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Rupture Propagation along Fault Segments: An Open Issue for Greece

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Greece is dominated by a dense network of faults, most of which are active. Activity is evident either directly from historically and instrumentally recorded events, or indirectly from palaeoseismological and morphotectonic evidence. Due to the extended coverage by the sea, detailed field observations can be only carried out onshore, although technological advance allows satisfactory results in meso-scale analysis in marine environments as well. The vast majority of active faulting in Greece is emergent. Nevertheless, rupture rarely creates a unique clear escarpment. Recent strong earthquakes have shown that faulting in Greece can create a rather complex pattern showing, sometimes, resemblance among various areas.

Examples of almost identical faulting behaviour and co-seismic ground rupture pattern comprise the 1978 Thessaloniki (Mw 6.3) and the 1995 Kozani-Grevena (Mw 6.4) earthquakes. Both areas belong to an extensional tectonic regime documenting an extension direction of (roughly) N-S in the broader area of Thessaloniki (Central Macedonia) to NW-SE in the broader area of Kozani-Grevena (West Macedonia). In the first case (Thessaloniki), the sequence took place in the Mygdonia Basin, a roughly E-W-trending basin, whose southern and, at a lesser extent, northern margins are controlled by faults. The major marginal faults have formed a distinctive escarpment; however they are not straight, but curvilinear, separating the alpidic basement (footwall) from the basin deposits (hanging-wall). Nevertheless, the co-seismic ground ruptures of the 1978 sequence, documented a more complex pattern. Three main lineaments were documented: the major one followed the N-dipping southern marginal fault scarp at its central part; the two others bifurcated from the previous one basinwards: one ran antithetically through the basin in a NW direction reaching the opposite SW-dipping margin, while the other had an almost sub-parallel but shorter trace, dipping towards NNE. In the second case (Kozani-Grevena), a similar co-seismic ground rupture pattern was formed after the 1995 earthquake. The main NW-dipping fault is evident by a clear fault scarp at its NE part, whilst, at its SW part, the non-continuous fault scarp has produced a rather subdued morphology. The ground ruptures were mainly aligned along two lineaments, one along the main fault escarpment, and the other along a pre-existing strike slip fault that was reactivated, as the aftershock distribution profiles clearly show, as an antithetic normal fault merging with the main one at depth. Several other minor ground ruptures were scattered in between the two lineaments. At the NE tip of the main fault, the rupture abruptly stopped on an angular boundary, although another prominent fault scarp bearing polished slickensides in lateral scree occurs less than 2 km distance, forming a right-stepping underlapping geometry.

There are more examples implying the complexity of surface rupturing. In 1954 a strong event (Mw 6.6) stroke Southern Thessaly near Sophades. The early observations of ground ruptures misguidedly suggested a N-S-striking, E-dipping fault. On the contrary, recent detailed morphotectonic mapping revealed a multi-segmented fault system consisting of four left-stepping, overlapping, sub-parallel scarps, striking WNW and aligned in a roughly E-W direction at the south-easternmost part of the basin and a group of discontinuous parallel NW-SE-striking scarps towards NW. The basinal margins are fully controlled by these faults changing the direction from roughly E-W (normal to the extensional field) to SE-NW (parallel to the alpidic structures). Based on palaeoseismological investigations and the earthquake’s magnitude, all the E-W aligned segments should have been ruptured, as well as some segments westwards.

In 1981, an earthquake sequence occurred in the Alkyonides Gulf (East Corinth). The third strongest shock (Mw 6.2) on March 4 is clearly related with the Kaparelli normal fault system, which consists of three major segments. The most prominent, morphologically, segments are the two S-SE-dipping ones that bound the southern front of the Korombili Mt. The eastern segment has an E-W strike, while the western segment changes direction towards SW. The March 4 event reactivated the eastern segment, but instead of continuing to the next segment, rupture jumped towards the SW, even before the nick-point of the strike change, on a sub-parallel, underlapping S-dipping fault which has a small influence on the topography. The in between area comprises a typical relay ramp consisting of a series of small discontinuous cracks.

