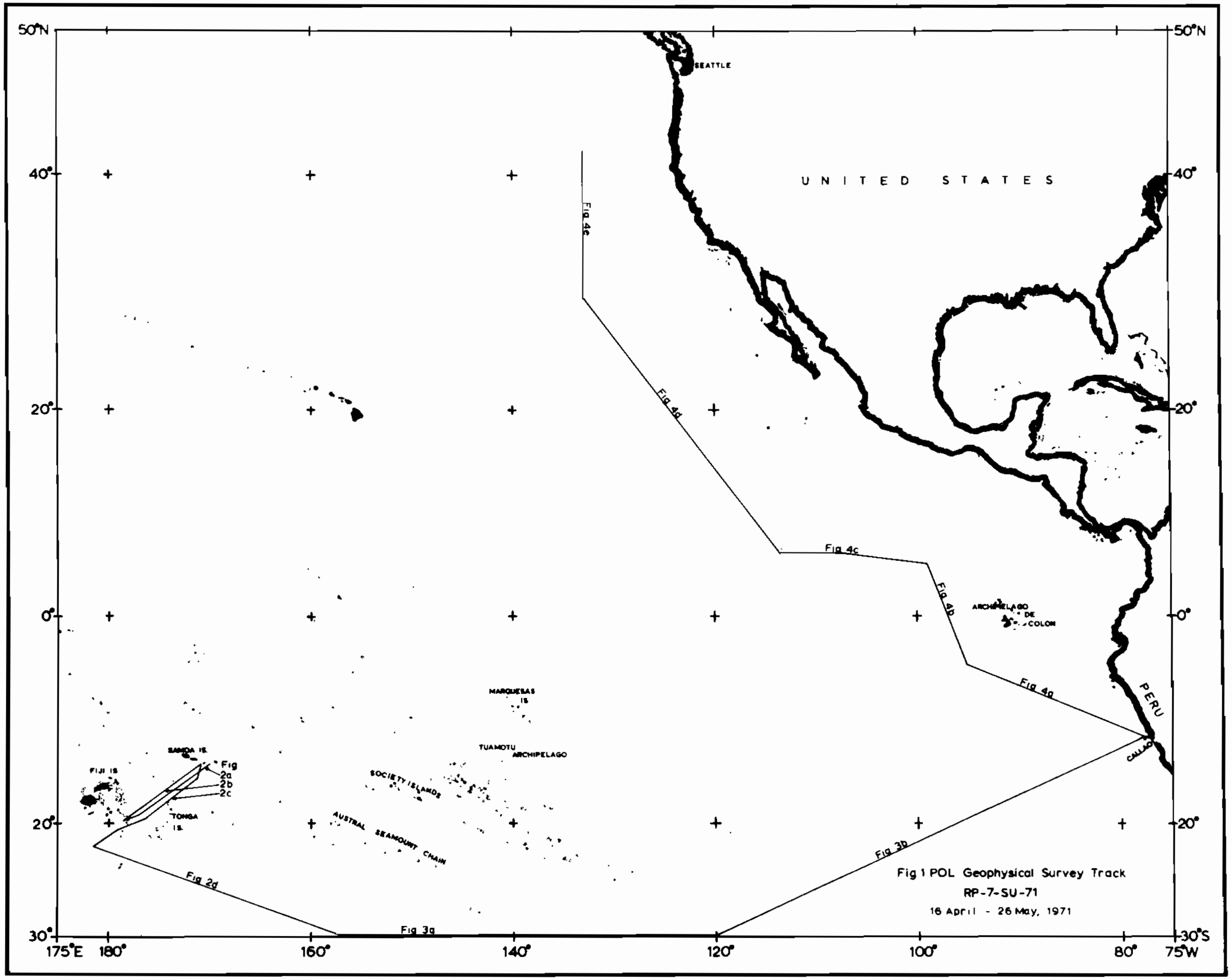

Figure 1. POL Geophysical Survey Track, 16 April - 26 May, 1971.

and thence southeastward across the Lau ridge and basin, the Tonga arch and trench, and then across the deep sea floor to 157°W, 30°S. The track continued due east to 120°W, northeast to Callao, and then northward across the East Pacific to Seattle.

1.2 Geologic setting

The hypothesis of plate tectonics holds that the earth's crust is comprised of rigid blocks or plates that move relative to one another. The boundaries of these plates represent zones of interaction and are of three types: ridges, trenches or subduction zones, and transform faults.

In the western portion of the South Pacific basin, west of the Tonga-Kermadec Island Arc system, lies the highly complex Melanesian region. In this area some marginal basins and ridges and trough structures are thought to be the result of secondary extension behind an active frontal arc (Karig, 1970a, 1971).

The Pacific plate, moving westerly from the East Pacific Rise, appears to be subducted along the Tonga-Kermadec trench. Although the configuration of primary features in the South Pacific basin is poorly known, it appears that the oldest portion of the oceanic crust in this area may lie just east of the southern Tonga trench.

2. DATA REDUCTION

2.1 General

Digitized data was furnished by the ship in the form of punched paper tape and corresponding printouts. The data are divided into three separate formats:

(1) A Raw Data Tape recorded in real time at one minute intervals containing: Day, time (GMT), depth, magnetics and gravity. Soundings are in fathoms and tenths, magnetic values in gammas, and gravity values in counterdial readings. Gravity values correspond to a time 3.5 minutes earlier than that for which they are listed.

(2) A Corrector Tape containing: Latitude and longitude of positions (including DR positions as scaled from the smooth sheets), 5 minute interval soundings (corrected for any digitizing errors), and soundings which constitute peaks or troughs between the 5 minute soundings.

(3) A Satellite Navigator Printout which includes fix information and alerts (no punched paper tape).

Analog data was furnished in the form of the following geophysical records:

(1) Fathograms

(2) Magnetometer records

(3) Gravity Analog data

(4) Graphical course record

(5) Sippican Expendable Bathythermograph

The bathymetric, gravity and magnetic data were further processed and edited at the Pacific Oceanographic Laboratory (POL), located at NOAA's Pacific Marine Center in Seattle, Washington. Following several edit procedures, the geophysical and navigation data furnished by the ship on punched paper tapes were transferred to fix cards and data cards using a 1620 computer. From these cards, as a further edit procedure, the ship's velocity between successive position fixes has been computed using a CDC 6400. The CDC 6400 was also programmed to transfer the data from cards to magnetic tapes, to calculate positions by time interpolation between navigation fixes, to convert fathoms to meters, and to compute free-air and Bouguer anomalies. The Bouguer anomalies in the present report were calculated assuming an infinite flat slab and using an assumed sea water to rock density differential of (2.67-1.03) g/cc.

