

Paleoseismological analysis in Central Alborz, Iran

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Abstract

Central Alborz corresponds to the E-W trending mountain range bounding the Caspian Sea to the South. It is an active mountain trend belonging to the Alpine-Hymalian seismic belt, connecting the Talesh and the Lesser Caucasus ranges to the West, and the Eastern Alborz structures to the East. The present tectonic activity Central part of the Alborz is distributed within two external opposed verging structures: The Qazvin, North Tehran, Parchin and Garmsar southwards thrusting fault zone to the South, and the Khazar fault northwards thrusting fault (hidden below young sediments in most places) to the North. Inside Alborz, the Taleghan, Mosha, Firouzkuh and Astaneh faults define a main left-lateral strike-slip corridor attesting of the partitioning of the deformation in Alborz. Among this strike-slip fault system, transtensional features are observed with measurable finite vertical deformations allowing estimating the beginning of the partitioning in Alborz to be around 1 Ma (Ritz et al., 2006), contemporaneously with the volcanic activity of the Damavand. Although, no strong instrumental event occurred in the area, several large historical earthquakes occurred along the above-mentioned faults, demonstrating the high seismic hazard in the region, notably for the Tehran (12 Millions). In order to assess the seismic hazard in Central Alborz, we started an analyse combining remote sensing, morphotectonics and paleoseismology to quantify precisely the geometry and the kinematics of the faults, and estimate their slip rates and earthquakes return periods.

Key words: Iran, Alborz, Paleoseismology, Slip rate, Recurrence time.

North Tehran fault:

The North Tehran Fault is located at the southernmost piedmont of Central Alborz (Figure 1). It stands out as a major active fault menacing directly the city of Tehran, a 12 millions inhabitants mega pole, and would have been the source of several major historical earthquakes in the past. The fault zone extends within the 110 km and corresponds mainly to a reverse fault crossing the northern suburbs of the Tehran metropolis. We found out a ~ 3 m fault scarp affecting Upper-Pleistocene and Holocene deposits within the central part of the fault, cumulating several events along a N115°E trending 30°N dipping fault plane (to which is added a small left-lateral component). Our paleoseismological (Figure 2) investigations within two trenches dug across the fault scarp zone reveals evidence for 8 surface-rupturing events within the past ~30000 yr (optically stimulated luminescence ages). The two last events involved 2.35 m of total reverse displacement along the fault during the last ~ 8000 yrs (0.77 m for the latest event and 1.58 m for the penultimate). The 8 events have magnitudes $M_w > 6.5$ and the mean return period is 3175-4075 yrs. The average slip rate along the North Tehran fault is 0.3 ± 0.05 mm/yr (Nazari, 2006; Nazari et al., In revision for JGR 2007).

Taleghan Fault:

The Taleghan Fault is located at the southern side of Taleghan Valley in Central Alborz, 90 km northwestwards of the Tehran mega pole (Figure 1). Usually described as a south-dipping reverse fault, it could be the source of some of the strongest historical earthquakes recorded in the Tehran region, notably the 958 AD (estimated magnitude M 7.7). The fault stands out as one of the major active structure menacing the cities of Tehran and Karadj, representing together 15 millions inhabitants. We found out an active branch that had never been described before whereas the fault classically mapped appears inactive. Detailed field work along that branch allows us to show that the fault had its vertical component recently reverted from reverse movement to normal movement. The maximum cumulated vertical displacement associated to the normal movement is about ~350 m. The strike, dip and rake of the eastern part are N105°E, 60°S and 50°E making it a normal-left-lateral strike slip fault. Our paleoseismological study provides evidences for 4 surface-rupturing events totalizing a minimum of 5 m displacement along the fault. These events occurred within the past ~ 5300 years yielding vertical and horizontal slip rates both about 0.6 mm/yr. The magnitudes (M_w) are comprised between of 6.5 and 7.2, and the mean return time is about 1200 yrs (Nazari, 2006). The two last events totalized 1.77 m of normal displacement and occurred between 134-339 cal AD and a date close to 1660 cal AD with evidences for a penultimate shortly after 134-339 cal AD, but cannot be connected with any historical data. The last event may correspond either to the 958 AD event classically attributed to the Taleghan fault or to the 1665 historical event classically reported to the eastern Mosha fault (Figure 2).

