CRUISE REPORT OF A SEA MAGNETOMETER SURVEY 
THROUGH THE ISLAND GROUPS OF NOMUKA 
AND HA’APAI, KINGDOM OF TONGA

by

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Tonga Project: TG.5

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[CR128 - Pflueger]
SUMMARY

During the period 10 September through 14 September 1989 a sea magnetometer survey was conducted through the Nomuka and Ha'apai island groups, Tonga. The objective of the survey was to determine whether these islands and their surrounding reefs are caps on uplifts of igneous material or chance outcrops of a thick sedimentary section. Necessary equipment and technical staff were supplied by CCOP/SOPAC and a vessel, crew and liaison man were supplied by the Department of Lands, Survey and Natural Resources of the Kingdom of Tonga.

About 490 kilometres of magnetic and bathymetric data were recorded in strip-chart analogue form. Navigation was by TRANSIT satellite, augmented by compass sights on islands. The track was finally fixed by adjusting the lines to give reasonable fits to published bathymetry.

Expertise to interpret the data is currently being sought.
ACKNOWLEDGEMENTS

I would like to acknowledge the very helpful assistance of Mr Robert Gatkiiff, Tonga Government Geologist, in organising the vessel, customs clearance of equipment and other administrative matters concerned with the survey; the invaluable shipboard liaison functions ably performed by Mr Mikaele ‘Apikotoa; and the help of the captain and crew of the Albacore.
BACKGROUND

Prior to this survey, no geophysical information had ever been acquired in the area because of navigational hazards. In general, islands in the area are the elevated portions of much more extensive reefs. Seismic, gravity and magnetometer data acquired by Shell Tonga Limited in 1970 was in general restricted to the channels between major shallow water platforms, with only a few incursions onto the platforms.

On most of the tracks covered by the current survey it is not possible to sail a deep draft vessel with a multi-channel seismic cable under tow.

OBJECTIVES

The islands of Tonumeia, Mango, Nomuka, Nomuka Iki, Fonoifua, Tanoa and probably Kelefeisia all have exposures of Miocene rocks (Mulder and Nieuwenhuizen 1971; Havard 1989). The object of the magnetometer survey was to determine whether these islands and their surrounding reefs are sedimentary caps on uplifts of igneous material or chance outcrops of a thick sedimentary section. If the islands have been uplifted then they could be either the tops of volcanos or the eroded remnants of uplifted fault blocks. Possibly, the islands do not have a uniform genesis.

IMPLEMENTATION

Appendix A summarises the timetable for the survey.

The vessel used for the survey was the RV Albacore, a 36-foot, fibreglass hull, shallow draft fishing vessel provided with crew by the Kingdom of Tonga. Personnel and equipment are given in Appendix B.

Total magnetic intensity was averaged over either a two second or four second duration on a continuous basis using a Proton Precession Magnetometer. The magnetometer, which was towed about fifteen meters behind the stern of the vessel, fed information to a strip recorder in the wheelhouse.
Simultaneously, a continuous bathymetric record was kept on a separate strip recorder.

Satellite fixes were recorded using the TRANSIT satellite network. The fix positions were manually logged, as were dead reckoning positions computed by the satellite recorder. From time to time when in the vicinity of islands, compass bearings were taken to islands using a hand held fluxgate compass.

The intent was to orient all traverses except cross lines in the direction of the local magnetic declination, (considered to be 14.5° East) but this was possible only roughly because the ships binnacle compass was not compensated for distortion of the magnetic field caused by the boat. Deviations from the ideal orientation were not severe, however, and should not affect the final results.

Lines were run as close as navigationally feasible past the islands of Nomuka, Tonumeia, Kelefasia, Mango and Mango Iki, Nukufaiau, Meama, Fonoifu, Lofanga, the Haafaa group, and Luahoko. Significant reefs were also surveyed. Additionally, polygonal traverses were run in the arcuate embayments on the western side of the Telekitonga-Telekivavau barrier reef group, and the western side of the barrier reef complex on which Limu Island is the only exposure at high tide.