2.2 Depth Measurements

Continuous depth recordings were made using a (McKiernan-Terry) precision depth recorder serial numbers 309 and 323 with a (General Instruments) narrow beam sonar for all deep water soundings. The width of the single vertical effective beam was 2-2/3 degrees. Calibration velocity is 800 fathoms per second.

The SURVEYOR recorded 13,200 n mi of bathymetry on this project. The line crossed itself near Tutuila Island (see fig. 1) where a difference of 4 fathoms was observed. Only a rough comparison of sounding with charted depths was possible since most areas traversed were very sparsely sounded. In general reasonable agreement was found considering the date and source of much of the charted information.

2.3 Gravity Measurements

Gravity measurements were made continuously during the cruise by using a La Coste and Romberg stable table meter (#S-51) which was set for 3.5 minute averaging and a table period of 4 minutes. The meter produces three continuous analog records. One contains the following traces:

1. Derivative of average beam position plus cross coupling (in black).

2. Counter dial reading (in green).

3. Cross coupling correction (in red).

4. Spring Tension (in orange) which every four hours was momentarily switched to record the instantaneous beam position for 5 minutes.

The other two records contain the output of the horizontal accelerometers (green for athwart-ship's component - red for fore and aft). Our record is for instantaneous output, the other for average output.

The gravity data were tied to the base stations at American Samoa, Pago Pago Fuel Pier Station #43.03, at the International Airport in Lima, Peru (Geodestico Inter-Americano - 1961) and at the Pacific Marine Center in Seattle, Washington #T-408 1965. The net drift of the instrument between ports was small. On the 18-day leg from Samoa to Callao it was -0.8 mgals and during the 19-day leg from Callao to Seattle -2.3 mgals. Corrections were applied to the data assuming the drift rate to be linear.

A plus 13.3 mgal correction had to be applied to all gravity values on the leg from Callao to Seattle. The gravity meter table "dumped" while alongside the dock in Callao and the resultant slippage in the auto reader unit resulted in all subsequent gravity values being recorded 13.3 mgals low. This was later verified by the Seattle land ties.

Excellent position control was obtained with the satellite navigation system. In addition, extremely calm seas for most of the project resulted in the character of the recorded gravity trace being very smooth. Consequently, high accuracy for the gravity measurements were obtained on the entire cruise. The line crossing produced a gravity difference of less than 1 mgal.

2.4 Magnetic Measurements

Magnetic data were collected using a Varian V4937 Direct Reading Proton Magnetometer (ser. #80). Sensing heads (numbers 127 and 664) were towed 900 feet behind the ship. The timing cycle of polarization was 60 seconds except during testing, tuning and periods of rapid changes in the magnetic field. Data were logged continuously on an analog trace and at five minute intervals on punch paper tape. They were later reduced by subtracting the International Geomagnetic Reference Field (IGRF 1965) values for the corresponding location. Problems with the sensing head and cable occurred during the first part of the cruise, resulting in several replacements and repairs.

3. PROFILE PRESENTATION

This report presents objectively all the bathymetric, magnetic and gravity (free-air and Bouguer anomalies) data of this survey in profile form so that any feature can be located with relative accuracy and the relationship between these three parameters along trackline segments can be seen clearly.

The CalComp plotter has also printed, in conjunction with the four profiles, three lines which show the distance traveled in nautical miles with tick marks every twenty miles. Course changes and ship's position are indicated on the bottom two lines of the profile. Latitude and longitude are indicated on the bottom line with tick marks to denote position fixes.

The bathymetry is shown in uncorrected meters with a vertical exaggeration of 37:1 and the profile is darkened where parameters overlap. Trackline locations are shown in fig. 1.

The profiles are presented in three groups. The first set (figures 2A thru 2D) cover the Tonga Trench and Melanesian Region. The second group (figures 3A thru 3B) shows the long Transpacific crossing arranged from west to east on successive figures. Group three (figures 4A thru 4E) shows the profiles from Callao to Seattle arranged from south to north on successive figures.

Other RP-7-SU-71 data which may be of special interest can be obtained by writing to:

National Oceanic and Atmospheric Administration
National Geophysical Data Center
Chief, Marine Geophysics Group
Gramax Building, 8060 13th Street
Silver Spring, Maryland 20910

4. DISCUSSION

4.1 Tonga Trench and Melanesian Region

The Melanesian area is one of the most complicated tectonic province bordering the Pacific basins. Half of the world's deep earthquakes occur along the Tonga-Kermadec arcs which are two of the world's most seismically active regions for shallow earthquakes (Sykes, 1966). The oceanic sea floor is rather smooth between Samoa and the Tonga Trench interrupted only by what appears to be a 200-500 fathom scarp trending southeastward. The scarp appears to lie along an extension of the slope defining the southwestern margin of the "Samoa Platform" and thus may be continuous across the northern arcuate tip of the Tonga Trench. Its position appears unrelated to the trench topography, occurring midway between American Samoa and the Trench and at the outer ridge on the northwestern profile (figures 2A, 2B and 2C). No marked expression of this feature is noted in the magnetic anomaly values which are generally nondescript and small in amplitude east of the Volcanic arc. Trench depths increase southeastward from 7867 m to 8677 m. Free-air anomalies reach a minimum of about -230 mgals, 3.7 n mi west of the bathymetric deep. Changes in mantle depth as reflected by the Bouguer anomalies generally occur west of the deep. The free-air anomalies which reach +100 to +150 mgals over the upper trench slope and volcanic arc abruptly decrease to about +60 mgals immediately west of the arc. The values then decrease rather uniformly to about +10 mgals at the base of the Lau ridge where values of +30 to +60 mgals are found. This region between the arc and the Lau ridge is characterized by magnetic anomalies of rather short (10 n mi) wavelengths and amplitudes of 300 to 600 gammas which, roughly correlated, suggest trends generally parallel to the island arc structure.

