LATE ARCHAEAN FELSIC ALKALINE MAGMATISM: GEOLOGY, GEOCHEMISTRY, AND TECTONIC SETTING

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Alkaline granite complexes are not abundant throughout Earth history. Most of them are of Phanerozoic (less frequently Proterozoic) age and are of great scientific interest due to their distinctive:

1. **Mineralogy (anhydrous primary phases, Fe- and Na-rich mafic silicates)**
2. **Geochemistry (low Ca, Al, Mg, high alkalis, elevated HFSE and some LILE (especially Nb, Zr, Y, Ga, Rb, REE (except Eu)), and depleted Sc, Cr, Ni, Ba, Sr)**
3. **Tectonic setting (most of studied complexes are of Phanerozoic age and it is for this period that their tectonic setting is well defined):**

   - **back-arc extension related to subduction (e.g., West Pacific Coast cases of MZ-KZ)**
   - **continental hot-spot and rift (e.g., Nigerian alkali ring complexes of MZ, Siberian and Mongolian complexes of PZ-MZ)**
   - **ocean island (e.g., Ascension, Reunion islands)**

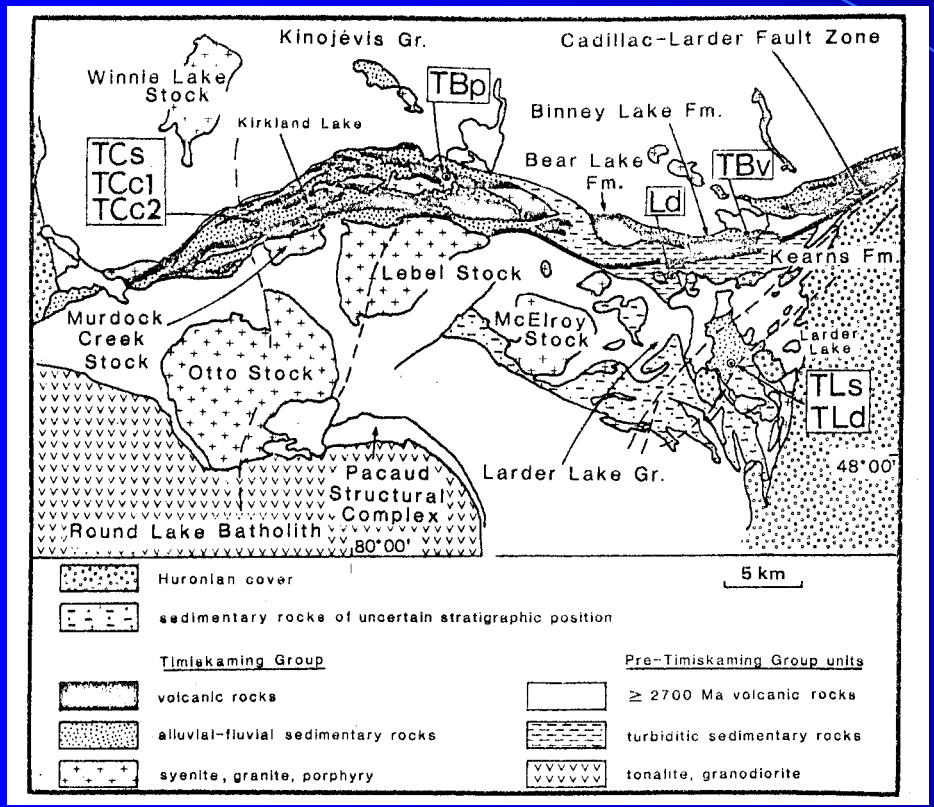
The Phanerozoic-Proterozoic alkaline felsic suites are A-types (as defined by Loiselle and Wones (1979)), and can be divided into two subgroups based on trace element discrimination (A1 (anorogenic granites of presumably 2nd and 3rd types of tectonic settings), and A2 (or post-orogenic granites corresponding to 1st type of tectonic setting)).

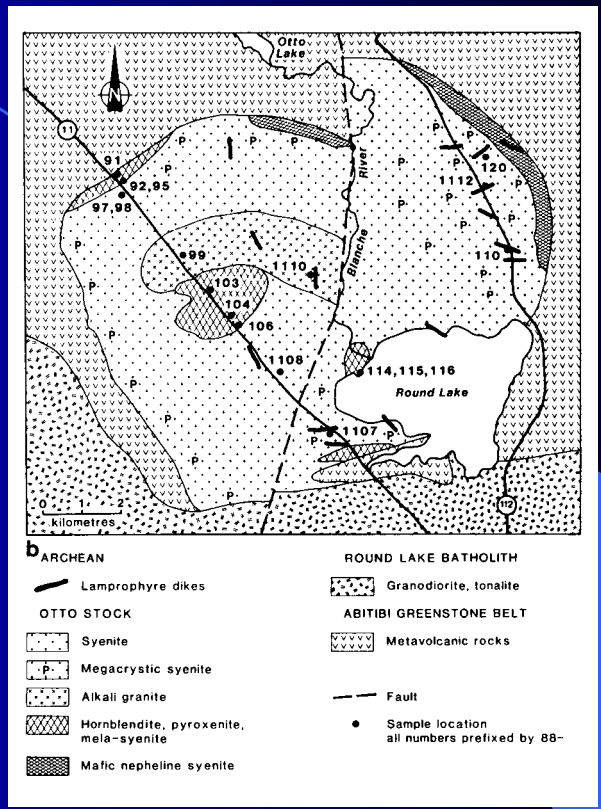
According to Pearce (1996) the within-plate granites (or A-type granites) generally have enriched mantle sources and show variable interaction with the continental crust.

