PUNCTUATED ANOROGENIC MAGMATISM

Robert F. MARTIN

Earth and Planetary Sciences,

McGill University, Montreal, Canada

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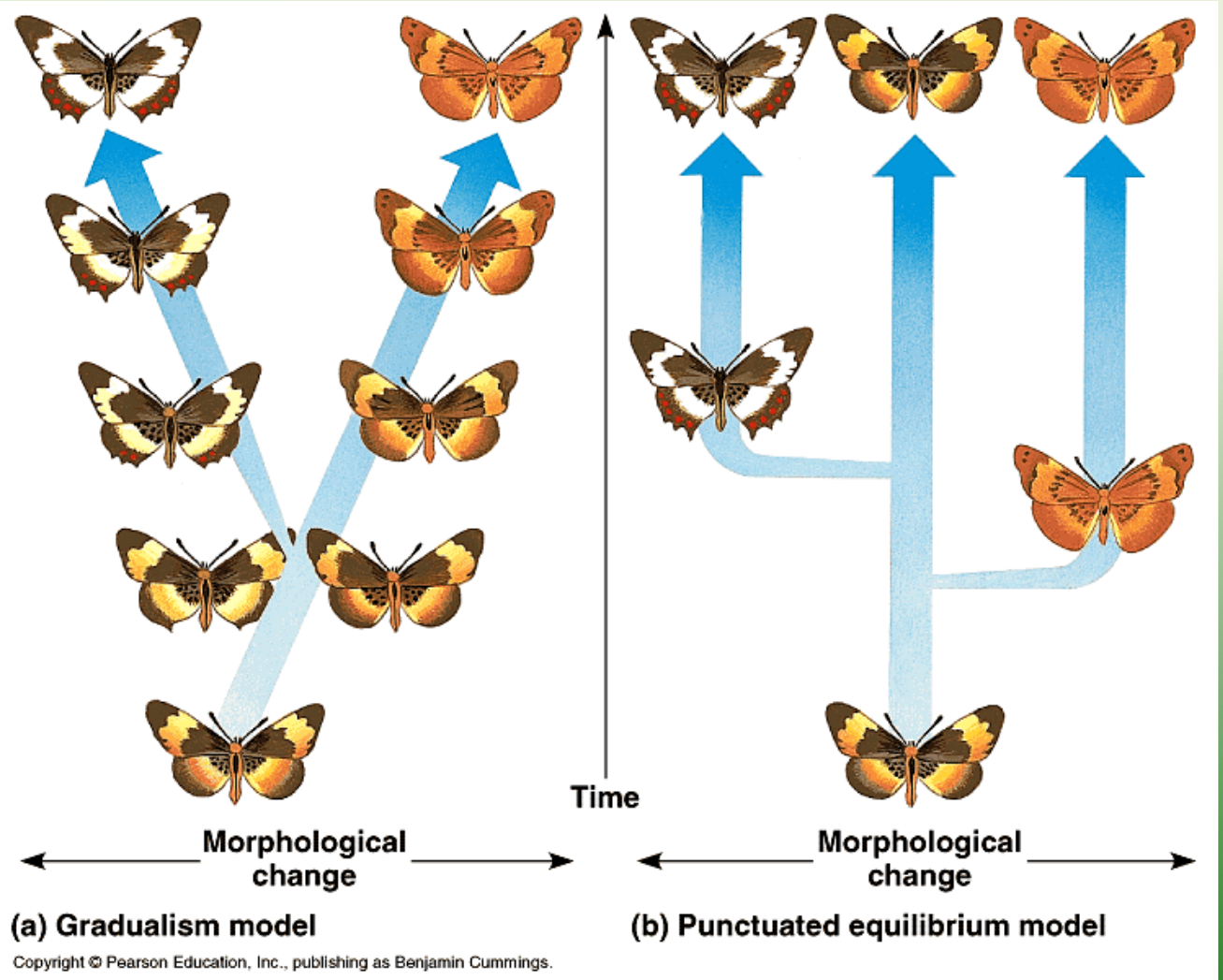
PERALK-CARB 2011