Two regions of anomalous topography in the Lau Basin (i.e., ridge and trough or seamount location) appear to correspond to the locations of shallow seismic trends (described by Sykes, Isacks and Oliver, 1969) and may be surface manifestations of associated fault zones.

The South Fiji Basin has relatively smooth topography, low amplitude magnetic anomalies, and near-zero free-air gravity anomalies. Similar relationships were observed along the southwest leg across the southern Tonga Arc (fig. 2D). Notably, the free-air anomalies decreased only to +40 to +50 mgals at the base of the Lau ridge. Free-air minimum was -269 mgals 3.7 n mi west of the bathymetric depth of 9396 m.

Hayes and Ewing (1968) found no evidence for an "outer ridge" seaward of the Tonga-Kermadec trench like that associated with many other trenches. The positive free-air anomalies over the ridge (figs. 2A, 2B, 2C) are complicated by the presence of a scarp (discussed earlier) and seamounts. The southernmost profile (fig. 2D) has a rather flat sea floor and a broad band of positive free-air anomalies over the outer ridge which, as reflected in the free-air (+10 to +40 mgal region) and Bouguer anomalies, extends over 200 n mi seaward of the trench. The free-air and Bouguer anomalies are very similar in appearance and amplitude to those which occur over the Hawaiian arch and are believed to be caused by "upbuckling" at mantle depths (Lucas, 1971).

Previous crossings of the Lau ridge have indicated free-air anomalies close to zero (Talwani et al., 1961). The profiles we present (figs. 2A thru 2D) show very sizeable free-air anomalies ranging as high as +80 to +90 mgals over the South Fiji ridge. The Lau basin also has large positive free-air anomalies even over local troughs.

Just beyond the limits of the outer ridge is what appears to be a dropped block (about 80 n mi wide along the track, fig. 4D) with a 7 n mi wide trough at the southeastern margin with depths of about 900 m below the regional 5500 m level. Magnetic anomalies through this region are not marked although a sequence of about 6 anomalies, near 169°W, bears some resemblance to a part of the western Pacific pattern.

4.2 Transpacific Crossing

Very few continuous geophysical traverses have been made across the South Pacific. The NOAA Ship OCEANOGRAPHER (October 1967) crossed at approximately the 35°S parallel from the Kermadec trench to Valparaiso, Chile (Keller and Peter, 1968). The Eltanin 20 and 21 cruises crossed at approximately the 45°S and 40°S parallel (Pitman and Heirtzler, 1966) and the Eltanin 29 cruise at 28°S.

For the profiles given in this report the SURVEYOR's trackline (see fig. 1) crossed a large portion of the South Pacific along the 30°S parallel to 120°W Longitude before heading northeast to Callao. Three major tectonic features, the Austral seamount chain, the East Pacific Rise, and the Peru-Chile Trench were crossed on this track (figs. 3A and 3B).

4.2.1 Austral Seamount Chain

An area about 300 n mi wide, characterized by elevated rough topography and bordered by seamounts occurs about 1170 n mi west of the East Pacific Rise crest, between 141°30'W and 136°00'W. The Austral chain trends in a southeasterly direction from Samoa (fig. 1). This trend coincides with the area of rough topography and bordering seamounts just described (fig. 3A).

4.2.2 East Pacific Rise

The crest of the East Pacific Rise is located at approximately 113°40'W (fig. 3B). The rift-like depression reported by Keller and Peter (1968) is not observed at this latitude.

Approximately 790 n mi down the east slope from the crest at 100°30'W (fig. 3B) a very striking change occurs in the bathymetry, the gravity and to a lesser extent the magnetics. The topography changes from relatively smooth to very rugged for about 520 n mi along the profile. This change is reflected in the free-air anomalies which average zero east of the crossing of the crest of the East Pacific Rise. This zone of rough topography may be related to the Easter Island fracture zone.

4.2.3 Peru-Chile Trench

The Peru-Chile Trench was crossed (fig. 3B) at approximately 78°50'W. Free-air minimum was -129 mgals, 7 n mi east of the bathymetric deep of 5804 m. The outer ridge of the trench as reflected in the topography and free-air anomalies extends 80 n mi seaward of the trench.

4.3 Callao to Seattle

The trackline made by the SURVEYOR from Callao to Seattle (fig. 1) was generally on a north-west heading. Changes in heading were made for best coverage of the Nasca Plate, Galapagos Rift, East Pacific Rise and several fracture zones on the Pacific Plate. These features are identified in figures 4A thru 4E.

4.3.1 Nasca Plate

The free-air anomaly over the trench (fig. 4A), while showing a pronounced "low", has a minimum value (-151 mgals) displaced landward about 7 n mi from the axis of the trench (6117 m). The topography on the outer ridge is noticeably more irregular than the preceding crossing and is also reflected in the free-air anomalies.

The profile extends for about 1130 n mi across the Nasca Plate to 95°W and shows generally smooth topography and free-air anomalies. Pronounced magnetic anomalies generally are absent along the profile.

4.3.2 Galapagos Rift

The Galapagos rift zone (fig. 4B) is about 213 n mi wide and is characterized by elevated, rough topography, free-air anomalies ranging from +58 to -32 mgals, and magnetic anomalies ranging from +295 to -354 gammas. These features distinctly set off this segment of the sea floor from that of the neighboring area.

The presence of a symmetric pattern of relatively large amplitude magnetic anomalies suggest that spreading of the sea floor occurs near the Galapagos rift. The zone of symmetry extends for only a short distance (approx. 90 n mi) on either side of the rift suggesting a youthful spreading ridge. The crustal rocks in this area appear to be only about 5 million years old (Herron and Heirtzler, 1967).

4.3.3 East Pacific Rise

At Latitude 5°00'N, Longitude 99°00'W the trackline runs almost due west for 878 n mi crossing the EPR (approximately 102°30'W) and extending out to 113°35'W. The rise (figure 4C) has relatively smooth topography on both flanks of the crest and free-air anomalies fluctuate around zero mgals with very little magnetic expression.

4.3.4 Pacific Plate

After crossing the EPR the trackline ran NW to 30°N then due north to 42°N crossing six of the major fracture zones on the Pacific Plate. These include the Clipperton, Clarion and Molokai Fracture Zones (fig. 4D) and the Murray, Pioneer and Mendocino Fracture Zones (fig. 4E).

