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Spatial, temporal and geochemical characteristics of Silurian collision-zone magmatism, Newfoundland Appalachians: An example of a rapidly evolving magmatic system related to slab break-off ☆

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Abstract

Silurian plutonic suites in the Newfoundland Appalachians include abundant gabbro, monzogabbro and granite to granodiorite and lesser quartz diorite and tonalite. Most are medium- to high-K, but included are some low-K and shoshonitic mafic compositions. Felsic rocks are of both alkaline (A-type or within-plate granite (WPG)) and calc-alkaline volcanic arc granite (VAG) affinity. Mafic rocks include both arc-like (Nb/Th < 3) calc-alkaline and non-arc-like (Nb/Th > 3) transitional calc-alkaline basalt to continental tholeiitic affinity compositions. $\varepsilon_{Nd}(T)$ values range from −9.6 to +5.4 and $\delta^{18}O$ (VSMOW) values range from +3.1 to +13.2‰.

A rapid progression from exclusively arc-type to non-arc-like mafic and then contemporaneous WPG plus VAG magmatism has been documented using precise U–Pb zircon dating. Earlier arc-like plutonism indicates subduction, while asthenosphere-derived mafic magmas support slab break-off, due to subduction of a young, warm back-arc basin. Contemporaneous mafic magmas with arc and non-arc geochemical signatures may reflect tapping of asthenospheric and subcontinental lithospheric mantle (SCLM) sources and/or contamination of asthenosphere-derived magmas by SCLM or crust.

The brevity (<5 Ma) of the mafic magmatic pulse agrees with the transient nature of magmatism associated with slab break-off. The subsequent ca. 1 to 2 m.y. period of voluminous WPG and VAG plutonism likely reflects mafic magma-driven partial melting of both SCLM and crustal sources, respectively. Continuation of VAG-like magmatism for an additional 2 to 5 m.y. may reflect lower solidus temperatures of crustal materials, enabling anatexis to continue after mantle melting ceased. East to west spatial variation of ε_{Nd} and $(La/Yb)_{CN}$ in Silurian plutons suggests a transition from shallow melting of juvenile sources proximal to the collision zone to deeper melting of old source materials in the garnet-stability field further inboard.

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Previous work has demonstrated that geochemical discriminaton of post-collisional granitoid magmatism (PCGM) is difficult in the absence of other constraints. Our example should contribute to the understanding and identification of PCGM if it can be employed as a 'fingerprint' for slab break-off-related PCGM within the Paleozoic geological record.

Keywords: Post-collisional; Slab break-off; Granite; Alkaline; Newfoundland

1. Introduction

Characterization and petrogenesis of granitoid magmatism within Phanerozoic arc–continent collision zones are ongoing subjects of debate (e.g., Pearce et al., 1984; Harris et al., 1986; Sylvester, 1989; Turner et al., 1992; Pearce, 1996; Liegeois, 1998). Reasons for this include: (1) distinguishing active arc intrusions from syn- to post-collisional and subsequent intraplate magmatism requires accurate regional geological constraints, including precise U–Pb zircon dating; (2) terminology, such as syn-/late-tectonic, syn-/post-collisional, post-orogenic and anorogenic, can be confusing in the interpretation of granitoids and can hinder understanding of their geodynamic setting; and (3) because mantle and crustal sources likely formed or were modified during preceding convergent margin and collisional processes, a disconnect may exist between magma compositions produced and their post-collisional tectonic environment (cf. Pearce, 1996; Arculus, 1997). Possible causative tectonomagmatic processes include crustal thickening-related anatexis (e.g., France-Lanord and Le Fort, 1988), slab break-off (e.g., von Blanckenburg and Davis, 1995), large-scale lithospheric delamination (e.g., Nelson, 1992) and convective lithospheric erosion (e.g., Houseman et al., 1981).

The Newfoundland Appalachians are interpreted as a relict collision zone between Laurentia, in the west, represented by Grenvillian basement of the Humber Zone, and Gondwanan terranes in the east, represented by Neoproterozoic basement rocks of parts of the Exploits subzone, and the Gander and Avalon zones (see insert in Fig. 1). Above these basement rocks lie Lower Paleozoic supracrustal and plutonic rocks, belonging to the Humber, Dunnage and Gander zones, that sequentially represent continental margin, arc, back-arc and associated oceanic vestiges of the Iapetus Ocean that formerly separated the Laurentian and Gondwanan microcontinents (Williams, 1979). Rocks with Laurentian and peri-Gondwanan affinity are now juxtaposed along the Red Indian Line (RIL), the main Iapetus suture zone in Newfoundland (Fig. 1).

In this paper, geochemical and Nd–O isotopic data from Silurian (ca. 440–423 Ma) igneous rocks from west of the RIL are employed to obtain a better understanding of tectonomagmatic processes that both accompanied and followed Iapetus closure. This study was facilitated by the greatly improved geological and geochronological framework for the area, provided by coworkers on the RIL Targeted Geoscience Initiative (e.g., Lissenberg and van Staal, 2002; Rogers et al., 2003; Zagorevski et al., 2003; Pehrsson et al., 2003; van Staal et al., 2004, in press-a,b).

2. Tectonic and geologic context

This brief overview is mainly summarized from van Staal et al. (1998, 2004, in press), van der Velden et al. (2004) and references therein. The Humber Zone (Fig. 1), an Early Paleozoic passive margin sequence deposited on the leading edge of Laurentia (western margin of Iapetus), is divided into western external and eastern internal sectors, based on increasing deformation and metamorphism toward the east. Prior to 470–475 Ma, a narrow ocean basin (Humber seaway) is thought to have separated the Humber Zone from the Notre Dame arc (NDA) (labelled Notre Dame subzone in Fig. 1). This continental magmatic arc is thought to have evolved on a ribbon continent, referred to as Dashwoods, which rifted from Laurentia between 550 and 530 m.y. (Waldron and van Staal, 2001). Closure of the Humber seaway along the Baie Verte Line by east-directed subduction beneath Dashwoods produced 488–480 Ma arc magmatism of the NDA and was terminated by ca. 475 Ma obduction onto the Humber margin of Tremadoc–early Arenig Humber seaway vestiges (Baie Verte oceanic tract). These events were followed by voluminous tonalite plutonism between 466 and 459 m.y. within the NDA, attributed to break-off of the oceanic slab previously attached to the downgoing Humber margin. Closure of the main Iapetan ocean basin was accomplished during the Caradoc (455–450 Ma) by simultaneous east- and west-directed subduction. These processes juxtaposed the peri-Laurentian NDA plus its