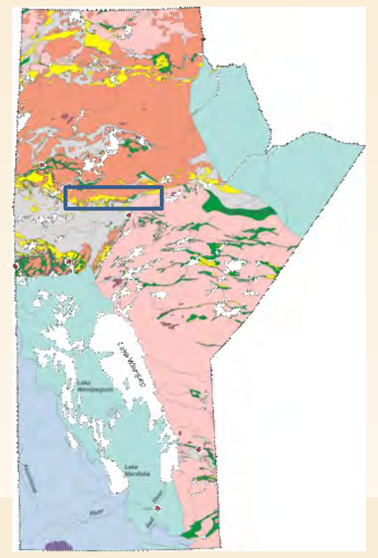
Petrogenetic types, tectonic settings and mineral potential of granitoid intrusions in north-central Manitoba: Evidence from reconnaissance mapping, geological sampling and lithogeochemistry



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Abstract

Granitoid rocks make up the vast majority of exposed bedrock in Manitoba's portion of the Canadian Shield. These rocks provide important information on the ages, origins and tectonic environments because they are the best preserving primary signatures. Different types of granitoid rocks may have potential for different type of mineral deposits, some of which are among the largest mineral deposits on Earth. Despite this, granitoid rocks have generally not been explored to the same extent as the belts of volcanic and sedimentary rocks that host the majority of Manitoba's Precambrian mineral endowment.

The Manitoba Geological Survey initiated the granitoid project in 2014 to investigate the nature and mineral potential of granitoid rocks throughout Manitoba, starting in southeastern Manitoba and then moving to north-central Manitoba this past summer.

This study has the following geology and mineral exploration implications.

1) Muscovite- and/or garnet-bearing granitic rocks characterized by very low magnetic susceptibility (MS) values (<0.1 × 10^{-3} SI units; i.e., strongly peraluminous S-type or ilmenite-series) are intruded mainly into domain boundaries, which may serve as a useful criterion for recognizing major tectonic or domain boundaries (or crustal-scale discontinuities). These peraluminous granitic rocks may have formed in thickened crust as a result of terrane assembly and/or continental collision, and may have potential to host rare-metal and/or Sn-W mineralization.

2) In contrast, plutons consisting of quartz monzonite, granodiorite and granite are characterized by higher MS values (>0.1 × 10^{-3} SI units) and mineral assemblages typical of I-type, or magnetite-series granitoid rocks (e.g., hornblende±biotite or biotite±hornblende). Such plutons are abundant across the region, suggesting that this magmatism contributed significantly to crustal growth in the Trans-Hudson orogen, largely related to subduction tectonics. Normal I-type, magnetite-series granitoid intrusions may have potential to host porphyry Cu, Au and Mo mineralization.

3) Evolved I-type granitoid intrusions in the region, despite being subducted in volume, may have potential for rare-metal (e.g., Nb, Ta) mineralization.

