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Analysis of Digital Waveforms Recorded at the Seismographic Station Esperanza

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Abstract - The evolution and structural properties of the Scotia region are extremely complex, as a result of the interaction of the Antarctic and South-American plates with at least four other minor plates (Scotia, Sandwich, Shetland and Drake). The area is characterized by high seismicity, concentrated along the plate margins with events of magnitude greater than 7. For this reason the methods of quantitative seismology are the most appropriate. They are also economically valid for the investigation of the structural characteristics of this area. The need for high-quality data, recorded by broad-band seismographic stations located in the region has induced OGS (Osservatorio Geofisico Sperimentale) and IAA (Instituto Antartico Argentino) to install a three component broad-band station in the Antarctic Argentinian Base Esperanza. It represents the first acquisition point of a network composed of five stations, which we plan to complete in 1996, in Antarctica, Tierra del Fuego, and the islands distributed along the margins of the region under study. The project is included in the *Programma Nazionale di Ricerche in Antartide* activities. For the construction of the complete network, the cooperation will be extended to the British Antarctic Survey and to the scientific institutions of the other countries, which are interested in the study of the region. The three-component station Esperanza has produced records which are extremely important for the definition of the best analysis methods to be applied to the data that will be collected. The tests, based on surface wave dispersion analysis, which require the availability of very good quality data, have been very successful. In fact, even if we now have available only data recorded by a single station, we have obtained some relevant information on the large-scale structure of the lithosphere, that gives us essential guidelines for the future developments of the project. As a consequence the modular development of the research activities, imposed by the logistics, is not conflicting with the goal of determining lithospheric structure.

INTRODUCTION

The very interesting geological, structural and dynamic evolution themes involved in the study of the Scotia Region have induced many international scientific institutions to focus a relevant part of their research activity on the Scotia arc (Dalziel, 1984).

The Scotia arc is formed by a group of submarine ridges and volcanic islands (South Sandwich Is.) closed to the East (Fig.1) which connects the southernmost South America to the Antarctic Peninsula. In the Scotia arc region at least four small plates interact among themselves and with the two major plates of South America and Antarctica (Barker & Dalziel, 1983). As a consequence, an intense seismic activity, associated with subduction phenomena in the South Sandwich trench area, is originated (Fig. 2).

Several earthquakes of magnitude 7 and more have been observed. A less intense seismic activity is observed along the transcurrent margins of the North and South Scotia ridges, that join the South Sandwich Is. to Tierra del Fuego and to the Antarctic Peninsula. A diffuse seismicity is evident also in the area West of the Drake passage (Pelayo and Wiens, 1989).

Because of this evidence, the methods of quantitative seismology (seismometry) appear to be a particularly suitable approach, also from a cost point of view, to increase the knowledge of the main structural characteristics of this area.

The study of the evolution and the investigation of the structures of the Scotia arc, within the wider and general framework of the Periantarctic and the Antarctic plate margins, on the basis of quantitative seismology data, requires the availability of a suitable seismological data base, which can be constructed only with the installation of a digital broad-band seismographic regional network. The seismological data base will of course be integrated with the data collected using other geophysical methods.

THE SCOTIA ARC BROAD-BAND SEISMOGRAPHIC NETWORK

The Osservatorio Geofisico Sperimentale (OGS) with the help of contributions already made by the Instituto Antartico Argentino (IAA), and the future contributions to be made by British and Spanish scientific institutions working in the Antarctic region has prepared a project for a seismographic digital network which will consist of five broad-band stations in Base Esperanza (Antarctic Peninsula, already operative), Tierra del Fuego (Ushuaia area), and on the islands limiting the Scotia Sea (South Orkney Is., South Georgia Is., South Sandwich Is.). This network will also be an important contribution to the Seismographic Antarctic Network (Fig. 3).

