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 Gatkiff, 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 Kelefesia 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 flux-gate 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, Kelepesia, Mango and Mango Iki, Nukufaiau, Meama, Fonoifua, Lofanga, the Haafae 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.
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 fix 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.
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 satellite fixes. 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: Magnavox 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]
APPENDIX C

JOHN PFLUEGER'S NAVIGATION LOG (Transcribed)

Mon 4 Sep
Left Suva. Arrive Nuku'alofa PM

Tue 5 Sep
Rigging up fishing vessel Albacore (about 36'). Use Mag. Declination 14.5'E.

Wed 6 Sep
Intended to leave late morning. By time crew and passengers aboard too late
to make Nomuka before nightfall. Anyway, weather deteriorated during the
day.

Thu 7 Sep
Assembled 6.00 a.m. at boat. Weather bad, postponed departure 24 hours.

Fri 8 Sep
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. 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.

Sat 9 Sep
7.00 a.m. weather too poor to safely work. Squals. Rode the hook all day.

Sun 10 Sep
Weather still too bad to work. At anchor at Nomuka.

Mon 11 Sep
Underway at Nomuka 0705.

0726 Changed course due south

0752 20°20.38S/174°45.97W (bad fix changed course to North - 20'

0829 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.

0853 North point Nomuka port abeam 0.6 miles

0857 Sat Fix 20°14.07S 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.

0934 Satfix 20°08.54S 174°44.95W. Changed course to 184'.

0949 Changed course 90°.
Note: Throughout survey full scale on depth recorder is .267
sec, corresponding to 200 m at 1500 m/sec
1044 Sat FIX NG RI (Sat not in angle range). Change course 202' to passage between Mango & Mango Iki.

1100 Dead Reckoning @ 8 min. past turn 20'11.8S 174'40.6W went between (?)

1137 Nukufaiau Abeam port 0.3 miles

1155 Midway between Mango and Mango Iki. No course change @ WP6.

1212 Breaking waves port 0.5 miles

1255 Tonumeia Abeam port 1.5 miles

1314 Course change 182'. Many course changes.

1427 Kelefesia abeam stb 1.0 miles through "Blind Rollers".

1539 Mango abeam port. 1.5 miles changed cse 014'. Changed slightly to port to go through passage west of Fonoifua.

1612 Passage between Lua'anga and Fonoifua.

1652 Brought in mag for the day 58 miles

Tue 12 Sep

0705 Last Sat Fix 0605 20'12.71S 174'37.19W (very calm)

0710 W end Fonoifua 175'/Nukutula 218' E. end Mango 196'.

0751 Underway to WP 121/2

0804 Turned north - probably we are 1/2 mile East of program line.

0835 Crossing 'blind rollers'.

0903 Immediately west of Alexander Reef course changed to 020' Mag. Going through Ava Bubu passage.

0919 Course change to clear rocks 035' Mag.

0925 Rocks port beam .05 miles

0926 Change course due north.

0918 Sat fix 20'04.24'S 174'33.48W

0932 Change course 3.20" Mag
0934 West tip VanukuhifHFU 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 Brng 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]
Course 220' To go around reef W. side Luahoka.

Course change 194' (but Captain didn't do it).

Luahoka Island abeam to port 0.4 miles

Course change to 215' to Hakauata Island. Prob course before change 220'

Nukubule Island 253' Mag/East End Lofanga 215'/Hakauata Island 198

Change course 200 Mag

W. end Lofanga 225'/Nukubule 300' Hakauata - 169' Mag

Still 260'

Sat 19' 48.10S 174' 31.40W

Middle of Lofanga Port Beam 0.8 miles

Course change l80. Out of Ava Mata Nukubule passage heading south

E. tip Oua 191'/Ono Iki 215' W. tip Vanukuhihifu Is. 124'. Lekaleka dead ahead (ships compass in error?)

Course change 190' to meet reef between Oua and Lekaleka

Sat 19' 52.62S (Ed's log says 52.69) 174' 35.24W

Clouded over. Sunshine till then.

Sat 19'56.33'S 174'35.83W

Sat 20'00.63 174'37.48W

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'

[CR128 - Pflueger]
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. Brng to Haafevi Is. 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 hand compass brng F325° From here all hand compass bearings will be from fantail w/prefix F. No other readings will have this prefix.

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.

