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# Geochemistry and $^{40}Ar/^{39}Ar$ geochronology of pseudotachylyte associated with UHP whiteschists from the Dora Maira massif, Italy

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**Abstract**

In situ UV-laser ablation $^{40}Ar/^{39}Ar$ geochronological and geochemical data, together with rock and mineral compositional data, have been determined from pseudotachylyte and surrounding mylonitic gneiss associated with the UHP whiteschists of the Dora Maira Massif, Italy. Several generations of fresh pseudotachylyte occur as irregular veins up to a few cm thick both parallel and at high angles to the foliation. Whole rock XRF data collected from representative lithologies of mylonitic gneiss are uniformly consistent with a mildly alkalic granitic protolith. Minimal compositional variation is observed between the pseudotachylyte and its surrounding mylonitic gneiss. The pseudotachylyte contains newly crystallized grains of biotite and K-feldspar in a matrix of glass with partially fused grains of quartz, zircon, apatite, and titanite. Electron microprobe analyses of the glass show significant compositional variation that is probably strongly influenced by micrometer-scale changes in mineralogy. UV-laser ablation ICP-MS traverses across the mylonitic gneiss–pseudotachylyte contact are consistent with cataclastic communition of REE carriers such as epidote, monazite, allanite, zircon, and apatite before melting as an efficient mechanism of REE homogenization in the pseudotachylyte. The $^{40}Ar/^{39}Ar$ data from one band of pseudotachylyte indicate formation at $20.1 \pm 0.5$ Ma, when the mylonitic gneisses were already in a near surface position. The variable effects of top-to-the-west shear deformation within outcrops of the coesite-bearing unit are reflected in localized zones of protomylonite, cataclasite, ultracataclasite, and pseudotachylyte. Preservation of several generations of pseudotachylyte suggests that seismic events may have played a significant role in triggering late unroofing of the UHP rocks. It is speculated that deeper crustal seismic events potentially played a role in the unroofing of the UHP rocks at earlier stages in their exhumation history.


*Keywords:* Pseudotachylyte; Cataclasite; Dora Maira; UHP; $^{40}Ar/^{39}Ar$ geochronology

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## 1. Introduction

The majority of pseudotachylytes are frictional melt products formed during coseismic faulting under brittle conditions at crustal depths of less than about 20 km (e.g., Magloughlin and Spray, 1992; Spray, 1992). However, pseudotachylyte containing garnet and omphacitic pyroxene from eclogites in Norway are believed to have formed at crustal depths of about 60 to 70 km (Austrheim and Boundy, 1994; Lund and Austrheim, 2003). The occurrence of pseudotachylyte in eclogite may be more widespread than previously recognized. The few descriptions in the literature may be due to a combined lack of recognition in the field and poor sample preservation. Fresh pseudotachylytes have been recently observed in proximity to coesite-bearing ultra high pressure (UHP) rocks of the Dora Maira massif, Italy (Chopin, 1984; Henry, 1990). The UHP rocks were formed at about 35 Ma (e.g., Tilton et al., 1991; Duchêne et al., 1997; Gebauer et al., 1997) at pressures of 3.5–4.2 GPa, and depths in excess of 100 km (e.g., Chopin, 1984; Chopin and Schertl, 1999). Moreover, zircon fission track ages indicate that these rocks were cooled to below ~250 °C by about 29 Ma (Gebauer et al., 1997) suggesting uplift of the UHP rocks occurred at rates of 2–3 cm/a. Such fast uplift rates, approaching those of tectonic plate spreading, have prompted different mechanisms and models to explain their presence at the Earth's surface (e.g., Chopin, 2003). The fact that pseudotachylytes can form within the eclogite facies indicates that brittle frictional melting occurs at depths corresponding to the base of the crust. Experimental data suggest that such brittle behavior may occur in subducted slabs at depths in excess of 300 km (Jung et al., 2004). The association of pseudotachylyte within UHP rocks of the Dora Maira massif is therefore significant because they may potentially record important information about their uplift history from UHP depths. Because pseudotachylytes form by localized deformation at high slip rates (>0.1 m/s) (Spray, 1992), one mechanism that may help explain the rapid uplift is episodic seismogenic faulting resulting in large vertical displacements.

A key piece of information critical to understanding if pseudotachylyte formation is tied to the uplift history of high pressure (HP) and UHP rocks is absolute age dating. Because pseudotachylyte often contains several weight percent (wt.%) potassium, it is a potential candidate for accurate age determinations using in situ UV-laser ablation $^{40}Ar/^{39}Ar$ methods. Geologically significant $^{40}Ar/^{39}Ar$ ages in pseudotachylyte depend upon many factors including bulk composition, partial melting, sample preservation (i.e., devitrification and alteration), excess argon, and argon recoil. Recent investigations dating pseudotachylyte by $^{40}Ar/^{39}Ar$ methods have evaluated some of these factors and in many cases geologically reliable ages have been obtained (e.g., Spray et al., 1995, 1999; Magloughlin et al., 2001; Sherlock and Hetzel, 2001; Davidson et al., 2003).

In this paper, we report electron microprobe, whole rock XRF, and in situ UV-laser ablation $^{40}Ar/^{39}Ar$ geochronological and ICP-Ms compositional data from one of several generations of fresh pseudotachylyte occurring within gneisses of the Dora Maira coesite-bearing unit (Chopin et al., 1991). We compare the mineralogical and compositional data of the pseudotachylyte to its host gneiss and further examine the concentrations of selected minor and trace elements along compositional traverses across the gneiss–pseudotachylyte contact. We also compare compositional data from a strongly mylonitized quartz–phengite–talc–kyanite schist interlayered with the gneiss and the pyrope-bearing UHP whiteschists. Collectively, these data constrain the timing of seismicity triggering local melting and provide insight into the compositional changes and elemental distributions accompanying pseudotachylyte formation.

## 2. Pseudotachylyte within Dora Maira UHP rocks

Several generations of fresh pseudotachylyte are exposed in mylonitic gneiss in the Val Gilba, about 5 km northwest of Brossasco (Fig. 1) within a quarry along the northeast side of the valley (coordinates 44°35′23N, 07°18′39E). The quarry is near the base of a ~300-m-thick section of protomylonitic rock visible as steep cliffs from the valley floor. Pseudotachylyte veins up to 5 cm thick occur within the metagranitic gneiss rooting in composite ultramylonite–cataclasite–pseudotachylyte bands roughly parallel to the mylonitic foliation (Fig. 2). Pseudotachylyte generally occurs sub-parallel to the foliation, however some pseudotachylyte intrudes fractures within the