Sm/Nd Geochronology of the Moyie Intrusions, Moyie Lake Map Area, British Columbia (82G/5)

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INTRODUCTION

Middle Proterozoic basaltic magmatism in the East Kootenay area marks a period of crustal instability in the Belt-Purcell basin. Uranium-lead dating of zircons from the Lumberton sill, north of Moyie Lake (Höy, 1988), gives a time of crystallization of 1445 ± 10 Ma. Zartman *et al.* (1982) reported a uranium-lead zircon age from the Crossport sill in Idaho of 1433 ± 13, a number within the analytical error of the age reported by Höy. The object of our program is to confirm these dates with a samarium-neodymium isochron. Samarium-neodymium analyses also provide data on the nature of the mantle at the time of intrusion and the evolution of the magma prior to crystallization.

The geochronology of the Purcell Supergroup has been the subject of study at the University of Alberta for many years. Potassium-argon dating of biotite and hornblende separates from the Moyie intrusions gave values ranging from 670 to 1580 Ma (Hunt, 1962). The wide spectrum was attributed to a combination of argon loss from biotite during Phanerozoic thermal events and excess argon incorporated into hornblende at the time of intrusion of the sills. A cluster of values near 1100 Ma was inferred to be the probable age of the sills.

In 1983, the authors sampled a sill within the Siyeh Formation at Lake Alderson in Waterton Park for rubidium-strontium dating. The data were inconclusive, with inferred limits of 1320 and 1665 Ma (Harrison, 1984). Assimilation of the country rock probably caused the scatter of data points.

Samarium-neodymium model ages for metasedimentary rocks of the Purcell Supergroup are close to 2.0 Ga (Frost and O'Nions, 1984). The underlying crystalline basement (Frost and Burwash, 1986) and overlying Windermere Supergroup (Burwash *et al.* 1988) give older samarium-neodymium model ages.

During the Lake Alderson fieldwork, a brief visit was made to sample the Lumberton sill. Preliminary isotopic analyses by Wagner in 1987 suggested that the range of $^{143}Nd/^{144}Nd$ ratios was sufficiently wide for a samarium-neodymium isochron to be attempted; the current study is the result.

FIELDWORK

A thick sill of Moyie metagabbro is exposed intermittently for almost half a kilometre in a series of railway cuts along British Columbia Highway 3, 18 kilometres south of the Cranbrook Canadian Pacific Railway station. Grain size and textural variations make this a regular stop on student field excursions, with samples also taken for teaching collections.

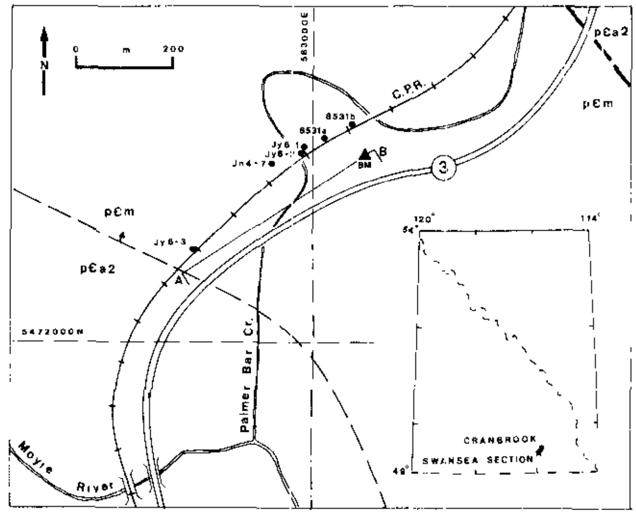

Figure 1-5-1. Location of samples used for Sm-Nd dating of Lumberton sill, Swansea section. Based on Energy, Mines and Resources Canada (1984) and Höy and Diakow (1982). BM is Bench Mark 85 CO 42; pC a2–Middle Aldridge, pC m–Moyie intrusions.