WORKSHOP ON PERALKALINE ROCKS AND CARBONATITES

The concept of punctuation in biology…



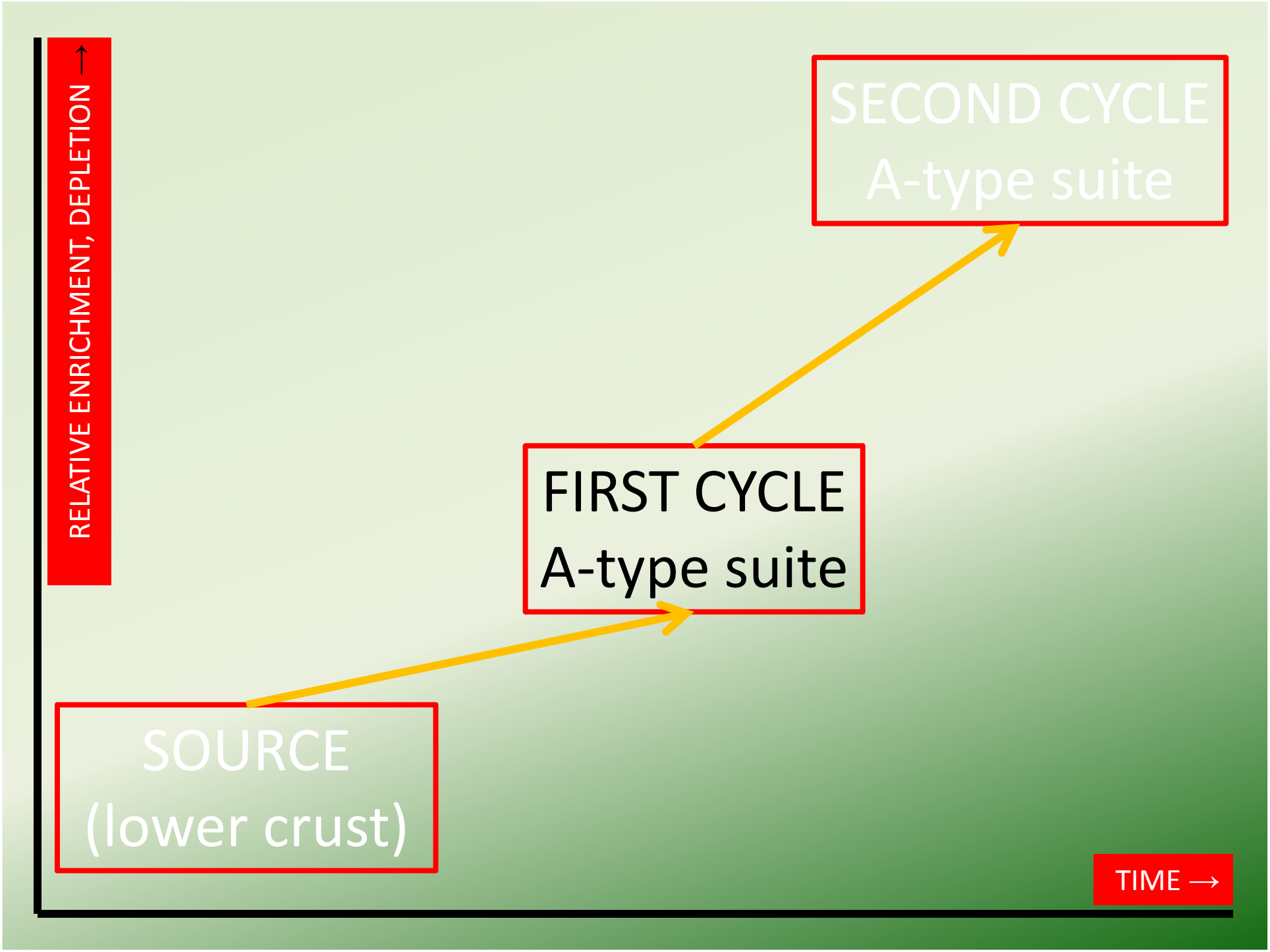
… applied to anorogenic magmatism

- Anorogenic magmatism, like lightning, can strike twice, separated by an interval of quiescence
- Examples to be discussed and compared in this talk:

  1) Nigeria, where the hiatus lasts 400 Myr, and
  2) the Grenville Province, where the hiatus is much shorter

