Journal of Asian Earth Sciences 42 (2011) 1091–1096

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

3-D velocity structure of Damavand volcano, Iran, from local earthquake tomography

Akram Mostafanejad [a,b,*], Z. Hossein Shomali [b,c], Ali A. Mottaghi [b]

[a] Center for Earthquake Research and Information, University of Memphis, 3890 Central Ave. Memphis, TN 38152, USA
[b] Institute of Geophysics, University of Tehran, 14155-6466, Iran
[c] Department of Earth Sciences, Uppsala University, Uppsala 75236, Sweden

ARTICLE INFO

Article history:
Received 21 May 2010
Received in revised form 4 March 2011
Accepted 9 March 2011
Available online 21 March 2011

Keywords:
Local earthquake tomography
Magma chamber
Crustal structure
Damavand volcano

ABSTRACT

Damavand volcano is a large intraplate Quaternary composite cone overlying the active fold and thrust belt of the Central Alborz Mountains in northern Iran. In this study, we present the first 3-D P-wave velocity model of the upper crust for the Central Alborz region using local earthquake data provided by the Iranian Seismic Telemetry Network. The final P-wave velocity model reveals several high and low velocity anomalies in the upper 30 km of the crust. A low velocity zone parallel to the main faulting system is imaged at a depth of 15 km. A relatively high velocity body to the north of the Damavand summit down to a depth of 20 km is resolved, which may represent the elderly crystallized magma chamber. Right below the Damavand cone, a low velocity area to the depth of 7 km can be interpreted as a shallow magma chamber.

1. Introduction

Much progress has been made in recent years in resolving the physical and chemical characteristics of volcanic fields. Improved datasets and methods have enabled 3-D imaging of volcanic areas with great detail (e.g. Lees, 2007; Salah and Seno, 2008; Waite and Moran, 2009; Zhao et al., 2011). High velocity anomalies observed in these areas are generally addressed to as older, consolidated magmatic bodies, and low velocity anomalies are regarded as the presence of molten zone or fluids (Lees, 2007).

The Alborz Mountain range in the southern margin of the Caspian Sea is a part of the Alpine–Himalayan orogenic belt. In the central part of this compressional ranges, Damavand volcano has been constructed in Quaternary (Allenbach, 1966; Davidson et al., 2004). Formation of such a large but isolated volcano, with regard to the overall compressional regime in the Alborz Mountains, has long been subjected to discussions. We performed a local earthquake tomography in this region for the first time, which aims at elucidating some undetermined aspects of this complex geological region, particularly internal structure of the Damavand volcano.

2. Geological setting

Damavand volcano, a young, dormant strato-volcano situated 50 km north of the metropolitan Tehran, is a large intraplate Quaternary composite cone of trachyandesite lava and pyroclastic deposits overlying the active fold and thrust belt of the Central Alborz Mountains. It has an altitude of 5670 m, which corresponds to the highest peak in the Middle East. Isotope dating, and geological studies, have revealed that the present cone (young Damavand) has been constructed over the last 600 k.y. a little to the south and on an older, eroded edifice of the old Damavand (Davidson et al., 2004).

The Alborz Mountains, with an arc shape fold and thrust belt borders the Caspian Sea in the south (Stöcklin, 1974; Axen et al., 2001; Davidson et al., 2004). According to gravity modeling the crustal thickness beneath the Alborz Mountains is about 35 km (Dehghani and Makris, 1984). The central part of the Alborz Mountains is characterized by a "V-shaped" structure (at about 50E to 54E) separating folds and faults with a NW–SE trend to the west from a NE–SW trend in the east (Berberian, 1976) (Fig. 1). The geology of the Alborz Mountains is controlled largely by major thrust faults. The Mosha fault (Fig. 1) is the most prominent structure in the southern part of the Central Alborz region (Moinabadi and Yassaghi, 2007). It is an active, high dip angle reverse fault with an approximate length of 400 km (Berberian et al., 1993), which had experienced several destructive earthquakes with magnitude greater than 6.5 (Berberian and Yeats, 2001). The maximum displacement along the Mosha fault is up to 4 km (Allenbach, 1966; Tchalenko et al., 1974). The North Tehran fault is another major feature in this region. 20 km to the east of Tehran, the North Tehran fault diverges from the Mosha fault and forms a north dipping, active, left lateral oblique thrust fault (Allen et al., 2003). Guest et al. (2006) suggested that the North Tehran thrust merges with

* Corresponding author at: Center for Earthquake Research and Information, University of Memphis, 3890 Central Ave. Memphis, TN 38152, USA.
E-mail address: mstfnjad@memphis.edu (A. Mostafanejad).

