Geochemistry and mantle sources for Archean alkaline rocks from Greenland, the Baltic, and Northern Norway

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Main Objectives of this Study

- **Obtain information on the isotopic composition of the subcontinental mantle in the Archaean**

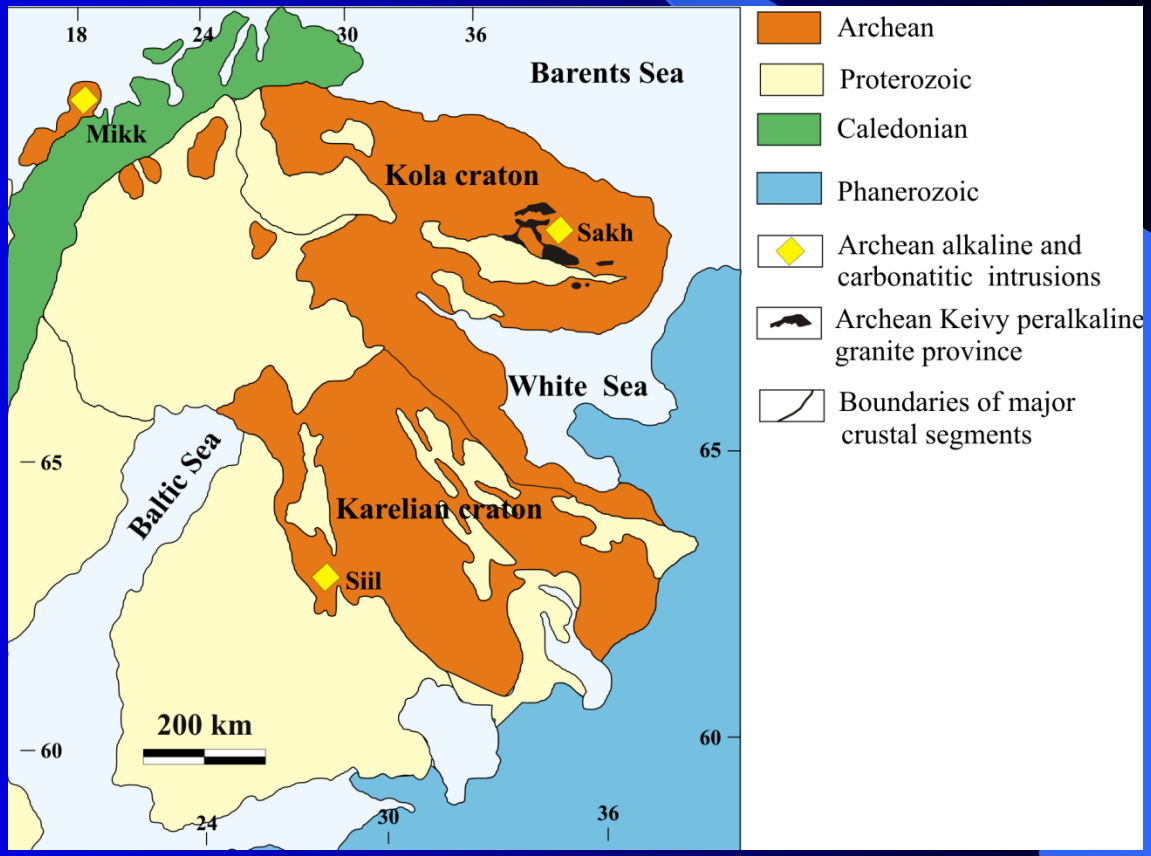
  Archaean alkaline complexes are particularly interesting because the magmas are of mantle origin and have high Sr and Nd contents (thus minimizing modification of isotopic signatures by crustal contamination). Isotopic data for these rocks reflect mantle isotopic ratios.

- **Obtain information on the combined evolution of Baltic-Greenland in the Archaean**

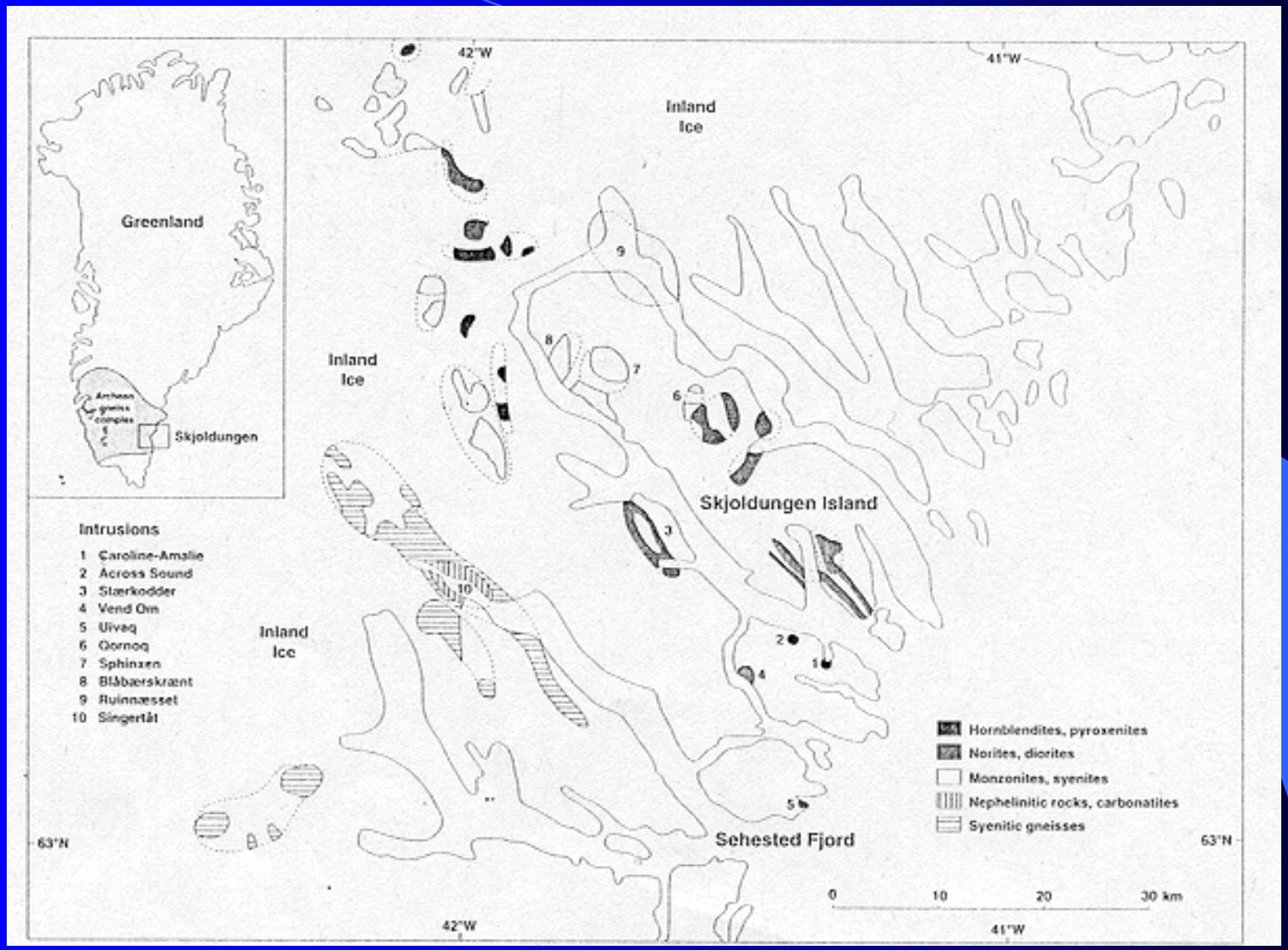
Archaean alkaline complexes are rare worldwide and in Greenland and the Baltic

The Greenland examples are the **Skjoldungen alkaline province** in SE Greenland (geology, geochronology and geochemistry compiled from Blichert-Toft et al (1995) and Nielsen & Rosing (1990)) and the **Tupertalic carbonatites** in West Greenland (Larsen & Rex, 1992).