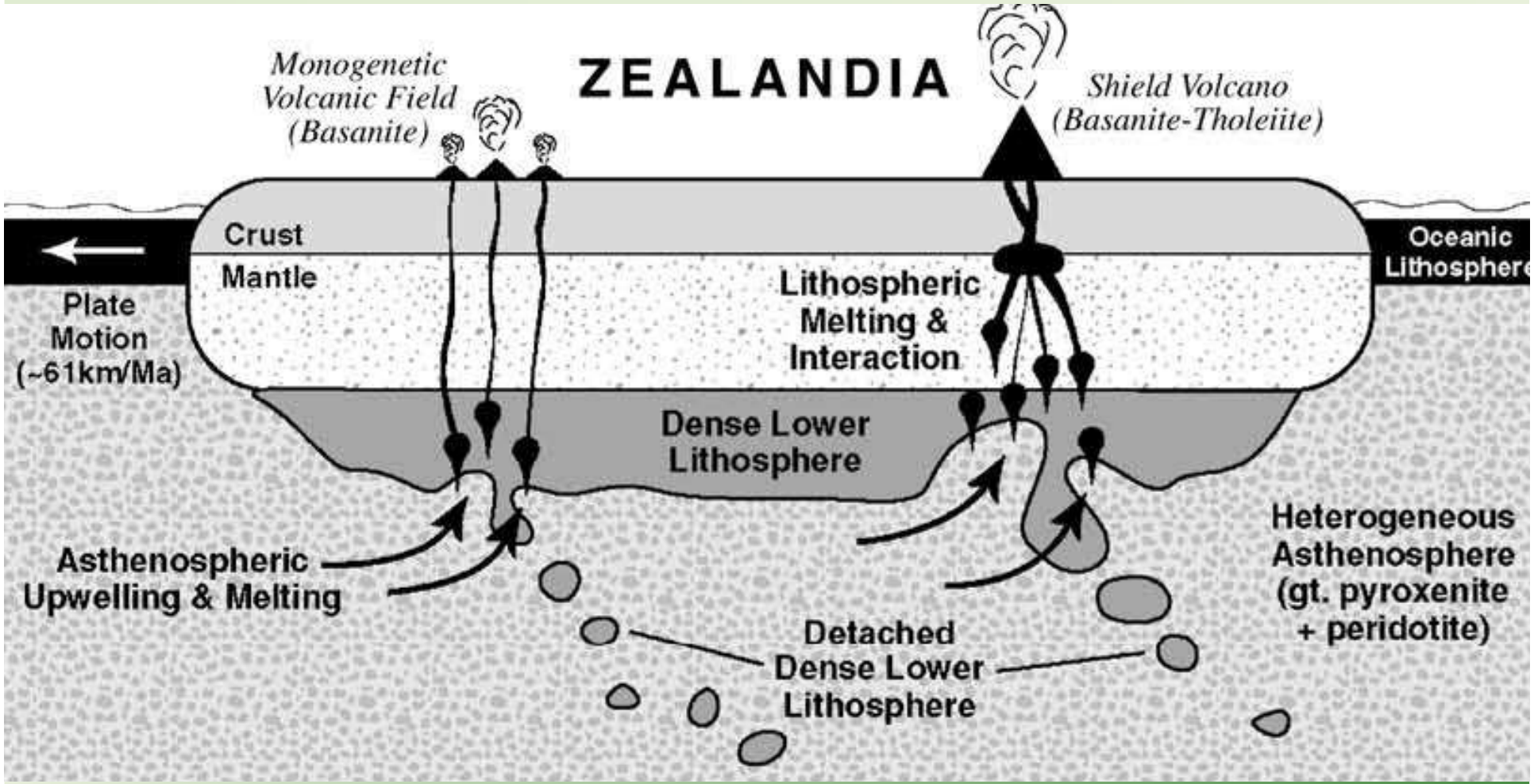
… punctuated anorogenic magmatism

- Where the source of magmas of EPISODE 2 is itself anorogenic, one can expect the resulting rocks to be exceptionally enriched in some constituents and, by the same token, highly depleted in others
- In a way, we are dealing with punctuated evolution in the fertility or sterility of magmatic products…


RELATIVE ENRICHMENT, DEPLETION →
SECOND CYCLE
A-type suite
FIRST CYCLE
A-type suite
SOURCE
(lower crust)
TIME →

TRIGGER OF ANOROGENIC ACTIVITY (1)

