Petrogenetic types, tectonic settings, and mineral potential of granitoids in southeastern Manitoba: evidence from reconnaissance mapping and geological sampling

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Abstract

In 2014, the Manitoba Geological Survey (MGS) initiated a project to investigate the petrogenesis and metallogeny of granitoid rocks in Manitoba. The objectives of this project are to identify the various petrogenetic types of granitoid rocks, and to investigate their geodynamic settings and mineralization potential. This project will result in a GIS-based database to capture the field relationships, petrography, lithogeochemistry and geochronology of granitoid rocks in Manitoba, and their relationships to Cu-Au-Mo, Sn-W and rare-metals mineralization.

The preliminary results of reconnaissance mapping and sampling of granitoid rocks conducted during the 2014 field season in the western Superior province of southeastern Manitoba is presented together wth some of key lithogeochemical characteristics. Granitoid rocks were examined and sampled in the field to document field relationships, textures (fabrics), mineral assemblages, magnetic susceptibilities (MS) and presence of mineralization and/or alteration. The major findings of this preliminary work are that muscovite- and/or garnet-bearing granitic rocks (i.e., strongly peraluminous S-type), commonly characterized by low MS values (<0.1 × 10-3 SI units) are intruded mainly into terrane boundaries, although they are also evidently present within metasediment-dominant areas, all of which are macro-recognizable geological criteria for subdividing tectonic units. These peraluminous granitoid rocks likely formed in thickened crustal setting(s) due to continental collision and are associated with rare-metal–enriched intrusions, or may have potential to host to Sn-W mineralization. In contrast, granitoid plutons, consisting dominantly of tonalite, trondhjemite and granodiorite (i.e., TTG suite) and characterized by higher MS values (>0.1 × 10-3 SI units) and mineral assemblages typical of I-type (e.g., amphibole ±biotite or biotite ±amphibole), are abundant across the region, suggesting that extensive granitoid magmatism greatly contributed to the continental crustal growth and expansion in the Archean, and may have been related to plate subduction. Some of the phases in the TTG suites contain porphyry Cu-Au (e.g., Cat Lake–Euclid Lake), shear-hosted Au (e.g., Little Bear Lake) and skarn Au-Ag mineralization (e.g., Cat Lake).

