

# A-type Granites

## Classification and Petrogenesis

### A Multi-Dimensional Problem



# The A-type Granitoids

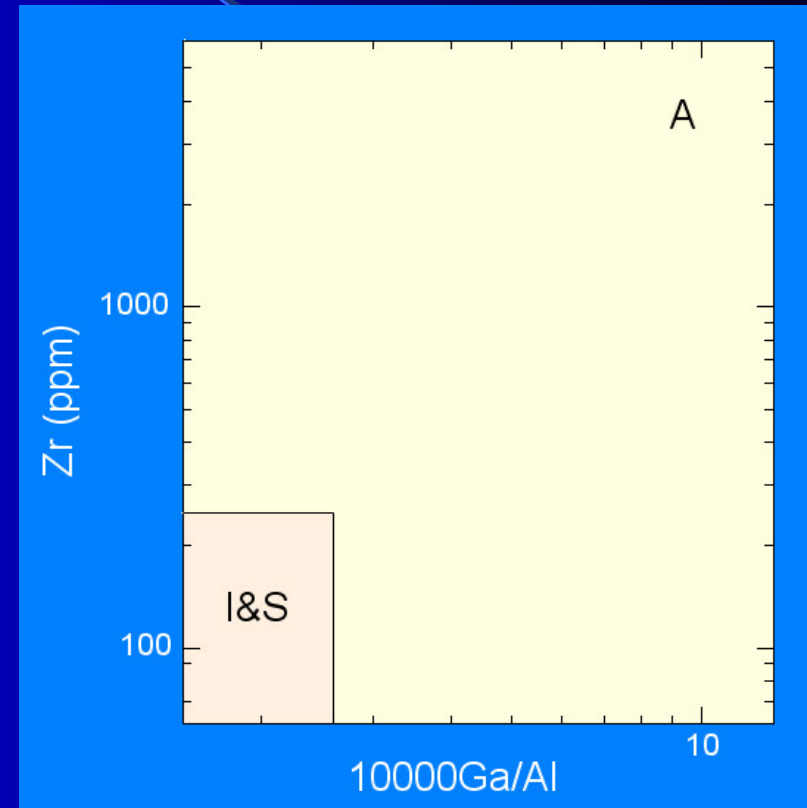
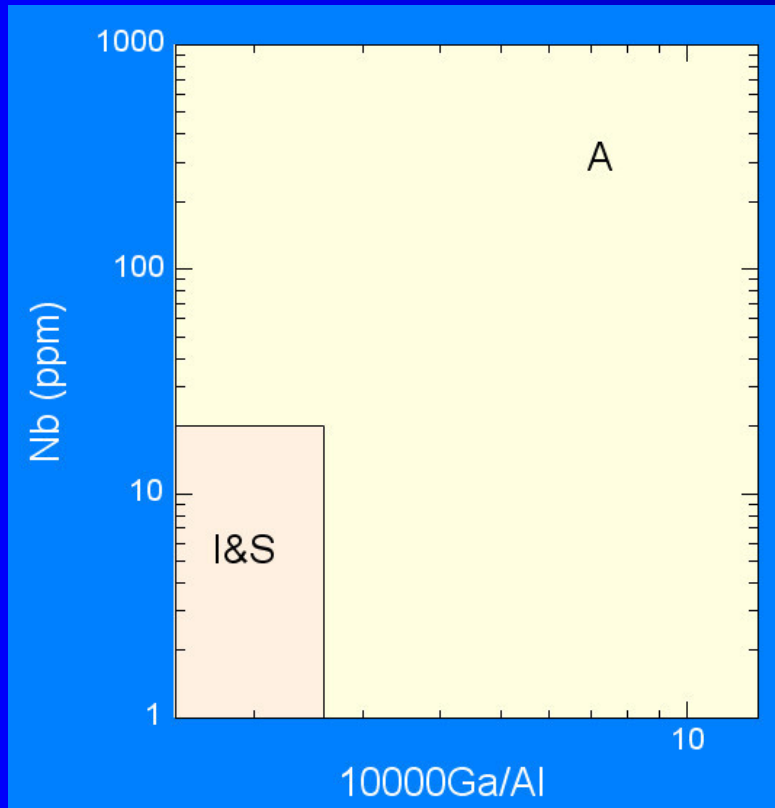
- Defined by Loiselle and Wones (1979)
- *A* stands for *A*norogenic or *A*nhydrous
- Magmas are emplaced in post-collisional or within plate settings, i.e., an extensional environment.
- May be produced by the melting of a lithospheric source from which a previous melt had been extracted or by differentiation of a basalt magma.

This is a very different definition from that of the I- and S-type granitoids because it includes both tectonic setting and chemical characteristics of the magmas. Many of us may know what we mean by the term A-type, but it does not fit with the other letters of the alphabet soup.

# Characteristics of A-type Granitoids

1. Nonorogenic setting
2. Subaluminous to peralkaline trends, sometimes peraluminous
3. For rocks of intermediate silica content, A-type granitoids generally have higher total alkalis and lower CaO than other granitoids.
4. High  $\text{FeO}_T/\text{MgO}$
5. High halogen, and particularly high F, content ( $\text{Cl} = 0.02 - 0.2 \text{ wt.}\%$  and  $\text{F} = 0.05-1.7 \text{ wt.}\%$ )
6. A characteristic mineralogy consisting of iron-rich mafic silicates (annite, ferrohendenbergite, ferrohastingsite, fayalite), and in peralkaline suites alkali-rich mafic silicates (aegirine, arfvedsonite, reibeckite) and perthitic feldspars

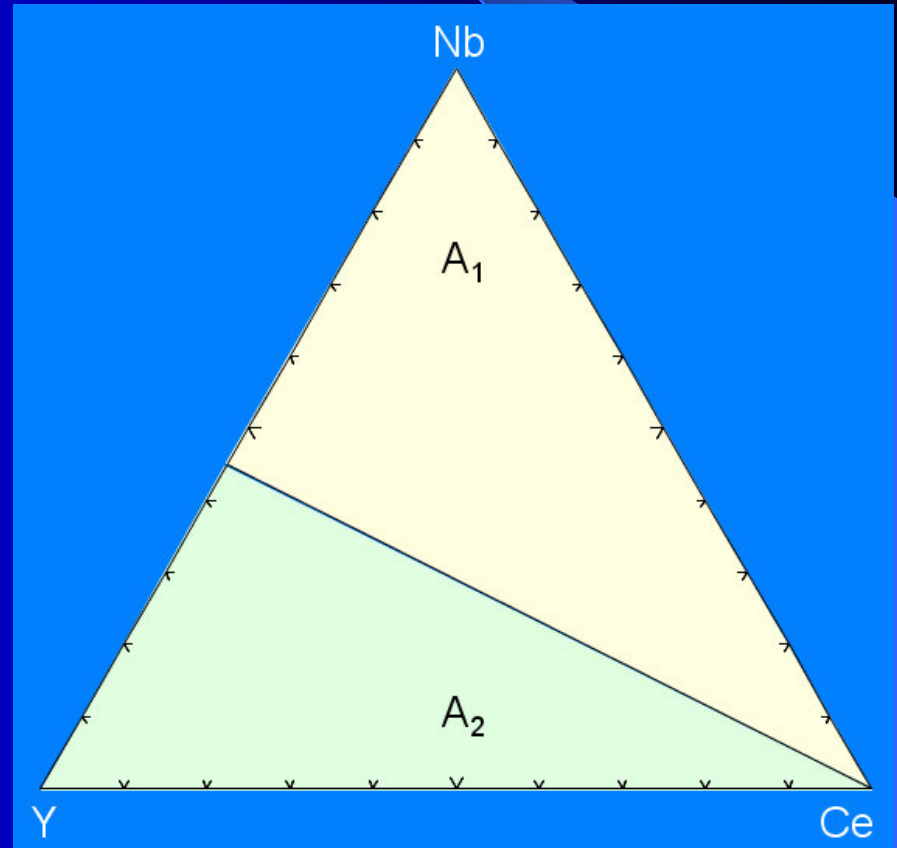
7. Characteristic trace element abundances as evidenced by enrichment in HFS elements. Plot in the WPG fields of Pearce et al. (1984) and the A-type fields of Whalen et al. (1987)



A-type discriminant diagrams of Whalen et al. (1987)

8. Eby (1992) suggested that the A-type granitoids, based on certain trace element distributions, could be divided into two groups. Granitoids that plot in the A<sub>1</sub> group were interpreted as differentiates of basalt magma derived from an OIB-like source while granitoids that plot in the A<sub>2</sub> group were derived from the subcontinental lithosphere or lower crust.

It should also be noted that A<sub>1</sub>-types invariably are associated with true anorogenic (within plate) settings while A<sub>2</sub>-types are often emplaced in post-collisional, post-orogenic settings.