The oldest known examples of felsic alkaline magmatism are from the Superior province, Yilgarn Craton, and Fennoscandian Shield. These are, correspondingly:

- **2680-2670 Ma alkaline granites, syenites and associated nepheline syenites of the Abitibi greenstone belt (Sutcliffe et al., 1990; Corfu et al., 1991)**
- **2650-2630 Ma alkaline granites and syenites of the Eastern Goldfields granite-greenstone terrane (Libby, 1989; Smithies, Champion, 1999)**
- **2610-2680 Ma alkaline granites, syenogranites, and nepheline syenites of the Keivy complex of the Central Kola granite-greenstone domain (Mitrofanov et al., 2000; Zozulya et al., 2001).**

Regional and local geology of the Superior felsic alkaline rocks

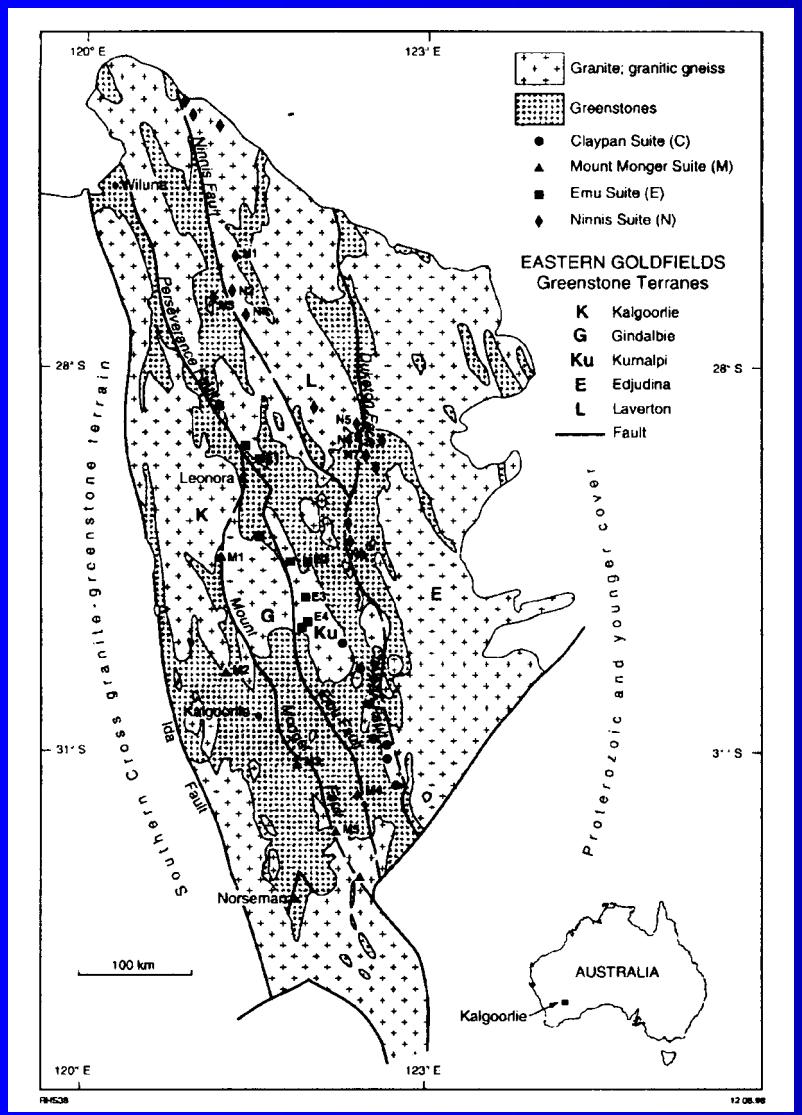




Otto, Garrison, Winnie Lake stocks from the Abitibi green-stone belt:

- Structural and genetic links to greenstone belts;
- Small (10-20 km^2) stocks;
- Spatial and temporal association with potassic volcanics and lamprophyres.

