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Intraplate seismicity across the Cape Verde swell: A contribution from a temporary seismic network

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ABSTRACT

We present an analysis and characterization of the regional seismicity recorded by a temporary broadband seismic network deployed in the Cape Verde archipelago between November 2007 and September 2008.
The detection of earthquakes was based on spectrograms, allowing the discrimination from low-frequency volcanic signals, resulting in 358 events of which 265 were located, the magnitudes usually being smaller than 3. For the location, a new 1-D P-velocity model was derived for the region showing a crust consistent with an oceanic crustal structure. The seismicity is located mostly offshore the westernmost and geologically youngest areas of the archipelago, near the islands of Santo Antão and São Vicente in the NW and Brava and Fogo in the SW. The SW cluster has a lower occurrence rate and corresponds to seismicity concentrated mainly along an alignment between Brava and the Cadamosto seamount presenting normal faulting mechanisms. The existence of the NW cluster, located offshore SW of Santo Antão, was so far unknown and concentrates around a recently recognized submarine cone field; this cluster presents focal depths extending from the crust to the upper mantle and suggests volcanic unrest. No evident temporal behaviour could be perceived, although the events tend to occur in bursts of activity lasting a few days. In this recording period, no significant activity was detected at Fogo volcano, the most active volcanic edifice in Cape Verde.
The seismicity characteristics point mainly to a volcanic origin. The correlation of the recorded seismicity with active volcanic structures agrees with the tendency for a westward migration of volcanic activity in the archipelago as indicated by the geologic record.

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1. Introduction

The Cape Verde archipelago comprises ten volcanic islands and several islets located 500 km off the coast of Senegal, West Africa. The archipelago stands on the southwest flank of the Cape Verde Rise, an elevated region of the ocean floor approximately 1200 km in diameter. The fact that the islands do not form a linear chain as observed in other hotspots is interpreted as the effect of a long-lived mantle plume underlying an almost stationary plate (Fig. 1).

The seismicity in Cape Verde is sparse and poorly known; most of the information is available only in old reports from 1947 to 1973. Previous data correspond to reports of felt earthquakes of low intensity mainly in Fogo and Brava, in the southwest of the archipelago and typically related to volcanic eruptions (Ferreira, 1956; Mendes, 1956; Neves, 1981), providing intensities and number of events but not locations. Local temporary networks (Fonseca et al., 2003; Heleno, 2001; Heleno and Fonseca, 1999; Helffrich et al., 2006; Matias et al., 1997) previously deployed in the archipelago had very focused objectives, such as local seismo-volcanic activity monitoring or teleseismic tomography, with limited results concerning the local seismicity in Cape Verde. Only very recently a permanent seismic network was installed in the archipelago by the Cape Verdean authorities (National Institute for Meteorology and Geophysics — INMG; Faria et al., 2013; Fonseca et al., 2013; Faria and Fonseca, 2014), but their results are still limited to the assessment of volcanic hazard.

Within the framework of project CV-Plume, a cooperation between GeoForschungsZentrum — Potsdam and Instituto Dom Luiz — Lisbon, 39 Broad-band (BB) stations were deployed on nine of the ten major islands of the Cape Verde archipelago between 2007 and 2008

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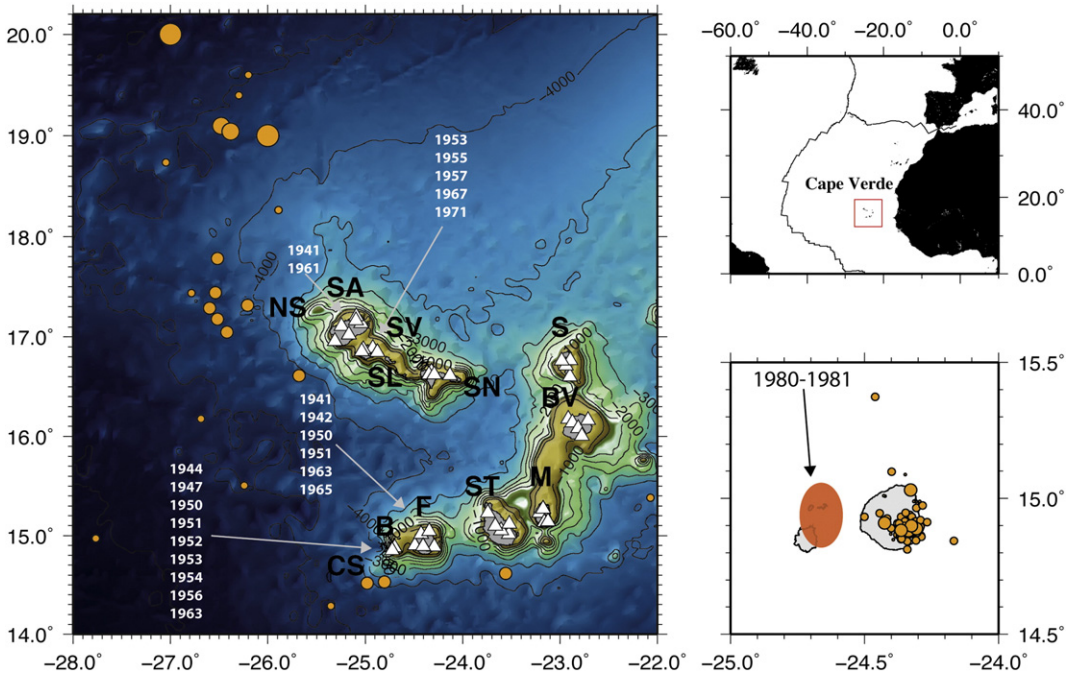

