The Tarímbaro-Álvaro Obregón Fault, a major structure of the Morelia-Acambay Fault System in central México

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Supplementary data

Ground Penetrating Radar (GPR) survey

Two GPR surveys were carried out perpendicularly to the eastern segment of the fault (G1 and G2). The first survey (G1) was acquired with a MALA radar and a 100 MHz antenna, aided by an odometer and a Garmin GPS to measure and locate the surveyed profiles. The second survey (G2) was done with 250 and 100 MHz antennas. We used the software Reflex v.3 (Sandmeier, 2016) for data processing, with a 0.11 m/ns average speed.

The profile G1, acquired with 100 MHz antennas, reached 3 m depth (Fig. 12A). Deformation was not observed due to the poor resolution of the record in shallower layers. However, an 8 m-wide disturbance zone was observed between 22 and 30 m along the profile. In this zone, red segmented lines indicate reflector discontinuities that cross sub-vertically all the reflector sequences below 1 m depth (Fig. 12A-right). Due to the short range in depth of the GPR record, no vertical offset can be evidenced in the reflector sequences. In the field, these discontinuities coincide with faults that displace old soils and sediments. However, the trench dug in this site was not studied due to the lack of recent displacement.

Profile G2 was surveyed with 100 and 250 MHz antennas. The radargram obtained with the 100 MHz antennas (Fig. 12B) shows lateral discontinuities between 60 and 80 m along the profile With the topographic correction, the discontinuities (lines in red) are interpreted as inclined planes of weakness, which sub-vertically cut reflector sequences up to the maximum depth reached with the equipment (~ 4 m depth). By analyzing the GPR record with field observations, there were no elements on the surface that correlated with the responses observed in depth between 58 and 64 m along the profile G2, therefore, the observed discontinuities could be related to the response of elements of interest under the shallow layers of the subsoil. Unfortunately, the limited depth range and the low resolution of the records in this sector make it difficult to identify the continuity of these deformation planes in depth.

There is no obvious vertical offset in the deformed sequences around 60 m along the profile G2, but in this zone, an area is visibly affected by some type of geological or anthropogenic structure (Fig. 12B-right). Considering the discontinuity identified at a distance of 84 m on the profile, a 20 m-width affected zone is suggested (between 60 and 84 m along the profile; Fig. 12B).

The radargram for profile G2, obtained with the 250 MHz antennas (Fig. 12C), shows a visible affected area of the shallow sequences that extends about 20 m (between 70 and 90 m along the profile; Fig. 12C-right). In this area, discontinuity planes are identified with red lines that cross the reflector sequences. Due to the low range in depth obtained with the 250 MHz antennas, it was impossible to identify the vertical extension of deformation planes. However, due to the similarity of the responses obtained with 100 and 250 MHz antennas for this profile, it can be indicated that these discontinuities correspond to the presence of elements in the subsoil that generate deformation of the shallow sequences.

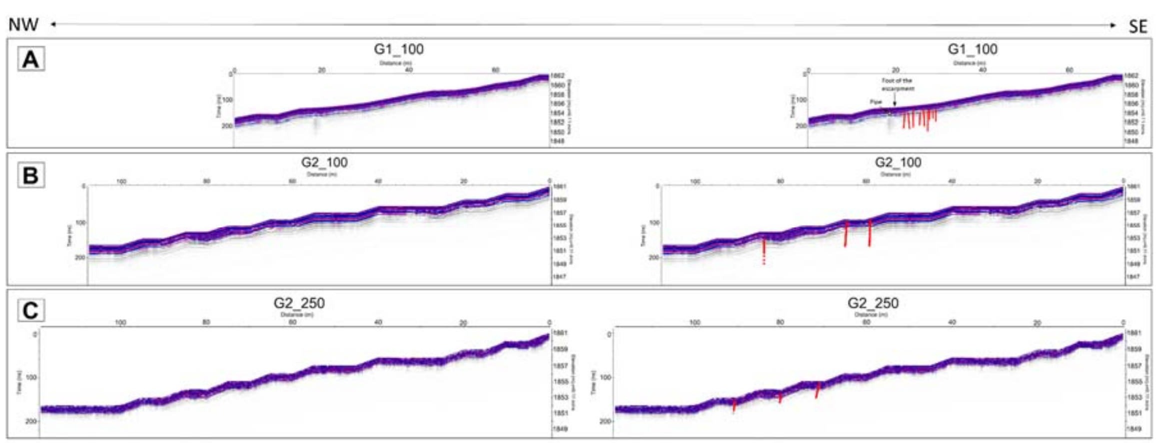

Fig. 12 Ground Penetrating Radar (GPR) record obtained from the eastern Tarímbaro-Álvaro Obregón fault. A, Uninterpreted and interpreted radargrams with 100 MHz antennas for the G1 profile. B, Uninterpreted and interpreted radargrams with 100 MHz antennas for the G2 profile. C,

