

APPLICATION OF A PASSIVE TOMOGRAPHY METHOD AND CORRELATION WITH ACTIVE SEISMIC OBSERVATIONS IN THE KYPARISSIAKOS GULF, SOUTHWESTERN HELLENIC ARC

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Abstract

In the frame of the FP6 EC SEAHELLARC project, we deployed, in Fall 2006, a combined on/offshore seismic array consisting of 17 4C ocean bottom seismographs and 15 3C land-stations in the Kyparissiakos Gulf and surrounding area, southwestern Hellenic arc. More than 3500 micro-earthquakes were located with a minimum of 6 records per event and by using a local velocity model formerly revealed by active seismic observations. For a selected data set of 273 most reliable events, an implementation of the linearized tomography code Simulps14 was carried out in order to determine the 3D velocity structure of the area. The application showed that both active and passive tomography results are in agreement, both indicating that the deformation of sediments and the upper crust is correlated with the thrust blocks of Zakynthos and Messinia, accommodated by strike slip faults. The strike slip deformation favors the development of extensional basins between the thrust fronts, in the Kyparissiakos gulf.

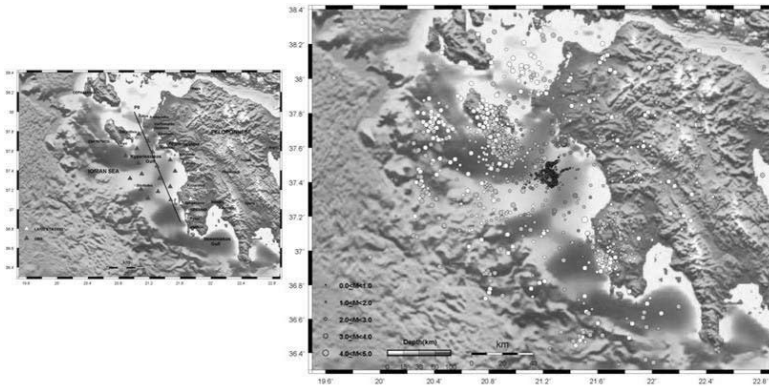
Keywords: microseismicity, 3D velocity structure, active deformation, Greece.

1. Introduction

One of the most seismically active areas in the Mediterranean is the southwestern section of the Hellenic arc. This area has been repeatedly affected by large magnitude earthquakes that have caused severe destruction and human loss (Papazachos & Papazachou, 1997) (i.e. 1886 Philiatra M7.3, 1893 Zakynthos-Keri M6.5, 1899 Kyparissia M6.5, 1947 Pylos M7.0, and 1997 Gargaliani M6.6). To accurately locate the seismic activity, we deployed, in Fall 2006, an onshore/offshore seismic array, consisting of 17 ocean bottom seismographs (OBS) and 15 stand alone land stations (Fig. 1). Both marine and land stations used were equipped with the SEDIS III seismic recorder of GeoPro, Hamburg (Makris and Moeller, 1990). Within the two-month period of array observations we recorded more than 3500 microearthquakes above a threshold of magnitude of M_L 0.3, observed by a minimum of six stations. Magnitudes were defined by the coda-length of the recorded events, (Crosson, 1972) previously calibrated using earthquakes recorded also by the Seismograph Network of the National Observatory of Athens. To locate hypocenters we used HYPOINVERSE software (Klein, 2002) and we adopted a 1D velocity model based on a controlled source seismic experiment (Makris & Papoulia, 2008) as presented in Table 1.

Table 1: Local velocity model for hypocentral location (after Makris & Papoulia, 2008).

Velocity V_p (km/sec)	Depth (km)
4.50	0.00
6.20	4.00
6.80	10.00
8.00	25.00

**Fig. 1:** Location of the on/off-shore seismic network and active seismic profile PII (left). Epicenter map of micro-earthquakes recorded by SEHELLARC array in southwestern Hellenic arc (right) (after Papoulia *et al.*, 2008).

From the epicentral distribution of the located events it is shown that shallow activity (0-15 km), associated with the deformation in the upper crust, is mainly detected at the southern part of Zakynthos island and at the offshore zone of Pylos area (Fig. 1). Seismicity associated with the deeper part of the crust (15 – 30 km) deepens gradually from west to east, from 20 to over 30 km, following the crustal thickening and the trend of the subduction zone. Subcrustal seismicity follows the subduction below western Peloponnese with gradually increasing hypocentral depths eastwards. Along the profile PII in NW-SE direction (Fig. 1), all events are crustal except for a major zone with deep seismicity that extends to nearly 90 km depth (Fig. 2). This unusual pattern coincides with a trans-tensional basin northeast of the island of Strofades, and is associated with fracturing of the oceanic lithosphere, in the subduction zone below the western Hellenides (Papoulia *et al.*, 2008).

