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Interactive Comment

# *Interactive comment on* “Exhumation of metamorphic rocks in N Aegean: the path from shortening to extension and extrusion” *by* R. Lacassin et al.

**R. Lacassin et al.**

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As there are some common points in reviews by D. Van Hinsbergen and Referee 2, we choose to write a common answer to both.

D. van Hinsbergen and anonymous referee 2 provided careful reviews leading to questions on the regional structure, tectonic rotations in the north Aegean, and on North Anatolian Fault (NAF) propagation models. Answering all these questions with a large discussion of published, often controversial, papers on these problems, would probably increase a lot the length of the paper. Instead of such a general discussion, not fully constrained by the results we present, we feel better to give short precisions (some of which below) on our interpretations with links to some papers that already discuss these questions. Our manuscript will be modified accordingly but without changing its short-paper nature.

Apart from a lot of minor remarks that will be taken into account in the revised version of our paper, D. van Hinsbergen's, and anonymous referee's reviews mainly concern three major points: (1) the way how block rotations in the Aegean, as deduced from paleomagnetism, should be integrated in the discussion of the structures we describe and date; (2) the geometric relations between top to the NE shear, likely extensional, and the thrust nappe contacts. (3) the relations between the structural evolution we deduce from our observations and dates, and the propagation of the NAF into the North Aegean. Here, we briefly give some precisions on these three points.

We fully agree with both referees that tectonic rotations have probably been important in the north Aegean. Although there is no data on Tertiary rotations in the Olympos - Ossa -Pelion range (OOP range) and its immediate vicinity, rotations of several tens of degrees are likely. According to the recent review by Van Hinsbergen et al. (2005), the OOP range should have rotated 30 to 50 degrees clockwise since about 15 Ma (western Greece up to Albania, parts of Peloponnesos and probably Evia island rotated 50 degrees cw, while the Chalkidiki region, Skyros and Limnos islands, NE of the OOP range, rotated 30 to 40 degrees cw). This implies that the direction of Hellenic thrusting and of syn-orogenic extension, we constrain around 40 Ma, occurred in nearly N-S direction. During Aegean extension accompanying slab retreat, the ranges bounding extensional basins such as the OOP range rotated towards a NE-SW trend (see for example Fig. 25 in Armijo et al. 1996). This was probably also the case of the ongoing direction of extension that remained at high angle of the ranges at every time. Recently, the syn-orogenic structures of Eocene age, as well as the Aegean Oligo-Miocene normal faults, were then cut by more E-W, presently active, normal faults (e.g. Armijo et al. 1996; Goldworthy et al. 2002). Following Armijo et al. 1996, we relate the inception of these faults to the effects of the propagating tip of the North Anatolian Fault. The joints that cut the 4 Ma dyke are parallel to these newly formed active normal faults.



eED

2, S54–S58, 2007

The relationships between these different structures and events will be discussed in more detail in our revised paper, and some interpretations will be moved in discussion.

As outlined by D. Van Hinsbergen, the extensional nature of ductile shear is often difficult to prove in the absence of clear, subtractive contacts putting old- or non-metamorphic rocks on top of higher-grade units. The indirect arguments we have are: the northeastward sense of shear is opposite to the general vergence of Hellenic thrusts; it occurred in retromorphic, greenschist conditions (Walcott 1988) and some outcrops display a progressive evolution from penetrative shear to localized ductile to brittle-ductile normal shear zones. As suggested by D. Van Hinsbergen the interpretation of this deformation as extensional will be moved to the discussion. In the case of Olympos, the steep, range front normal fault (Figure 2b of our paper) clearly cut the whole thrust stack. It exhumes gently-dipping units of marbles with evidence of NE-ward shear (Figure 3b of our paper). Our section effectively suggests that the basal fault contact of the marble units cut off the bedding in limestones of the Olympos core, and the thrusts on top of it. The ductile shear of these marbles is presently undated, and could have occurred earlier, coevally with thrusting. This point remains conjectural however.

Anonymous reviewer 2 puts some doubts on the relations we draw between the NAF propagation, the large-scale structures it produced, and the small-scale deformations we observed and dated along the Pelion coast. Without doubt, the NAF propagated from E to W, starting around 10 Ma in eastern Anatolia (e.g. Barka 1992), crossing the Dardanelles area at ca. 5 Ma (Armijo et al. 1999; see also comment by Yaltirak et al. 2000 and reply by Armijo et al. 2000). It likely enhanced the opening of the Corinth rift at 1 Ma (Armijo et al. 1996) and strongly affects the kinematics of Aegean deformations as deduced from GPS (Flerit et al. 2004). In this framework, our interpretation of the joints and dyke cross-cutting relationships is probably the simplest one. In our paper, the very small size of the map on Figure 2 made comparison with mapped offshore and onshore faults very difficult. This will be changed in the revised version. Here are



eED

2, S54–S58, 2007

some precisions on our sources for fault traces on this map. Onshore faults are from unpublished mapping of active faults and Holocene scarps by R. Armijo and B. Meyer and from Goldworthy et al. (2002). Offshore faults along the NAF and North Aegean trough are deduced from bathymetry of Papanikolaou et al (2002). Their sketchy fault map (Figure 10, Papanikolaou et al., 2002) has been substantially modified to better fit bathymetry.

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