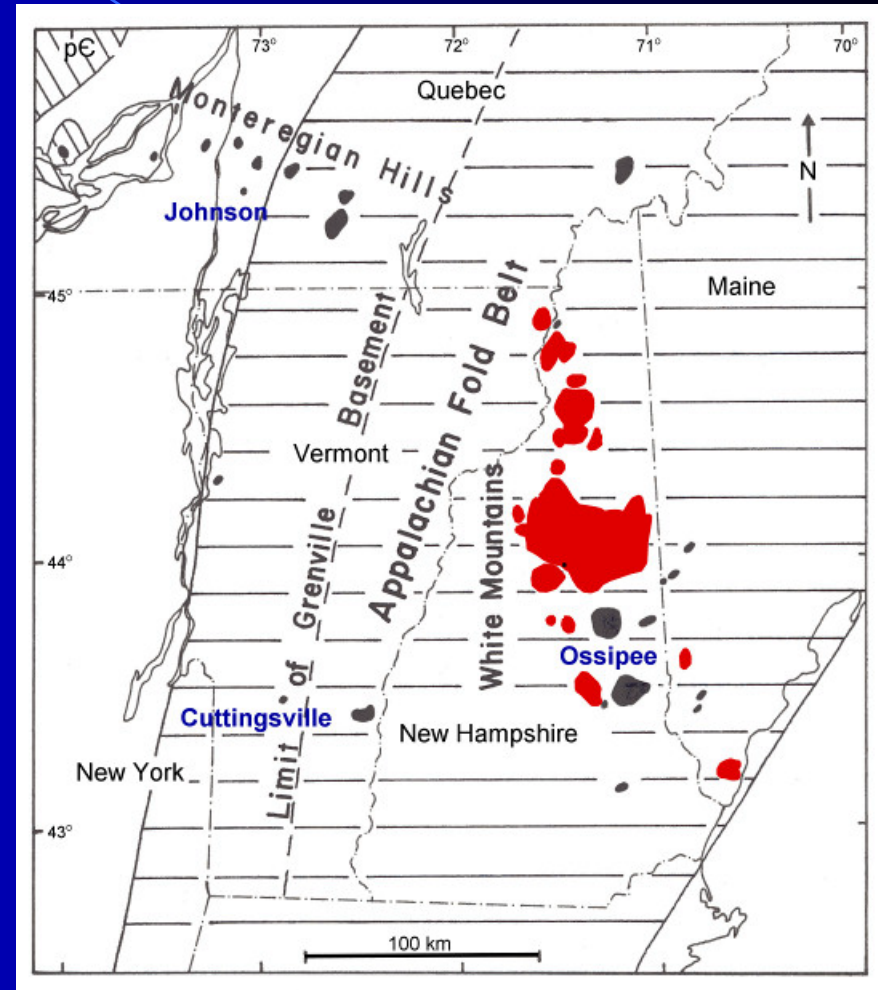


# A<sub>1</sub>-type Magmatism

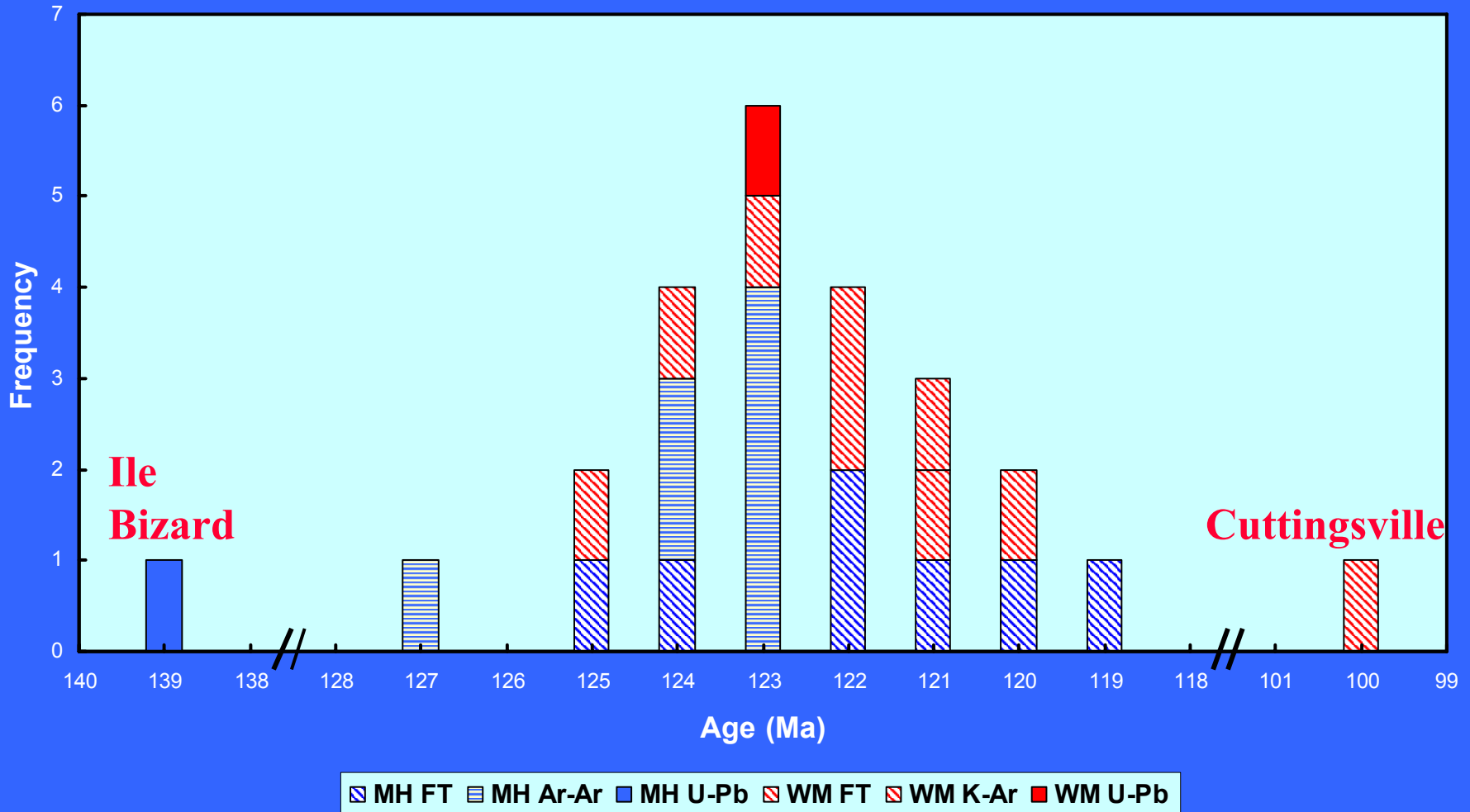
1. Occurs in a true anorogenic within-plate setting. Generally separated from periods of compressional tectonics by 50 to 100 million years or more.
2. Is often associated temporally and spatially with silica-undersaturated alkaline rocks.
3. In terms of trace elements, these magmas have OIB-like signatures.
4. In some provinces mafic lithologies are abundant, in others mafic lithologies are rare.
5. Examples include the White Mountain igneous province (160 to 200 Ma and ~124 Ma) of North America and the North Nyasa (~720 Ma) and Chilwa (138-110 Ma) alkaline provinces of Malawi.

# Examples of A<sub>1</sub>-type Granitoid Provinces – White Mountains, NH, USA

Two periods of granitoid magmatism (White Mountain province) in Eastern North America at ~180 Ma and ~124 Ma. This is well after amalgamation of the North American craton and is precursor to the opening of the North Atlantic Ocean. Rocks of a correlative age to the younger period of igneous activity (124 Ma), but forming a silica-undersaturated suite (Monteregian Hills), are found in Canada.



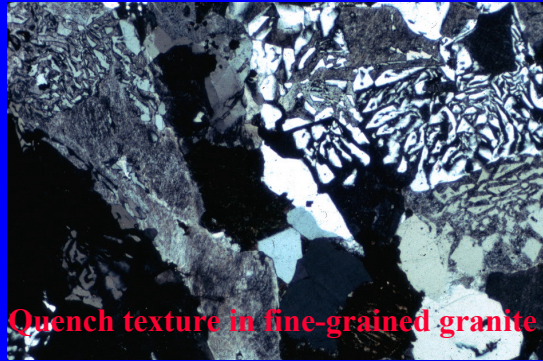
# Age relations for Monteregeian Hills and Younger White Mountains



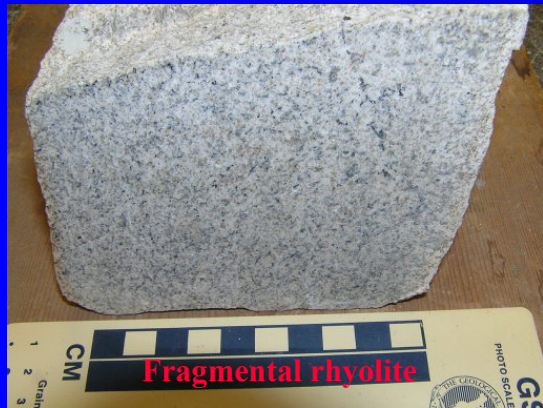
With the exception of Ile Bizard and Cuttingsville, there is essentially a complete overlap in ages for the two provinces.



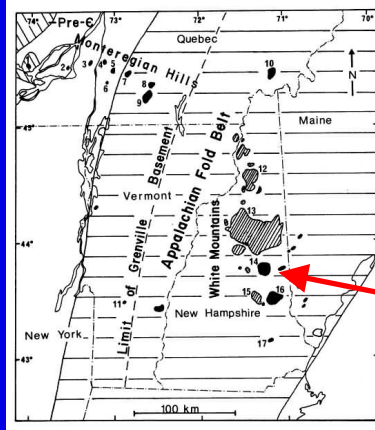
# The Ossipee Ring Complex – an example of younger White Mountain magmatism



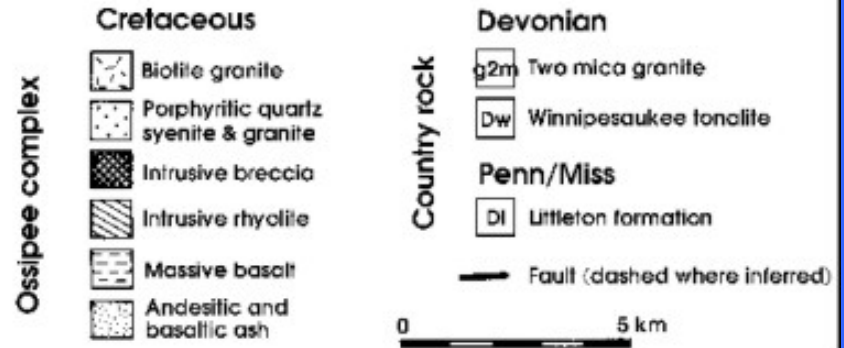
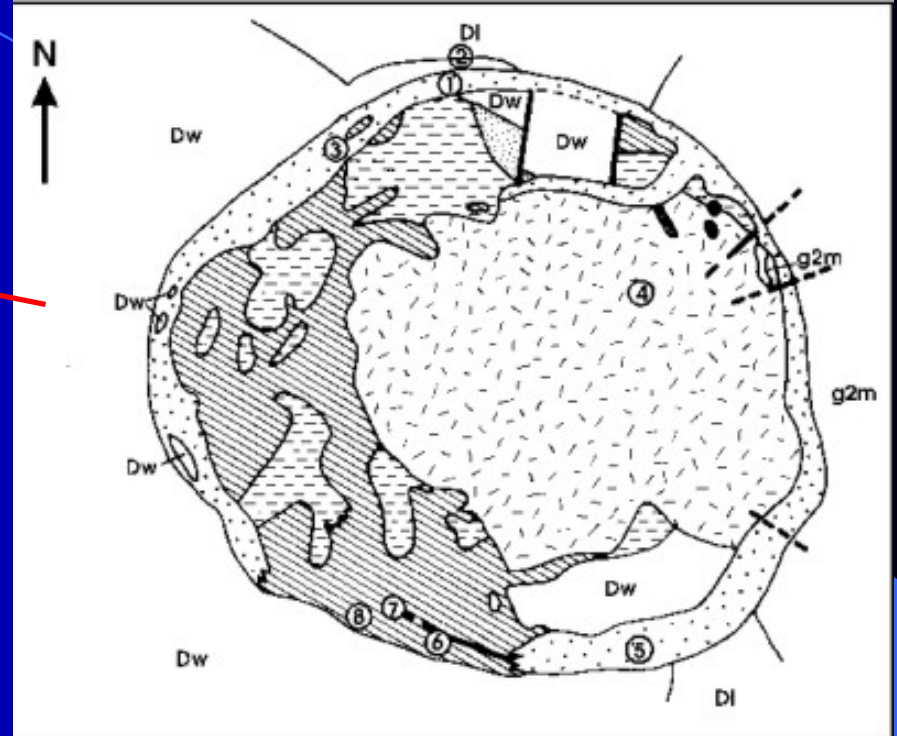
Quench texture in fine-grained granite