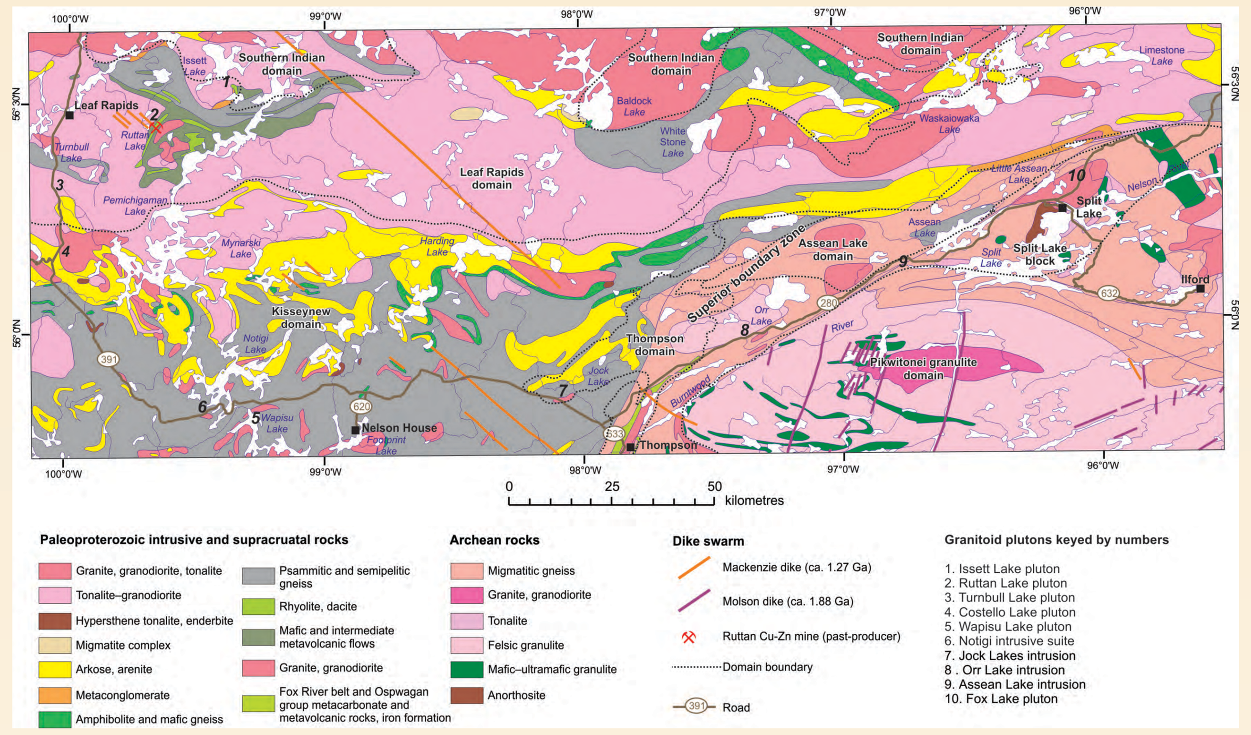
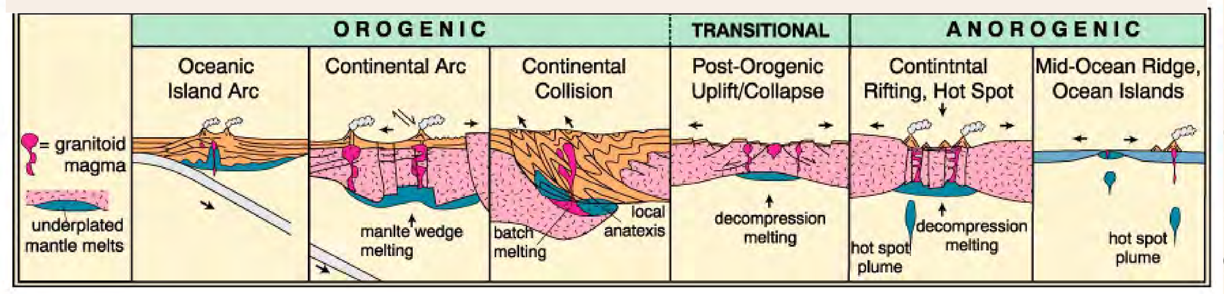


Fig. 1 Simplified geology of north-central Manitoba, showing the dominance of granitoid rocks in different tectonic units including the Southern Indian, Leaf Rapids (Lynn Lake) and Kisseynew domains, and the Superior boundary zone (SBZ) that includes the Thompson, Split Lake and Assean Lake domains. Numbered granitoid plutons or intrusions are examined and sampled in this study. Nomenclature of tectonic units or domains is modified from Manitoba Energy and Mines (1986), Zwanzig et al. (2001) and Zwanzig and Bailes (2010).

Petrogenetic types of granitoids

Classification of granitoid rocks 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). In addition, A-type granites are characterized by the presence of annite-rich biotite and/or sodic amphibole or sodic pyroxene, with high silica, alkalis, Fe/Mg, F, Zr, Nb, Ga, Sn, Y, and REE (except Eu) contents, and low Ca, Ba, and Sr (Whalen et al., 1987). The Manitoba Geological Survey would use these schemes in the study of granitoids in Manitoba. More importantly, different types of granitoids occur in different tectonic settings (Fig. 2), and may have different mineral potential.

Fig. 2 A classification of granitoid rocks based on tectonic settings (Winter 2001)



Granitoids in the Leaf Rapids domain (LRD)

The LLD is dominated by I-type and/or magnetite-series granites (localities 1 to 3 in Fig. 1), with minor S-type garnet-bearing granite which displays very low MS values of <10^{-3} SI, comparable to ilmenite-seris granites (Figs. 3 & 4). The S-type granites occur at the terrane boundary between the LRD and the South Indian Lake domain to the north (Fig. 1).

