BRAZILIAN RESEARCH IN EXTREME ENVIRONMENTS: NEW PERSPECTIVES FOR INTEGRATED BIOLOGICAL AND GEOLOGICAL ACTIVITIES

*Campos, L.S.; **Gamboa, L. P.; *Lavrado, H.P.; & ***Falcão, A.P.C.

* Universidade Federal do Rio de Janeiro,CCS, Instituto de Biologia, Av Pau Brasil, 211, Cid. Universitária, Ilha do Fundão, Rio de Janeiro-RJ, CEP 21941-590, Brazil, e-mails: campos-lucia@biologia.ufrj.br; hpasseri@biologia.ufrj.br

** Petróleo Brasileiro S.A. E&P IABS, AV. Chile 65, 1301, Centro, Rio de Janeiro,RJ, CEP 20031-912, Brazil e-mail: gamboa@petrobras.com.br

*** Centro de Pesquisas e Desenvolvimento (CENPES), PETROBRAS, Cid. Universitária, Ilha do Fundão, Rio de Janeiro-RJ, CEP 21949-900, Brazil, e-mail: apfalcao@cenpes.petrobras.com.br

Abstract

Extreme sea environments are considered here as those that are difficult to access and mostly require high technology logistics for any research work to be undertaken, i.e., mainly the deep sea and polar regions. Approximately 80-90 % of the oceans have over 3000 m water column (Gage & Tyler 1991), and most ecosystems within this large area are still to be investigated in more detail. The main ecosystems of these extreme environments include the continental margins, seamounts, abyssal plains, ocean ridges, hydrothermal vents and cold seeps.

Brazilian activities in the deep sea and the southern polar region have been financed partially or completely by national agencies, and are fairly recent (just over 23 years). Petrobras, the Brazilian Oil Company has played a major role in stimulating these activities.

The first biological reports on bathyal and abyssal fauna from Brazil were obtained at the end of the nineteenth century through the Hassler, Challenger and Albatross expeditions (Tavares 1999). The number of deep-sea stations accomplished by these was very limited, and since then until the 1980's the rare deep-water samples had only an occasional and qualitative character. Only in 1987, a Franco-Brazilian Expedition MD55 carried out a series of deep-water biological samples in the South Atlantic off the southeastern Brazilian slope from 200 to 5155 m depth. This was to track the faunistic evolution from Cabo Frio, where the upwelling of sub-Antarctic water occurs, to the Abrolhos Continental Slope situated at the limit of tropical coralline ecosystems (Tavares 1999). Still in the late 1980's an integrated research programme off São Paulo state down to 600 m generated information on the slope faunistic composition (Sumida & Pires-Vanin 1997). Other biological programmes occurred from the mid to late 1990's, covering especially the S, SE, and NE Brazil: mainly the "Talude" Programme, Brazilian-German JOPS II, PADCT-2, and the Brazilian EEZ (REVIZEE). Recent cruises from the REVIZEE programme sampled pelagic and benthic fauna from the margin of the continental shelf down to 2000 m (Lavrado et al 2003).

Petrobras began its deep-sea activities in the early 80's on the Brazilian Continental Slope, and made some important discoveries related to its geology (Guardado, Gamboa and Lucchesi, 1990). It has also played a relevant scientific role on the National Antarctic Research Programme through the investigation of the deep bottom structure in the area adjacent to the Antarctic Peninsula (Gamboa and Maldonado, 1990). Petrobras has significantly helped Science advance in the Brazilian EEZ delimitation through the acquisition, processing and interpreting geological and more recently biological data (Marqueslet al 1989, Rangel & Azevedo 1991, Lavrado et al 2003). Through requirements from the regulating agencies and the oil and gas exploration offshore beginning in 1984-85, a number of cruises for environmental assessment and monitoring began. These have produced some valuable physical, geological, and biological information, although comparison of results from all these different cruises is difficult because samples have been collected with different sets of equipment and /or different sampling strategies across the Brazilian continental margin.

Biologically, a significant bathymetric variation in relation to the benthic community structure generally occurs from 800 to 1900 m. Diversity may be highest between 800-1000 m, but depth ranges may vary considering environmental heterogeneity and all different taxa. Like other worldwide deep-sea areas, the major components of the fauna concentrate in the first 5 cm of sediment with a high percentage of rare species (30-40% with one individual). Identification resolution is not yet calibrated across the country and this is an area that reflects the need for investment.