Fragmental rhyolite



High level intrusion, classic ring-complex structure

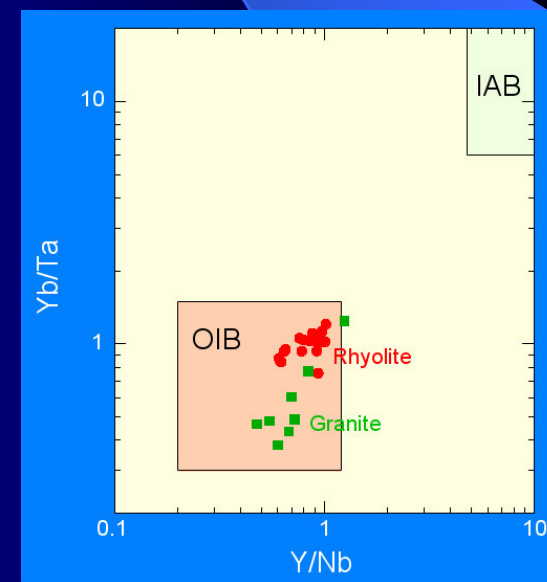
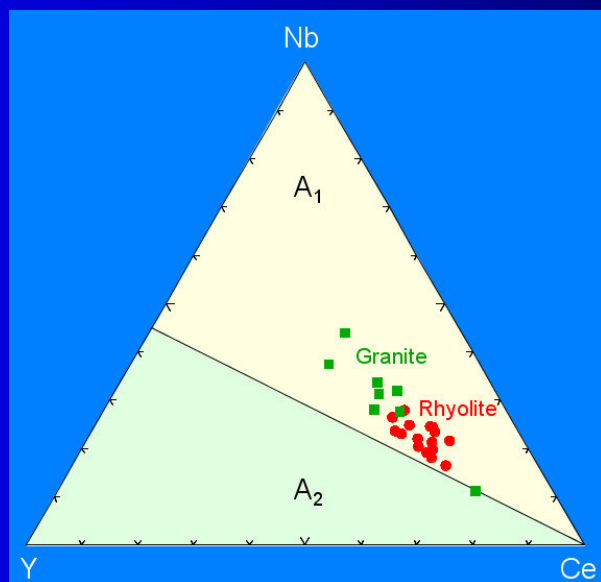
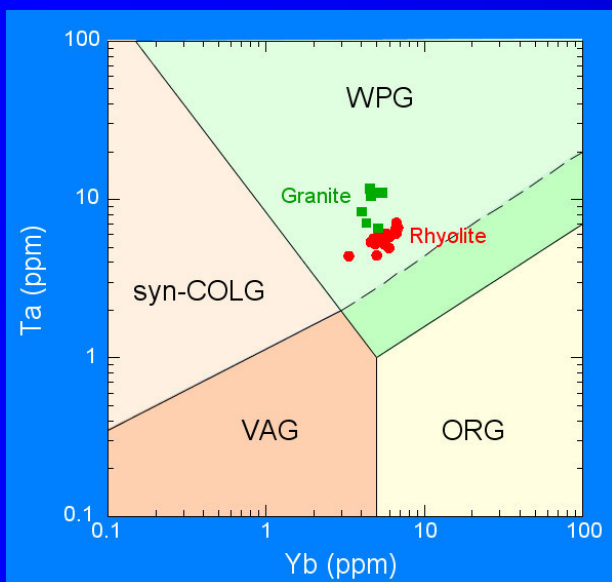
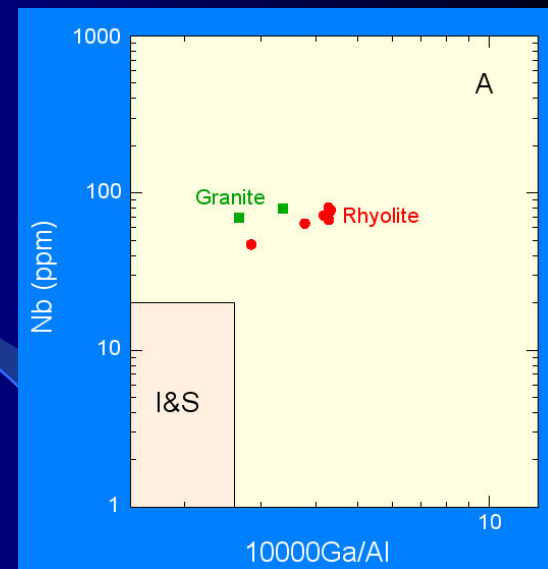


Bimodal volcanics + quartz syenites and granites

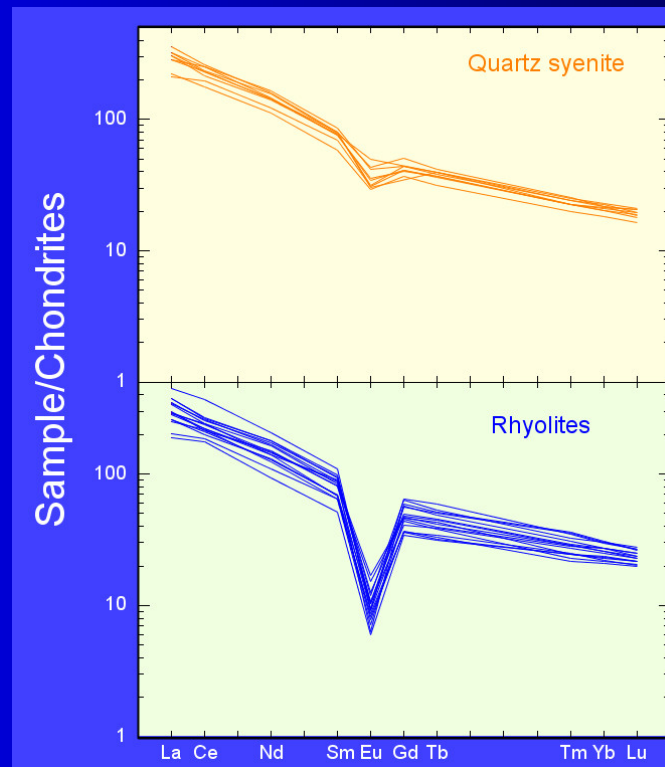
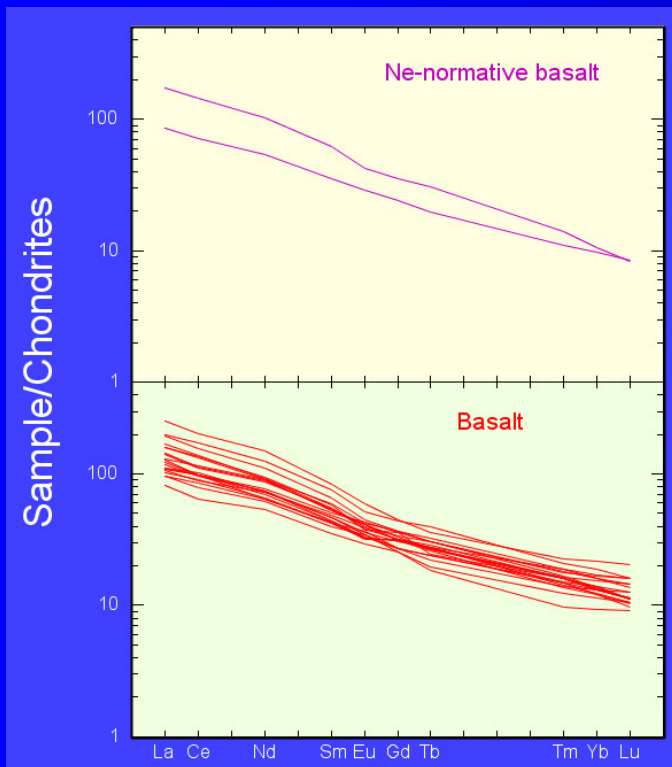
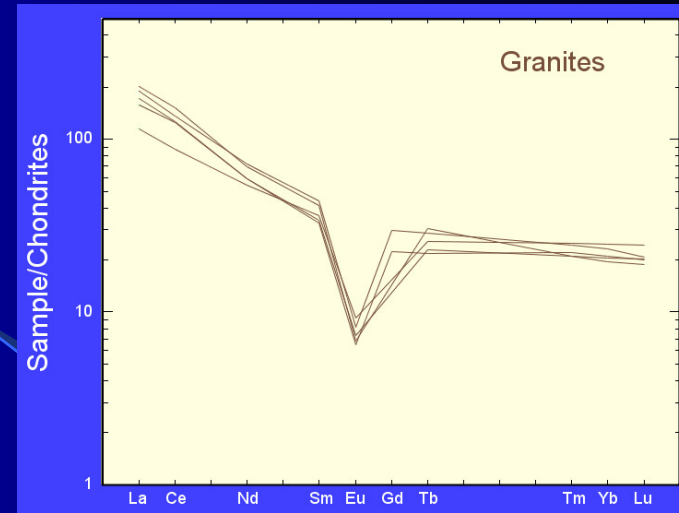