The presence of a felsic pegmatitic phase of the Moyie intrusion in these railway cuts led to resampling in 1983. The section was designated "Swansea section" from the abandoned railway siding 1.6 kilometres north of the base of the sill (Energy, Mines and Resources Canada, 1984; Höy and Diakow, 1982).

Fieldwork in 1988 was aimed primarily at finding a mafic-rich differentiated phase of the sill which could be used to extend the range of $^{147}Sm/^{144}Nd$ values away from the felsic pegmatites. To this end, particular attention was paid to the basal portions of the sill exposed on both sides of Palmer Bar Creek (Figure 1-5-1). Samples Jn 4-1 to Jn 4-7 are from outcrops outside the blasted railway cuts. Criteria for selection were that the rock showed limited fracturing and no visible weathering. Accurate estimation of mafic content proved difficult in the field due to variation in the degree of deuteric alteration of hornblende to epidote and chlorite. Thin-section studies subsequently indicated the presence of significant amounts of fine-grained biotite as well. From the outcrop and thin-section observation it was concluded that:

The samples which cluster close together in Figure 1-5-3 (8531a, 8531b and Jy 6-3) give model ages of 1.43, 1.44 and 1.45 Ga respectively. Their average value is concordant with the zircon date. The concept of neodymium-samarium model ages implies that these three analysed samples represent material derived from the mantle at 1.44 Ga. Furthermore, the source had a composition which had not been depleted in samarium and neodymium, but conformed to the CHUR model of mantle evolution. The E values near zero reflect a mantle which has not lost material to sialic crustal differentiates.

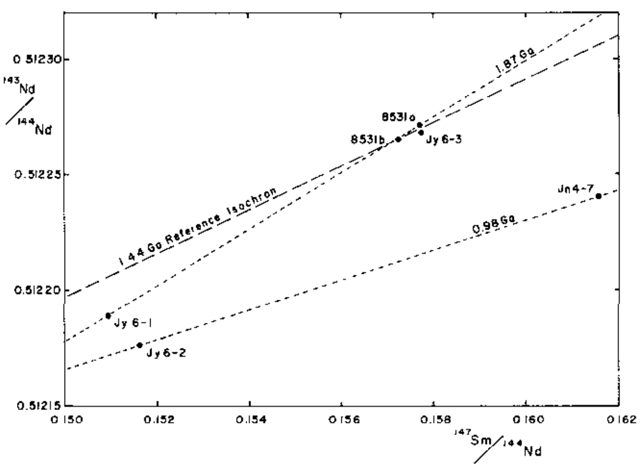

Figure 1-5-3. Sm-Nd analyses plotted on $^{143}Nd/^{144}Nd$ vs $^{147}Sm/^{144}Nd$. Four samples give an apparent age of 1.87 Ga. The two remaining samples lie on a 0.98 Ga line. A reference isochron through the clustered points suggests assimilation of country rock by magma for three samples below this line.

With respect to the cross-section of the sill (Figure 1-5-2), the three points which cluster on the isochron plot represent the two samples closest to the top of the sill and the sample closest to the base. When a reference isochron for 1.44 Ga is plotted through this cluster it is apparent that the three other points must have crystallized from melts with lower $^{143}Nd/^{144}Nd$ ratios or from the same melt with contamination. The T^{CHUR} values and small negative ϵ^{1440} CHUR values support assimilation of older crustal material.

When a pegmatitic phase was observed in the section of the Lumberton sill it was assumed that it represented a magmatic differentiate. This idea was strengthened by the abundance of granophyre in thin section. An anomaly is evident in Table 1-5-2: the two pegmatitic samples Jy 6-1 and Jy 6-2 have the highest neodymium and samarium contents. Normally felsic differentiates have lower contents of these elements than their parent magma as the rare earths are concentrated in the mafic minerals. This anomaly, coupled with the T^{CHUR} and ϵ^{1440} CHUR values seems to confirm that samples Jy 6-1 and Jy 6-2 are not differentiates but are the result of assimilation of older felsic material. The most obvious candidate is the siltstone of the enclosing Aldridge Formation. The augmented samarium and neodymium may be from the argillite units.

