DEPARTMENT OF GEOLOGICAL SCIENCES
UNIVERSITY OF BIRMINGHAM

Marine geophysical and geological investigations in the Scotia Arc and Weddell Sea, Antarctica

Cruise Report
RRS Shackleton Cruise 4/80

November 1980 - April 1981

April, 1981

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University of Birmingham, Antarctic Research Group

November 1980 to April 1981

Personnel

Ship

Master	P. Warne
Mates	N. Jonas, S. Mayl, S. Jones, M. Putman, G. Merries, A. Brigdon
Engineers	J. Parks, R. Crook, P. Byrne, D. Anderson, R. Perrian, P. March, R. Cotter, P. Sharpe, P. Edgell
Doctors	G. Shuster, R. Butler
Radio Officer	P. Webster
Catering Officers	R. Overton, R. Morris
Bosun	H. Morgan.

R.V.S. Barry

D. Lewis, C. Paulson, I. Chivers, S. Jones, S. Smith G. Knight C. Jackson

Birmingham University

P. Barker, E. King, P. Barber, A. Wilson

Acknowledgements

Our greatest debt is to the ship's company of RRS Shackleton, who kept the ship at sea and working, endured uncomfortable and cramped conditions and responded cheerfully and helpfully to the demands of the scientific programme. Also included are the RVS personnel for keeping the scientific equipment running, and helping with scientific watchkeeping. We also had willing and conscientious watchkeeping assistance from Gabe Schuster, Kevin Murphy and Rufino Comes, who was official (Argentine) observer for legs 4 and 5.

The success of the cruise owed much to the British Antarctic Survey's willingness to provide fuel (twice) and fresh water (three times) at Grytviken, which saved much passage time, and for the very friendly attitude of the BAS bases there and on Signy I, which made our port calls into pleasant and effective breaks from routine and provided the ship's company with some insight into base life and the Antarctic.

Finally, we must not forget the shore-based members of RVS, in all departments, without whose help the ship would never put to sea initially, nor stay at sea for long.

2. Introduction

RRS Shackleton left the United Kingdom on 8th November 1980 and is due to return on 14th April, 1981. Her main purpose, and the concern of this Report, was to continue the Birmingham University programme of marine geological and geophysical investigation of the Scotia Arc and Weddell Sea region of the Southern Ocean. This programme has included similar Shackleton cruises in 1971-2, 1973-4 and 1975-6, and short periods of work abroad RRS Bransfield (British Antarctic Survey) in each of the three seasons 1977-80.

The area of interest for this work does not extend north of 48°S so that, from the Birmingham point of view, the passage to and from there is necessarily but unfortunately wasted time. However, on this cruise this time (Legs 1 and 6) has been used by Liverpool University Department of Oceanography to collect airborne dust, and a 4 - day magnetic and bathymetric profile in the equatorial Atlantic was obtained by RVS personnel for Dr. E.J.W. Jones of University College, London.

A track chart for the Scotia Sea region (Figure 1) may be found at the back of this Report. The four operational Legs (2 to 5) were made up of specific surveys, in areas A to J, interspersed with fast passage from and to port. The generous agreement by the British Antarctic Survey to provide fuel and water at Grytviken (South Georgia) saved considerable passage time compared with the alternative of calls at the Falkland Islands or South America. The Birmingham party joined and left the ship at Rio de Janeiro: RVS personnel and most of the officers changed over both there and at Montevideo in January.

3. Objectives

The objectives of the cruise were all concerned with aspects of the tectonic evolution of the Scotia/Weddell Sea region. This is a large-scale study, now nearing completion at the chosen level of detail. Thus, the wide distribution, apparent unrelatedness and peculiar shape of individual surveys (Figure 1) stem partly from the distribution of existing data.

Besides filling certain crucial gaps, the 1980-1 season's work aimed at a more detailed examination of those tectonic processes particularly well-displayed in the region. Figures 2, 3 and 4, showing names, present plate boundaries and seafloor ages respectively, permit some explanation of the aims and achievements of the cruise.

The Scotia Sea region acts at present as a complication of the South American - Antarctic (SAM-ANT) plate boundary. The slow sinistral SAM-ANT motion is split in unknown proportion between the North and South Scotia Ridges; much more rapid back-arc extension in the East Scotia Sea is coupled to vigorous subduction at the South Sandwich Trench. We have been able to show that the Scotia Sea has probably evolved in a similar manner over the past 30 or 40 Ma; that is, as a series of short-lived, related but different complications on the SAM-ANT boundary, essentially involving subduction of SAM oceanic lithosphere and back arc extension in the broad sense. The age of most of the Scotia Sea floor (Fig. 4) is now known. We saw one of our remaining tasks as establishing the starting position for Scotia Sea evolution: how many of the shallow bodies making up the Scotia Ridge and southeast Scotia Sea are fragments of an originally more extensive South American or Antarctic continent (like South Georgia), dispersed as the Scotia Sea grew, and how many are younger, produced by the Atlantic-directed subduction which accompanied that growth (like the South Sandwich Is)? For the first time since 1975-6 we were able to dredge the seabed, and it was our intention to dredge suitable scarps on as many of these enigmatic shallow bodies as possible. We were particularly interested in the South Orkney block (area E and E.C. King's current Ph.D. thesis area), the South Scotia Ridge west of there (area F) and the central North Scotia Ridge where it is necessary also to distinguish between continental fragment and younger accretionary wedge (area A). These are all areas where geophysical data are numerous, and can be explained in more than one way until direct evidence of composition and age is available.

Our second main objective was concerned with the Why? of Scotia Sea evolution. Having mapped the succession of spreading regimes within the Scotia Sea and recognised their essential affinity with back-arc extension, it seemed likely to us that the agent for change from one regime to the next most probably was connected with the primary subduction process, and therefore lay outside the Scotia Sea itself. We proposed (Barker et al, in press, Barker & Hill, in press) that this controlling factor was ridge crest - trench collision, a process which Figure 3 shows will occur again in about 5 Ma from now, when the fast, eastward moving Sandwich plate will overtake the southernmost spreading section of the slowly-spreading SAM-ANT boundary. We considered that in the past other, more southerly sections of that spreading centre had collided with ancestors of the South Sandwich trench, whereupon subduction at that part of the trench had stopped and the Scotia Sea back-arc extension had been re-adjusted. The confused bathymetry of the eastern South Scotia Ridge we explained as a remnant of this collision zone, which we thought could extend as far west as the eastern end of the Antarctic Peninsula.