coarse-grained biotite granite

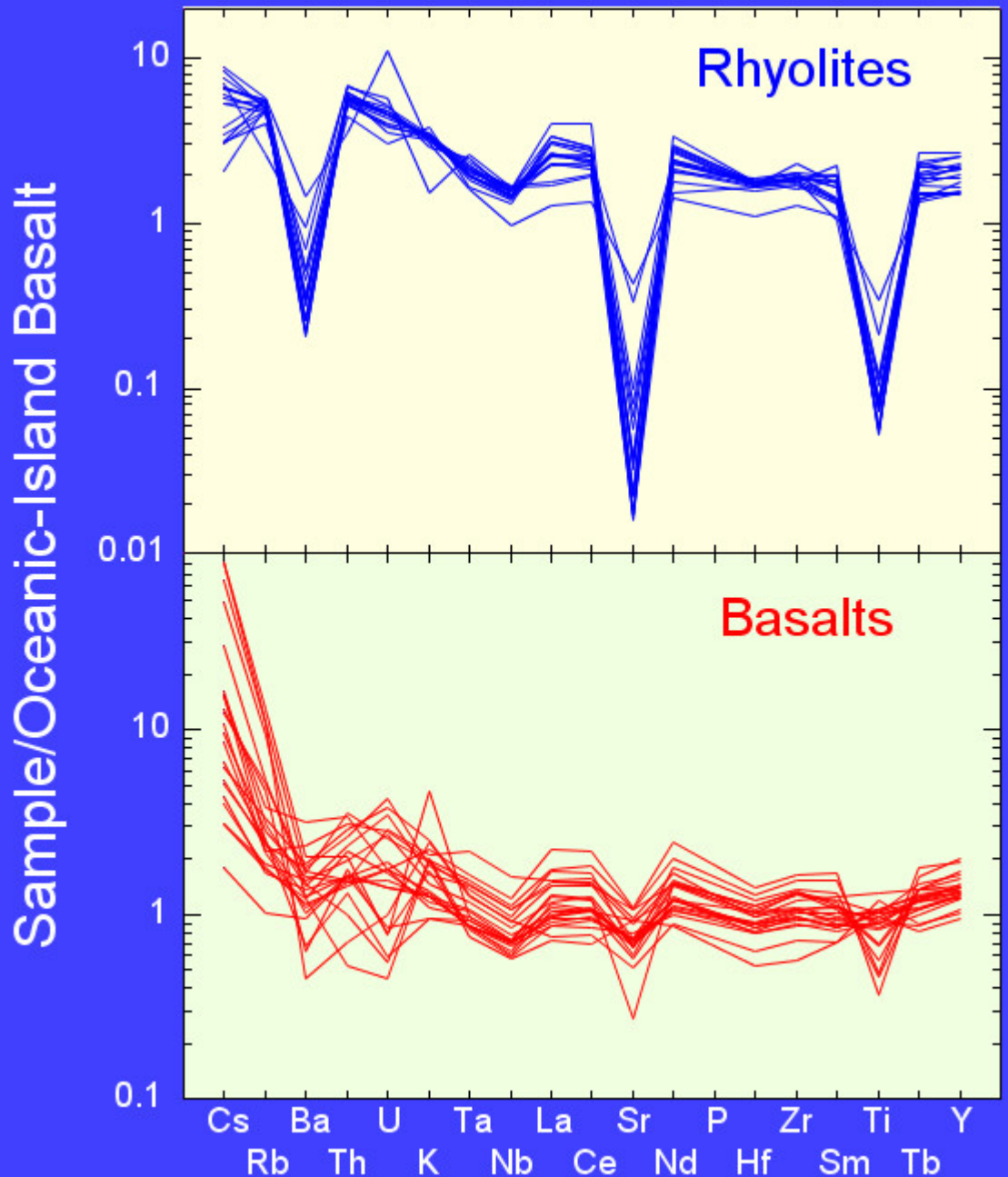
The Ossipee granites and rhyolites plot in the A-type field on the Ga discrimination diagrams, in the Within Plate Granite fields on the tectonic discriminant diagrams, and are A<sub>1</sub>-type, presumably indicating that they were derived from a plume or hotspot OIB-like source. Note that the samples plot in the OIB field.



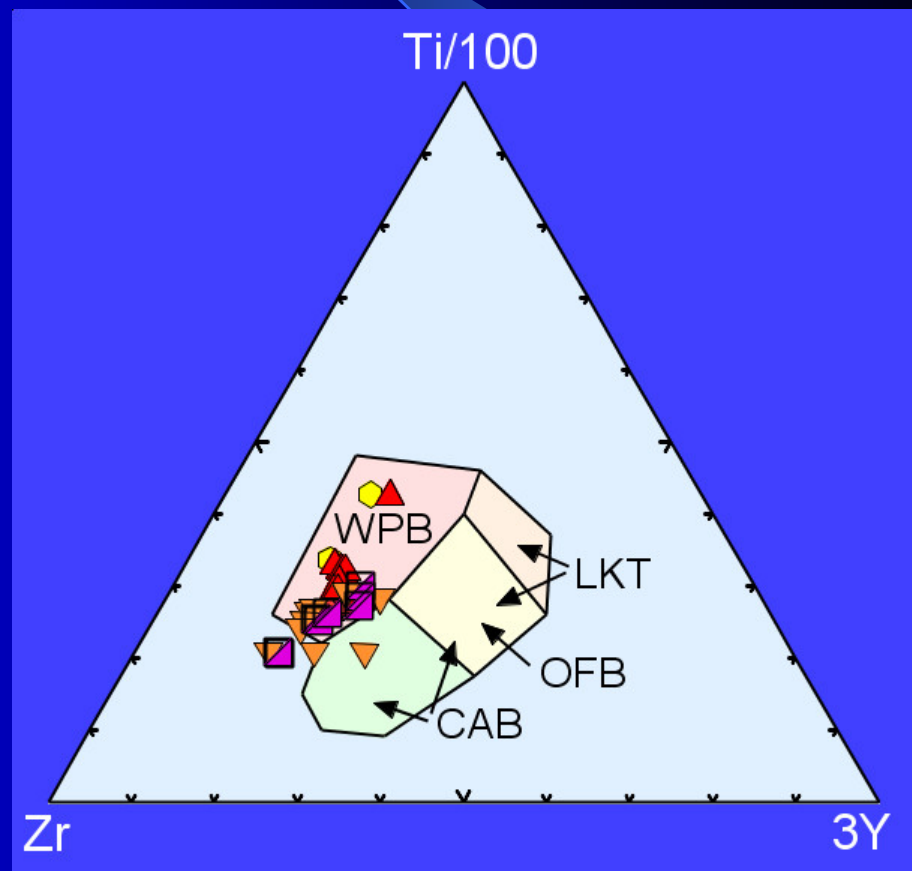
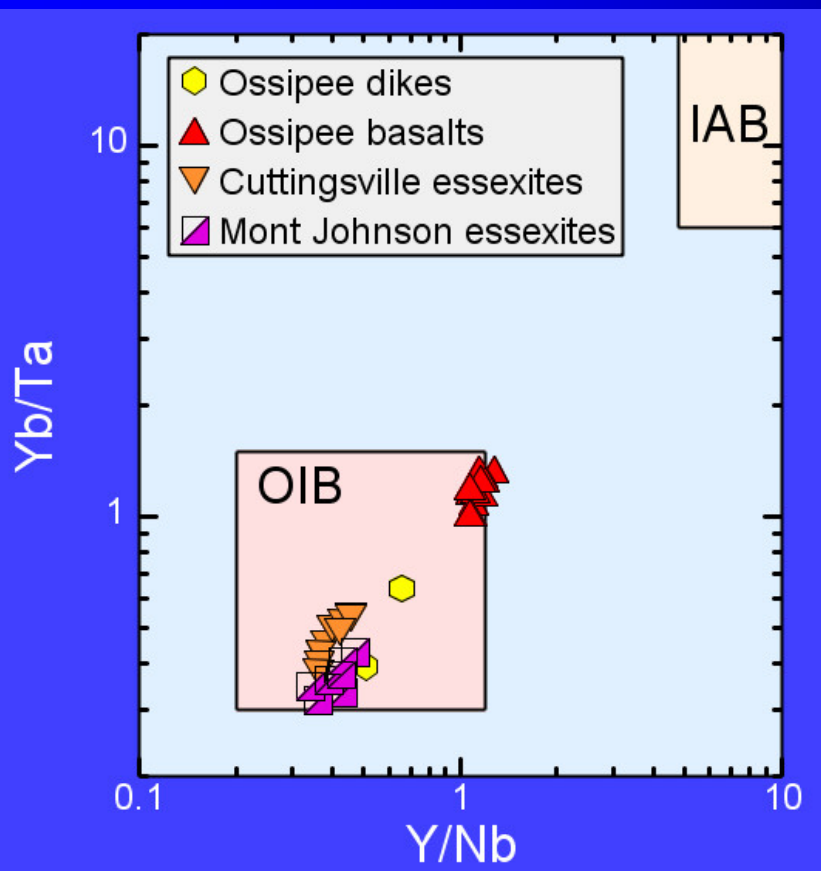
Chondrite normalized REE plots for the various lithologies of the Ossipee ring complex. Note the similar slopes of the REE patterns for all lithologies with the exception of the granite which shows a flattening at the HREE end.



OIB normalized spider diagrams for Ossipee rhyolites and basalts. Note the similarity of both lithologies to OIB. Variations can be explained by the fractionation of alkali feldspar and opaque oxide minerals. Cs enrichment in basalts is due to late-stage hydrothermal alteration as evidence by the partial replacement of plagioclase by epidote.

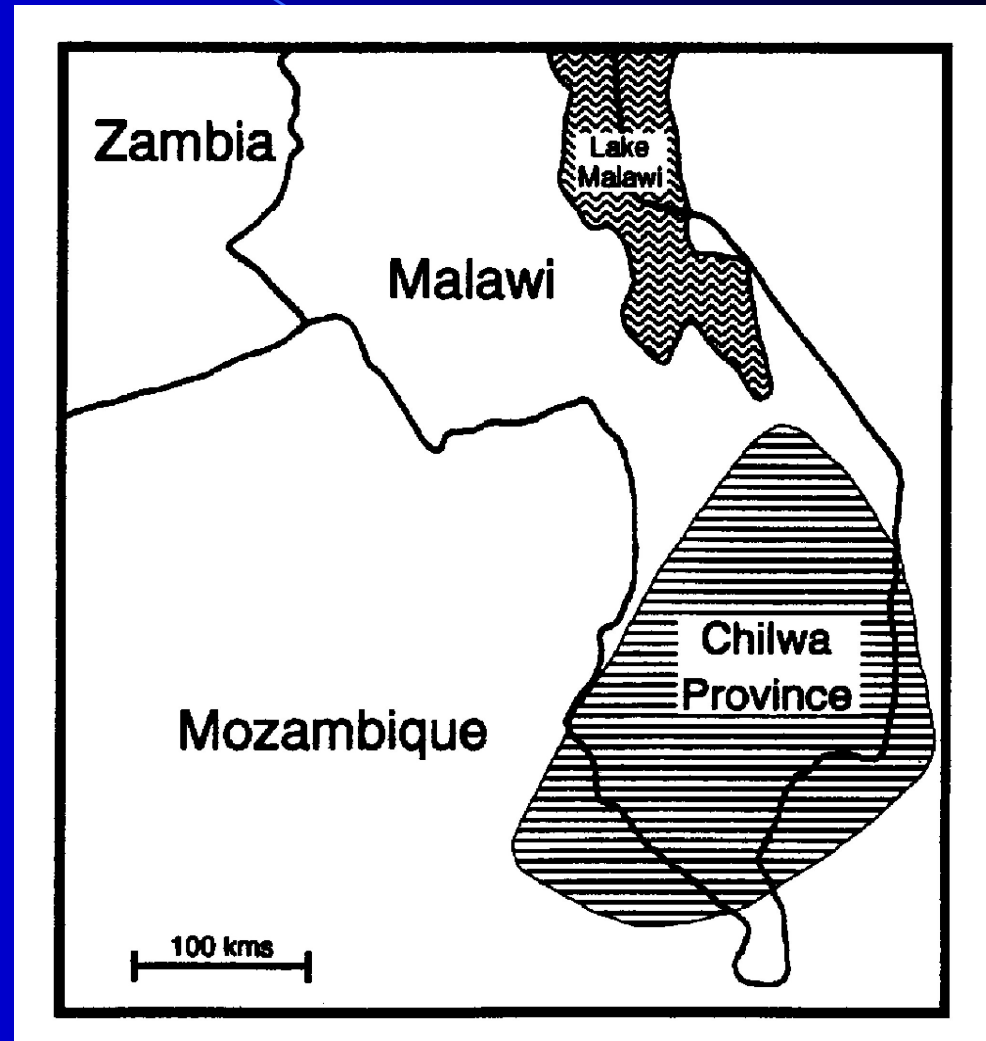


The Ossipee basalts plot in the Within Plate Basalt field and also fall in the OIB-source field. CV and MJ are temporally related intrusions in the White Mountain – Montereian Hills provinces. MJ is a nepheline syenite – nepheline diorite intrusion. All of these magmas were drawn from a similar source, but experienced variable degrees of crustal contamination – essentially none in the case of MJ and minor in the case of the Ossipee basalts. This inference is confirmed with isotopic data.



