MOMARNET: EXTRACT FROM FIRST YEAR REPORT

WP2 - Monitoring fluid flow and seismicity at vent scale :

Activities at National Oceanography Centre, Southampton, UK

submitted by Prof. Martin Sinha

Activity during the first year of MOMARNET by the University of Southampton/National Oceanography Centre, Southampton (UK) has focused on two specific activities. Firstly we have recruited a PhD Student, Mr Igor Denijs, to work on this theme for a three year period. Secondly we carried out and successfully completed a major geophysical cruise (Cruise CD 167/2004) to the Saldanha area of the Mid-Atlantic Ridge in November-December 2004. This document reports on progress in each of this areas in turn.

1. PhD Student recruitment and induction.

Following national and international advertising, we appointed Mr Igor Denijs to the Momarnet PhD studentship position on '*Sub Sea Floor Structure and Fluid Penetration at the Saldanha Massif, Mid-Atlantic Ridge from Electromagnetic Sounding Studies'.* Mr Denijs's start date was 1 July 2005. His studies will be divided equally (18 months at each) between the Centro de Geofísica, Universidade de Lisboa, Portugal and the Graduate School of Southampton Oceanography Centre, University of Southampton, UK – with the first period to be spent at Southampton. While studying and carrying out research at Southampton, Mr Denijs will follow the programme for our Master of Research in Marine Geology and Geophysics degree, in addition to fulfilling his specific MOMARNET project work. It is anticipated that on completion of his appointment he will graduate with a PhD from Lisbon.

Since his appointment Mr Denijs has been working on initial data reduction and analysis from the CD 167 cruise. During the first week of October 2005 he is attending the MOMARNET short course in Paris. Thereafter he will commence work on a number of relevant, Master's level, taught units at NOCS relevant to his training, given his background as a physicist.

2. Cruise CD 167/2004: Active source electromagnetic survey of hydrothermal venting area at Saldanha Massif, Mid-Atlantic Ridge.

a) Cruise dates and ports: 27/11/2004 Funchal, Madeira to 20/12/2004 Ponta Delgada, São Miguel, Azores

b) Scientific Participants:

Martin Sinha[1] (chief scientist), Zalina Dzhatieva[1], Simon Dean[1], Nadia Frerichs[1],Ágata Dias[3], A. Filipa Marques[3] , Nuno Silva[2], Anna Maxey[1], Michelle Ellis[1], Edward Morris[1], J. McIntosh[1], A Burchell[4].

Additional scientific planning input: Fernando A. M. Santos[2], F. Barriga[3]

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[3]CREMINER, Universidade de Lisboa, Lisboa, Portugal;
[4] Department of Earth Science, University of Durham, UK

c) Introduction

In November-December 2004 RRS *Charles Darwin* carried out a geophysical and geological sampling study of a non-transform offset of the Mid-Atlantic Ridge at 36^{o} 35' N (cruise CD 167). The science party were from the National Oceanography Centre, Southampton, UK and the University of Lisbon, Portugal. The project was jointly supported by research funds from the Universities of Lisbon and Southampton, and ship time from the UK Natural Environment Research Council. The project was centred on a section of the ridge that encompasses the Saldanha massif – a site of exposed ultramafic rocks corresponding to unroofed mantle, where low temperature hydrothermal discharges have been observed (Costa *et al.* 2001, Dias *et al.* 2005). Data from the project will contribute to the objectives of the MOMARNET research training network.

d) Scientific purpose of CD167

The primary objective was to investigate the physical properties *in situ* within the upper few kilometres of the seafloor beneath and around the Saldanha Massif. The CD167 experimental data will be analysed using 1-D and 2.5-D forward modeling and inversion (see *e.g.* Constable *et al* 1987, MacGregor 1999, Flosadottir & MacGregor 1999), and geophysical effective medium modelling (Greer 2000). This should enable us to determine the 3-D distribution of porosity and hence of hydrothermal fluid penetration into the crust and uppermost mantle beneath the survey site. We shall compare our models with those determined for volcanically hosted sites elsewhere on the Mid-Atlantic and other ridges, and use these to test models of possible heat sources resulting in the Saldanha venting activity. We will also look for any differences in sub-seafloor hydrology between volcanically- and non-volcanically-hosted sites.

e) CD167 survey geometry

The survey geometry was designed to provide optimum spatial coverage of both in-line and broadside EM field modes. During the survey the Deep-towed Active Source Instrument (DASI)

system transmitted electromagnetic signals from its horizontal electric dipole antenna at 0.25 and 1 Hz. These signals were detected and measured by an array of 17 autonomous ocean-bottom geophysical recorders deployed in a 10 km^2 grid centred on the Saldanha Massif.