A series of surveys was planned to test this speculation. In logical order, these comprise firstly areas E, C, and D around the present South Sandwich fore-arc and on the east-west transform trough which extends from the northern end of the trench. These surveys were intended partly to provide models of fore-arc morphology and composition for use in the collision zones, partly to understand the morphologic differences between the northern and southern halves of the fore-arc region (Barker and Hill, in press).

The collision zone itself was sought in areas I, J and G. Area I we thought may have been the site of a quite recent collision (perhaps only 1 - 2 Ma ago) which would thus be well-exposed. In area J, there was already some evidence of collision to which we could hope to add. Area G, which we attempted unsuccessfully to reach last season aboard RRS Bransfield, we thought should contain the boundary between the collision regime (arc/for-arc opposed to young spreading centre) in the east, and an old extensional margin (western Weddell Sea and Antarctic Peninsula) in the west. Thus, areas I,J, and G seemed likely to contain complementary aspects of the ridge crest - trench collision story. In addition, under this hypothesis, the southeastern margin of the South Orkney block (Area H) becomes a likely site of any associated arc volcanism.

A third objective, of a lower priority only because it represented a step beyond the problem of regional tectonic evolution rather than an aspect of it, was concerned with palaeo-circulation. In the Southern Ocean, the influence of plate motions upon circulation is clear: the Antarctic Circumpolar Current (ACC), which today dominates Southern Ocean circulation, could not start until after Drake Passage had started to open in the Late Oligocene (Barker and Burrell, 1977 and in press). Its subsequent development would have been greatly influenced by changes in Scotia Sea morphology. The other great component of Southern Ocean circulation. Antarctic (Weddell Sea) Bottom Water, probably started to develop in the Early Oligocene. However, its northward migration has almost certainly been controlled by tectonic changes, either directly by changing seabed topography or indirectly by the agency of the ACC.

The importance of the history of Southern Ocean circulation is recognized by its presence as a prime component of the newly formed Ocean Margin Drilling Program, in the form of a Weddell Sea transect. The objective would be to study the history of Antarctic Bottom Water. However, no satisfactory model exists for the dependance of present-day sedimentation upon AABW production and flow. We proposed to make a start on this problem by collecting a series of cores along a line running southeast into the Weddell Sea from the South Scotia Ridge.

4. Cruise Summary

Briefly, in most respects the cruise was successful. Time lost by ship or equipment failure was minimal, as was time lost in port. The weather was better than we expected. However, our intentions were to some extent upset by pack ice. Abnormally far north last Winter, it had been slow to clear and even by Christmas (Figure 1) obscured most of our high priority objectives. The ice front receded rapidly in mid-January (compare 24/12 and 30/1 ice messages from the US Naval Polar Oceanography Centre, in Figure 1) but by then we were short of time for our objectives along the South Scotia Ridge. Also, in areas D and G we met isolated stringers of pack ice some way north of the reported ice front. While they were of no danger to the ship, these were sufficiently large and dense to threaten the towed equipment, and thus to cause large diversions and waste time.

The large part played in this season's programme by dredging (we recovered over 10 tons of rock from 61 sites), also makes it difficult to assess at this stage the extent to which our objectives have been achieved. To permit some quick examination of the dredge hauls we installed rock sectioning equipment and microscopes on board. A considerable number of thin sections were made and in many instances helped in planning the remainder of a particular survey. However, it was usual for the in situ lithology to be diluted in the dredge haul by glacial dropstones, occasionally to an extent which will make its identification difficult or impossible. Thus, although there is little doubt that most of the problems tackled in this way have been solved, further detailed study of the dredge hauls is required, for the exact nature of the solutions to be revealed.

In summary, the surveys in areas A, C, D and E are very probably adequate. In A we have samples of the continental component of the North Scotia Ridge and now know how to map geophysically the boundary between that and the accretionary wedge. Most of the difference between areas C and D results from the more extensive development in the latter of the trench slope break. The southern margin of the east-west trough sampled in area E provides an attractive model for the trench slope break of a future trench. Areas F and H are now probably adequately mapped and sampled. Area I was deliberately neglected in favour of areas J and K on the final Leg, and the northern Weddell Sea coring proposal abandoned completely, because of the shortage of time caused by the late clearance of pack ice. There is little doubt of the reality of the ridge crest - trench collision zone in area J, although we are not sure how much of the detail of this process our survey will reveal. The western boundary of the collision province, sought in area G, was more elusive. A; sharp boundary between young and old ocean crust was not seen, and fracture zone orientation may not have the 120° Weddell Sea trend.

Our attempts to examine the Antarctic Peninsula shelf were thwarted by ice but some progress has been made in understanding Powell Basin evolution.

5. Narrative

(a) Leg 1 Barry to Rio de Janeiro (Brazil)

RRS Shackleton left Barry on 5th November, 2 days late as a result of delays in fitting an airgun towing winch to the after A frame. Much of this time was recovered on passage to Rio because of favourable winds and currents, and the ship arrived on 26th November. Scientific work was confined to program development on the data logger and 4 days magnetic and bathymetric survey (between 11.5°N 23.3°W and 3.0°S 26.9°W) conducted by RVS staff for University College London, and to Liverpool University's airborne dust collection programme. In Rio the ship berthed alongside HMS Endurance.

(b) Leg 2 Rio de Janeiro to Grytviken (South Georgia)

Shackleton left Rio only on 1st December, again largely because of the airgun towing winch, thus losing again the time made up on passage. The first week at sea was spent in setting up equipment ready for a start at 48°S. During this period the first pack ice report received via RRS Bransfield showed the ice edge extending from 62°S near the Peninsula to ∿ 58°S at the South Sandwich Islands(see Figure 1).

In view of this we decided to start work in the northwest (area A, Figure 1) in the hope that more of the South Sandwich area would be accessible after Christmas (Leg 3). After delays due to bad weather and engine repairs on 7th and 8th December (days 342 and 343) we finally streamed the reflection profiler at about 50°S on day 344 for the approach to the North Scotia Ridge. The Falkland Trough was crossed on day 345 and a reflector at 3 seconds depth could be clearly seen for 40km south of the chaotic moss of overlying sediment on the trough's northern wall. The profile was continued into the Scotia Sea and, as expected, showed a number of scarps suitable for dredging.

