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Post-Messinian evolution of the Florence Ridge area (Western Cyprus Arc), Part I: Morphostructural analysis

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ABSTRACT

The Florence Ridge, part of the western Cyprus arc, is a compressional relief that was eroded during the Messinian salinity crisis while deposition of salt occurred North (Antalya basin) and South (Herodotus abyssal plain). In order to better assess the impact of salt-tectonics in the Florence Ridge region deformations, we conducted a morpho-structural analysis of available multibeam and seismic data (Simed and Prismed II campaigns). It is indeed a crucial issue to distinguish crustal and gravity driven structures in the compressional to strike-slip belts of the eastern Mediterranean.

Along the Antalya basin, we mainly observed multi-directional tectonic rafts typical of gravity gliding above salt. On the Florence Ridge itself, the base of salt evolves laterally to a Messinian erosional surface that erodes a series of stacked nappes. This surface is involved in recent faulting. South of the Florence Ridge, a nearly 100 km wide fold belt characterizes the Herodotus abyssal plain. Three different zones parallel to the Florence Ridge appear within this fold belt. Those are respectively from North to South zones A, B and C. Zone A is characterized mainly by small-wavelength folding and faulting. Approaching Zone B, a long extensional graben deforms the seafloor. Zone B stands ~100 to 200 m higher than zones A and C. There, salt welding seems common. In the easternmost zone B deep sub-circular bathymetric depressions are associated with extremely thick and fan-shaped depocenters probably emplaced in relation with active sub-salt thrusts. Many evidences suggest post-Messinian uplift in this zone. Zone C shows medium to high wavelength salt-cored folds. Wavelength of those folds increase approaching the distal Nile deep-sea fan. Within zone C, a nearly undeformed domain exists approaching the Eratosthenes seamount. 'En echelon' folds bound this flat domain suggesting lateral salt extrusion at the junction between zone C and the distal Nile deep-sea fan.

To conclude, numerous evidences argue for a post-Messinian reactivation of the pre-Messinian Florence Ridge accretionary wedge (numerous folds, uplifted zones). The salt, as on the nearby Mediterranean Ridge, decouples deep and surface deformations and even allow the development of isolated grabens and associated salt ridges in the heart of the Florence compressional zone. We propose in this case that local basal slope of salt increase related to basement fault activity triggered gravity gliding and thus extensional deformation despite the regional compressional regime. Finally, this study shows that the eastern Nile deep-sea fan, submitted to extremely vigorous salt tectonics seems to have collided with the Florence Ridge fold belt and to have generated a "salt extrusion" zone.

1. Introduction and aim of the study

The eastern Mediterranean basin was subject to a period of net evaporation during the Messinian (latest Miocene), which led to the deposition of thick evaporitic sequences in bathymetric troughs (Hsü et al., 1973; Ryan et al., 1982; Sage and Letouzey, 1990). At the same time, in response to the northward convergence of the African plate toward the Anatolian and Eurasian plates, the eastern Mediterranean basin was crossed by an active subduction zone leading to the formation of the Hellenic and the Cyprus Arcs (Fig. 1A). The Messinian evaporites accumulated on the both sides of the contractional structural highs

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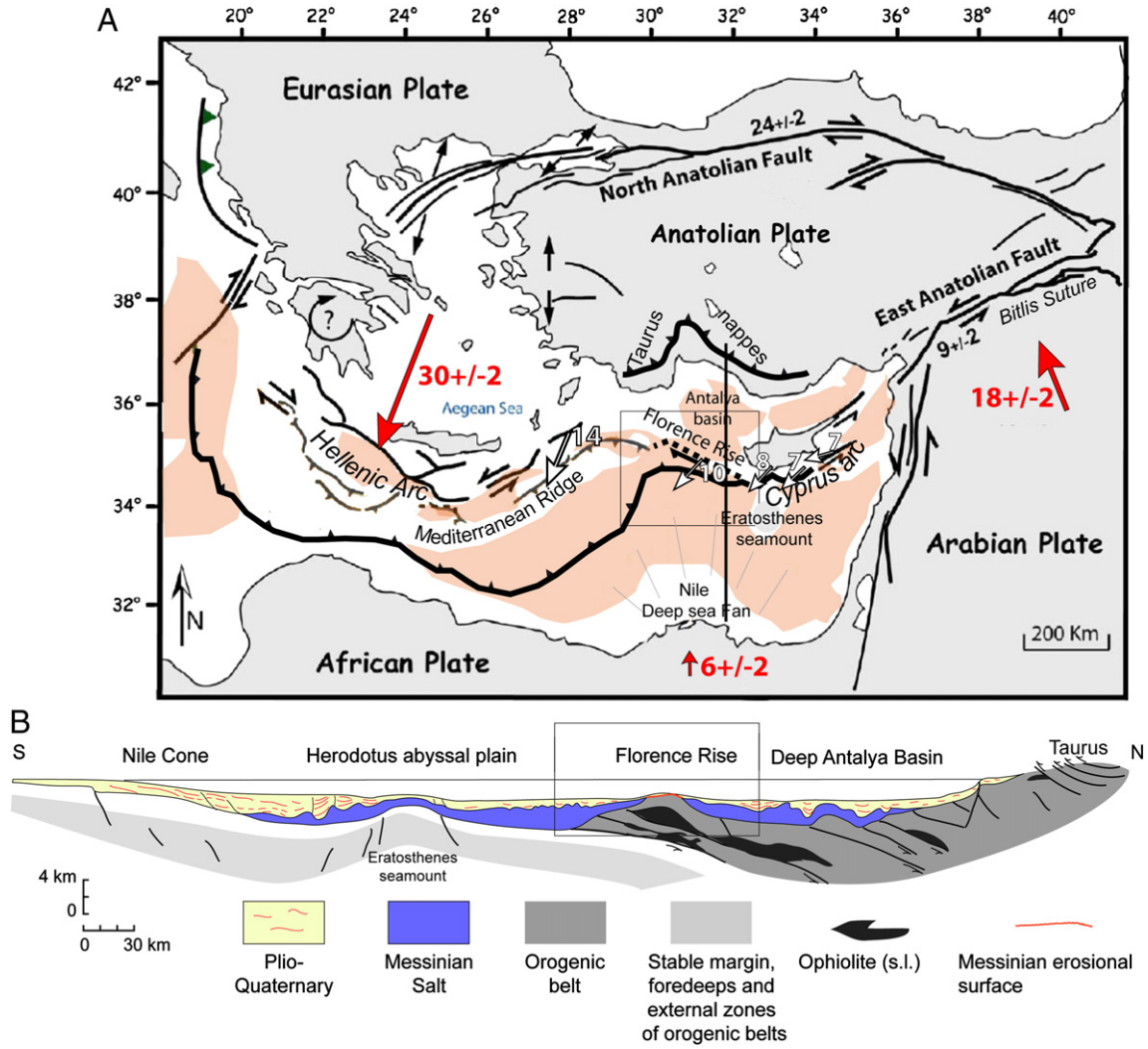