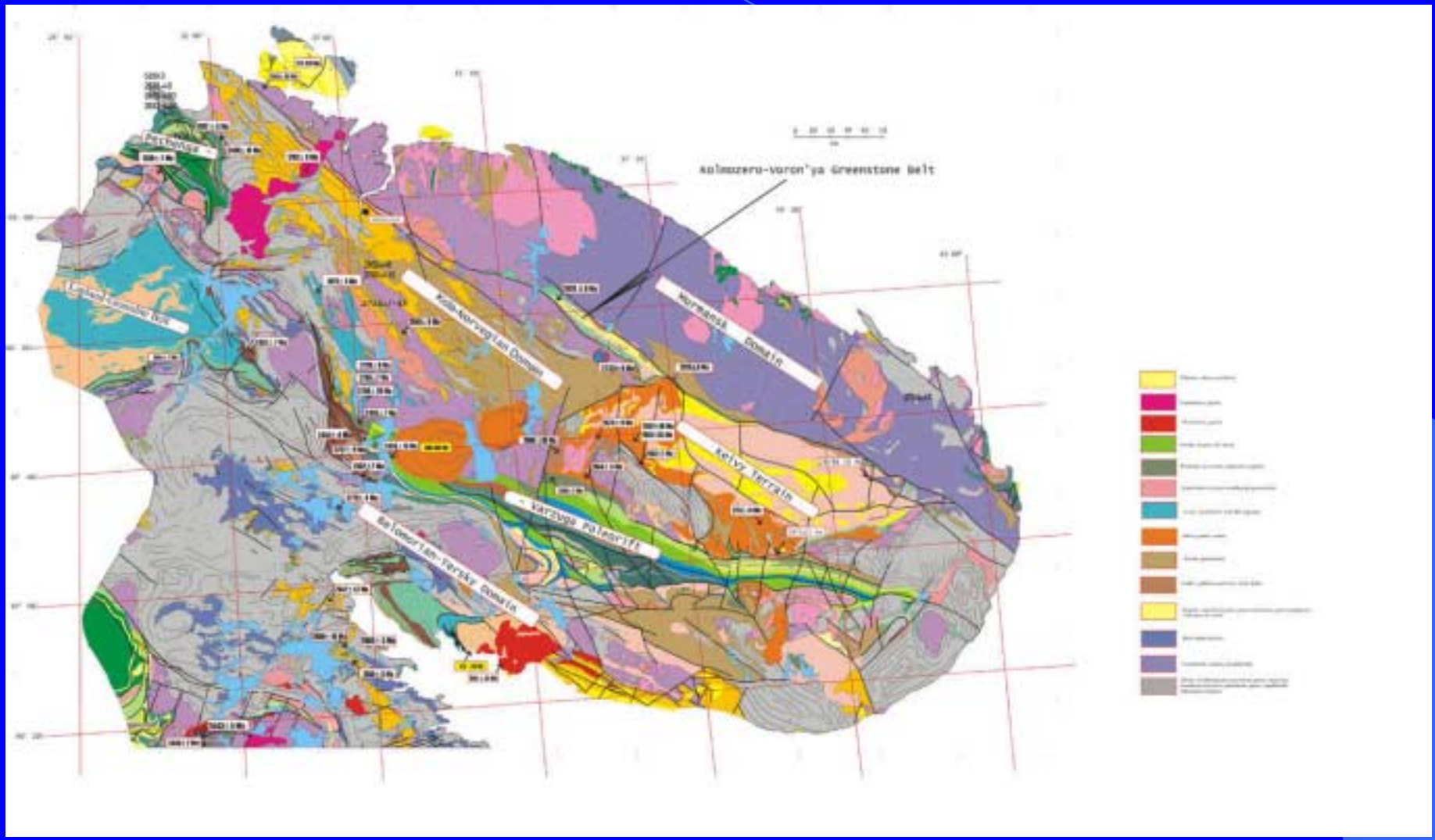
Regional and local geology of the Yilgarn felsic alkaline rocks



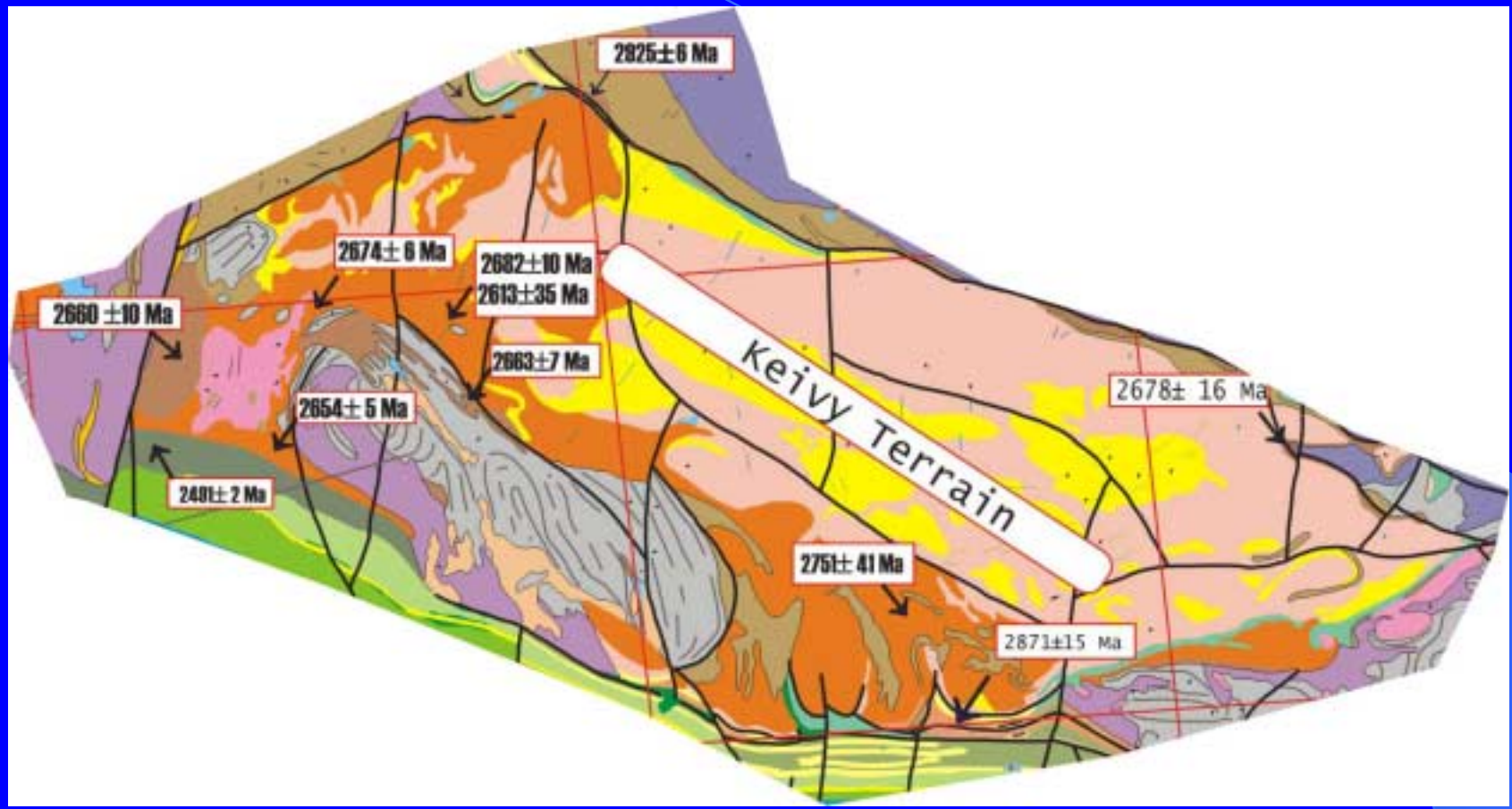
Over thirty intrusions of the Mount Monger, Emu, Claypan, and Ninnis suites:

