# The Chilwa Alkaline Province, Malawi – Geochemistry, Isotope Geology, and Petrogenesis

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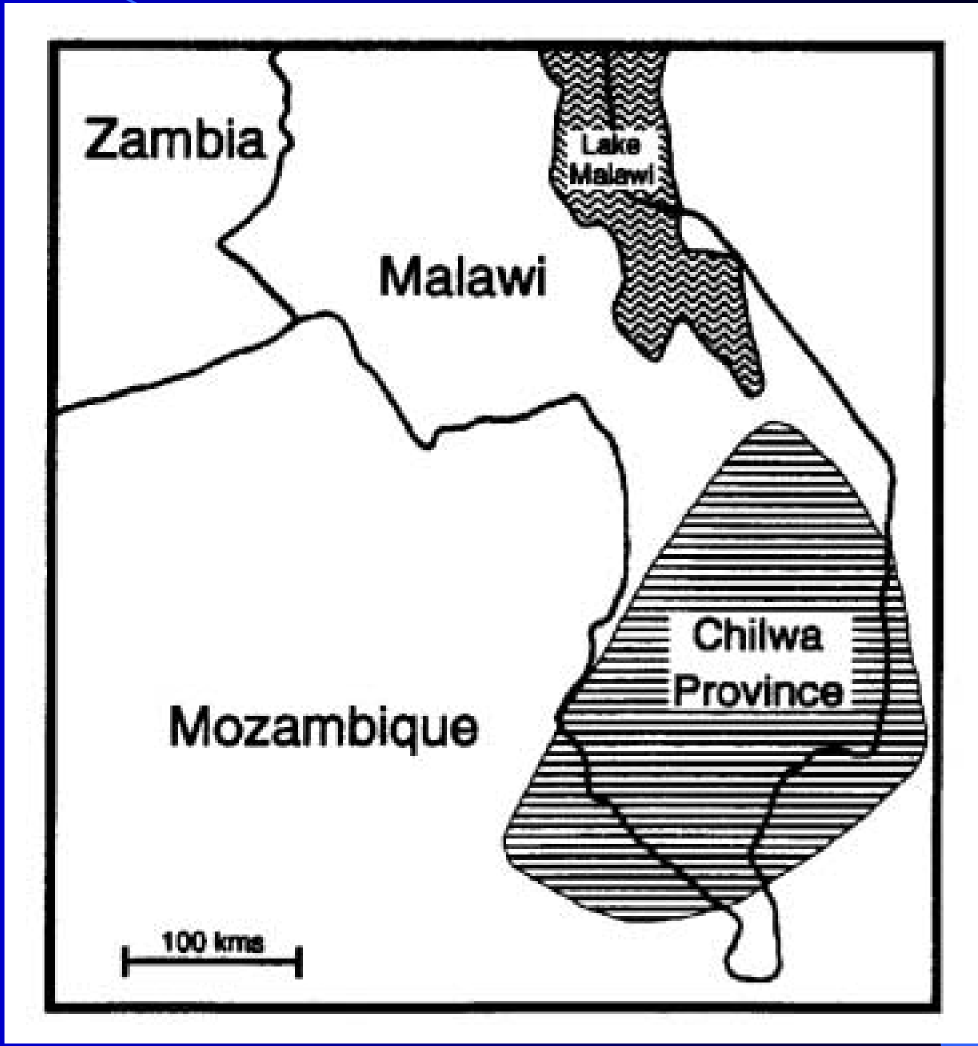
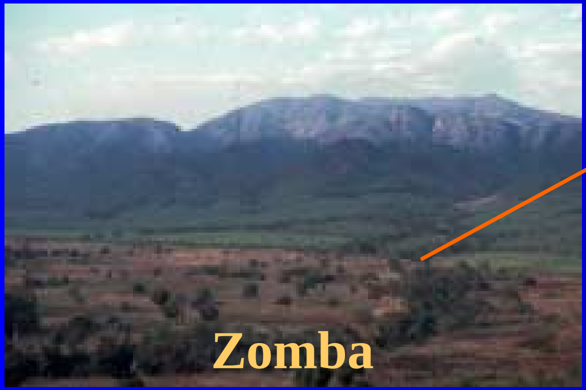
# Chilwa alkaline province – Location

The Cretaceous age Chilwa Alkaline Province (CAP) is located in southern Malawi near the southern end of the present-day East African Rift System.

