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A weakening mechanism for intermediate-depth seismicity? Detailed petrographic and microtextural observations from blueschist facies pseudotachylytes, Cape Corse, Corsica

N. Deseta [a,*], T.B. Andersen [b], L.D. Ashwal [a]

[a] Department of Geosciences, University of the Witwatersrand, Private Bag 3, 2050 Johannesburg, South Africa
[b] Department of Geosciences, CEED, University of Oslo, PO Box 1047, Blindern, 0316 Oslo, Norway

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ABSTRACT

Gabbro- and peridotite-hosted pseudotachylytes from the Alpine Schistes Lustres Unit in Corsica, previously determined to have formed at blueschist to lawsonite-eclogite facies conditions, have been causally linked to the generation of intermediate-depth earthquakes, which occur at depths of 50–300 km. Detailed petrographic and microtextural analyses of these pseudotachylytes suggest that their initiation may be controlled by a thermally-activated shear runaway process that is controlled by rheology rather than mineralogy. This is documented by sheared out, prolate, kinked and twinned wallrock clasts that have been peeled off and entrained into the pseudotachylyte vein as sigmoid survivor clasts. The presence of metastable high temperature crystallisation products in the pseudotachylyte, such as hoppers and dendrites of olivine, enstatite and diopside (peridotite) and Al-rich omphacite and Fe-rich anorthite in metagabbro, are suggestive of a short-lived high-temperature event resulting from thermal instability. These high temperature mineral assemblages are overprinted by ones indicating a return to ambient conditions of lower temperatures, but still high pressures: glaucophane, albite and epidote in metagabbro and clinochlore; and fine-grained granoblastic olivine, enstatite and diopside in peridotite. The observations from this detailed study of natural samples suggest that intermediate-depth seismicity may be generated by a thermal runaway process.

1. Introduction

The initiation of intermediate-depth earthquakes has long been a subject of debate. These phenomena occur at depths from 50 km to 350 km, which, due to high confining pressures, preclude traditional brittle failure (Green and Houston, 1995; Hacker, 2003; Jung et al., 2004; Ogawa, 1987). In order to address this problem researchers have put forth several hypotheses, which include dehydration embrittlement, transformational faulting and thermal runaway processes. These hypotheses can be divided into brittle — (solid-state dehydration embrittlement and transformational faulting) and crystal-plastic — (shear-heating and thermal runaway) controlled processes. These models are based on experimental, numerical and geophysical modelling, with no field observations and little work on natural samples (Green and Houston, 1995; Hacker, 2003; John et al., 2009; Kelemen and Hirth, 2007; Ogawa, 1987). In the past two decades however, several discoveries of high pressure pseudotachylytes associated with intermediate-depth earthquakes have been made (Austrheim and Boundy, 1994; Jin et al., 1998; John and Schenk, 2006; Kanamori et al., 1998), providing researchers with natural material with which to evaluate previous models. This paper presents detailed petrographic and microstructural observations of peridotite- and metagabbro-hosted pseudotachylytes associated with subduction zone seismicity, in the Cima di Gratera area of Cap Corse, Corsica. Previous work suggests that faulting and pseudotachylyte generation took place during subduction at blueschist to lawsonite-eclogite facies conditions under pressures of 1.8–2.6 GPa (Austrheim and Andersen, 2004; Andersen and Austrheim, 2006; Ravna et al., 2010; Vitale Brovarone et al., 2011). A detailed discussion on the geochemistry of these rocks and the role that water plays in earthquake generation will be addressed in a separate paper.

2. Geological setting

The study area is located on the SSW side of Cima di Gratera, Cape Corse, northern Corsica (Fig. 1). The pseudotachylytes, first described by Austrheim and Andersen (2004), occur within lenses of gabbro and mantle peridotite enclosed by serpentinite (Fig. 2). These rocks form part of the Schistes Lustres Complex (part of the Alpine age high pressure–low temperature subduction complex), and which has been interpreted as either nappes of exhumed Ligurian oceanic lithosphere, which have slivers of crystalline continental material, or hyper-stretched continental lithosphere interleaved with mantle imbricates (Agard et al., 2002; Beccaluva et al., 1977; Jolivet, 1993; Mohn et al., 2009; Vitale Brovarone et al., 2011). This rock package was thrust onto

* Corresponding author.
E-mail address: suridae@gmail.com (N. Deseta).