The Baltic examples are represented by the **Siilinjarvi carbonatite** complex in Finland, the **Keivy alkaline province** in the Kola Peninsula, and the **Mikkelvik alkaline massif** in the West Tromso basement, Northern Norway.



Skjoldungen alkaline province

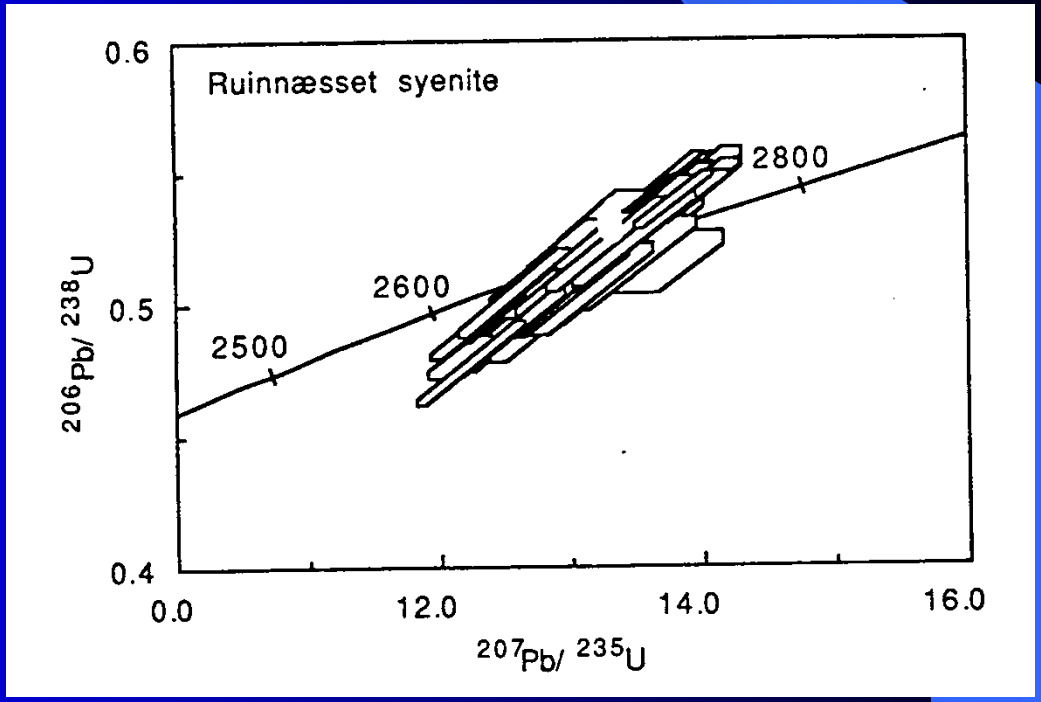


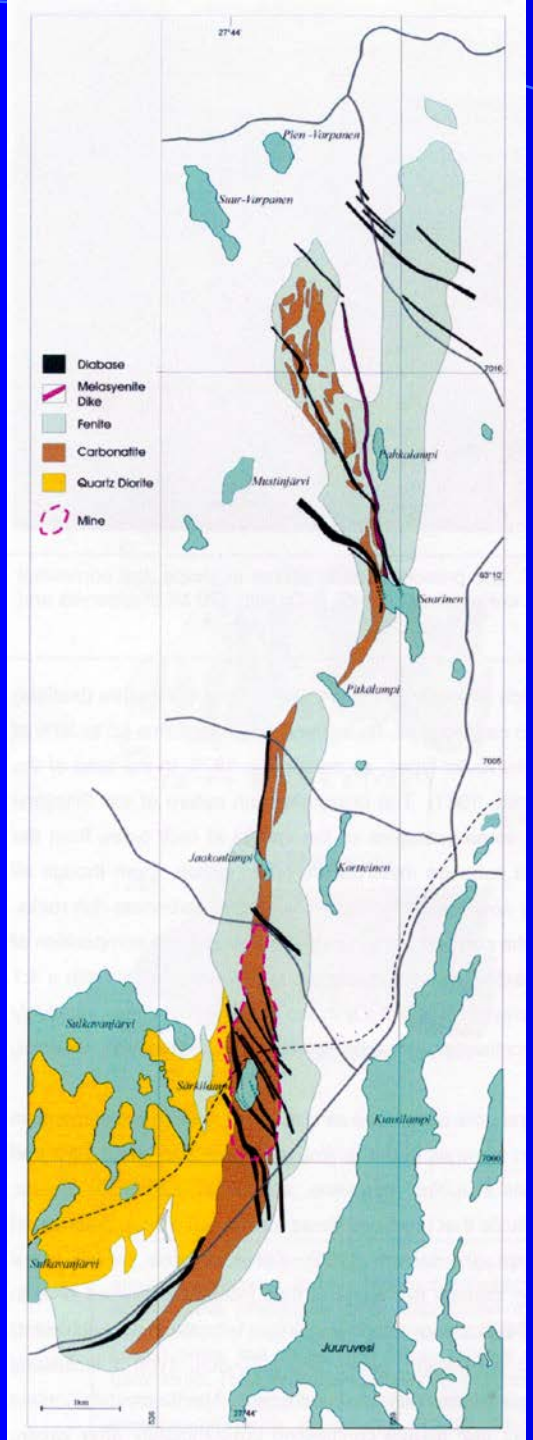
The complex consists of twenty mafic to felsic silica-undersaturated to silica-saturated intrusive complexes.

Geology and geochronology of the Skjoldungen alkaline province

The intrusives are composed of hornblende pyroxenites, hornblendites, hornblende norites and diorites (Across Sound, Caroline-Amalie, Stadkodder, Vend Om, Uivak), monzodiorites, monzonites, syenites (Ruinnasset, Qornoq, Spinxen, Blabarskrant), nephelenitic rocks and carbonatites (Singertat). Mafic-ultramafic rocks intruded syn- to post-kinematically throughout the province as either swarms of dikes or small plugs and sheets, the syenite bodies were emplaced mostly post-kinematically as large massive plutons.

A minimum estimate of the mafic-intermediate magmatic activity is the age of crystallization of the Ruinnasset syenite (U-Pb single zircon age of 2698+/-7 Ma). Carbonatites and nephelenitic rocks (melteigite-ijolite-urtite series) represent the youngest event in province (2664+4/-2 Ma).