The OGS seismological research activity in Antartica

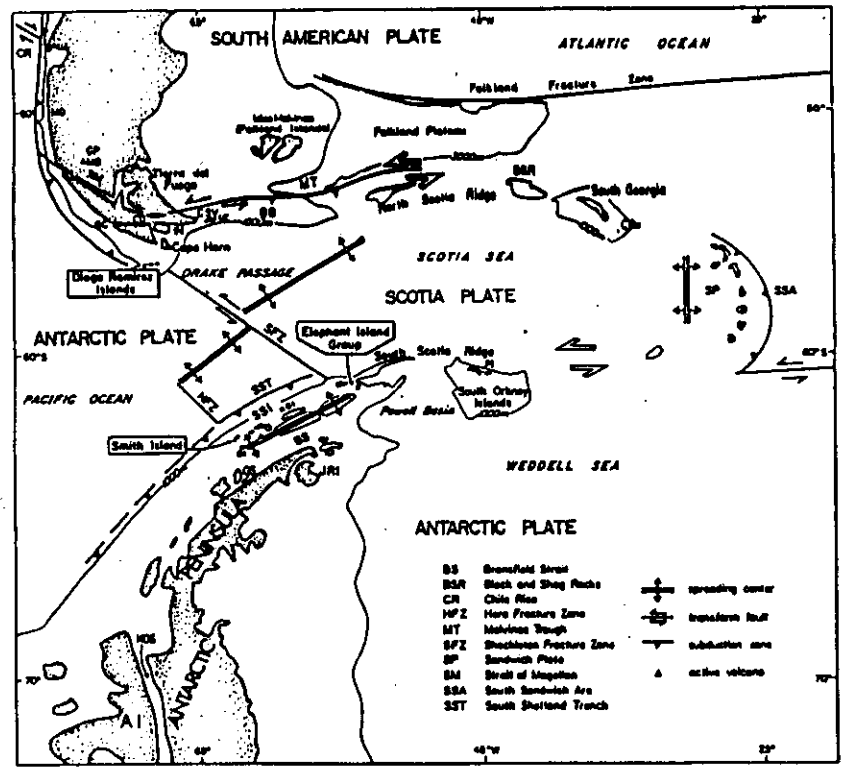

Fig. 1 - Simplified map of the Scotia arc region showing main tectonic boundaries (from Dalziel 1984). AI-Alexander Island; BB-Burdwood Bank; BC-Beagle Channel; CD-Cordillera Darwin; CP-Cerro Paine; CRx-Clerke Rocks; CSV-Cabo San Vicente; DI-Deception Island; GS-Gerlache Strait; IE-Isla de los Estados; IN-Isla Navarino; JRI-James Ross & Seymour Islands; KGI-King George Island; KGS-King George VI Sound; MB-Monte Burney; MD-Madre de Dios Archipelago; PI-Powell Island; SSI-South Shetland Islands.

