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A new interpretation of the structure of the Sept Iles Intrusive suite, Canada

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Abstract

The layered mafic intrusion at Sept Iles, Canada, is one of the largest intrusions in the world. A new interpretation of its structure is proposed, based on a review of its geology and a comparison with the Skaergaard intrusion, Greenland. Several different magmatic components are recognized; hence the name Sept Iles Intrusive suite (SIIS) is proposed. Emplacement of the suite may have been preceded by eruption of flood basalts. The first magmas of the suite rose in the crust to accumulate beneath the density filter afforded by the basalts. The largest component is the Sept Iles Mafic intrusion (SIMI). The Lower series of the SIMI is dominated by leucotroctolites and leucogabbros. Above it lie the Layered series, which is largely comprised of gabbro and troctolite. Both these units are unchanged from earlier interpretations. The anorthosites (s.l.), gabbros and monzogabbros, formerly called the Transitional series, are now considered to be the Upper Border series, developed by floatation of plagioclase. Common autoliths in the Layered series are parts of the hydrothermally altered Upper Border series from towards the interior of the intrusion, which have foundered and settled through the magma. The contamination of the magma that accompanied this event oxidised iron in the magma and led to the precipitation of magnetite around the periphery of the intrusion. The subsequent depletion of Fe^{3+} and/or increase in SiO_2, CaO and P_2O_5 may have induced apatite saturation and accumulation to form two layers rich in apatite, near the base and at top of the Layered series. Granitic magma was developed by fractional crystallisation and was emplaced along the roof of the chamber, where it acquired large quantities of xenoliths. These were probably derived from the flood basalts, their evolved members and fragments of mafic dykes chilled by the granitic magma. Accumulations of monzonite pillows in this unit testify to another magmatic event and a floor to the granitic magma chamber, indicating lateral transport of magma. Chemically distinct syenites in the upper part of the intrusion are part of the Point du Criade intrusion, a large, late composite sill. Diabase and leucogabbro components show a close link with the SIMI and all the acidic magmas may have originally formed by differentiation of the main magma in cupolas towards the centre of the intrusion. A series of late gabbro intrusions that cut the SIMI may represent a rejuvenation of magmatism. The Border zone is a mass of fine-grained rocks that occurs along the border of the SIMI: it may be another magmatic component, or just the lateral border series of the SIMI.

Keywords: Layered mafic intrusion; Plagioclase floatation; Fe–Ti oxides; Apatite; Anorthosite; Skaergaard

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1. Introduction

The shape and internal structure of major layered mafic intrusions are generally poorly known, not just through lack of research, but because they have commonly been deformed, dissected and partly buried deeper by later events (Cawthorn, 1996). Both the Stillwater intrusion, USA, and the Bushveld intrusion, South Africa, are such fragments of larger intrusions. It is only in the smaller intrusions that we may see all, or most, of the components: the roof, walls, floor and core. The best-known small mafic intrusion is the Skaergaard intrusion, Greenland (Wager and Brown, 1968). This young intrusion has never been deeply buried and is very well exposed in an area of considerable relief. Hence, all parts of the intrusion have been examined intensely by petrologists during the last 70 years. Although the Skaergaard and Sept Iles intrusions differ greatly in size, they share many characteristics. In this paper I use the clearly exposed structure of the Skaergaard intrusion to clarify many aspects of the structure of the Sept Iles intrusion.

The Sept Iles intrusion is recognised now as one of the largest layered mafic intrusions in the world (Higgins and Doig, 1986; Loncarevic et al., 1990), however, this was not always so. The early descriptions of the geology of the Sept Iles area emphasized the presence of the anorthosite and, indeed, the 'Sept Iles anorthosite complex' was considered to be a type example of an undeformed Proterozoic massif-type anorthosite complex (Wynne-Edwards, 1972). The intrusion was first mapped in detail by T. Ahmedali in the 1960s and although his data were never published, it showed that the intrusion was much more complex than previously thought. He distinguished a series of layered gabbros, overlain by anorthosite and finally syenite and granite (Fig. 1). He also defined a series of late gabbros, which crop out principally on the eastern islands. This broad division was confirmed by the unpublished mapping of T. Feininger (Geological Survey of Canada) in 1985–1990.

Dating of parts of the intrusion by the Rb–Sr method (Higgins and Doig, 1977, 1981) showed that the intrusion was much younger than the ~1000 million year old surrounding Grenville province, with an age of about 540 million years old. Their most precise ages were based on isochrons from the granite and syenite. The ages were also confirmed by measurements on granitic and syenitic granophyre 'pods' in the anorthosites. The age of the intrusion, and its location, connected it with the St Lawrence rift system and the opening of the Iapetus Ocean (Kumarapeli and Saull, 1966).

Interest in the intrusion and the need for greater precision prompted redating of the intrusion by the U–Pb zircon method (Higgins and van Breemen, 1998). Zircon extracted from a granophyric pod in the layered gabbros, a unit not dated previously, gave an age of 564 ± 4 Ma. The difference between the U–Pb and Rb–Sr ages is not surprising, considering the errors associated with earlier dates. On the basis of this date, and the ages of other igneous rocks and uplift, Higgins and van Breemen (1998) proposed that the Sept Iles intrusion was associated with an important mantle plume (Sept Iles Mantle Plume).

The size of the Sept Iles intrusion is clearly indicated by gravity measurements. The gravity anomaly is about 80 km in diameter and has a maximum Bouguer anomaly of 80 mGal, making it the largest in eastern North America (Loncarevic et al., 1990). Detailed measurements of the density of surface samples suggested that the intrusion must have a hidden zone to account for the gravity anomaly (Loncarevic et al., 1990). However, more detailed measurements from sub-surface samples indicated a higher density, and hence removed the necessity for a hidden zone (Dion et al., 1998).

An important magnetic anomaly overlies the body. It comprises a narrow magnetic high that lies about 1 km in from the border of the intrusion and a series of three arcuate 1 km wide anomalies that lie in the northwest part of the intrusion (Fig. 1). The latter are associated with magnetite-rich layers at the surface (Cimon, 1998).

The size of the intrusion and its composition suggested that it might host nickel and platinum group deposits. To this end, two holes 2 and 2.5 km deep were drilled into the layered gabbros on the mainland. Metallic deposits were not found, but instead two important layers rich in apatite were intersected (Cimon, 1998). As a result, Cimon (1998) remapped the mainland part of the intrusion and made a detailed study of the mineral and rock chemistry of the whole intrusion, with extra detail on the apatite deposit itself.