Two navigation logs were kept - one by John Pflueger recording satfixes, compass shots to islands and other pertinent information (Appendix C); the other by Ed Saphore recording satfixes and dead reckoning positions.

**NAVIGATION**

A combination of factors made it difficult in the field to follow precisely the programmed track. Contributing factors were the inexperience in this type of survey of the crew (including SOPAC staff), the fact that neither the ships compass nor the satellite navigation compass were adjusted for the magnetic field associated with the ship, difficulties in estimating the speed of the vessel, and unknown variable currents.

Satellite fixes were obtained at intervals ranging from eleven minutes to over two hours between valid fixes. Between fixes the satellite navigation electronics continuously updated and displayed the instantaneous dead reckoning position using ships speed as manually input and bearing

[CR128 - Pflueger]
as read from a digital flux-gate compass. Dead reckoning positions were manually logged from the satellite receiver read-out at 15 minute intervals and at all course changes. When a satellite far was received which passed the built-in validity criteria imposed by the satellite electronics, the dead reckoning position was automatically updated. Although each satellite was tracked from horizon to horizon, corresponding to a receiving time of about 20 minutes, the ship's location computed by the satellite was referenced to the closest approach of the satellite to the antenna. Dead reckoning updates were therefore not performed until about 10 minutes after the finally computed fix time.

Ship's positions computed from satellite passes are only coarsely accurate, and not considered fine enough for the requirements of the survey. Other factors were taken into account in producing the "best estimate" track chart: compass shots on islands, bathymetry from Admiralty Charts, and the location of reefs, also from Admiralty Charts.

Production of the final track map proceeded in two stages:

1) All satfixes and dead reckoning positions were plotted to give a raw plot;

2) Using the raw plot as a framework, and taking into account notes in the logs made when passing islands or reefs, hand-held compass bearings to islands, and comparisons between recorded bathymetry and that published in the Admiralty Charts, a final "best estimate" track chart was devised.

Comparisons of the total magnetic intensity values and bathymetric values were then made at intersections between two lines at their "best estimate" intersection. Appendix D shows the results of these comparisons.

Most of the intersection ties look good. Those that do not are:

1) 1034 (9-11) vs 1332 (9-13). This intersection is in deep water far from any island. Control is poor and there were several turns between satfixes on both tracks.

2) 0936 and 0922 (9-12) vs 1722 and 1734 (9-13). The two lines have portions which are parallel. The magnetic signatures on the two lines have the same shape but that of the 9-13 track is 120 nT greater. Probably the reduced navigation is still not accurate.

[CR128 - Pflueger]
In the final analysis, I believe that navigation is accurate to 0.2 n.m. (390 meters) or better in the vicinity of islands but could deteriorate to as poor as 0.6 n.m (1170 meters) accuracy when the track was not close to islands and there was a long time between satfixes. Appendix E gives my estimate of navigational accuracy. These figures are considered "worst case" and track accuracy is probably better than this appendix would seem to indicate.

DATA OBTAINED

A list of acquired and derived data is given as Appendix F.
CONCLUSIONS

The data when interpreted should satisfy the objective of the survey, that is, to determine whether the islands of the Nomuka and Ha'apai island groups have shallow cores of igneous material.

RECOMMENDATIONS

Since the expertise to interpret geopotential data does not reside at SOPAC, it is recommended that the data be interpreted by a third-party expert in the analysis of magnetic data from a sedimentary environment.