2. Methods

Passive tomography inversion applied in the present study is a 2-step procedure. At first both P and S wave arrivals are inverted with the algorithm VELEST (Kissling *et al.*, 1994) in order to obtain the minimum 1D velocity model. In a second phase the resulted model is used as an initial model for the 3D linearized tomography code Simulps14 (Thurber, 1983, Ebenhart-Phillips, 1986, 1990) in order to determine the 3D velocity structure of the area. In the present application, the initial 1D velocity model used was the one obtained from active seismic observations along profile PII (Fig. 2). Also hypocentral relocation for the final 3D velocity model was accomplished by applying least-squares inversion within the firtran code processing of Smulp1

From the initial data set we selected the most reliable events depending on the number of phases and the location of the epicenter (within or outside the network array). 273 events were selected using criteria such as the hypocenter RMS value (calculated by hypoinverse location program) and number of phases used for the location. Only events with absence of T-phases were selected. Epi-

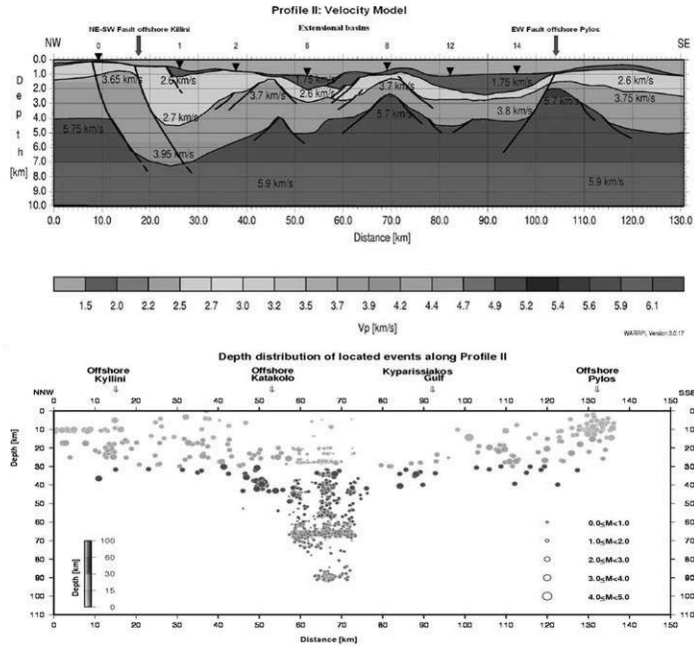


Fig. 2: Velocity model along profile PII (upper part) with fault indication and depth distribution of located events along the profile (below) (after Papoulia et al., 2008).

central distribution of the selected events before and after the simultaneous inversion of Simulps14 relocation process is presented in Figure 3.

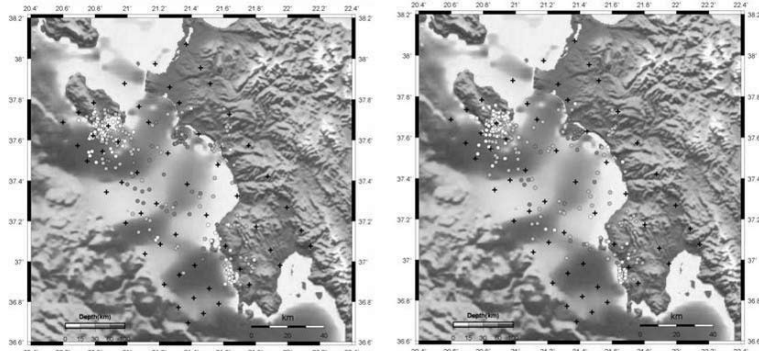


Fig. 3: Initial epicenter distribution of a data set of 273 selected events (left) and relocated epicenters after the simultaneous inversion procedure (right). 2D projection of the 3D grid used during the inversion (crosses) is also presented.

