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Paleocene and Early Eocene volcanic ash layers in the Schlieren Flysch, Switzerland: U–Pb dating and Hf-isotopes of zircons, pumice geochemistry and origin

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ABSTRACT

Thin mm to cm thick bentonite layers of Paleocene to Early Eocene age in the Tonsteinschichten of the Schlieren Flysch represent volcanic ash layers. Heavy mineral analysis of the layers indicates basic to acidic volcanic sources. U/Pb dating of single zircon crystals of a Paleocene layer (WW1948) by LA-ICP-MS points to an eruption at 59.87 ± 0.41 Ma, whereas ID-TIMS shows an eruption age of 60.96 ± 0.07 Ma. Taking into account the external precision of LA-ICP-MS analyses of 1–2% both ages are overlapping and indicate an apparent minimal durations of zircon crystallization of 350 ka. Hf-isotope analysis of the same zircon crystals reveals the hybrid character of the source magma. The geochemical composition of the pumice grains of all bentonite layers is strongly affected by alteration. Nevertheless, the original character of the volcanic source can be evaluated. The Paleocene ashes (Lower Tonsteinschichten, LT) show a more fractionated multi-element pattern than the ashes of Early Eocene (Upper Tonsteinschichten, UT). The LT ash series are of rhyodacite to dacite character whereas the UT ashes fall in the field of alkali basalts. Both ash series seem to originate from a within-plate volcanic setting according to their trace element concentrations. Geochemical and temporary counterparts can be found in ash layers from Anthering (Austria) and the Danish Basin. As proposed for those ashes, volcanism connected to the opening of the North Atlantic might be the source as well for the ashes in the Schlieren Flysch. By comparison of the composition of rocks from the British Paleogene Igneous Province BPIP and the Schlieren Flysch ashes many correlations can be drawn which supports the suggestion of a North Atlantic origin of the Alpine ashes.

1. Introduction

The presence of bentonite layers in the Lower (LT) and Upper Tonsteinschichten (UT) formations ("claystone fms") of the Alpine Gurnigel-, Schlieren- and Wägital Flysch nappes in Switzerland was first reported by Winkler (1983) and Winkler et al. (1985a,b). Their characteristic abundance of almost pure montmorillonite, their heavy mineral assemblage and the presence of pyroclasts suggest a volcanic origin (Winkler et al., 1985a). The mm to cm thick bentonite layers in the Tonsteinschichten formations of the Schlieren Flysch are remnant ash layers and document the past volcanic activity. However, the origin of these preserved ashes remains poorly understood. The present work is aimed at providing mineralogical and geochemical arguments for localizing the volcanic sources of the ash layers encountered in the Schlieren Flysch.

Alpine syn-orogenic volcanism is generally poorly known. Only few events in the Veneto volcanic province are reported along the Southern Alpine Tethys margin (e.g. Beltran-Trivino et al., 2013; Macera et al., 2003; Mayer et al., 2004; Ruffini et al., 1997) close to the paleogeographic sedimentation area of the Schlieren Flysch (Fig. 1). In Eastern Europe, alkaline magmatism developed in the Carpatho-Balkanides after the closure of the Mesozoic Tethys (Cvetkovic et al., 2013). During Paleocene and Early Eocene, volcanism to the north of the Alps is on the one hand reported in the Massif Central in France (Wilson and Downes, 1991) linked to the extensive-rift-system of the Limagne Graben and on the other hand in the British and Faroe–Greenland Province linked to the opening of the North Atlantic (Knox and Morton, 1988; Pedersen et al., 1975).

This study analyzes zircons and other heavy minerals from the bentonite layers, and their major and trace element concentrations. We expect that U/Pb age dating of zircons will represent the time of eruption of the source volcanoes. The corresponding Hf-isotope analyses are used to distinguish between mantle and crustal sources. The heavy mineral assemblage is used to provide the information about the grade of fractionation of the magma source as well as the geochemistry of the bentonites which is separately evaluated on bulk rock and pumice grain