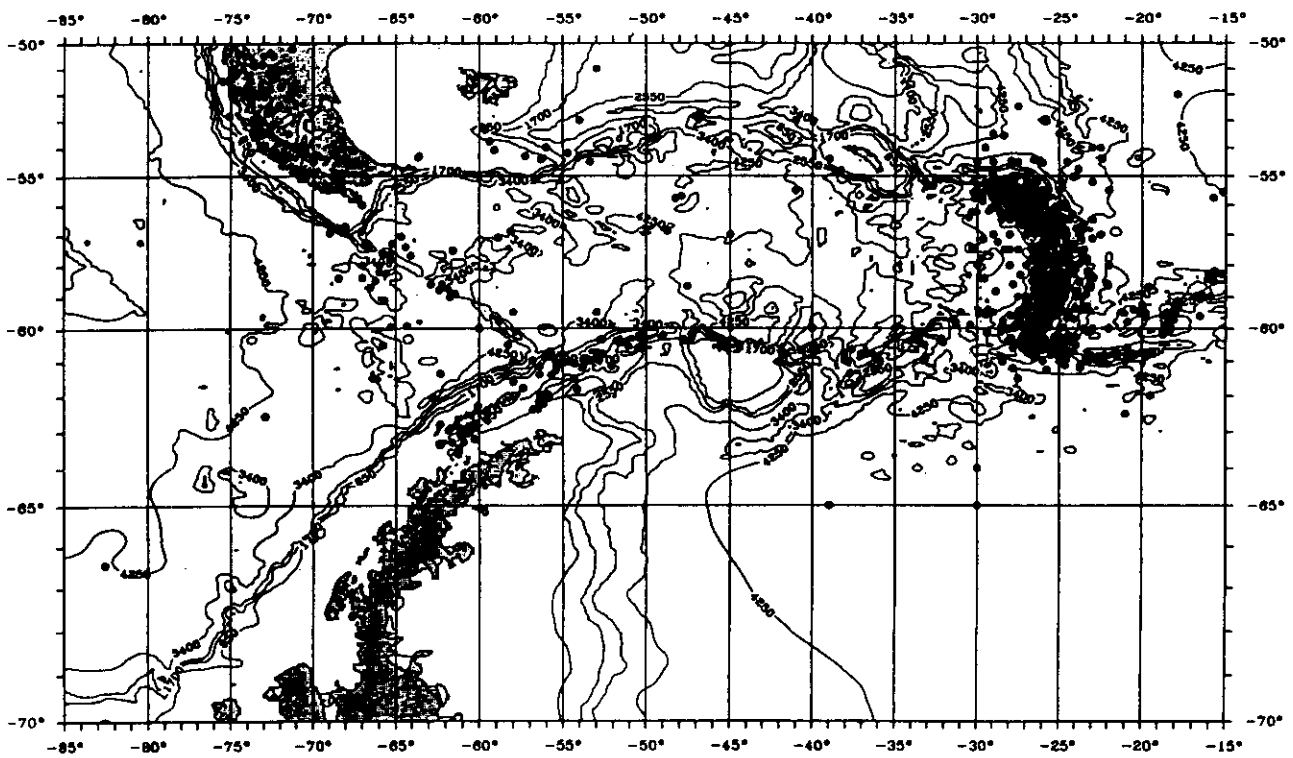

Fig. 2 - Scotia arc seismicity map: events from 1907 to 1988 (USGS/NEIC Global Hypocenter Data Base, Version 1.0). Depth in meters.

