

GEOCHEMISTRY OF GRANITOID ROCKS FROM THE WESTERN SUPERIOR PROVINCE - EVIDENCE FOR 2- AND 3-STAGE CRUSTAL EVOLUTION MODELS; G.P. Beakhouse, Precambrian Geology Section, Ontario Geological Survey, 77 Grenville St. 64910643
Toronto, Ontario, M5S 1B3, Canada and R.H. McNutt, Department of Geology, McMaster University, Hamilton, Ontario, L8S 4M1, Canada.

MQ205386

The Superior Province is divisible into subprovinces that can be classified as greenstone-tonalite, paragneiss or batholithic terranes and are distinguished by differences in lithologic proportions, metamorphic grade and structural style [1]. This paper discusses the origin and significance of contrasting geochemical characteristics of plutonic rocks from the Winnipeg River subprovince (a batholithic terrane) and the Wabigoon subprovince (a greenstone-tonalite terrane).

In the western Wabigoon subprovince well preserved, low- to medium metamorphic grade supracrustal sequences, in which metavolcanic rocks predominate over metasedimentary rocks, are deformed into arcuate belts which wrap around elliptical granitoid batholiths [2]. This volcanism and plutonism took place over a restricted time interval between 2700 and 2750 Ma [3, 4, 5]. The batholiths are composite, consisting of; 1) foliated to gneissic, tonalitic to granodioritic diapirs and 2) later, massive to foliated dioritic to granitic plutons [6].

The Aulneau batholith was selected as an example of a greenstone-tonalite terrane batholith. Ziehlke [7] recognizes 19 phases which can be broadly grouped in order of decreasing relative age as early migmatitic phases, hornblenditic and/or biotitic foliated phases and late massive phases. Tonalitic to granodioritic compositions predominate and there is a general trend of decreasing colour index and increasing microcline abundance with decreasing relative age [7]. The Aulneau batholith displays limited chemical heterogeneity reflecting relatively uniform mineralogy. Noteworthy geochemical characteristics include (averages in brackets); high Na_2O (5.4%), Sr (690 ppm) and low K_2O (1.6%), Rb (54 ppm), Ce (26 ppm), La (14 ppm) and Y (2 to 3 ppm). These characteristics are typical of Early Precambrian tonalites [8] and have been widely interpreted to reflect an origin involving partial melting of tholeiitic basalt at mantle or lower crustal depths [8, 9, 10, 11, 12].

The Winnipeg River batholithic terrane is underlain principally by variously deformed and recrystallized plutonic rocks including: 1) pre-tectonic, heterogeneous gneissic complexes, 2) pre- to syn-tectonic sodic plutons and 3) syn- to post-tectonic potassic plutons [13]. The gneissic complex and some of the sodic plutons range in age from 2830 Ma to 3168 Ma [14, 15, 16] and are significantly older than Wabigoon subprovince volcanism and plutonism. The potassic plutons range in age from 2660 to 2700 Ma [15]. Inclusions of supracrustal rocks are predominantly of volcanic origin and underlie less than 10 percent of the terrane but are widely distributed. Metamorphic grade is upper amphibolite to granulite facies and evidence of in situ partial melting is common in the supracrustal inclusions and gneissic complex.

The youngest regional tectonic deformation, involving the development of nappe-like structures and subsequent doming of tectonically thickened crust, occurred between 2710 and 2702 Ma [16].

Two distinct geochemical affinities are recognized within the plutonic rocks of the Winnipeg River subprovince. The heterogeneous gneissic complex and sodic plutons are predominantly of tonalitic composition; they are

characterized by low LIL element abundances, depleted HREE and low initial Sr isotopic composition and are interpreted to be the product of 10 percent melting of a mafic garnet granulite of tholeiitic basalt composition [17, 18]. Potassic plutons range in composition from granodiorite to granite and are more geochemically evolved than the tonalitic rocks. For example, compared to the Aulneau batholith, the Lount Lake potassic batholith has higher K_2O (3.8%), Rb (116 ppm), Ce (53 ppm), La (53 ppm) and Y (11 ppm) and lower Na_2O (4.3%) and Sr (415 ppm). Other potassic plutons in the Winnipeg River belt (e.g. the Lac du Bonnet pluton [19]) are even more geochemically evolved. The initial Sr isotopic composition of granodioritic phases from the Lount Lake batholith range from .7022 to .7044 [15]. The following suggest potassic plutons are derived from the partial melting of the earlier tonalites:

