Structural anatomy of the Ligurian accretionary wedge (Monferrato, NW Italy), and evolution of superposed mélanges

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ABSTRACT

We document in this study the internal structure of the Late Cretaceous–late Oligocene Ligurian accretionary wedge in northwestern Italy, and the occurrence in this exhumed wedge of broken formation and three different types of mélanges that formed sequentially through time. The broken formation is the oldest unit in the accretionary wedge and shows bedding-parallel boudinage structures, which developed as a result of layer-parallel extension at the toe of the internal part of the Alpine wedge front during the Late Cretaceous–middle Eocene. This broken formation experienced an overprint of tectonic, diapiric, and sedimentary processes as a result of continental collision in the late Oligocene. The NE-vergent thrusting and associated shortening produced a structurally ordered block-in-matrix fabric through mixing of both native and exotic blocks, forming the tectonic mélange. The concentration of overpressurized fluids along the thrust fault planes triggered the upward rise of shaly material, producing the diapiric mélange, which in turn provided the source material for the downslope emplacement of the youngest, late Oligocene sedimentary mélange. The sedimentary mélange units unconformably cover the collisional thrust faults, constraining the timing of both this episode of contractional deformation related to continental collision and the combination and overlap of tectonic, diapiric, and sedimentary processes. Our multiscale structural analysis of the Ligurian accretionary wedge shows that tectonic, diapiric, and sedimentary processes played a significant role in its evolution, and that the interplay between and the superposition of these different processes strongly controlled the dynamic equilibrium of the accretionary wedge in the NW Apennines–western Alps. This kind of polygenetic mélange development may be common in many modern and ancient accretionary complexes, and the processes involved in their formation are likely to be responsible for major tsunamic events in convergent margins.

INTRODUCTION

The shape and growth of the frontal wedge of modern accretionary complexes repeatedly change to maintain the dynamic equilibrium in the wedge through alternating tectonic and sedimentary (i.e., gravitational) activities (e.g., Davis et al., 1983; Scholl et al., 1987; von Huene and Lallemand, 1990; Gutscher et al., 1998; Clift and Vannucchi, 2004; Wang and Hu, 2006; Buiter, 2012; Graveleau et al., 2012; Haq, 2012). Highly sheared, disrupted, and fragmented rock units and tectonic mélanges are the products of tectonics occurring along the basal décollements in accretionary wedges and out-of-sequence thrust faults, and within the subduction channels (e.g., Karig and Sharman, 1975; Cloos, 1982; Moore and Byrne, 1987; Taira et al., 1992; Dileonardo et al., 2002; Collot et al., 2011). Mass-transport deposits and sedimentary mélanges result from slope instability in the trench-inner slope and in the upper parts of frontal wedges (e.g., Lallemand et al., 1990; Duperret et al., 1995; Goldfinger et al., 2000; von Huene et al., 2000; Collot et al., 2001; McAdoo et al., 2004; Sage et al., 2006; Mosher et al., 2008; Ogawa et al., 2011; Strasser et al., 2009, 2011). Shale and mud diapirism represent the upward rise of overpressurized fluids migrating along the basal décollement or channeled along megasplay faults (e.g., Brown and Westbrook, 1988; Moore and Vrolijk, 1992; Kopf, 2002; Chamot-Rooke et al., 2006; Camerlenghi and Pini, 2009).

Mélanges commonly occur in ancient examples of exhumed accretionary wedges on land, showing a complex internal block-in-matrix fabric that may vary both laterally and vertically (e.g., Maxwell, 1974; Cloos, 1984; Raymond, 1984; Cowan, 1985; Byrne and Fisher, 1990; Barnes and Korsch, 1991; Onishi and Kimura, 1995; Ogawa, 1998; Dilek et al., 1999, 2005, 2012; Pini, 1999; Dilek and Robinson, 2003; Codegone et al., 2012a, 2012b; Festa et al., 2010a; Ukar, 2012; Wakabayashi, 2012; Singleton and Cloos, 2013). The primary internal structures of mélanges and mélange-forming processes are commonly obscured by subsequent deformational events, resulting in superposed and mixed mélanges types, such tectonic, sedimentary, and diapiric mélanges. Much effort has been made to establish a set of useful criteria by which to distinguish mélange types in ancient accretionary complexes (e.g., Aalto, 1981; Naylor, 1982; Raymond, 1984; Cowan, 1985; Barber et al., 1986; Bettelli and Panini, 1989; Harris et al., 1998; Orange, 1990; Pini, 1999; Cowan and Pini, 2001; Dela Pierre et al., 2007; Yamamoto et al., 2009, 2012; Festa et al., 2010a, 2012; Vannucchi and Bettelli, 2010; Festa, 2011; Osozawa et al., 2009, 2011; Wakabayashi, 2011, 2012; Codegone et al., 2012a, 2012b). These criteria are mainly based on mesoscale structural observations and analyses (e.g., Hsü, 1968; Cowan, 1985; Barber et al., 1986; Lash, 1987; Orange, 1990, Pini, 1999; Bettelli and Vannucchi, 2003) and more rarely on map-scale or microscale studies (e.g., Aalto, 1981; Bettelli and Panini, 1989;

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