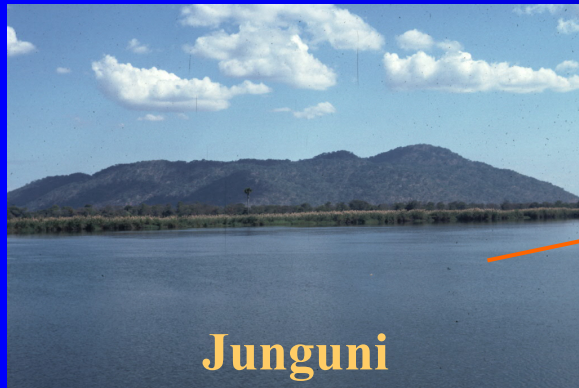
# Examples of A<sub>1</sub>-type Granitoid Provinces - Chilwa Alkaline Province, Malawi

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

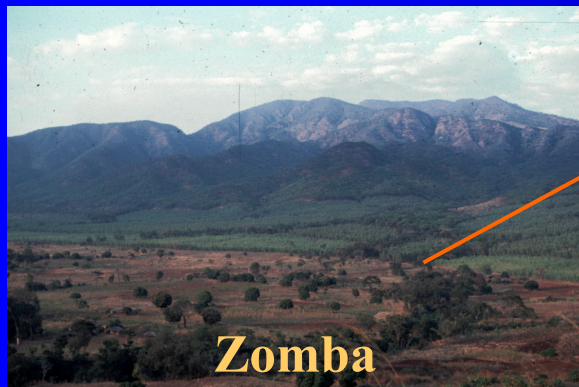
**Lithologies:** carbonatite, nepheline-sodalite syenite, nepheline syenite, syenite, granite