Fig. 1. The Cape Verde archipelago showing the location of the CV-Plume temporary broadband seismic network stations deployed in 2007–2008. Seismicity available in the ISC catalogue 1938–2014 is resumed to 24 events (International Seismological Centre, 2011) and registered earthquakes felt in the islands during the 20th century. Top right: location of Cape Verde in the Atlantic. Bottom right: presumed epicentral area of the 1980–81 seismic crisis and epicentres of the 1995 Fogo volcano eruption.

(cf. Fig. 1). While aimed mainly to image the seismic structure beneath the archipelago, this dense seismic network covering it entirely, provided a rare opportunity to characterize the seismicity in the region.

Therefore, this work presents the analysis of the data collected by the CV-Plume BB seismic network during the ten months of the project. From the numerous events detected during the processing stages described below several low-frequency signals, eventually associated with volcanic tremor or other similar sources, were detected but were discarded for future analysis. We have focused on the signals that could be attributed to earthquakes in order to assess the nature of the recorded seismicity, ignoring other signals of possible volcanic origin. Thus, the analysis scheme followed is a typical one for local seismicity: detection stage, phase and amplitude picking, relocation tests with simultaneous inversion of a new 1D model, waveform cross-correlation to assess the similarity between events, eventual location refinement, and calculation of focal mechanisms for source assessment and correlation with geological features.

2. Geological setting

The Cape Verde archipelago, located off the West African coast between 14.5° and 17.5° N, is a volcanic archipelago composed of ten islands (nine of which inhabited) and a few islets. The islands, presenting a horseshoe shaped distribution opened to the west, are built on top of the largest oceanic swell in the Atlantic Ocean – the Cape Verde Rise – and formed by persistent volcanic activity since the Oligocene (Torres et al., 2002) until present times. The swell and the long-lived volcanism are attributed to a persistent mantle plume underlying an almost stationary plate producing underplating and dynamic uplift (Pim et al., 2008; Ramalho, 2011; Ramalho et al., 2010c). The islands stand on 150–122 Ma-old oceanic crust (M2–M16 anomalies; Heyes and Rabinowitz, 1975; Stillman et al., 1982).

In terms of their state of evolution, the islands can be divided into two main groups: some islands still present youthful strong relief (Santo Antão, São Nicolau, Santiago and Fogo) while at others topography has been levelled by both subaerial erosion and marine erosion (São Vicente, Santa Luzia, Sal, Boavista, and Maio). Brava, although presenting a strong relief, has been deeply eroded in a way that its southern half corresponds to exhumed magma chambers represented by a plutonic complex of pyroxenites, syenites and carbonatites that contacts to the north with pillow lavas and hyaloclastites forming an uplifted submarine sequence. Volcanic rejuvenation in Brava is represented by a Middle Pleistocene to Holocene post-erosive volcanic sequence (Madeira et al., 2010; Mourão et al., 2010).

Historical volcanism (postdating settlement in mid-15th century) is reported solely for the island of Fogo, for which coeval texts describe the occurrence of 26 on-going eruptions (Ribeiro, 1960). Eleven of these descriptions present sufficient detail to allow mapping of the correlative cones and lava flows (including the most recent events in 1951 and 1995; Torres et al., 1997, 1998), while the earliest references (since 1500) are very laconic and in some cases may refer to different observations of the same eruptive episode by ships passing off the island, or even to an almost continuous state of eruption of Pico do Fogo volcano (Torres et al., 1997; 1998). Geological evidence from the islands of Brava and Santo Antão, where very recent (probably Holocene) volcanic events occurred, also points to the presence of active volcanic systems (Holm et al., 2008; Madeira et al., 2010). The remaining islands, with the exceptions of Boavista and Maio, present post-erosive volcanism of Pleistocene age (Duprat et al., 2007; Holm et al., 2008; Plesner et al., 2003; Torres et al., 2002).

Bathymetric multibeam surveys of sea-floor areas around the islands of Santo Antão, São Vicente, Fogo and Brava recognized the presence of youthful cone fields to the northwest and southwest of Santo Antão, south of São Nicolau, between the islands of Santiago and Fogo, and between Fogo and Brava (Masson et al., 2008), indicating apparent active volcanic fields on the submarine flanks of these volcanic edifices. A growing seamount – Cadamosto – is located southwest of Brava (Grevemeyer et al., 2010).

Most islands present important but variable uplift resulting in the subaerial exposure of sedimentary and volcanic submarine sequences (Madeira et al., 2010; Ramalho et al., 2010a, b; Ramalho, 2011). The different uplift rates of each island are explained by local processes with a small contribution from a swell-related episodic component (Ramalho, 2011).

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