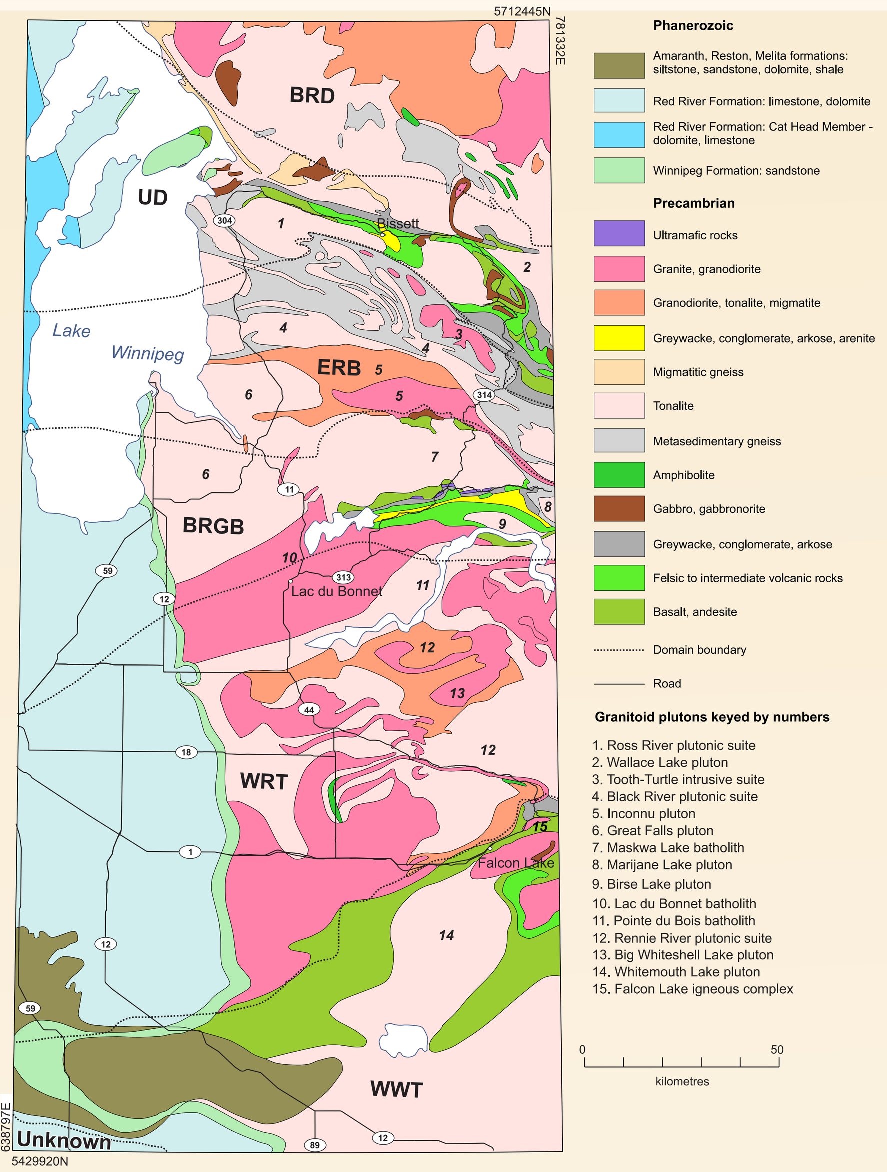

Fig. 1 Simplified geology of southeastern Manitoba, showing the dominance of granitoid rocks in the region. Abbreviations: BRD, Berens River domain; BRGB, Bird River greenstone belt; ERB, English River basin; UD, Uchi domain; WRT, Winnipeg River terrane; WWT, Western Wabigoon terrane. Numbered granitoid plutons or batholiths are referred to in the text. Nomenclature of tectonic entities or units modified from Percival et al. (2006), Gilbert et al. (2008) and Stott et al. (2010).

Petrogenetic types of granitoids

Classification of I- and S-type granites is based on their source rocks: I-type granites are derived from igneous sources, whereas S-type granites are sourced from sedimentary rocks (Chappell and White, 1974, 1992, 2001). Magnetite- and ilmenite-series granites are classified in terms of the abundance of Fe-Ti oxides that reflect redox conditions of granites. Magnetite-series granites contain appreciable amount of magnetite and ilmenite, while ilmenite-series granites contain ilmenite as dominant Fe-Ti oxides (Ishihara, 1977, 1981, 2004). The MGS would use these schemes in the study of granitoids in Manitoba.

Granitoids in the Uchi domain

The Uchi domain is characterized by I-type and magnatite-series granites in terms of mineral assemblages, magnatic susceptibility (MS), and lithogeochemical characteristics, although evolved I-type granites are evident and display the signature of ilmenite-series with low MS values (<0.1x10^{-3} SI). Fig. 2 shows some typical granitoids. Shear zone control, granite-hosted Au deposits occur in the Ross River pluton (e.g., Ogama-Rockland).

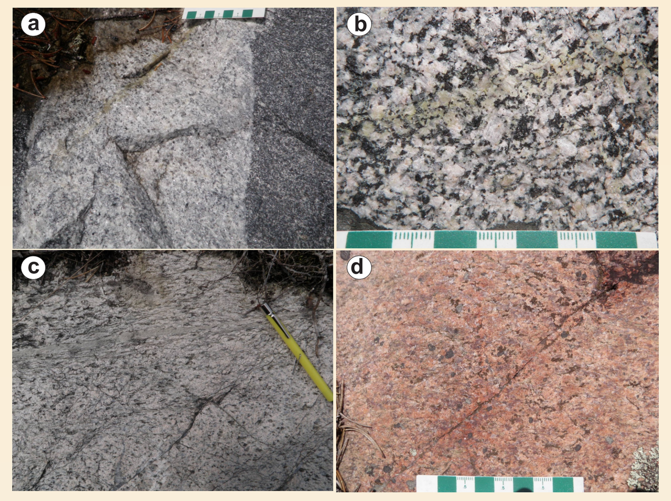

Fig. 2 Granitoids from the Uchi domain, southeastern Manitoba: a) medium grained granodiorite cuts fine to medium grained quartz diorite in the Ross River pluton; b) granodiorite with euhedral feldspar phenocrysts in the Ross River pluton; c) medium- to coarse-grained granodiorite in the western part of the Ross River plutonic suite, that is deformed and sheared with sinistral sense and cut by quartz veins; d) salmon-red, medium- to coarse-grained biotite granite in the Wallace Lake pluton.

