UPLIFT MOVEMENTS IN KING GEORGE ISLAND ASSOCIATED BRANSFIELD RIFT ACTIVITY

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Abstract: The results of gravimetry campaigns carried out in Punta Arenas and Teniente Marsh Station are presented. This work has been accomplished since 1980, utilizing two gravimeters LaCoste and Romberg, model G411 and G64. The measurements made in 1983 and in 1987, yielded a negative difference of 107 µgal. Therefore we think there has been a rise in the South Shetland Island Block due to the fitting process and to eustatic movements. If we suppose that this change shows just a shift in elevation, i.e. variations in the free-air anomaly, there would be an average elevation change of about 35 cm. Magnitudes of these movements would agree with the active tectonism that affected the Bransfield region.

Key words: Bransfield Strait, rift, uplifting, gravity, tectonics

Introduction

The main purpose of precise gravimetry measurements is to investigate changes in gravity and to correlate them with evolutionary dynamics occurring, in this case, at the Bransfield Rift. These measurements were carried out since 1980 at the Chilean Teniente Marsh Antarctic Station, as part of the “Secular variations in gravity of Nazca, South America and Antarctic plates” project.

Surveys started in April 1980, with the LaCoste and Romberg gravimeter model G411. Later on, in October 1981, measurements were carried out with two gravimeters, models G411 and G64, with the purpose of establishing three first-order gravity acceleration basis stations at Teniente Marsh Station. They were considered preliminary since “g” at closure was not within the allowed error for the present kind of studies. It is worthwhile mentioning that the closure error was $g = 0.6 \mu\text{gal}$ (gravimeter G411). For that reason, the obtained data were not included in the gravity network adjusting program. This closure error may have originated during transportation; the instrument (on the seat of a Hercules C-130 aircraft), was without additional damping and hence, subjected to uncontrolled vibrations. In the case of precise gravity measurements, necessary cautions have to be considered to prevent this type of error (i.e. to assign only one gravimeter per operator).

This experience was taken into account during the October 1983 (Araneda, 1985) and October 1987 field seasons.

Gravity Measurements

They were carried out during a period of four years, in the same month (October), a necessary caution for this type of measurements, since existing conditions, such as ice masses, which could have some effect on the measurements should not present error due to additional masses or absence of them. Figure 1 shows the area possibly involved in the discussed uplift.

Instruments used in the last two campaigns (1983 and 1987) were LaCoste and Romberg gravimeters, one belonging to the Department of Geophysics of the University of Chile (G411) and the other one on loan from the Interamerican Geodetic Survey (G64). Both were re-calibrated in July 1983 and December 1987, respectively, by the manufactures.

These calibrations were carried out shortly before the 1983 campaign. Later on, for measurements to be taken in 1987, the instruments were fixed at the gravity control base stations, allowing the determination of the scale constants for the range of approximately 1000 µgal.

Scale factors of 1.00049 and 0.99925 were used for gravimeters G411 and G64, respectively.

Network adjustment were carried out with the above data, yielding the following values for the vertical gravity component in 1983 and 1987 (Araneda and Avendaño, 1987).

For the adjustment of Marsh Station data, the values of Puerto Montt and Punta Arenas were taken as reference (see Fig. 2, gravity stations) and were kept invariable during the last four years. Another favorable feature is the steadiness of the reference base stations, as well as the Antarctic one. The latter was fastened on a concrete support founded on bedrock. The values determined at Puerto Montt and Punta Arenas were:

<table>
<thead>
<tr>
<th>Locality</th>
<th>Code</th>
<th>Station</th>
<th>Gravity value µgal</th>
<th>Determined Lat.</th>
<th>Long.</th>
<th>Height (m)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puerto Montt</td>
<td>PMC</td>
<td>J</td>
<td>980282253</td>
<td>41° 25.9'S</td>
<td>73° 05.7'W</td>
<td>81.0</td>
<td>1981</td>
</tr>
<tr>
<td>Punta Arenas</td>
<td>PUQ</td>
<td>J7915</td>
<td>981297591</td>
<td>53° 00.5'S</td>
<td>70° 50.8'W</td>
<td>35.9</td>
<td>1981</td>
</tr>
</tbody>
</table>

It is worthwhile mentioning that in order to obtain accurate measurements in both campaigns, normal monthly records were established for sensibility and transverse level. Figure 3 shows the gravity variation at Marsh Station.

**Genesis of the Bransfield Rift**

For thorough comprehension of the dynamic processes, evolution and age of the Bransfield Rift and its relation to gravity changes associated with vertical uplifts, some characteristics of its evolution are summarized according to available geological and geophysical data taken from field work and current literature. Figure 4 shows the fundamental features of the Bransfield Rift tectonics following González-Ferrán (1991).

It has been mentioned that the extensive back-arc cycle is characterized by a longitudinal faulting associated with vertical movements, favoring the development of a differential block tectonics and the formation of a graben or longitudinal valley in the Bransfield Strait. In the latter case, it would have reached about 100 km in width, forming an opening towards the sea and the strait, coinciding with the graben postulated by Aschoft (1972). This process was similar to the block tectonics originating the mountain chain called Cordillera de la Costa, the Central Valley and the blocks of the Andean Cordillera in Chile.

