Thermomechanical Erosion of Footwall Andesites by Komatiites at the Alexo Ni-Cu-(PGE) Deposit, Abitibi Greenstone Belt, Canada

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Introduction

Most komatiite-associated Ni-Cu-(PGE) deposits exhibit stratigraphic, geological, geochemical, isotopic, and/or theoretical evidence for thermomechanical erosion of footwall rocks and incorporation crustal S via devolatilization or melting of country rocks (e.g., Lesher, 1989; Lesher et al., 2001). However, Cas & Beresford (2001) and Rice & Moore (2001) have recently suggested that this process did not occur. The purpose of this contribution is to describe a spectacularly well-preserved example of thermomechanical erosion at the Alexo Mine in Dundonald Township, Ontario, which is being studied as part of a PhD dissertation by the senior author.

Alexo Mine

The Alexo Mine is located on the NE-dipping central limb of the Dundonald fold structure, in an area that has been metamorphosed to prehnite-pumpellyite facies and contains some of the best preserved 2.7 Ga komatiites in the world (Arndt, 1986). The stratigraphic succession comprises four sequences of komatiitic rocks intercalated with intermediate volcanic rocks (Davis, 1999). Younging indicators in the komatiites (e.g., flow-top breccias, asymmetrically-zoned spinifex textures, transgressive lower margins of lava channels, disseminated/net-textured/massive ore segregation profiles) and andesites (e.g., flow-top breccias, pillows) consistently face northward to westward and the compositions of the andesites vary systematically from more tholeiitic in the south to more calc-alkaline in the north, indicating that the sequence is located on the same limb of the regional fold.

The Fe-Ni-Cu-(PGE) sulfide mineralization at Alexo is hosted by a ~70 m thick olivine cumulate komatiite unit that is partially localized within embayments in the footwall andesites (Lowther, 1950; Naldrett, 1966; Davis, 2001). The ores exhibit a classic magmatic ore segregation profile: a thinner lower zone of massive to semi-massive sulfides overlain by a thicker zone of net-textured and disseminated sulfides. The massive zones extended laterally for 10’s of metres along strike and contain 15-20% pentlandite, 80-85% pyrrhotite, and trace amounts of unevenly distributed chalcopyrite and, where oxidized, hazelwoodite and violarite (Coad, 1979). Small massive to semi-massive veinlets extend into the footwall rock. Massive ores contain, on average, 5.39% Ni, 0.35% Cu, and 3.8 g/tonne ∑ PGE in 100% sulfides, whereas net-textured and disseminated ores contain, on average, 6.35% Ni, 0.58% Cu, and 4.3 g/t PGE (Barnes & Naldrett, 1987; Davis, 2001), implying a higher R factor (mass ratio of silicate to sulfide liquid) in the net-textured and disseminated ores compared to the massive ores.

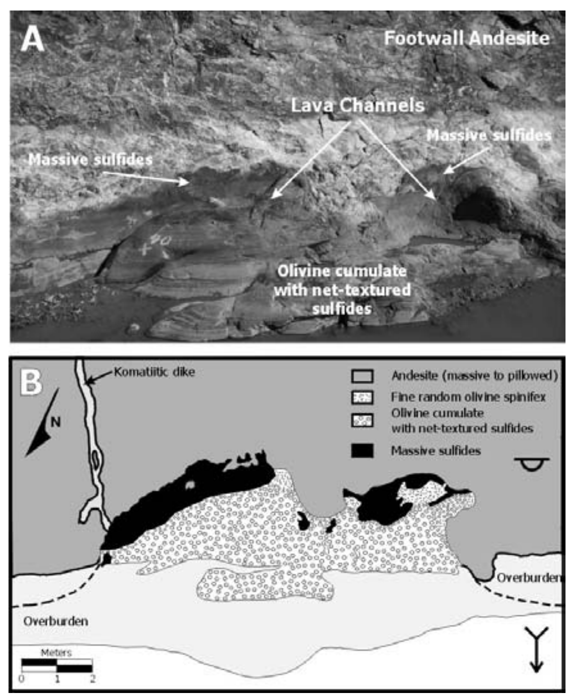

Figure 1. *A) Photo and B) map of two second-order embayments in the West Area at Alexo. A similar geometry was produced in the analog model of Huppert and Sparks (1985, figure 12).*

