

Can Alkaline Magmatism Destroy a Craton? Lessons Learned from the Greenland-Labrador Diamond Province

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Introduction

The successful rifting of a craton to the point of oceanic crust production is a rare phenomenon and a prime example is the Cenozoic opening of the Labrador Sea that now splits the North Atlantic craton (NAC). The NAC has a long-lived breakup history over a 1200 Myr time span that is accompanied by repeated injections of deep-sourced alkaline magmas (e.g., Tappe et al., 2007). These magmas, some of which are diamond-bearing, formed extensive dyke swarms along the present-day Labrador Sea margins in Greenland and Labrador. One hallmark of this alkaline magmatism is the overall volatile-rich nature and particularly, the predominance of carbonate-rich magma types such as aillikite. Here we give an overview of emplacement patterns, the petrology and isotope geochemistry of the various alkaline intrusive suites that line the Labrador Sea margins. Although conventional thinking interprets this recurrent alkaline magmatism as a product of step-by-step lithosphere removal, we propose a different view that this magmatism was key to the destruction of the NAC lithosphere.

Emplacement patterns

Major rifting affected the NAC during the Mesoproterozoic, Neoproterozoic, and Mesozoic-Cenozoic, and all of these extensional episodes were accompanied by potassic-to-carbonatitic magma production giving rise to extensive aillikite-carbonatite dyke swarms and central-complex intrusions between 1300-1160 Ma, 610-550 Ma, and 200-150 Ma, respectively. Whereas the Meso- and Neoproterozoic aillikite-carbonatite suites were emplaced at the craton margins, their Jurassic analogues are confined to the craton interior. Of particular significance, however, is the cessation of this potassic-to-carbonatitic magma production at ca. 150 Ma; from then on nephelinitic magmas of sodic lineage were produced (150-100 Ma).

Petrology and isotope geochemistry

The high-Mg, potassic-to-carbonatitic nature of diamond-bearing aillikites is coupled to extreme incompatible element enrichment suggesting derivation from carbonated peridotite sources that contained residual phlogopite (among other metasomatic phases). This places aillikite melt production at the cratonic lithosphere base at 150 to 180 km depth. Aillikite Sr-Nd-Hf-Pb isotope compositions are mildly depleted clearly showing that the incompatible element enrichment of the lithosphere base occurred shortly prior to magmatism by convective mantle-derived melts/fluids. In contrast, the Cretaceous nephelinitic magma suites require residual pargasitic amphibole in their sources, which is restricted to depths above 100 km. These sodic alkaline magmas show strikingly similar incompatible element patterns to the potassic-to-carbonatitic aillikites but are characterized by isotopic long-term enrichment. Geochemical modeling suggests that these nephelinitic magmas tapped metasomatic components that had been distributed throughout the shallower cratonic lithosphere during earlier pulses of aillikite magmatism.

Craton destruction

If we assume that aillikite and nephelinite melts formed at the lithosphere base, then it is reasonable to speculate that at least 50 km of the mantle lithosphere had been replaced by hotter convective mantle between ca. 550 and 150 Ma, and that mantle lithosphere destruction progressed laterally from the craton margins towards the interior. Our data show that the NAC mantle had been significantly modified by widespread and recurrent alkaline magmatism so that its structural integrity was weakened and deep parts could be effectively removed by stretching during plate tectonic stresses.

Acknowledgements

We gratefully acknowledge discussions with Bruce Kjarsgaard, Graham Pearson, Lotte Larsen, and Hugh O'Brien. Our research at the University of Alberta is partially funded by NSERC and Alexander von Humboldt Foundation grants.

Reference

Tappe, S., Foley, S.F., Stracke, A., Romer, R.L., Kjarsgaard, B.A., Heaman, L.M., and Joyce, N., 2007, Craton reactivation on the Labrador Sea margins: $^{40}\text{Ar}/^{39}\text{Ar}$ age and Sr–Nd–Hf–Pb isotope constraints from alkaline and carbonatite intrusives: *Earth and Planetary Science Letters*, 256, 433-454.