Dredging continued from day 346 to day 348 on this section (D37-43), supplemented later by other sites (D44,5) on known scarps to the west. The Antarctic Circumpolar Current, which conveniently had kept these scarps free of sediment, made it difficult on many sites to manoeuvre the ship slowly upslope.

This dredging session was followed by two reflection profiles near 49°W, where the North Scotia Ridge is least well developed, to examine the accretionary wedge, then a further dredge station (D46) on day 351, on a known scarp to the southeast. By this time it appeared clear that the southern margin of the accretionary wedge had a clear gravity signature. This prompted further gravity and magnetic lines before the final dredge station in this area on day 352 (17th December).

Since the sea ice farther south had not receded to any extent meantime, it was decided to devote the remainder of Leg 2 to a reflection profilerexamination of the boundary between the Drake Passage and Central Scotia Sea spreading systems (Figure 4 and Figure 1, area B), Magnetic anomaly identifications in the Central Scotia Sea (Hill & Barker, 1980) retain some ambiguity because of the short length of the anomaly sequence, and it seemed possible that a comparison of sediment cover at the boundary with the Drake Passage province would resolve the ambiguity. The ship tracks were designed to connect with existing profiles and extend the mapped area of the oldest Drake Passage anomalies (A8 - 10) before crossing the boundary. The work started in quite rough weather on day 352 and was plagued by compressor and airgun stoppages. The former resulting from air bubbles entering the cooling water system, disappeared as the ship rolled less in the improving weather; the latter, caused by the gun solenoid icing, was cured by use of the new antifreeze injection system.

An intermittent oscillation of the cross gyro of the gravimeter also developed during this period, and was finally traced to a shorted heater circuit.

On the first two crossings, the boundary between the two spreading systems was marked by a broad, sediment-free basement ridge which although not hitherto recognised as such, may well be a continuous north-south feature. Thus, although no comparison of sediments across it is likely to be possible, it may well be related to the formation of the boundary and its morphology therefore give some indication of relative age.

The reflection profile was continued to the South Georgia margin, the third boundary crossing also showing discontinuous sedimentation. The ship arrived at Grytviken on day 358 (23rd December) mooring off the dismantled KEP jetty to take fuel before moving across to the Wha'ing station jetty for the remainder of a most enjoyable Christmas break.

(c) Leg 3 Grytviken to Montevideo (Uruguay)

This leg was devoted to an examination of the fore-arc region of the South Sandwich trench, and its northern transform fault extension. We intended to follow the same plan as in area A, of initial reflection profile surveys followed by a suite of dredge stations. The ship left Grytviken on 26th December (day 361) heading 085° to obtain a reflection profile firstly across the northeast margin of South Georgia, hitherto unknown, and then along the southern flank of the "North Georgia Rise", a presumed ridge jump expression (see Barker, 1979), and onto old Atlantic ocean floor. In 29.5°W we turned south for a crossing of the northern extension of the trench (area E). The sediments on the northern slope were clearly faulted, but the reduced penetration which this caused prevented our seeing what happened to the older basement in the floor of the trough. The south wall was very steep and there was an isolated high in the trough at about 6000m.

On reaching the young ocean floor of the back-arc basin (Figure 4) we recovered the profile gear and headed east for the fore-arc region at full speed. <u>En passant</u>, we came within a mile of the reported site of a possible new volcanic island (56°01.5'S, 27°00'W, reported by Atlantis II). No island was seen and the water depth exceeded 2000m; the "island" was probably an iceberg, of irregular shape and possibly ash-covered or otherwise darkened. We thought it worthwhile to pursue this sighting since the reported position was well east of the main arc so that an unusual, particularly primitive chemistry might have been expected.

From there, on day 365, we headed for area D. Over the next few days, we were able to achieve most of our objectives in areas C and D, although our plan of "profile first, dredge second" was partly upset by rough weather. Also, our dredging was confined to the outer slope of the trench slope break (Karig 1974), and was somewhat difficult because of adverse currents and sediment cover. In addition, isolated stringers of pack ice prevented our working south of 59.5°S.

Both EM log and the ship's Bergen log failed during this period, the former due to a water leak around the head, the latter possibly by contact with brash ice, It proved impossible at first to seal the ball valve of the former, so that the unit could not be replaced, and the possibility was considered of breaking off early to enable divers in Grytviken or Montevideo to effect a seal. On day 006, however, the valve was finally sealed and the log changed.

The survey results in areas C and D are quite promising: the tectonic elements of the arc are now well-defined and the essential similarity of its northern and southern halves is unmistakeable. We chose not to sample the accretionary wedge, when time became short, arguing that the very large sampling programme necessary to map the extent of its expected heterogeneity was in any case beyond our means.

After nine days in the fore-arc region the ship again headed west to dredge the steep southern margin of the trough in area E. Part of the time allocated to this was used up in very slow steaming in thick fog, but is still proved possible to occupy 6 dredge stations (D56-61), on days 008 to 010, before heading for Grytviken, steaming initially in the back-arc province and then along the trough to the north. The dredging was successful, recovering fresh basalt at all depths and permitting a further look at back-arc geochemistry (see Saunders & Tarney, 1979).

The diversion to Grytviken, for ships and Base mail, was small in distance, but the fog persisted for the next three days and, with the head winds which were its cause, slowed our passage to Montevideo. We finished watchkeeping on day 014 and reached Montevideo at noon on 18th January, about one day late.

(d) Leg 4 Montevideo to Grytviken (South Georgia)

The RVS engineers and many of the officers changed at this mid-cruise port call, and we were joined also by Dr. R.A. Comes of the Argentine Antarctic Institute, as official observer, and K. Murphy of Liverpool University to collect airborne dust.

As at the beginning of Leg 2, it was not clear when Shackleton left Montevideo on 22nd January in what order the remaining tasks of the cruise would be completed. Indeed, the last ice report received before Montevideo had still shown all of the South Scotia Ridge, where all our remaining high priority problems lay, to be completely ice-covered. However, a report received on day 024 via the BAS Base on Signy I. showed that the ice front had receded considerably over the previous two weeks, so that nearly all of the South Scotia Ridge was now clear. So as to minimise passage time, we chose to work the western area first, so altered course to head directly for the first dredge station, on the Shackleton Fracture Zone near 60°S 58°W. This was reached late on day 029, after a fairly direct magnetic/gravity line started on day 026 at 48°S and again slowed at times by fog. The object of dredge stations D82-3 was to discover the nature of the long, elevated southern part of the SFZ, speculated upon by Barker and Burrell (1977). The main in situ components were of volcanic origin but their geochemical nature is not yet known.