Regional changes in depth across the fracture zones generally range from 300 to 350 m with the exception of the Pioneer and Mendocino which indicate larger displacements and in the opposite direction (south side down). There are many peaks and troughs within the fracture zones with some peaks reaching 1600 m above the regional depth and troughs 650 m below the regional depth. This rough topography is reflected in the free-air anomalies although they never get far above zero mgals. The great width of the Clipperton (180 n mi) at this longitude is possibly due to branching of the fracture zone.

5. ACKNOWLEDGEMENTS

I wish to express my sincere thanks to Capt. A. R. Benton, Jr. and to the officers and crew of the NOAA Ship SURVEYOR who made this study possible and to B. H. Erickson, J. M. Wageman and F. P. Naugler, who offered many helpful suggestions in their review of this report. I would also like to express my appreciation to R. R. Uhlhorn who assisted in the drafting and Mrs. Kim Hamasaki for typing the manuscript.

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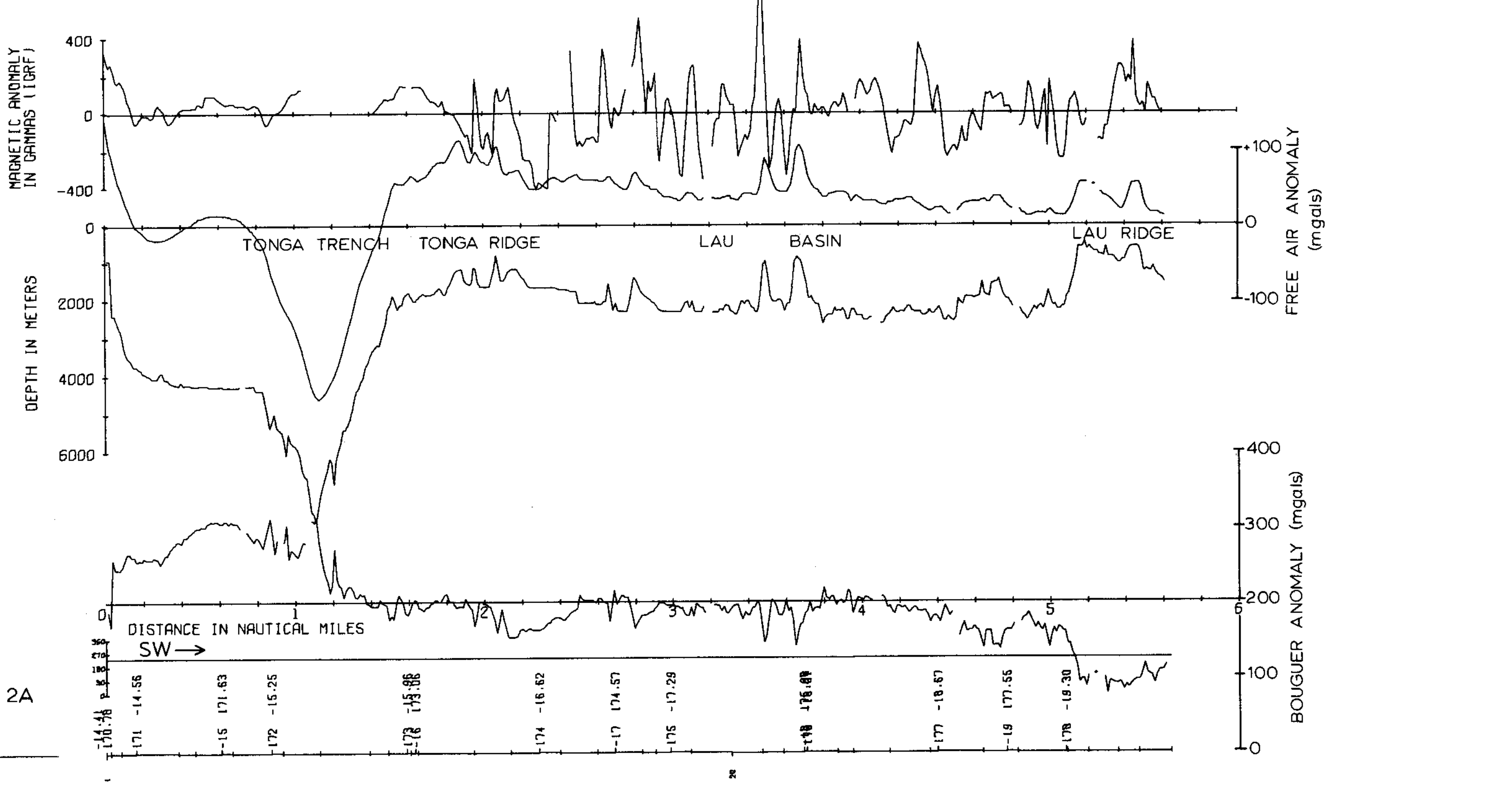