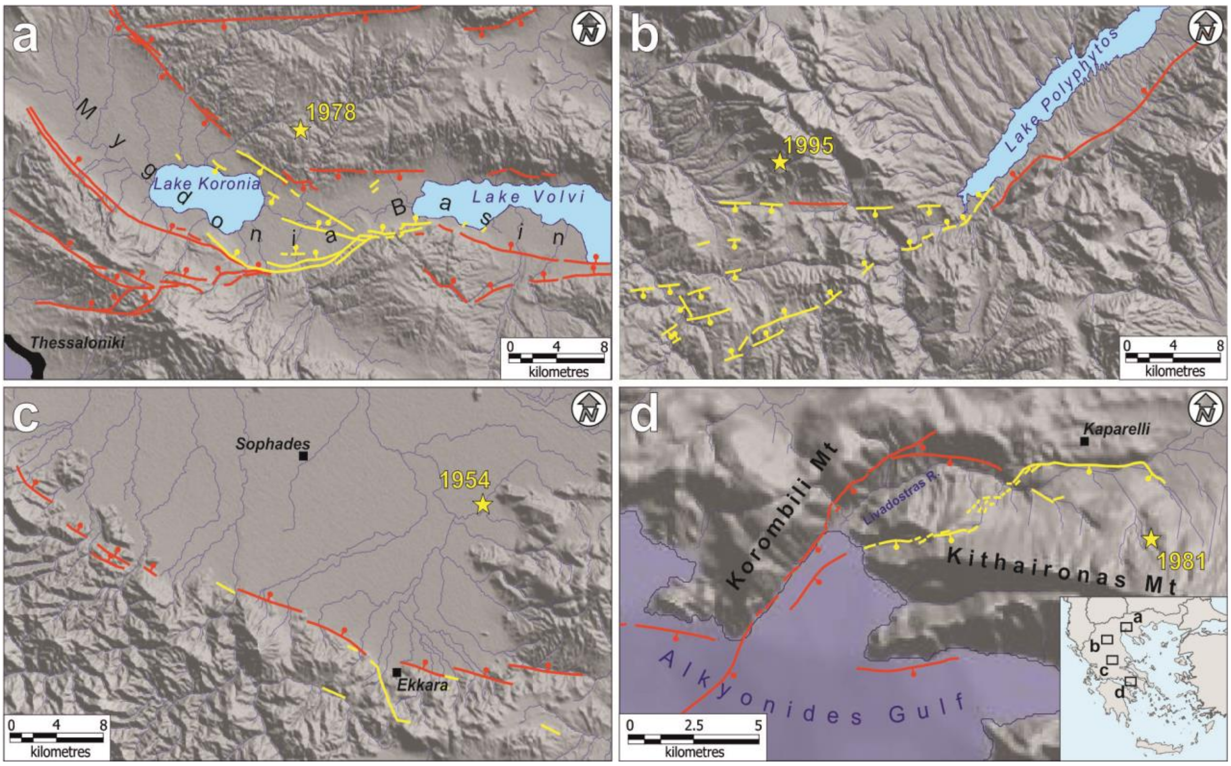

Fig. 1: The four examples of various fault patterns as discussed in the text (a: Thessaloniki, b: Kozani-Grevena, c: Domokos and d: Alkyonides Gulf). Red and yellow lines represent fault scarps and co-seismic ground ruptures respectively, with downthrown block indicated; numbered stars are earthquake epicentres with the year of occurrence; towns are indicated with small solid black squares.

All the examples above belong to extensional regimes. There are possible reasons that could explain the diversity (and similarities) of the faulting patterns. For example, the post-alpidic extensional regime probably tries to imprint the E-W to NE-SW striking faulting on the inherited NW-SE-trending structures of the compressive alpidic regime. This is probably the reason of the abrupt strike changes and curvatures of faults from the favourable orientation (with respect to the stress field) to the quasi NW-SE direction of the alpidic structures. This difference in the mechanical properties of rocks can be also reflected in the upwards rupture propagation from the underlying coherent basement to the less coherent basin deposits. Rupture may deflect its original course or bifurcate in several splays, and along with the deformation within the deposits, a complex pattern of ground ruptures may appear on the surface. On the other hand, there are many cases where ground rupture abruptly stops even though there is another parallel fault near its tip point. Either barriers are mechanical or geometric, they can significantly affect (lateral) rupture propagation.

The examples discussed in this abstract are characteristic but not the only ones. Coulomb stress transfer change models, currently under development, can reveal how susceptible NW-SE-trending inherited structures are to stress accumulation in respect to the reactivation of E-W-trending faults. Moreover, the calculation of displacement distribution is expected to show the linkage degree along fault segment arrays. This way, there will be a better understanding of fault linkage and segmentation processes.