



Geology and mineralogy of the Ashram Zone carbonatite, Eldor Complex, Québec



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ABSTRACT

The Ashram Zone, which is host to the Ashram Rare Earth Element (REE) Deposit, occurs within the Eldor Carbonatite Complex, Québec, Canada. The complex is located within the Paleoproterozoic New Québec Orogen (Labrador Trough), and has been subjected to greenschist metamorphism and folding during the Hudsonian Orogeny at 1.75 Ga. To date, consanguineous undersaturated alkaline rocks have not been recognized within or adjacent to the complex. It is evident that the bulk compositions of the rocks, essentially magnesio-carbonatites and ferrocarbonatites, do not represent those of liquid compositions, as many are complex breccias which have been subjected to later hydrothermal activity. The Ashram Zone is dominated by diverse textural varieties of carbonatite which include: fluorite-rich schlieren carbonatites; coarse-to-medium grained granular carbonatites; fine grained, commonly mosaic-textured, quartz-bearing carbonatites; and colloform carbonatites. Compositional and textural data are provided for the minerals present in the carbonatites. The major rock-forming minerals are diverse Ca-Mg-Fe carbonates, fluorite, and quartz. The carbonates range in their compositional evolution from rare dolomite through ferrodolomite and magnesian siderite to siderite. The principal REE-bearing minerals of the Ashram Deposit are monazite-(Ce) and monazite-(Nd), with lesser amounts of bastnaesite-(Ce) and bastnaesite-(Nd). The minor and accessory mineral suite is characterized by the presence of apatite, phlogopite, xenotime, diverse Sc- and Sn-bearing Nb-Ti-minerals (niobian rutile, nioboeschynite, samarskite), barite, sphalerite, several uncommon, but here relatively abundant, Ba- and Ba-Be minerals (bafertsite, magbasite, barylite, betrandite, sanbornite, cebaite), yangzhumingite, cassiterite, galena, pyrite, and rare magnetite and potassium feldspar. Pyrochlore is absent and the Nb-Ti oxide assemblage is similar to that found in NYF-pegmatites associated with F-rich, A-type granitoids. The mineralogy of the Ashram Deposit, compared to that of other carbonatites associated with undersaturated silicate rocks is unique, especially with respect to the abundance of fluorite and monazite (commonly with Nd-enrichment), Ba-Be-enrichment, the NYF-type Nb-Ti oxide assemblage (especially xenotime, Y-Nb-aeschynite, samarskite), phlogopite-potassium feldspar quartz-rich residua with granitoid characteristics, paucity of magnetite, pyrochlore, and Sr-bearing carbonates. The Ashram Deposit is considered to be a late-magmatic-to-hydrothermal F-REE magnesio-to-ferrocarbonatite derived from as yet unknown consanguineous antecedents.

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1. Introduction

1.1. Scope of this investigation

The principal objective of this study is to introduce the geological community to the major geological and mineralogical characteristics of the Ashram Zone, which is host to the Ashram Rare Earth Element (REE) Deposit, located within the Eldor Carbonatite

Complex, Québec, Canada. The Ashram Zone also includes the BD-Zone carbonatites and diverse phlogopite dolomite carbonatites marginal to the main resource. In this work we use a mineralogical-genetic classification to assess the character of this rare earth occurrence and consider relationships to possible parental magma types. The paper presents data gathered during preliminary investigations of the Ashram Zone and does **not** attempt to provide a comprehensive geological or genetic model as such requires significant further geological, mineralogical, and geochemical studies.

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1.2. Carbonatite nomenclature and mineralogical-genetic classifications

Carbonatites are defined in the IUGS system of classification as igneous rocks composed of more than 50 vol.% primary, i.e. magmatic carbonates, and less than 20 wt.% SiO₂ (Le Maitre, 2002). Varieties of intrusive carbonatite can be named on the basis of their bulk composition (Woolley and Kemp, 1989) as calcio- or calcite carbonatites, magnesiocarbonatites, ferrocarnatites and silicocarbonatites. The IUGS system of nomenclature is non-genetic, thus modally similar, but genetically different, rocks can be given the same name, leading in many instances to incorrect genetic interpretations. Recognizing the deficiencies of the IUGS system for diverse alkaline rocks and carbonatites, Mitchell (2005a) and Mitchell and Bergman (1991) have proposed mineralogical-genetic classifications for alkaline rocks which are based upon the principle that a spectrum of modally diverse rocks can be derived from a single magma type. Such rocks can be recognized by the presence of a typomorphic or characteristic assemblage of major, minor, and accessory minerals. Note that *all* minerals are considered to be of importance in this type of classification and not just the major modal mineral assemblage. In mineralogical-genetic classifications it is *not* necessary to know the origins of a particular magma type.

Mitchell (2005a, 2015) has defined carbonatites (*sensu lato*) as any rock containing greater than an arbitrary 30 vol.% primary igneous carbonate *regardless* of silica content. The objective of this definition is to recognize that any carbonatite-forming magma will, by differentiation, generate a suite of genetically-related rocks in which the carbonate and other minerals (pyroxenes, magnetite, olivine, perovskite, etc.) content varies significantly. Thus, a given carbonatite complex can be considered as package of rocks that are modally diverse but have a common magmatic origin.