Because of difficulties in navigation it is further recommended that future surveys of this type be controlled by the Global Positioning System (GPS) satellite network.
REFERENCES


APPENDIX A

TIMETABLE

4 Sept  SOPAC staff departed Suva, arrived Nuku’alofa. Equipment had already been shipped and cleared by Tonga.
5 Sept  Rigging up vessel RV Albacore.
6 Sept  Weather too strong to leave port.
7 Sept  Weather too strong to leave port.
8 Sept  Sailed Nuku’alofa to Nomuka Island. Although magnetometer data were collected the track was along the western outside passage and of no value to the survey. Navigation was inaccurate. Rough weather.
9 Sept  At anchor in Nomuka anchorage. Weather too strong to work.
10 Sept At anchor in Nomuka anchorage. Weather too strong to work.
11 Sept  Started survey. Surveyed 58 nautical miles.
12 Sept  Surveyed 79 nautical miles.
13 Sept  Surveyed 71 nautical miles.
14 Sept  Finished survey. Surveyed 57 nautical miles.
15 Sept  Derig Albacore and arrange shipment of SOPAC equipment to Suva.
16 Sept  SOPAC staff departed Nuku’alofa, arrived Suva.

Of the thirteen days allocated to the survey, four days were spent acquiring data, two days on travel, one day sailing to Nomuka, two days rigging and derigging the vessel and four days waiting for a break in the weather.
APPENDIX B

PERSONNEL AND EQUIPMENT

Personnel

Party Leader and Navigator          John Pflueger*
Instrument Technician and Navigator Edward Saphore*
Liaison man                          Mikaele 'Apikotoa**
Captain plus crew of five***

* SOPAC Technical Secretariat, Suva
** Department of Lands, Survey and Natural Resources, Kingdom of Tonga
*** Fisheries Department, Kingdom of Tonga

Equipment

Magnetometer                         Barringer M-123 analogue recorder
Satellite Navigation                 Magnavoux MX402 and flux gate digital compass
Fathometer                           Transceiver electronics: Raytheon PTR-106C-1
                                      Display unit: EPC 1650S
                                      Transducer: Raytheon TC-3.5/7 2000 watt output.

The fathometer transducer was run at 7 kHz. The fathometer stylus speed was adjusted to traverse
full scale in 0.267 seconds, corresponding to 200 meters of water depth at 1500 m/sec sound velocity.

[CR128 - Pflueger]
[CR128 - Pflueger]
# APPENDIX C

## JOHN PFLUEGER'S NAVIGATION LOG (Transcribed)

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon 4 Sep</td>
<td>Left Suva. Arrive Nuku’alofa PM</td>
</tr>
<tr>
<td>Tue 5 Sep</td>
<td>Rigging up fishing vessel Albacore (about 36'). Use Mag. Declination 14.5'E.</td>
</tr>
<tr>
<td>Wed 6 Sep</td>
<td>Intended to leave late morning. By time crew and passengers aboard too late to make Nomuka before nightfall. Anyway, weather deteriorated during the day.</td>
</tr>
<tr>
<td>Thu 7 Sep</td>
<td>Assembled 6:00 a.m. at boat. Weather bad, postponed departure 24 hours.</td>
</tr>
<tr>
<td>Fri 8 Sep</td>
<td>Assembled 6:00 a.m. Weather better. Decided to leave Nuku’alofa and left 8:15. Rough seas, 2 meter waves. Because of mis-communication with Captain went directly to Nomuka along west side of all islands. Anyway, it was a good shakedown run. Magnetometer about 15 meters behind vessel. Satnav wouldn't give update results initially but finally was made to work. Only one good satfix was recorded during the run. Arrived Nomuka about 1530. Discharged passengers (about 8 people, one pig). Ed worked on equipment; John worked up next day’s run. Ed and John slept on board. Good satfix received @ 1758 at anchor in Nomuka anchorage.</td>
</tr>
<tr>
<td>Sat 9 Sep</td>
<td>7:00 a.m. weather too poor to safely work. Squals. Rode the hook all day.</td>
</tr>
<tr>
<td>Sun 10 Sep</td>
<td>Weather still to bad to work. At anchor at Nomuka.</td>
</tr>
<tr>
<td>Mon 11 Sep</td>
<td>Underway at Nomuka 0705.</td>
</tr>
<tr>
<td>0726</td>
<td>Changed course due south</td>
</tr>
<tr>
<td>0752</td>
<td>20°20.38'S/174°45.97'E (bad fix changed course to North - 20'</td>
</tr>
<tr>
<td>0829</td>
<td>Between Nomuka Iki and Mango Iki Way points 1, 2 ignored because of navigation problems. Nomuka Iki 1 mile port Mango Iki 2 miles Stb.</td>
</tr>
<tr>
<td>0853</td>
<td>North point Nomuka port abeam 0.6 miles</td>
</tr>
<tr>
<td>0857</td>
<td>Sat Fix 20°14.07'S 174°44.16'W Speed advance 6.6 knots. About 0.9 miles East of Program track. Ignore waypoint 3 and continue bearing due north.</td>
</tr>
<tr>
<td>0934</td>
<td>Satfix 20°08.54'S 174°44.95'W. Changed course to 184'.</td>
</tr>
<tr>
<td>0949</td>
<td>Changed course 90'. Note: Throughout survey full scale on depth recorder is .267 sec, corresponding to 200 m at 1500 m/sec</td>
</tr>
</tbody>
</table>