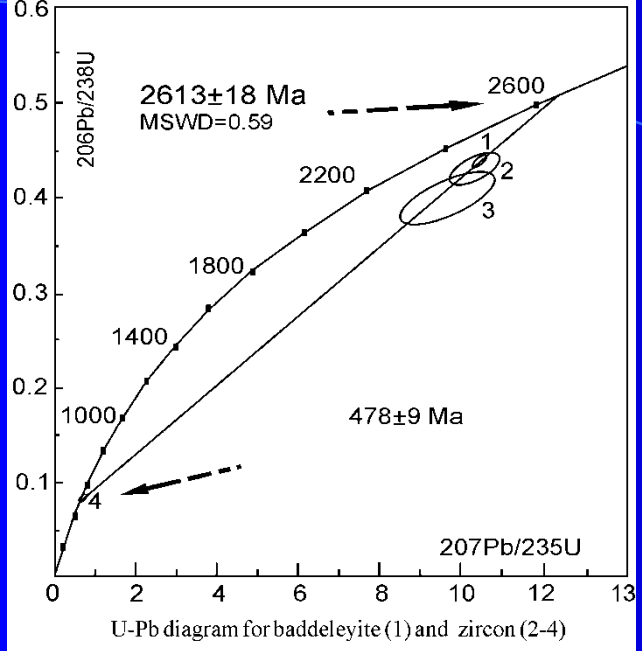




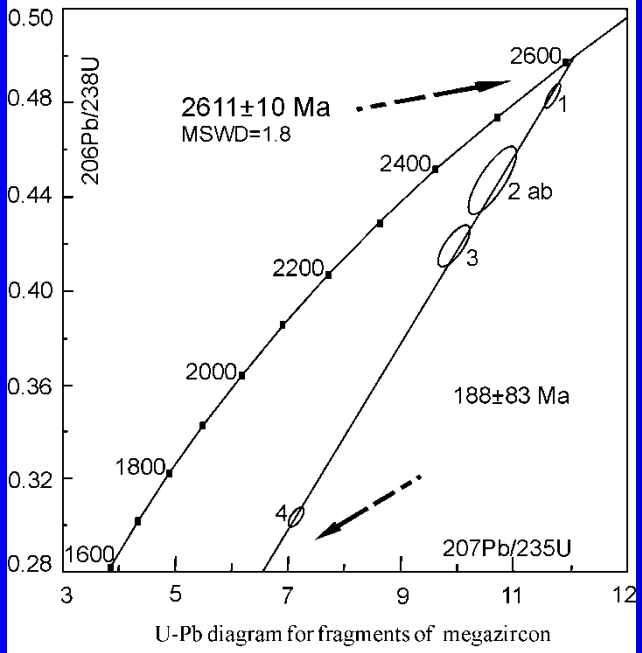
Geology of the Siilinjarvi carbonatite complex

The Siilinjarvi carbonatite complex consists of a steeply dipping lenticular body roughly 16 km long with a maximum width of 1.5 km intruded into granite gneiss. The main rock types are: calcite carbonatite, phlogopite carbonatite, glimmerite and their apatite-bearing varieties. The fenite halo is represented mainly by quartz-aegirine syenite. Crosscuting the bedrock, the halo, and main body is a 4 km long, 20-30 m wide, melasyenite dike related to the same intrusive event as the carbonatite.

Geochronology of the Siilinjarvi carbonatite



U-Pb diagram for baddeleyite (1) and zircon (2-4)

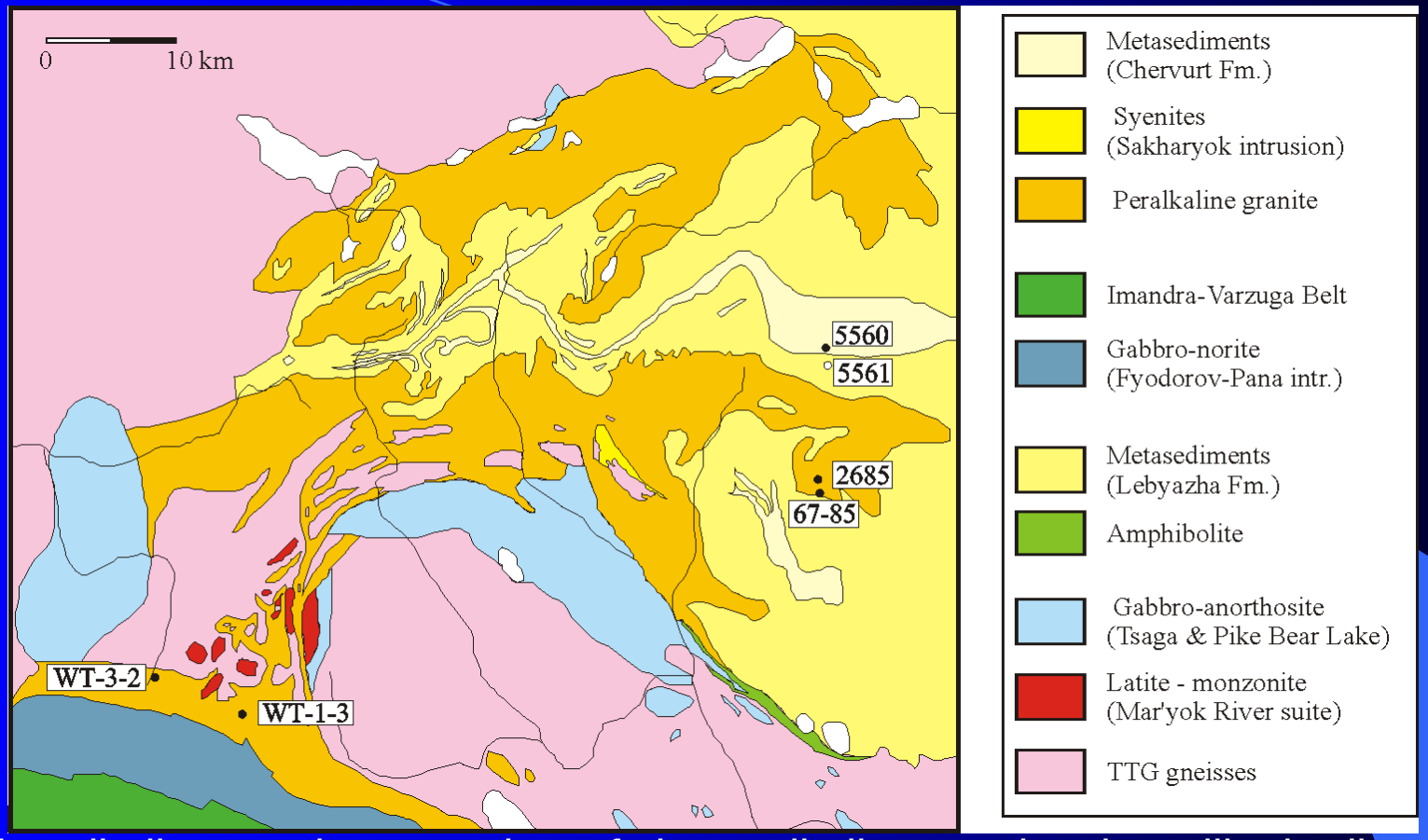


U-Pb diagram for fragments of megazircon

The previously reported ages ranged from 2.58 to 2.61 Ga (Patchett et al., 1981; Lukkarinen et al., 2003).