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Fig 2A

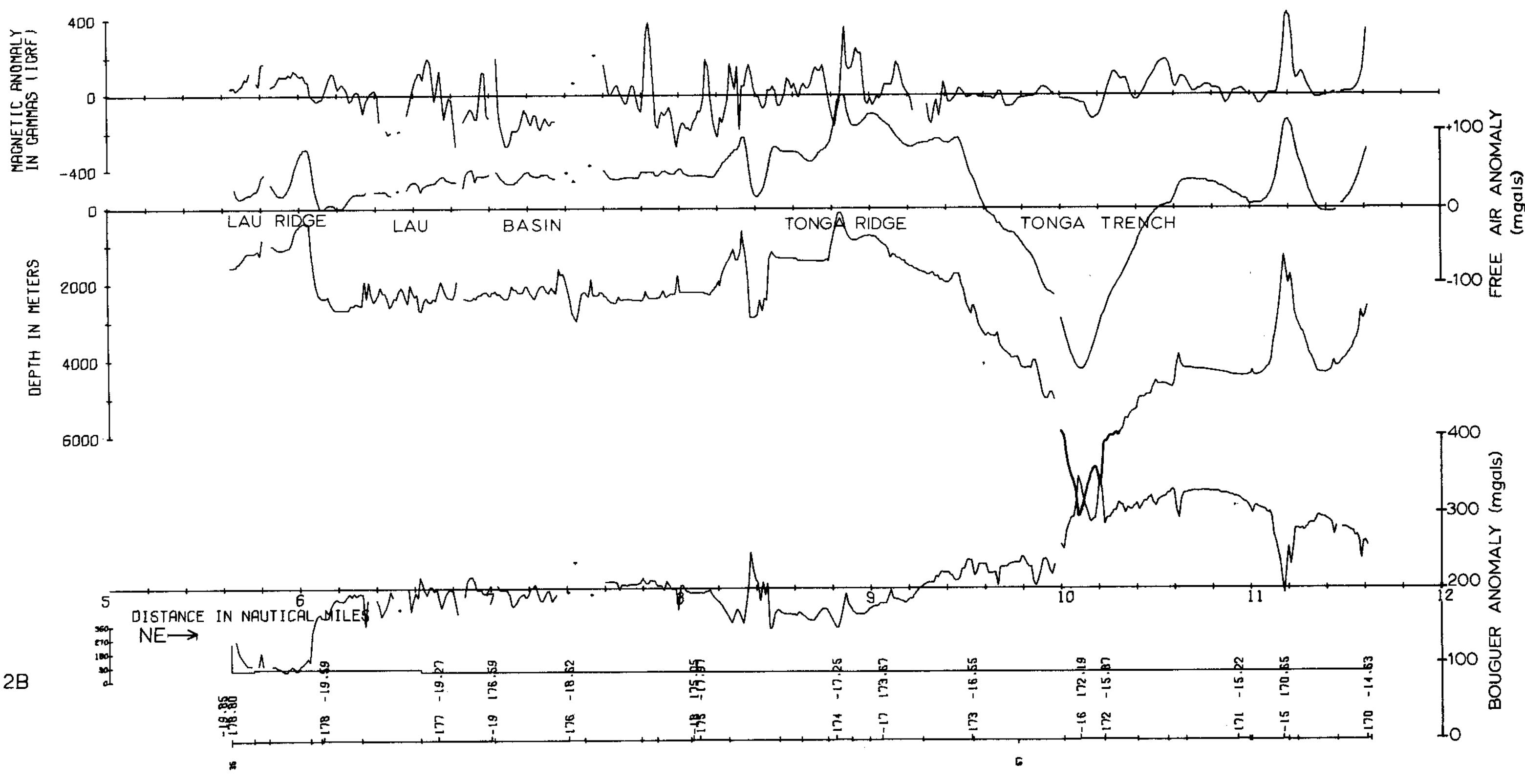

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Fig 2B

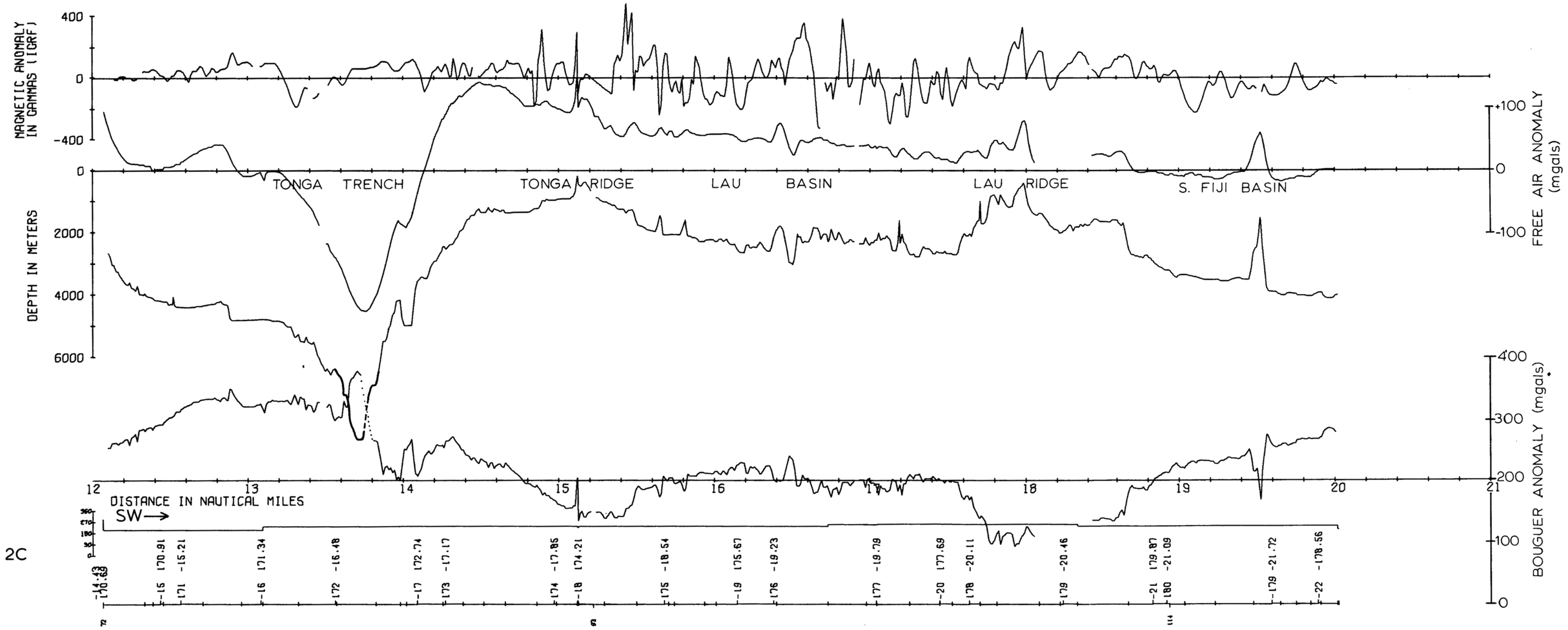

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Fig 2C

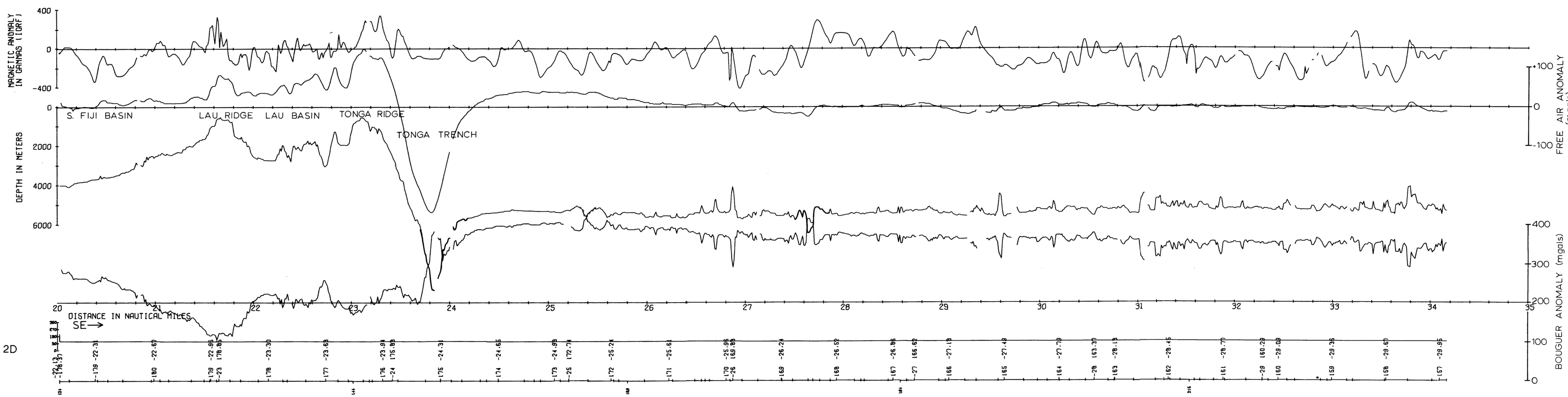

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Fig 2D

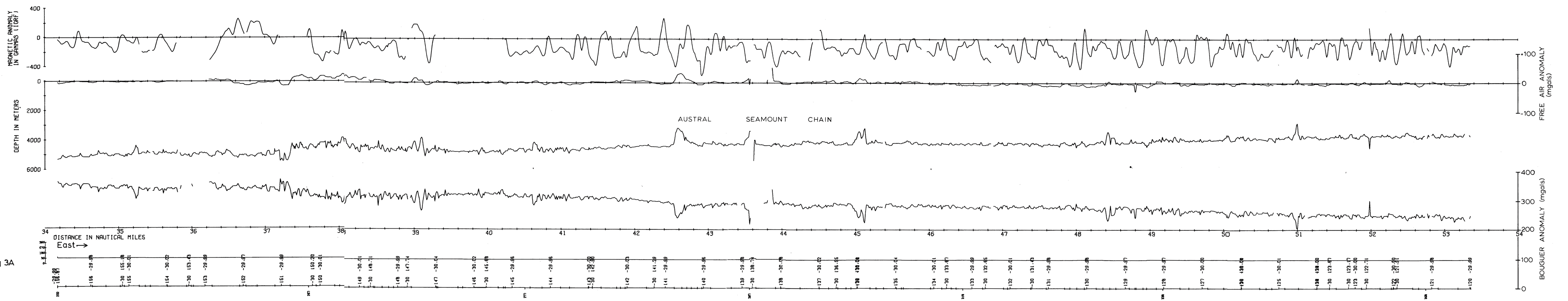