Granitoid rocks in the English River basin

Coexistance of I- and S-type granites is a notable feature of the English River basin (Fig. 3), although the S-type granites with low MS values and muscovite and/or garnet are confined at the southern margin of the basin flanked to the Bird River greenstone belt to south.

Fig. 3 Granitoids from the English River basin: a) fine- to medium-grained weakly foliated biotite granite from the Tooth-Turtle intrusive suite; b) pinkish grey, medium- to coarse-grained, gneissic granodiorite cut by pegmatite dike from the Black River plutonic suite; c) grey, equigranular, medium grained tonalite (T) cut by pink massive coarse grained granite (G) from the Black River plutonic suite; d) weakly deformed, medium grained muscovite–biotite granodiorite in the Inconnu pluton II; e) grey gneissic tonalite cut massive granodiorite (GD) and pinkish pegmatite dike or vein; f) pink to red coarse grained leucogranite.

Granitoid rocks in the Bird River greenstone belt (BRGB)

The BRGB is dominated by intrusions consisting of tonalite, trondhjemite, granodiorite (TTG) suites that are of typical I-type and magnetite-series with high MS values (Fig. 4). Evolved I-type granites usually display low MS values, similar to ilmenite-series. S-type granites with low MS values and muscovite and/or garnet are confined at the northern margin of the belt and also occur when they are emplaced into cordierite-bearing metasediment areas. Late sanukitoids occur as dikes or small stock in both the northern and southern limbs of the belt.

It is noted some phases of TTG contain porphyry Cu (Au) mineralization (e.g., Cat Lake); skarn-type Cu-Au-Ag mineralization is evident in the Cat Lake; shear zone control Au mineralization hosted in the Little Bear Lake. Rare metals (Li, Cs, Ta) in pegmatites are likely linked to S-type granites.

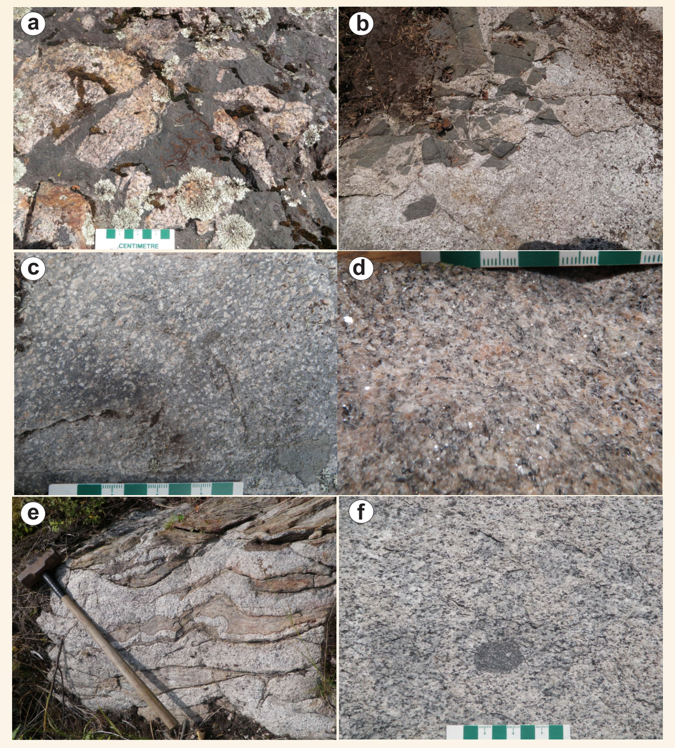

Fig. 4 Granitoids from the Bird River greenstone belt: a) coarse grained granodiorite in the Maskwa Lake batholith I, which fragmented and brecciated by MORB-type basalt; b) medium-grained granodiorite from the Maskwa Lake batholith II intruding very fine grained basalt and containing angular basalt fragments; c) two-feldspar porphyry; d) undeformed medium grained, muscovite-biotite granodiorite in the Marijane pluton; e) medium grained muscovite-biotite granite dikes and veins intrude cordierite porphyroblast-bearing greywacke; f) pinkish grey, medium to coarse grained granodiorite with subhedral to anhedral K-feldspar phenocrysts up to 10 mm from the Birse Lake pluton.