Uninterpreted and interpreted radargrams with 250 MHz antennas for the G2 profile. The dashed lines in red represent the most prominent lateral changes in the record

Seismic tomography

PROFILE G1'

A P-wave velocity model is obtained, reaching depths between 10 m to the SE and 30 m to the NW. Three different layers are interpreted according to the main changes in the velocity gradients. The first layer is the shallowest, having an average of 10 m thick along the profile and velocities varying between 600 to 900 m/s. The second layer presents more thickness variability, in the SE is about 10 m, with a 5 m shortening around 60 m of distance in the profile, and then getting thicker to the NW, reaching approximately 22 m. The velocities of layer 2 vary between 1000 and 1500 m/s. Layer three is the deepest layer of the velocity model, it is shallower in the SE and deeper in the NW. Its average velocity is greater than 1700 m/s. The transition between layer 1 and layer 2 is abrupt, obtaining fast changes of the velocity gradients, as well as the transition between layers 2 and 3, excepting the NW end of the profile where the velocity gradient changes are smooth (Fig. 13). In the middle part of the profile, the observed shortening of the layer thicknesses could be related to the deformation caused by one of the parallel branches of the TAO Fault.

PROFILE G2'

Even though this profile is not far from profile G1', the layer's geometry is slightly different, as well as the thickness variations and the P-wave velocity values. In general, in this profile, we obtained a more homogeneous layering being thinner to the SE and thicker to the NW. The P-wave velocities are lower than in profile G1. The first layer is less than 5 m thick along the velocity model, and it has probably been eroded at the SE. It has an average velocity of 585 m/s. The second layer is 2 m thick at the SE and rapidly gets thicker to the NW, reaching almost 20 m. This layer has velocities of 600 – 850 m/s. The third layer is 4 m depth in the SE and 25 m in the NW, having an average velocity greater than 900 m/s. This last layer could be correlated with the second layer of profile G1'. As the profile G1', the change between layers 1 and 2 is abrupt, while the one between layers 2 and 3 is more transitional, at least between 35 m to 120 of distance in the profile (Fig. 13). The layers in this profile still are not being deformed due to the movement of the TAO fault. Rather than this, the layer geometry shows a normal deposition of lacustrine sediments at the end of the fault scarp.

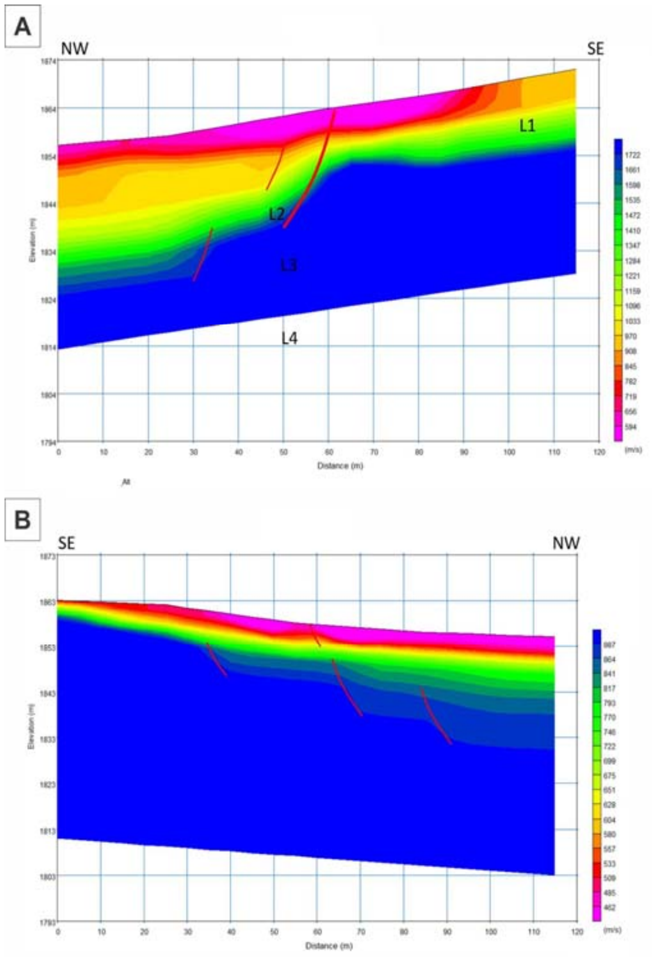

Fig. 13 Results of the seismic tomography surveys in the eastern segment of the Tarímbaro-Álvaro Obregón fault. A, G1’ profile. B, G2’ profile. See the location of both profiles in Fig. 4