Deep-sea and Antarctic biology research in Brazil require the involvement of industry, environmental agencies and

the scientific community, taking account of national and scientific interests in these areas. Nonetheless, Brazilian scientists have been involved in specific worldwide programmes such as the Census of Marine Life and projects related to it, which involve the study of extreme environments. The Census of Marine Life (CoML) is a 10-year international programme that addresses diversity, abundance and distribution of life in the oceans. Brazil is involved in at least 3 of its projects concerning extreme environments: 1) ChEss (Biogeography of Chemosynthetic Ecosystems), which through international collaboration and coordination of efforts aims to improve our knowledge of the biogeography of species from chemosynthetically-driven ecosystems (i.e., hydrothermal vents, cold seeps, whale carcasses, sunken wood and OMZs) at a global scale, and to understand the forces driving them; 2) CoMargE (Continental Margins Ecosystems on a Worldwide Scale) related to the analyses of the continental margins scales of habitat heterogeneity and processes which are important in creating and maintaining high bathyal diversity; and 3) CAML (Census of Antarctic Marine Life) recently implemented will be one of the main Life Sciences SCAR (Scientific Committee for Antarctic Research) activities during the International Polar Year (2007-2008). The latter is related to retrieve past information and intensively gather data on present marine life surrounding Antarctica from shallow to the deep sea. Brazil has been very much involved in Antarctic research for the past 22 years and will contribute do CAML.

A sound knowledge of biodiversity, biogeography patterns of species, gene flow, biotic and abiotic processes that control these patterns is essential to develop management and conservation options. These studies are crucial in extreme environment ecosystems as the high degree of endemicity, dynamism and patchy traits of these habitats may result in an increased risk of habitat loss or population extinction (Campos et al in press). As much as the deep sea, Antarctica's biodiversity has high conservative value because of its relative pristine state, its high adaptation, and sensibility to environmental changes.

How climate change and anthropogenic impacts affect critical habitats for several organisms that depend on energy generated in polar regions, latitudinal gradients towards or from the polar regions; also, natural versus anthropogenic impacts in relation to spatial and temporal variability in biodiversity are important issues to be addressed in order to facilitate the comprehension of the connections between, for instance, Antarctica and South America. The study of Antarctica's isolation from other continents by the Southern Ocean and its basins is relevant for understanding circulation patterns in the world oceans and atmosphere, and how biological communities have responded to past and present environmental changes. A detailed knowledge of Antarctica's past and present status is globally significant for predicting how its future may affect the Earth's System. Comparisons between Antarctica and other fragments of Gondwana, such as South America, the study of climate change, and anthropogenic influences to the Antarctic environment are critical for understanding the evolution and present biological community structures in Antarctica. The ultimate separation of Antarctica from South America happened during the Oligocene, and was responsible for the Antarctic isolation, northward flow of the AABW, formation of the Southern Ocean, and existence of numerous unique geological processes observed along the northern end of the Antarctic Peninsula (e.g. an active spreading centre in the Bransfield Strait, ridge trench collision and gas hydrates on modern sediments). The combination of isolation and climate change has lead to an Antarctic biota rich in endemic taxa, and a strong contrast between marine, terrestrial, and limnetic biotas.

Similarly hydrothermal vents and cold seeps are isolated ecosystems because of their unique characteristics as they can function independently of sunlight, with chemosynthesis being the primary energy source for the development of complex faunal communities in these environments (Campos et al in press). The discovery of hydrothermal vents along the Galapagos rift in the 70's (Lonsdale 1977a, b, Corliss & Ballard 1977), and the subsequent discovery of cold seeps at the base of the Florida escarpment (Paul et al. 1984) has stimulated one of the most dynamic periods in the history of deep-sea biology for the past 27 years.