Day 50 % clouds; no wind, no chop, very low swell

1028 Wpt Haafeva F155' N. pt Pudupudua F185' N. pt Niniva F034'
1036 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 Teauba
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 Teauba Is. and Fetoa Is.
1126 Photo Teauba Is.
1126 Course 160°
1138 Fona Is. to stbd. 0.6 miles abeam brng F255°
N end Luanamu Is. S end Oua I in line, Tongua Is. abeam stbd 2 miles
N end Luanamu Is. and N. end Oua in line
N end Luanamu Is. 0.7 miles port brng F72'
Sat fix 20'00.10'S 174'43.44'W
N end Nukulai I. stb 0.4 miles F232' brng
Course change 132'
Course change 155'
Shoal water right off stb, right off port 0.05 miles
Course 150' to passage
N end Fonuaila I. off port brn F98' 0.6 miles
Course change 1850
No returns from depth sounder
Sat fix 20' 08.57S (Ed's log says 08.52) 174' 43.88'W
Make turn 1.42 miles from 1242
Course change 90'
E. end Nukutula I (?) Brng F154' 2.0 miles est.
Cse change 00' Due north
Still cse 00'
Reef ahead 0.1 miles
Turn to 112' approached reef midway between Oua Island and Lekaleka Is.
S end Oua I. F300'/W end Lekaleka I. F57'
Ship compass 112'? Hand compass F 120'
Sat fix 20' 07.32 174' 36.16 (Farther South than we want to be).
Cse change 350' (est direction to Bubu passage)
Cse change 330' (better course to Bubu ref. Captain)
1527 E end Lekaleka dead ahead 1.5 miles +_
1531 Cse change 5' to go through Bubu
1602 Passed over pinnacle
1556 Sat fix 20°04.54'S 174°32.45'W
1609 Cse change 34' to get to WP 36 based on last satfix
1622 Sat fix 20°03.29'S 174°28.86'W
1631 Course change 30'°
1640 N end Limu Is F55'/W end Vanukuhiifu Is F335'
1642 Sat fix 20°01.51'S 174°28.97'W
1703 Cse change 180'
1725 Cse change 190' to avoid reefs
1726 Cse change 180'
1729 S end Lekaleka F240' (shoals to port)
1740 Shutdown/Traverse 71 miles cumul. 208 miles
1933 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
2056 Sat fix at anchor same place (65' Elev) 20°05.38S 174°33.63W

Thu 14 Sep 0643 Sat fix at anchor. (7') 20°05.16S 174 33.87W
0740 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°05.34S 174°33.68W
0753 Maggy in water. Going along south side Alexander Reef. Cse 090'
0806 Cse change to 180' to east of Fonoifua Is.
0914 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°17.89'S 174°36.99'W
0942  S. point Mango Is. F255°
      Breakers abeam Sb. 0.4 miles
      E. point Fonoifua Is. F348°
0947  Cse 185°
0936  Sat fix 20°19.51'S 174°37.44'W 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  Spt Telekitonga  F104'/S. point Lalona Is. F32°
1020  Sat fix 20°23.69'S 174°33.55'W
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°17.59'S 174°34.05'W.
      Changed course while fix coming in
1126  Cse change to Mango Iki 270°
1128  N. end Fonoifua L 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'. Nukutaiau 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
        Fonoifua I. F014'
1242  Cse change 200' to E. end Kelefasia or maybe 1 mile east of
        E. end
1247  N. pt. Tonumeia F226'/Mango Iki F310'
        E. pt. Fonoifua F003'
1303  N. pt. Tonumeia F224'/Mango Iki F326'/
        E. pt. Kelefasia F119'
1306  Course still 200'
1309  Course change 175' to avoid reef
1313  W. pt Kelefasia F208'/N. pt Tonumeia F261'
1322  Course 180'
1330  N. end Kelefasia F265'/NE side Tonumeia F299'
1345  Through blind rollers. Change course to 180'
1345  Probe aboard
1349  Probe in water
1349  E. pt Kelefasia 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]
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?

Fri 15 Sep  De-rig Albacore
Sat 16 Sep  Left Nuku'alofa 1105 arrived Suva 1400.

[CR128 - Pflueger]
## APPENDIX D

### LIST OF LINE INTERSECTIONS

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Note: Intersections are from "best estimate" reduced navigation charts.
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

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<th>Accuracy</th>
</tr>
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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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Five bathymetry strip chart rolls as follows:

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<td></td>
</tr>
<tr>
<td>2</td>
<td>11 Sept</td>
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<td>12 Sept</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:

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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.

[CR128 - Pflueger]
Having just finished an expedition to Earth’s newest landmass, Hunga Tonga-Hunga Ha’apai (HTHH) in the Kingdom of Tonga a few days ago, I thought I’d write a few thoughts on this latest expedition to Earth’s newest landmass. Shortly after the volcanic eruption that constructed this new island began in December 2014, we were alerted at NASA’s Goddard Space Flight Center, in Greenbelt, Maryland, and initiated collection of relevant satellite imagery. In mid-2018, with the island just over 3 1/2 years old, I was extremely fortunate to be invited to join a leg of the Sea Educational Association’s SEA Semester/SPICE (Sustainability in Polynesian Island Cultures and Ecosystems) program cruise through the southwest Pacific that passes conveniently close to HTHH. A Report on Geodetic Infrastructure of the Kingdom of Tonga. Table of contents. 2. The four circuits are: Tongatapu/Eua, Nomuka, Ha’apai and Vava’u. The purpose of the survey control network or circuit was to provide a homogenous framework from which to survey and subdivide land parcels into town and tax allotments of 8¼ acres each. The area of 8¼ acres is based on a land parcel having the nominal dimensions of (100 fathoms x 100 fathoms). In remote and isolated islands or group of islands not covered during the Cadastral Survey Operations, DOS Surveyors established six more additional Survey Control Circuits and Datums (Horizontal and Vertical), where the Horizontal Datum in each case was either scaled from nautical chart or adopted from the Shoran Trilateration Survey. 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.