GRAVITY MEASUREMENTS IN THE FALKLAND ISLANDS

By J. L. MARTIN *and* L. J. S. STURGEON

ABSTRACT. Further results from a gravity survey of the Falkland Islands are presented. A positive Bouguer anomaly associated with the southern part of West Falkland is attributed to Precambrian basement rocks, while a significant negative anomaly centred over western East Falkland suggests an increase in sedimentary thickness with maximum values of 4.0 to 6.5 km.

AN opportunity arose in November 1975 to continue the gravity survey of the Falkland Islands initiated by McNaughton (1972). Travel facilities are somewhat limited over the islands, except for back-packing, and for this reason gravity station distribution was largely controlled by transport available at the time. Land Rovers provided an alternative overland means of transport and on three occasions flights were arranged in a De Havilland Beaver float aircraft operated by the Falkland Islands Government Air Service (FIGAS). Thirty-eight gravity stations were occupied, 31 on East Falkland and seven on West Falkland. Three of the stations were re-occupations of those previously established by McNaughton (1972).

Lying 450 km north-east of Tierra del Fuego, the Falkland Islands consist of two principal islands, West Falkland and East Falkland, with areas of approximately 3 500 and 5 000 km^2, respectively. They are separated by Falkland Sound which trends north-east to south-west, averages 20 km in width and has depths approaching 40 m. Several hundreds of smaller islands contribute to the very irregular coastline. The south-western coasts of West Falkland, Weddell Island, Beaver Island and New Island display a severe topography with steep wave-battered cliffs. In contrast, calm sheltered waters and dune-fringed beaches are often found along the north-east coasts of the islands. The inland terrain is gentle and rolling though there are several low mountain ranges of 450–600 m elevation rising above the peat-covered, often boggy lowlands.

The geology of the Falkland Islands has been described by Baker ([1924]) and Greenway (1972). Essentially, it consists of a thick succession of marine and terrestrial sediments of Lower Devonian–Upper Jurassic age resting unconformably on a Precambrian basement, the latter being exposed only along a narrow 5 km coastal strip at Cape Meredith on the southern tip of West Falkland. Recent K-Ar age determinations (Rex and Tanner, in press) on Precambrian gneisses from Cape Meredith gave ages of 953 and 977 Ma. Apart from some intrusive rocks in the basement, the only other igneous representatives are dolerite dykes of (?) Jurassic or Lower Cretaceous age found almost exclusively in West Falkland (Brown, 1967). In the Falkland Islands there are two major structural trends to which all of the folding can be related. One trending west-north-west to east-south-east crosses the north of both islands, swinging to an east–west attitude towards the east. The second trends north-east to south-west and predominates in the east of West Falkland. The folding affects all of the sediments and has been attributed to block faulting in the basement during the late Jurassic–early Cretaceous. There is a distinct parallelism between the direction of folding and that of the subsequent faulting and dyke intrusions, all of which are considered to be related to the same tectonic episode. It is considered that the Falkland Islands lie on a basement platform and their geological development has been compared to that of South Africa and to the Deseado Massif in Argentina.

THE GRAVITY SURVEY

The survey was carried out using Worden gravity meter No. 743 with a calibration constant (determined in August 1975) of 0.2370 mgal div.$^{-1}$ at 30° C. The meter was not thermostatically

Fig. 1. Gravity station at Malo Creek, East Falkland.

controlled during the survey but the range of temperatures encountered was small, introducing a maximum possible error of 0.025 mgal.

The gravity base station at Stanley, previously established by Griffiths and others (1964) and Kennett (1965), was re-occupied whenever possible. With the exception of the gravity stations at Stanley, Beaver Island and Douglas Settlement, all others were located next to tidal waters at what was considered to be the maximum high-tide mark (Fig. 1). It is estimated that the error in elevation, including that due to local tidal variations, does not exceed 1.5 m; thus errors in the elevation correction should not exceed 0.35 mgal.

Terrain corrections were applied using the zone method of Hammer (1939) over the 1 : 250 000 Directorate of Overseas Surveys topographical maps. On West Falkland the terrain-correction values lay within the range of 0.5–0.8 mgal, while those on East Falkland were all less than 0.4 mgal.