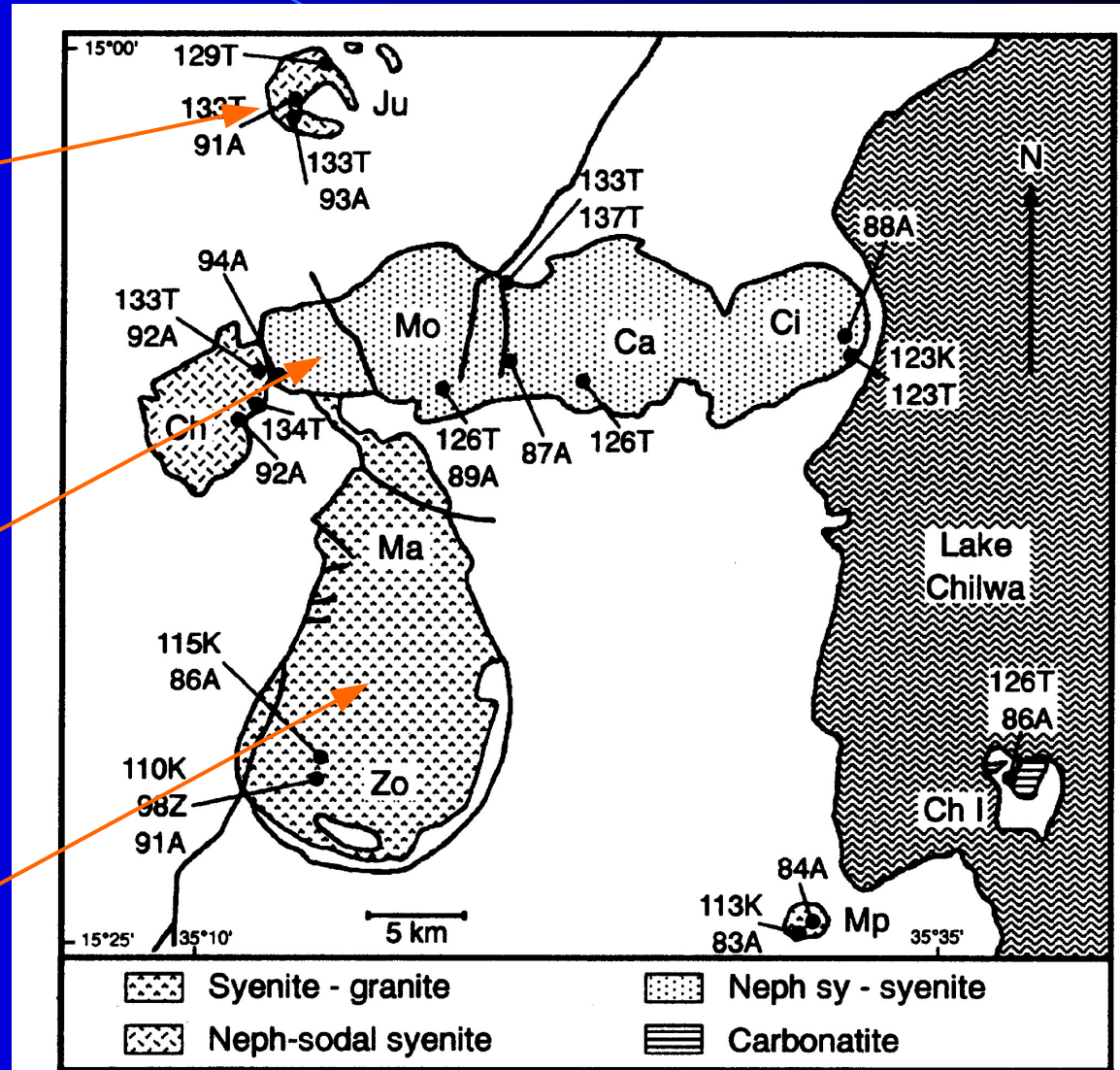
Junguni



Chaone & Mongolowe



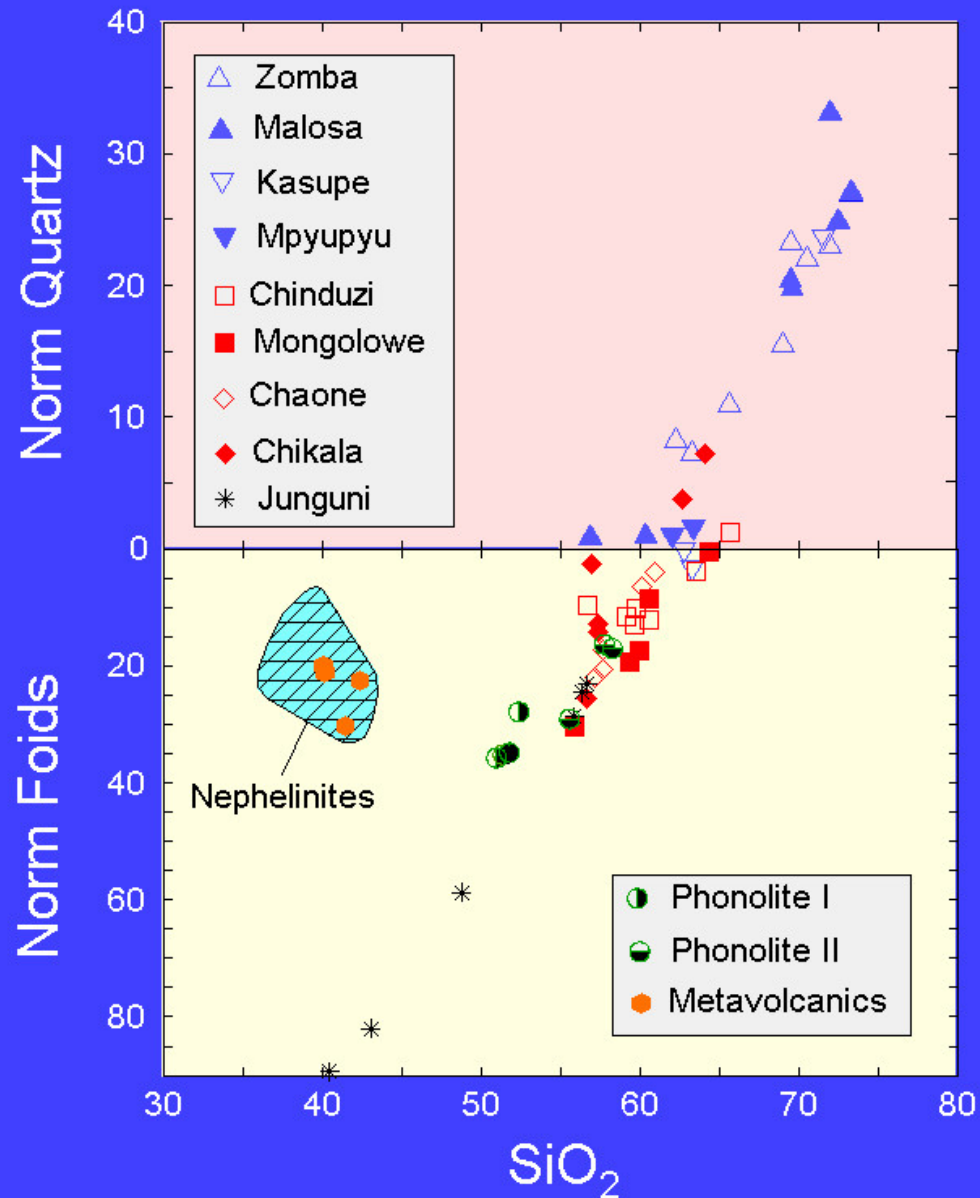
Zomba



# 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.

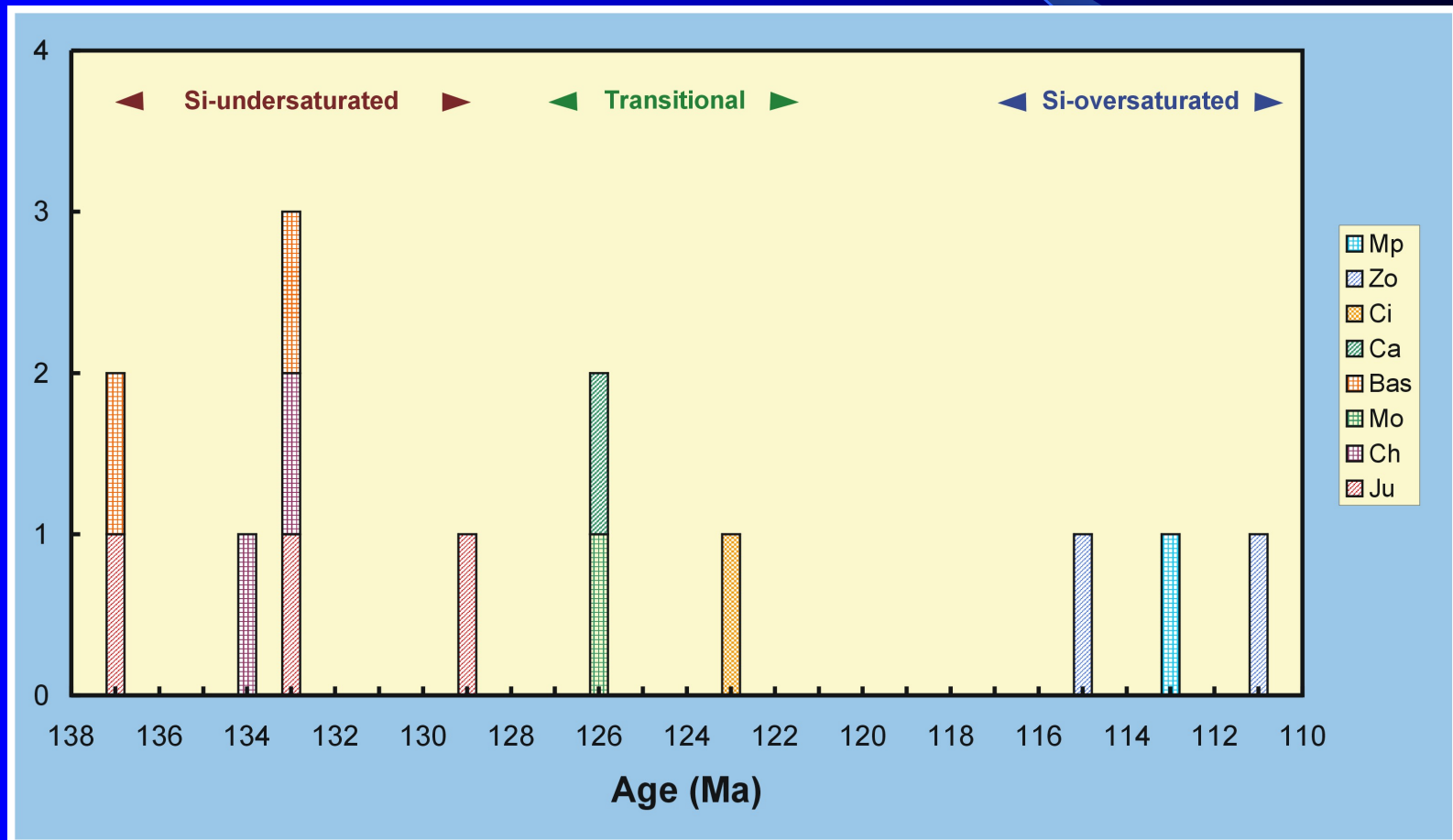




# Age versus degree of silica saturation

## Sequence of emplacement:

- Basanites + nepheline-sodalite syenites (138-132 Ma)
- Nepheline 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

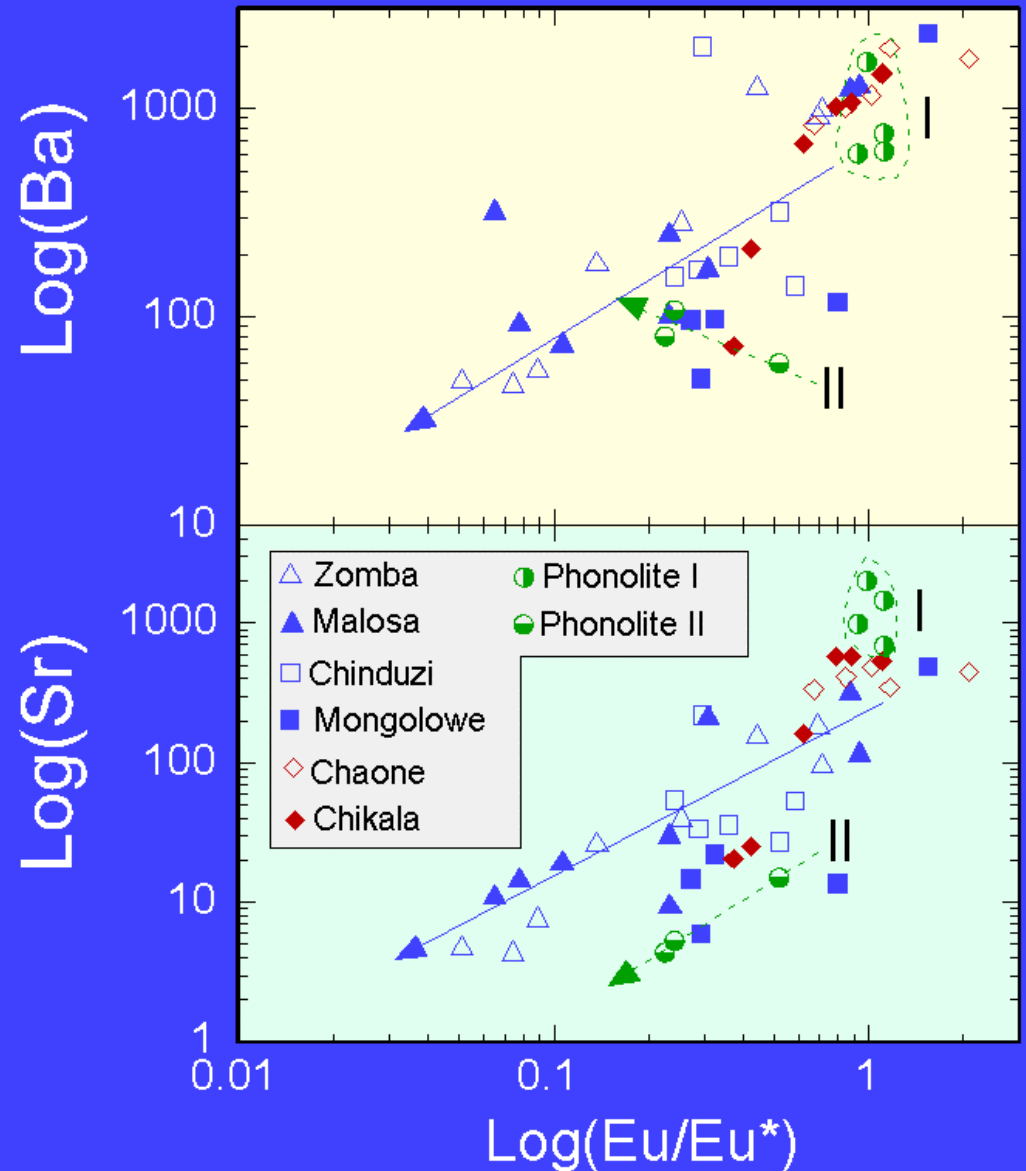
## **Sequence of emplacement**

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

**The pattern is increasing silica content with decreasing age**

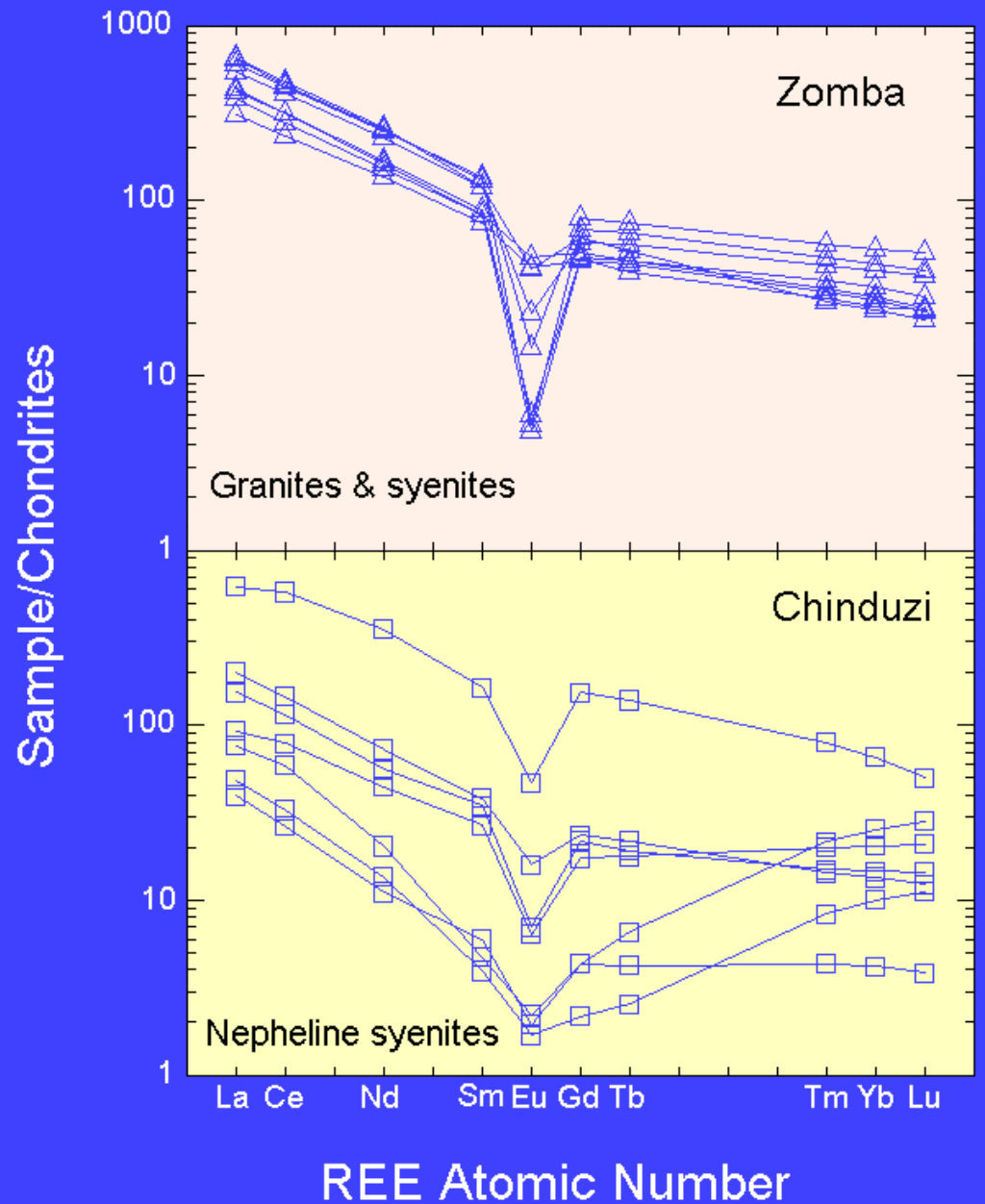
## Log Eu\* vs log Sr, Ba

- 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.