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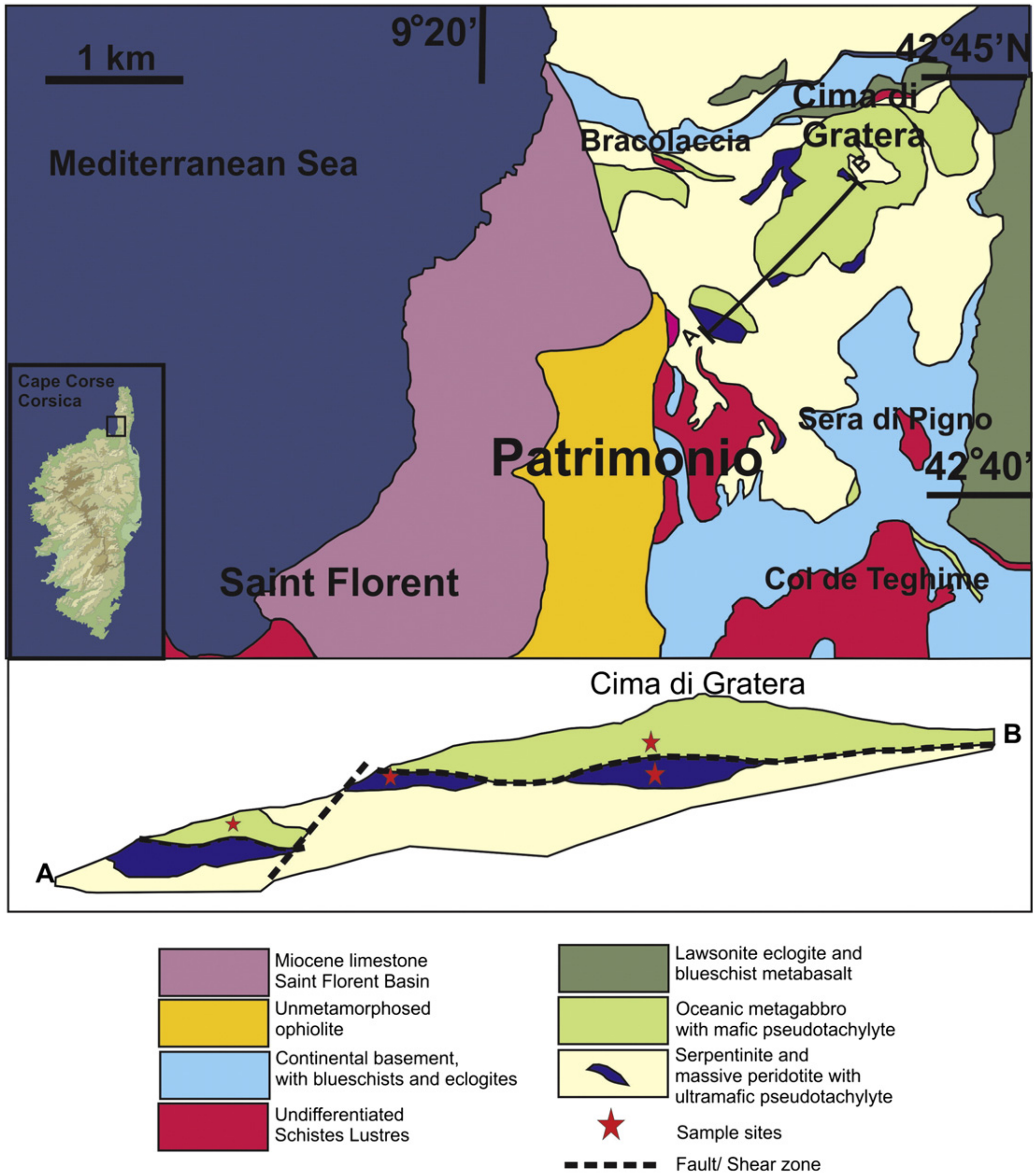

Fig. 1. Simplified geological map of the study area in Cima di Gratera. Modified after Andersen and Austrheim (2006).

the continental margin of Europe during the Late Cretaceous to Tertiary Periods (Fig. 1) (Jolivet, 1993).

The metagabbros are compositionally uniform and encompass a range of igneous textures marked by differences in grain size. Common textures are cumulate layering and the interfingering of irregularly shaped domains of fine- and coarse-grained gabbro. Conversely, the peridotites are relatively uniform in terms of composition, texture and grain size. The pseudotachylyte-bearing fault rocks have been partially metamorphosed to blueschist and greenschist facies only in patches, except within the shear zones where the metamorphic reactions are fully equilibrated. The pseudotachylytes occur within the pristine lenses of gabbro and peridotite that are relatively undeformed and least affected by the regional HP–LT metamorphism (Andersen and Austrheim, 2006).

2.1. Field observations

In outcrop the pseudotachylytes typically have a positive relief with respect to the host rocks. The pseudotachylyte veins weather to a rust-red colour but on fresh surfaces are black-grey and aphanitic (Fig. 2). Comminuted wallrock clasts and flow banding are commonly observed. In the peridotite, the pseudotachylytes occur in two sets that extend for up to 1 km: a sub-vertical set and a sub-horizontal set. Within the vein sets the pseudotachylytes form complex vein networks that over-print and re-inject one another, indicating multiple generations of pseudotachylyte (Fig. 2). In the peridotite, the pseudotachylyte veins occasionally form radial 'explosive' networks. These veins are thicker than other injection or fault veins and contain more re-injections and comminuted wallrock material (Fig. 2b). In contrast with the peridotite-hosted veins, those in the gabbro are thinner and more discrete, commonly (but not always) occurring along the boundary between the very coarse-grained (<15 mm) metagabbro and fine-grained (<2 mm) metagabbro (Fig. 2). The peridotite pseudotachylytes show cross-cutting relationships with serpentinised host rocks, which have been entrained into the veins as sigmoidal lozenges, indicating a brittle–ductile overprint relationship. In the metagabbro fault rock, the pseudotachylytic crystallisation products (glaucophane) have formed CPO (crystallographic preferred orientation) fabrics and contain boudinaged wallrock clasts, indicating a ductile overprint post-dating pseudotachylyte generation (Fig. 12) (Andersen and Austrheim, 2006). Many of the pseudotachylytes are cut by later serpentine veins and show a hydration