Eight transmission lines were towed along a set of four N-S and two E-W tow lines across the survey area (Figure 1). This survey geometry gives source - receiver ranges of up to 14 km and so should provide information on the resistivity structure to a depth of at least three kilometres beneath the seafloor. This, in turn, will be translated into constraints on pore space distribution and interconnectedness as well as pore fluid properties. We shall use these results to investigate whether the Saldanha vent site owes its existence to the presence of a deep fracture network, extending downwards into the underlying mantle rocks and to test models of possible hydrothermal heat sources.

f) Cruise instrumentation

The DASI transmitter emits a continuous wave signal for frequency-domain sounding over a range of 0.1 - 256 Hz, with most energy at the fundamental frequency and its third and fifth harmonic (Sinha 1990). The transmitting horizontal electric dipole antenna is 100 m long, neutrally buoyant, and streams behind the DASI vehicle. The antenna is earthed into seawater at both ends using copper cable electrodes placed at 30 m and 130 m behind the vehicle. All transmissions were made with a peak-to-peak current of approximately 200 A. Transmission parameters such as frequency and current are controlled from the ship via a fibre optic cable. The tow tracks of the DASI system were determined using ship-based ultra-short baseline navigation (USBL, Sonardyne) and ship GPS.

The ocean bottom receivers used during CD167 record time series of two electric field components at the seafloor, using orthogonal horizontal electric dipoles. Each dipole is 13 m long and supports low noise electrodes at the ends of the arms. The sensors are able to measure an electric field signal of 10 picoVolts per metre over the frequency range 0.1 - 60 Hz. The receivers used were a combination of older, 'Low-frequency Electro Magnetic Underwater Recorder' (LEMUR) systems and a new generation of LC-2000EM receivers. The instrument positions on the seafloor were accurately determined by acoustic ranging and ship-board GPS.

g) Data Collected

During the CSEM survey the transmission lines were mostly towed at a frequency of 0.25 Hz to ensure deep penetration data across the entire survey area. Three profiles were made at 1 Hz, to provide a higher resolution of the resistivity structure in the upper crust. Since the source signal is a square wave, significant amounts of signal are emitted at the third and fifth harmonics. Therefore it should be possible to analyse signals at frequencies of 0.25, 0.75, 1.0, 1.25, 3, and 5 Hz.