The majority of stations were occupied on the north-east of East Falkland during a travel from Stanley to Laguna Lorenzo. The outward journey by Land Rover was over very irregular terrain and because of this the gravity meter assembly was initially placed in its shipping container inside a padded crate. However, this arrangement was found unsatisfactory, so for added stability the meter remained in its carrying case and was tended by the passenger. Static overnight drift averaged 0.012 mgal h^{-1} with a negative drift being recorded on one occasion. At one locality, overnight drift registered 2.7 mgal. This was omitted from the average drift calculation and was attributed to a reading jump, the meter having earlier suffered an exceptionally severe jolt. Overall travelling drift during this period averaged 0 mgal h^{-1}, which is perhaps a reflection of the uneven terrain traversed. The return journey to Stanley from Douglas Station was by aircraft.

Two shorter Land Rover traverses were also completed in East Falkland. One to the east of Stanley and the other, again over very rough terrain, north-west towards Green Patch

Settlement. Each was completed within a day with ties to Stanley base station. Drift rates were calculated at 0.024 and 0.054 mgal h^{-1}, respectively.

The authors were fortunate in being offered a flight to West Falkland, although gravity station occupations were governed by the particular flight schedule. The reading at Beaver Island was measured under adverse weather conditions with strong winds causing reading difficulties. However, the resulting Bouguer anomaly has been incorporated due to the isolated locality and must at present be used with caution. In addition to those stations occupied at aircraft landings, a short back-packing traverse was completed from Port Howard towards Fox Bay East. The original intention had been to operate east of the coastal ridge but severe weather prevented this and made it necessary to restrict sea-level measurements to those inlets where the sea had breached the ridge. The latter half of the traverse was completed by Land Rover. The West Falkland survey lasted 4 days, during which time the average travelling drift rate was 0.28 mgal h^{-1}.

Density determinations have been carried out on rock samples collected by Drs C. G. Smith and P. W. G. Tanner. The results are tabulated in Table I. In the Bouguer correction a density

TABLE I. DENSITY VALUES FOR ROCKS FROM THE FALKLAND ISLANDS

Stratigraphical age	*Rock type*	*Locality*	*Number of specimens*	*Mean dry density* (Mg m^{-3})	*Standard deviation*
Upper Lafonian Group	Siltstones, mudstones	Bleaker Island south	3	2.70	±0.02
Lower Lafonian Group	Siltstones, fine-grained sandstones (all slightly weathered)	Bluff Cove	4	2.53	±0.02
Devono-Carboniferous Group	Quartzites	Near Stanley	5	2.61	±0.02
Precambrian	Gneiss, schists, granites, acid pegmatites	Cape Meredith	15	2.56	±0.03
	Amphibolite	Cape Meredith	1	2.91	–
?	Coarse feldspathic grit	Beauchêne Island (lat. 52°53′S, long. 59°12′W)	2	2.52	–

value of 2.0 Mg m^{-3} was used, this being considered representative of the superficial deposits to sea-level.

The results of the survey are tabulated in Table II and the Bouguer anomalies, including those of McNaughton (1972), are plotted and contoured in Fig. 2. It is considered that the maximum error in Bouguer anomaly is less than ±0.5 mgal. Reference to marine gravity data (personal communication from P. Simpson) has allowed greater control to contour extrapolations.