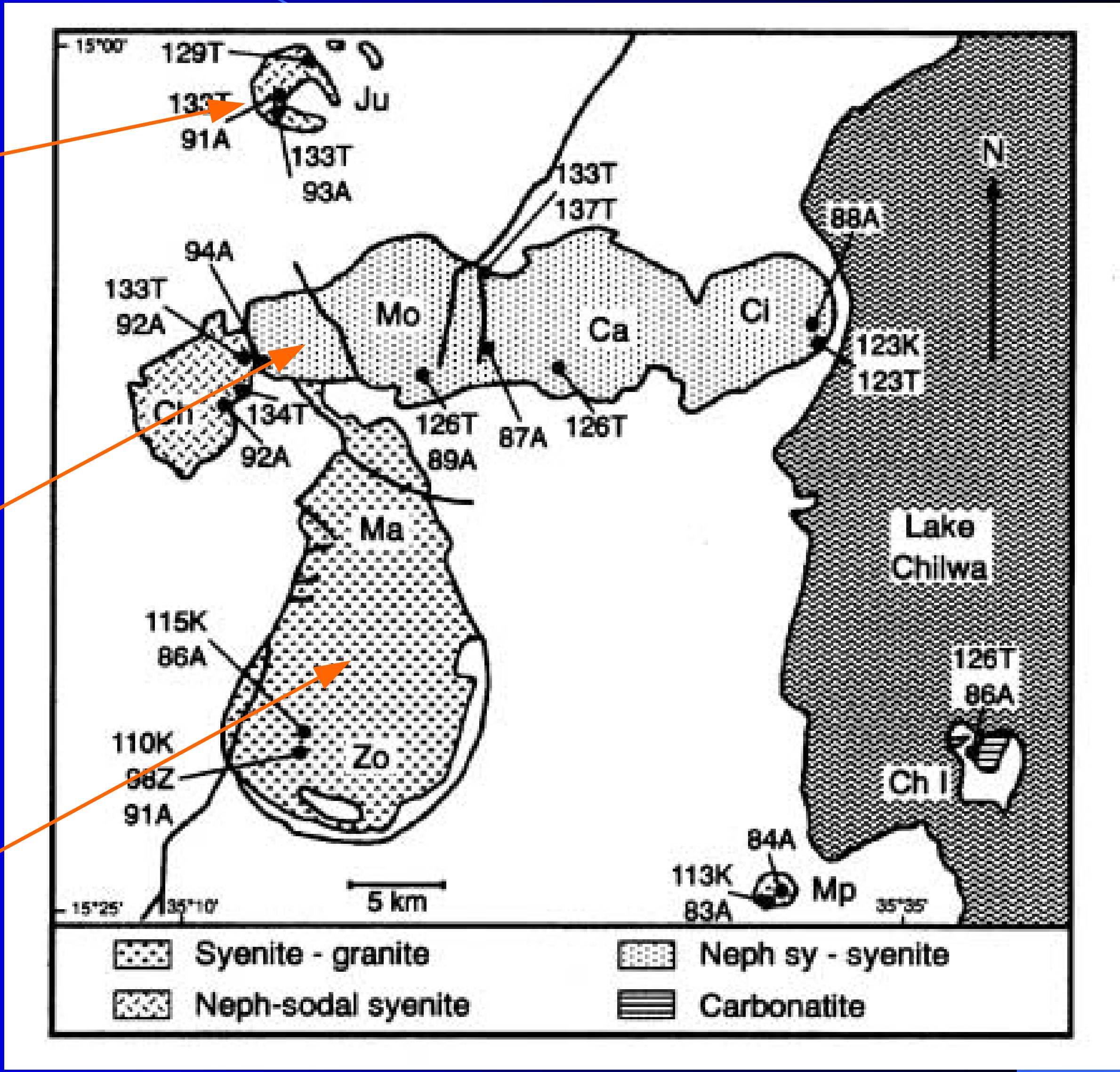


# Geology of the Chilwa Alkaline Province





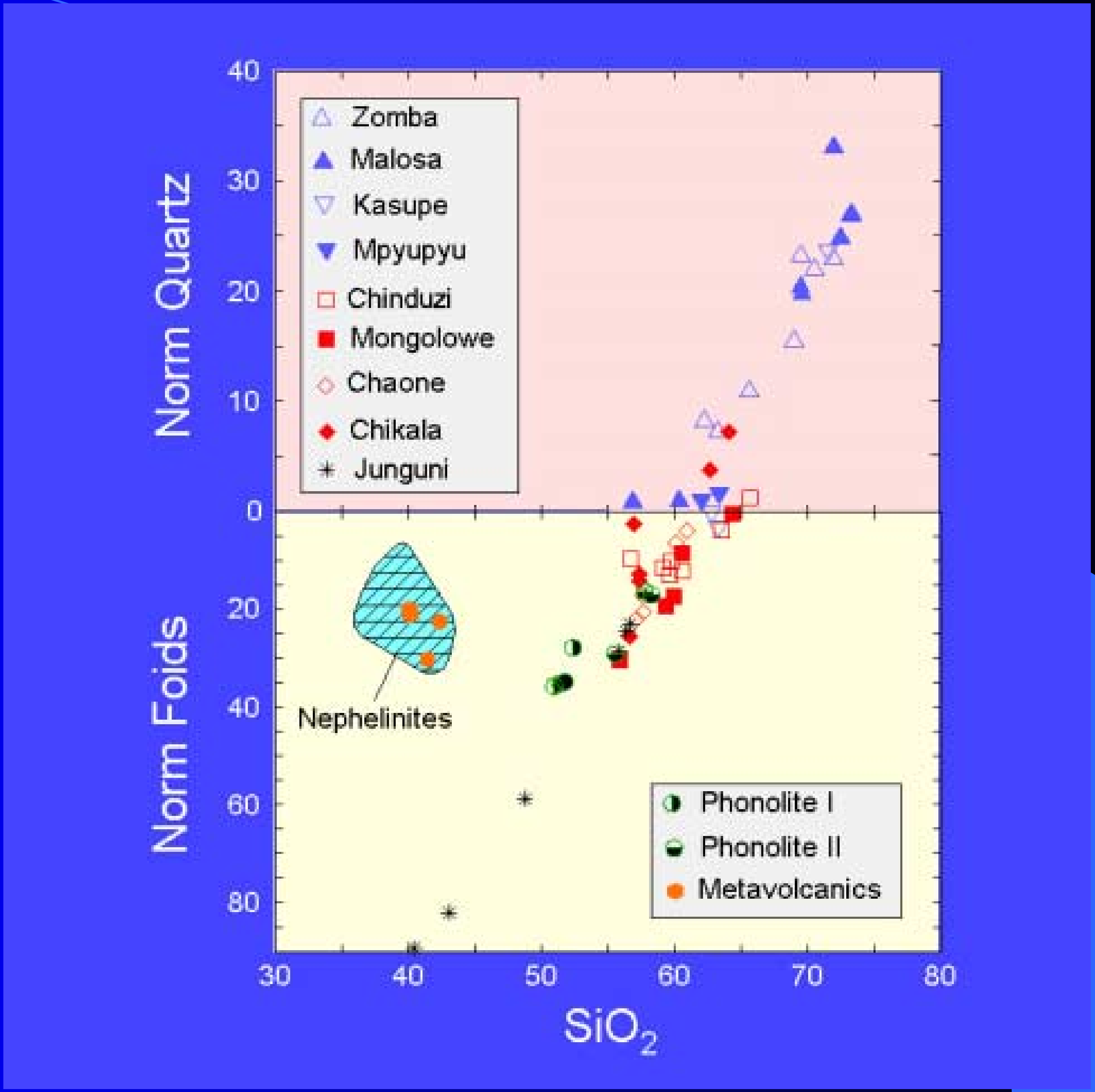

Lithologies: carbonatite, neph-sodal syenite, neph syenite, syenite, granite



# Degree of silica saturation for the major plutonic and volcanic units

Felsic rocks vary from strongly silica-undersaturated nepheline-sodalite syenites to alkali granites.