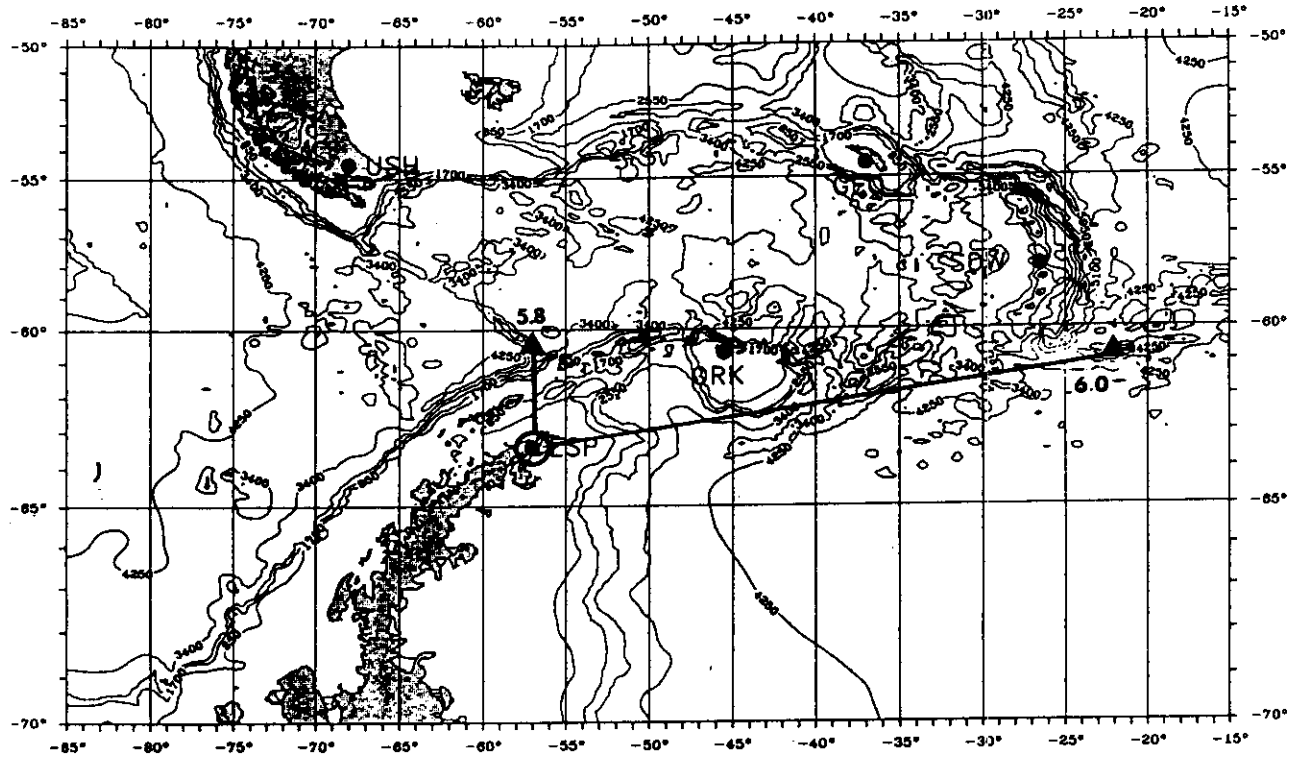

Fig. 3 - Scotia arc Broad-Band Seismographic Network project. ◉ Esperanza station; ● planned stations; ▲ Analyzed events recorded by Esperanza station. Depth in meters.

and surrounding areas is carried out as part of the Italian *Programma Nazionale di Ricerche in Antartide* (PNRA) and contributes to several international scientific projects.

We quote, as an example, the Three-Dimensional Modelling of the Earth's Tectosphere (3DMET), Project II-4 of the International Lithosphere Program (ILP) of the Inter-Union Commission for the Lithosphere (ICL). The goal of the 3DMET project is the three-dimensional mapping of the lithosphere and astenosphere, and of seismic sources, in selected regions of the Earth, one of them being Antartica.

THE BASE ESPERANZA SEISMOGRAPHIC STATION

The first observation point of the Scotia arc network was materialized during the Antarctic Summer 1991-1992 in the Argentinian Antarctic Base Esperanza where a broad-band three-component station, with PDAS-100 acquisition system, and three broad-band BB13 Teledyne Geotech seismometers (supplied by the PNRA), was put into operation (Fanzutti et al., 1992).

We have used continuous recording of the seismic signals using three primary channels recording at a rate of 2 samples per second and three secondary channels recording at a rate of 0.2 samples per second. Timing is provided through the PDAS-100 internal clock. The limitation in the sampling rate is due to the limited amount of storage available. In these conditions the recovery of the data has to be done every three days.

The station coordinates are:

Lat.: 63° 23' 53" S Lon.: 56° 59' 47" W Height: 32 m

Argentinian army personnel takes care of the Esperanza Base throughout the year. The maintenance of the instrumentation, backup and data transmission to IAA and OGS is the responsibility of an IAA technician who is living at the Base.

FREQUENCY TIME ANALYSIS AND DATA INTERPRETATION

Several events at regional and teleseismic distances have been recorded. The two analyzed events directly sample the area of the Scotia arc (Fig. 4, 5 and Tab. 1).

Some tests on the data quality have been performed applying the method of the Frequency Time Analysis to these events. The method is fully described in Levshin et al. (1972), Keilis-Borok (1989) and Craglietto et al. (1989).

In figure 6 and figure 7 the results of the analysis of event n°1, located 335 km from the Esperanza station and of event n°2, located 1831 km from the Esperanza station, are shown. The dispersion curves (group velocity) of the fundamental mode of Rayleigh waves, derived from the experimental data, for both events are shown in Fig. 8 together with "standard" dispersion curves for shallow oceanic, deep oceanic and continental paths.