- Small (<10 km^2) intrusions
- Spatial and temporal association with lamprophyres
- Alkaline granites, quartz-bearing syenite, monzonite
- Setting along the regional NNW-trending faults within the Eastern Goldfields granite-greenstone terrane

Regional and local geology of the Kola felsic alkaline rocks, NE Fennoscandian Shield



Regional and local geology of the Kola felsic alkaline rocks, NE Fennoscandian Shield



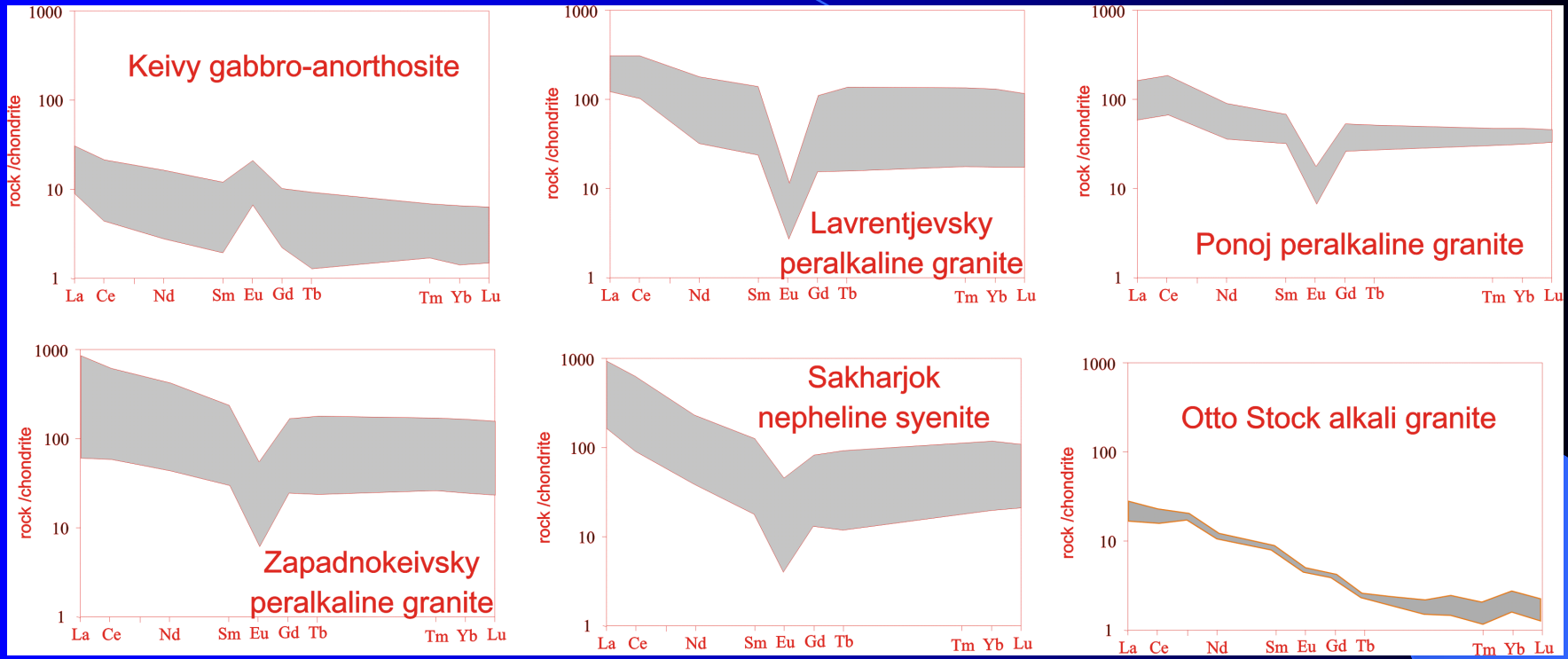
- Six peralkaline granite massifs, confined to the margins of the Keivy terrane
- Sheet-like bodies with thickness of a 100-500m and of vast exposed areas (100-1300 km^2)
- Spatial and temporal association with massif-type anorthosite bodies

Granites from the various provinces have common mineralogical and petrochemical characteristics:

- **anhydrous primary phases,**
- **Fe- and Na-rich mafic silicates,**
- **low Ca, Mg, Al, and high total alkalis.**

At the same time the granites show different trace element characteristics and mineralization types. Coupled with different geological structure this suggests the different tectonic settings.