h) Other data and samples collected

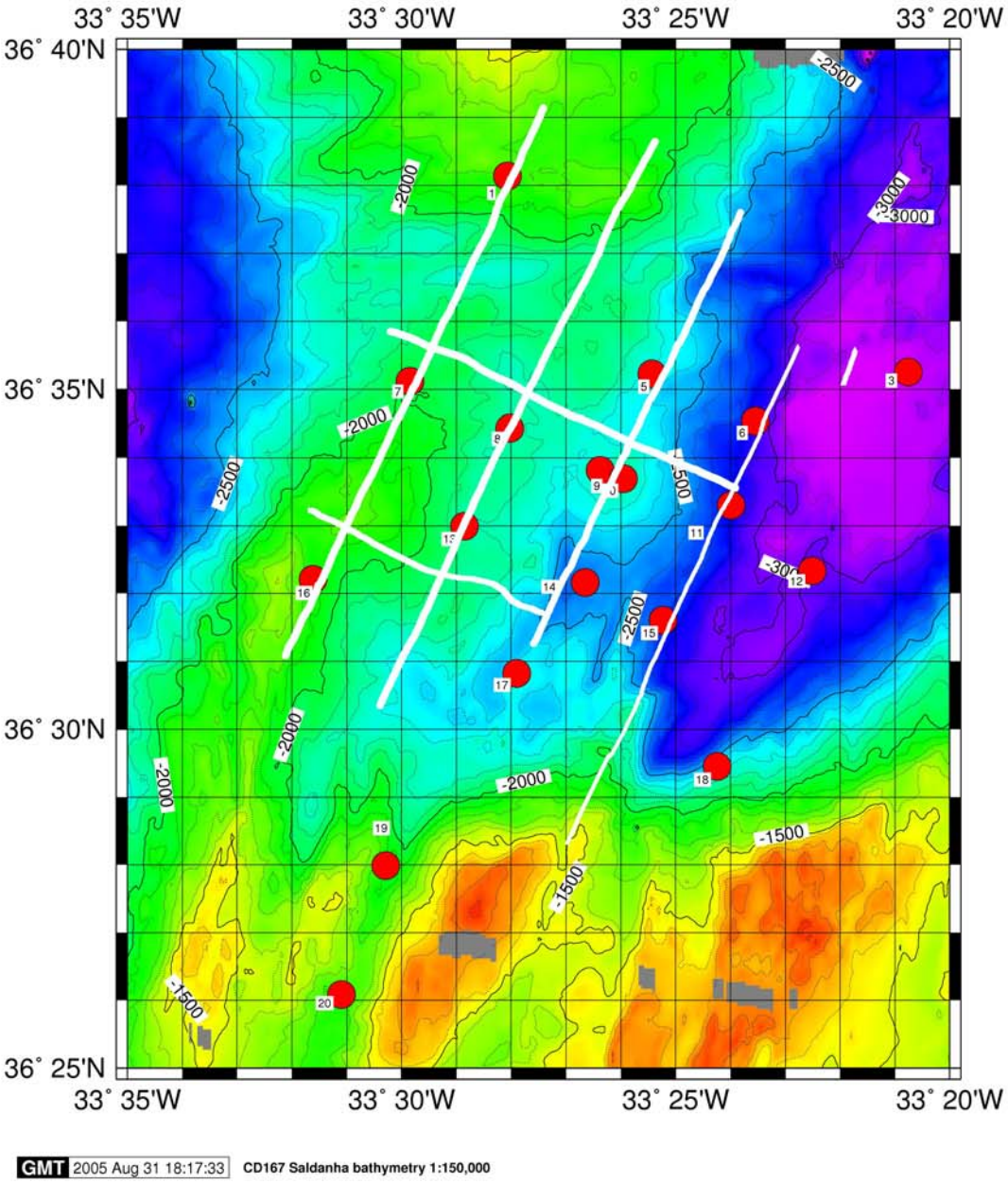
To provide background data for the CSEM study, a set of three current meter moorings, which record current speed and direction, temperature and salinity were deployed across the survey area. Additional data on the physical properties of the water column were obtained using 14 expendable bathythermographs (XBT) and a sound velocity meter profile. Between the start and end of the survey, gravity data were collected continuously, and total field magnetic data for part of the time, giving gravity and magnetic profiles across the ridge. During the cruise the whole survey area was remapped with Simrad EM12 swath bathymetry. To investigate the history of hydrothermal activity eleven short sediment gravity cores were collected on and around the Saldanha massif, with nine of these providing valuable material. Four dredges were attempted for hard rock samples from sites around the massif, and two of these retrieved samples.

i) Acknowledgements

We thank the RRS *Charles Darwin* crew members and all SOES and UKORS staff involved for their successful and highly professional contributions. Many thanks to Dr Mathilde Cannat for helping us with swath bathymetry data. The work was supported by the UK Natural Environment Research Council, the SEHAMA project POCTI/MAR/15281/1999 and the University of Southampton.

j) Figure caption:

Figure 1 shows the location of the survey, within the non-transform right-lateral offset of the Mid-Atlantic Ridge at 36^{o} 35' North. White lines show the tracks of the DASI deep-towed CSEM transmitter system during transmitting periods. Red circles show the locations on the sea floor of the electric field receiver instruments.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