The group velocity curve for event 1 seems to indicate the presence of the continental crust between Esperanza and the epicenter. This is in good agreement with the fact that most of the path crosses the continental platform (Fig. 3). For the second event the comparison is not so easy. The identification of an oceanic path is less clear-cut at short periods and this is due to the probable

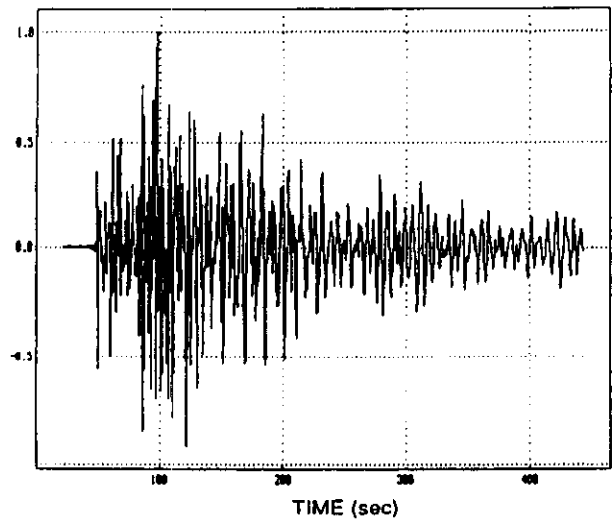

Fig. 4 - Vertical component of event of June 17, 1992, South Shetland is. area. Normalized amplitude.

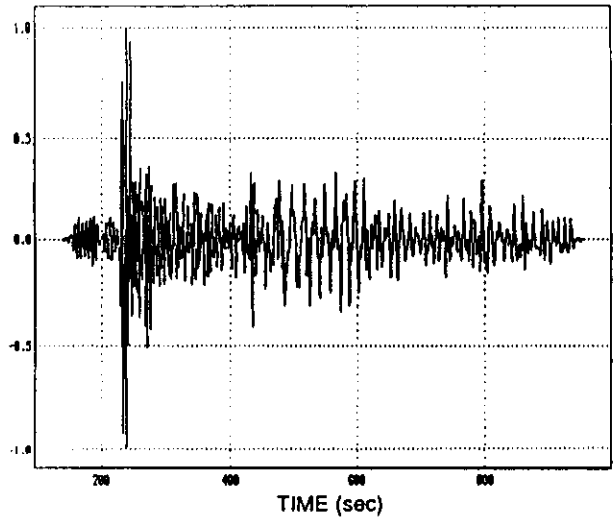

Fig. 5 - Vertical component of event of June 22, 1992, South Sandwich is. area. Normalized amplitude.

Tab. 1 - Data from preliminary determination of epicenter (monthly listing), National Earthquake Information Center.

Date	Time	Lat.	Lon.	Mb	Area
1 jun 17,1992	8:39:15.4	60.373 S	57.074 W	5.8	(South Shetland is. area)
2 jun 22,1992	4:00:41.0	60.728 S	21.969 W	6.0	(SW Atlantic, in proximity of South Sandwich is.)

presence of a sedimentary cover thicker then the one given in the standard oceanic structure (Harkrider, 1970) on top of an oceanic crust overlain by about 2 km of water.

The data actually available do not allow us to make any further elaboration now, but with the extension of the network in space, and of the time interval of observations, we will produce a considerable amount of dispersion relations, that will permit the regionalization of the different paths (Yanovskaya,1984; Yanowskaya et al., 1988; Yanovskaya et al. 1990).

Subsequently the regionalized dispersion curves will be inverted using linear and non-linear inversion schemes (e.g. Knopoff & Panza, 1977; Panza 1981) that will permit the delineation of the main features of the lithosphere-asthenosphere system in the studied area. Once the complete network will be operating we will apply to the collected data the specialized software, presently developed within the framework of 3DMET, which makes use of Connection Machines and permits the complete three-dimensional modeling of waveforms.