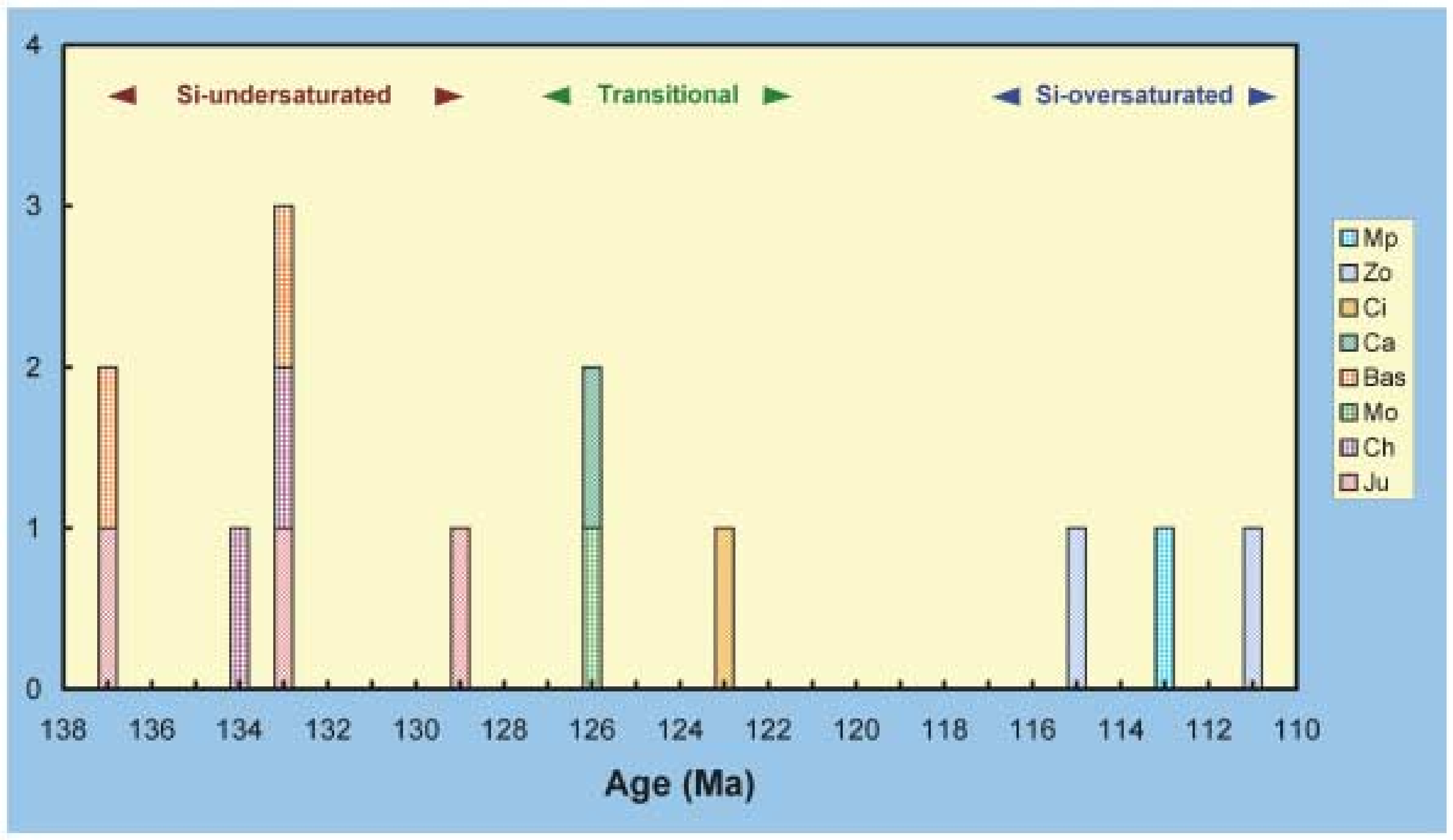
Mafic rocks are silica-undersaturated basanites and nephelinites.



# Age versus degree of silica saturation

**Sequence of emplacement:**

- **Basanites + neph-sodal syenites (138-132 Ma)**
- **Neph syenites + syenites (129-123 Ma)**
- **Syenites + granites (115 – 111 Ma)**



## Major lithologies of the Chilwa Province

- Metavolcanics (basanites) and olivine nephelinites
- Nepheline- sodalite syenites and nepheline syenites
- Syenites and alkali granites

