Short Cruise Report M62/3

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Topic

Deep-seismic investigations of the Cape Verde hotspot volcanism – a seismic study of isostasy and plume dynamics

Acronym

CHARISMA - Cape Verde Hotspot: A Seismic Refraction study of ISostasy and MAgmatic underplating

Geological framework

Plate tectonics introduced in the sixties and seventies of the 20th century provided the framework for a unifying theory to describe all major geotectonic processes occurring on Earth. Plate tectonics not only allowed scientists to describe the motion of the rigid outer shell of the Earth, but also provided an explanation why long linear chains of ocean islands (like the Hawaiian Islands) occur within the deep oceans. Thus, while a plate moves over the Earth's surface island chains are generated parallel to the vector of plate motion where a plate passes over a magma source fixed within the Earth interior. The magma source responsible for this form of intaplate volcanism is called a hotspot. Both plate tectonics and hotspots, however, are caused by the same basic fundamental process occurring in the Earth interior: internal or radioactive heat production.

The Cape Verde islands are located about 300-400 km offshore the African coast and sit on lithosphere created roughly 140 Mio. years ago. The activity of the Cape Verde hotspot can be traced over the last 180 Mio. years. The most recent event occurred in 1995 on the island of Fogo. A regional heat flow anomaly indicates that the swell is caused by deep-seated thermal processes; numerical modelling suggests that in addition to thermal forces dynamic uplift due to mantle convection contributes to cause the prominent swell. This idea is supported by a large regional anomaly in the Earth's gravity field and by a dome like morphological seafloor anomaly. The maximum geoid anomaly is 14 m, the depth anomaly is > 3 km, and the affected area is 17° by >10° in W-E, and N-S direction, respectively. These features indicate that the Cape Verde hotspot province is the most prominent hotspot in the east Atlantic and its size clearly suggest a deep-seated origin. Several scientist believe that the Cape Verde hotspot is perhaps the best example of a terrestrial hotspot. The fact that the islands and swell sit on a slowly drifting plate suggests that the hotspot may represent a good analogue to planetary hotspots on Mars and Venus.

The goal of the expedition with Meteor was to use seismic refraction and wide-angle techniques to investigate the “shallow” structure of the hotspot; thus, to study the impact of hotspot volcanism on the structure of the lithosphere and crust. A characteristic feature over a hotspot is the geoid anomaly, which is generally accompanied by an uplifted seafloor. In the early days of research on hotspot

volcanism, it was believed that the swell is caused by a thinning of the lithosphere. Other models suggest that the swell is caused by processes sitting deeper in the asthenosphere and is supported by either higher mantle temperatures or that hotspot melting changes the chemical composition and causes a lower mantle density. However, seismic, gravimetric, and petrological work on some volcanic islands indicate that large intrusive complexes (called magmatic underplating) occur at the base of the crust. Such features are buoyant and may therefore cause an isostatic uplift and hence may contribute to the swell amplitude.

The field programme of M62-3

On September 3, 2004 *RV Meteor* left at 13:00 local time Recife, Brazil and sailed towards the Cape Verde islands. In the night of September 8 to 9 the working area was reached and for the next 18 days a seismic campaign was conducted in Cape Verdian waters. On September 27, 2004 at 7:00 a.m. *RV Meteor* met the pilot off Mindelo, Sao Vicente, Republic of Cape Verde.

To obtained imaged of the deep structure of the crust and the uppermost mantle in the vicinity of the Cape Verdian islands, we deployed ocean bottom seismometers and hydrophones which recorded airgun shots fired at the sea surface. As seismic source an airgun array consisting of 8 guns with the volume of 32 litres were fired at 210 bars. For the seismic field work, 40 ocean bottom seismometers (OBS) and ocean bottom hydrophones (OBH) were available. In total 70 ocean bottom stations were deployed and recovered.

To study the mechanical properties of the lithosphere over the hotspot, a roughly 600 km long deep seismic line – profile 01 - was shot across the swell to image tomographically the crustal structure of the swell (Fig. 1). The seismic data are of excellent quality and will be used to quantify the amount of magma intruded at the base of the crust to form a large underplating body, which may contribute to cause the hotspot swell. The investigations supplement earlier seismic reflection and geothermal work. The structural models from the seismic data will be used to estimate the contribution from deep-seated forces – like thermal and dynamic processes – required to cause the observed features.

Detailed seismic investigations in the area of the volcanically active islands of Fogo and Brava were aimed to reveal magma reservoir's and the magma plumbing system of the islands (Fig. 2). Three profiles have been obtained. Profile 02 run from the island of Santiago towards Fogo, went around the island and continued roughly 100 km to the west, providing a 170 km long profile across Fogo. Two shorter lines – between 60 to 80 km long – provided additional deep seismic data from the Fogo and Brava area. The major goal behind this approach was to assess mechanisms governing the eruptive processes shaping the islands. The offshore study benefitted form the Golbal Seismic Network station (GSN) on Santiago and landstations operated be the Cape Verdian Institute of Meteorology and Geophysics on Fogo. Along most lines underway geophysical data have been collected, which provided information on the local gravity and magnetic field and imaged the seafloor topography (Fig. 2).