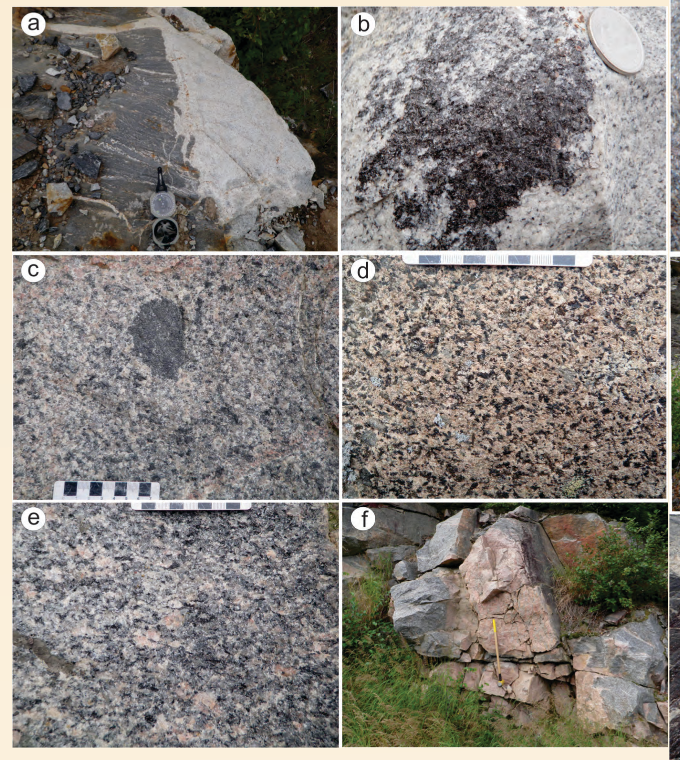


Fig. 3 Granitoid rocks from the Leaf Rapids domain: a) fine- to medium-grained biotite-muscovite granite, Issett Lake pluton (locality 1), cutting sulphide-bearing gneissic metasedimentary rock; b) medium-grained granite containing metasedimentary xenoliths rich in biotite and garnet; c) medium- to coarse-grained granodiorite with mafic inclusion, Issett Lake pluton; d) medium- to coarse-grained quartz monzonite, Ruttan Lake pluton (2); e) foliated porphyritic granodiorite, Turnbull Lake pluton (3); and f) pinkish, fine- to medium-grained granite cutting the porphyritic granodiorite, Turnbull Lake pluton.

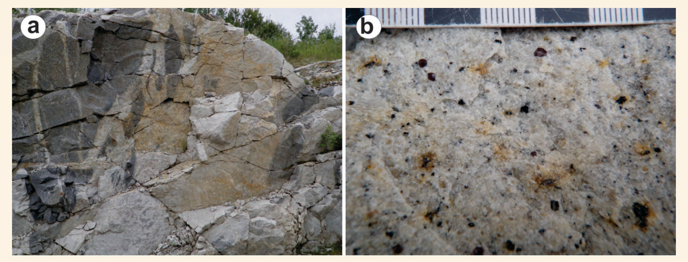


Fig. 4 In the northern margin of the LRD, a) medium-grained garnet-muscovite granite (S-type) intruded into foliated tonalite (I-type), Issett Lake pluton (1); and b) medium-grained garnet-muscovite granite, Issett Lake pluton.

Granitoid rocks in the Kisseynew domain (KD)

Granitoid rocks in the KD include granodiorite to granite at Costello Lake (locality 4); garnet-bearing granodiorite of the Wapisu Lake intrusion (locality 5); and granodiorite to garnet-bearing granite and garnet-muscovite–bearing granite of the Notigi Lake intrusive suite (locality 6; Fig. 1). They occur as stocks, and dikes, containing both S- and I-type granites (Fig. 5).