- 1) LIL element mass balance requirements are consistent with derivation of the potassic plutons by partial (<50%) melting of tonalite. A tholeiitic basalt source would require unrealistically low degrees of partial melting (1-2%).
- 2) Y abundance in potassic plutons is highly variable but in general they are comparable to or greater than abundances in potential source rocks suggesting that it is unlikely that significant garnet or amphibole was retained in the source material. Felsic rocks are more likely to satisfy this requirement than mafic rocks.
- 3) The initial Sr isotope ratios of the potassic plutons are similar to those expected in the older tonalites at the time of potassic plutonism [15] and are more radiogenic than would be expected for 3.0 to 3.2 Ga tholeiitic basalt [20].
- 4) Pods of in situ melt rocks observed in the older tonalites have geochemical characteristics that resemble those of the potassic plutons.

The geochemical diversity of the Winnipeg River terrane can be interpreted in terms of a 3-stage magma evolution model, the first two stages of which are identical to that proposed for greenstone-tonalite terranes.

Stage I - Partial melting of the mantle to produce tholeiitic basalt

Stage II - Partial melting of tholeiitic basalt to produce magmas of tonalitic affinity.

Stage III - Partial melting of the bi-modal assemblage formed in stages I and II to produce the potassic plutons.

Possible implications of this model include: 1) The paucity of potassic plutons suggests that a Winnipeg River type basement complex is thin or absent beneath the Wabigoon subprovince. 2) The lower crust beneath the Winnipeg River and Wabigoon terranes may be different with the former being depleted as well as dehydrated. 3) Sialic microcontinents, parts of which are as old as 3.0-3.2 Ga, were present in the Superior province prior to widespread volcanism and plutonism which took place between 2700 and 2800 Ma.

Synchronous (2710-2700 Ma) cessation of volcanism in the Wabigoon subprovince and tectonic thickening and initiation of extensive crustal anatexis in the Winnipeg River subprovince suggests that the late history of these terranes is related. This is interpreted within a plate tectonic model to reflect the docking of a volcanic arc (Wabigoon subprovince) against a craton lying to the north of it. This led to the cessation of subduction and volcanism in the Wabigoon subprovince and tectonic thickening in the Winnipeg River subprovince with the latter resulting in extensive crustal anatexis that generated the potassic plutons. Local unconformable

relationships along the Wabigoon-Winnipeg River interface are a consequence of late sequences within the Wabigoon lapping on to the Winnipeg River terrane prior to and during collision.

