Extrusive and Intrusive Komatiites and Komatiitic Basalts, Peperites, and Ore Genesis at the Dundonald Ni-Cu-(PGE) Deposit, Abitibi Greenstone Belt, Canada

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Introduction

Following the recognition of the volcanic nature of ultramafic rocks in the Barberton greenstone belt by Viljoen & Viljoen (1969), the existence of extrusive komatiites is now accepted by most workers. Nevertheless, there are also numerous examples of komatiitic dikes, sills, and invasive flows (e.g., Williams, 1979; Duke, 1986; Arndt, 1994; Davis, 1997, 1999; Stone & Stone, 2000; Beresford & Cas, 2001; Lesher et al., submitted; Lévesque, this volume). Here we describe spectacularly preserved examples of komatiitic sills and peperites in Dundonald Township, Ontario, which are being studied as part of a Ph.D. dissertation by M.G.H.

Dundonald Komatiitic Sequence

The volcanic sequence in Dundonald Township comprises, from base to top (Davis, 1997, 1999): komatiitic flows intercalated with mafic to felsic volcanic flows, a thick layered tholeiitic mafic-ultramafic sill (Dundonald Sill), felsic to intermediate volcanic flows containing thin komatiitic dikes, and komatiitic volcanic flows intercalated with thin graphitic, sulfidic argillaceous metasediments and rare high-Ti tholeiitic basalts. The sequence is exposed in glaciated outcrops throughout the township, but is best exposed in the Dundonald South area, which was stripped by Falconbridge Ltd. in 1989 and by Hucamp Mines in 2001, exposing 9000m^2 of glacially-polished outcrops known locally as Dundonald Beach. The volcano-sedimentary package in this part of the area lies on the south-facing limb of a regional fold, strikes roughly east-west, and dips steeply to the south. The metasediments are locally sheared subparallel to bedding, but most of the volcanic rocks and peperites are not penetratively deformed.

The upper komatiitic sequence in the Dundonald South area comprises three cycles that exhibit an overall decrease in MgO content with increasing stratigraphic height. However, the MgO contents of the rocks within each cycle increase upwards. Each cycle comprises i) a lower member of thick differentiated komatiitic basalt flows with lower olivine-pyroxene cumulate zones and upper acicular pyroxene spinifex-textured zones, ii) a central member of thick differentiated cumulate komatiite flows with lower olivine cumulate zones and upper olivine spinifex-textured zones, and iii) an upper member of thick cumulate komatiite flows with thick olivine mesocumulate to adcumulate lower zones and thin upper olivine spinifex-textured zones. The first and second cycles are exposed in the western part of Dundonald Beach (Fig. 1) and the second cycle and lowermost part of the third cycle are exposed in the eastern part of the same area (not shown). The third cycle hosts most of the Fe-Ni-Cu sulfide mineralization in the Dundonald South area, only parts of which are exposed in outcrop.

Ni-Cu-(PGE) mineralization in the Dundonald South deposit occurs as i) stratiform contact disseminated/net-textured/massive sulfides, ii) stratabound internal disseminated, blebby, and amygdaloidal sulfides, and iii) minor metasediment-associated sulfides (Muir & Comba, 1979; Eckstrand & Williamson, 1985; Barnes & Naldrett, 1987). The ores are hosted by (or associated with) olivine cumulate rocks that are discontinuous along strike and probably represent channelized lava flows. The mineralization within the metasedimentary rocks includes both primary (peperitic) and secondary (metamorphically-mobilized) types. The sulfides are composed of pyrrhotite, pentlandite, chalcopyrite, millerite, electrum, and PGE alloys (Muir & Comba, 1979; M.E. Fleet, pers. comm. to P.C.D., 1993). Massive ores contain, on average, ~47.5% Ni, 0.35% Cu, and 19 g/t ∑PGE in 100% sulfides, whereas disseminated ores contain, on average, ~38.1% Ni, 0.88% Cu, and 24 g/t PGE (Barnes & Naldrett, 1987; Davis, 2001). Grab samples of massive sulfides in the first cycle at Dundonald Beach contain 20-34% Ni, 4.4-45 g/t Pt+Pd, 1.8 g/t Os+Ir+Rh, and 2.4 g/t Ru. The very high metal tenors imply very high R (mass ratio of silicate to sulfide liquid) and very reducing conditions, but the differences between ore types suggest higher R in disseminated ores than in massive ores.

Intrusive, Invasive, and Extrusive Komatiites and Komatiitic Basalts

The komatiites and komatiitic basalts exposed at Dundonald Beach (Davis, 1997) and in drill core (Muir & Comba, 1979) range in thickness from 1m to >150m and display all of the textures typical of komatiites: glassy and rubbly flow-top breccias, fine-grained random olivine spinifex textures, coarse-grained platy olivine or acicular pyroxene spinifex textures, and a wide variety of crescumulate, orthocumulate, mesocumulate, and adcumulate textures. Some of the thicker flows (e.g., "Empire flow") are well differentiated with lower meso- to adcumulate zones and upper gabbroic zones, suggesting that differentiation occurred after the flow had ponded (Vicker, 1991), but most of the thicker flows contains an excess component of olivine and therefore appear to have accumulated substantial amounts of this mineral prior to ponding (Davis, 1997).