Granitoids in the Winnipeg River terrane

Gneissic tonalite, granodiorite and late equigranular granitoid rocks are dominantly present in the Winnipeg River terrane, which are generally characterized by very high MS values of magnetite-series and I-type, although highly evolved I-type granites with the signature of ilmenite-type are also evident. Few outcrops of muscovite-garnet-bearing S-type granites occur at the southern margin of this terrane (Fig. 5), most likely due to partial melting of thickened crust as a result of collision with the adjacent Western Wabigoon terrane to south. Alternatively, crustal contamination may have led to such strongly peraluminous feature of the granites.

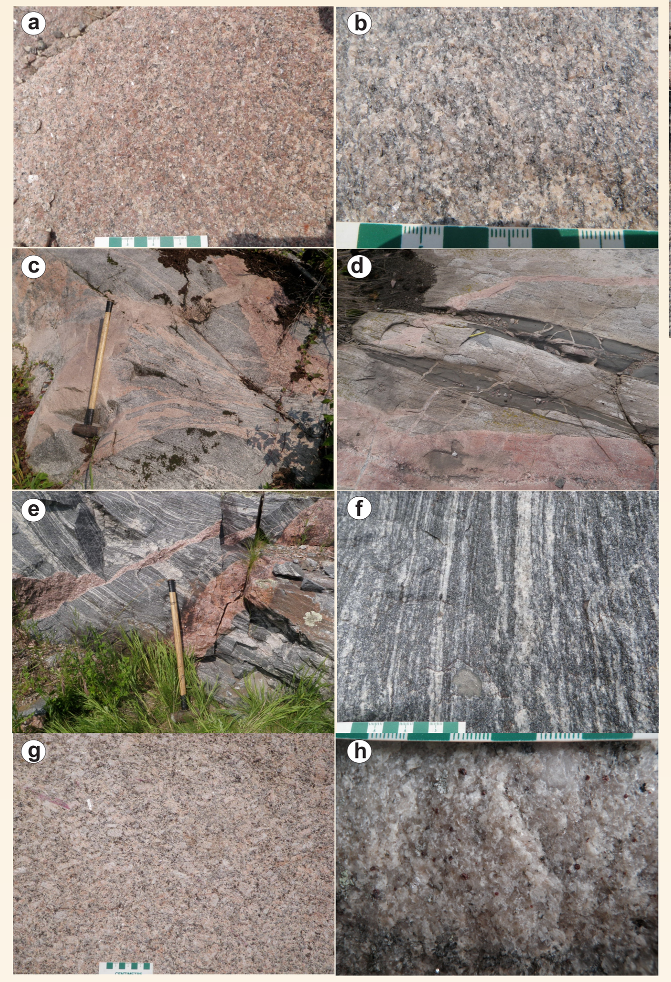

Fig. 5 Field photographs of granitoids from the Winnipeg River terrane: a) pink, medium grained biotite granite from the Lac du Bonnet batholith; b) medium grained leucogranite from the Lac du Bonnet batholith; c) grey medium grained gneissic tonalite cut by pink biotite granite in the Pointe du Bois batholith; pinkish grey gneissic granite cut by fine grained mafic dikes (about 30-40 cm wide), and both of them then cut by pink pegmatite-aplite dikes and/or veins from the Pointe du Bois batholith; e) grey, medium grained gneissic tonalite with very high MS values of up to 45.7×10-3 SI, cut by pinkish pegmatitic granite dikes from the Pointe du Bois batholith; f) zoom in of e showing gneissic fabrics consisting of biotite-rich alternating with felsic layers; g) pink porphyritic granodiorite with megacrystic K-feldspar as phenocrysts from the Rennie River plutonic suite; h) medium grained, massive garnet-bearing granite from the Ronnie River plutonic suite.