Interpretation of the petrogenesis of sample Jn 4-7 remains uncertain. Its neodymium and samarium bulk composition falls within the range of the samples with T^{CHUR} values near 1.44 Ga, yet it has a distinctly higher T^{CHUR} of 1.72 Ga. None of our field observations indicate a multiple rather than simple mode of intrusion for the Lumberton sill. If Jn 4-7, in fact, represents a separate injection of magma after the main body of the sill was in place, this late magma might have assimilated mafic material from the base of the crystalline basement ($T^{CHUR} \equiv 2.8$ Ga) during its assent. Much more work would be required to substantiate this hypothesis.

CONCLUSIONS

Samarium-neodymium model ages confirm the uranium-lead zircon date of the intrusion of the Lumberton sill at 1440 $\pm$ 10 Ma. The six samples analysed, representing the full range of textural, mineralogical and spatial variables in the sill, did not define a valid isochron. Three samples which cluster on the $^{143}Nd/^{144}Nd$ versus $^{147}Sm/^{144}Nd$ plot have almost identical model ages; 1.43, 1.44 and 1.45 Ga. Isotopically, they also represent a mantle source for this magma which had not been depleted in samarium and neodymium prior to 1440 Ma.

A lens of pegmatitic material, inferred from field observations to be a magmatic differentiate, is proved by isotopic data to be the result of assimilation of the enclosing strata. A single anomalous point, with a crustal residence age of 1.72 Ga, may be a late injection of melt which assimilated crystalline basement.

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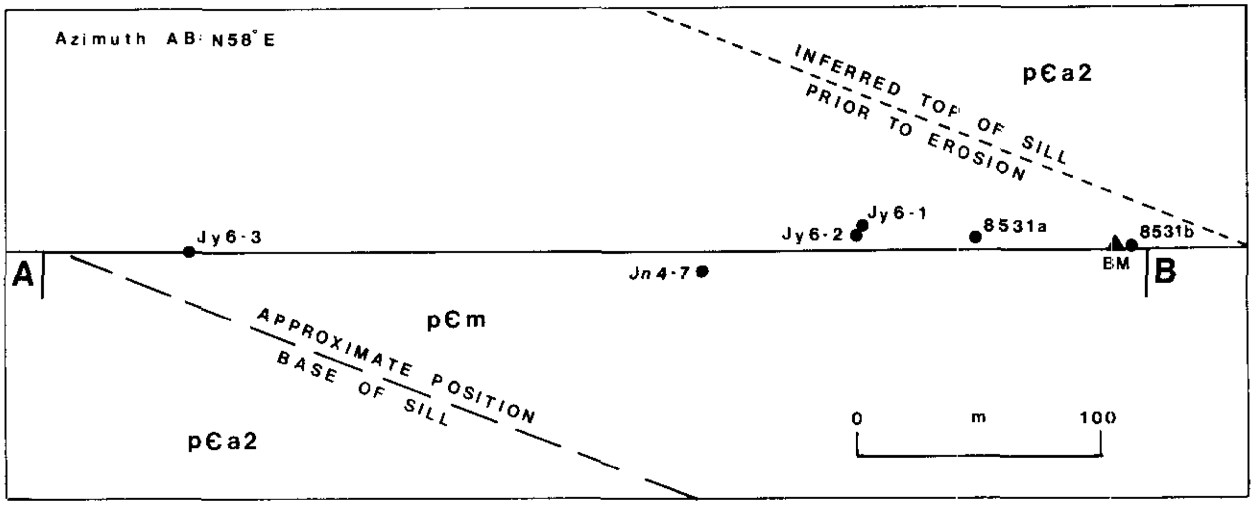

Figure 1-5-2. Cross-section of Swansea section of Lumberton sill ("D" sill of Höy and Daikow, 1982). Relative stratigraphic position of dated samples projected onto AB through Bench Mark 85 CO 42. C.P.R. 1 ne is datum.

(1) we had not succeeded in finding a mafic differentiate formed by gravitational settling, analogous to that in the Palisade sill, New Jersey (Walker, 1940).