Some komatiitic basalts in the first cycle form sills with thin (1-2 cm) symmetric upper and lower chilled margins that cross-cut previous komatiitic basalt flows and invade the graphitic argillaceous sediments, forming peperites and graphite "egg-shell breccias" (Davis, 1997, 1999). Several thin (~5-10 cm) spinifex-textured dikes occur in the underlying felsic volcanic rocks (Davis, 1997, 1999). The sills may be subdivided into two types. Type I sills are relatively thick (~4 m), are composed of fine- to medium grained komatiitic basalt, and have straight contacts with thin (~2-3 cm) very fine-grained lower and upper chilled margins. They do not appear to have interacted extensively with wall rocks. Type II sills are thinner (<50 cm), are composed of fine-grained komatiitic basalt with local globular textures (Fig. 2B) indicative of contamination, and have wavy, irregular contacts (Fig. 2A) with very thin (<1 cm) chilled margins. They appear to have interacted extensively with wall rocks.

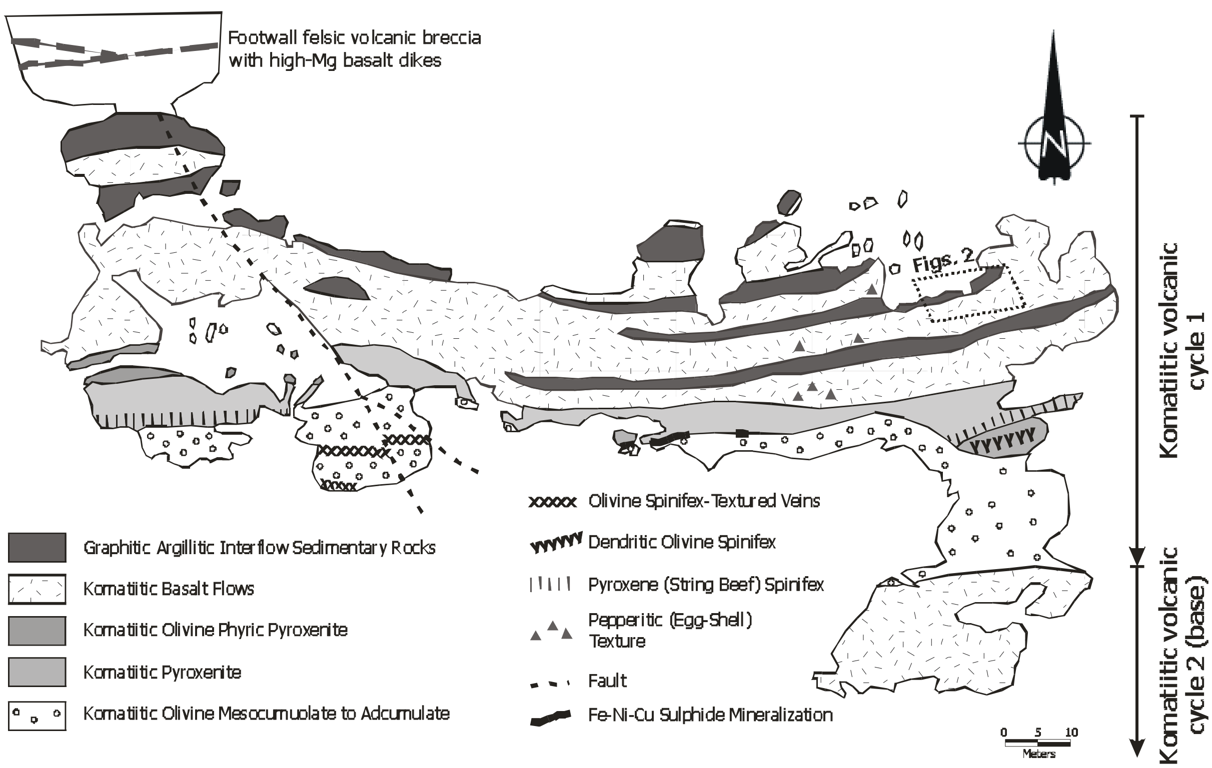

Figure 1. *Simplified geological map of the western part of the Dundonald Beach area (modified from Davis, 1999). Rocks young to the south.*

