

A New Locality of Postorogenic Carbonatites and Carbonatite-Hosted Rare-Earth Mineralization at Paint Lake, Superior Boundary Zone, Manitoba

Anton R. Chakhmouradian*

Department of Geological Sciences, University of Manitoba, Winnipeg, Manitoba, Canada
chakhmou@cc.umanitoba.ca

Chris Couëslan

Manitoba Geological Survey, Winnipeg, Manitoba, Canada

Ekaterina P. Reguir

Department of Geological Sciences, University of Manitoba, Winnipeg, Manitoba, Canada

and

Attila Demény

Institute for Geochemical Research, Budapest, Hungary

Summary

A swarm of subparallel steeply dipping carbonate dikes is exposed on numerous small islands in the central part of Paint Lake in the Superior Boundary Zone in central Manitoba. The swarm has been traced over a distance of 21 km and is generally conformable to the regional tectonic structure and gneissosity. The principal constituent of all dikes is calcite enriched in Sr, Y and rare-earth elements (REE) and showing evidence of plastic deformation and cataclasis, but the modal composition and texture of individual bodies vary from anchimonomineralic zones of coarse-grained calcite to fine-grained saccharoidal rocks with phlogopite-rich stringers to inequigranular foliated varieties containing a large proportion of calcic amphiboles, apatite, diopside, scapolite and xenocrysts. Regardless of these textural variations, the rocks are consistently enriched in Sr, light REE and show $\delta^{18}\text{O}_{\text{SMOW}}$, $\delta^{13}\text{C}_{\text{PDB}}$, Y/Ho, Zr/Hf, Th/U and Nb/Ta ratios similar to the primitive-mantle values. The contents of chalcophile and high-field-strength elements are systematically low. On the basis of the available structural, petrographic and geochemical data, the examined rocks are interpreted as calcite carbonatites of postorogenic affinity. The Paint Lake carbonatites host a variety of REE minerals, including (in order of decreasing abundance): allanite, titanite, monazite and bastnäsite.

Introduction

Mapping of the Paint Lake area, located 20-40 km SSW of Thompson in central Manitoba, by Couëslan (2008), revealed the presence of variably textured carbonate rocks emplaced intrusively into metamorphic rocks of the circum-cratonic Superior Boundary Zone. Subsequent fieldwork showed that the carbonate rocks form a well-defined extensive linear feature striking at least 21 km through the central islands of Paint Lake. Two major carbonate units were identified: light-gray magnetite-phlogopite-olivine-bearing dolomitic (10a) and salmon-pink clinopyroxene-amphibole-bearing calcitic (10b); modally transitional rocks were not observed. The present report will focus on the key petrographic and geochemical characteristics of unit 10b and their petrologic interpretation.

Geological Setting

The Paint Lake area is underlain by a variety of Archean and Proterozoic rocks (predominantly, gneisses, amphibolites and pegmatites: Couëslan, 2008, 2009). The pink carbonate rocks occur as a swarm of dikes aligned generally parallel to the regional gneissosity with an overall trend of 040° and a steep dip. In outcrop, weathered surfaces of the dikes are recessed and characterized by a chalky, yellow-orange coating, but the colour of fresh rock is bright pink.

Individual bodies have a variable thickness along strike, which may locally reach 3 m. All dikes are characterized by metamorphic textures (cataclasis, polysynthetic twinning of calcite, bent phlogopite, foliation), but their modal composition is highly variable, ranging from anchimonomineralic zones of coarse-grained mosaic-textured calcite to fine-grained saccharoidal rocks with biotite-rich stringers to inequigranular foliated varieties enriched in silicate minerals and apatite. Contacts between the dikes and their host rocks are sharp, but irregular and commonly interrupted by apophyses and stoping structures. The exocontact gneiss and amphibolite show evidence of modal and cryptic metasomatism. Locally, the carbonate dikes cross-cut foliated pink granitic pegmatite, but in their turn, are cross-cut by massive pegmatite. This suggests a time of emplacement between 1785 and 1725 Ma.

Petrography and mineralogy

The dikes consist predominantly of calcite and contain subordinate amounts of (in order of decreasing abundance) amphibole, diopside, biotite, apatite, titanite, scapolite, allanite, barite, magnetite and sulfides. Anhedronal xenocrysts of quartz, feldspars and alkali-poor calcic amphiboles are also common. Calcite grains range from 50 μm to 3 cm in size; in contrast to the saccharoidal calcite, larger grains are strongly deformed, aligned with the foliation and contain abundant primary micro-inclusions of celestine and Sr-rich anhydrite, whose identity was confirmed by Raman spectroscopy. The calcite shows some variation in Mg and Fe contents (ca. 0.3-0.8 wt.% oxides) at generally low levels of Mn (< 0.3 wt.% MnO). Analysis by laser-ablation inductively-coupled-plasma mass-spectrometry shows that both morphological varieties of calcite are characteristically enriched in Sr, Y and rare-earth elements (REE = La...Lu), i.e. ~4000 ppm Sr, 100 ppm Y and $n \times 10^2$ ppm REE. The amphibole-group minerals cover a wide range of compositions from actinolite to magnesiohornblende to edenite to magnesiohastingsite. Most amphibole crystals are probably xenocrysts derived from the wall-rock amphibolites and gneisses, but reaction rims of magnesiohornblende on resorbed diopside crystals can be unambiguously identified as primary. Phlogopite is common in stringers of saccharoidal calcite in foliated rocks and shows relatively little variation in composition (mg# 0.65–0.74, 14.3–14.6 wt. % Al_2O_3 , ~2.0 wt. % TiO_2).

