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From soft sediment deformation to fluid assisted faulting in the shallow part of a subduction megathrust analogue: the Sestola Vidiciatico tectonic Unit (Northern Apennines, Italy)

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Abstract – The Sestola Vidiciatico tectonic Unit (SVU) accommodated the early Miocene convergence between the subducting Adriatic plate and the overriding Ligurian prism, and has been interpreted as a field analogue for the shallow portion of subduction megathrusts. The SVU incorporated sediments shortly after their deposition and was active down to burial depth corresponding to temperatures around 150 °C. Here, we describe the internal architecture of the basal thrust fault of the SVU through a multi-scale structural analysis and investigate the evolution of the deformation mechanisms with increasing burial depth. At shallow depth, the thrust developed in poorly lithified sediments which deformed by particulate flow. With increasing depth and lithification of sediments, deformation was accommodated in a meter scale, heterogeneous fault zone, including multiple strands of crack-and-seal shear veins, associated with minor distributed shearing in clay-rich domains and pressure solution. In the last stage, slip localized along a sharp, 20 cm thick shear vein, deactivating the fault zone towards the footwall. The widespread formation of crack-and-seal shear veins since the first stages of lithification indicates that failure along the thrust occurred at high fluid pressure and low differential stress already at shallow depth. Progressive shear localization occurs in the last phases of deformation, at temperatures typical of the transition to the seismogenic zone in active megathrusts.

Keywords: Thrust, crack-and-seal veins, weak fault, updip limit

1. Introduction

Modern subduction megathrusts have been extensively investigated during International Ocean Discovery Program (IODP) / Ocean Drilling Program (ODP) expeditions over the last 50 years, with great improvements in the understanding of their architecture, fluid-transport properties and lithological composition (for a review, Saffer & Tobin, 2011). However, because of the extremely challenging conditions of drilling in several kilometer-deep oceanic trenches, scientific drilling is limited in depth, and cores offer just one-dimensional insights on the internal architecture of faults. Moreover, the acoustic transparency and the small scale of features within fault zones (meters to tens of meters), well below standard seismic resolution, allow only large scale imaging of the active megathrust faults by means of seismic reflection surveys.

Hence, field-based studies of fossil subduction zones are the only method to investigate the mesoscale architecture of megathrusts. Detailed studies on exhumed subduction-related shear zones provided useful information by documenting that their shallow portion is commonly characterized by heterogeneous composition and architecture (e.g., Vollmer & Bosworth, 1984; Cowan, 1985; Moore & Byrne, 1987; Meneghini & Moore, 2007; Vannucchi, Remitti & Bettelli, 2008; Fagereng & Sibson, 2010; Festa *et al.* 2012; Kimura *et al.* 2012; Ujiie & Kimura, 2014). In fact, subduction megathrusts commonly incorporate poorly to non-consolidated sediments from the seafloor level and transport them at depth, where tectonic deformation is superimposed on sediment consolidation and diagenesis at increasing pressure and temperature (Maltman, 1994). The resulting heterogeneous rock assemblage (i.e., mélange and broken formation) displays strong internal contrasts in rheology and fluid transport properties, inferred to play a significant role in controlling the complex seismic behavior typical of shallow megathrusts settings (Fagereng & Sibson, 2010; Wei, McGuire & Richardson, 2012).

In this paper, we describe the internal structure of the thrust bounding the base of the Sestola Vidiciatico tectonic Unit (SVU hereafter) in the Northern Apennines (Fig. 1) through multiscale field- and laboratory-based structural studies. The SVU records deformation in a range of temperature and depth comparable to the extent of the shallow portion of active megathrusts (i.e. maximum temperatures of ∼150 °C and ∼4–5 km burial depth). We discuss then the implications of our

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