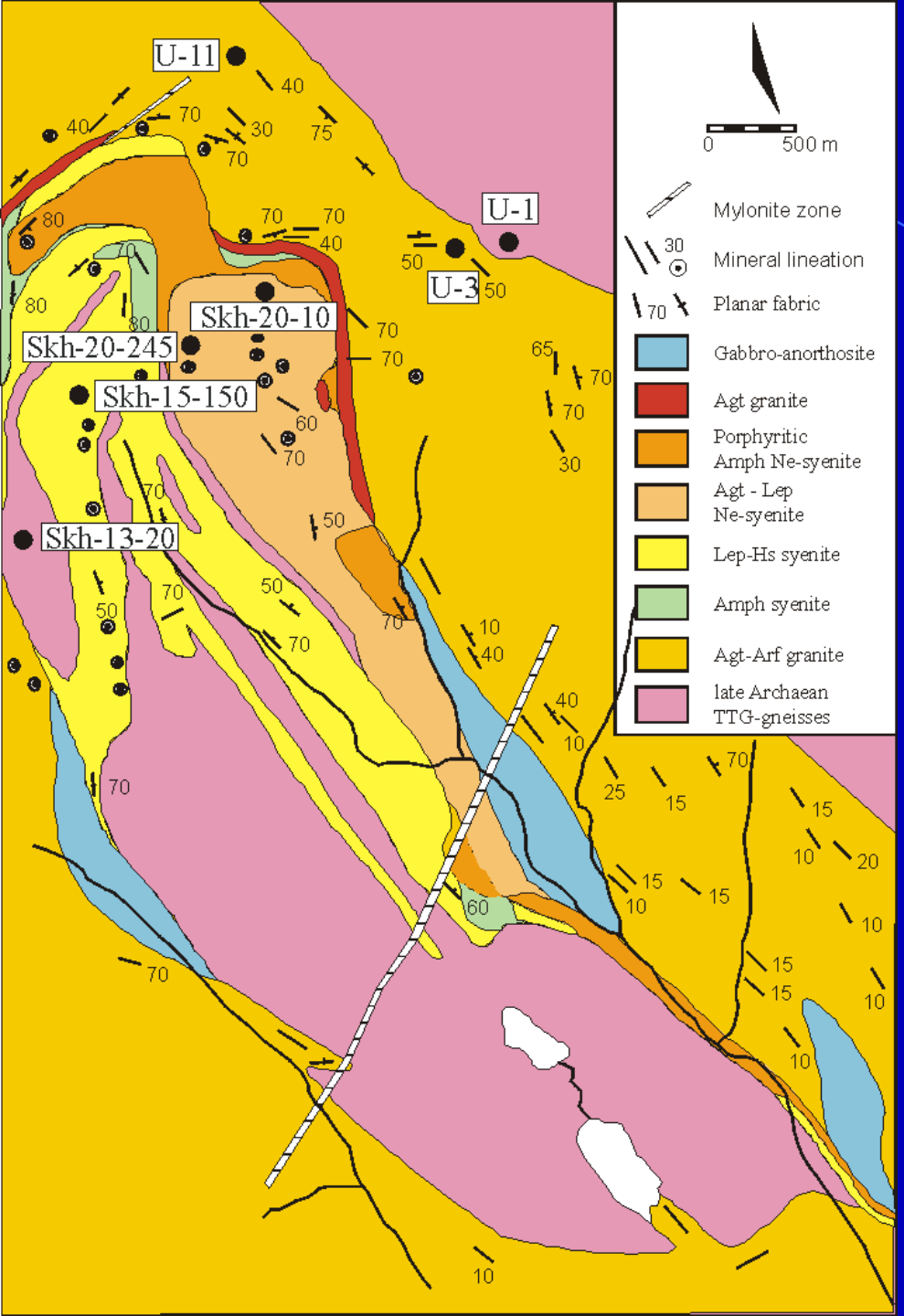
U-Pb zircon and baddeleyite age determinations yield a weighted mean age of **2610 Ma** for the Siilinjarvi carbonatite.