[CR128 - Pflueger]
Sat FIX NG RI (Sat not in angle range). Change course 202' to passage between Mango & Mango Iki.

Dead Reckoning @ 8 min. past turn 20'11.8S 174'40.6 W went between (?)

Nukufaiiau Abeam port 0.3 miles

Midway between Mango and Mango Iki. No course change @ WP6.

Breaking waves port 0.5 miles

Tonumeia Abeam port 1.5 miles

Course change 182'. Many course changes.

Kelefesia abeam stb 1.0 miles through "Blind Rollers".

Mango abeam port. 1.5 miles changed cse 014'. Changed slightly to port to go through passage west of Fonoifua.

Passage between Lua'anga and Fonoifua.

Brought in mag for the day 58 miles

Tue 12 Sep

Last Sat Fix 0605 20'12.71S 174'37.19W (very calm)

W end Fonoifua 175'/Nukutula 218' E. end Mango 196'.

Underway to WP 121/2

Turned north - probably we are 1/2 mile East of program line.

Crossing 'blind rollers'.

Immediately west of Alexander Reef course changed to 020' Mag. Going through Ava Bubu passage.

Course change to clear rocks 035' Mag.

Rocks port beam .05 miles

Change course due north.

Sat fix 20'04.24'S 174'33.48W

Change course 3.20° Mag
0934  West tip Vanukuhhiifu Island Bearing 024°.
0945  Change course 00° Mag.
1000  Very calm, no wind, no chop, no swell.
1048  N. end Luangahu Island 075°/E. end Hakauata 319°/W. end Lofanga 292°
       All mag bearings.
1051  Cse change 034° Mag.
1010  Sat fix 19° 57.61'S  174°32.84'W
1118  Shoal Abeam Port 0.1 miles (Hakau Faha) No Shoal to starboard (How we got here I don't know).
1124  Chang cs. North Mag.
1135  Luahoko Island dead ahead.
1137  Cse change 00° Mag.
1146  Change cse to steer to east tip Haano Island 030° Mag. Ships compass reading 10° to much at this bring.
1154  Sat 19°46.41'S  174°23.20'W
1200  Hakau Fakaosi Toume 1 mile to port.
1207  S. Tip Lifuka 183’ M No. Tip Lifuka 112” M
1205  Sat. 19' 45.43'S  174°21.40'W
1222  Bng to South tip Foa Island 194° Mag Course change 350°
       North End Haano Island to stb 1.0 mile.
1301  North end Haano Is. Brng 97° Mag. 1 mile +_  
1308  Sat 19' 36.82'S  174°19.40'W (Ed's Log 174° 14.40'W)
1320  Course change 270°
1322  North end Ofalanga dead ahead, Ship compass 270° hand compass 260°
1332  Course change to 210° to west side at Luahoko Island.
1326  Sat 19° 35.70'S  174°20.42'W.
1352  Same course 210°