Allanite is the principal REE host in all textural types of the rock. The mineral exhibits irregular zoning reflecting variations in the distribution of REE, Ca, Al and Fe; marginal zones are enriched in REE relative to the core (up to 21.5 wt.% and 16.6-18.0 wt.% REE_2O_3 , respectively). In some samples, allanite is associated with REE-bearing titanite (1.1-4.7 wt.% REE_2O_3) and small crystals of bastnäsite (REECO_3F) and monazite (REEPO_4).

Geochemistry

The major-element composition of pink carbonate rocks is highly variable (6.0-24.6 wt.% SiO_2 ; 1.8-5.9 wt.% MgO ; 38.2-48.9 wt.% CaO), as can be expected from the observed modal variations, whereas their trace-element composition shows a number of consistent trends, including: (1) low levels of compatible and chalcophile elements; (2) elevated levels of incompatible elements and, in particular, Sr (3120-3930 ppm) and REE (540-2170 ppm); (3) enrichment in light REE over heavy REE [$(\text{La}/\text{Yb})_{\text{CN}} = 12-54$]; (4) low abundances of high-field-strength elements (Ti, Zr, Hf, Nb and Ta) and K relative to other incompatible elements; (5) mantle-like Y/Ho, Zr/Hf, Th/U and Nb/Ta ratios (on average, 28, 34, 3.2 and 22, respectively); (6) high Rb/K and Ga/Al ratios exceeding the primitive-mantle values (on average, 0.022 and 0.0015, respectively).

The carbon-oxygen isotopic compositions of calcite from coarse- and fine-grained samples overlap and span a wide range of $\delta^{18}\text{O}_{\text{SMOW}}$ and $\delta^{13}\text{C}_{\text{PDB}}$ values (7.8 to 9.1 and -4.3 to -7.8‰, respectively). However, all measured data plot in the field of primary igneous carbonate (Taylor et al., 1967).

Discussion and conclusions

Distinguishing between carbonatites and texturally similar metamorphic rocks is not straightforward, even in cases where the intrusive mode of emplacement can be established beyond doubt. Ductile flow of non-igneous carbonate rocks in the presence of pressure gradient obliterates primary textures, facilitates fluid-rock interaction and produces intrusive bodies that can be mistaken for carbonatites. Unambiguous identification of carbonatites in the field is not feasible and requires a follow-up multi-analytical study focusing on the trace-element and isotopic composition of the rock and its constituent minerals. On the basis of the available field, mineralogical and geochemical evidence, the examined carbonate rocks from Paint Lake can be identified as intrusive calcite carbonatites emplaced in a post-orogenic setting and tectonically remobilized after the peak metamorphism (cf. Chakhmouradian et al., 2008a). The trace-element and isotopic data indicate that the Paint Lake carbonatites retained their mantle-derived geochemical signature; there is no evidence to suggest re-equilibration of these rocks with crustal fluids. Further mapping in the north-western part of the Superior craton is required to establish if carbonatite magmatism was a wide-spread event postdating the Hudsonian orogeny. Preliminary examination of the grey silicate-carbonate rocks (unit 10a) showed their extreme textural, modal and compositional variability. Their detailed isotopic geochemical study is required to rule out a metasedimentary origin and establish their petrogenetic relation to unit 10b.

Potential implications of the present work extend beyond the task of providing accurate tectonic interpretation of the Superior Boundary Zone in the Paleoproterozoic. Carbonatites are economically important igneous rocks associated with the largest known REE ore deposits. For example, carbonatites of the Himalayan collision zone host some of the largest REE deposits in China, including Maoniuping and Dalucao (Xu et al., 2008). Recently, potential carbonatites have also been recognized at Cinder Lake some 200 km ESE of Paint Lake toward the interior of the Superior craton (Chakhmouradian et al., 2008b). Both localities host REE mineralization and are situated in what can be interpreted as a paleocontinental margin. It is important to note that carbonatites had not been known in this part of the Canadian Shield prior to our work and, hence, there had been no exploration activity targeting REE or any other carbonatite-related resources in the Province. The present report expands our understanding of the distribution and emplacement styles of Manitoba carbonatites, showing that the Superior Boundary Zone was a setting favourable to the emplacement of carbonatites with a post-orogenic REE-enriched geochemical signature, i.e. similar to those found in the Himalayan collision zone in China.

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