The ice front shown on Figure 1 was not reported until day 031; the earlier report showed greater cover of the Antarctic Peninsula margin at about 63°S, so it was decided to site the initial reflection profile of this leg farther to the east, where it would cross a wide portion of the central trough of the South Scotia Ridge. This trough is part of the Scotia-ANT plate boundary (Figure 3), probably extensional in an otherwise long transform section, and also separates the very different northern and southern parts of the Ridge (see Watters, 1972). The reflection profile was continued across the Powell Basin towards the eastern "nose" of the Antarctic Peninsula continental margin, as an approach to the western boundary of the ridge crest-trench collision province, explained in section 3 of this Report. However, on day 032 we met with pack ice, not at all dense and probably long stringers detached from the main body of pack, but nevertheless a threat to the 8-channel hydrophone streamer and other outboard equipment. As Figure 1 suggests, the remainder of day 032 was spent heading reluctantly eastward, hoping for clear water to the south. The hypothetical boundary we sought should trend approximately 120° from a point close to 63.5°S, 50°W (maybe ± 60 miles east or west). At this stage we judged its detection to be sufficiently important for us to persist despite evidence of ice to the east of the forecast position. During the next five days of reflection profiling we searched for a single large fracture zone, oriented 120°, with significantly older (deeper) ocean floor to the southwest. It is difficult even now to be sure of the significance of what we <u>did</u> find - a 120° orientation in the southern part of the survey area (G) but <u>not</u> great depths to basement, and in the north a fracture zone orientation possibly closer to 070° and perhaps related to Powell Basin trends.

Since at the time we were not making sense of the incoming data, it seemed best to head north for the other problems now scheduled for this leg. Accordingly, on day 038 we came back into the Powell Basin and occupied two dredge stations (D64,5) on its steep southwest margin. The reflection profiler had worked well over this period, although a certain amount of damage had been sustained; one airgun tail and clamp had fractured after a clamp nut had come off (day 035), one depth controller had collapsed (day 037) and two snake sections split while being recovered prior to dredging.

The dredge stations appeared successful. With the intention of demarcating the magnetic/non-magnetic boundary on the Antarctic Peninsula margin (see Watters, 1972) we then headed west, but were once again turned back by long stringers of loose pack ice (Figure 1) on day 032, and finally chose to approach area F by way of the Powell Basin instead. After a reflection profiler traverse of the active trough perpendicular to the initial (day 031) traverse, we started on a 3 day dredging programme (days 040 to 043) on suitable scarps of both the thin, non-magnetic northern ridge of the South Scotia Ridge and the strongly magnetic broader southern ridge (Figure 4 and Watters 1972). Eight sites were occupied (D66-73) and some success achieved, although several hauls were clearly heavily contaminated with glacial dropstones.

We had hoped to call at the BAS Signy I base before heading for Grytviken at the end of this leg, but because time was short arranged instead a brief rendezvous with RRS Bransfield at the western end of Coronation I, late on day 043. This dictated the end of the dredging programme in area F, and fast passage eastward permitted better definition of the central trough, which will be useful for rotation pole determination. After the rendezvous we started a reflection profile eastward across the South Orkney block, which filled a crucial gap in the previous (Bransfield) season's work - Sufficient time had been set aside following this profile for a dredge station, either on the northeast margin of the South Orkney block or on the isolated elevation to the north across the S. Orkney trough (Figure 4), but a crack in the exhaust manifold of one generator prevented this. An alternative site was selected farther north, on a seamount at $\sim 56^{o}$S, but fog and head-winds slowed the ship, and on arrival at the site the weather was too rough for dredging, so the ship continued northward for Grytviken. Watchkeeping stopped about 4 hours out of Grytviken, which was reached in the afternoon of day 047. The ship tied up at the Whaling station jetty, to take water, and most aboard spent a quiet but enjoyable two days, thanks to the weather and the friendliness of the Base.

(c) Leg 5 Grytviken to Rio de Janeiro (Brazil)

On the morning of February 18th (day 049) the ship shifted to the by now essentially rebuilt KEP jetty, to inaugurate its use and take on fuel from the Base tank, before sailing in the afternoon. Watchkeeping started at approximately 8 p.m. as the ship headed eastabout and then south, for the eastern part of the South Scotia Ridge. Despite being slowed by fog, and by longer periods of slow night time steaming as the season advanced, we reached the first dredge site in area I, at 60°S 32.5°W (D74) on day 051. The haul of indurated sediments appeared compatible with our conception of this block (Figure 4) as a recently detailed fore-arc fragment and we moved on eastward to dredge two other isolated elevations, essentially in a reconnaissance spirit as there was clearly not time left for thorough studies of area I and area J and to complete work in area H (South Orkneys). The blocks in area I were found to be separated by a spectacular trough with 4000m relief, oriented $\tilde{\sim}$ 100° and completely mis-contoured previously. The trough probably indicates dissection of the fore-arc along Sandwich-ANT fracture zone trends but the nature of the dredged ridges is not yet known.

From area I the ship headed firstly southwest then west towards area J, with the reflection profiler being streamed late on day 054. Our approach to the study of the ridge crest - trench collision zone had three components - (a) profiling for fracture zones and undeformed trench fill, (b) fast oceanic magnetics lines along ∿100° and (c) dredging, and our aim was to distribute the available time among them according to the weather. In really bad weather we could happily profile, but could move fast only downwind, and could not dredge. This system worked reasonably well, but we encountered superficial sediment cover on many of our prime dredge scarps, and the northern part of area J did not obviously fit our preconception of the nature of the collision zone. Nevertheless, the close juxtaposition of one flank of a spreading centre and a fore-arc province is almost certainly demonstrated in area J (subject only to detailed study of the dredge hauls), which was our prime objective.

