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Salt tectonics in the SW Alps (Italy–France): From rifting to the inversion of the European continental margin in a context of oblique convergence

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ABSTRACT

The SW Alps result from the inversion of the European continental margin during the oblique convergence between Europe and Adria since the Cretaceous. The orogenic deformation is controlled by two factors: the inherited sedimentary and structural record and the geodynamic interaction between the two plates. In this paper we present a stratigraphic and structural analysis of the external SW Alps (Ventimiglia–Menton area) in order to define the sedimentary and deformational geometries of the chain and to reconstruct the evolutionary history. The field-data highlight the preeminent role played by inherited salt-structures, which derive from the depositional history experienced by the European margin since the Mesozoic onwards. From Late Triassic to Jurassic, evaporites and carbonates deposited as a response to the Thetyan rifting. The following emplacement of the Cretaceous flysch and of the Eocene foreland basin succession was strongly influenced by the extensionally-triggered salt diapirism and by the interactions with deformations connected to the Pyrenees dynamics. The resulting geologic discontinuities (i.e. diapir-induced highs and basins, inherited normal and trasform faults) strongly influenced the successive Oligo-Miocene evolution of the belt in the study area. Observed changes in the thrusts and folds kinematics are considered as the results of rotation during their approaching to inherited highs. Furthermore, the overturning of thrusts and folds in the front of the diapiric flanks are associated with the progressively salt squeezing into the anticlines cores promoted by ongoing Alpine compression.

Finally, the kinematic data from the study area show radical differences in the tectonic transport direction with respect to the rest of the SW Alps (NW- to W-ward in the Ventimiglia–Menton area, S- to SW-ward in Provence and Ligurian Alps). This difference is interpreted to be caused by the relative motions of crustal blocks dominated by transpressive tectonics in the frame of the Oligo-Miocene western Mediterranean geodynamics.

1. Introduction and regional framework

The evolution of thrust systems in collisional belts is closely controlled by the stratigraphic setting, the geometry and the orientation of inherited structures with respect to the stress-field (e.g. Butler, 1989; Coward, 1994; Gillcrist et al., 1987; Holdsworth et al., 1997; Williams et al., 1989). In addition, the presence of evaporite layers induces the development of complex structures, such as anticlines associated with detachment (décollement) faults (Blay et al., 1977; Jamison, 1987). Mobilization of ductile salt in the fold core may evolve to syn-kinematic diapirism, which results into "injection folds" (Beloussov, 1959; Bonini, 2003). Salt-structures, however, may also pre-date thrusting, as in extensionally triggered diapirs developed along rifted margins (Jackson and Vendeville, 1994). As such, the inherited salt-structures strongly influence the genesis and the propagation of the thrust system (Costa and Vendeville, 2002). The lateral variations of structural style, shortening value and kinematics add up to the inherited three-dimensional variation of the pre-collisional salt-structures. In a context of oblique convergence, as in Taiwan or Western Alps (Lu and Malavieille, 1994; Vialon et al., 1989), the kinematics of deformation is further complicated by the combination of contraction and rotation, which results in partitioning between thrusting and wrenching.

In absence of seismic data, the reconstruction of the pre-collisional salt structures and the role of the evaporite layers in the development of a orogenic belt may be evaluated only by an integrated structural and stratigraphic field-analysis. Resolving the relationships among pre- and syn-collisional stratigraphic and structural features is thus crucial to define the evolution of a continental margin which experienced the inversion from rifting to orogenic belt. In the present paper we address this method to reconstruct the role of the salt-related structures during the formation of a passive margin and the subsequent evolution of a fold-and-thrust belt in a context of oblique convergence. We focused on the Meso-Cenozoic stratigraphic record of the Dauphinois domain of the external SW European Alps (also known as

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the Southern Subalpine Chains, Italy–France, Fig. 1). The Dauphinois domain represents the southernmost part of the European Tethyan passive margin (Fig. 2) and it is constituted by a Variscan basement overlaid by Mesozoic carbonate platform sediments (Lemoine et al., 1986) and a Tertiary foreland basin succession (Sinclair, 1997). Since the beginning of the Tethyan rifting cycle, salt diapirs, rising from Triassic evaporites, have deformed the younger deposits (Dardeau and De Graciansky, 1990a,b). The salt displacement and migration continued in the proximal passive margin during the successive steps of the orogenic cycle, also with the local formation of salt nappes that are proved to reach the sea bottom before the Cretaceous (Graham et al., 2012), thus during the oceanization process (Handy et al., 2010). During the subsequent Alpine collision the European passive margin was inverted into a fold-and-thrust belt mainly with a main S- to SW-directed tectonic transport (Fry, 1989; Lickorish and Ford, 1998; Lickorish et al., 2002). Since the Late Oligocene the evolution of the chain was influenced by the rifting of the Liguro–Provençal basin associated with the eastward migration of the Apennines arc and the Corsica–Sardinia drifting, which induced a regional rotation of the Ligurian and internal SW Alps (Maino et al., 2013; Vanossi et al., 1994). Until now, the study area (Ventimiglia–Menton, Fig. 1) has been considered kinematically coherent with the rest of the SW Alps (e. g. Lickorish et al., 2002; Ford et al., 2006; Lardeaux et al., 2006). However, whereas the general stratigraphic setting, the major strike-slip faults and the large-scale folds has been described since the 60's and 70's (Campredon, 1977; Julien and Rossi, 1971; Lanteaume, 1968) an integrated stratigraphic and structural analysis has never been worked out. In this paper we present new data collected during an extensive field work that bring to the surveying of more than 200 km^2 (Seno et al., 2012a,b). The resulting kinematic reconstruction shows a main direction of the tectonic transport toward NW, locally rotating toward W or SW in correspondence of some emerging evaporite diapirs. Our study suggests that such peculiar kinematic evolution of the Ventimiglia–Menton area with respect to the other SW Alps is a consequence of two causes:

1) a pre-collisional setting conditioned by the presence of Mesozoic salt-structures, which strongly influenced the style of folds and the thrusts development.
2) the position of the study area located at the junction among the foreland-ward propagating fold-and-thrust belt of the external SW Alps, the coeval oceanization of the Liguro–Provençal basin and the counterclockwise rotation of the Ligurian Alps. The stratigraphic analysis of the Meso-Cenozoic deposits and the provided balanced cross-sections allows the discussion of the formation of salt

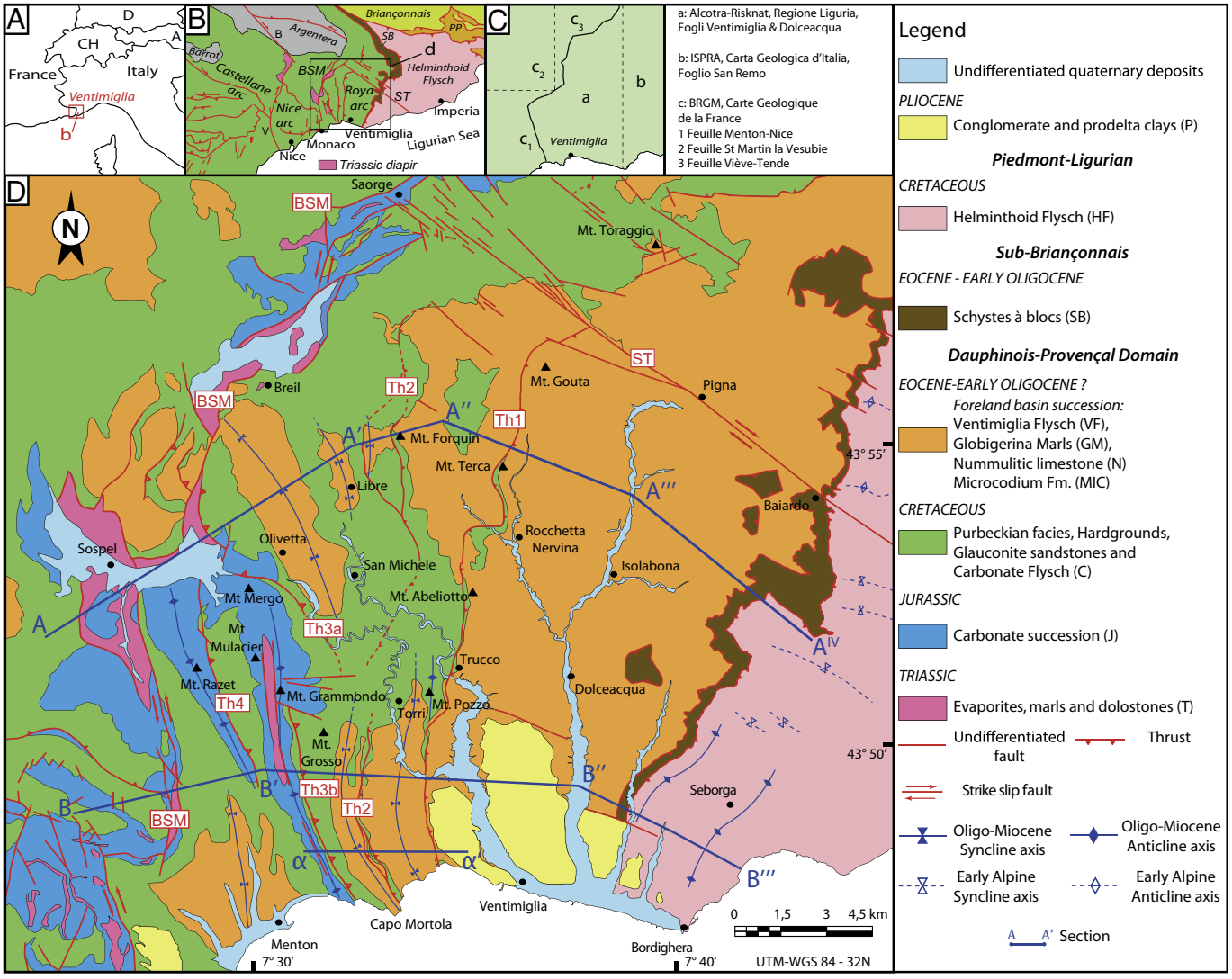

Fig. 1. A) Location of the study area B) Structural sketch of the investigated sector of the SW Alps. B: Bersezio fault, BSM: Breil-Sospel-Monaco fault, PP: Pre-piedmont palaeogeographic domain, SB: Sub-Briançonnais palaeogeographic domain, ST: Saorge-Taggia fault, V: Vésubie fault. C) Sources of mapping and field-data; (B.R.G.M., 1967, 1991, 2008). D) Original geological map of the Ventimiglia-Menton area, with simplified lithological legend and main structural elements. Th1-4 indicate the main thrusts mapped in the area.