[CR128 - Pflueger]
1353  Course 220’ To go around reef W. side Luahoka.
1404  Course change 194’ (but Captain didn’t do it).
1410  Luahoka Island abeam to port 0.4 miles
1437  Course change to 215’ to Hakauata Island. Prob course before change 220’
1508  Nukubule Island 253’ Mag/East End Lofanga 215’/Hakauata Island 198
1516  Change course 200’ Mag
1525  W. end Lofanga 225’/Nukubule 300’ Hakauata - 169’ Mag
1532  Still 260’
1529  Sat 19’ 48.10S 174’ 31.40W
1542  Middle of Lofanga Port Beam 0.8 miles
1550  Course change 180’. Out of Ava Mata Nukubule passage heading south
1621  E. tip Oua 191’/Ono Iki 215’. W. tip Vanukuhihifu Is. 124’. Lekaleka dead ahead (ships compass in error?)
1627  Course change 190’ to meet reef between Oua and Lekaleka
1619  Sat 19’ 52.62S (Ed’s log says 52.69) 174’ 35.24W
1530  Clouded over. Sunshine till then.
1645  Sat 19’56.33’S  174’35.83W
1717  Sat 20’00.63 174’37.48W
1728  Shutdown for day. Reached reef midway between Oua and Lekaleka island. Days traverse 79 miles Cumul = 137 ml. EPC went out before reaching end of traverse. Bearing 185’ mag between last two sat fixes. Ships course was 190’ mag. Dropped anchor at Haafeva Island 1815.

Wed 13 Sep

Up anchor at 0730, went out of Anchorage. Trouble with Maggy and generator (water in gas?).
0917  Maggy in, underway, course 320’
0928 Course change 295°
0934 Fono Mukka Is., abeam port 0.2 miles
0935 Course change 00° (Due north) (hand compass says 07°). Nav 19°55.12′S 174°42.46′W.
0953 Note all previous hand compass readings taken from wheelhouse and are suspect. Bng to Haafevi I. is 198′ from wheelhouse/184′ from fantail. (Ship cse north)
0950 Sat 19°53.64′S 174°41.62′W
1011 Course change 255°
1019 Fetohaa Is. abeam Stbd about 2.5 miles

East point good handcompass brng F325° From here all hand compass bearings will be from fantail w/prefix F. No other readings will have this prefix.
1025 Note, before course change at 1011 I went past programmed waypoint to see if magnetic anomaly would turn over but finally decided it wouldn’t so turned to new course.
1028 Day 50 % clouds; no wind, no chop, very low swell
1036 Wpt Haafeva F155′/N. pt Pudupudua F185′/N. pt Niniva F034′
1039 Cse change 154′ sat coming in
1046 Satfix 19°52.84′S 174°44.42′W
1105 Cse adjustment to 1650 to go between Fetoa and Teauha
1112 2 photos Matugu Is. then Fetoa Is.
1116 S. end Haafeva Is and North end Ono Iki in line
1118 Between Matugu and Haafeva
1120 Course is 162′ (not steady)
1125 Midway between Teauha Is. and Fetoa Is.
1126 Photo Teauha Is.
1126 Course 160′
1138 Fona Is. to stbd. 0.6 miles abeam brng F255°