Geology of the Keivy alkaline province

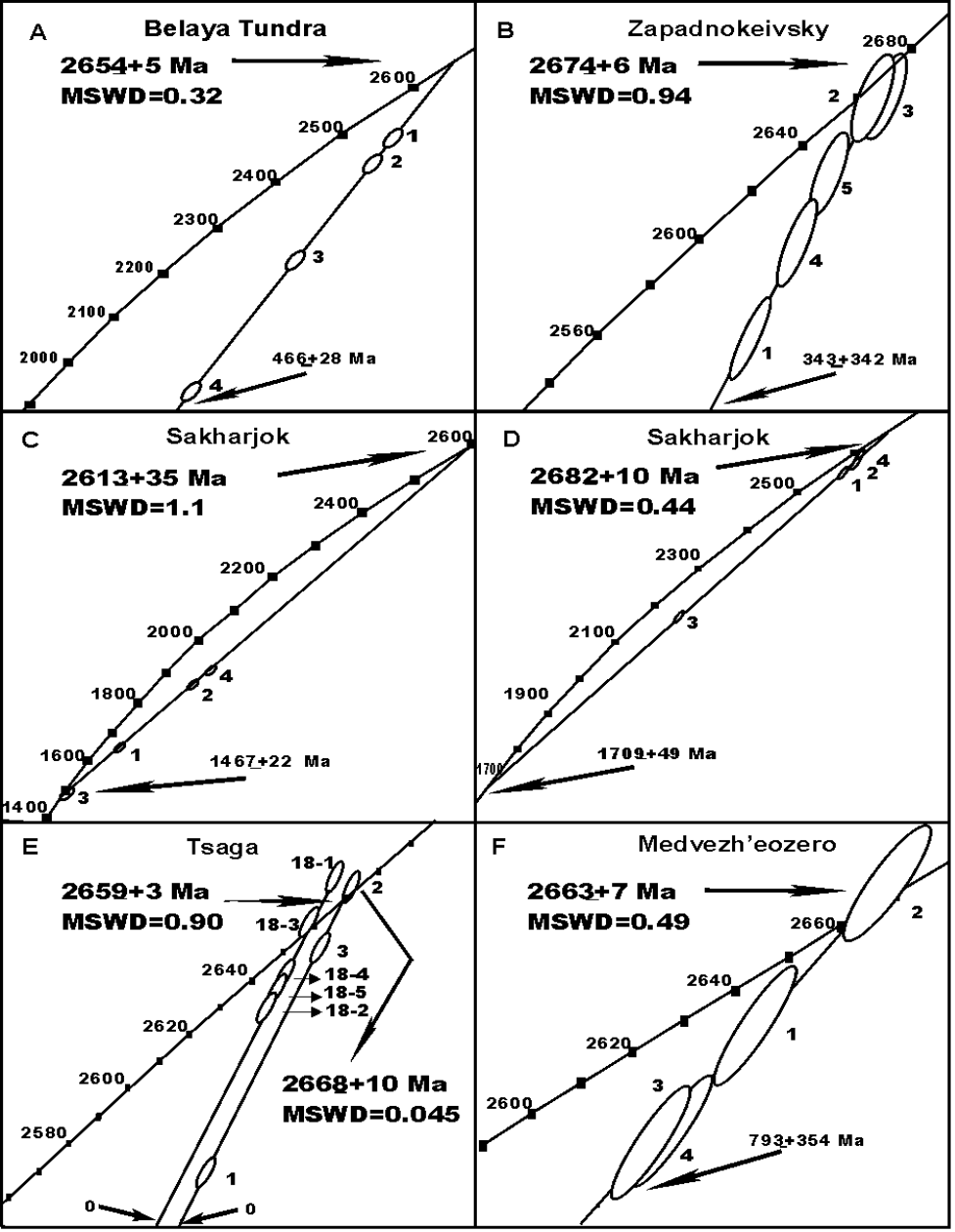


The Keivy alkaline province consists of six peralkaline granite sheet-like bodies with a total exposure of 2500 km^2 and two nepheline syenite fault-type intrusions, confined to the margins of Keivy terrane. There are six petrographic groups: aegirine-arfvedsonite (most abundant), aenigmatite-arfvedsonite, lepidomelane-arfvedsonite, lepidomelane, aegirine-and magnetite granites and ferrohastingsite-lepidomelane-aegirine-augite syenogranites (represent the first magmatic phase). The Keivy terrane is composed of Late Archean acid-medium orogenic volcanics, sedimentary rocks of sub-platform origin, and massif-type anorthosites having an anorogenic setting.

Geology of the Sakharjok alkaline massif



The Sakharjok (5-6 km^2) fault-type alkaline intrusion occurs in the central part of the West Keivy peralkaline granite massif and consists of nepheline-bearing phlogopite-omphacite gabbro, ferrohastingsite-lepidomelane syenite, and aegirine-lepidomelane nepheline syenite. The alkali gabbro occurs as large (10 x 80 m) patches in the nepheline syenites. The most abundant magmatic phase is alkali syenite. The nepheline syenite intrudes the alkali syenite and peralkaline granite.



$^{206}Pb/^{238}U$

$^{207}Pb/^{235}Pb$

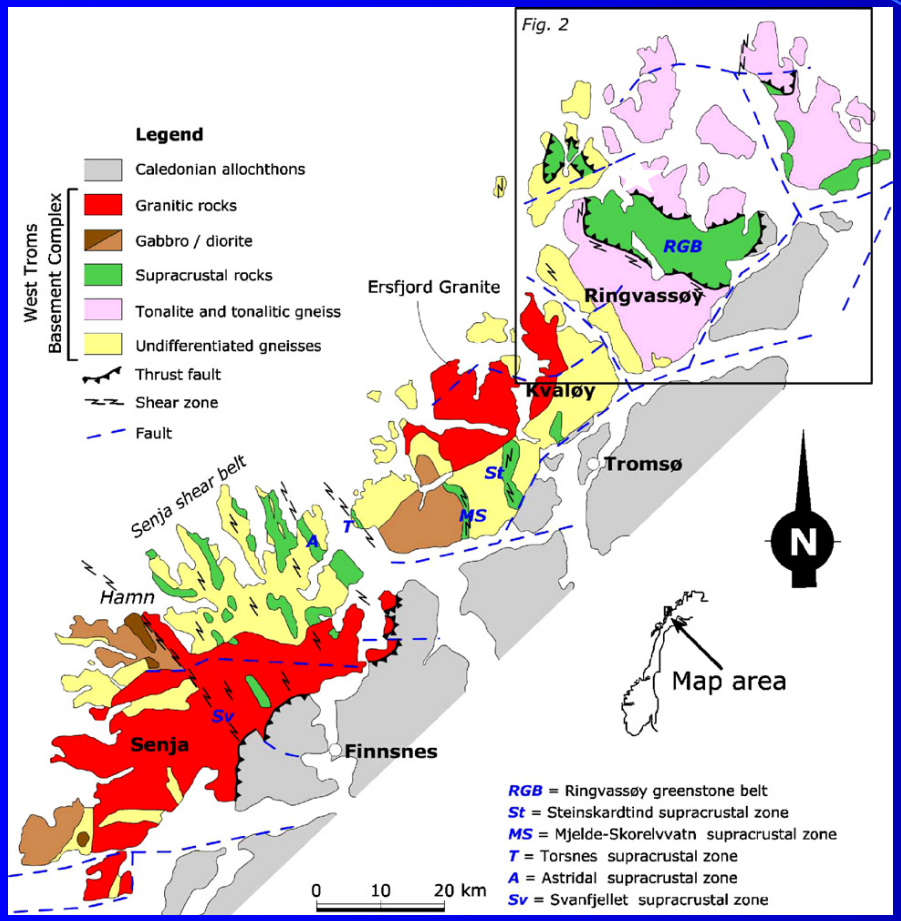
A - peralkaline granite; B - syenogranite; C - nepheline syenite;

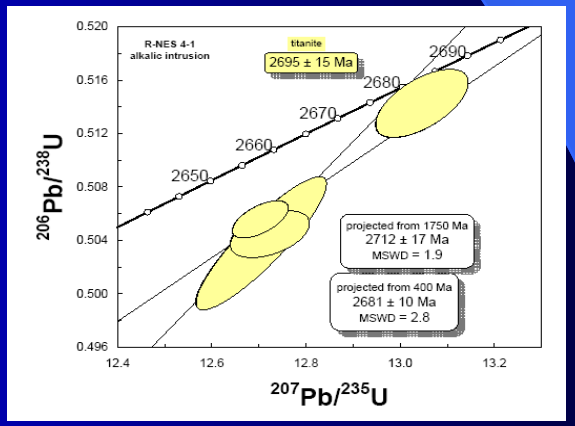
D - alkaline syenite; E-F - gabbro-anorthosites

Geochronology of the Keivy alkaline province

Based on U-Pb zircon dating the sequence of emplacement is the alkaline syenites at 2680 Ma, the alkaline felsic rocks between 2670 and 2650 Ma, and the nepheline syenites at 2610 Ma. This sequence agrees with the geological relationships. A close temporal association is found for the felsic alkaline rocks and the gabbro-anorthosites (emplaced between 2663 and 2659 Ma).

