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Frictional melt pulses during a ∼1.1 Ma earthquake along the Alpine Fault, New Zealand

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Abstract

Our understanding of frictional melting that occurs during large earthquake slip events has been hampered by the extremely fine-grain size of frictionally fused rock, and the lack of detailed high-resolution microscopy studies that describe features at the crystal lattice scale. In such a study, we here report the complex nature of melting and crystallization in a symmetrically layered, pseudotachylyte vein from the Alpine Fault, New Zealand. Two melt pulses are recognized, attributed to successive, but rapid, injections of frictionally generated material. The initial injection, preserved at the vein margins, was proximally derived and contains a high concentration of clasts and a Si-rich glass. This was quickly followed by a second generation of a more distally derived, melt-dominated fraction, which was injected into the weak vein center. Whereas fragments of wall-rock biotite are preserved in the marginal zones, neocrystallized microlitic biotite characterizes both margins and center. The vein biotite is different in composition, microstructure and polytypism from the metamorphic biotite of the wall rock. In all melt layers, newly formed biotite shows notable signs of syn-flow crystallization, strain features and erosion at crystal–glass contacts, with breakdown of neocrystallized microlites along both crystal edges and faces. These characteristics imply cyclic pulses of heating, melting and crystallization occurred during a single, large earthquake episode, and probably reflects the stick-slip propagation properties of coseismic faulting. $^{40}Ar/^{39}Ar$ total gas ages from the vein center give a 1.11 ± 0.04 Ma date for cyclic melting which, based on current exhumation rates, occurred at a crustal of depth ∼11 km.
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1. Introduction

The coseismic frictional melting of the Earth's crust is now a widely reported phenomenon within fault zones. It has been described in fused rocks (pseudotachylytes) formed at various depths and under a broad spectrum of *P–T–X* and fluid conditions [1–3]. A variety of characteristics reflect a melt origin [4], which include quenched vein mar-

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