[CR128 - Pflueger]
1142  N end Luanamu Is.  S end Oua I in line, Tongua Is. abeam stbd 2 miles
1143 N end Luanamu Is. and N. end Oua in line
1146  N end Luanamu Is. 0.7 miles port brng F72°
1138  Satfix 20'00.10'S  174°43.44'W
1158  N end Nukulai I. stb 0.4 miles F232° brng
1159  Course change 132°
1160  Course change 155°
1163  Shoal water right off stb, right off port 0.05 miles
1165  Course 150° to passage
1166  N end Fonuaika I. off port brn F98° 0.6 miles
1167  Course change 1850
1169  No returns from depth sounder
1212  Sat fix 20' 08.57S (Ed's log says 08.52) 174° 43.88'W
1215  Make turn 1.42 miles from 1242
1225  Course change 90°
1314  E. end Nukutula I (?) Brng F154°  2.0 miles est.
1320  Cse change 00° Due north
1400  Still cse 00°
1423  Reef ahead 0.1 miles
1428  Turn to 112° approached reef midway between Oua Island and Lekaleka Is.
1441  Ship compass 112° Hand compass F 120°
1454  Sat fix 20° 07.32 174° 36.16 (Farther South than we want to be).
1507  Cse change 350° (est direction to Bubu passage)
1514  Cse change 330° (better course to Bubu ref. Captain)

[CR128 - Pflueger]
E end Lekaleka dead ahead 1.5 miles +_
Cse change 5' to go through Bubu
Passed over pinnacle
Sat fix 20°04.54'S 174°32.45'W
Cse change 34' to get to WP 36 based on last satfix
Sat fix 20°03.29'S 174°28.86'W
Course change 30°
N end Limu Is F55'/W end Vanukuhififu Is F335'
Sat fix 20°01.51'S 174°28.97'W
Cse change 180°
Cse change 190' to avoid reefs
Cse change 180°
S end Lekaleka F240' (shoals to port)
Shutdown/Traverse 71 miles cumul. 208 miles
Sat fix 20°05.47'S 174°33.55'W (8' Elev) @ anchor (speed in sat memory = 0.0 knots) so sat fix should be good. Taken at anchor. Anchor was dropped at about 1750 at end of days traverse
Sat fix at anchor same place (65' Elev) 20°05.38S 174°33.63'W
Thu 14 Sep 0643 Sat fix at anchor. (7') 20°05.16'S 174°33.87'W
Up anchor to go through Bubu passage. Captain doesn't want to risk the narrow passage on east end of Alexander Reef. Not recording data. Avg of three sat fixes at anchor last night is:
20°05.34'S 174°33.68'W
Maggy in water. Going along south side Alexander Reef. Cse 090°
Cse change to 180' to east of Fonoifua Is.
N. tip Fonoifua +_ Brng F257' 1.0 miles

[CR128 - Pflueger]
0915 Cse still 180°

0930 Adjust course to 190° to pass breakers

0923 Sat fix 20'17.89S 174'36.99W

0942 S. point Mango Is. F255°
Breakers abeam Sb. 0.4 miles
E. point Fonoifua Is. F348°

0947 Cse 185°

0936 Sat fix 20'19.51S 174'37.44W slight chop, swell

0953 Cse change 085° to S. tip Telekitonga Is.

1000 S. tip Mango F281/N. tip Fetokopunga F032°
E. tip Fonoifua F344°

1020 Approaching S. point Telekitonga Island at about 93' ahead

1022 Cse change to 019° to south point Telekivavau Is.

1025 S.pt Telekitonga F104°/S. point Lalona Is. F32°

1020 Sat fix 20'23.69S 174'33.55W

1043 Cse change 324° (No island to steer toward). Make next course when N. side Fonoifua is at bearing F255°

1051 S. point Telikivavau F042°/S. point Lalona F116°
Compute ship speed from 942 to 1025 from compass positions. dist. 5.3 miles time difference 43 min.
5.3 (60)/43 = 7.4 knots

1112 Offtrack maybe 1 mile too far west so changed course to 180°

1111 Sat fix 20'17.59S 174'34.05W.
Changed course while fix coming in

1126 Cse change to Mango Iki 270°

1128 N. end Fonoifua I. F308°/N end Fetokopunga F053°
Bearing to Mango Iki. F253°
Make next cse change when Nukufaiau bearing F320°