While the ocean bottom instruments have been on the seafloor, some stations did record signals associated with volcanic activity, including earthquakes and volcanic tremors.

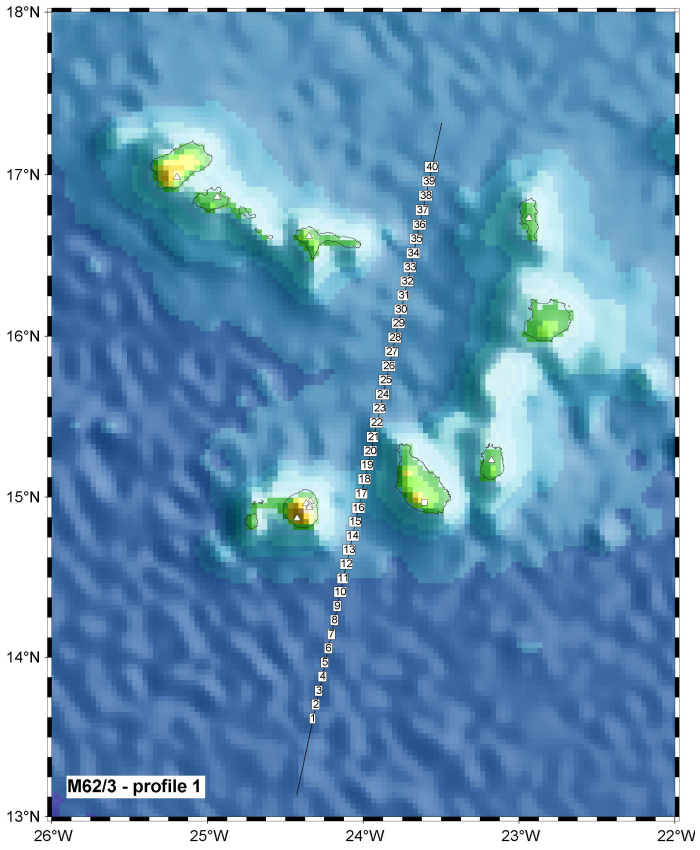

Fig 1. Lacation map for seismic profile 01 crossing the Cape Verde hotspot swell

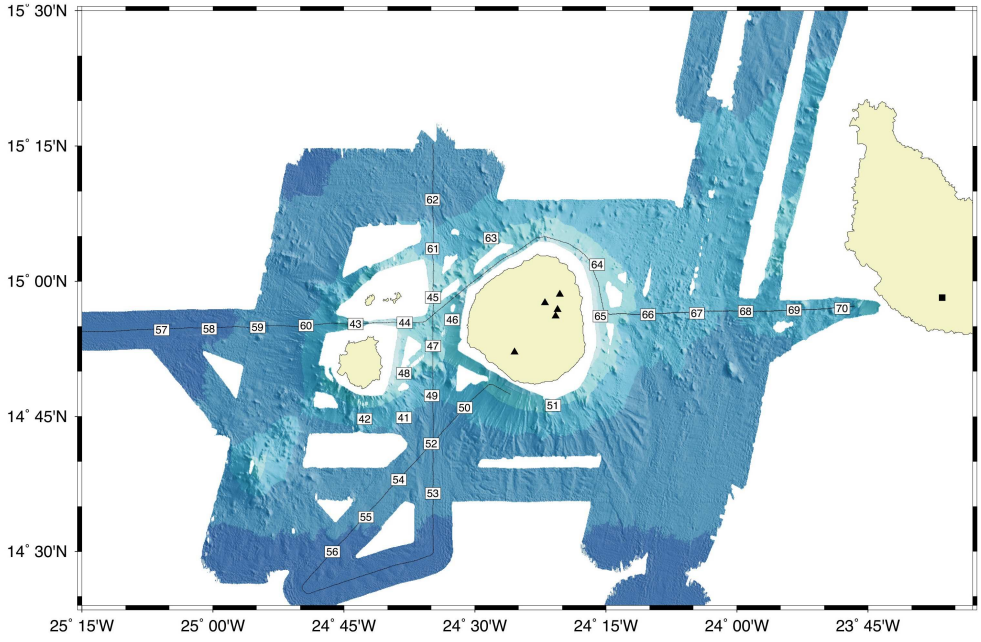

Fig 2. Seismic profiles 02, 03, and 04 in the area of Fogo and seafloor bathymetry obtained with the HYDROSWEEP swathmapping system of RV METEOR