References

- [1] Beakhouse, G.P., 1985. The relationship of supracrustal sequences to a basement complex in the western English River subprovince. In, Ayres, L.D. Thurston, P.C., Card, K.D. and Weber, W., eds.: Evolution of Archean supracrustal sequences, Geological Association of Canada, Special Paper 28.
- [2] Blackburn, C.E., 1981. Kenora-Fort Frances sheet. Ontario Geological Survey, Geological Compilation Series, Map 2443, scale 1:253,440.
- [3] Davis, D.W. and Trowell, N.F., 1982. U-Pb zircon ages from the eastern Savant Lake - Crow Lake metavolcanic-metasedimentary belt, northwest Ontario: Canadian Journal of Earth Sciences, 19, p.868-877.
- [4] Davis, D.W. and Edwards, G.R., 1982. Zircon U-Pb ages from the Kakagi Lake area, Wabigoon subprovince, northwestern Ontario: Canadian Journal of Earth Sciences, 19, p.1235-1245.
- [5] Davis, D.W., Blackburn, C.E. and Krogh, T.E., 1982. Zircon U-Pb ages from the Wabigoon-Manitou Lakes region, Wabigoon subprovince, northwest Ontario: Canadian Journal of Earth Sciences, 19, 254-266.
- [6] Schwerdtner, W.M., Stone, D., Osadetz, K., Morgan, J. and Stott, G.M., 1979. Granitoid complexes and the Archean tectonic record in the southern part of northwestern Ontario. Canadian Journal of Earth Science, 16, 1965-1977.
- [7] Ziehlke, D.V., 1974. Aulneau batholith project: Geology and Petrology. University of Manitoba, Centre for Precambrian Studies, 1974 Annual Report, p.150-184.
- [8] Glikson, A.Y., 1979. Early Precambrian tonalite-trondhjemite sialic nuclei: Earth Science Reviews, 15, 1-73.
- [9] Hanson, G.W. and Goldich, S.S., 1972. Early Precambrian rocks of the Saganaga Lake-Northern Light Lake area, Minnesota-Ontario. Part II: Petrogenesis. Geological Society of America Memoir 135, 179-192.
- [10] Arth, J.G. and Hanson, G.N., 1972. Quartz diorites derived by partial melting of eclogite or amphibolite at mantle depths: Contributions to Mineralogy and Petrology, 37, p.161-174.
- [11] Arth, J.G. and Hanson, G.N., 1975. Geochemistry and origin of the early Precambrian crust of northeastern Minnesota: Geochimica et Cosmochimica Acta, 39, p.325-362.
- [12] Condie, K.C. and Hunter, D.R., 1976. Trace element geochemistry of Archean granitic rocks from the Barberton region, South Africa: Earth and Planetary Science Letters, 29, 389-400.
- [13] Breaks, F.W., Bond, W.D. and Stone, D., 1978. Preliminary geological synthesis of the English River Subprovince, northwestern Ontario and its bearing upon mineral exploration: Ontario Geological Survey, Miscellaneous Paper 72, 55p.
- [14] Krogh, T.E., Harris, N.B.W. and Davis, G.L., 1976a. Archean rocks from the eastern Lac Seul region of the English River gneiss belt, northwestern Ontario, part 2. Geochronology: Canadian Journal of Earth Sciences, 13, p.1212-1215.
- [15] Beakhouse, G.P., 1983. Geological, geochemical and Rb-Sr and U-Pb zircon geochronological investigations of granitoid rocks from the Winnipeg River belt, northwestern Ontario and southeastern Manitoba: unpublished Ph.D. thesis, McMaster University, Hamilton, Ontario.

- [16] Corfu, F., Beakhouse, G.P., Stott, G.M. and Sutcliffe, R.H., 1985. U-Pb geochronology and tectonic history of the Winnipeg River granitoid terrain, northwestern Ontario, abstract. 31st Annual Institute on Lake Superior Geology.
- [17] Gower, C.F., 1978. The tectonic and petrogenetic history of Archean rocks from the Kenora area, English River subprovince, northwest Ontario: unpublished Ph.D. thesis, McMaster University, Hamilton, Ontario, 622p.
- [18] Gower, C.F., Paul, D.K. and Crocket, J.H., 1982. Protoliths and petrogenesis of Archean gneisses from the Kenora area, English River subprovince, northwest Ontario. *Precambrian Research*, 17, 245-274.
- [19] Cerny, P., Trueman, D.L., Ziehlke, D.V., Goad, B.E. and Paul, B.J., 1981. The Cat Lake - Winnipeg River and Weskusko Lake pegmatite fields, Manitoba: Manitoba Department of Energy and Mines, Mineral Resources Division, Economic Geology Report ER 80-1, 216p.
- [20] Peterman, Z.E., 1979. Strontium isotope geochemistry of late Archean to late Cretaceous tonalites and trondhjemites: in Barker, F., ed., *Trondhjemites, Dacites and Related Rocks*, Amsterdam, Elsevier, p.133-147.

This abstract is published with the permission of the Director of the Ontario Geological Survey.