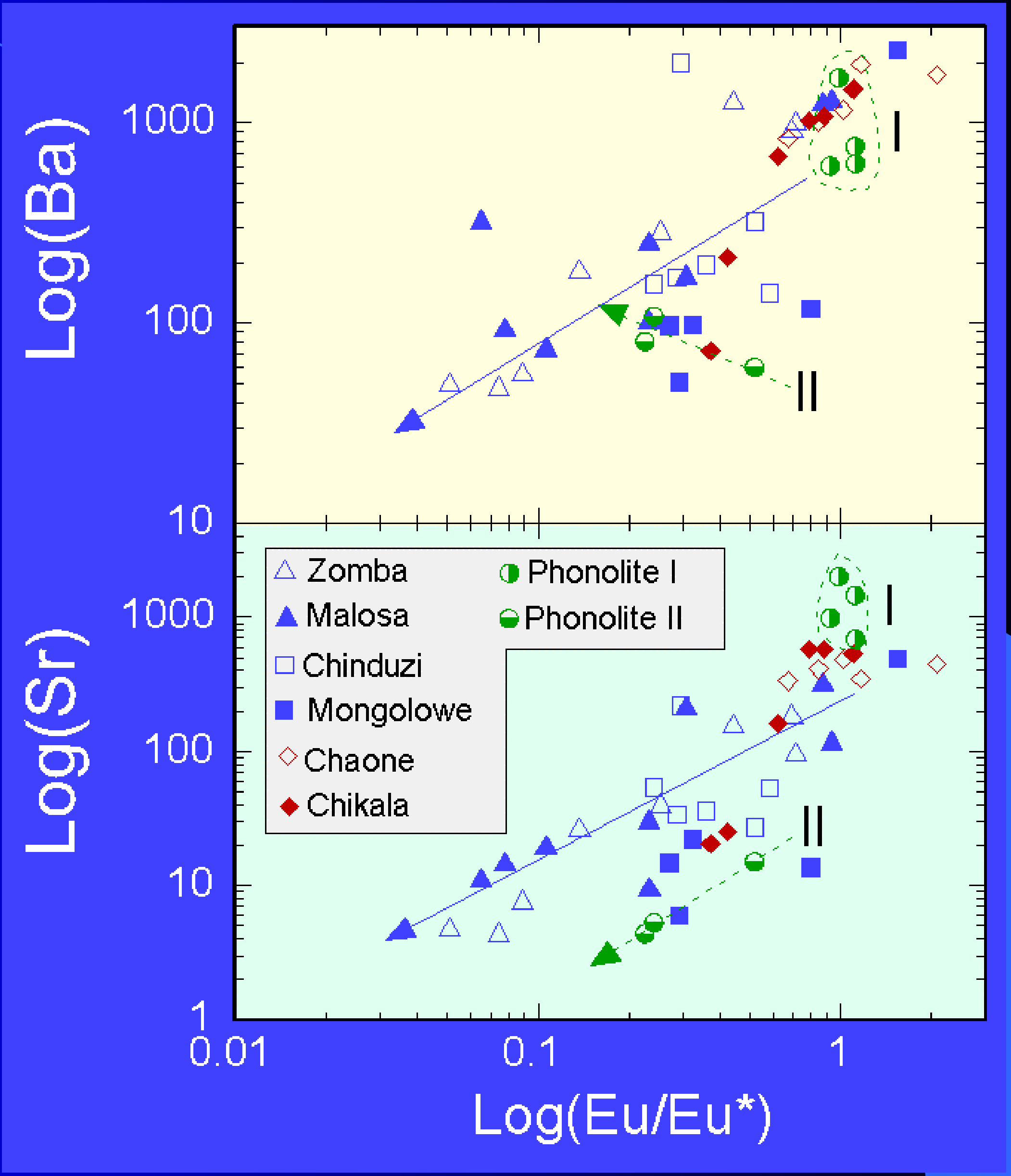
## Sequence of emplacement

- Lava flows (basanites) and nepheline-sodalite syenites
- Nepheline syenites and syenites
- Syenites and alkali granites

## The pattern is increasing silica content with decreasing age

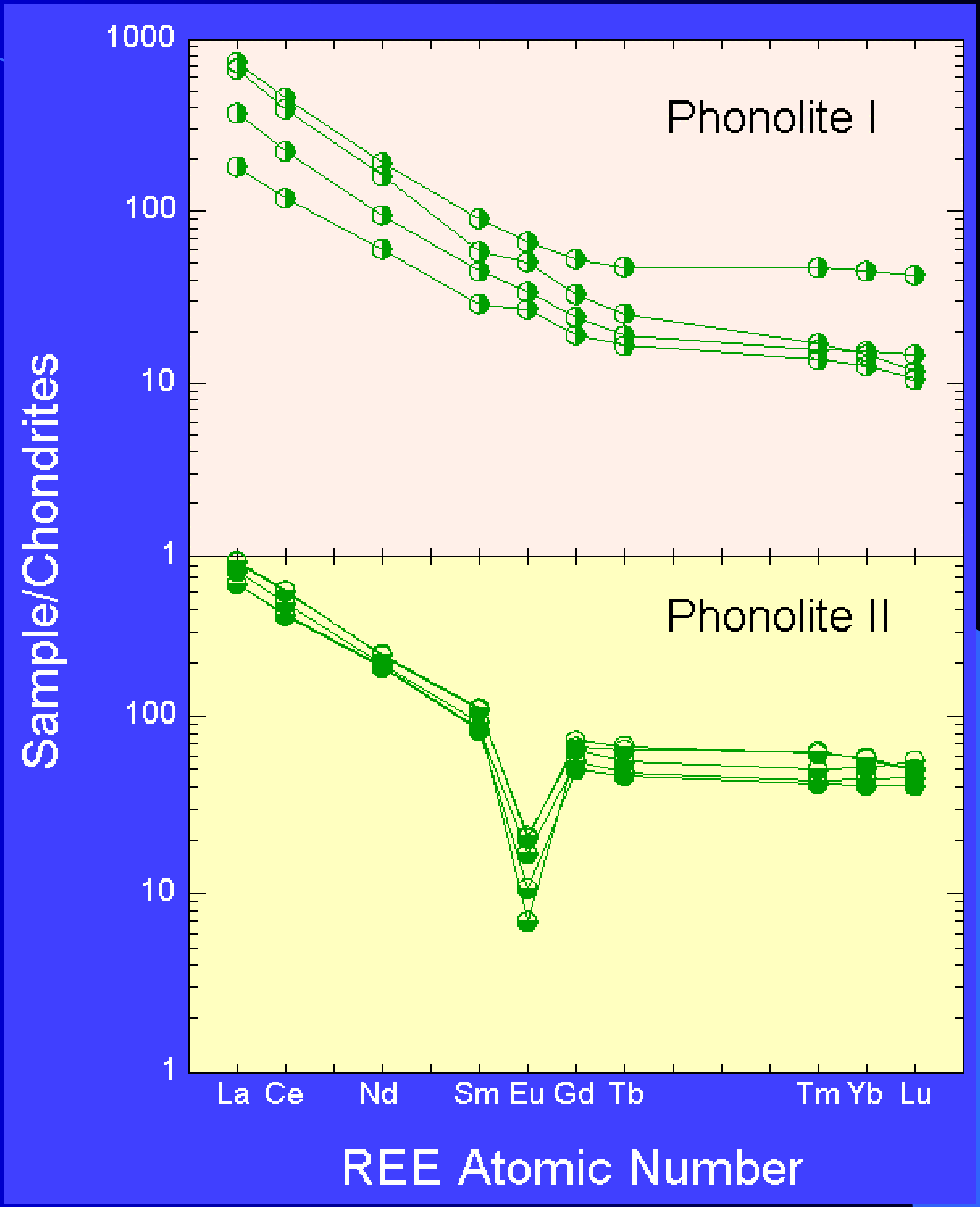
# Log Eu* vs log Sr, Ba

- Two groups of phonolites can be distinguished, one that shows negative Eu anomalies, one that doesn't
- The alkali granites and syenites (Zomba & Malosa) roughly fall along alkali feldspar + plagioclase fractionation vectors.
- Many of the nepheline syenites also show negative Eu anomalies indicating that feldspar fractionation played a role in their evolution.