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Fig 3A

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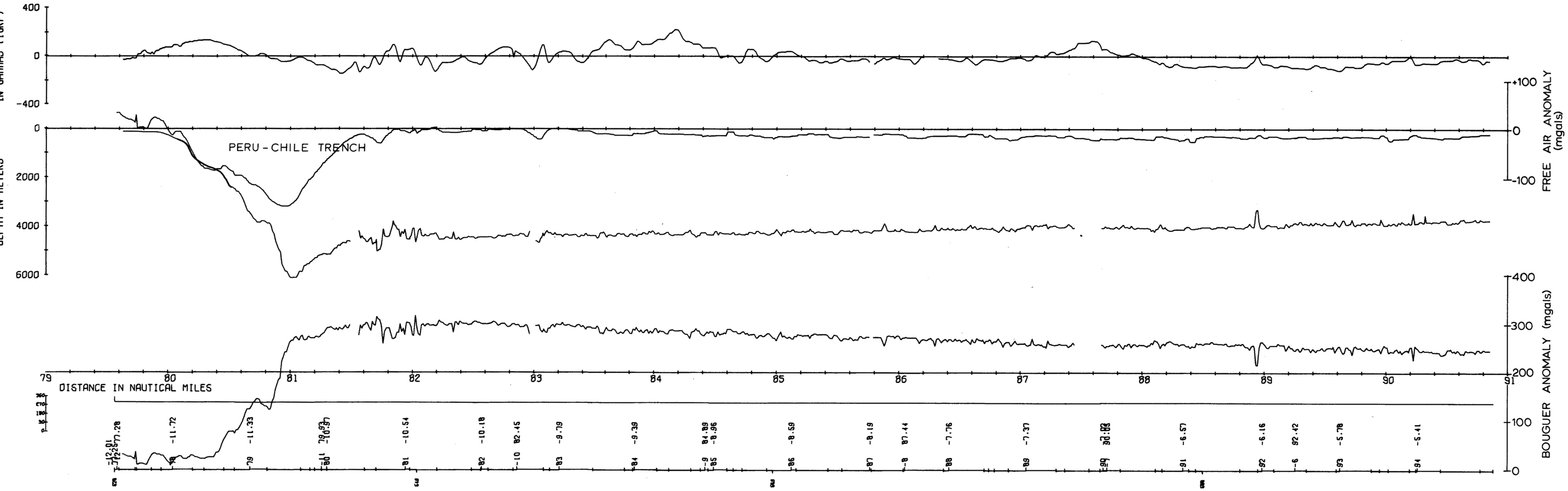
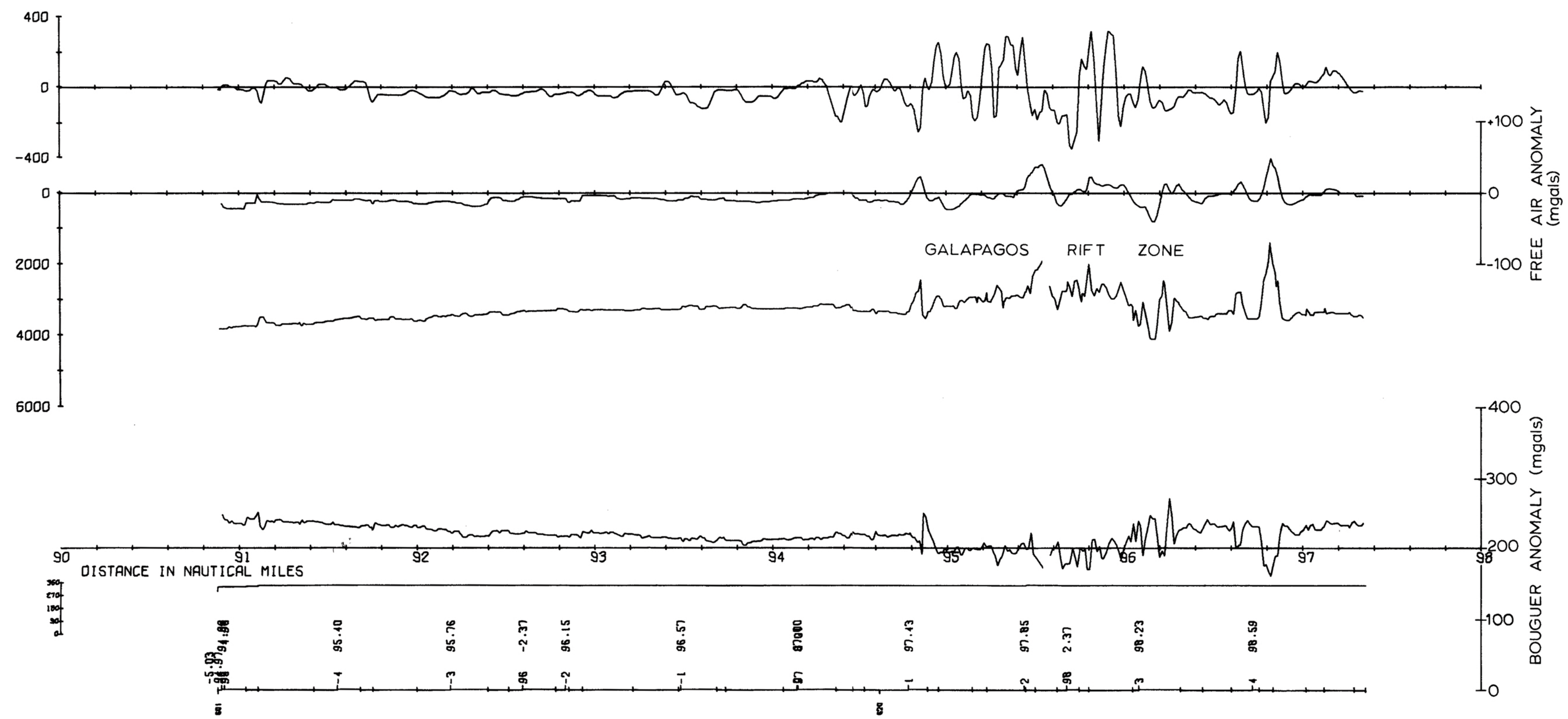
Fig 3B



MAGNETIC ANOMALY IN GAMMAS (IGRF)
400
0
-400
DEPTH IN METERS
0
2000
4000
6000
PERU-CHILE TRENCH
FREE AIR ANOMALY (mgals)
+100
0
-100
BOUGUER ANOMALY (mgals)
400
300
200
100
0
79
80
81
82
83
84
85
86
87
88
89
90
91
DISTANCE IN NAUTICAL MILES

4A



MAGNETIC ANOMALY IN GAMMAS (IGRF)
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0
-400
DEPTH IN METERS
0
2000
4000
6000
GALAPAGOS RIFT ZONE
FREE AIR ANOMALY (mgals)
+100
0
-100
BOUGUER ANOMALY (mgals)
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300
200
100
0
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92
93
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95
96
97
98
DISTANCE IN NAUTICAL MILES