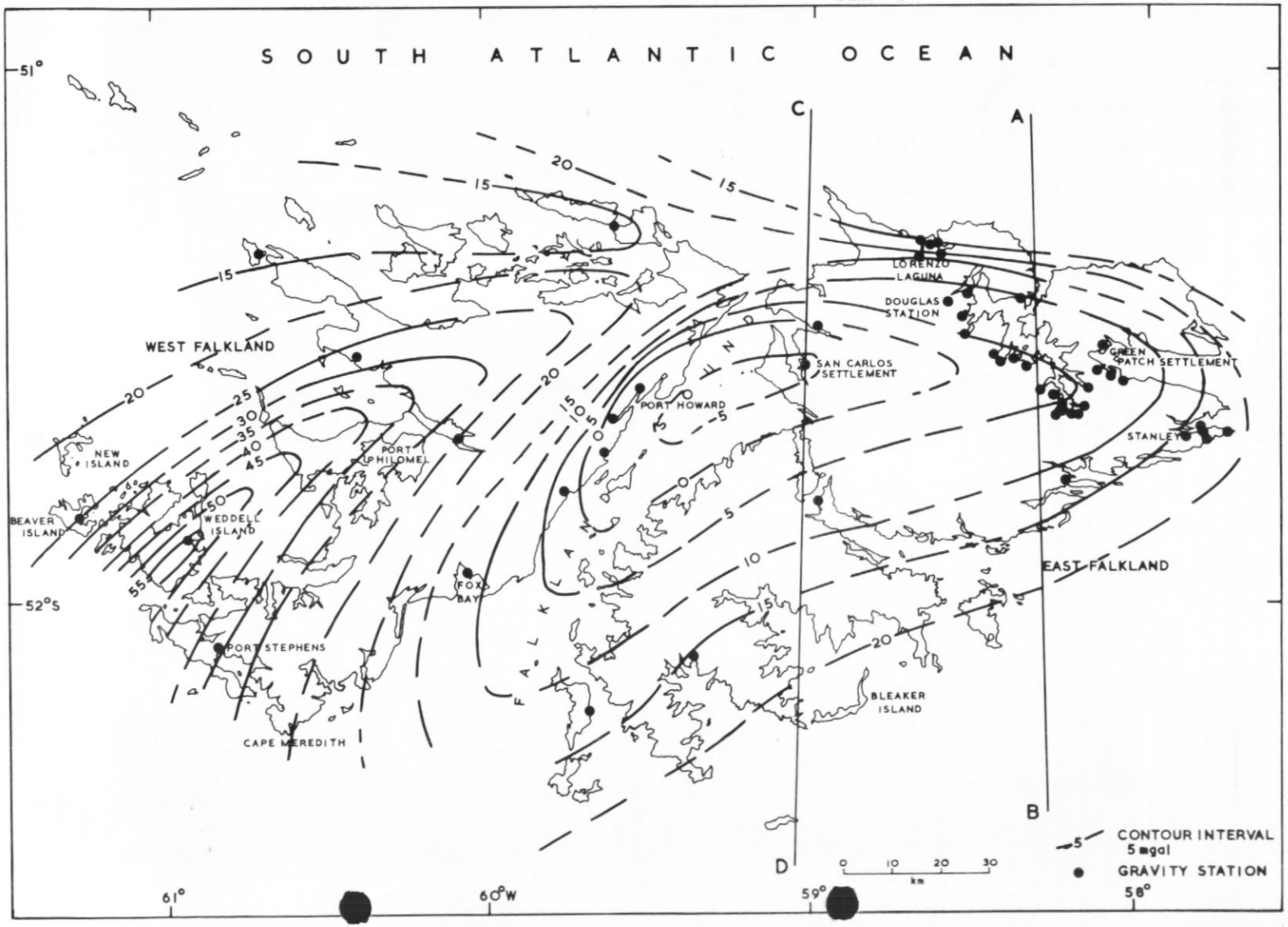

Fig. 2. Bouguer anomaly map of the Falkland Islands.