Fig. 5 Granitoid rocks from the Kisseynew domain: a) fine-grained granite, Costello Lake pluton (locality 4); b) medium- to coarse-grained granodiorite, Costello Lake pluton; c) medium- to coarse-grained garnet-bearing granite dikes of the Notigi Lake intrusive suite (6) intruding biotite-garnet-quartz-feldspar paragneiss; d) medium-grained, massive, garnet-bearing granite (close-up the dike shown in photo c); e) medium- to coarse-grained to pegmatitic garnet-bearing granites (at least two phases) in gneissic to migmatitic protolith, Notigi Lake intrusive suite; f) medium-grained granodiorite intruded and fragmented by garnet-bearing pegmatitic granite, Notigi Lake intrusive suite; inset is an enlargement of the pale phase in veins or veinlets that contains garnet.

Granitoid rocks in the Superior Boundary Zone (SBZ)

Granitoid rocks the SBZ are dominated by I-type gneissic granitoid rocks although S- type granites are locally present (Fig. 6). The S-type granites are likely much younger than the Archean TTG suites based on their unfoliated fabrics.

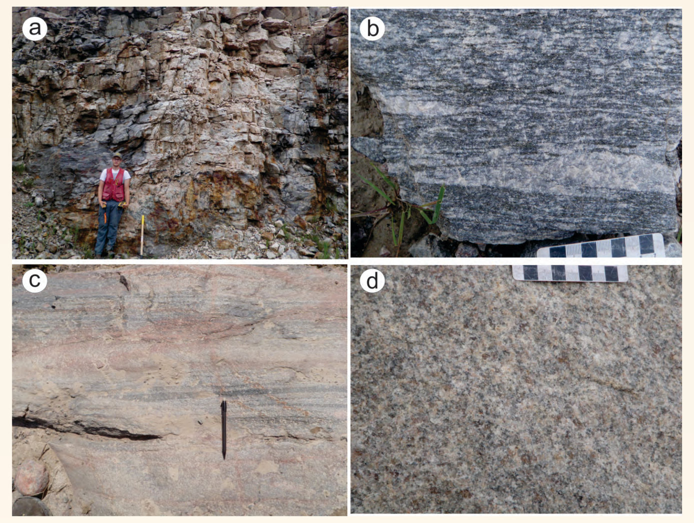


Fig. 6 Granitoid rocks from the Superior boundary zone: a) garnet-muscovite-bearing pegmatite and pegmatitic granite dike intrudes into paragneiss, Jock Lake intrusion (locality 7); b) medium-grained granite gneiss, Orr Lake intrusion (8); c) medium-grained gneissic granodiorite, Assean Lake intrusion (9); and d) medium- to coarse-grained, massive biotite granite, Fox Lake pluton (10).

Lithogeochemistry

Some key geochemical characteristics of granitoid rocks from different tectonic units in north-central Manitoba are shown in Fig. 7, which are summarized as follows.

- Most granitoids are calcalkaline to high-K calcalkaline (Fig. 7a, b, c), typical of magmatic arc products associated with plate subduction;
- Most granitoids are metaluminous to peraluminous, consistent with I-type granites (ACNK<1.1; Fig. 7d). However, some are strongly peraluminous (ACNK>1.1), consistent with S-type granites; Compostionally, these granitoids range from tonalite to granite (Fig. 7e).
- These granitoids are dominantly orogenic, and could be related to subduction magmatism (Fig. 7a, f, g) with moderately to unevolved features;
- 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. 7f, g; Fig. 2);
- A spectra of granitoid rocks occur at a magmatic arc setting (Fig. 7f-g, i-k), exhibiting pronounced Nb (Ta), Ti negative anomalies; moderately evolved phases display relatively higher REE conetnts with pronounced negative Eu anomalies (Fig. 7i, j).