1147 Bearing Tanoa F346°/Bearing Mango Iki F253°
E. end Fonoifua F001°/Nukufaiau F281°

[CR128 - Pflueger]
1155 Tanoa F025'/Mango I F254'  
Nukufaiu F292'  

1205 Cse change to 140'. Nukutai au Brng F320'/Mango I F253'  

1158 Sat fix 20°19'.21S 174°40.11W  

1215 Compute speed from compass 1205 and 1128 Distance = 5.7 miles/time diff. = 37 min/(5.7) (60)/37 = 9.2 knots  

1223 High thin clouds; slight chop, 0.5 meter swell  

1228 N. point Tonumeia F211'/E end Mango F303'/E point Fonoifu'a I. F014'  

1242 Cse change 200' to E. end Keleifesia or maybe 1 mile east of E. end  

1247 N. pt. Tonumeia F226'/Mango Iki F310'  
E. pt. Fonoifu'a F003'  

1303 N. pt. Tonumeia F224'/Mango Iki F326'/  
E. pt. Keleifesia F119'  

1306 Course still 200'  

1309 Course change 175' to avoid reef  

1313 W. pt Keleifesia F208'/N. pt Tonumeia F261'  

1322 Course 180'  

1330 N. end Keleifesia F265'/NE side Tonumeia F299'  

1345 Through blind rollers. Change course to 180'  

1345 Probe aboard  

1349 Probe in water  

1349 E. pt Keleifesia F314'/No Name Is F333' (Error. One of these compass readings is N.G. Maybe readings reversed?)  

No Name Island is 0.5 miles South of Nuku Island  

From here going 180' ships compass because there are no islands to fix from  

1401 Still on 180'  

1410 Sat fix 20°35.52S 174°44.63W fix good 40' elevation  

[CR128 - Pflueger]
Fri 15 Sep  De-rig  Albacore

Sat 16 Sep  Left Nuku'alofa 1105 arrived Suva 1400.

1420    Shutdown for day.  57 miles cumulative = 265 miles
1910    Sat  fix at anchor 20°38.69S  174°51.15W
2113    Sat  fix at anchor 20°39.46S  174°51.25W
         Maybe fix at 1910 not at anchor?
### APPENDIX D

**LIST OF LINE INTERSECTIONS**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Mag Value (nT)</th>
<th>Water Depth (meters)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-11</td>
<td>1018</td>
<td>43295</td>
<td>560</td>
<td>In deep channel</td>
</tr>
<tr>
<td>9-13</td>
<td>1249</td>
<td>43215</td>
<td>No value</td>
<td></td>
</tr>
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<tr>
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<td>43100 est.</td>
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Note: Intersections are from "best estimate" reduced navigation charts.

[CR128 - Pflueger]
**APPENDIX E**

**NAVIGATION ACCURACY ESTIMATE**

The following estimates are based on how well all navigational data could be reconciled in deriving the "best estimate" navigation charts. The final reduced track map is referenced to the positions of islands and reefs, not to absolute geographical co-ordinates. Estimated accuracy ranges are:

- Accuracy better than 0.6 nautical miles : Poor
- Accuracy better than 0.4 nautical miles : Fair
- Accuracy better than 0.2 nautical miles : Good

<table>
<thead>
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<th>Time Range</th>
<th>Accuracy</th>
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<tbody>
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<td>0910-1100</td>
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<td>110-1120</td>
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<td></td>
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<td></td>
<td>1320-1415</td>
<td>Poor</td>
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<tr>
<td></td>
<td>1415-1420</td>
<td>Fair</td>
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<td></td>
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<td>1620-1651</td>
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<td>1620-1645</td>
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<td></td>
<td>1135-1215</td>
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[CR128 - Pflueger]
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## APPENDIX F

## LIST OF DATA

**Field Data:**

Three magnetometer strip chart rolls as follows:

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<th>Roll #</th>
<th>8 Sept</th>
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<th>0742-1406</th>
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<td>Roll # 2</td>
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<td>Roll # 3</td>
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<td>1531-1740</td>
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<td>0755-1420</td>
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Five bathymetry strip chart rolls as follows:

<table>
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<th>8 Sept</th>
<th>1020-1459</th>
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<tbody>
<tr>
<td>Roll # 1</td>
<td>11 Sept</td>
<td>0755-1651</td>
</tr>
<tr>
<td>Roll # 2</td>
<td>12 Sept</td>
<td>0754-1651</td>
</tr>
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<td>Roll # 3</td>
<td>13 Sept</td>
<td>0938-1741</td>
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<td>Roll # 4</td>
<td>14 Sept</td>
<td>0755-0951</td>
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<td>Roll # 5</td>
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One exercise book containing Ed Saphore's navigation log.
One exercise book continuing John Pflueger's navigation log.

**Derived data:**

One set of three Admiralty Charts used as work copies for reducing navigation data as follows:

<table>
<thead>
<tr>
<th>No.</th>
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<tbody>
<tr>
<td>774</td>
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</tr>
<tr>
<td>3100</td>
<td>Ha'apai Group, Southern Portion</td>
</tr>
<tr>
<td>3099</td>
<td>Ha'apai Group, Northern Portion</td>
</tr>
</tbody>
</table>

Same three Admiralty Charts with final “best estimate” survey track.
A few years ago I was going through the process of splitting up with my first serious girlfriend. She went away to Greece for the summer and when she came back she'd had a holiday romance with some Belgian guy. As if that wasn't enough, it seemed that the guy in question was going to show up in London some time over the next few weeks. Ha'apai is the name given to a group of islands, islets, reefs and shoals that is located in the central part of the Kingdom of Tonga, with the Tongatapu group to the south and the Vava'u group to the north. Seventeen of the Ha'apai islands are populated. All the larger islands are in the east, the Lifuka group. The two larger islands are Lifuka and Foa which constitute 4249 people. After the two larger islands are Nukunamo and Ha'ano which have four villages with a population of 728. To the south of these islands is E[Uilaha, which contains two villages, ancient burial ground... Towards the far south are the islands of the Nomuka group, locally known as 'Otu Mu'omu'a. Wikipedia article: http://en.wikipedia.org/wiki/Haapai. Nearby cities Air transfer to Ha'Apai island. Transfer to the port (20 mins). Looking for whale sightings and swimming with them on our way to the island our hotel is located on. Check in to the hotel. Free time after 4pm. Jeep transfer through the jungle to the starting point of the trek (1 hour). Trekking to the campsite through the jungle observing palms, lianas and giant ferns. Lunch at the campsite. The Ha'apai group is comprised of 62 islands. The islands include barrier reefs, shallow lagoons, coral shoals, and even active volcanoes, but most are small low-lying coral atolls. The size of the smallest island is less than 1 hectare, and even the largest is less than 18 square miles. The total land mass of the Ha'apai group is less than 43 square miles, and those islands are spread over less than 4,000 square miles of ocean. There are east-west passes between islands which somewhat separate islands in to groups. The larger Nomuka Island is inhabited, and somewhat like Ha'afevaAlso on this near shore is the remains of an old prison and the wreck of the Takuo. The Takuo was a fishing vessel that foundered on Hakaufisi reef during a storm, and some of the men on board were lost. Ha'apai group where he discovered and charted many islands. One of Cook's greatest friends was Finau, the Chief of Vava'u. brief stop at the island of Late, reached the main tsland of Vava'u on. 5 May 1781 and anchored near the present village of Longamapu in the. bay to which he gave the name "Port of Refuge" (the name now applies to. the whole of Vava'u's harbor). potential value of Vava'u and upon his return to Spain he reported on. it and its people in such glowing terms that the King ordered Don. Alejandro Malaspina to include Vava'u on the great voyage of discovery.