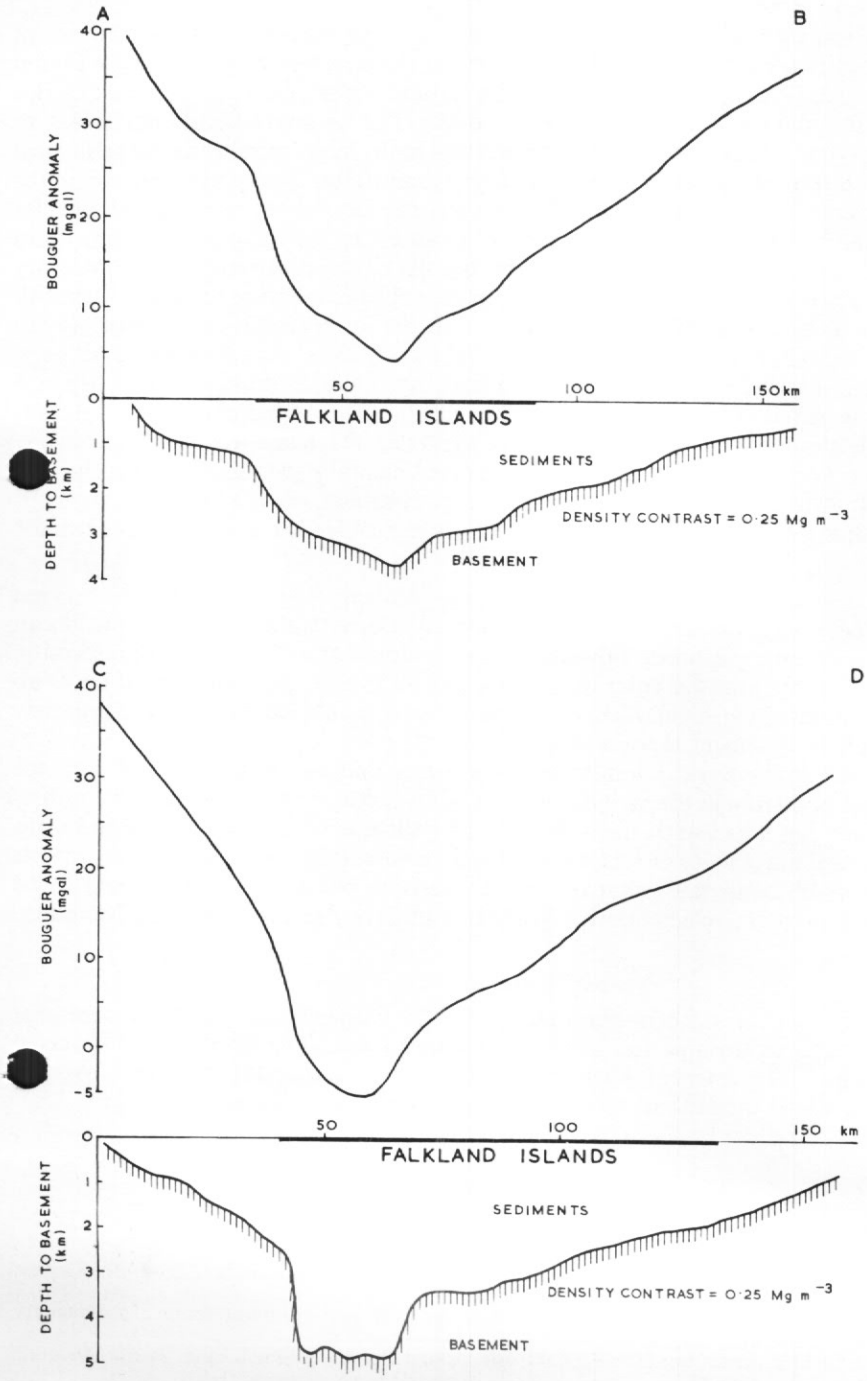

Fig. 3. Interpreted cross-sections along profiles AB and CD in Fig. 2.

Discussion

The absence of representative inland gravity values and the non-uniform distribution of stations occupied restricts contour interpolations to major regional trends. From the contoured Bouguer anomaly map (Fig. 2), a significant negative anomaly is seen centred over San Carlos Settlement on East Falkland and over Falkland Sound. The anomaly trends north-east to south-west and is asymmetrical with a steep north-western limb closely paralleling the geological grain along the western shore of Falkland Sound. Quantitative interpretation, using the two-dimensional iterative technique of Bott (1960), was carried out on north–south profiles AB and CD on the assumption that the anomaly is caused by an increase in sedimentary thickness over East Falkland. Selection of a suitable density contrast between the sedimentary and basement rocks was somewhat subjective because the densities measured at Cape Meredith are considered low and atypical of basement values. For the interpretation of marine gravity data to the south of the Falkland Islands, Davey (1972) incorporated the relationship between densities and seismic velocities. Using similar derived density values, a contrast of 0.25 Mg m^{-3} was selected for the initial model computation. The results (Fig. 3) indicate that maximum depths of sediments along profiles AB and CD are of the order of 3.8 and 4.8 km, respectively. The severity of the northern limb of the interpreted sedimentary sections may signify that faulting is present. Alternative solutions, using density contrasts of 0.2 and 0.3 Mg m^{-3}, give maximum depths to basement of 3.5–5.2 km for profile AB and 4.0–6.4 km for profile CD.