The term *carbonatite* can be used as a name for a specific rock type which depending on the mineralogy can be described by varietal names which might, or might not be, synonymous with the Woolley and Kemp (1989) bulk rock classification nomenclature. For example, with relevance to the Ashram carbonatites, a rock whose modal mineralogy is dominated by magnesian siderite-siderite solutions can be termed a siderite carbonatite in a mineralogical-genetic classification scheme or a ferrocarnatite on the basis of bulk composition. However, note that it is the actual mineralogy which determines the bulk composition and not vice versa, as most plutonic/intrusive carbonatites in alkaline rock-carbonatite complexes do not in their bulk compositions represent liquid compositions (Mitchell, 2005a, b). Many carbonatites are actually cumulate rocks and/or have been subjected to post-magmatic hydrothermal alteration, and in some instances supergene processes (Mitchell, 2005a, 2015; Chakhmouradian et al., 2016).

Mitchell (2005a, 2015) has recognized the value of mineralogical-genetic classifications in classifications of potential Nb, phosphate, and REE deposits, and noted that it is important to distinguish, for example, between carbonatites derived from nephelinitic versus melilititic magmas as differentiation of each magma type leads to a specific type of Nb and REE deposit.

2. Location and geology

2.1. Regional geology

The Eldor Carbonatite Complex, also known as the Le Moyne intrusion, is located in the Province of Québec, approximately 130 south of the community of Kuujuaq. The centre of the complex is at longitude 68°24'0" west and latitude 56°57'0" north

(Fig. 1). The complex was discovered in 1981 during a regional survey by Eldor Resources Ltd., and has subsequently been investigated by Unocal Canada Ltd., Molycorp Inc., Virginia Mines Inc., and is currently held by Commerce Resources Corp. The primary targets for exploration are Nb-Ta and rare earth element (REE) mineralization although, in addition, the property has a defined fluorine resource (i.e. fluorite), as part of the Ashram Deposit, as well as having potential for phosphate resources. The Ashram Deposit, located near the centre of the complex, is important with regard to its potential as a source for critical metals as the main ore mineral is monazite which is commonly enriched in Nd, and by the presence of accessory xenotime, enriched in Dy and Tb.

The Eldor Complex is located within the Paleoproterozoic New Québec Orogen (Labrador Trough), a group of supracrustal rocks which forms a boundary between two lithotectonic domains (Fig. 1). To the east is the South East Churchill Province and to the west the Superior Province. The New Québec Orogen is considered to be an Apehian fold and thrust belt with ages ranging from 2.17 to 1.77 Ga (Machado et al., 1997; Clarke and Wares, 2006). The New Québec Orogen consists of three cycles of sedimentation and volcanism, forming the Kaniupiskau Supergroup (Clark and Wares, 2006). The depositional sequences thicken eastwards and are separated by erosional unconformities. In the development of the New Québec Orogen the Superior Province formed a rigid buttress towards which the supracrustal rocks were thrust during the Hudsonian orogeny. The belt is subdivided into eleven lithotectonic zones separated by major thrust faults (Clarke and Wares, 2006).

The first two cycles are volcano-sedimentary rocks with emplacement U-Pb ages of 2.17–2.14 Ga and 1.88–1.87 Ga, respectively. The first cycle was initiated by continental rifting, followed by passive continental margin development, marine platform and shallow basin sedimentation, additional rifting, and finally the re-establishment of the platform. Cycle 2 is characterized by a transgressive sequence of platform sandstones, iron formations and turbidites (sandstones and mudstones), mafic volcanic rocks of the Hellancourt Formation (1874 ± 3 Ma), and mafic-felsic volcanics (1870 ± 4 Ma) of the Lac Douay belt (Machado et al., 1997). Although no age determinations of the Eldor Carbonatite Complex are available, it is considered to have been emplaced near the end of the second cycle within basaltic-to-rhyolitic volcanic rocks of the Doublet and Le Moyne Groups (Machado et al., 1997; Clarke and Wares, 2006). Cycle 3 is a *syn*-orogenic suite of molasse-type sandstones and conglomerates rocks deposited between 1.82 and 1.77 Ga at the margin of the Superior Province.

The Eldor Carbonatite Complex has undergone greenschist facies metamorphism and was deformed, together with the surrounding rocks, during the Hudsonian Orogeny at 1.75 Ga.

Metamorphic grade increases from west-to-east across the New Québec Orogen. The foreland changes from sub-greenschist to upper greenschist facies, and the hinterland from upper greenschist to amphibolite/granulite facies.

2.2. Eldor Complex

The Eldor Complex is situated near the eastern margin of the New Québec Orogen, (Fig. 2). The carbonatites are emplaced within Cycle 2 rocks of the New Québec Orogen. These are the older Doublet Group (mafic pyroclastics, basalts, gabbros, dolomites), and a younger Le Moyne Group. The latter consists of an older sequence of rhyolites, rhyodacites, felsic tuffs, dolomites, shales, and pelites of the Lac Douay Formation, and detrital sediments (conglomerates, dolomitic tuffs) of the Aulneau Formation. The complex is elliptical in shape (c. 8 × 4 km) and the margins are sub-parallel to the prevailing strike of the country rocks (Fig. 2). The eastern margin of the complex has not been adequately delineated but

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