



Review Article

Aegean tectonics: Strain localisation, slab tearing and trench retreat



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ABSTRACT

We review the geodynamic evolution of the Aegean–Anatolia region and discuss strain localisation there over geological times. From Late Eocene to Present, crustal deformation in the Aegean backarc has localised progressively during slab retreat. Extension started with the formation of the Rhodope Metamorphic Core Complex (Eocene) and migrated to the Cyclades and the northern Menderes Massif (Oligocene and Miocene), accommodated by crustal-scale detachments and a first series of core complexes (MCCs). Extension then localised in Western Turkey, the Corinth Rift and the external Hellenic arc after Messinian times, while the North Anatolian Fault penetrated the Aegean Sea. Through time the direction and style of extension have not changed significantly except in terms of localisation. The contributions of progressive slab retreat and tearing, basal drag, extrusion tectonics and tectonic inheritance are discussed and we favour a model (1) where slab retreat is the main driving engine, (2) successive slab tearing episodes are the main causes of this stepwise strain localisation and (3) the inherited heterogeneity of the crust is a major factor for localising detachments. The continental crust has an inherited strong heterogeneity and crustal-scale contacts such as major thrust planes act as weak zones or as zones of contrast of resistance and viscosity that can localise later deformation. The dynamics of slabs at depth and the asthenospheric flow due to slab retreat also have influence strain localisation in the upper plate. Successive slab ruptures from the Middle Miocene to the Late Miocene have isolated a narrow strip of lithosphere, still attached to the African lithosphere below Crete. The formation of the North Anatolian Fault is partly a consequence of this evolution. The extrusion of Anatolia and the Aegean extension are partly driven from below (asthenospheric flow) and from above (extrusion of a lid of rigid crust).

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1. Introduction

1.1. Different visions of the rheology of the continental lithosphere

There is still no consensus on the mechanical behaviour of the continental lithosphere. Experimental observations on rock mechanics led to the formulation of rheological yield-stress envelopes that explain reasonably well the brittle–ductile layering and long-wavelength phenomena such as lithospheric flexure (Armijo et al., 2003; Burov and Watts, 2006; Goetze and Evans, 1979; Handy and Brun, 2004; Jackson, 2002; Kohlstedt et al., 1995; Molnar, 1992; Watts and Burov, 2003). However, lithospheric deformation and rheology appear more complex as it becomes more intense and localised (Bürgmann and Dresen, 2008; Burov, 2011; Gueydan et al., 2004, 2005; Handy et al., 2007; Précigout and Gueydan, 2009). So, two end-member models have been discussed (Armijo et al., 2003; Burov and Watts, 2006; Goetze and Evans, 1979; Handy and Brun, 2004; Jackson, 2002; Kohlstedt et al., 1995; Molnar, 1992; Watts and Burov, 2003). They oppose by a more or less important propensity to localise deformation, some explaining the propagation of strike-slip faults over large distances (Armijo et al., 2003;

Tapponnier et al., 1982), others, more “ductile”, explaining continental extension or shortening over large areas (England and Houseman, 1986; Wernicke, 1992). It is also argued that plate boundaries are characterised by some very specific rheological properties (Bürgmann and Dresen, 2008). This has resulted in a specific “banana split” yield-stress model that considers the weakness of major crustal fault zones caused by various strain weakening and rheological feedback processes.

The observations of localised large-scale strike-slip faults in the continental lithosphere have raised the problem of continental extrusion (or escape tectonics). After the large-scale Asian strike-slip faults were described north of the Indian indenter and the rigid-plastic indentation model published (Molnar and Tapponnier, 1975, 1978; Tapponnier and Molnar, 1976, 1977), the conceptual jump to the extrusion model (Tapponnier et al., 1982, 1986) has not been accepted by all researchers. Two trends have been independently followed, extrusion and localising rheology on one hand (Tapponnier et al., 1982, 1986), or distributed deformation of Asia and the Tibetan plateau on the other hand (Dewey et al., 1988; England and Houseman, 1986; England and Molnar, 1990, 1997; Royden et al., 1997). This discussion results from different visions of the rheology of the continental lithosphere in the international community.

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