West Falkland is associated with a positive Bouguer anomaly which reaches an observed maximum of 56 mgal over Weddell Island. The anomaly closes to the north-east but it can be traced for considerable distances offshore to the south-west (personal communication from P. Simpson). Apart from the outcrop of basement rocks at Cape Meredith, there is no other indication of underlying higher-density material but it would appear that the anomaly must be attributable to basement topography.

The results suggest that several kilometres of sediments underlie East Falkland with the maximum thickness occurring in the vicinity of San Carlos Settlement. The western margin of the negative anomaly lies adjacent to the west coast of Falkland Sound, where a steep north-east to south-west striking gravity gradient confirms a rapid easterly thickening of sediments (Baker, [1924]), possibly with fault control. By comparison, West Falkland appears to be underlain by basement rocks which show a gradual southerly rise towards Cape Meredith.

Acknowledgements

The authors wish to express their gratitude to R. D. Clements for his encouragement and assistance throughout their period in the Falkland Islands. The invaluable help given by the Falkland Islands Government Air Service is also recognized and that of the Governor whose permission enabled the authors to use their time in Stanley to some advantage.

MS received 12 April 1978

REFERENCES

Baker, H. A. [1924.] *Final report on geological investigations in the Falkland Islands, 1920–1922.* Stanley, Government Printer.

Bott, M. H. P. 1960. The use of rapid digital computing methods for direct gravity interpretation of sedimentary basins. *Geophys. J. R. astr. Soc.*, **3**, No. 1, 63–67.

Brown, J. W. 1967. Jurassic dolerites from the Falkland Islands and Dronning Maud Land. *British Antarctic Survey Bulletin*, No. 13, 89–92.

Davey, F. J. 1972. Gravity measurements over Burdwood Bank. *Mar. geophys. Res.*, **1**, No. 4, 428–35.

Greenway, M. E. 1972. The geology of the Falkland Islands. *British Antarctic Survey Scientific Reports*, No. 76, 42 pp.

TABLE II. GRAVITY VALUES MEASURED IN THE FALKLAND ISLANDS, 1975
(Relative to gravity value at Stanley of 9.812433 m s^{-2} (Kennett, 1965))

