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Application of actualistic models to unravel primary volcanic control on sedimentation (Taveyanne Sandstones, Oligocene Northalpine Foreland Basin)

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ABSTRACT

This work is focused on the Taveyanne Sandstones (*Grés de Taveyanne*), an Oligocene volcaniclastic turbidite sequence cropping out in the Northern Alpine Molassa between SE France and Central Switzerland, with the aim to investigate the temporal relationship between volcanic activity and sediment supply. Detailed stratigraphic, sedimentological, and petrographic (XRD analyses on mudstones and point counts on sandstones) studies conducted on three sections (Col de l'Oulette and Flaine in SE France, Taveyanne in SW Switzerland) allow a discrimination of three main facies, among which only one is extremely enriched in volcaniclastic detritus and characterized by features similar to those of disaggregated pyroclastic density current deposits. The other two facies are characterized by variable to no volcanic detritus but supplied by crystalline and sedimentary detritus. Such sediment trends are similar to those of modern, volcanically controlled source-to-sink systems. This allows a reinterpretation of the Taveyanne Sandstones as a syn-volcanic turbidite system, episodically supplied by large amounts of volcanic detritus, which periodically modified the drainage paths. Moreover, the well-known temporal and spatial persistence of such modifications in modern settings leads to conciliate the syn-volcanic supply with the location of the volcanic centers in the internal part of the Alps, without invoking particular climatic and tectonic conditions controlling foreland sedimentation.

1. Introduction

For three decades, spatial and temporal persistence of the impact of explosive volcanism on source-to-sink systems has been investigated both onshore (e.g., Smith, 1988; Manville et al., 2005; Umazano et al., 2008; van Gorp et al., 2013) and offshore (e.g., Alexander et al., 2010; Sisavath et al., 2011, 2012; Le Friant et al., 2015), and many authors have highlighted that explosive volcanism episodically inundates the environments with a complex patterns of primary and secondary dispersal across tens to hundreds of kilometers (e.g., Smith, 1991; Manville et al., 2009; Sohn et al., 2005). Nevertheless, the significance of thick volcaniclastic sequences across foreland/foredeep basin records is often obscure when neither volcanic centers nor primary volcaniclastic deposits (such as pyroclastic density current (PDC) or fall-out deposits) are preserved (e.g., Critelli and Ingersoll, 1995; Critelli and Le Pera, 1995, 1998; Schneider et al., 2001; Critelli et al., 2003; Caracciolo et al., 2011; Perri et al., 2012; Cuitiño and Scasso, 2013; Di Capua and Groppelli, 2014; Di Capua et al., 2016). PDCs, in particular, are common events that contribute to the production and transport of detritus across a source-to-sink (e.g., Manville et al., 2009), but they are usually disaggregated entering the water and deposited as cold, water-supported flows, apparently without diagnostic features (e.g., Trofimovs et al., 2006, 2008; Le Friant et al., 2009, 2010).

In this work, we focus on the volcaniclastic turbidite sequences of the Taveyanne Sandstones, deposited into the Northern Alpine Molassa basin between SE France and Central Switzerland (Fig. 1) during the Oligocene (32–29 Ma; Sinclair, 1992, 1997; Ruffini, 1995; Ruffini et al., 1997; Boyet et al., 2001). New fieldwork (stratigraphic logs and facies analyses) and minero-chemical data (sandstone point counts and X-ray powder diffraction analyses) reveal that the entire sequence includes three main facies. One of them shows sedimentary features comparable to those of modern submarine disaggregated PDC deposits (Trofimovs et al., 2006, 2008). Such features have been discussed if diagnostic or not for the recognition of disaggregated PDC deposits. Anyway, only petrographic analyses definitively unravel the temporal relationship between volcanism and sedimentation in the Oligocene Northern Alpine Molassa. The complex sedimentary trends obtained in this work, in fact, have been successfully compared to sedimentary trends of modern, volcano-supplied basins (e.g., Smith, 1991; Manville et al., 2009; Sisavath et al., 2011, 2012; Le Friant et al., 2015), indicating a volcanic control on the sediment supply. This reconciles three decades