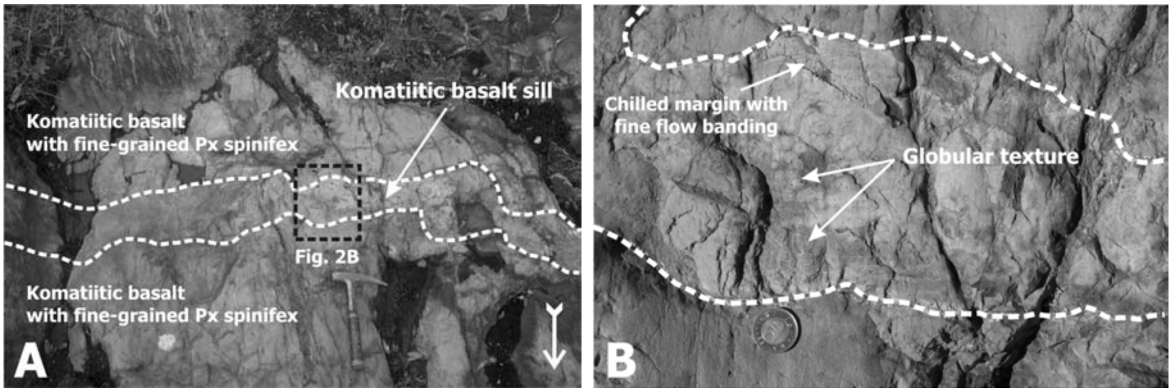

Figure 2. A) *Type II komatiitic basalt sill showing globular textures wavy and irregular contact with the host unit (hammer for scale).* ***B)*** *Close up of the figure 2A showing globular texture (coin for scale).*

Peperites are produced when hot magma intrudes unconsolidated or poorly consolidated sediments (e.g., White et al., 2000). This interaction appears to have occurred between unconsolidated graphitic argillaceous sediments and the komatiitic magma in the Dundonald Beach area, producing *blocky peperites,* containing angular clasts of desiccated sediment in a komatiitic basaltic matrix ("egg-shell breccias: Fig. 3B) and *fluidal peperites*, containing rounded clasts of komatiitic basalt in a metasedimentary matrix (Fig. 3B). Peperites containing clasts of komatiite surrounded by metasediment occur on larger scales (meters) than peperites containing clasts of sediments surrounded by komatiites (centimeters), but both textures generally occur close to one other.

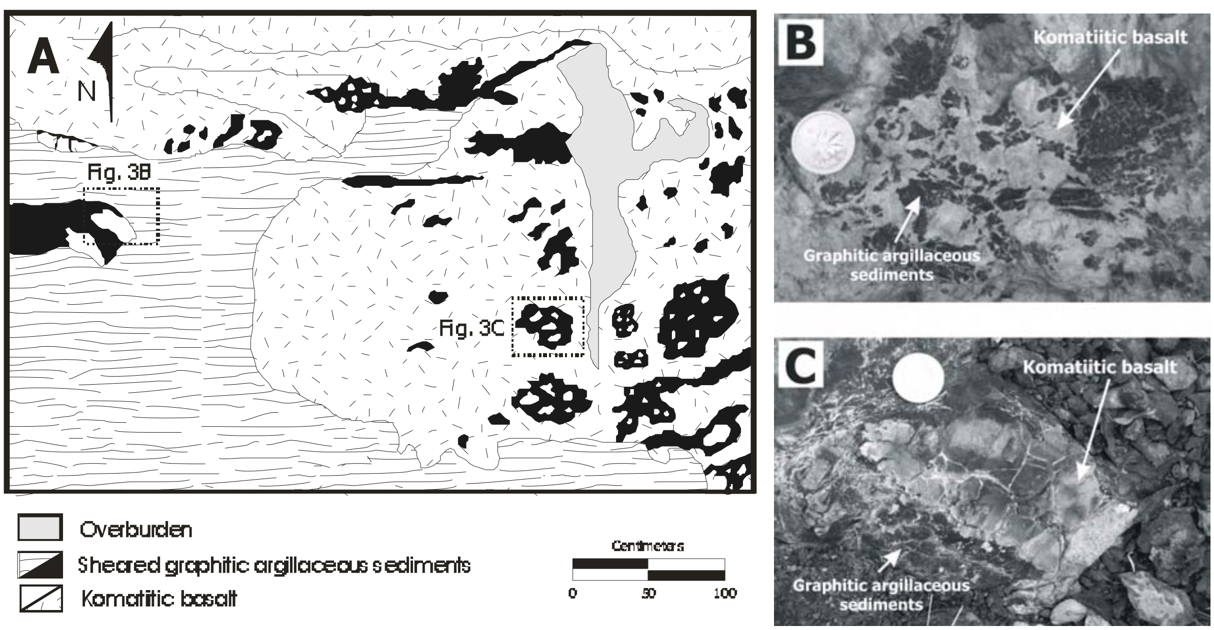

Figure 3. A) *Detailed map showing relationship between graphitic argillaceous metasediments and komatiitic basalts at Dundonald Beach.* ***B)*** *Peperite comprising clasts of desiccated graphitic, argillaceous metasediment in a matrix of bleached (contaminated?) komatiitic basalt.* ***C)*** *Peperite comprising clasts of bleached (contaminated?) komatiitic basalt in a matrix of graphitic, argillaceous metasediment.*

Conclusions

Although the peperites and contaminated komatiitic basalt sills described here contain only minor Ni-Cu-(PGE) mineralization, the very high metal tenors of the mineralization in the lava channels and the contaminated geochemical signatures of the komatiites (Davis, 1997) provide indirect evidence for interaction between those komatiites and sulfidic, graphitic sediments to generate the magmatic Ni-Cu-(PGE) ores. Thus, the peperites and sills exposed on Dundonald Beach probably represent a less dynamic end-member in a larger system of lava channels, sills, and dikes.

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