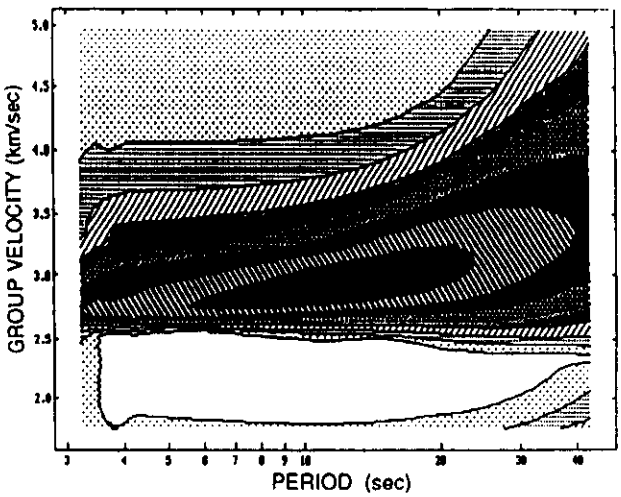

Fig. 6. -Spectral amplitude contoured as a function of period and group velocity for event 1 of table 1.

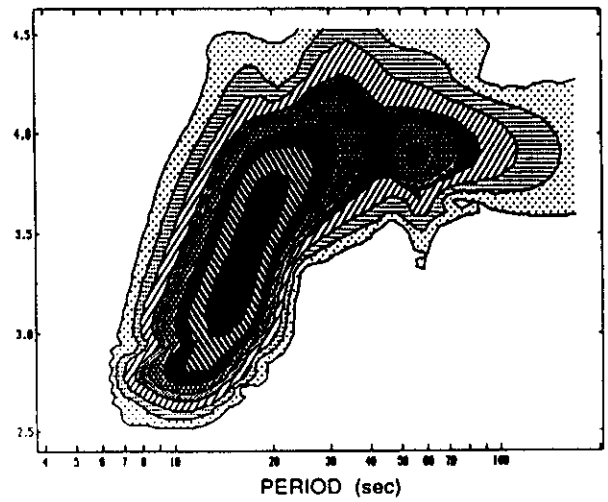

Fig. 7 - Spectral amplitude contoured as a function of period and group velocity for event 2 of table 1.

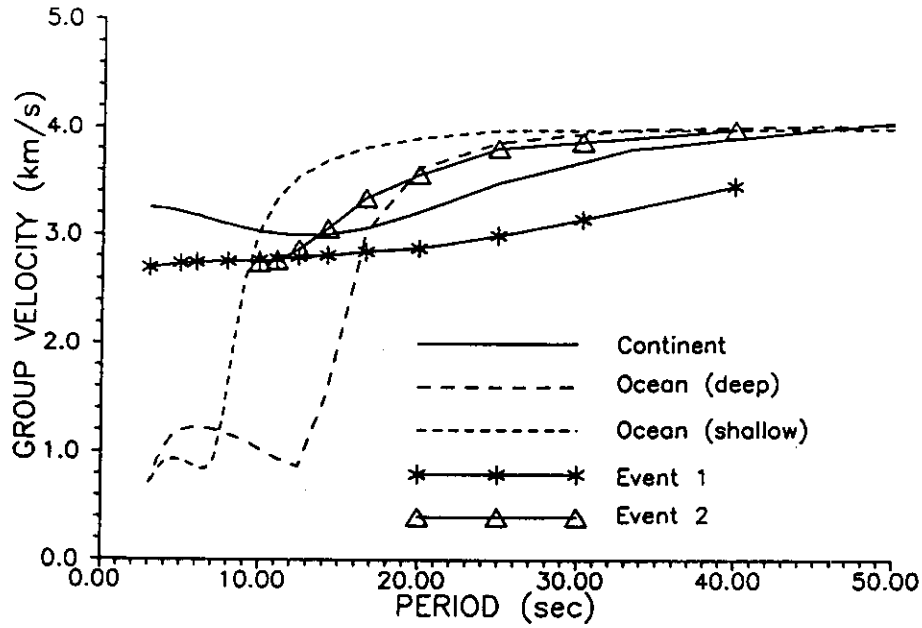

Fig. 8 - Dispersion curves for the events of table 1 in comparison with standard oceanic and continental curves.