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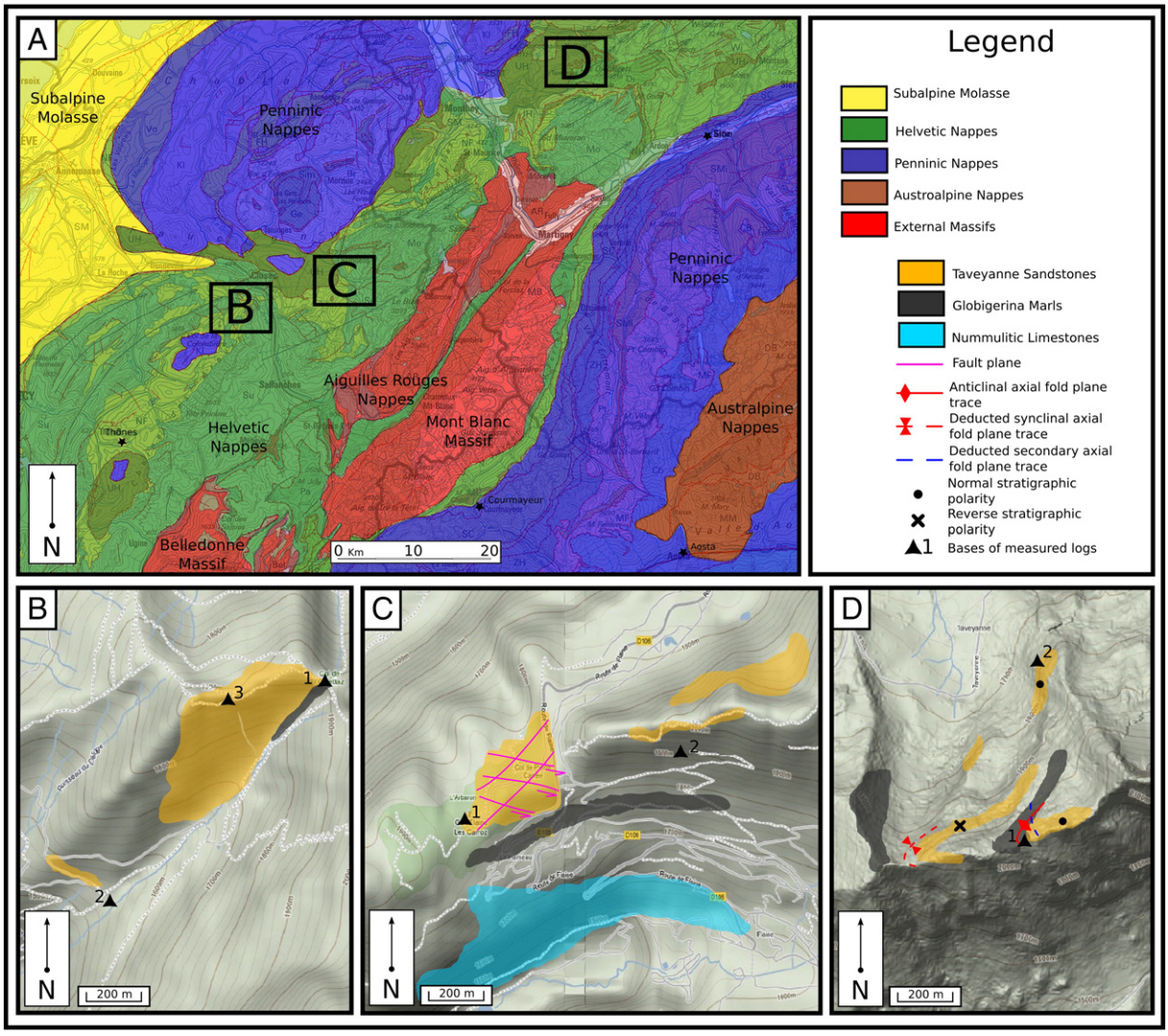

Fig. 1. (A) Geological sketch map of Alpine domains and fieldwork locations, modified from the Tectonic Map of Switzerland (Pfiffner et al., 2005); (B) Col de l'Oulette fieldwork map and log locations; (C) Flaine fieldwork map and log locations; (D) Taveyanne fieldwork map and log locations.

of debates on the temporal and spatial relationship between Northern Alpine Molassa sedimentation and activation of volcanic centers during the Oligocene in the internal Alps (e.g., Dal Piaz and Venturelli, 1983; Lateltin, 1988; Ruffini et al., 1997; Boyet et al., 2001).

2. Geological settings

Taveyanne Sandstones (or *Grés de Taveyannaz*) are a turbidite sequence deposited in the Oligocene Northern Alpine Molassa between 32 and 29 Ma (Ruffini, 1995; Boyet et al., 2001) and now exposed between SE France and Central Switzerland (Fig. 1A; Rivaro Garcia, 1978; Doudoux et al., 1987; Sinclair, 1992). It is one of the clastic sequences of the informal group of the Priabonian Trilogy, above the Globigerina Marls (*Marnes à Globigerines*) and the Nummulitic Limestones (*Calcaires Nummulitiques*), with the *Grés d'Annot* and *Grés de Champseur* formations (Sinclair, 1997; Ford and Lickorish, 2004). The Taveyanne Sandstones are characterized by fine-to-coarse-sand turbidite deposits, extremely enriched in volcanic detritus, interbedded by fine marly layers with a strong continental-derive of sediment signature (Ruffini, 1995). Volcanic detritus has been constrained between 32.5 Ma and 30.5 Ma through $^{40}Ar/^{39}Ar$ analyses on amphiboles (Féraud et al., 1996; Ruffini et al., 1995; Boyet et al., 2001). Temporal correspondence between volcanic detritus production and supply to the basin has been debated between those who interpret the Taveyanne Sandstones turbidite system as fed by *in situ* phreato-magmatic explosions (Lateltin, 1988, and ref. therein), and those who invoke rapid, tectonically driven transport and erosion of a volcanic suite from the internal part of the Alpine belt to the basin, as no *in situ* volcanism has ever been recognized in the SE France–Central Switzerland area (Dal Piaz and Venturelli, 1983; Vuagnat, 1983; Ruffini et al., 1997). Partially in agreement with the latter interpretation, Sinclair (1992) suggested complex interactions among climatic variations, eustatic sea level fluctuations, and changes of horizontal in-plane deviatoric stress on the lithosphere to explain the cyclical pattern of sedimentation alternating between sandstone and mudstone deposition.

3. Methods

This work is focused on three main sections (Col de l'Oulette and Flaine, SE France, Figs. 1A–C, 2, 3A; and Taveyanne, Western Switzerland, Figs. 1A, D and 3B), already studied by other authors (e.g., Ruffini, 1995; Boyet et al., 2001), in order to combine different analytical techniques (chemical, $^{40}Ar/^{39}Ar$, quantitative point-count analyses following the Gazzi–Dickinson methods; Ingersoll et al., 1984, from previous works) with our facies analyses, texture microscopic observations, quantitative sandstone petrographic compositions following the method of Folk (1965), and quantitative mudstone mineralogical compositions through X-ray powder diffraction (XRPD). For sandstone