Locality	*Station description*	*Lat. °S*	*Long. °W*	*Elevation* (m)	*Absolute value of gravity* (m s^{-2})	*Bouguer anomaly* (mgal)
WEST FALKLAND						
Port Howard	At settlement on shore alongside jetty	51°37.1′	59°31.1′	1.9	9.812168	−3.8
Port Howard	Southern end of Port Howard	51°40.4′	59°35.7′	1.9	9.812241	−1.4
Chartres	At settlement close by small landing jetty	51°42.8′	60°04.4′	1.9	9.812545	+25.2
Shag Cove	On coast close to Shag Cove House	51°44.3′	59°38.9′	1.9	9.812321	+0.9
Hill Gap	Western side of inlet breaching coastal ridge, 4 km north of Hill Gap Island	51°48.4′	59°45.1′	1.9	9.812432	+5.9
Beaver Island*	On jetty at Beaver Settlement	51°51.2′	61°14.5′	2.5	9.812664	+25.0
Fox Bay East	By gasoline tank between small and main jetties	51°57.3′	60°04.2′	1.9	9.812634	+12.7
EAST FALKLAND						
Stanley	Base station (Griffiths and others, 1964; Kennett, 1965)	51°41.5′	57°51.1′	4.24 (levelled to bench mark at Government jetty)	9.812433	+16.1
Sand Point	—	51°20.0′	58°40.3′	1.9	9.812206	+24.5
Limpet Creek	—	51°20.4′	58°37.5′	1.9	9.812239	+27.1
Limpet Creek	—	51°20.4′	58°38.2′	1.9	9.812236	+26.8
Limpet Creek	—	51°21.5′	58°36.9′	1.9	9.812226	+24.3
Laguna Lorenzo	On shore by Lorenzo House	51°22.4′	58°40.4′	1.9	9.812160	+16.4
The Moro	On shore north side of jetty	51°25.8′	58°31.1′	1.9	9.812152	+10.6
Douglas Settlement	Settlement manager's house	51°27.4′	58°36.4′	~17	9.812108	+7.2
Long Creek	Near junction with Angelina Ditch	51°28.8′	58°33.3′	1.9	9.812165	+7.6
Chata Creek	On track 10 m east of west bank	51°30.4′	58°31.6′	1.9	9.812173	+6.0
Teal Inlet	At ford 2 km north-west of settlement	51°32.8′	58°27.4′	1.9	9.812182	+3.4
Teal Inlet	At settlement on shore alongside jetty	51°33.1′	58°25.7′	1.9	9.812199	+4.7
Pot Rincon	—	51°33.9′	58°22.5′	1.9	9.812219	+5.5
Pot Rincon	—	51°34.3′	58°20.8′	1.9	9.812221	+5.0
Corral Pass Creek	—	51°34.4′	58°08.0′	1.9	9.812231	+6.0
Duberrey Harbour	—	51°35.1′	58°06.2′	1.9	9.812241	+5.9
Uranie Bay	Where track approaches shore	51°35.5′	58°03.5′	1.9	9.812250	+6.3
Green Hill	By cattle pen at inlet 1.3 km south of Green Hill	51°36.7′	58°08.3′	1.9	9.812258	+5.4
Malo Creek	At creek by fishing hut	51°37.1′	58°18.3′	1.9	9.812246	+3.5
Malo Rincon	—	51°37.4′	58°16.7′	1.9	9.812260	+4.5
Sparrow Rincon	Midway along eastern shore opposite The Tarbarrel	51°38.3′	58°14.1′	1.9	9.812291	+6.2
Estancia Brook	—	51°38.6′	58°10.1′	1.9	9.812294	+6.2
Estancia	North-east corner post of cattle pen at Estancia House	51°38.6′	58°10.5′	1.9	9.812304	+7.2
Rumford Brook	Southern side of ford	51°39.3′	58°14.1′	1.9	9.812319	+7.7
Long Creek	Western side of ford	51°39.6′	58°11.7′	1.9	9.812324	+7.7
Corral Creek	South-west shore	51°39.6′	58°13.0′	1.9	9.812327	+8.0
Rumford Creek	At stream junction	51°39.7′	58°16.6′	1.9	9.812320	+7.2
Yorke Bay	Gypsy Cove	51°40.5′	57°48.2′	1.9	9.812425	+16.1
Cape Pembroke	On old jetty near lighthouse	51°40.9′	57°42.8′	1.9	9.812455	+18.5
Port Stanley	At east end of harbour, on shore near wreck of *Princess Elizabeth*	51°41.3′	57°47.8′	1.9	9.812443	+16.6
Surf Bay	By rock pile midway between Hookers Point and track	51°41.9′	57°46.5′	1.9	9.812459	+17.5

* Strong winds causing instrument instability, therefore possible reading inaccuracies.

[face page 142

GRIFFITHS, D. H., RIDDIHOUGH, R. P., CAMERON, H. A. D. *and* P. KENNETT. 1964. Geophysical investigation of the Scotia arc. *British Antarctic Survey Scientific Reports*, No. 46, 43 pp.

HAMMER, S. 1939. Terrain corrections for gravimeter stations. *Geophysics*, **4**, No. 3, 184–94.

KENNETT, P. 1965. Revision of gravity links between South America and the Antarctic. *British Antarctic Survey Bulletin*, No. 7, 25–28.

MCNAUGHTON, N. C. 1972. Gravity survey of the Falkland Islands. (*In* GREENWAY, M. E. The geology of the Falkland Islands. *British Antarctic Survey Scientific Reports*, No. 76, 39–42.)

REX, D. C. *and* P. W. G. TANNER. In press. Precambrian age for gneisses at Cape Meredith in the Falkland Islands. (*In Third Symposium on Antarctic Geology and Geophysics*. Madison, Wisconsin, 22–27 August 1977.)