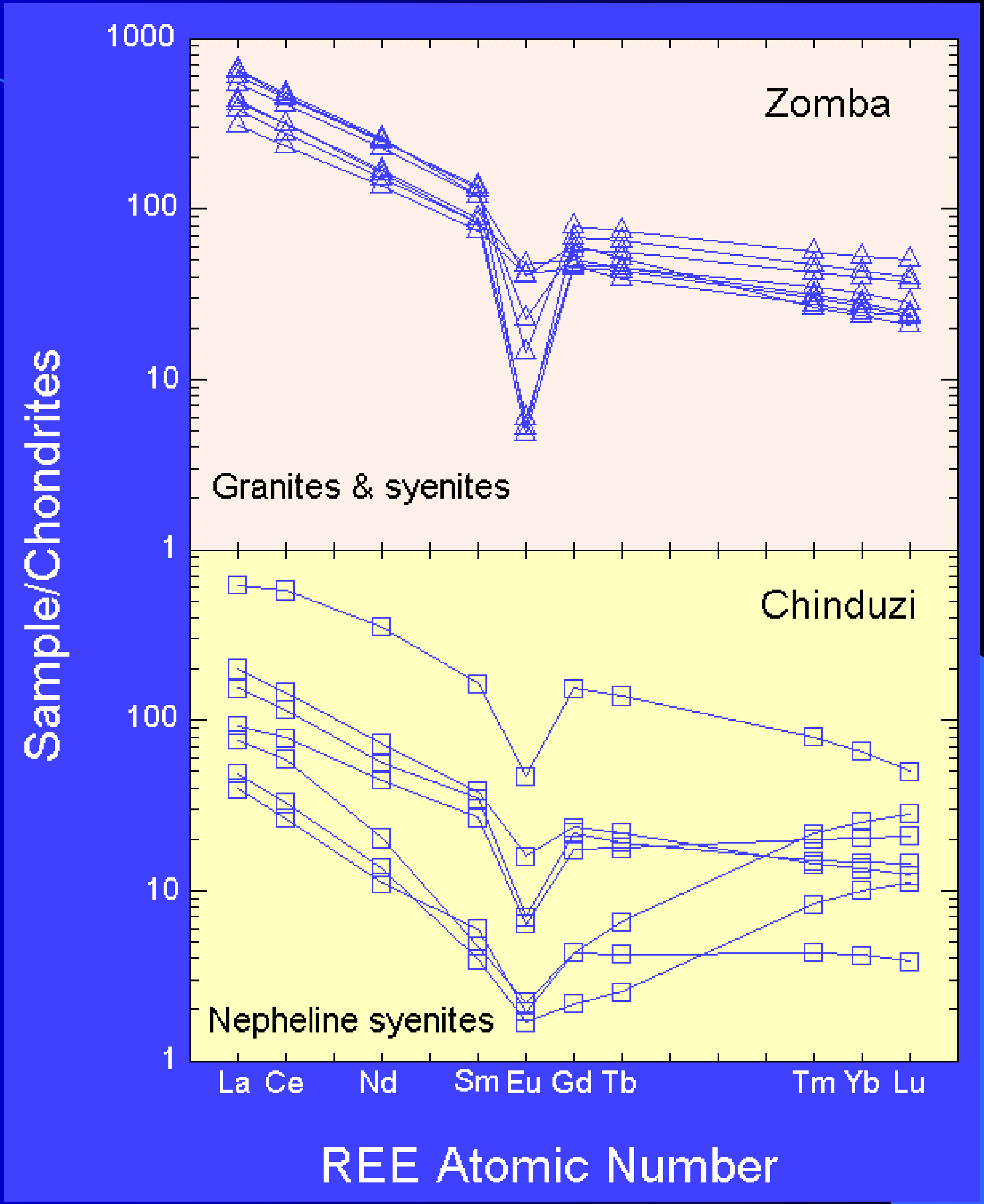
**The two phonolite groups are distinguished on the basis of the presence or absence of an Eu anomaly. Note that the REE patterns are broadly similar for both groups. Several Phonolite I samples show small positive Eu anomalies suggesting the presence of cumulus feldspar.**

**The inference is that the evolution of group I phonolites occurred at high pressures where plagioclase crystallization was suppressed.**

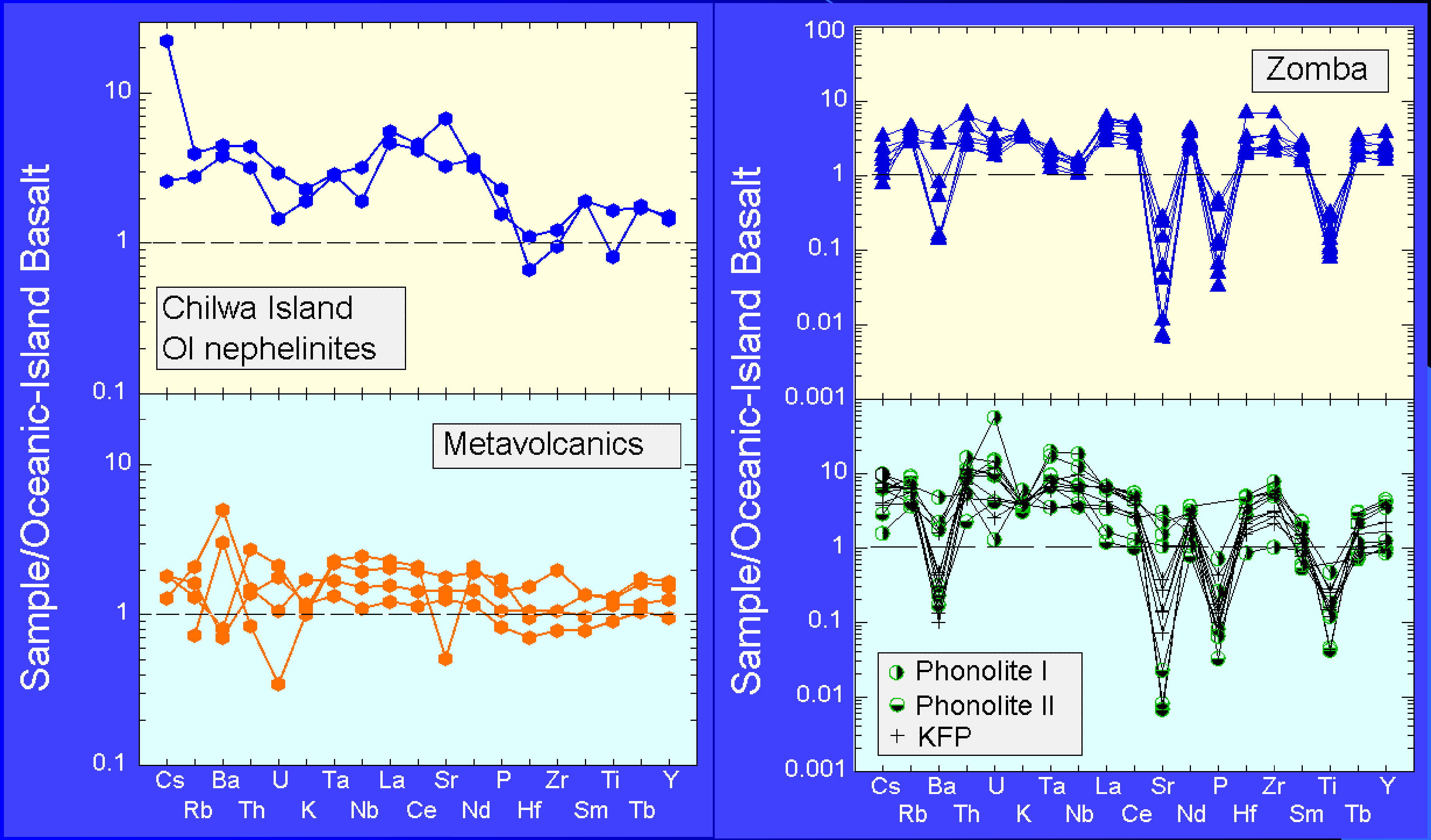


**REE patterns for Zomba are subparallel and show increasing negative Eu anomalies with increasing total REEs, typical of a feldspar fractionation trend.**