Geology and geochronology of Mikkelvik alkaline stock



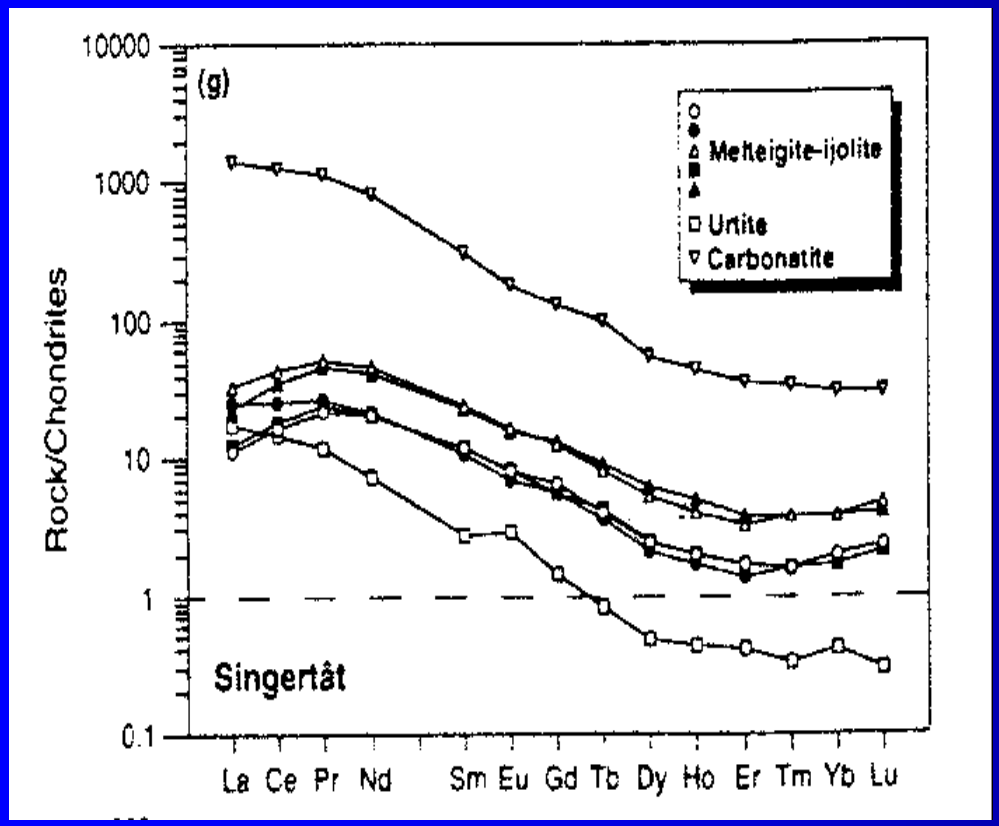


At Mikkelvik on Ringvassoy Island a small 30x50 m stock of nepheline syenite cuts the TTG gneisses of the W. Tromso basement. U-Pb dating of titanite yields an age of 2695 Ma (p.c. of F. Corfu). The stock is composed mainly of coarse-grained nepheline syenite and medium-grained cancrinite syenite dykes.

Summary of Radiometric Ages

Complex	Location	Rock type	Ages (Ma)
Skjoldungen	Greenland	Mafic-inter	2698
		Carbonatite	2664
Siilinjarvi	Finland	Carbonatite	2610
Keivy	Russia	Alkali syenite	2680
		Alkali granite	2670-2650
		Neph syenite	2610
		Gabbro-anorthosites	2663-2659
Mikkelvik	Norway	Neph syenite	2695

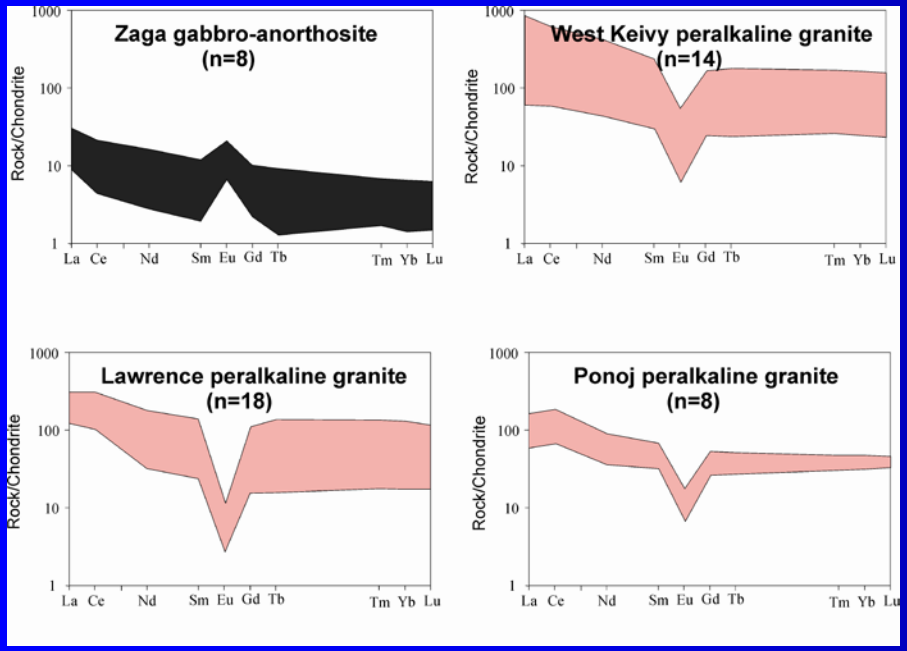
Geochemistry of the Skjoldungen alkaline rocks (from Blichert-Toft et al., 1995)

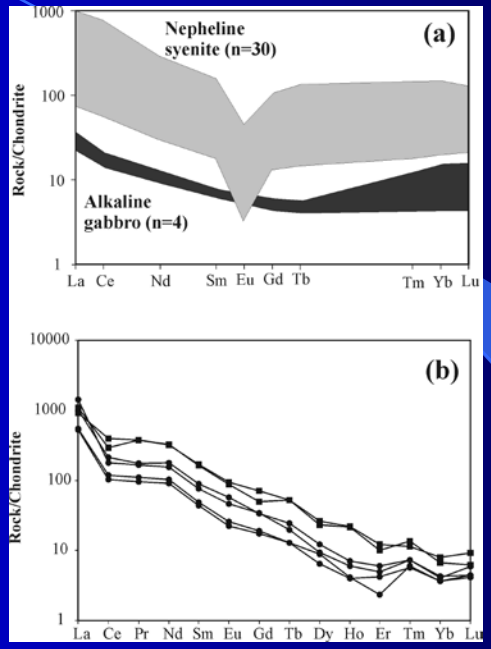


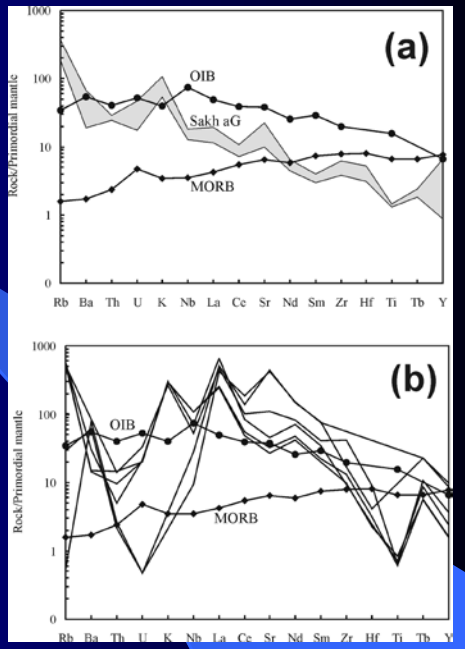
Trace element and REE systematics indicate:

- All intrusive complexes are genetically related.
- Fractional crystallization of olivine, hypersthene, hornblende, and plagioclase is responsible for the SAP compositional variability.
- The parental mafic magma had shoshonitic affinities, was close to Si saturation, and rich in volatiles.