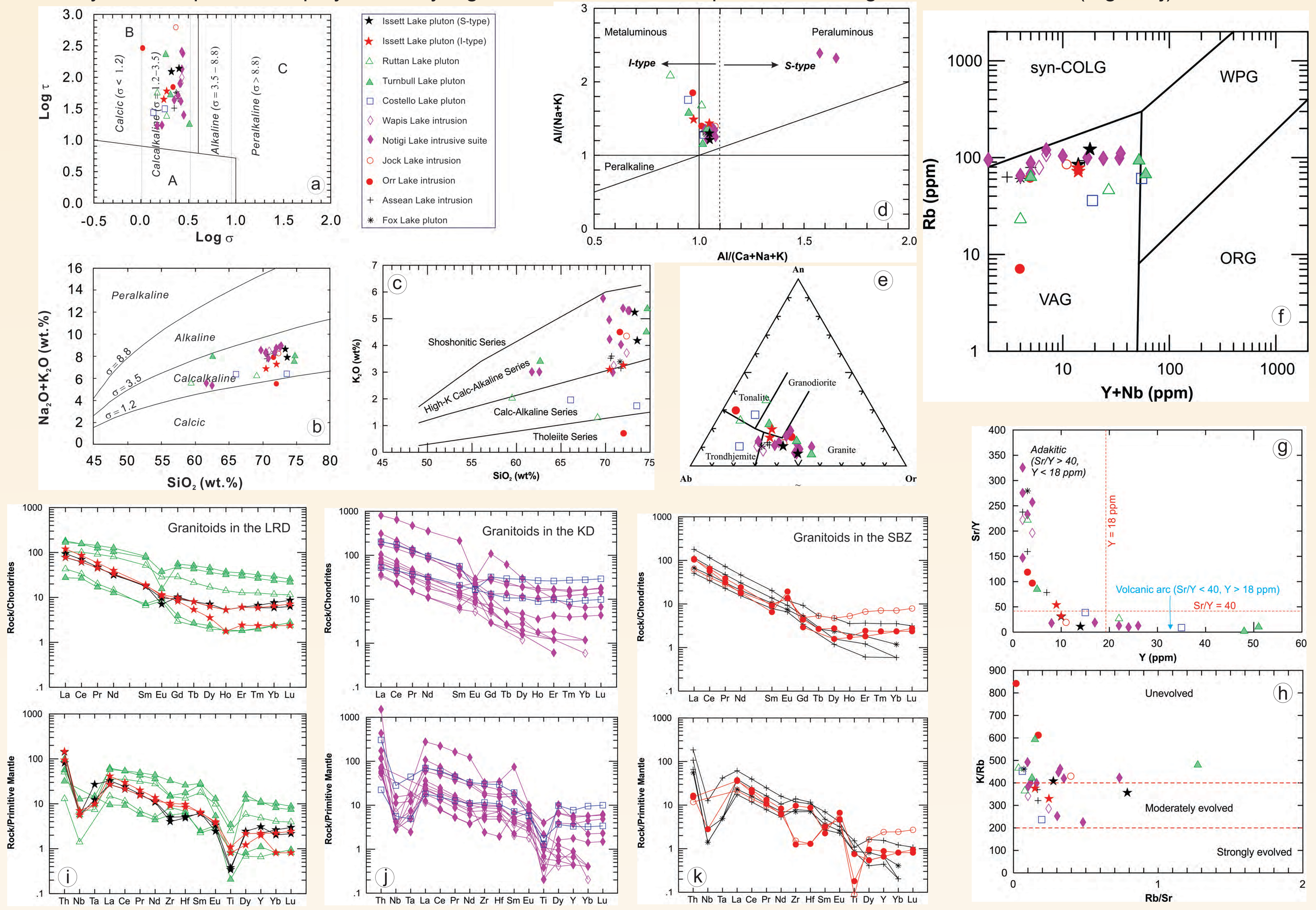


Fig. 7 Geochemical discrimination diagrams for granitoids in north-central Manitoba: a) Log σ versus Log τ diagram used for the granitoids, where $\sigma = [Na_2O + K_2O]^2/[SiO_2 - 43]$ (the Rittmann Serial Index; Rittmann, 1962) and $\tau = (Al_2O_3 - Na_2O)/TiO_2$ (Gottini, 1968); Field A represents anorgenic, B orogenic belts and island arc, and C alkaline derivatives of A and B (from Rittmann, 1973); b) alkalinity of the granitoids (from Yang, 2007); c) Plot of K_2O (wt%) vs. SiO_2 (wt%) (after Peccerillo & Taylor, 1976); d) 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; e) normative Ab-An-Or classification of granitoids (after Barker, 1979); f) 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; g) plot of Sr/Y vs. Y (ppm), and h) plot of K/Rb vs. Rb/Sr (unevolved, moderately and strongly evolved fields from Blevin, 2004). Chondrite-normalized REE and primitive-mantle normalized extended element plots for granitoids from the LRD (i), KD (j) and SBZ (k); normalized value from Sun and McDonough (1989).

References cited in this poster are available from the Xue-Ming (Eric) Yang (eric.yang@gov.mb.ca) upon request.

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