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Elastic-plastic growth of the North Anatolian Fault constrained by geologic and geodetic data.

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We use an elastic-plastic model to explain the evolution of a major continental strike-slip fault, the North Anatolian Fault (NAF), associated with the westward extrusion of Anatolia in the Arabia Eurasia collision zone.

The NAF has grown for the last 10 Myrs by westward propagation of its tip from Karliova (eastern Turkey) toward the hellenic subduction zone. The fault has progressivelly decoupled Anatolia and Eurasia along a discontinuity, which has a lenght of around 1600 km today. GPS data show that the NAF behaves like a transform fault, altough the trace of the fault does not connect any plate-boundaries. 500 km still separates the tip of the NAF from the the hellenic subduction. Instead of localised strike-slip deformation, a more distributed deformation is observed in Greece, at the tip of the fault. The shear deformation imposed by the NAF is transfered from the NAF (24mm/yr strike slip) to secondary extensional structures: the Rift of Corinth (10mm/yr of extension), the Rift of Eubee (<5mm/yr of extension), and the North Aegean Trough (>10mm/yr of extension).

We aim at reconciling the real geometry of the fault, the seismicity and the geologic deformation with the bloc models supported by GPS observations. The latter show piecewise-rigid continents, while the former require large-scale transfer of elastic-stress between the faults, localised deformation on the main fault and distributed deformation at the tip of the fault. We assume that the NAF behaves like a shear crack, neither able to open nor to close. This crack (NAF) is embedded in an incompressible elastic-plastic lithosphere in a plane regime of strain. Pure shear stress is imposed at infinity and we propose that the normal traction stress remains unchanged along the hellenic arc during the process of extrusion. The stress singularity arising at the tip of the crack is absorbed by the deformation of the plastic zone of the NAF, which is observed in the geology of Greece (rifts listed above). The present-day deformation of the plastic zone observed by GPS, is used to determine the elastic-plastic yield stress (Tresca type), and the associated plastic flow rule of the model. Once the constitutive plastic behavior is determined, the length of the NAF remains the only state variable controlling the size and the shape of the plastic zone of the NAF and the amount of slip taken up by the NAF.

Our model is consistent with the present-day deformation and with the finite deformation. It can explain the shape and the size of the present-day plastic zone. Inside the plastic zone, the localisation of the extension and of the shear are also predicted. The time scale of the model is given by the velocity of propagation of the tip of the NAF wich is a priori imposed by the geology. Two distinct regimes are predicted as the NAF grows. For a NAF-tip located to the East of the Sea of Marmara, the growth of a single crack is possible in the plane of the NAF. For a NAF-tip located in the Aegean, the response of the Hellenic Arc to the loading due to the NAF brings the Aegean Sea close to failure. This has caused the nucleation of the southern branch of the NAF around 5 Ma ago when the tip of the NAF propagated trough the Sea of Marmara. The main NAF had to take a different path and has propagated 100 km to the North along the northern branch of the North Anatolian Fault. Thus the remarquable position of the NAF-branching point at mid distance in between the Karliova triple junction and the Hellenic subduction receives a mechanical explanation.