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News

MABEL: a Multidisciplinary Benthic Laboratory for Deep Sea, Long-Term Monitoring in the Antarctic

M. Calcara[1*], L. Beranzoli[1], T. Braun[1], D. Calore[2], A. De Santis[1], G. Etiope[1], P. Favali[1], F. Frugoni[1], F. Gasparoni[2], C. Montuori[1], G. Smriglio[1]

[1]Istituto Nazionale di Geofisica, Via di Vigna Murata 605, 00143 Roma - Italia
[2]Tecnomare S.p.A., Venezia - Italy

Introduction

In the next decades, the challenge for earth and environmental sciences will be that of extending to the seafloor those measurements usually carried out on land; these measurements will help better understand terrestrial physics and environmental processes (Montagner & Lancelot, 1995). At the same time, poorly monitored oceanic masses will be identified, and strategic places for the acquisition of long-term data from the multidisciplinary benthic observatory will be indicated. The information gap is greater in the southern hemisphere and in the peri-Antarctic regions. Continuous and long-term monitoring, regularly spaced observation points and the simultaneous measurement of different parameters are important for regional and global earth studies. The availability of continuous, long-term and time referenced observations is of great importance for the elaboration of descriptive and evolutionary models of studied phenomena.

The guidelines for environmental and geological research, developed and consolidated during the Italian Antarctic expeditions started in 1986, could greatly benefit from the integration of data from multidisciplinary benthic observatories with that from current land-based measurements.

In the last decade some international organisations have favour the development of marine technological systems in aid of scientific research. The most recent example of a benthic observatory is represented by GEOSTAR (GEophysical and Oceanographic STation for Abyssal Research), a prototype developed in the context of a Marine and Technological Project coordinated by the Istituto Nazionale di Geofisica and funded by the EC MAST III (Beranzoli et al., 1998). After a set of tests in dry and wet conditions, GEOSTAR's first scientific mission lasted from August 13, 1998 to September 1, 1998 and took place in the Adriatic Sea (44°30'11'' N, 12°56'39''E, 42 m deep), 50 km off the coast of the Italian city of Ravenna (Fig. 1); the first phase of the Project was successfully concluded. GEOSTAR was equipped with a triaxial broad band seismometer, two magnetometers (scalar and fluxgate), an acoustic doppler current profiler, a CTD and a transmissometer. The mission produced 440 hours of data (97.8% of the total mission time) and demonstrated the functionality of all the developed technological systems. The station was also able to correctly sustain all scientific instrumentation. Details on the mission and on scientific results are reported in Beranzoli et al. (1999). In January 1999 the second phase of the GEOSTAR project started; it aimed to complete the first long- term scientific mission in deep seas (Tyrrhenian Sea, 3400 m).

Taking advantage of this experience, a new observatory (MABEL) will be developed; it will have enhanced electronic and scientific instrumentation and will be adapted

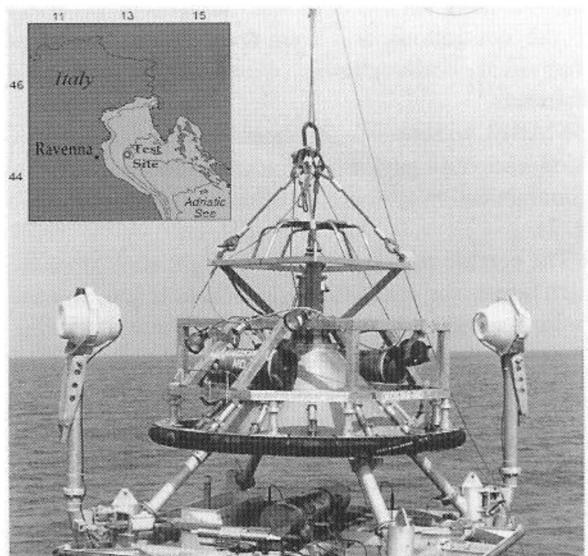

Fig. 1 - Picture of the recovery phase of GEOSTAR at the end of the Adriatic mission. The cone-shaped frame is the Mobile Docker, a vehicle devoted to the recovery and deployment of the station. An enhanced version of the Mobile Docker will be used to handle the MABEL station. The upper left panel shows a map of the GEOSTAR test site.