**REE patterns for Chinduzi are much more irregular and, in particular, the presence of U-shaped (or V-shaped) patterns suggests that there may have been postmagmatic redistribution of the elements by F- and/or $CO_3$-rich hydrothermal fluids.**



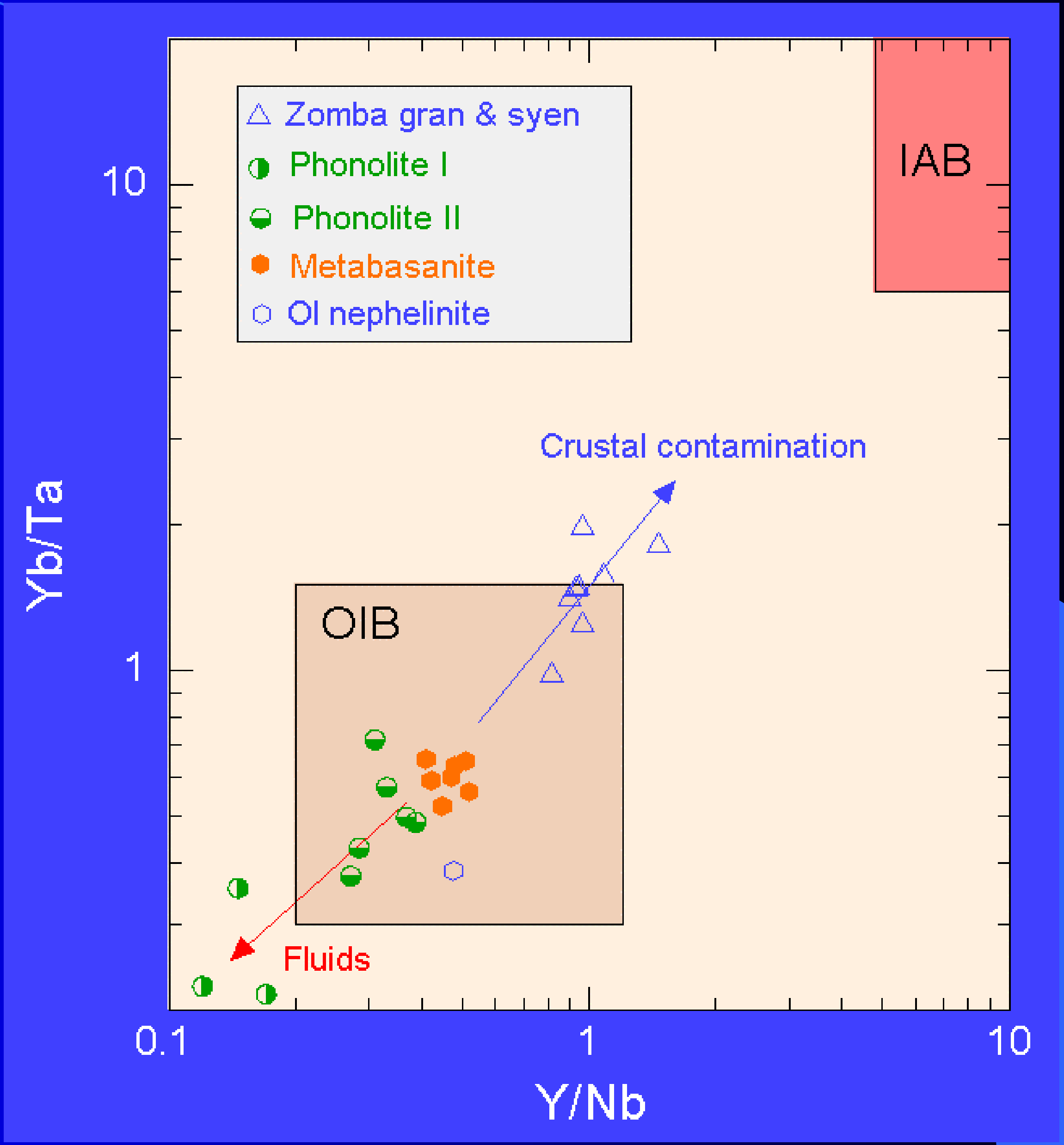
**Spider diagrams:** Note the similarity to OIBs. Depletion of Ba, Sr, P, and Ti in the more evolved rocks is indicative of feldspar, apatite, and ilmenite/magnetite fractionation.