Mosha Fault:

The Mosha fault is one of the major active faults in Central Alborz (Figure 1) as shown by its strong historical seismicity and its obvious morphological signature. Situated at the vicinity of Tehran city, this ~150 km long ~N100E trending fault represents an important potential seismic source that threatens the Iranian metropolis. Our investigations within the Tar Lake valley, along the eastern part of the fault – potentially the site of the 1665 (VII, 6.5) historical earthquake - allows us to calculate a preliminary 2.2 ± 0.5 mm/yr minimum left lateral slip rate (Ritz et al., 2003). If we assume a characteristic coseismic average displacement comprised between 0.35 m (M_w 6.5) and 1.2 m (M_w 7.1) – calculated from Wells & Coppersmith's functions (1994) and taking the moment magnitudes attributed to the 1665 and 1830 earthquakes (e.g. Berberian & Yeats, 2001) – the mean maximum recurrence intervals along this segment of the Mosha fault are comprised between 160 and 620 yrs (Figure 2).

Firouzkuh and Astaneh faults:

The Firouzkuh fault with a length of approximately 70 kilometers and Astaneh fault with more than 100km length are visible on satellite images from the Eastern end of the Mosha fault (Figure 1). Both faults have SW-NE strike and skirt the reliefs located at the south-east of the Firouzkuh valley and Astaneh valley. The Firouzkuh fault is a south-dipping sinistral strike-slip fault (Jackson et al., 2002; Nazari, 2006). Our preliminary morphotectonic study in west of Firouzkuh and west part of Astaneh allowed us to determined the geometry and the kinematics of the fault which are sinistral-normal N060E 70S 05E (Azimuth, dip, pitch). Trenching across these faults allowed identifying four to six paleo-earthquakes of magnitudes M_w ranging from 6.6 to 7.5 along each one of these strike-slip fault (Figure 2).

Discussion-Conclusion:

Our preliminary data suggest that a major part of the present shortening in Alborz is localized on the Northern face of the chain along the Khazar fault zone. This border can be interpreted as frontal contact between Alborz and the South-Caspian basin – it is however worth noting that this contact might be located further to the North under the sea - e.g. in the West of Noor. A recent stratigraphic study on the upper Holocene –Pleistocene in the valley of Garm Rud, in the East of the valley of Haraz, suggests a minimum incision rate of 1.25 mm/year as calculated for the last 12 Kyr (Antoine et al., 2006). If it is assumed that the incision is related to the vertical component along the Khazar fault, the horizontal N-S shortening along

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this fault would be 2.5 mm/year (for a 30° S-dipping fault). We did not detect significant quaternary deformations between the Northern edge and the zone of major sinistral shearing consisting of the faults of Firouzkuh, Mosha, Taleghan, and Kandevan.

The fault zone of Taleghan, Mosha, Firouzkuh and certainly their extensions to the NW (Kandevan) and SE (Astaneh) appears to be very active and localizing most of the sinistral shearing deformation of Alborz. According to the slip rate data calculated for the Holocene period over Mosha and Taleghan, a sinistral shear (long term slip rate) of 1 to 2 mm/year would be absorbed on this fault zone corresponding to a major fraction of the shearing estimated for the whole Alborz by GPS stations (i.e. 4 ± 2 mm/year by (Vernant, 2004b), and 2.5 ± 1.5 mm/year by (Djamour, 2004).

The Southern edge of Alborz (the faults North Tehran and Parchin) shows a primarily reverse kinematics with a slight sinistral component. From a strictly morphological point of view, this zone is less active than the Northern edge. Our preliminary paleosismologic data seem to confirm this qualitative analysis with an estimate of only about 0.26 mm/year for the shortening through North Tehran fault (Nazari et al., in revision for JGR 2007). This is only 1/10th of the total shortening of Alborz, estimated 5 ± 2 mm/year by Vernant et al (2004) and re-evaluated 4.5 ± 1.5 mm/year by Djamour (2004). The vertical displacement rate along the fault is about 0.1 mm/year. These results altogether are to be regarded with caution since the deformation in a reverse system of this kind can be distributed over several fault segments, although our investigations within the classically mapped North Rey, South Rey faults (Berberia, 1983; Berrberian and Yeast, 1999) tend to show that they are simply terraces risers.