**Corresponding author* (m.calcara@ingv.it)

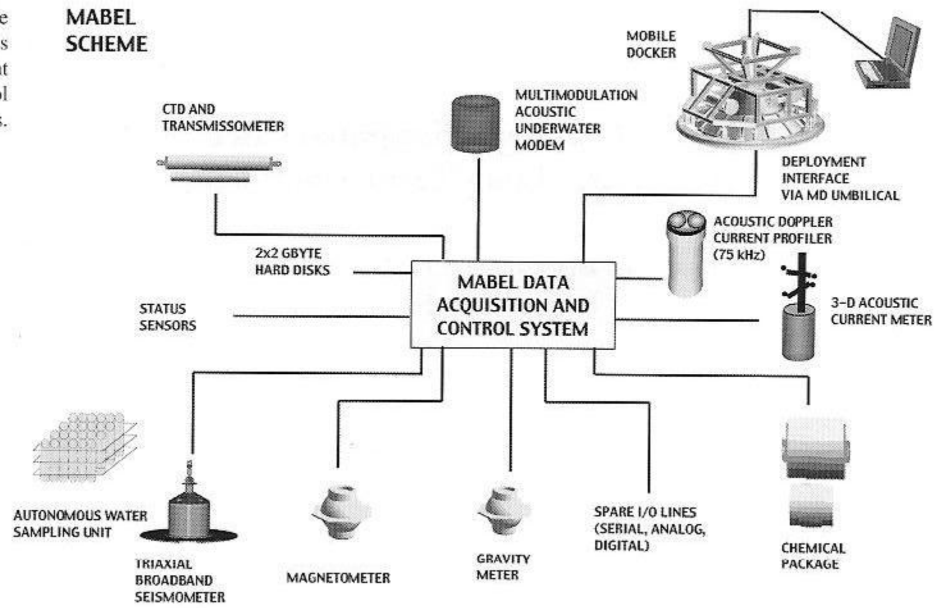

Fig. 2 - MABEL configuration for the Antarctic mission. The scheme shows logical connections with the intelligent unit - the Data Acquisition and Control system - and free standard connections.

for extreme environmental conditions. MABEL will be deployed at the end of the year 2001 on the floor of the Weddell Sea, about 70 km from the Neumayer Antarctic station (German), at a depth between 500 and 1000 m.b.s.l.

Technical outline of MABEL

The MABEL project was developed in the framework of the Italian PNRA (National Program for Research in Antarctica). It aims to assemble and operate, for the first time in Antarctic sea waters, a multidisciplinary observatory for the continuous and long-term measurement of geophysical, oceanographic, chemical and biological parameters.

MABEL will consist of four main subsystems: a benthic station, a scientific payload, a deployment/recovery vehicle, a communication system (see reference configuration in Fig. 2).

The benthic station consists of a light alloy structure which houses the scientific payload, data acquisition and mission management electronics, mass memory, batteries, communication systems and auxiliary systems. The scientific payload selected for this mission includes: a triaxial broad-band seismometer, a magnetometer, a gravity meter, a CTD (conductivity, temperature and depth), a transmissometer, an ADCP (a 75 KHz acoustic doppler current profiler), a chemical analyser and a water-plankton sampler.

The MABEL data acquisition and control system will be based on the electronic instrumentation successfully developed and tested in the GEOSTAR project. Its main features are:

- low power consumption; in order to guarantee greater autonomy most instruments are on stand-by between measurements; in case of malfunction, failure or reconfiguration of mission strategies, each single instrument can be automatically switched off;
- capability of managing a large number of I/O lines or communication channels due to instrumentation and peripheral devices that can be mounted on board the bottom station; future expansions are also foreseen;
- capability of managing the large amounts of data produced by the instruments, particularly the seismometer; for the MABEL mission, an average of about 1 Mbyte/hour is estimated;
- monitoring of the station in terms of: distance from seabed, tilt, heading, temperature and water leakage inside the pressure vessels, battery voltage and current.