Cold seeps are now known to occur at both passive and active continental margins, where seepage of cold fluids with high concentrations of methane, and/or sulphide from the underlying sediments, are characteristic (Sibuet & Olu,1998). Hydrogen sulphide and methane present in seep fluids provide energy for micro-organisms that chemosynthetize organic matter from carbon dioxide and mineral nutrients (Juniper 2002,Tunnicliffe et al 2003). This type of primary production may sustain a remarkably high biomass (500-1000 times higher than the surrounding deep-sea floor), and diverse fauna (Juniper 2002) with specific physiological and ecological adaptations to the highly toxic, dynamic and patchy ecosystem. Some of these adaptations may be of interest to the biotechnological and pharmaceutical industries (Campos et al *in press*). There have been both indirect and direct evidence for the existence of cold seeps on the southeast Brazilian continental margin (Campos et al *in press*). A vesicomyid shell, *Calyptogena birmani* collected in Santos Basin has been identified by Domaneschi & Lopes (1990), erosional events on the upper continental slope have evidenced gas-venting at Campos Basin (Kowsmann & Carvalho 2002), and pockmarks associated with deepwater corals off the SE Brazilian continental slope in Santos Basin (Sumida et al 2004).

The Brazilian continental margin is currently under development for extraction of gas and oil by Petrobras and other oil companies, who have acquired a wealth of relevant, but un-published ‘commercially sensitive’ data. This margin also harbours a resident population of humpback whales and probably falls on a migration route for this and other cetacean species (Campos et al *in press*). The potential seep and whale-fall communities of the Brazilian continental margin could be linked to communities on the African continental margin through the eastward flow of NADW via the Rio de Janeiro Fracture Zone and with the southern ocean via whale-falls along SE American margin migration routes (Campos et al *in press*).

Considering past deep-sea projects and more recent information gathered in the Brazilian Continental Margin, Seamounts and in the proximities of St Peter and St Paul Islands, Brazil stands in a positive position to further advance the knowledge on major extreme environments in cooperation with other countries.

Currently, the Brazilian Antarctic Programme proposes to act in two phases for the International Polar Year: 1) allowing the continuity of relevant research that investigate signals of global and regional changes in Antarctica, also gathering all available metadata collected through the programme into a format that can be linked to major world databases; and 2) an exploring phase integrating geophysics, geosciences and life sciences contributing to the following:

A. Study the timing of separation between South America and Antarctica and the creation of the AABW; opening of the Drake Passage, and implications for faunal distribution across continents (past and present - this in collaboration with CoMargE). Sediment deposited along the South American margin will be used in this study, and the impact of the AABW will be investigated through microfossils present in the sediments.

B. Study the timing of the opening of the Bransfield Basin using stratigraphy observed in some of the islands, seismic profiles, and other geophysical tools. The precise time of opening may bear direct correlation with the final separation of Antarctica.

C. Study the consequences for marine, terrestrial and limnetic ecosystems function of the Antarctic separation and the impact of past, current and predicted environmental change on biodiversity (CAML). Study the nature and extent to which interactions between changing abiotic conditions change biotic responses.

D. Through sampling across the Bransfield Strait spreading axis, which is tectonically active and has an expressive bathymetric range, and explore patterns of gene flow along its bathymetric range will also add to the ChEss project.

Studies on the functional diversity of species, nutritional pathways and evolutionary radiation are essential in order to understand the relationships amongst extreme environment communities. The high degree of endemicity, dynamism and patchy traits of some specific extreme ecosystems like hydrothermal vents, cold seeps, and that found in Antarctica may result in an increased risk of habitat loss or population extinction in certain areas. A thorough knowledge of the biodiversity, biogeography patterns, gene flow, the biotic and abiotic processes that control these patterns, is fundamental to develop management and conservation strategies for extreme environments (Campos et al in press).

As the Census of Marine Life programme involves many projects with broad international scientific collaboration, high-quality internationally-led research, and diverse expertise (geological, biogeochemical, physical, biological, and from microbes to megafauna, from taxonomy to physiology) (O'Dor 2003), it has tools, scientific knowledge, and the necessary framework essential for the development of environmental assessment of extreme ecosystems. It is important to broaden the interdisciplinary discussion with the industry, and optimise efforts in collaboration with local and International authorities, so that appropriate management and conservation options for the potential exploitation of extreme ecosystems are always considered.

Despite being recent the Brazilian Extreme Environments' Research has been based on robust data acquired in collaborative work between industry and the scientific community. Over the years, the geophysical and geological data have provided background information for biological investigations, and also biology data have provided signals for environmental features, spatial and temporal changes. The interdisciplinary focused research work can significantly improve our knowledge of geological and biological oceanographic processes and functioning for a better understanding of the Earth System.

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