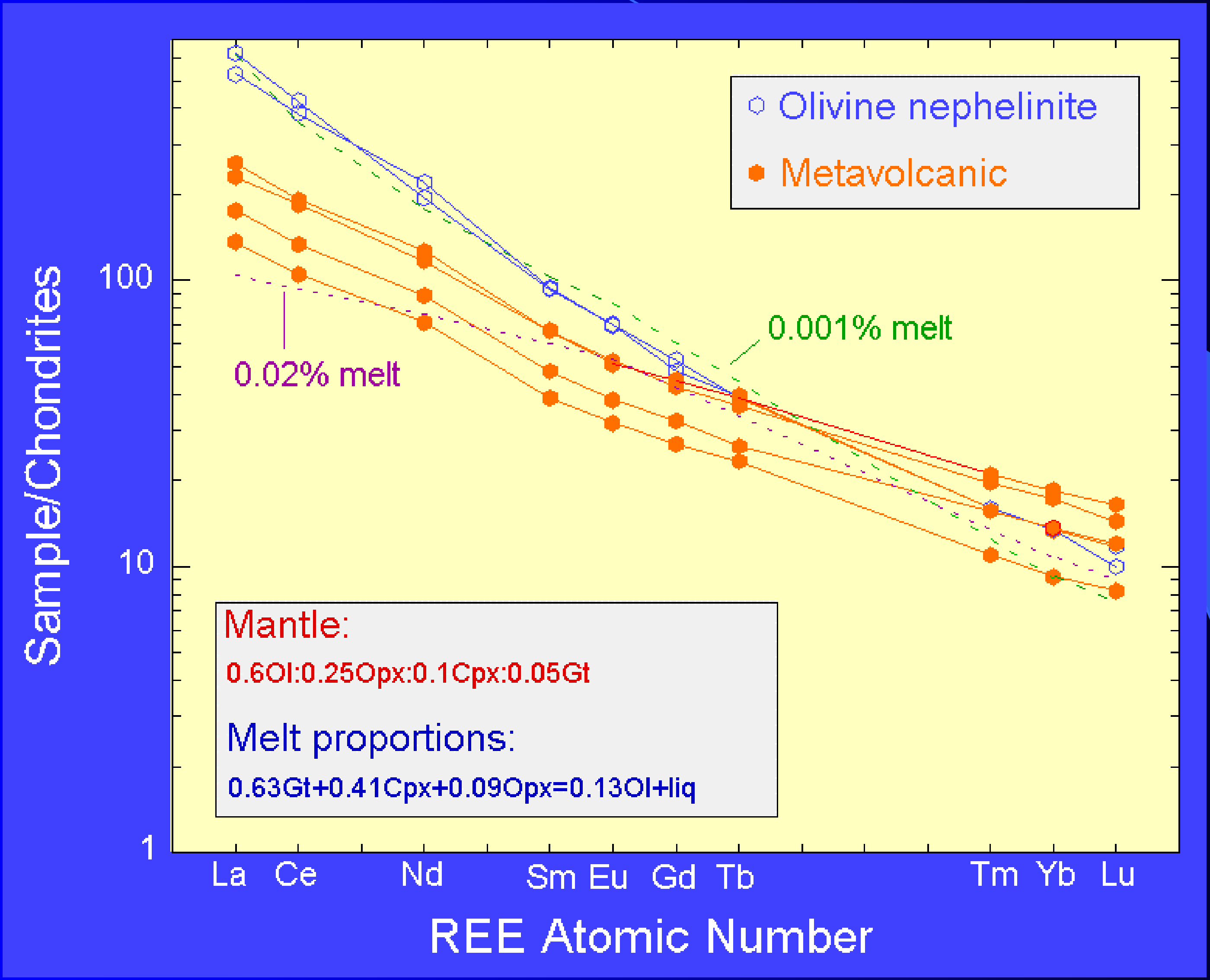
**Y/Nb vs Yb/Ta diagram:** The metabasanites and olivine nepehlinites plot in the OIB field.

The blue vector indicates the effect that crustal contamination would have on these ratios.

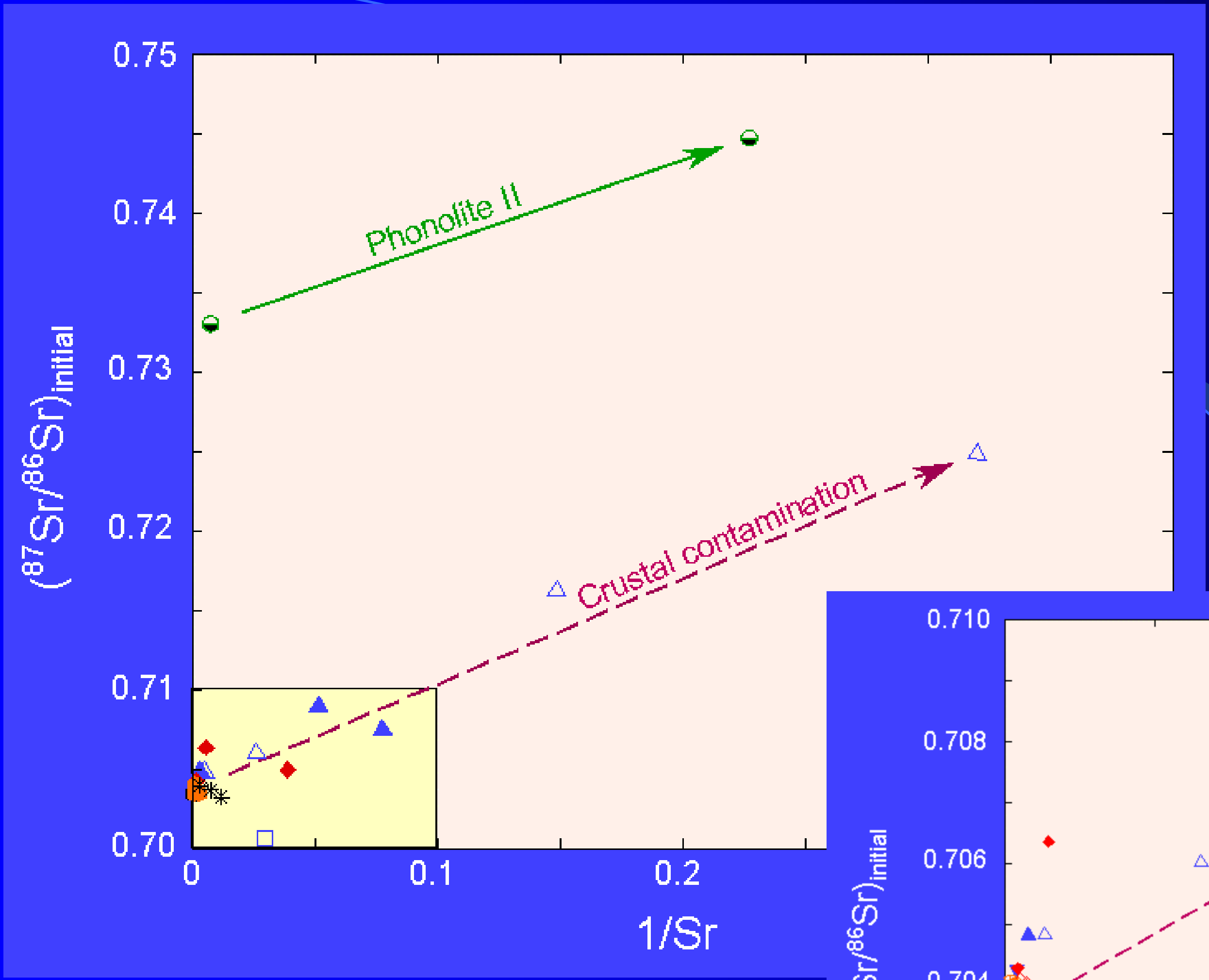
The red vector indicates the effect that F- and/or $CO_3$-rich fluids would have on these ratios.