4B

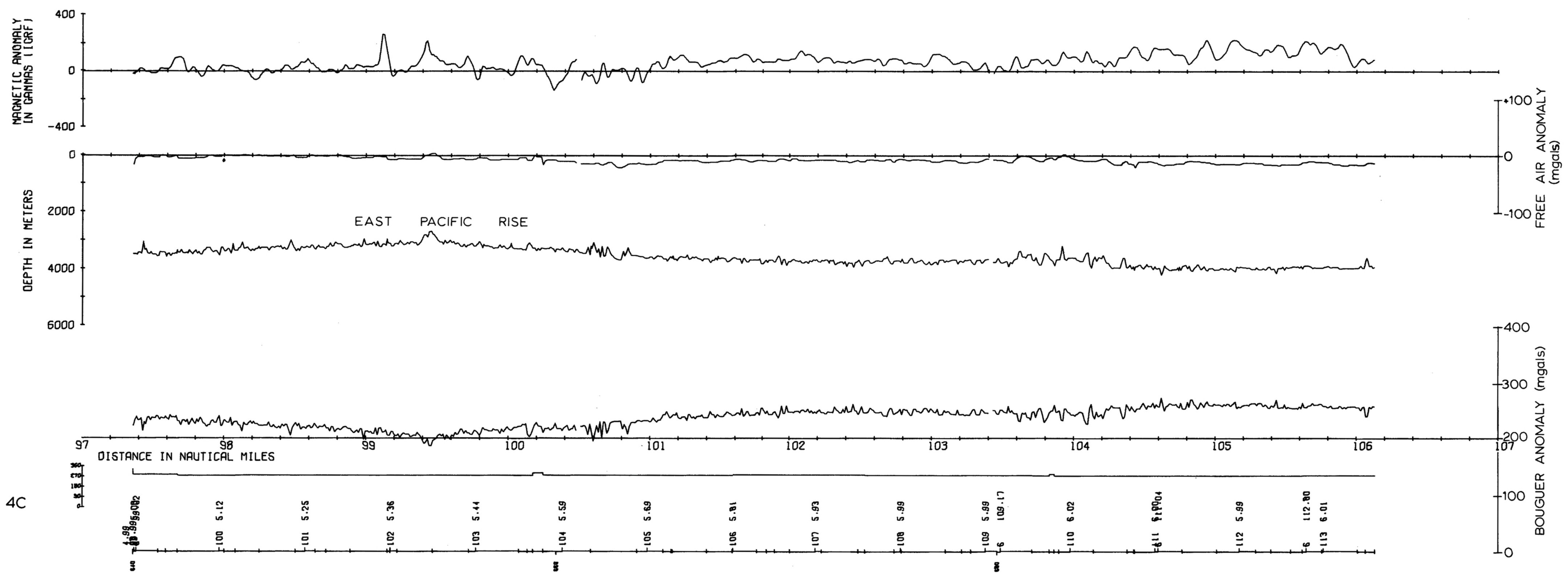

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Fig 4C

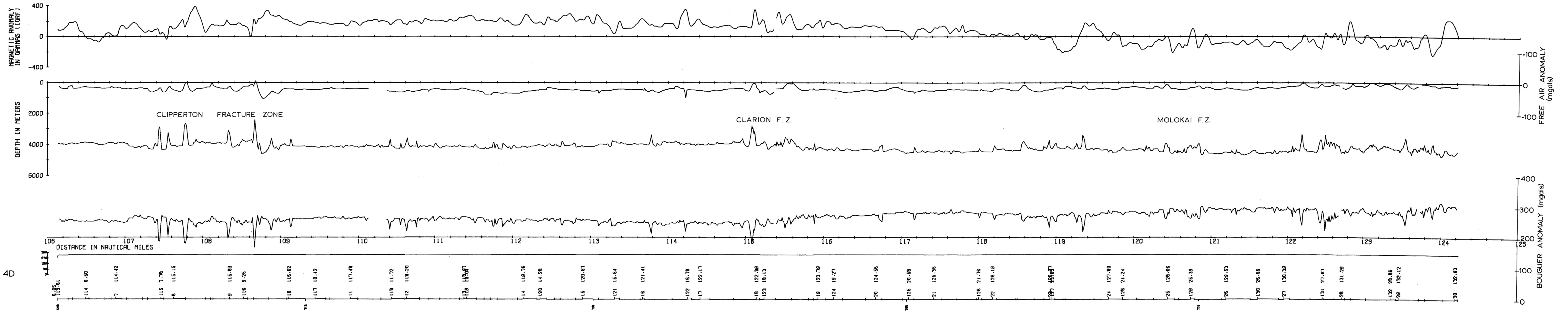

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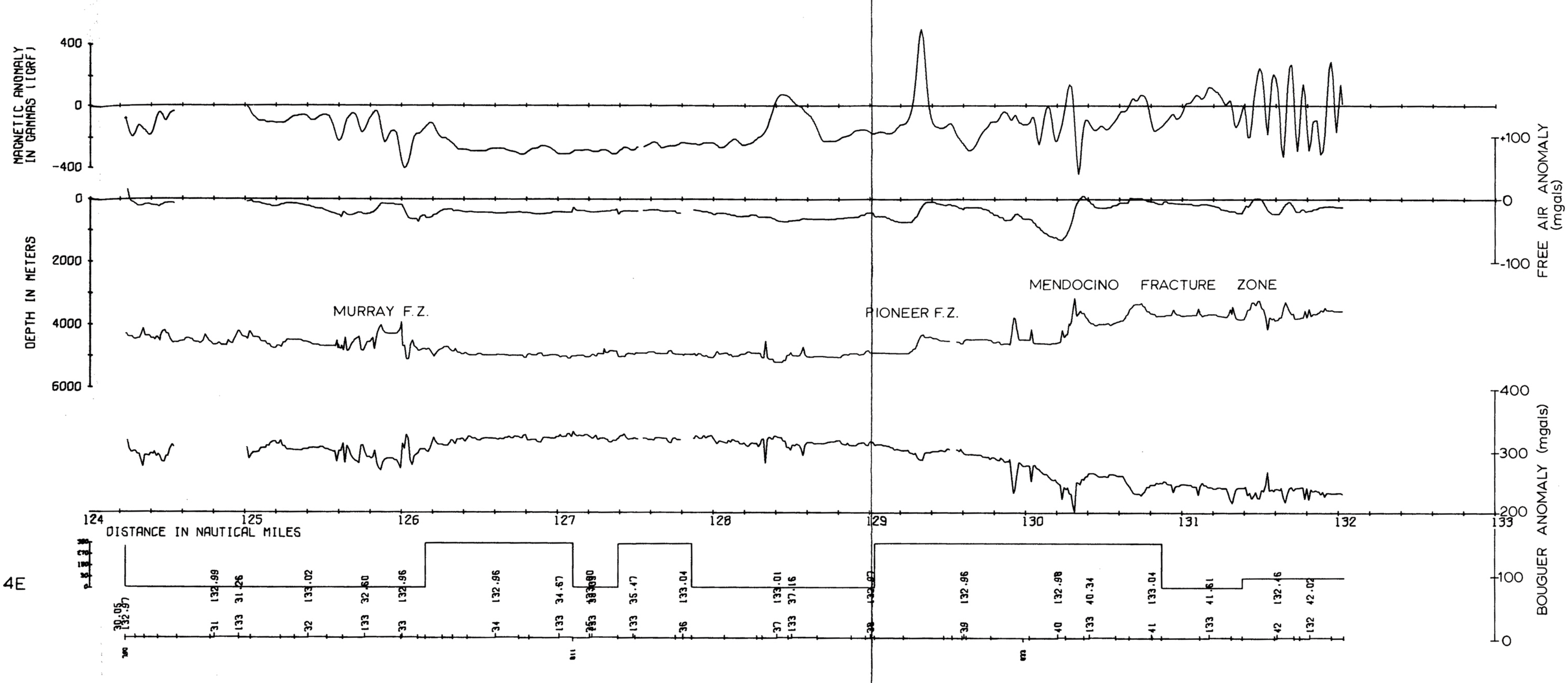
Fig 4D


MAGNETIC ANOMALY IN GAMMAS (IGRF)
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MENDOCINO FRACTURE ZONE
BOUGUER ANOMALY (mgals)
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124
125
126
127
128
129
130
131
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DISTANCE IN NAUTICAL MILES

7101
Fig 4E