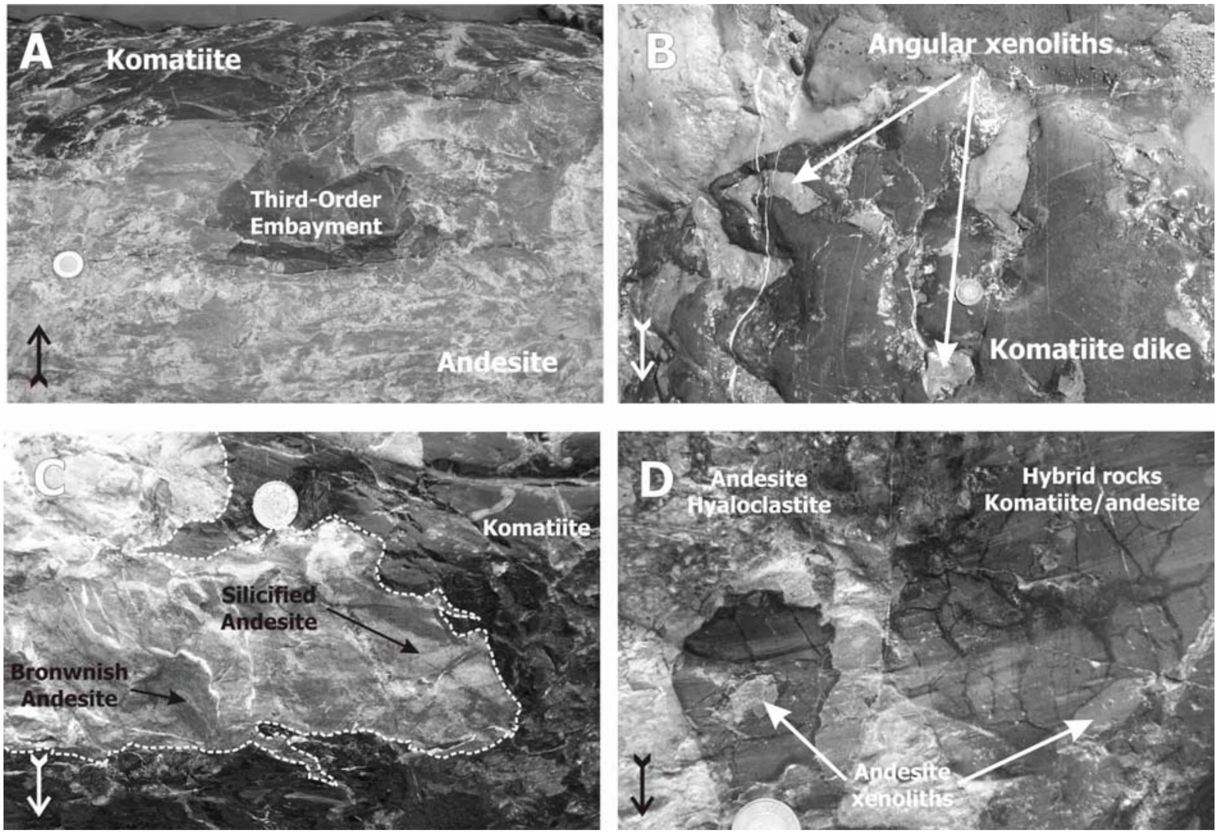

Figure 2. *A) Third-order embayment (10-30 cm wide, 10-50 cm deep) in East Area at Alexo. B) Small angular xenoliths in a komatiitic dyke in the pillowed andesitic footwall. C) Contact metamorphic areole along the lower contact grades from bleached and recrystallized (remelted?) andesite through recrystallized andesite. D) Brown (lighter grey in photo) aphyric komatiite along the footwall contact with the underlying flows, which appears to represent contamination.*

Evidence for Thermomechanical Erosion

The komatiite/andesite contacts east and west of the Alexo Mine shaft were stripped by Hucamp Mines in 2001, exposing the basal contact of the mineralized lava channel. These areas provide almost complete exposure of the well-preserved contact between the pillowed, massive, and hyaloclastic footwall andesite and the overlying mineralized cumulate komatiite unit. The following indicate thermomechanical erosion of the footwall andesitic rocks:

1) There are multiple scales and multiple orders of embayments, all of which clearly transgress the andesites without any evidence of regolith, shearing, or folding along the contact or of folding in any of the underlying andesites or overlying ore horizon. The first-order embayment that localizes the Alexo mine komatiite host unit is a ~120 m wide and ~25 m deep concave depression (Naldrett, 1966) that contains numerous re-entrant second-order embayment ranging 10-20 m in width and 3-6 m in depth (Fig. 1A-B), and third-order embayments ranging 10-30 cm in width and 10-50 cm in depth (Fig. 2A), resulting in a highly contorted lower contact that cannot have been produced by folding or faulting.

2) Narrow (<5 cm), irregular, aphyric komatiite dikes extend from the host unit downward into the underlying footwall rocks (Fig. 2C). They appear to have exploited thin fractures, but clearly cross-cut the selvages of andesite pillows.

3) Small (<10 cm) angular (mechanically eroded) xenoliths (Fig. 2B), subrounded (partially melted) xenoliths, and globular (completely melted) xenomelts of andesite occur in the komatiite near the contact and in the dikes.

4)There is a continuous contact metamorphic areole along the lower contact that grades from bleached and recrystallized (remelted?) andesite through recrystallized andesite (Fig. 2C), to weakly metamorphosed andesite over a distance of ~ 30 cm (Fig. 1A).

5)The aphyric komatiite along the footwall contact is browner in colour than the black aphyric komatiite in the dike and in overlying flows, which appears to represent contamination (Fig. 2D).

Together, these features provide strong if not unequivocal evidence for both thermal and mechanical erosion. We are in the process of determining the degree of contamination in these particular komatiites, but other komatiites in the Alexo Mine sequence are characterized by $[Nb/Th]_{MN}$ ~ 0.8 and $[La/Sm]_{MN}$ = 0.9 compared to unmineralized komatiites in the underlying sequence, which are characterized by ($[Nb/Th]_{MN}$ ~ 1.3-1.8 and $[La/Sm]_{MN}$ = 0.5-0.6, providing evidence of local crustal contamination (Sproule et al., 2002).

These relationships are similar to those reported by Groves et al. (1986), Frost & Groves (1989), Lesher (1989), Dowling et al. (2001), and Prendergast (2001) and are consistent with thermal and fluid dynamic models by Huppert & Sparks (1985) and Williams et al. (1999), which suggest that andesites should be more erodable than basalts but less erodable than felsic volcanic rocks or sediments. They clearly contradict the suggestions of Cas & Beresford (2001) and Rice & Moore (2001) that komatiites should not be capable of thermal erosion.

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