Our morphotectonic and paleosismologic study in the region of Central Alborz provides also new elements related to the issue of the current kinematics of peri-Caspian chains. We showed that the present activity of the Taleghan, Mosha, and Firouzkuh fault correspond to a sinistral strike-slip motion with a normal component. Before that, during the Miocene-Pliocene, they worked with a main reverse component (Ritz et al, 2006). We estimate this inversion of to be around 1Ma, which is consistent with the fact that the reliefs are yet reversed. As these structures are related to the sinistral shearing which affects the whole Alborz and this shearing is related to the movement of the South Caspian basin towards the North-West respectively to Eurasia. We therefore that conclude that the kinematic reorganization touching the South-Caspian region and its neighboring regions dates back to the Pleistocene and not to the Pliocene as proposed earlier.

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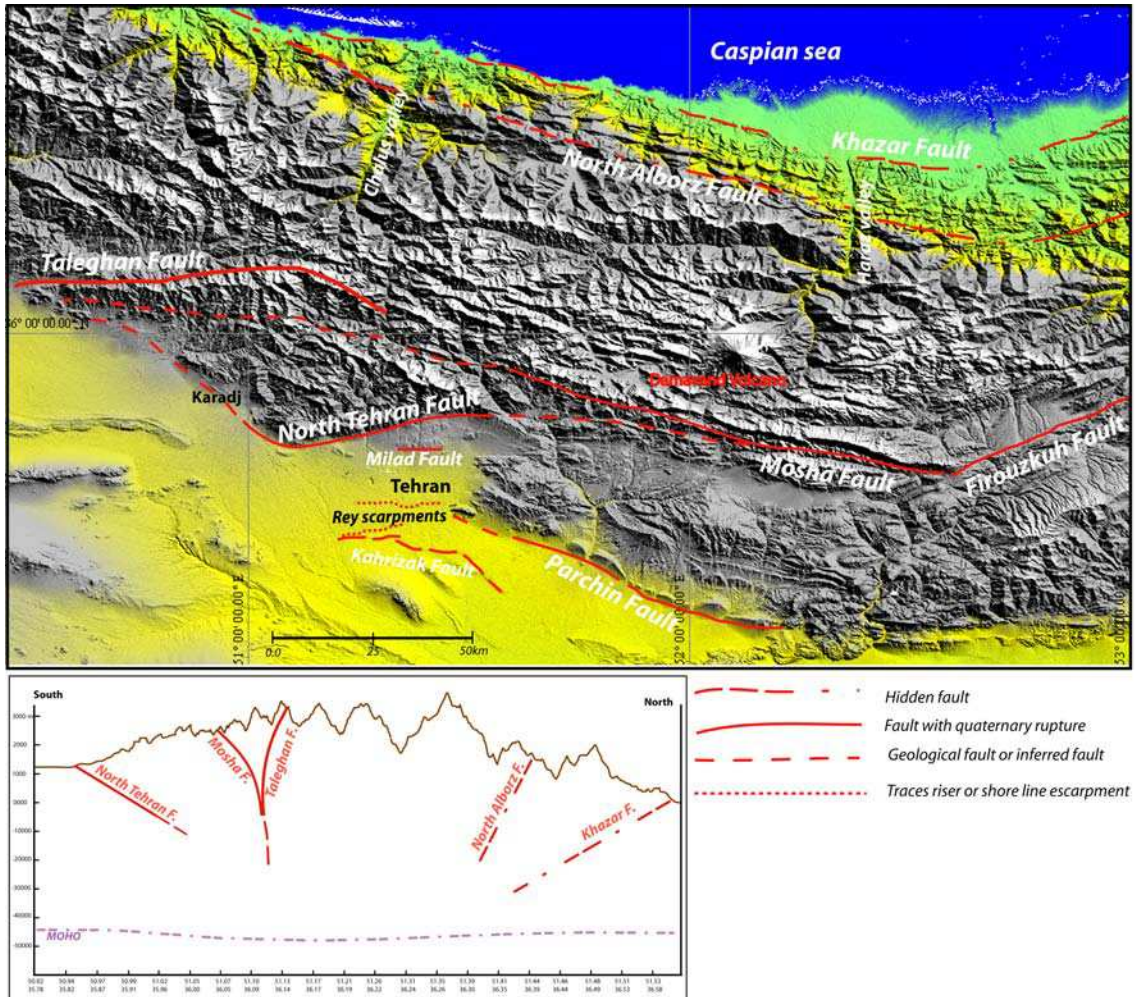