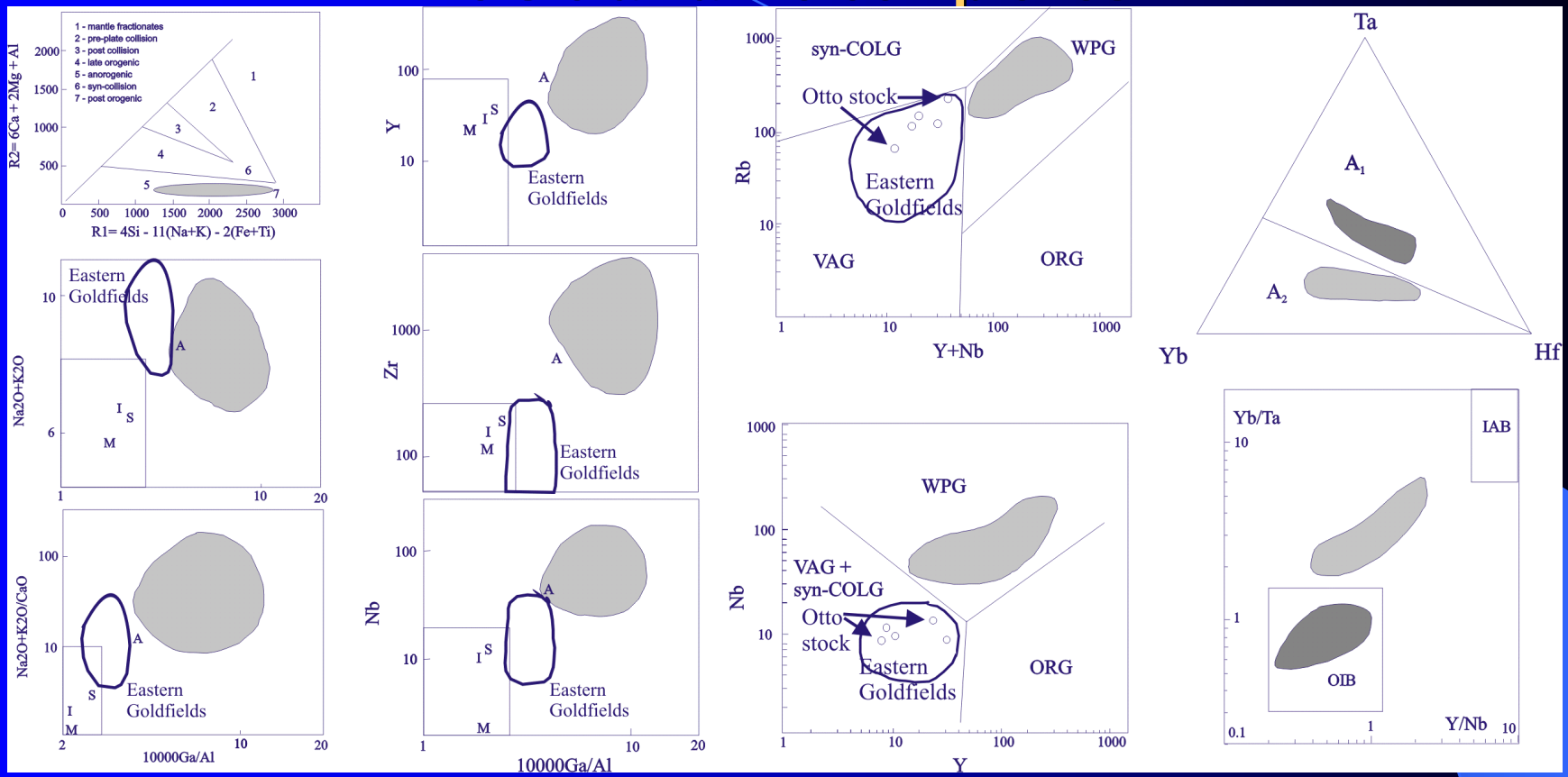
REE chondrite-normalized patterns for the Superior and Keivy felsic alkaline complexes



Superior alkaline granites and syenites show:

- **Moderate and low REE abundances**
- **High $(La/Yb)_n$ ratios**
- **No Eu anomaly**

Geochemical features and tectonic discrimination diagrams for Superior, Yilgarn and Keivy felsic alkaline complexes