1367-9120/$ - see front matter
doi:10.1016/j.jseaes.2011.03.011

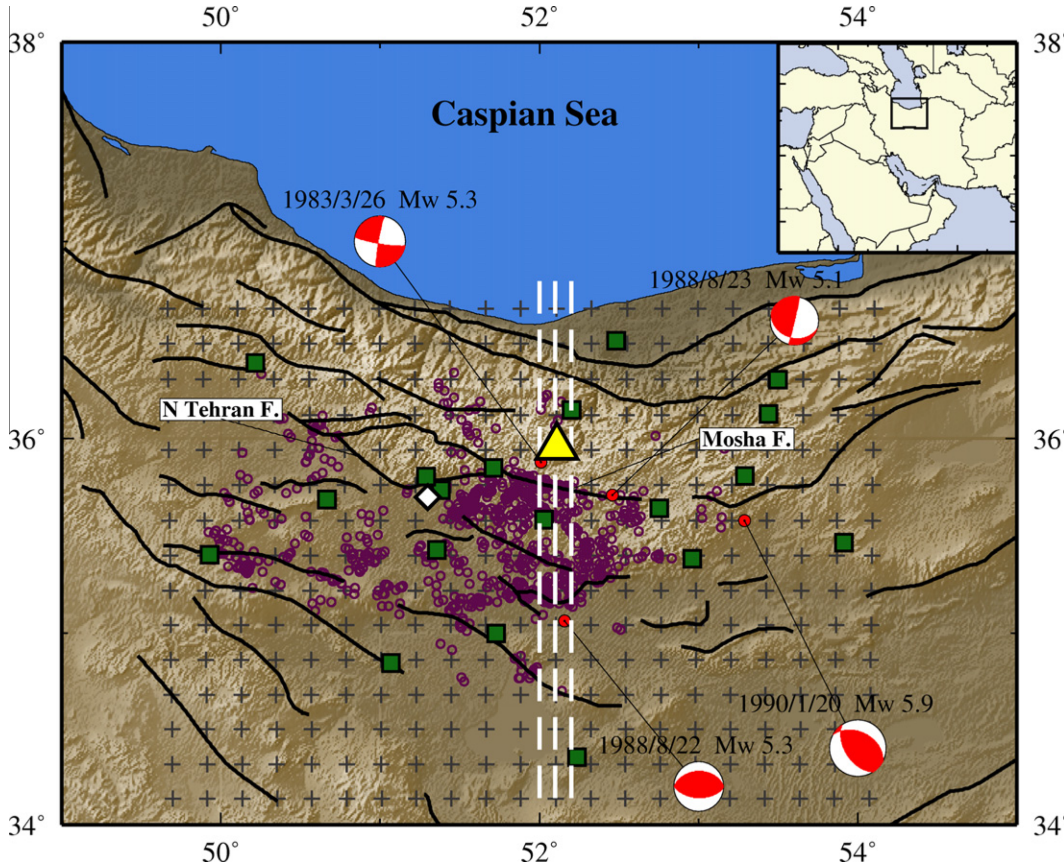

Fig. 1. (a) Map of Central Alborz Mountains showing stations (green squares) and local earthquakes (from 1996 to 2006, purple circles) used in this study. Yellow triangle: Damavand volcano, black lines: main faults in the region, diamond: Tehran, white dashed lines: profile along Damavand volcano and 10 km to the east and west side, cross: grid node. Node spacing is 20 km. Fault plane solutions of large events (Mw > 5.0) are from Harvard University (2009). Inset map shows location of studied area in the Middle East. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Mosha fault at depth. Damavand volcano is situated 20 km northwards from the Mosha active fault and lies unconformably on folds and thrusts (Liotard et al., 2008). Tectonic activity in the Alborz Mountains is due both to the convergence of central Iran toward stable Eurasia, and to motion of the South Caspian Basin, with respect to Eurasia. Coupled with the NS convergence of central Iran (52 mm/yr), the south-westward motion of the South Caspian Basin, with respect to central Iran, leads to a NNE-SSW transpressional regime in the Alborz (Vernant et al., 2004; Ritz et al., 2006). Ritz et al. (2006) documented a transition from transpression to active transtension in very recent time in the Central Alborz region. According to their estimation, the transtension started between 1 and 1.5 Ma. This is contemporaneous with the Damavand volcanic activity, which Davidson et al. (2004) dated as occurring between 1.8 Ma and 7 Ka.

3. Data and method

Fig. 1 shows the locations of the seismic stations and epicenters of relocated earthquakes. The seismic array consists of 19 permanent stations of the Iranian Seismic Telemetry Network (IRSC) equipped with 3-component short period (SS1) seismometers. The location of earthquakes was improved through using the hypoDD method (Waldhauser and Ellsworth, 2000). HypoDD determines relative locations within clusters using the double-difference algorithm. This algorithm improves relative location accuracy by removing effects due to an un-modeled velocity structure through the propagation path. A significant improvement in hypocenter locations is observed by comparing the relocated earthquakes using hypoDD and those routinely determined by IRSC (Mottaghi et al., 2010). We selected 895 relocated earthquakes between 1996 and 2006 based on the following criteria: (1) all the local earthquakes used are located within the seismic network with azimuthal gap less than 180°, (2) the uncertainties of the hypocentral locations (both horizontal and vertical) are, on average, less than 6 km during relocation with the 1-D background model and (3) all the selected earthquakes are recorded by at least four stations. Our final dataset is composed of 5559 P-wave observations, giving an average of 6 P-wave observations per event (Figs. 1 and 2). For the initial 1-D velocity model, we used the model developed by Ashtari et al. (2005), which is based on 1-D inversion of the arrival times for local events (Kissling, 1988). We used a damped least-squared iterative method (SIMULPS14), (Thurber, 1983; Eberhart-Phillips, 1990; Evans et al., 1994) to solve the non-linear tomography problem (Haslinger and Kissling, 2001; Husen et al., 2003). Hypocenter locations are included in the inversion as unknowns, due to the coupling of hypocenter locations and velocities (Thurber, 1992). Travel times through the velocity model are calculated using full 3-D shooting ray tracing (Virieux and Fara, 1991; Haslinger and Kissling, 2001). Having considered the ray coverage of the dataset (Fig. 2), we chose a horizontal model parameterization of 20 × 20 km for the regional model. This model parameterization represents the finest possible model grid spacing without showing a strongly heterogeneous pattern of the derivative weight sum (DWS) (Husen et al., 2000, 2003). Grid node spacing with depth is 5 km. Following the method introduced by Eberhart-Phillips (1986) for estimation of an optimum damping