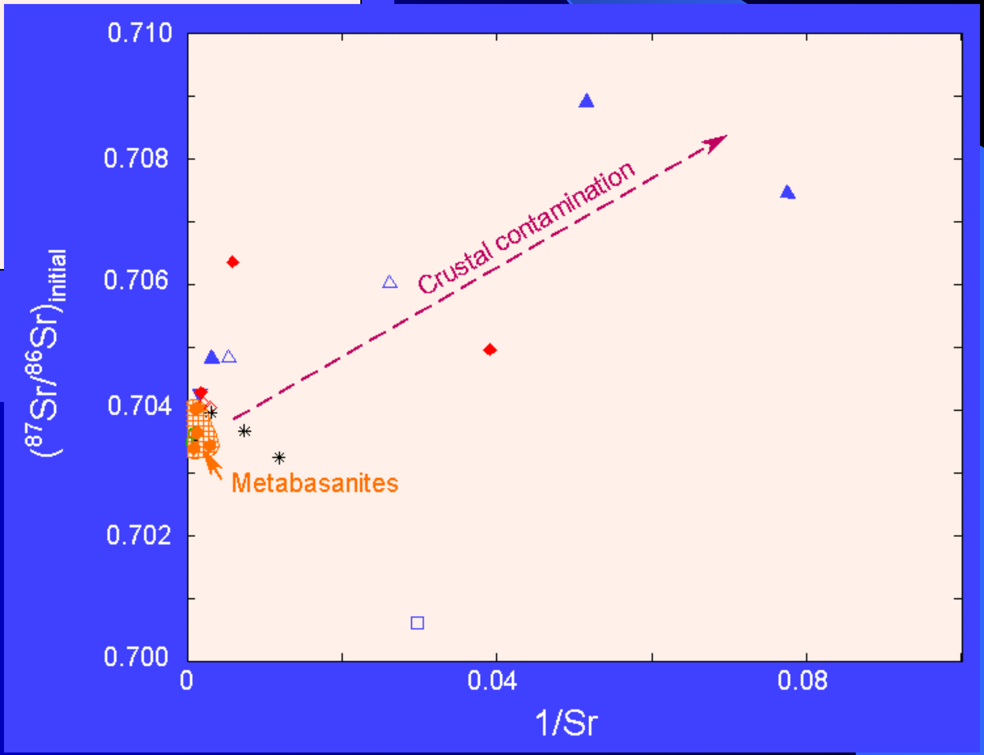


# Melting model for the generation of the olivine nephelinites and basanites (metavolcanics) from a garnet lherzolite, chondritic mantle.



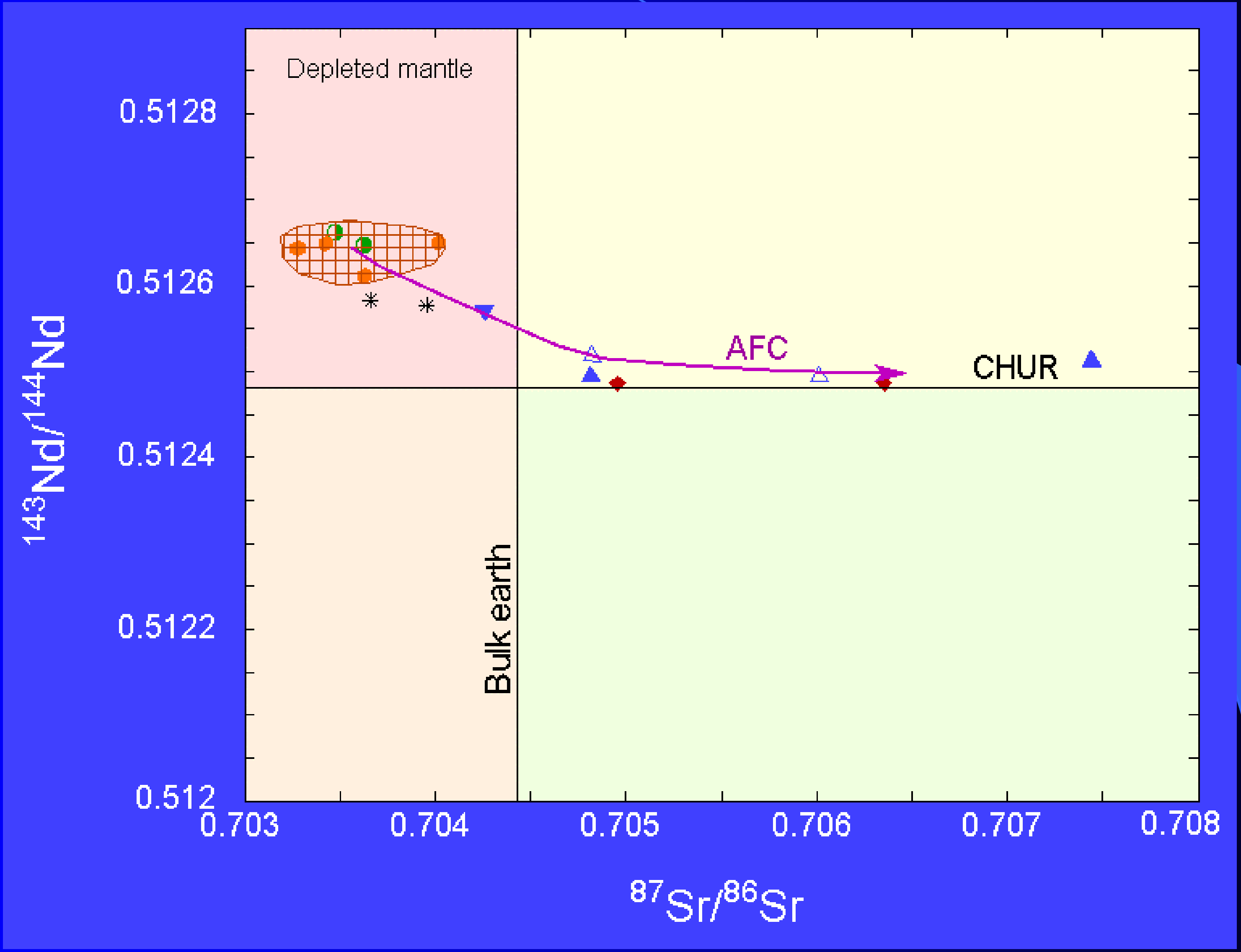
# 1/Sr vs initial $^{87}Sr/^{86}Sr$ for the various lithologies




**Note that the phonolites also form two isotopically distinct groups. Vector indicates effect of crustal contamination on isotopic compositions.**

**The majority of the CAP samples fall in the depleted mantle field. Samples that plot outside this field lie along a possible AFC curve.**



## Conclusions:

- **The CAP magmas were drawn from a depleted mantle source**
- **This source does not need to be enriched, small volume melts can generate the observed REE patterns for the olivine nephelinites and basanites**
- **All the lithologies show a strong OIB-like source imprint and can largely be related by fractional crystallization + some crustal contamination (AFC)**
- **With time, the magmas became relatively enriched in silica presumably due to crust-magma interactions at depth**
- **Late-stage fluid interactions played an important role in redistributing HFSE**