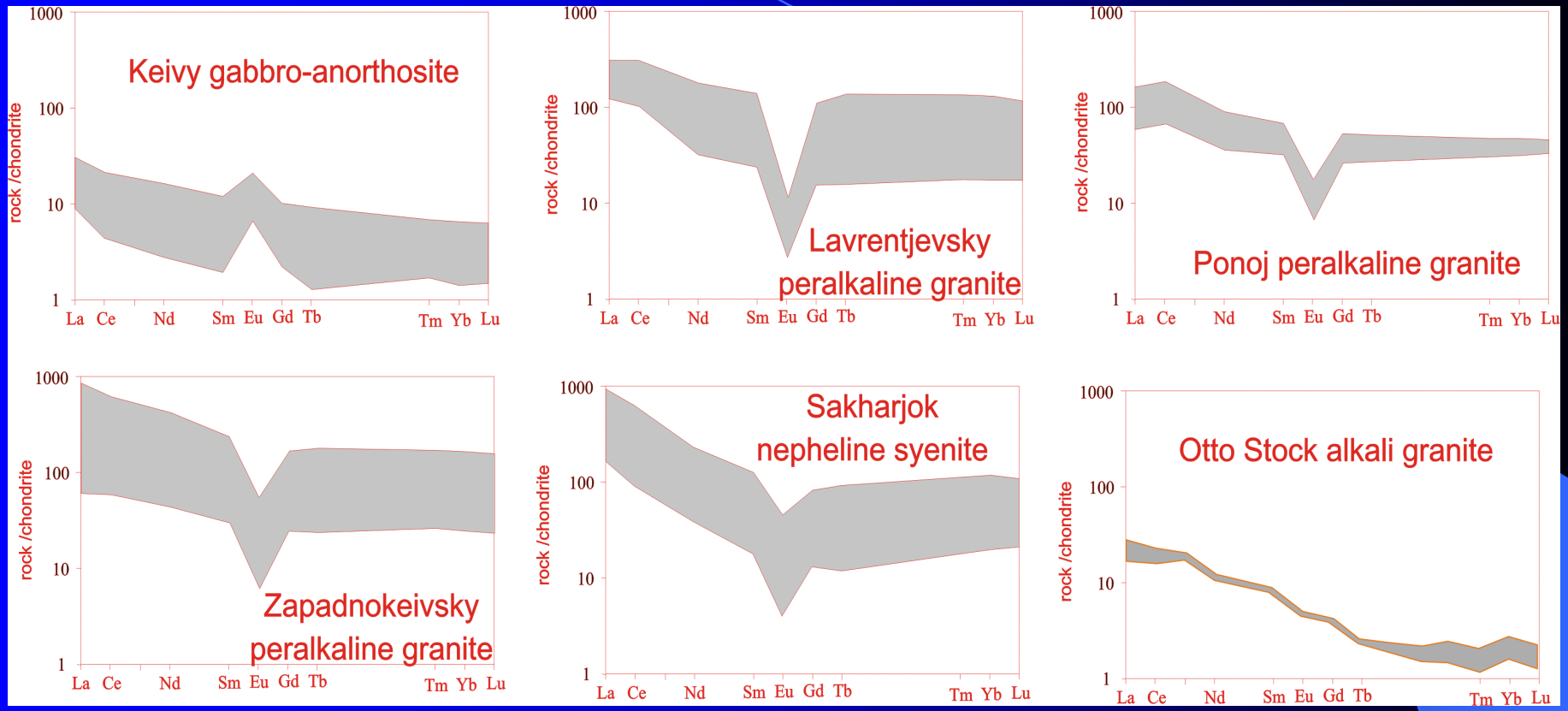


Superior and Yilgarn felsic alkaline rocks:

- extremely high concentrations of Ba (c. 500-4500ppm) and Sr (c. 300-3000ppm)
- depleted in Zr, Y, Nb, Ta, and Rb
- low Ga/Al and high Y/Nb ratios

Based on these geochemical features the granites were formed in a subduction environment and correspond to volcanic arc granites.