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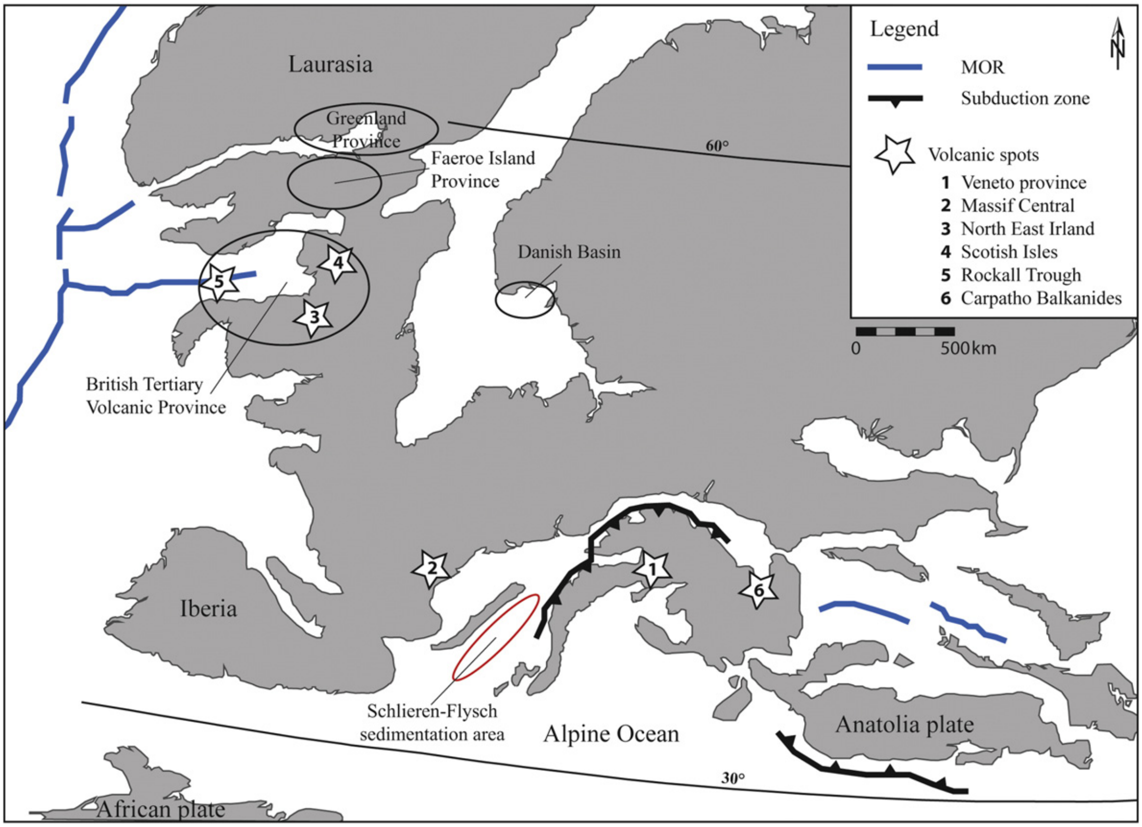

Fig. 1. Sedimentation area of the Schlieren Flysch and probable volcanic source centers of the ashes are marked on the map. Simplified paleotectonic map in the Early Eocene (50 Ma) after Blakey (2011).

fractions to evaluate and eliminate diagenetic alteration effects and synsedimentary contamination. Conclusions on the type of magma source will be mainly drawn from the geochemistry of the pumice in the bentonite layers. Finally, the integration of results allows us to identify the volcanic origin.

2. Geological background

2.1. Overview

The Late Maastrichtian–Early Eocene host rock of the bentonite layers belongs to the Upper Penninic sediment nappe, which extends from the Western Prealps in France to central Switzerland (Fig. 2). The Schlieren Flysch forms a SW–NE oriented, oval complex between Sörenberg and Alpnach, which is mildly folded into two roughly E–W running synforms, overlying the basal mélange or "Wildflysch" package (Bayer, 1982). The Schlieren Group is approx. 1500 m thick. The thin (mm–cm) bentonite layers preferentially occur in the Tonsteinschichten facies (Lower and Upper Tonsteinschichten formations; in the following abbreviated as LT and UT, respectively) (Fig. 3). The LT and UT formations represent hemipelagic-rich abyssal plain deposits of the outer (northern) margin of the remnant oceanic trench basin (Winkler, 1983). The paleogeographic affiliation of the Flysch is still a matter of debate (Trumpy, 2006). However, a South Penninic derivation is agreed by most researchers as also depicted on the newest tectonic map of Switzerland (Bundesamt für Wasser und Geologie, 2005).

2.2. Bentonite layers

Thin bentonite layers are also observed in the western and eastern counterparts of the Schlieren Flysch (Winkler, 1984; Winkler et al., 1985a). Until now, a total of 15 layers have been observed in the Late Maastrichtian, Paleocene and Early Eocene Schlieren Flysch series. Due to scattered outcrop conditions and the dominating turbidite sedimentation dynamics, it has not been possible to correlate single bentonite layers across the Flysch (Winkler, 1983). Such correlations are also hampered by strong lateral facies variations.

Bentonite layers, ranging in thickness from a few millimeters to 2.5 cm occur at an irregular frequency. A preferred preservation of the ashes in the abyssal plain facies is expected. The poorly consolidated layers show a typical yellowish to white/beige weathering color. Grading can sometimes be observed in the thicker layers. The lower contact of the bentonite layers is generally sharp, whereas the transition to the hemipelagic sediments on top is rather gradual. The clay fraction is composed mainly of montmorillonite in free phase (up to 100%) or in mixed-layer phase montmorillonite/illite (up to 80%). This indicates that these layers originally contained remarkable amounts of volcanic material (Winkler et al., 1985a). Both bentonite layers and hemipelagic shales are free of calcite, implying that sedimentation occurred below the calcite compensation depth (Winkler, 1983). Impurities in the ash layers are the result of the long transport through the water column and the dragging effect of the settling ash particles. Fission track dating on zircons from bentonite layer WW1948, in the LT, was performed by Winkler et al. (1990), and revealed a preliminary age of 57.8 ± 2.7 Ma.

3. Methods

3.1. Heavy liquid separation and mineral analysis

The bentonites were carefully extracted in the field by hand and knife from the surrounding host rock to avoid contamination. Approximately 1 kg of material per bentonite layer was crushed by high voltage pulses in a Selfrag rock-crusher to minimize destruction of single grains. Organic material was removed using hydrogen peroxide treatment and potential diagenetic carbonate cement was removed using acetic acid. The crushed samples were mixed with a strong surfactant to destroy