We left area J on day 063 (4th March), heading for the South Orkney block via a series of dredge stations, the first (D87) on the northern margin of a small ridge extending eastward from the northwast corner of the S. Orkney block. Dredge stations D88 and 89 occupied on day 064, sampled the steep southern scarp of one of the large elevations of the southeastern Scotia Sea (Figure 4) and we moved from there to the northeast corner of the South Orkney block itself. In the time remaining, which was not long, we wanted to dredge as many as possible of our targets within the large and complicated magnetic province which occupies more than half of the block but which is not represented on the islands (see Harrington et al 1972). Dredges D90 and 91 were on the steep northeast continental slope, which truncates the magnetic province, D93 and 94 on two small scarps in about 1000m water depth on the very gently sloping eastern margin, and D95 and 96 on the western, Powell Basin margin, which also truncates the magnetic province. These dredges hauls were all contaminated with glacial dropstones, but not to a disabling extent. The track between D94 and D95 was profiled, and located so as to fill in the remaining gaps in the previous season's gravity and profiler coverage. Stations D95 and D96 were adversely affected by drifting icebergs, oddly enough the only occasion this season when we were seriously inconvenienced in this way.

A fast magnetics and gravity line brought us to the BAS base on Signy I in the afternoon of day 068, where we stayed for about 5 hours. Base personnel kindly organised an excursion to a penguin rookery and fur seal colony on the island for as many of the ship's companay as wished to go. The ship headed east from Signy I and through Lowthwaite Strait towards a dredge site (D97) on the isolated elevation north of the islands (Figure 4). An unexpectedly strong eastward current here made dredging difficult, and the haul is undoubtedly contaminated by glacial dropstones.

The track northward from D97 was chosen to add to our knowledge of the north-south ridge encountered on Leg 2. It ended at a core station on the northwest margin of the South Georgia block, many times postponed through the season. Its object was to compare sediments on the crest of the frontal fold of the accretionary wedge lying north of the block, with those being deposited on the abyssal plain to the north and in the current-scoured troughs directly north and south of the anticline. On the initial northward run late on day 071 we dropped three "boomerang" free-fall corers in the two troughs and on the flank of the fold, before turning for a gravity core on the crest. Before this last was complete the lights of the second and third free-fall samplers could be clearly seen (ranges 0.5 and 1 mile, sea state 4, darkness). We recovered only about 0.7 metres of white diatom ooze from the crest. The nearest (flank) free-fall sampler yielded only 0.15 metres of a similar ooze and the next (north trough) had lost its core liner. We used the remaining time for a second gravity core on the northern lip of the scour trough rather than chase the third free-fall sampler, recovering $\sim$ 1.2 metres of green siliceous ooze before heading for Bird I (South Georgia) to deliver mail. Leaving there via Bird Sound we reached Grytviken, where we needed to take on water, in the afternoon of day 072. The necessity of investigating a probably blocked filter in the main engine tube oil sump delayed departure for Rio until $\sim$ 0500 on day 073. However, the weather we encountered directly outside which meant that more than 24 hours later we could still see South Georgia on radar, made such a delay immaterial. On day 074 the weather improved and the ship was able to make reasonable speed. Geophysical watchkeeping was ended on the afternoon of day 075 at 48°S but on day 076 the weather was again rough and it became clear that the ship would arrive late in Rio. Some time was saved by favourable currents subsequently, and the ship arrived finally 1 day late, on day 082 (23rd March). We were about a mile from our previous berth, so the gravity difference of 2 mgal remains only an approximate indicator of low drift, which must be checked when Shackleton arrives back in the United Kingdom in mid-April. The Birmingham party disembarked late on 24th March and the ship was due to sail an hour or two later.

6. Cruise Statistics

(a)	Cruise Length, U.K. to U.K. (assuming arrival 14th April)	159 days
	Cruise Length Rio to Rio	112 days
(b)	Time in port or at anchor	
	U.K. to U.K.	18.1 days
	Rio to Rio	10.1 days
(c)	"Dead" passage time - no geophysical data collection	
	U.K. to U.K.	61.7 days
	Rio to Rio	24.0 days

All subsequent statistics are Rio to Rio, and concern only the Birmingham programme.

(d)	Useful ship time	77.9 days
(e)	Time collecting underway data	64.0 days
(f)	Useful underway data collected	
	bathymetry	64.0 days
	magnetics	61.4 days
	gravity	62.3 days
	reflection profiles	31.7 days
(g)	Total profile lengths	
	bathymetry (19,300km)	10440 miles
	magnetics (18,600km)	10020 miles
	gravity (18,800km)	10160 miles
	reflection profiles(8,300km)	4480 miles
(h)	Average data collection speeds	
	All underway data	6.80 kts
	reflection profiles	5.89 kts
	magnetics and gravity only	7.89 kts
(i)	Time on station	13.9 days

Station time included 61 dredge stations, numbered D37 to D97 inclusive, one core station (93) and small amounts of passage time between closely spaced stations.

Comments

(f) gravity downtime resulted partly from clamping in bad weather and partly from equipment downtime (mainly gyro failure)

Magnetics time was reduced only because, for some short distances between dredge stations on known tracks, we didn't think it worth streaming.

(f,g,h,) Several factors influenced ship speed. Firstly we did not profile above 8kts because of towing noise, and often profiled much more slowly if deep penetration was required.

In calm weather, at full speed, the ship could expect to make 10kts, so the attendant speed penalty meant we did not profile unless it was necessary. Secondly, south of the Antarctic Convergence we were required to slow to 5kts or below during hours of darkness or reduced visibility. We spent 77 nights south of the Convergence, underway or on station, and the time spent at slow speed varied between 6 and 8.3 hours per night.

7. Equipment

Almost all of the equipment used during the cruise was on loan from RVS, and once again we are grateful for the skill and devotion of the RVS engineers who looked after it for us.

In the main, the equipment proved very reliable, and down time was small. In some instances the considerable redundancy thought necessary for a cruise of this length and remoteness contributed to this overall reliability.

In contrast, some equipment was not used at all (Sparker, sonobuoys, side-scan sonar, Digitrak) or very little (3.5 kHz sounder, corers) for various reasons, and is not discussed further here.

(a) Satellite Navigator

Two complete shipboard units were carried, but only the spare teletype was ever used, and that only briefly. The system performed well throughout the cruise.

(b) E M Log

A seawater leak at the junction of head and stem caused the only trouble, compounded by difficulty in sealing the ball valve in the ship's hull. We were without the log for 4 days during Leg 3. The log remained extended during dredge stations and proved extremely useful in judging ship motion.

(c) Precision Echo Sounders

One of the recorders was damaged by seawater entering the main lab through an incompletely closed port at the beginning of the cruise, but after repair worked reasonably reliably throughout the cruise. One of the towed fish vibrates badly at ∿ 5kts, but is not noticeably more noisy acoustically than the other.