Deployment and recovery of the benthic station shall be ensured by a specially built system, the Mobile Docker. This tool, developed for the GEOSTAR project, can handle heavy payloads (up to 5 t). Manoeuvrability in the horizontal plane is ensured by two thrusters operated from the ship's operation console, while two other thrusters help to regulate vertical movements.

An umbilical cable allows power transmission and data exchange. A specially adapted fibre optic telemetry system is available, ensuring that the surface operator has full control of the guidance and functionality of the Mobile Docker. During deployment, the Bottom Station is also cable-connected to the surface unit via the telemetry system of the Mobile Docker. This allows the operator to carry out real-time checks on the condition of the Bottom Station, to correct the operation of all scientific instrumentation and to start missions.

Visual and instrumental systems (dGPS, USBL) enable the operator of the Mobile Docker to locate the pre-determined installation. Accordingly, during the re-entry phase the Mobile Docker can be steered to the bottom system for recovery. An operational range of about 5 % of the water depth has been calculated and experimentally verified.

Communication will be based on an Acoustic Telemetry System, ensuring bi-directional interface with a user onboard a ship. The system is a multi-modulation acoustic underwater modem, capable of operating at rates of up to 2400 baud.

MABEL Objectives in the Weddell Sea

The Weddell Sea is one of two continental seas in Antarctica; its sea-floor morphology generally presents a

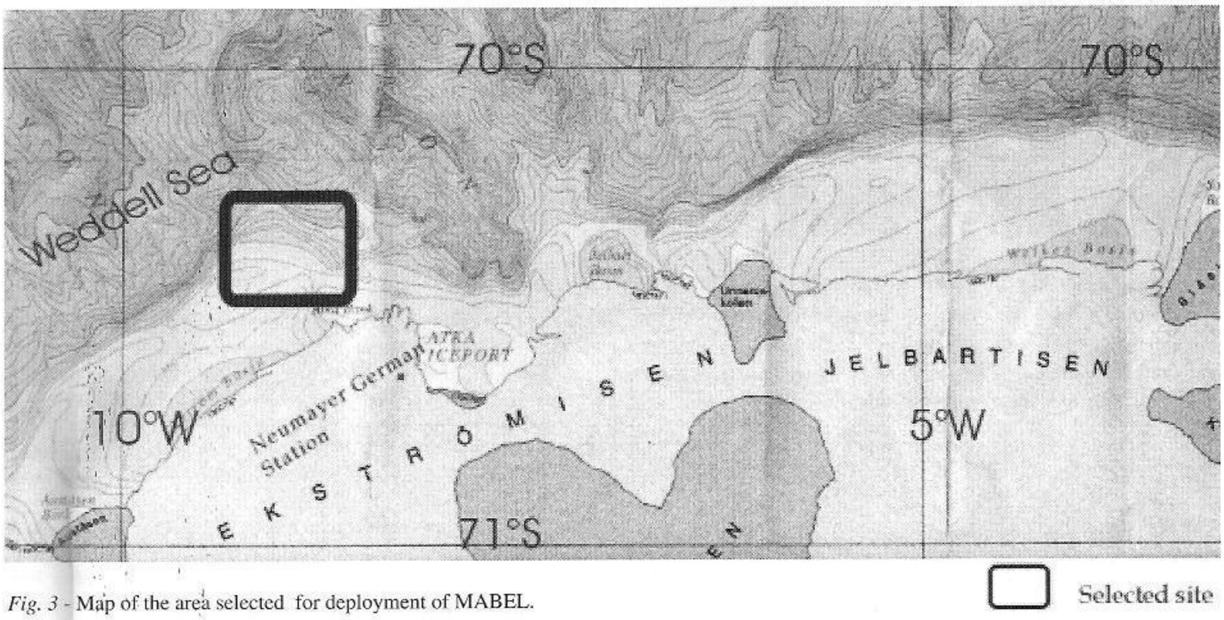

Fig. 3 - Map of the area selected for deployment of MABEL.