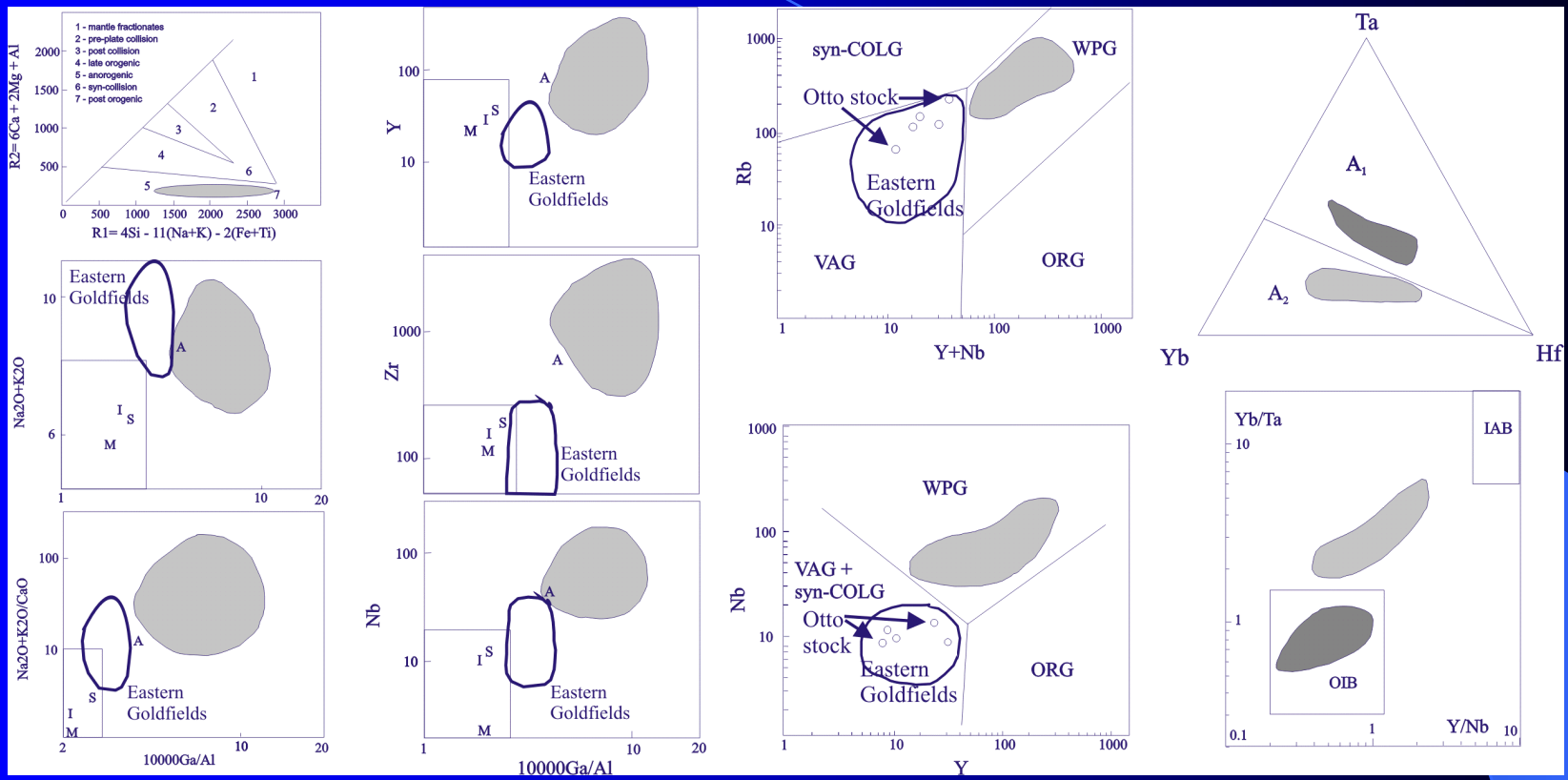
REE chondrite-normalised patterns for the Superior and Keivy felsic alkaline complexes



Keivy peralkaline granites and nepheline syenites show:

- **High REE abundances**
- **Low $(La/Yb)_n$ ratio**
- **Distinct negative Eu anomaly**

Geochemical features and tectonic discrimination diagrams for Superior, Yilgarn and Keivy felsic alkaline complexes



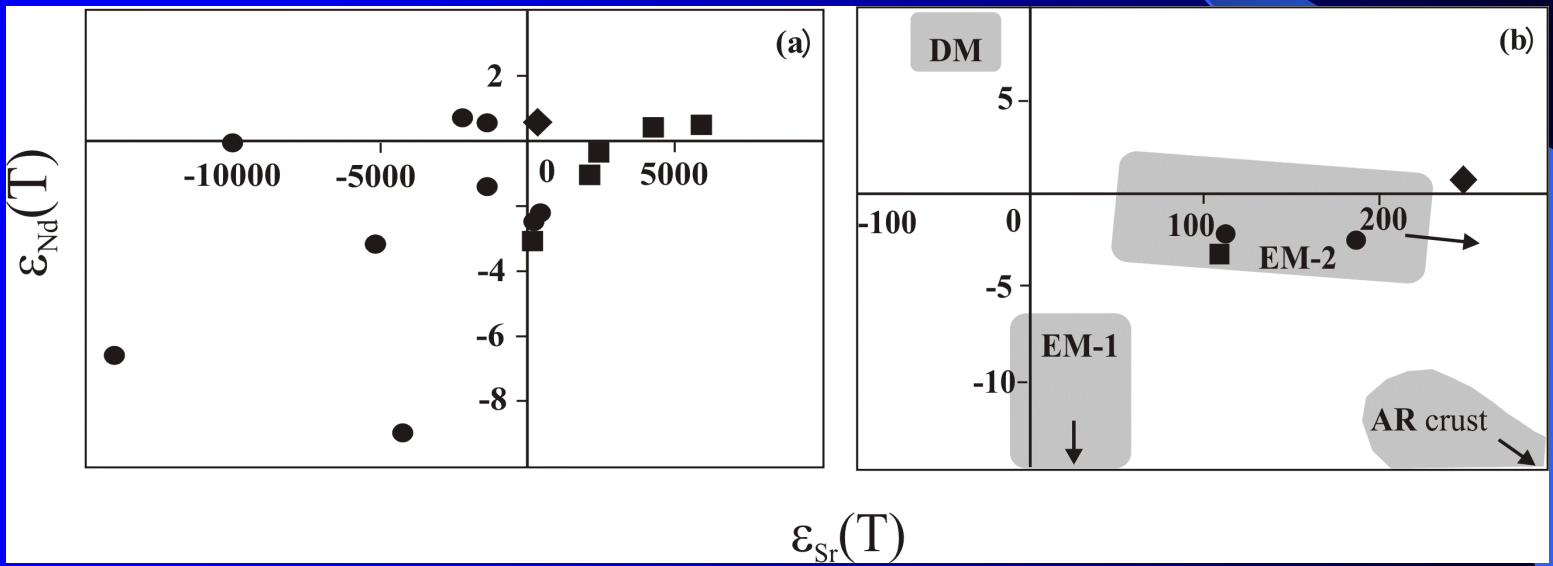
Keivy felsic alkaline rocks:

- Extremely enriched in Zr, Y, Nb, and Rb
- High Ga/Al (for granite) and low (for syenite) Y/Nb ratios
- Very low in Ba (c.40-200ppm) and Sr (c. 5-30ppm)

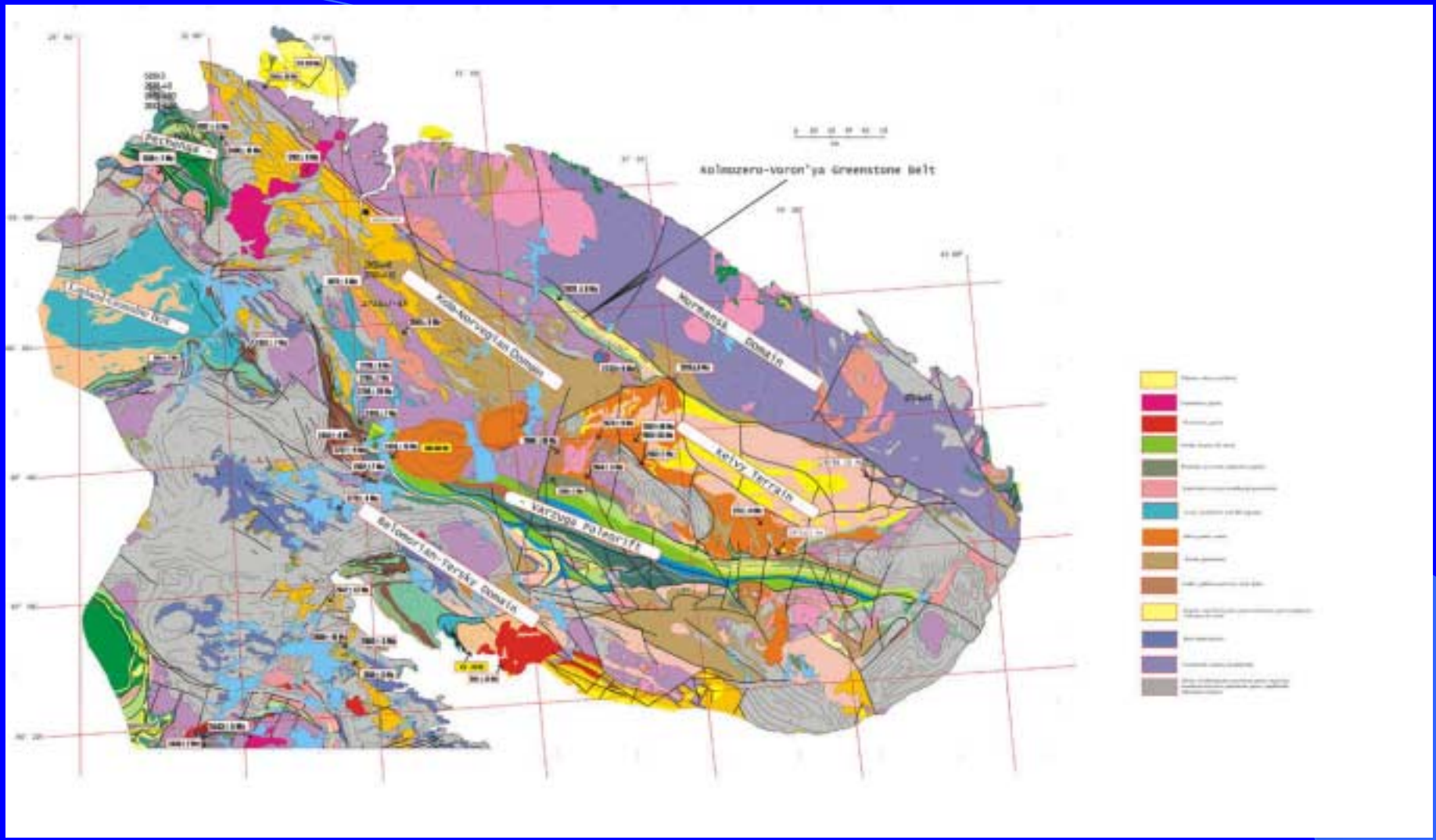
Granitoids were formed in within-plate setting. Nepheline syenites have the geochemical affinities of OIB magma.

The source problem for the Archaean felsic alkaline magmas

Sutcliffe et al. (1990) and Shirey & Hanson (1984), based on Nd isotope studies and elemental constraints, suggested that the "Superior" type granites are derived from depleted mantle sources that were enriched in LILE shortly before melting.



It is likely that the Keivy granites are the product of a high degree of fractional crystallization of a mantle-plume-derived alkaline basalt magma.



The enriched mantle source for Keivy felsic alkaline rocks was a result of the subduction process in the adjacent Kolmozero-Voron'ya greenstone belt which evolved in the period 2.92-2.83 Ga.

Conclusions

- **The oldest known examples of felsic alkaline magmatism are of 2.63-2.68 Ga age.**
- **Two types of Archaean alkaline felsic suite are identified based on different magma sources and tectonic settings.**
- **The "Superior-Yilgarn" type has a depleted mantle source enriched in LILE just before melting. The granites were formed in a subduction environment and correspond to volcanic arc granites.**
- **The "Keivy" type has a highly evolved enriched mantle source. The granites were formed in a within-plate setting under the influence of a mantle plume.**