REE and trace element geochemistry of the Keivy alkaline rocks and Siilinjarvi carbonatite



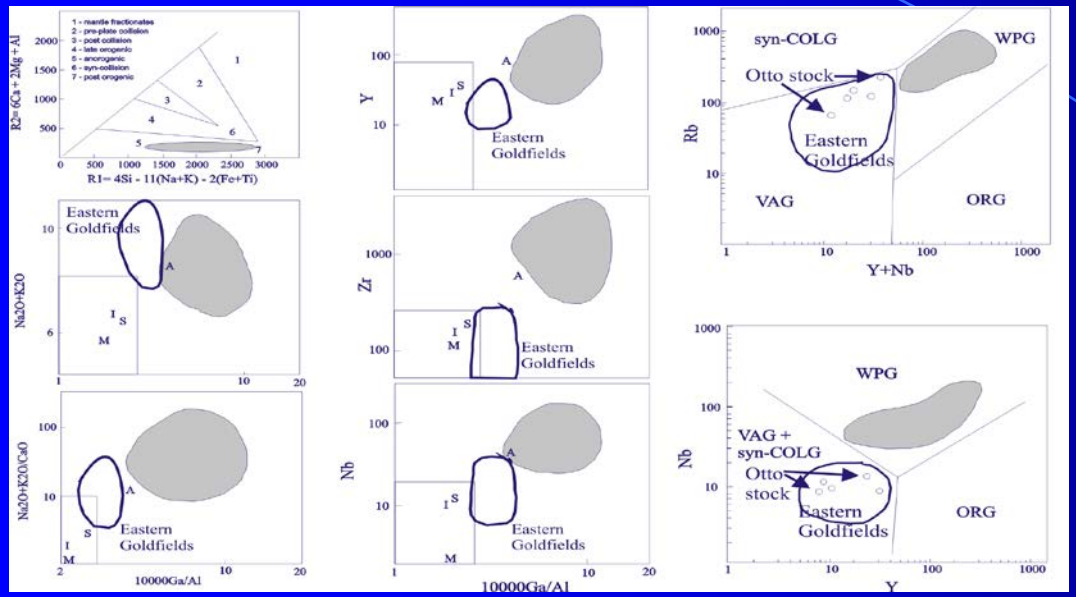




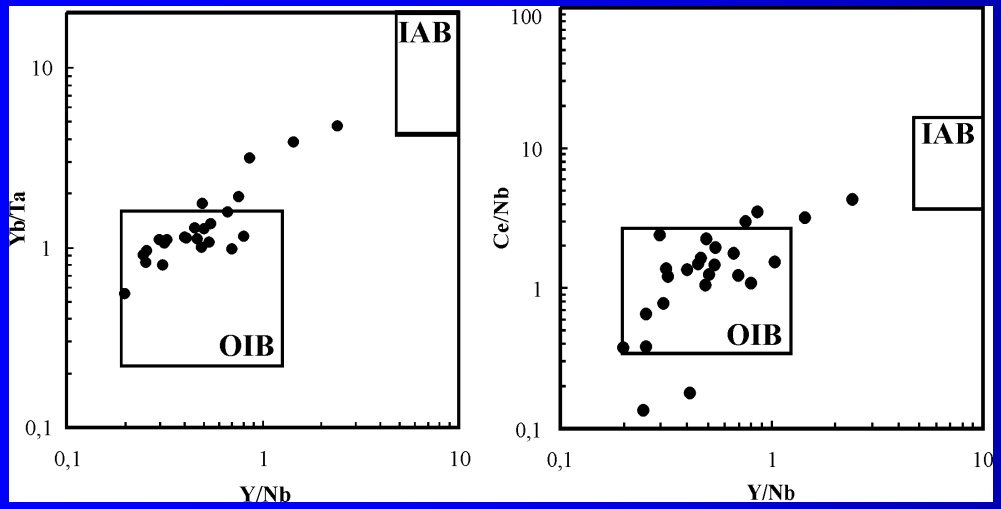
The Keivy peralkaline granites show high REE abundances, low $(La/Yb)_n$ ratios, and distinct negative Eu anomalies indicating the role of fractional crystallization in the evolution of the granites.

(a) The Sakharjok nepheline syenite is highly enriched in REE, has a steep normalized REE pattern, and a negative Eu anomaly. The alkaline gabbro has the most primitive REE distribution and shows no Eu anomaly. (b) The carbonatite has a steep REE normalized pattern and no Eu anomaly. Normalized incompatible trace element concentrations for (a) the Sakaharjok alkaline gabbro and (b) the Siilinjarvi carbonatite show patterns similar to OIB-type magmas.

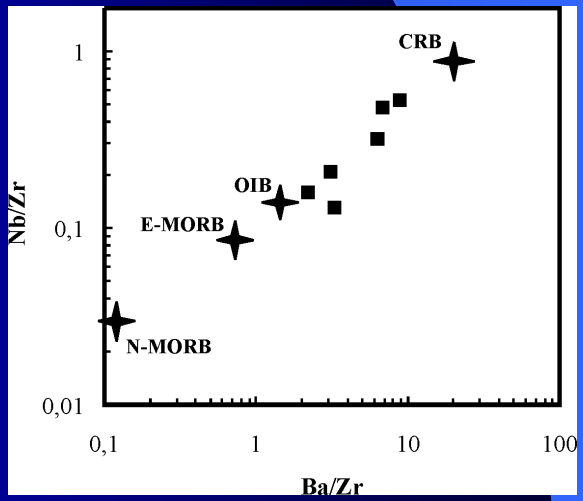
Geochemical features and tectonic discrimination diagrams for Keivy alkaline rocks



The Keivy over- and under-saturated alkaline rocks show very low Ba (c.40-200 ppm) and Sr (c. 5-30 ppm); extremely high Zr, Y, Nb, and Rb; high Ga/Al (for granite); low Y/Nb and Yb/Ta (for syenite). The Keivy peralkaline granitoids were formed in a within-plate setting (left). The Sakharjok nepheline syenite is geochemically similar to OIB. The alkaline gabbro has geochemical affinities similar to OIB-CRB magma (bottom).