(2) the samples from near the base of the sill showed evidence of assimilation of argillite from the enclosing Aldridge Formation, expressed by increased biotite content.

Sample Jn 4-7 was collected from the topographic depression below the railway embankment and corresponded closely to the mid-point of the sill section (Figure 1-5-2). In subsequent thin-section studies of samples from the Swansea section, it showed the least evidence of deuteric alteration and was therefore added to the suite for samarium-neodymium analysis. Brief petrographic data for the dated samples shown on the cross-section of the sill (Figure 1-5-2) are given in Table 1-5-1.

ANALYTICAL METHODS

Hand specimens were cleaned, crushed and pulverized to -200 mesh. One gram splits were tumbled for 24 hours and divided into two fractions, one for $^{144}Nd/^{143}Nd$ initial isotopic ratio (IR) measurement and the other for the determination of the samarium and neodymium concentrations (ID).

IR samples were decomposed according to the method used by Wagner (1982) and the ID samples using standard teflon bomb techniques. Samarium and neodymiun separation, isolation and purification was accomplished using a modified version of the process used by DePaolo (1978).

Individual rare-earths were converted to perchlorate form, dissolved in water and loaded onto the side filament of a double Rhenium filament assembly and analysed in a fully automated Aldermaston VG 354 mass spectrometer operating in a multi-collection configuration. Data are presented in Table 1-5-2.

INTERPRETATION

Data in Table 1-5-2 show the isotopic ratios of $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ are confined to a limited range, despite a moderate range in total neodymium and samarium concentrations. The attempt to define an isochron failed, mainly because of the limited ranges of isotopic ratios, but also because of the scatter of points (Figure 1-5-3). A best-fit line through three points gives 1.87 Ga, a value which does not agree with the uranium-lead zircon discordia date.

The scatter of points is well beyond analytical error and must reflect some geologic factors. Clues to these are evident in the model ages (T^{CHUR}) and values of E^{CHUR} calculated for a time of 1440 Ma. The value of 1440 Ma is chosen to accommodate the data of Zartman *et al.* (1982) as well as that of Höy (1988).

TABLE 1-5-1
LITHOLOGY OF ANALYSED SAMPLES

Sample Number	Height Above Base of Sill	Texture	Grain Size (average)	Colour Index
Jy 6-3	20 m	Diabasic	1.5 mm	65
Jn 4-7	90	Diabasic	1	55
Jy 6-2	125	Pegmatitic	4	35
Jy 6-1	130	Pegmatitic	6	35
8531a	140	Diabasic	3	50
8531b	160	Diabasic	1	55

TABLE 1-5-2
ISOTOPIC ANALYTICAL DATA

Sample I.D.	$^{143}Nd/^{144}Nd^{a}$	$^{147}Sm/^{144}Nd^{a}$	Nd ppm	Sm ppm	CHUR^{b}	CHUR^{b}
RAB 83Jy6-1	0.512188	0.150941	19.508	4.8761	1.50	−0.41
RAB 83Jy6-2	0.512176	0.151610	30.212	7.5849	1.56	−0.77
RAB 83Jy6-3	0.512268	0.157745	7.1469	1.8669	1.45	−0.10
UA 8531a	0.512271	0.157718	9.4267	2.4620	1.43	−0.11
UA 8531b	0.512265	0.157246	8.1590	2.1246	1.44	−0.06
RAB 88Jn4-7	0.512240	0.161559	7.5500	2.0199	1.72	−0.34

a: Ratios are normalized to $^{146}Nd/^{144}Nd = 0.7219$: estimated error in $^{143}Nd/^{144}Nd \pm .000012$ (2); ir $^{147}Sm/^{144}Nd \pm .00008$ (2).

b: Bulk Earth parameters used for calculation are: $^{143}Nd/^{144}Nd_{chur}(0) = 0.512638$; $^{147}Sm/^{144}Nd_{chur} = 0.1967$. References for methods of calculation are given by Burwash *et al.*, 1985.

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