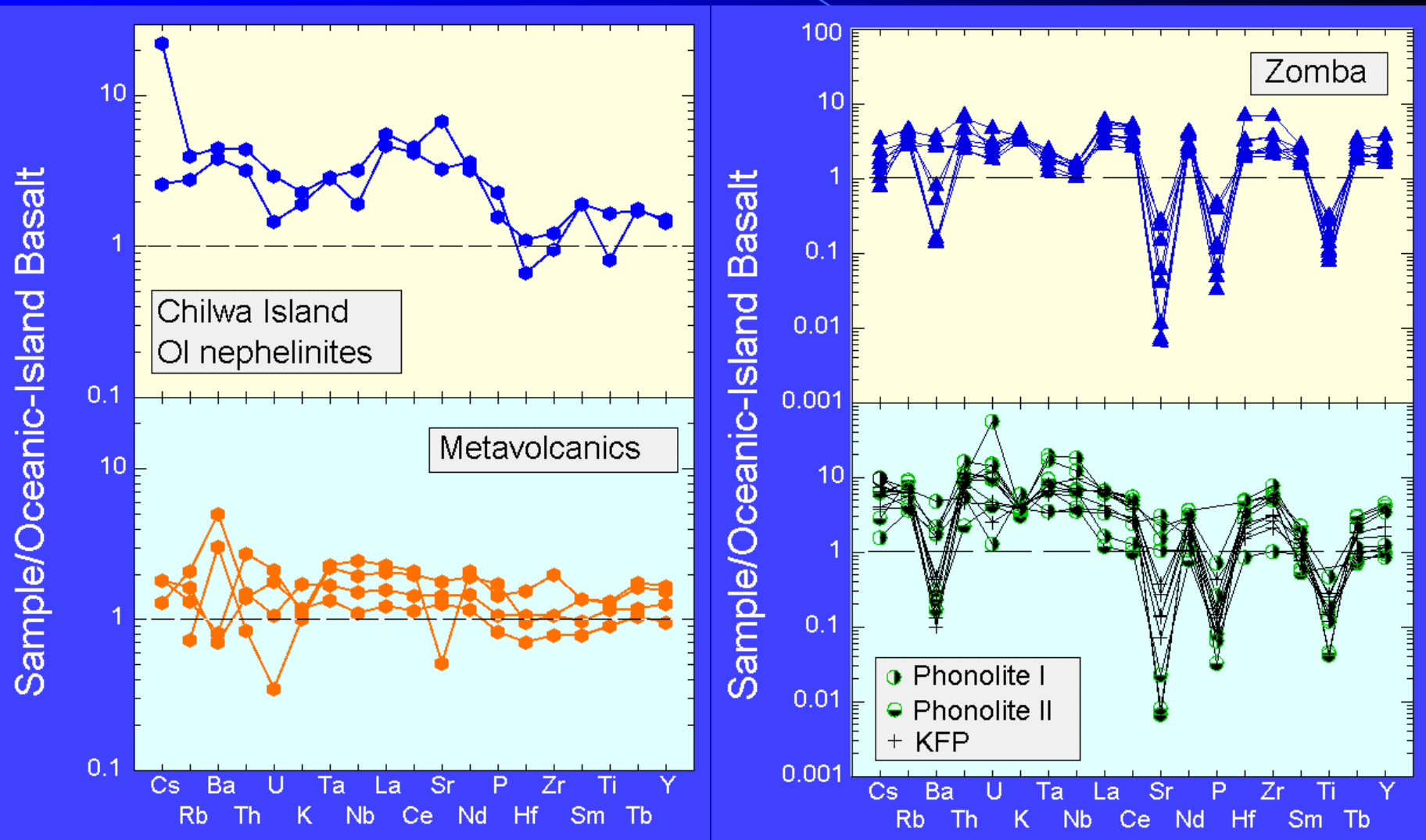


REE patterns for Zomba are subparallel and show increasing negative Eu anomalies with increasing total REEs, typical of a feldspar fractionation trend.

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<sub>2</sub>-rich hydrothermal fluids.



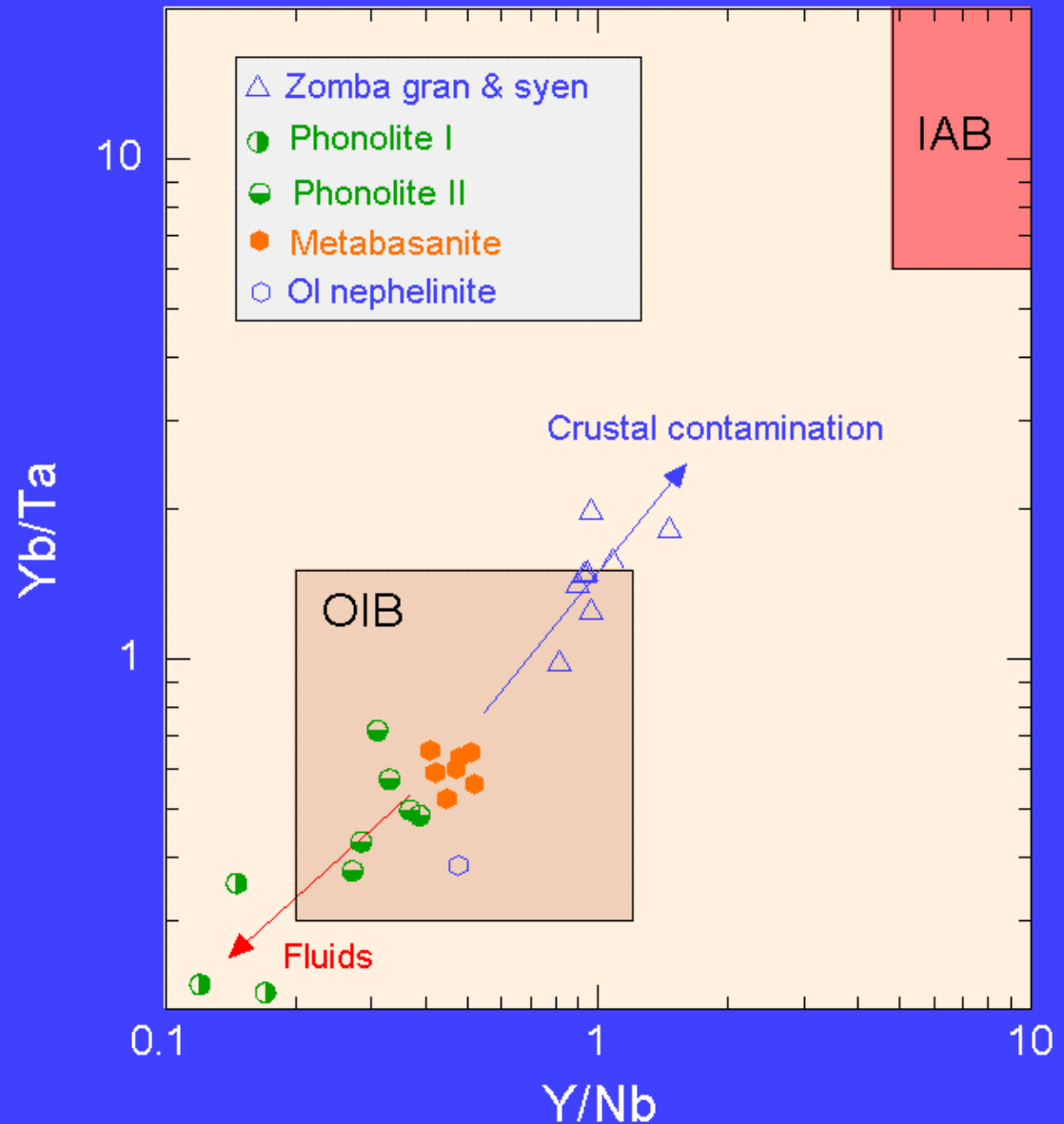
**Spider diagrams:** Note the similarity to OIBs. Depletion of Ba, Sr, P, and Ti in the more evolved rocks is indicative of feldspar, apatite, and ilmenite/magnetite fractionation.



**Y/Nb vs Yb/Ta diagram:** The metabasandites and olivine nephelinites 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<sub>3</sub>-rich fluids would have on these ratios.



# A<sub>2</sub>-type Magmatism

1. Occurs in post-collisional or post-tectonic setting. Usually, but not always, shortly (10 – 20 million years) after compressional tectonism.
2. With few exceptions, never temporally and spatially associated with silica-undersaturated alkaline rocks.
3. In terms of trace elements, a variety of source signatures, both subcontinental lithosphere and crust. Never OIB-like signatures.
4. In some provinces mafic lithologies are abundant, in others mafic lithologies are rare.
5. Numerous examples. This is the most common A-type granitoid magmatism.