gentle slope. Relatively unexplored, the Weddell basin presents structural and tectonic complexities; for instance, the northern boundary is close to the south Scotia Ridge, one of the major transcurrent plate boundaries on earth (Pelayo & Wiens, 1989; Maldonado et al., 1998). The basin is therefore a key to understanding the opening of the Scotia Sea and offers the opportunity to study the tectonics and geodynamics of neighbouring plates. The Weddell Sea is also important for its role in the circulation of oceanic waters in Antarctica (Camerlenghi et al., 1997) and for its effects on water chemistry (Löscher et al., 1997).

Neumayer Station, located on the nearby Ekström Ice Shelf, has been operational since 1981 and was completely upgraded in 1993 (Eckstaller et al., 1997). Existing facilities at this permanent, land-based station may be exploited for long-term monitoring of the seafloor. MABEL data can also be integrated with and compared to data from the seismological, geomagnetic and gravimetric instruments of Neumayer Station. MABEL will be deployed by the *R/V Polarstern* on the floor of the Weddell Sea at the end of the year 2001 and at a depth of 500 to 1000 meters (see map in Fig. 3) thanks to the cooperation with the Alfred Wegener Institute. The acquisition of time series data through MABEL has the following aims.

Seismology: to study the signal/noise ratio recorded by the benthic observatory and compare it with that of other land-based Antarctic stations; to characterise local seismicity; to contribute to the study of high energy events, terrestrial tides and free oscillations on a global scale.

Geomagnetism: to improve the radial reliability of models of the Antarctic geomagnetic field (project ARM, Antarctic Reference Model, De Santis et al., 1999). Data from the BOOMERANG experiment (Balloon Observation Of Millimetric Extragalactic Radiation And Geophysics, Lange et al., 1995), acquired at stratospheric altitudes (about 38 km) along a circumpolar route, can also be integrated.

Oceanography: to characterise the benthic stratum through the integration of physical parameters (temperature, salinity, sea current velocity along vertical profiles and optical properties) and bio-geochemical ones, especially solid transport of sediments. The deployment of MABEL in a continental sea allows the study of all phenomena affected by seasonal changes: the melting and formation of ice produces cyclical variations in the circulation of water masses and also affects their chemical and chemico-physical parameters.

Geochemistry: to define temporal variations in chemico-physical parameters (*e.g.*, temperature, pH, salinity) and geochemical parameters (*e.g.* ions, dissolved gas, isotopes) related to oceanographic, geophysical, geodynamic and environmental factors.

Biology: to understand the composition and trophic structure of zooplankton and its possible variation in time; to identify key species in the transfer of energy from the sea-floor to the surface and *vice-versa*; to identify and quantify the fraction of organic particles reaching the seafloor.

The presence of various geophysical and environmental instrumentation on the benthic station, referenced in time and space allows the study of possible relationships between different parameters.

Conclusions

Monitoring the geophysical and environmental parameters of the Weddell Sea shall greatly contribute to the understanding of the tectonics of the basin and of surrounding plates. It will also allow the characterisation of environmental processes, with special attention to temporal variations in the circulation of sea water. The scientific mission in the Weddell Sea represents a first step towards the creation of the first Antarctic network of multidisciplinary seafloor observatories. The controlled deposition procedure of MABEL and of future observatories or instruments may lead to the exploitation of array techniques, for example, for submarine seismic networks. The coverage of areas with regularly-spaced observation points allows the application of most of on-land techniques to marine environments. It also allows the extension of research to other areas of interest of the Italian *Programma Nazionale di Ricerche in Antartide* (PNRA), without the limitations usually imposed by traditional monitoring methods.

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