Figure 1: Faults map in Central Alborz.

Perspectives of paleoseismology projects in Central Alborz, Iran

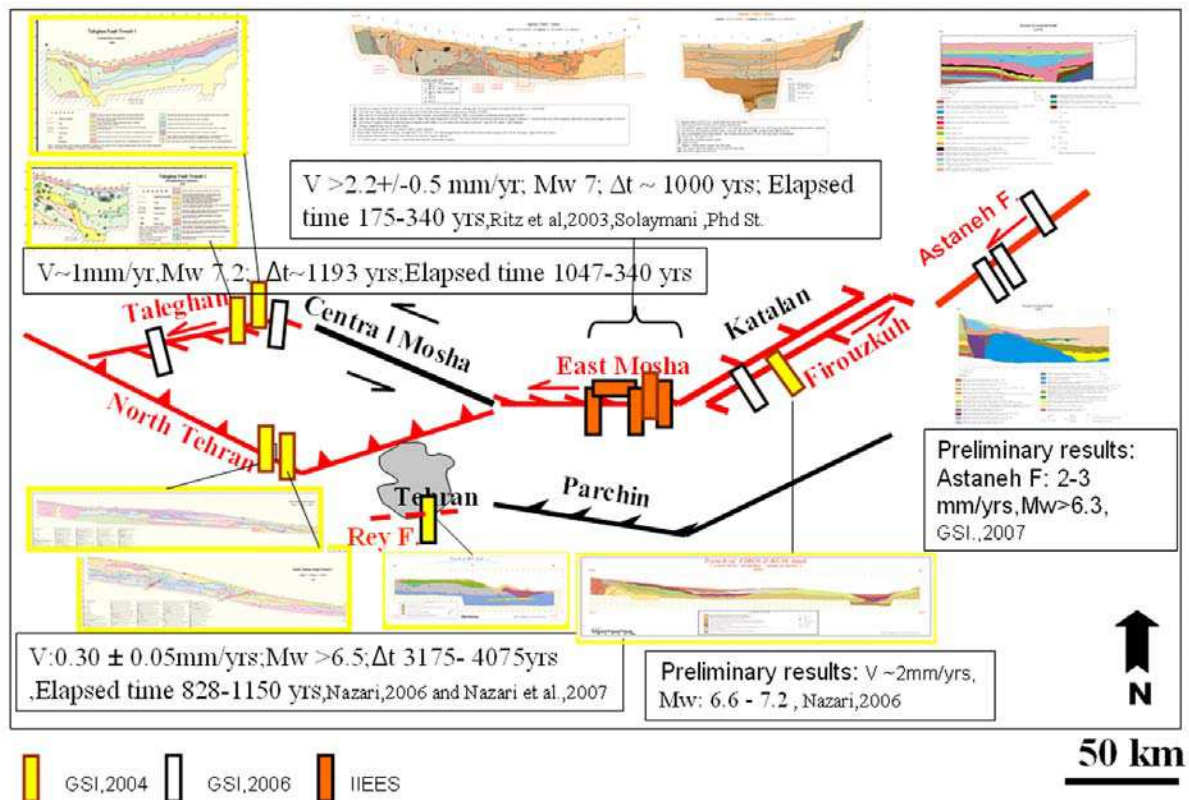


Figure 2 : Paleoseismological map in Central Alborz.

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