The Bransfield region (González-Ferrán, 1985) was affected by a longitudinal faulting, developed in asymmetric and overlapping segments with respect to the axis of the strait, associated with volcanism of the rift. Its extension are bounded by the Hero and Shackleton fracture zones. These differential movements would have generated the main morphological features of regions such as the Antarctic Peninsula and South Shetland Islands. These uplifts have been associated, in turn, with the eustatic movements generated by the loss of the glacial cover and major vertical movements produced by the rift tectonics itself. As the change in gravity would suggest, during the last four years, there was at least a local uplift of 35 cm of the South Shetland block. This process is also evidenced by the existence of uplift (22.6 m) marine terraces along the coast of the South Shetland Islands (Araya and Hervé, 1972; López-Martinez et al., 1991). Aschoft (1972) estimated a thickness of 14 km for the Bransfield crust. This fact, the continuity of the extensive process, the thickness of the continental crust and the proximity of asthenospheric material would have generated a zone of weakness which favored the breaking up and the beginning of the activity at the rift (González-Ferrán, 1985).

Weaver et al. (1982) suggested that the movement by which the rift would have begun could have occurred about

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*Fig. 1. Geographic location of the study area and uplifted region.*
two million years ago. On the other hand, González-Ferrán (1985) held that the width of the rift varies between 5 and 15 km, and according to this, the gathered data, and the continuous tectono-volcanic activity up to present times, the expansion velocity of the rift could range between 0.25 and 0.75 cm/y within the last two million years (González-Ferrán, 1991).

Renner et al. (1985) remarked that, starting from the northeastern narrowing, there is a series of positive gravimetric anomalies which could correspond to volcanic centers composed of rocks with a higher density than the surrounding ones. Parra et al. (1984) pointed out aeromagnetic anomalies in the same zone. This information, together with data contained in bathymetric charts of the Bransfield allow to suppose the existence (González-Ferrán, 1991) of a volcanic submarine chain, composed at a series of oceanic shield type volcanoes. Some of these volcanoes have risen above the sea level, as is the case of Deception, Penguin and Bridgeman islands. These volcanoes are located on échelon-like blocks, generated by differential tectonics. At the same time, they were fed by hot spots, within the system of dike injections, activated by the rift expansion process.

The same author estimated a volume of 235 km$^3$ for those eruptive centers (Deception and Bridgeman islands and the
submarine volcano “Orca”) respectively, considered as the largest ones of the area. In the same way, this author also postulated that petrologic and geochemical characteristics of the submarine volcanoes would be essentially alkaline basic lavas, similar to those recognized for the above mentioned islands.

The Bransfield Strait Active Dynamics

Considering that the formation of the Bransfield Rift and magmatic processes have occurred during the last two million years mentioned, as by Weaver et al. (1982), there is also the historical volcanic activity registered at Deception Island (Baker et al., 1975) and Penguin Island (González-Ferrán and Katsui, 1970) and recent observations of seismic and volcanic activity. Ortiz et al. (1991) postulates that the study of Deception Island should not be separated from the Bransfield rift context, since seismic events are temporally grouped in zones, and generally aligned according to the direction of main NE-SW structures. It has been estimated that volcanic activity along the Bransfield is still in development, and therefore different tectonic events as eruptions in Deception Island, important seismic and vertical and horizontal displacements of the different existing tectonic units can still be observed at present.

Another parameter studied related to the active dynamics of the Bransfield Strait is the variations of heat flow in the King George Basin of the Bransfield Strait; Lawver and Nagihara (1991) show values between ~50 and 600 mWm⁻² that are generally high and significant variations. The highest values are in the central part of the basin along the southeastern edge of the basin, in contrast to the values in the west and northeastern part of the basin where they are generally lower. These values support the idea that active hydrothermal circulation depletes the normal convective heat transfer near the linear volcanic line postulated by Lawver and Nagihara (1991). These data reinforce the idea of strong, internal dynamic activity in the Bransfield Strait at present. The study of variations of the vertical component of gravity associated with the vertical displacement could show a clear reactivation of the region, since in a period of four years an uplift of about 35 cm has taken place.

Conclusions

Information obtained by the survey of changes in the gravity field and its relation with changes in height occurring at King George Island, South Shetland, is no doubt valuable contribution to the study of dynamic processes at the rift. The possibility to qualify uplifts and subsidence in regions of difficult access is always very expensive and slow. To study the evolution of this type of phenomena, it is desirable to use geodetic measurements, but, in most cases, this is not possible in the Antarctic.

The methodology used in this study is both adequate and expeditious when logistic air support is available, as was the case of the Chilean Air Force collaboration during the present investigation. It is important to analyze the result of the gravimetric network adjustment in its reliability. Measurements carried out with the type of G model gravimeters used may include

Fig. 3. Gravity variations at the Teniente Marsh Station, Chile.

Fig. 4. Interpretative map obtained from the total field aeromagnetic map (after González-Ferrán, 1991).
errors of up to 25 \mu gal. This value may increase due to data adjustment, since the used gravimetric network has a standard deviation of 40 \mu gal. In this case, the values would be below the calculated figure (107 \mu gal), still indicating a positive uplift of the study area.

Finally, the referred 35 cm uplift seems to be too high for the period of time of the investigation and should be considered as possibly temporary. For example values may become high before a seismic adjustment event occurs, the subsequent decrease can be an important percent of the change and occur within a relatively short time after the highest value has been reached. This has occurred in historical times along the Chilean southern coast, in association with the earthquakes of 1960 (Plafker and Sabage, 1970) and 1985 at the central coast of Chile (Araneda and Avendaño, 1991).

REFERENCES


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