(d) Magnetometer

The same inboard units were used throughout the cruise and the towed fish and cable were changed only as a check that both were serviceable.

(e) Gravimeter (Lacoste-Romberg 586)

Two gyros were changed during the cruise; one may have worn excessively while being overheated. Preliminary indications are that meter drift was very low.

(f) Reflection Profiler

We experienced airgun firing problems caused we think by the solenoid freezing, and cured by proper regulation of the antifreeze injection circuitry. One large gun tail assembly was cracked after a clamp nut had come loose. Three snake sections in all split while being streamed or recovered; some discolouration at each split suggested that the plastic skin had become denatured. The hydrophone winch and airgun towing winch both worked well.

We carried four EPC recorders and experienced some trouble; one EPC 4100 has worn stylus drive shaft end bearing. The optic coupler on the other gave repeated trouble through carbon accumulation on the coupler and the stylus. The EPC 3200 did not impress, being subject to similar problems with carbon build-up but showing more diverse and less easily diagnosed symptoms. We had trouble also in the second half of the cruise with playback of the key pulse. One depth controller and a tail buoy collapsed.

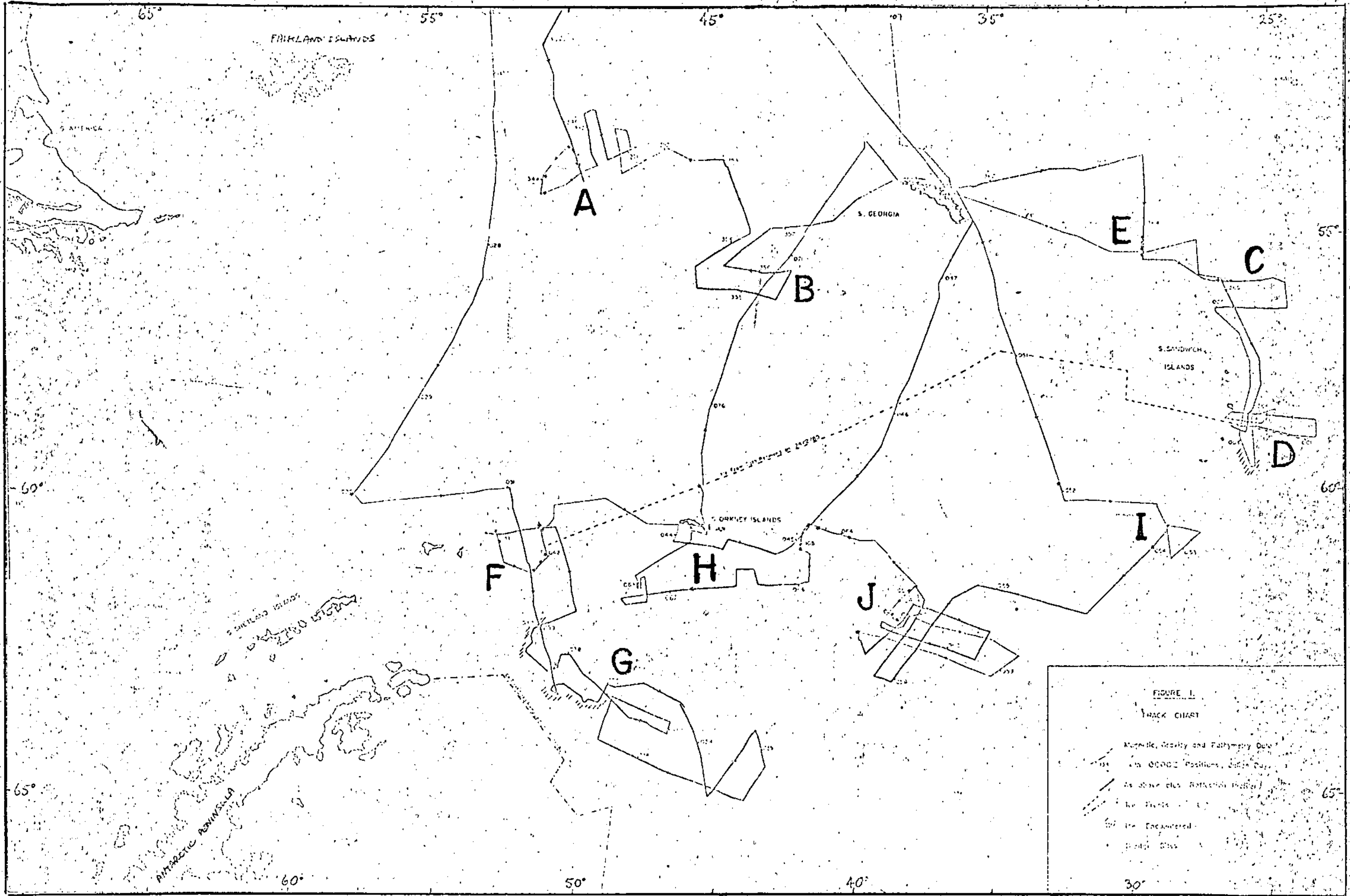
(g) Dredging

We dredged with the usual rig of 5 ton, 3 ton and 6 inch nail weak links, standard RVS box dredge and large pipe dredge.

Wire tension was monitored on a Servoscribe recorder and, usually but not always, an IOS pinger was attended 160m above the dredge. The pinger was hung from a chain rather than rigidly clamped, as this improved the signal, but the directional character of the pinger made it of little use in deep water with wire angles exceeding 15 or 20°. We lost no dredges (but demolished two) and no Pingers and only about 200m of wire by stranding, after 61 dredge stations. We used the towed PES fish, less susceptible to bow thrust and winch noise than the hull-mounted unit, and kept the EM log extended. This last option meant that the wire was not permitted to go under the ship (it did so only twice) which at times made dredging awkward. Bow thrust and main engines were used (in opposition) on almsot all dredge stations. The success rate was high, the main cause of poor dredge hauls being a sedimented bottom rather than any deficiencies in ship handling. The pipe dredge was located astern of the box dredge, and was intended to collect soft sediment. However, it often collected a better in situ sample than the box dredge. The pipe dredge was not used in very deep water or where the bottom was expected to be particularly rough (e.g. on young ocean floor). This was because the failure of the 3 ton week link could not be expected to change greatly the angle of attack of the pipe and thus to dispose of a snag unlike its intended effect on the box dredge.