3. Results

From the simultaneous inversion performed both for P and S phases of our selected data set a new 3D velocity model for the upper part of the crust was developed. P- and S-wave velocity distribution at different crustal depths after the 3D simultaneous inversion is presented in Figure 4. Grid-values of the resolution matrix (KHIT) elements at all depths that have been adopted in the ini-

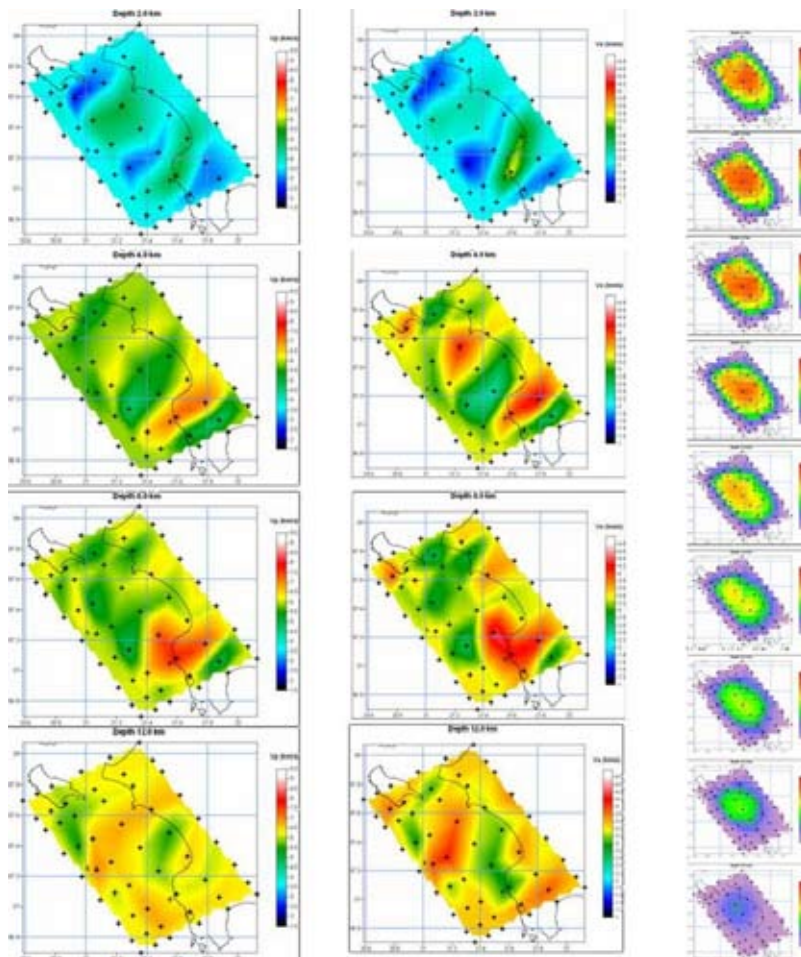


Fig. 4: P- (left column) and S-wave velocity distribution (middle column) for the depths of 2, 4, 8 and 12 km after the 3D simultaneous inversion. Elements of the observation matrix KHIT (right column) corresponding to the layers where the 3D grid was applied (0, 2, 4, 8, 12, 15, 20, 25 and 35 km) are also presented. KHIT matrix indicates the integer ray-node 'hit-count' (Evans et al., 1994).

tial velocity model are also presented. Depth distribution of the initial and relocated seismic events along profile PII is presented in Figure 5.

4. Discussion

From the V_p - and V_s -wave velocity distribution at different crustal depths (Fig. 4) the uplifted blocks of Messinia to the south and Zakynthos to the north are well discriminated. Also the Strofades block is present in the central part of the profile. Lower V_p and V_s -wave values are in accordance with the existence of basins in between the uplifted blocks.

On the other hand and because of the restricted grid position (based on our network array), only two of the three semi-basins, indicated from the active experiment (Fig. 2, upper part), are visible by the application of the passive tomographic inversion. In spite of the limitations, passive tomography implementation results are in good agreement with active tomography profiles and confirm the

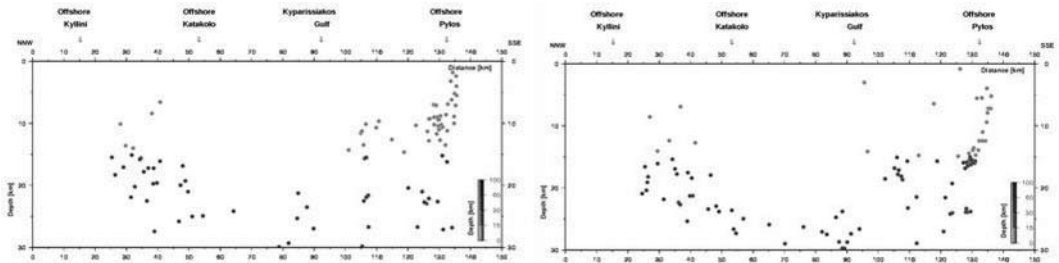


Fig. 5: Depth distribution of located events along profile PII: original data (left) and relocated events after simultaneous inversion (right).

dominant geometry of the main structure features offshore Kyparissiakos Gulf area. This is evident from Figure 5, where fault delineation at both north and south margins of the Kyparissiakos gulf is better demonstrated after the 3D simultaneous inversion.

5. Acknowledgements

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