Fig. 1. (A) Geodynamic framework (modified from, Chamot-Rooke et al., 2005; Chaumillon et al., 1996; Huguen et al., 2006; Le Pichon et al., 1995; McClusky et al., 2000; Reillinger et al., 1997; Robertson, 1998a; Ten Veen et al., 2004) and distribution of the Messinian salt (modified from Loncke et al., 2006; Rouchy and Caruso, 2006; Sage and Letouzey, 1990). The grey frame shows the study area. The light red areas represent the extent of the Messinian deep evaporites. (B) Regional deep cross section passing through the Florence Ridge (modified after Biju-Duval et al., 1978a).

that formed along these arcs (i.e. the Mediterranean Ridge, the Florence Ridge and Cyprus, Sage and Letouzey, 1990). Several authors (Chaumillon and Mascle, 1997; Chaumillon et al., 1996; Kastens, 1991; Kastens et al., 1992; Reston et al., 2002) showed that accretion has been active during and after the Messinian evaporite deposition along the Mediterranean Ridge. The base of the Messinian unit is there acting as a major décollement level (Chaumillon and Mascle, 1997; Reston et al., 2002). Chaumillon and Mascle, 1997 even defined two imbricated accreted wedges in the Mediterranean Ridge: a recent and outer one, above a Messinian décollement layer and a deeper and older one in internal zones. These authors showed that the slope of the Mediterranean accretionary wedge was extremely low (1 to 2°) especially where the Messinian salt is present. This has been attributed to extremely low effective basal friction along the Messinian décollement (Reston et al., 2002). Another consequence of the presence of salt in the external Mediterranean ridge is that deformations above salt are characterized by small-amplitude folds that are quite symmetrical. Costa and Vendeville (2002) showed by experimental modeling that the structural vergence of folds and thrusts is rather symmetrical on foldbelts detaching on salt. Along the Cyprus arc, several authors described compressional to strike-slip activity after the Messinian event (Benkhelil et al., 2005; Biju-Duval et al., 1978a,b; Hall et al., 2005; Maillard et al., 2011; Sage and Letouzey, 1990; Woodside et al., 2002). The Cyprus Island is believed to have been rapidly uplifted during and after the Miocene, probably as a result of the entrance of the Eratosthenes seamount in the subduction zone (Biju-duval et al., 1978a; Kempler, 1998; Robertson, 1998a,b). Along the eastern Cyprus arc, post-Messinian transpressional structures offset the Messinian salt basins (Benkhelil et al., 2005; Maillard et al., 2011; Sage and Letouzey, 1990). Along the western Cyprus arc, the Florence Ridge separates the Antalya basin in the northeast from the Herodotus basin to the southwest (Fig. 1). This ridge is the expression of a pre-Messinian accretionary wedge (affected by several northward dipping thrusts) that was partly emerged during the Messinian salinity crisis (Hsü et al., 1978; Sage and Letouzey, 1990). Immediately south of the Florence Ridge, an important fold belt appears on bathymetric data (MediMap group et al., 2005, Fig. 2) and suggests post-Messinian contraction. This domain is prolonging quite continuously the Mediterranean Ridge and is in contact with the distal Nile deep-sea fan.

The aim of this work is to better show how gravity-driven salt tectonics and crustal tectonics interfere to shape the seafloor along the Florence Ridge region.