CONCLUSIONS

The data recorded at Esperanza during the first five months of operation have produced very important information both for scientific purposes and for the choice of the appropriate methodological approach to be used in the analysis of data. This, in turn, has given us extremely valuable information for defining the necessary logistic and instrumental improvements.

The tests made with the application of the Frequency Time Analysis demonstrate very clearly that the quantitative seismology approach allows to very important information to be obtained on the large scale structure of the lithosphere, even using data recorded by a small number of stations. This property of the methodology we have used is particularly suitable in areas of difficult access, like the one under investigation. The other main benefit of the methodology we have used is the possibility to develop the research project in a modular way both from an instrumental and from an interpretational point of view.

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REFERENCES

Barker P.F. & Dalziel, I.W.D., 1983. Progress in geodynamics in the Scotia arc region. In: R. Cabre (Ed.), *Geodynamics of the Eastern Pacific Region, Caribean and Scotia arcs., Geodynamics Series*, American Geophysical Union, Vol. **9**, 137-170.

Craglietto A., Panza G.F., Mitchell B.J. & Costa G., 1989. Anelastic properties of the crust in the Mediterranean area. *American Geophys. Union, Geophys. Monograph*, **51**, IUGG Vol.6, 179-196.

Dalziel I.W.D., 1984. The Scotia arc: an international geological laboratory. *Episodes*, 7, 3, 8-13.

F. Fanzutti, J.M. Febrer, D. Nieto Yabar & M. Russi, 1992. Installazione di una stazione sismica e una gravimetrica alla base argentina Esperanza. Programma Nazionale di Ricerche in Antartide. *Rapporto sulla Campagna Antartica Estate Australe 1991 - 92*, ENEA, Roma.

Harkrider, D.G., 1970. Surface waves in multilayered elastic media. Part II. Higher mode spectra and spectral ratios from point sources in plane layered elastic model. *Bull. Seis. Soc. Am.*, **60**, 1937-1978.

Keilis-Borok V.I., 1989. *Seismic surface waves in a laterally inhomogeneous Earth*. Edited by Keilis-Borok, Kluwer Academic Publishers.

Knopoff L. & Panza G.F., 1977. Resolution of upper mantle structure using higher modes of Rayleigh waves. *Ann. Geof.*, **30**, 491-505.

Levshin A.L., Pisarenko V.F. & Pogrebinsky G.A., 1972. On a frequency - time analysis of oscillations. *Annales geophys.*, Vol. **28**, 211 - 218.

Panza G.F., 1981. The resolving power of seismic surface waves with respect to crust and upper mantle structural models. In: R. Cassinis (Ed.), *The solution of the Inverse problem in Geophysical interpretation.*, Plenum Pub. Corp., 39-77.

Pelayo A.M. and Wiens D. A., 1989. Seismotectonics and relative plate motions in the Scotia sea region. *J. Geophys. Res.*, **94**, B6, 7293-7320.

Yanovskaya. T. B., 1984. Solution of the inverse problem of seismology for laterally inhomogeneous media. *Geophys. J. Roy. astr. Soc.*, **79**, 293-304

Yanovskaya T.B., Maaz R., Ditmar P.G. & Neunhoefer H., 1988. A method for joint interpretation of the phase and group surface waves velocities for estimation of lateral variations of the Earth's structure. *Phys. Earth Planet. Inter.*, **51**, 59-67.

Yanovskaya T.B., Panza G.F., Ditmar P.G., Suhadolc. P & Mueller St., 1990. Structural heterogeneity and anisotropy based on 2-d phase velocity patterns of Rayleigh waves in Western Europe. *Atti Accad. Naz. Lincei*, **1**, 127-135.