(h) Data Logging

The only disappointment of the cruise was the performance of the PDP 11/04 data logger. Malfunction of the gravity room air conditioning on Leg 1 led to the planned program development and testing being incomplete at Rio, with the result that, for Legs 2 and, 3 satellite fix data were recorded only for the first few hours of each tape. The gravimeter interface appears to incorporate a design fault somewhere and gravity was never logged correctly on the 11/04. The EM log interface displayed several somewhat subtle faults through the cruise, and it is uncertain for just how long they had survived undetected. Thus, only magnetic field may be extracted from the tapes with confidence for the entire cruise.



RRS SHACKLETON CRUISE 4/80

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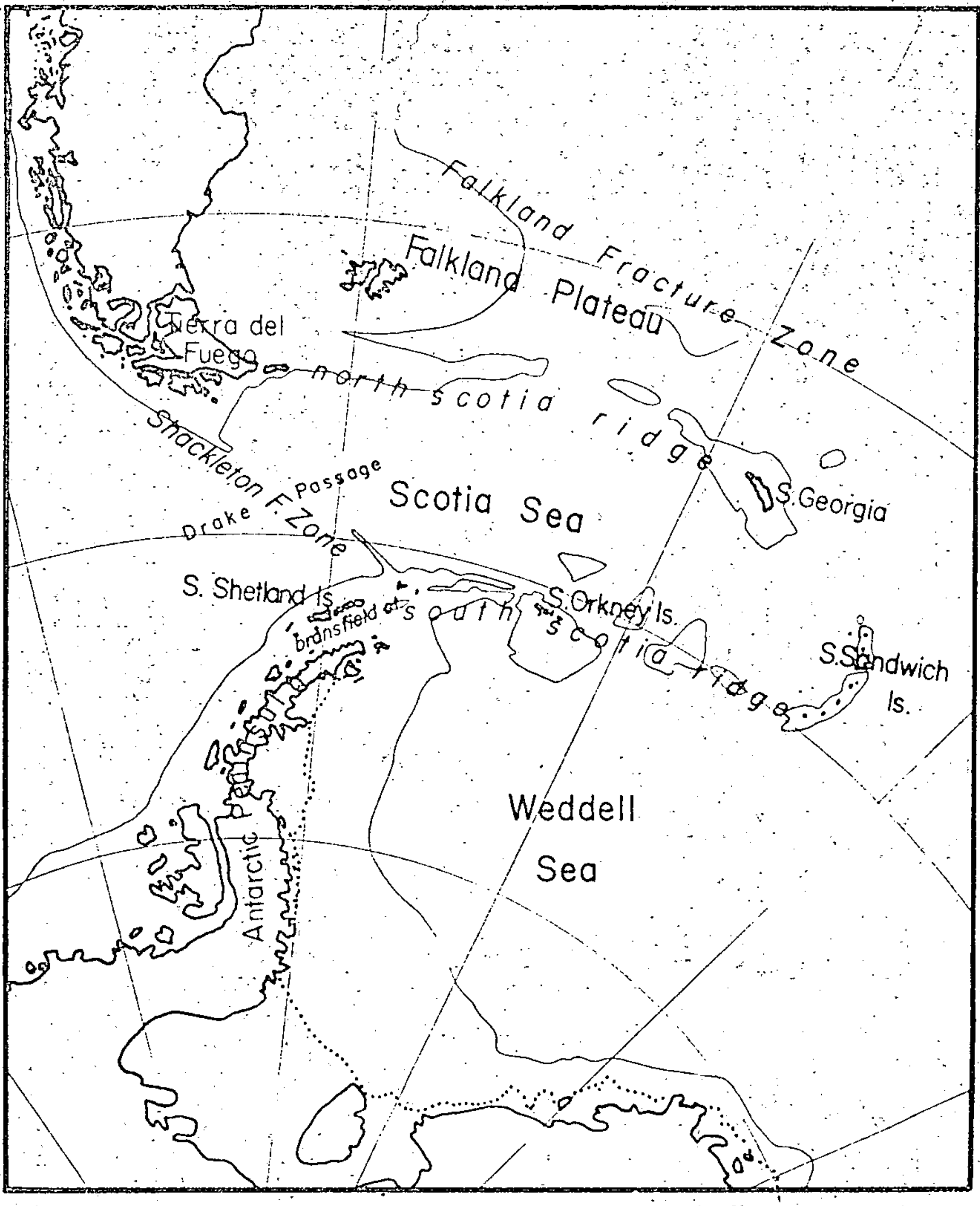

