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Geodetic evidence for shear instability in the west part of the North Aegean Trough, in a 100+ years scale

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Overview

GPS data describe well deformation of the crust in tectonically active regions, but they cover a period of up to few decades only, and this interval is very short compared to geological processes and the repeat intervals of earthquakes. A possibility to expand this geodetic record is to exploit historical geodetic data.
In this article we analyze triangulation data covering the west edge of the North Aegean Trough (NAT), an area of complicated tectonics, and document an instability in the kinematics of the study area in time scale of a few tens of years. This result is consistent with the distribution of earthquakes and may provide some clues on the termination of major strike slip faults.

The North Aegean Trough (NAT)

The North Aegean Trough (NAT) is a prominent, about 1000m deep, tectonically active marine basin in North Aegean, at the continuation of the North Anatolian Fault (Taymaz et al, 1991; Kreemer et al, 2004; Saltogianni et al, 2015). At its eastern part, at the continuation of the North Anatolian Fault, NAT is identified with a narrow basin which hosted, among others, the 2014, strike slip M_w6.9 Samothraki-Imvros (Gokceada) earthquake (Saltogianni et al, 2015). At its middle part, the NAT is overprinted by a transtensional basin, while farther west its width increases and becomes a rather diffuse, double half-graben structure (Papanikolaou et al. 2002; Georgiou et al. 2016), also marked by essentially strike slip earthquakes but with more diffuse pattern (Taymaz et al, 1991; Roumelioti et al, 2004; Ganas et al, 2005). The overall pattern is confirmed by displacement vectors of the HEPOS GPS network, the first homogeneous and well-tested permanent GPS network analyzed in this area (Mouslopoulou et al 2014).
In the past, it was thought that NAT and the North Anatolian Fault continue through the Greek mainland, but this seems not likely. First, the active tectonic and morphotectonic pattern of continental Greece do not support this hypothesis. Second, the streamlines of slip vectors from the permanent HEPOS GPS are characterized by bending near the coast of the Greek mainland, indicating a kind of barrier in the kinematics and deformation of the area (Mouslopoulou et al, 2014).

Historical geodetic (triangulation) data and tectonic information

High quality triangulation data cover southern and central Greece and part of the Sporades Isles. These data were collected during three major surveys, in the 1890's, 1920's and 1960's, are homogeneous and of exceptionally high quality, and many of the pillars of the first survey were also used in the two later surveys so that a comparison of data of successive surveys can be made. Available historical triangulation data are reliable, especially because they cover all three angles of triangles, so that the error control in excellent (Stiros, 1991).
The problem with triangulation data is that they do not provide information on the scale (distances between triangulation stations), and for this reason it is not possible to derive displacement vectors (unless certain a priori assumptions are made), and among the three elements describing the deformation tensor, only shear can be computed (Stiros et al 2013). This is, however, an ideal information for strike-slip environments (Fig. 1).

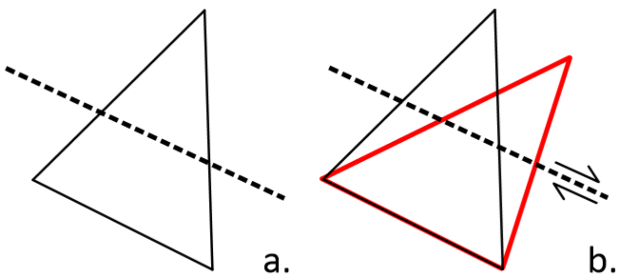

Figure 1. Conceptual model for derivation of shear from triangulation data. Fault activity tends to deform angles of a triangle crossed by a strike slip fault. Inversely, from the analysis of measured angles in historical triangulation data (i.e. of angles in triangles), shear deformation can be identified and quantified.

Analysis of data from the western part of the NAT

The available triangulation data were analyzed using the algorithm summarized in Stiros et al (2013) and there have been computed estimates of shear for the two different intervals, 1890's-1920's and 1930's-1960's.
During the second interval, between the 1920's-1960's, shear deformation was found compatible with that derived from modern GPS data and morphotectonic and seismological observations. On the contrary, during the first interval, 1890's-1920's, no evidence of significant estimate of shear deformation exists.
These results are statistically significant and reliable, and likely to indicate true contrasts in the kinematics of the study area.

Seismotectonic and structural constraints and implications

The inferred instability in the deformation pattern derived from historical geodetic data is intriguing because short-term (of the order of tens of years) fluctuations in the deformation pattern are not expected in a major strike slip fault.
Still, the inferred change in shear is consistent with changes in seismicity (e.g. Papazachos and Papazachou, 1997). The interval 1890's-1920's of no shear is marked by seismic quiescence at least for the western part of the NAT, while the interval 1930's-1960's is characterized by moderate and strong earthquakes, and such a correlation may have a structural significance.
On these grounds and based on the morphotectonics of the west edge of the NAT, and on the pattern of streamlines of the GPS-derived tectonic displacements (Mouslopoulou et al, 2014), we can propose the following scenario.
The west part of the NAT represents a structurally composite area (cf. Papanikolaou et al., 2002; Georgiou et al, 2016) and not a simple strike slip-controlled environment, and its overall deformation reflects the cumulation of different tectonic processes at different stages, as well as the influence of adjacent tectonic provinces (boundary effects). Superimposition of the deformation rates from these effects and sources may temporarily obscure certain regional effects (e.g. shear from the east), emphasize transient effects and lead to alternation of clusters of strong earthquakes with relatively short aseismic intervals.

Structural and tectonophysical implications: how strike-slip faults terminate?

Deformation of this area may also provide some clues for the problem of how major strike slip faults terminate. In fact, this is a question of both theoretical and practical (seismic hazard) importance, but for lack of data, no convincing answers have been given so far. The kinematics of the western part of the NAT may shed some light to this important problem.

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