Granitoid rocks in the Western Wabigoon terrane

The Western Wabigoon terrane contains various types of granitoid rocks, although the outcrops are limited. Magnetite-series and I-type granites with high MS values appear to be dominant, although strongly peraluminous gneissic garnet-bearing granite of S-type occur at the northern margin of the terrane that was emplaced into tonalitic rocks (Fig. 6). This S-type granite displays high MS value of 3.28 × 10^{-3} SI, suggesting that the redox condition of this S-type granite may have been buffered by oxidized wallrocks.

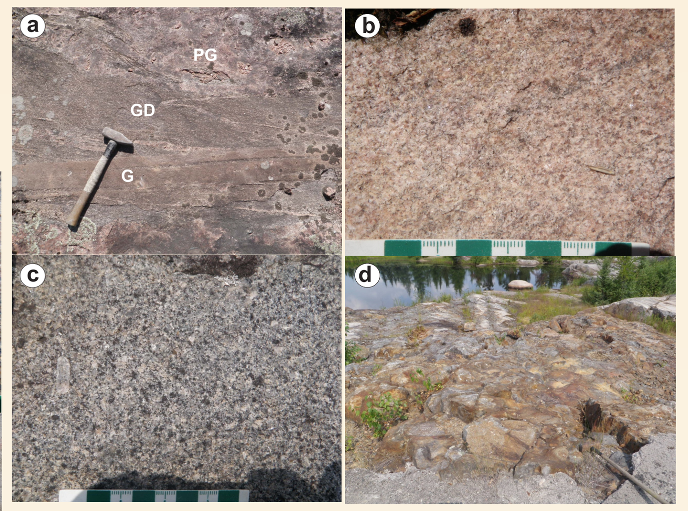

Fig. 6 Field photographs of granitoids from the Western Wabigoon terrane: a) multiple phases of granitoids occur, including granodiorite (GR) that is cut by fine grained granite (G), which are then intruded by pegmatitic granite (PG) in the Whitemouth Lake pluton; b) fine- to medium-grained leucogranite from the same outcrop as a); c) medium grained, quartz monzonite with few euhedral K-feldspar phenocrysts from the Falcon Lake igneous complex; d) sulphide-bearing breccia in the quartz monzonite, about 20 metres west of the location c.

Lithogeochemistry

Fig. 7 shows some key geochemical charateristics of granitoids from different plunic suites in different tectonic units in western Superior province of southeastern Manitoba. A few important features can be summarized as followings.

- Most granitoids are calcic to calcalkaline (Fig.7a), typical of magmatic arc products associated with plate subduction;
- Most granitoids are metaluminous to peraluminous, consistent with I-type granites (ACNK<1.1; Fig. 7b). However, some are strongly peraluminous (ACNK>1.1), consistent with S-type granites;
- These granitoids are dominantly orogenic, and could be related to subduction magmatism (Fig. 7c);
- Most granitoids are formed in volcanic arc environment (i.e. subduction-related), albeit some S-type granites may have been formed in thickened crustal environment due to continental collision (Fig. 7d);
- Sanukitoids vary from calcalkaline to alkaline in magmatic alkalinity, and from metaluminous to strongly peraluminous, consistent with their unique origin (Yang and Gilbert, 2014).