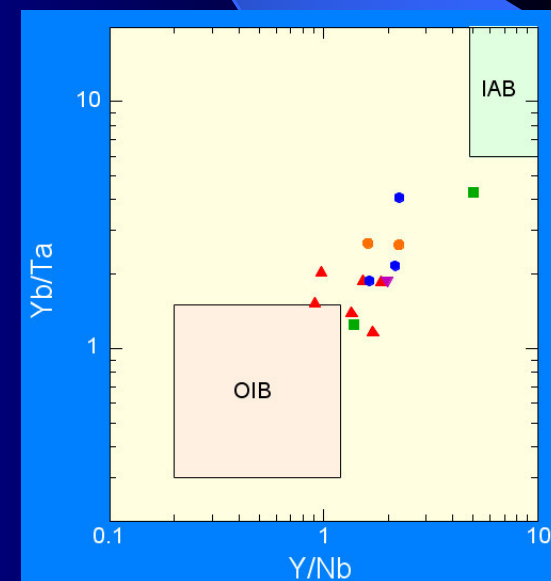
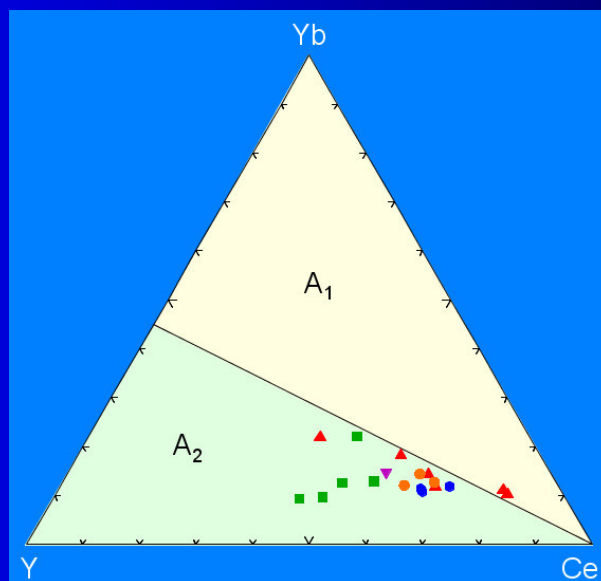
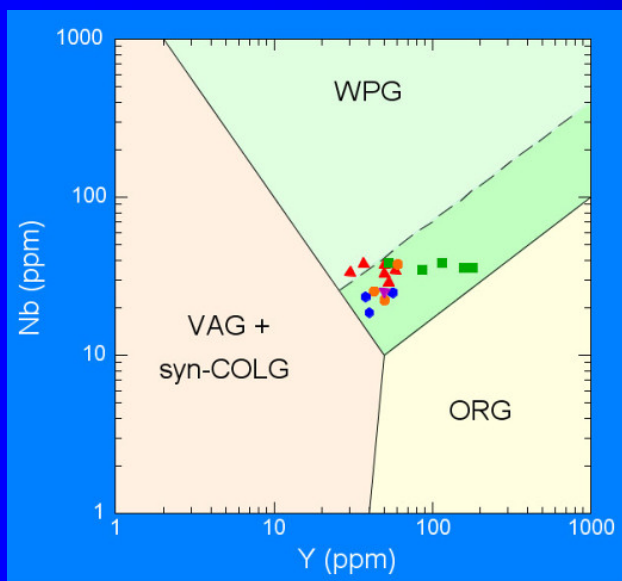
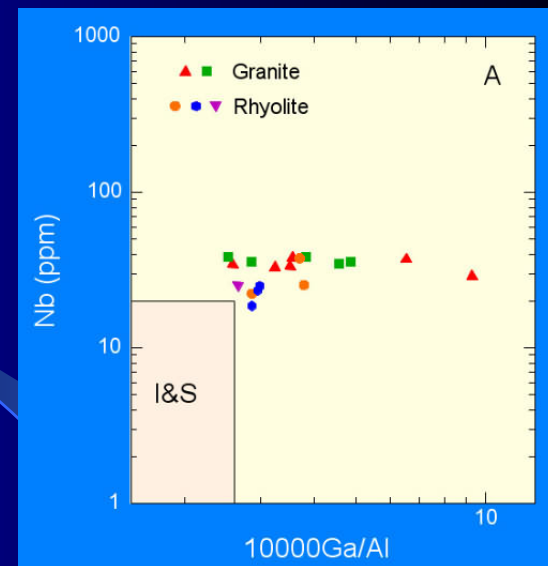
# Example of an A<sub>2</sub>-type Granitoid Province

In southern China, the assembly of microplates occurred during the Triassic Indosinian orogeny. This was followed by north-south extension and the emplacement of Jurassic age granites and bimodal volcanism. This is a post-collisional setting.

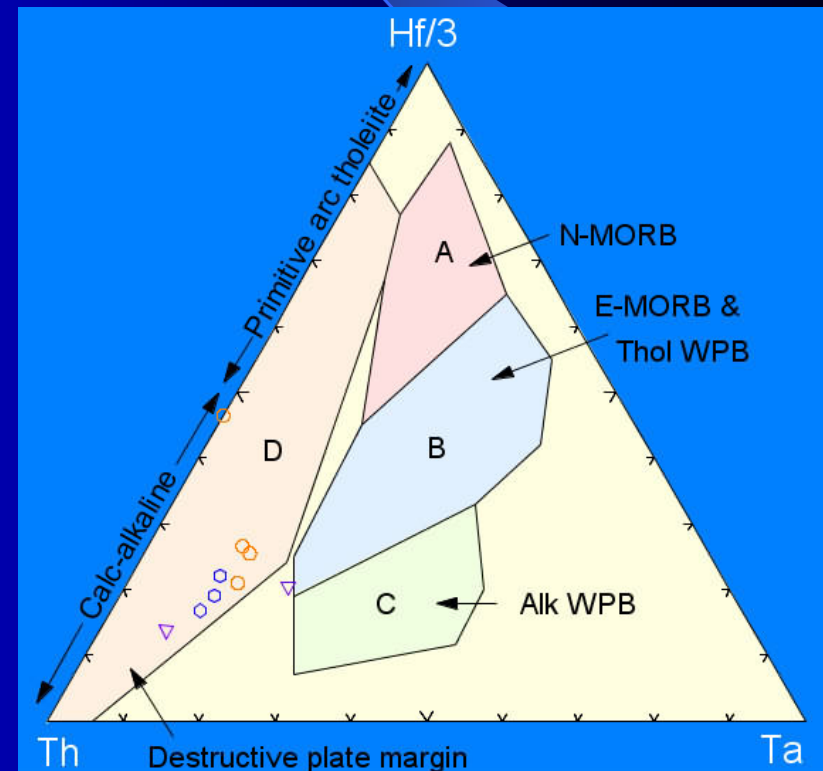
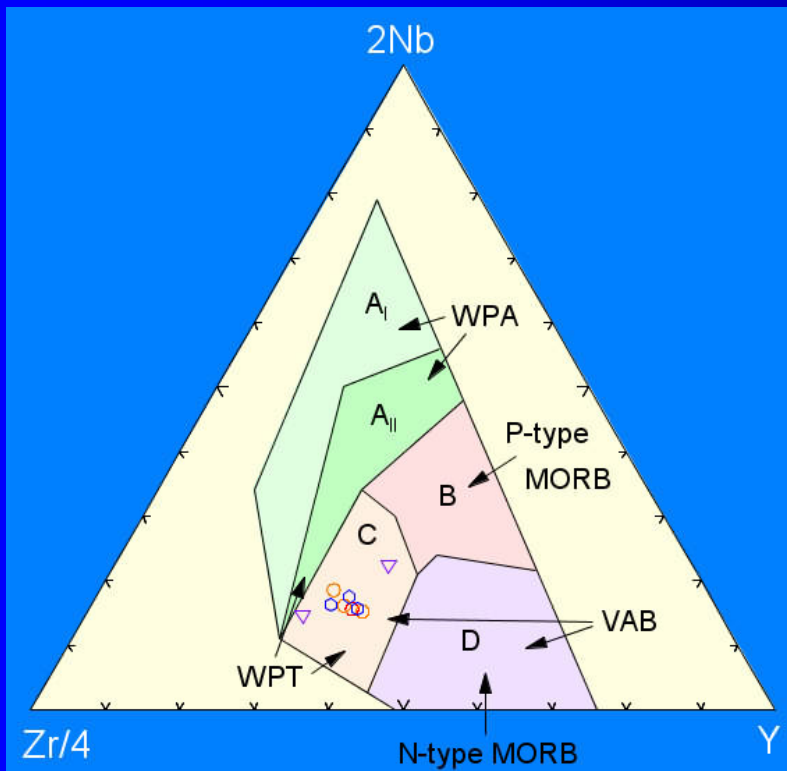




These granites and rhyolites plot as A-type on the Ga discriminants diagrams, in the Within Plate field on the tectonic discriminant diagrams, and plot as A2-type indicative of emplacement in a post-collisional setting. Note that the samples do not plot in the OIB field.

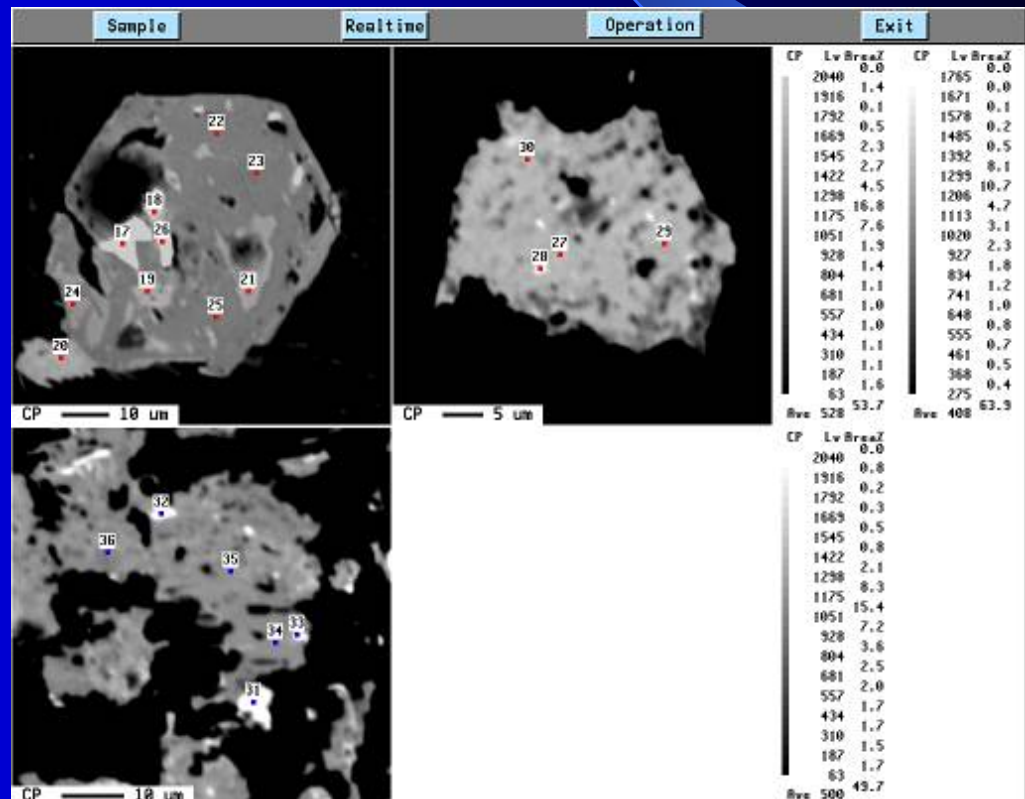


The basalts from the bimodal volcanic sequences plot as Within Plate tholeiites or calc-alkaline basalts from a destructive plate margin. Note the mixed settings from the discriminant diagrams. The geologic setting favors the interpretation of these basalts as Within Plate tholeiites. The granites and rhyolites show evidence of variable degrees of contamination of these basaltic magmas by crustal material. The contamination is greater for the granites.



As a generality, the A<sub>2</sub>-type tend to be more frequently mineralized. In this case the granites have accessory xenotime, allanite, monazite, and to date unidentified REE containing phases. These granites are being prospected as potential U-Th ore deposits. Because of lateritic weathering in this area there is also the potential for REE ore deposits (particularly for the heavy REE). In this same region, deep weathering of S-type granites has produced significant REE deposits.

REE-containing accessory phases in granites. Some of these phases are enriched in HREE relative to LREE. This has potential mineral economic significance.



# Conclusions:

- Granites and rhyolites classified as A-types can form by a variety of processes.
- There seem to be three fundamentally different petrogenetic schemes that can produce A-type granites: (1) differentiation from an OIB-like basaltic magma ( $A_1$ ); (2) differentiation from a Continental tholeiite basaltic magma ( $A_2$ ); and (3) partial melting of lower continental crust ( $A_2$ ). In both case (1) and (2) interaction with crustal material modifies the chemistry of the initial magma(s).
- The tectonic setting can either be within plate (anorogenic) or post-collision, post-subduction.
- The  $A_2$ -types are the more likely targets for mineral exploration.