Figure 2

PLACE NAMES, SCOTIA SEA REGION

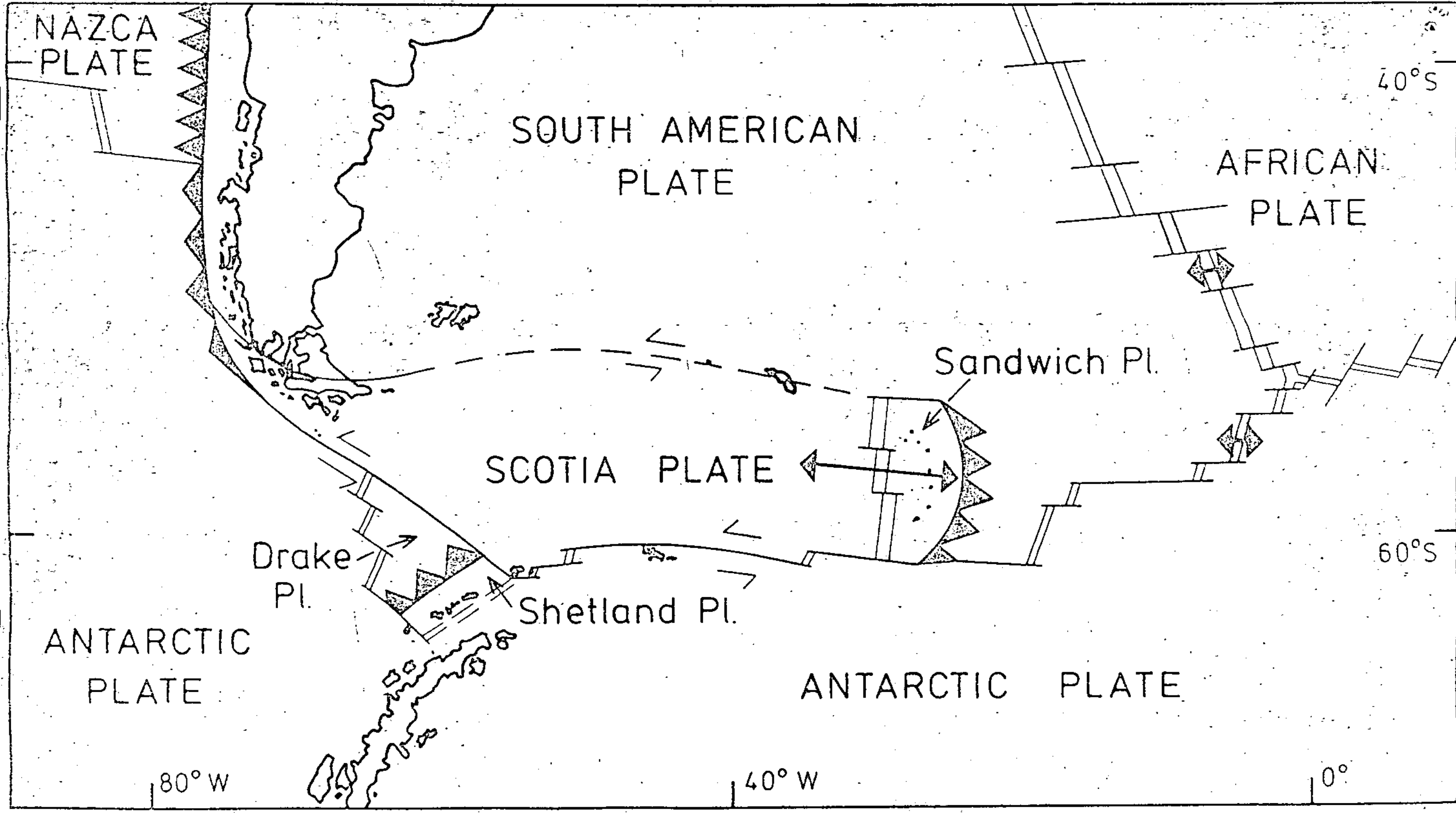

Figure 3

PRESENT PLATE BOUNDARIES, SCOTIA SEA REGION

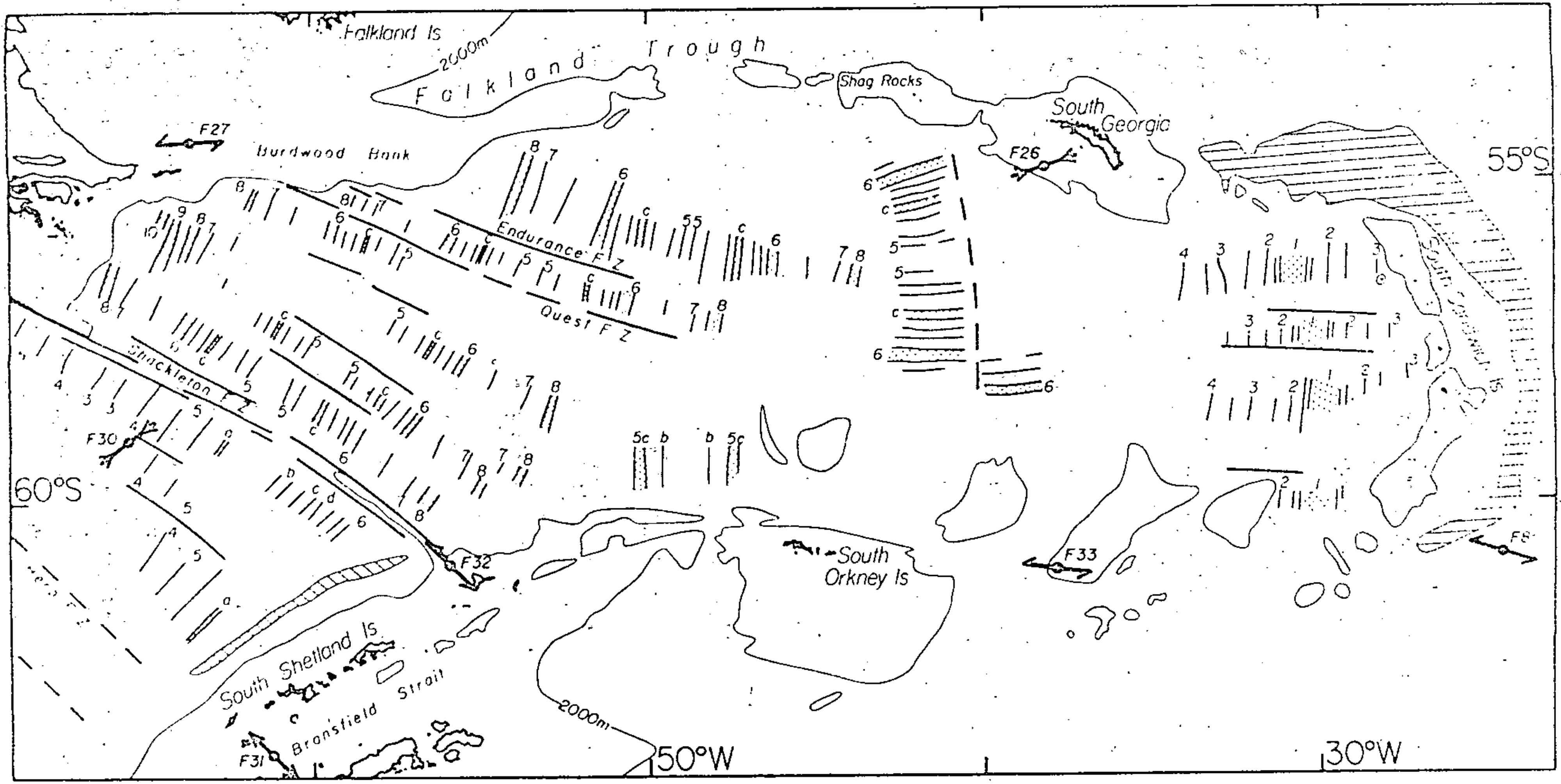

Figure 4

MAGNETIC ANOMALY IDENTIFICATION AND EARTHQUAKE FIRST MOTIONS, SCOTIA SEA REGION