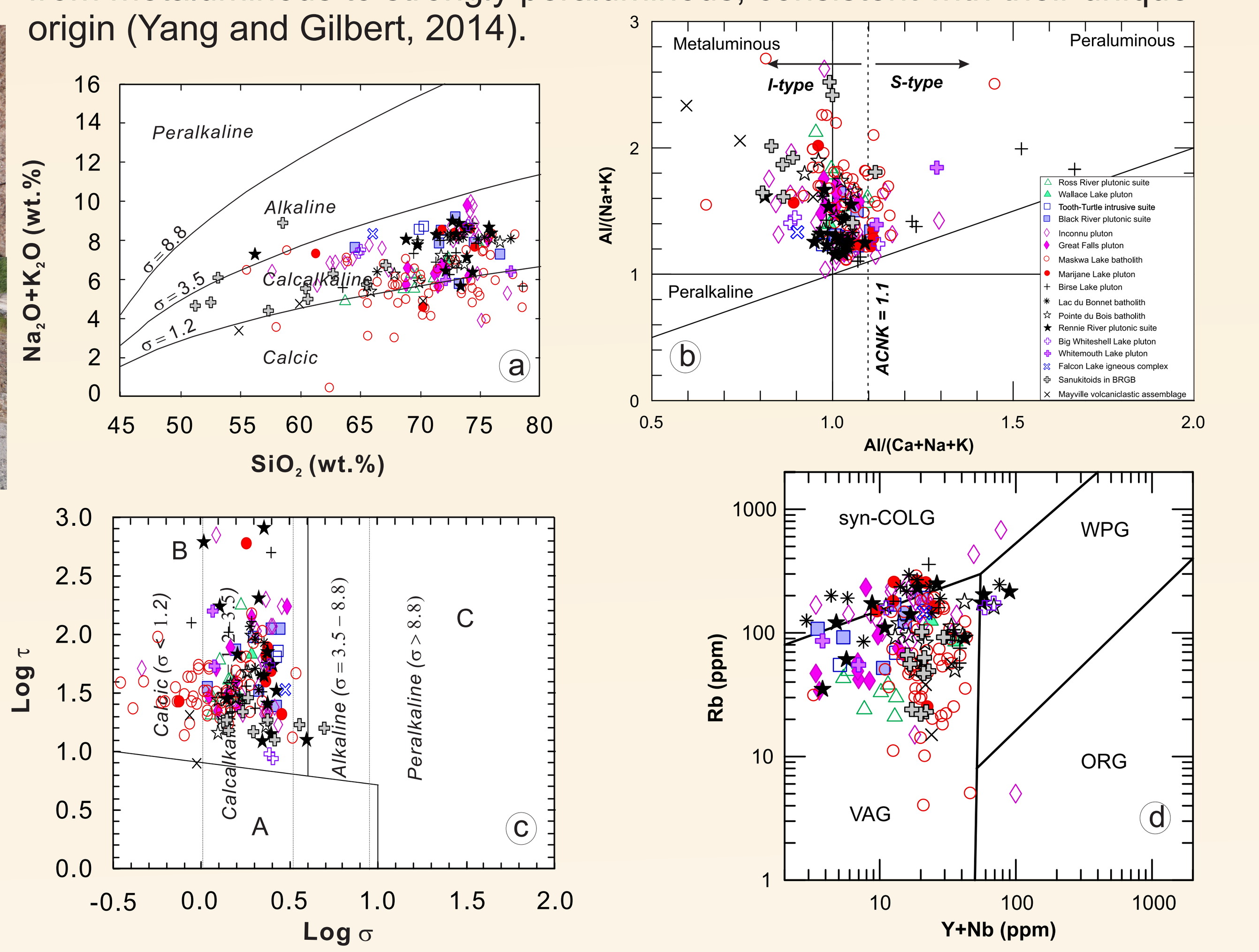

Fig. 7 Geochemical discrimination diagrams for granitoids from the Bird River greenstone belt (BRGB), southeastern Manitoba: a) alkalinity of the granitoids (boundaries between the fields of calcic, calcalkaline, alkaline, and peralkaline from Yang, 2007; the Rittmann Serial Index $\sigma = [Na_2O + K_2O]_2/[SiO_2 - 43]$, Rittmann, 1962); b) the Shand index plot (after Maniar and Piccoli, 1989) for the granitoids; ACNK = 1.1, used as the boundary of I- and S-type granites defined by Chappell and White (1974, 1992, 2001); S-type granites are strongly peraluminous with ACNK > 1.1; I-types metaluminous to moderately peraluminous (likely due to hornblende fractionation leading to residual melts rich in alumina relative to alkalis (Na_2O and K_2O); c) Log versus Log diagram used for the granitoids, where $\tau = (Al_2O_3 - Na_2O)/TiO_2$ (Gottini, 1968); Field A represents anorgenic, B orogenic belts and island arc, and C alkaline derivatives of A and B (from Rittmann, 1973); d) tectonomagmatic discrimination diagram for the granitoids; The fields from Pearce et al. (1984): ORG - ocean-ridge granitoids, Syn-COLG -- syncollision granitoids, VAG - volcanic-arc granitoids, WPG - within-plate granitoids.

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