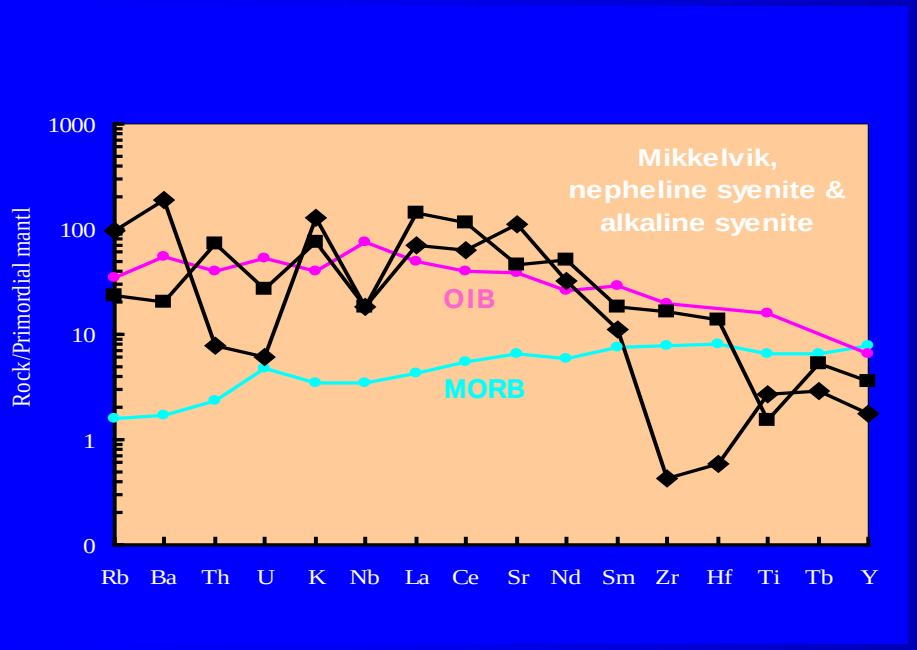


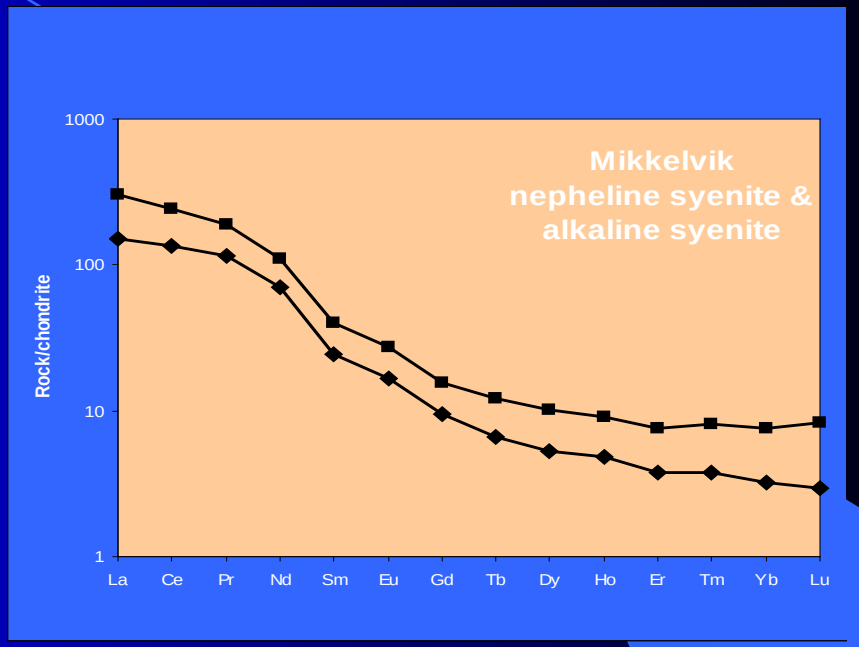
Nepheline syenite



Alkaline gabbro

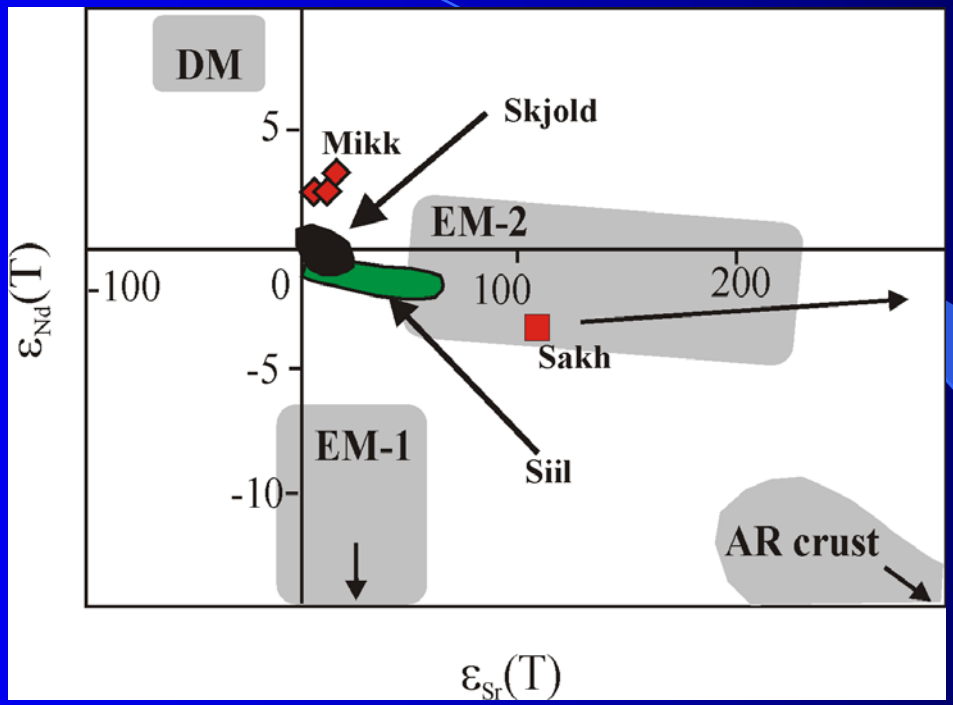
REE and trace element geochemistry of the Mikkelvik nepheline syenite





- Normalized incompatible trace element concentrations for the Mikkelvik nepheline syenites show a pattern similar to OIB-type magmas.
- The syenites have no Eu* anomaly and are enriched in LREE (La/Ybn=40-46).
- The composition of the Mikkelvik nepheline syenite is similar to the nephelinitic rocks of the Skjoldungen alkaline province.

Isotopic geochemistry of the Baltic-Greenland Archaean alkaline rocks



- Near chondritic εNd and positive εSr for SAP reflect characteristics of the mantle source in a subduction zone environment, involving ocean crust recycling. The εNd for SiilC are negative and near chondritic, εSr are variable, showing the transition between SAP source and EM2 source.
- The εNd and εSr for rocks from the KAP vary significantly, showing the disturbance of the isotopic systems at 1980 Ma and 1940 Ma, respectively. Nevertheless the least evolved alkaline gabbro plots in the EM2-field on the εSr - εNd diagram. Parental magmas for KAP were derived by melting of the lithosphere due to impingement of a mantle plume.

Origin and geodynamic setting of the Archaean alkaline complexes from the Baltic-Greenland

- Geochronological and geochemical studies of Archean alkaline complexes from the Baltic and Greenland shields provide some evidence for combined geological development in the time span 2.7-2.6 Ga.
- The similar geochemical signatures suggest that the Archaean alkaline magmatism resulted from development of plume in the sub-lithospheric mantle having enriched characteristics due to subduction processes.
- The observed differences in geochemical features are in accordance with this sequence of magmatic events during plume development: 2.70-2.66 Ga – start, slightly enriched reservoir due to subducted and recycled oceanic crust, mafic shoshonitic parental magma; 2.65-2.61 Ga – evolved enriched reservoir, OIB-like and Na-rich parental magma.