- The key concept is gravitational instability of the lithosphere, and its foundering into the mantle: DETACHMENT, DELAMINATION, COLLAPSE
- This concept has been used to explain the “diffuse” development of intraplate magmatic centers of Cenozoic age in New Zealand, for example. The detachment of the dense lower lithosphere leads to the rise of the asthenosphere, and its partial melting induced by decompression

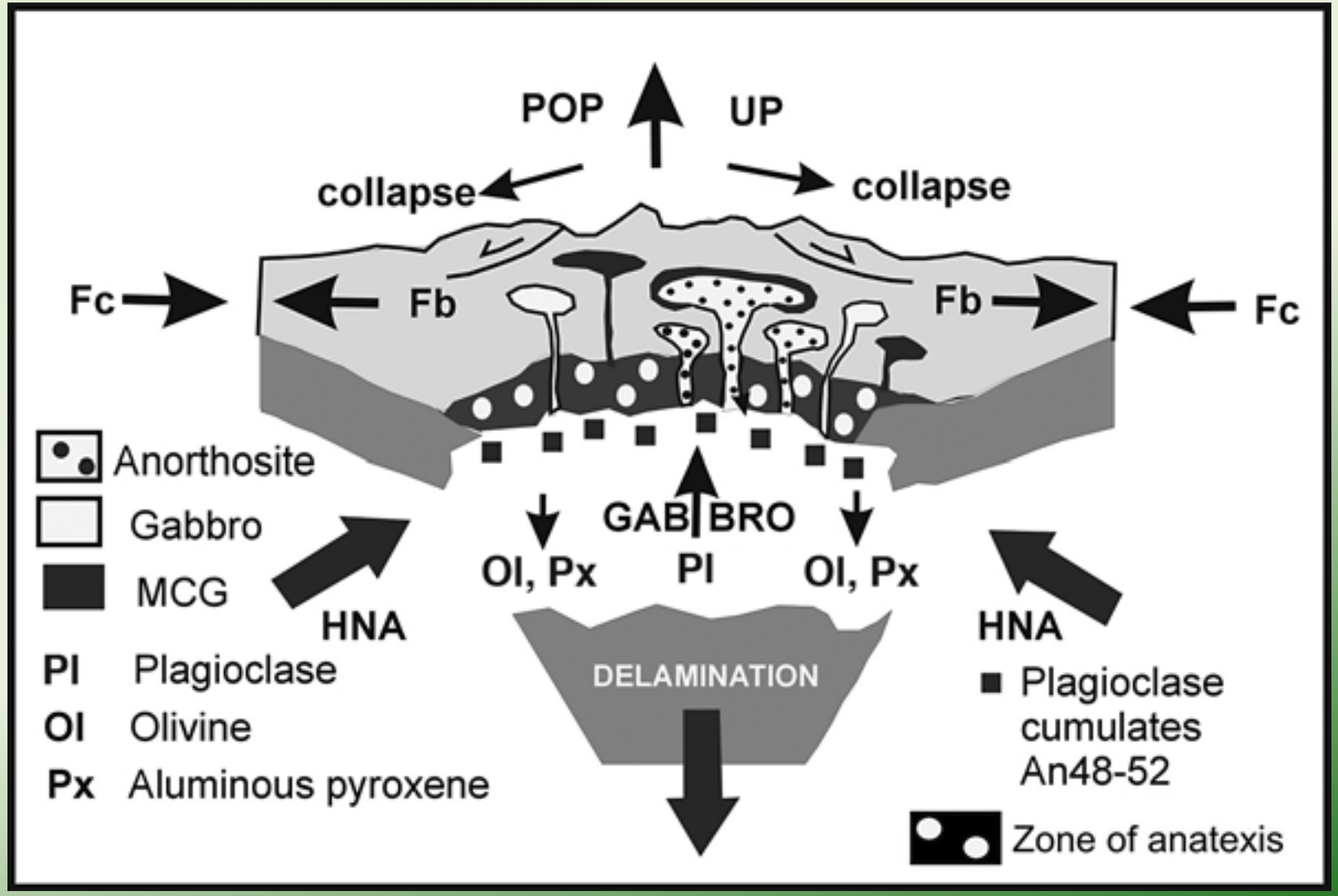


Hoernle *et al.* (2006)

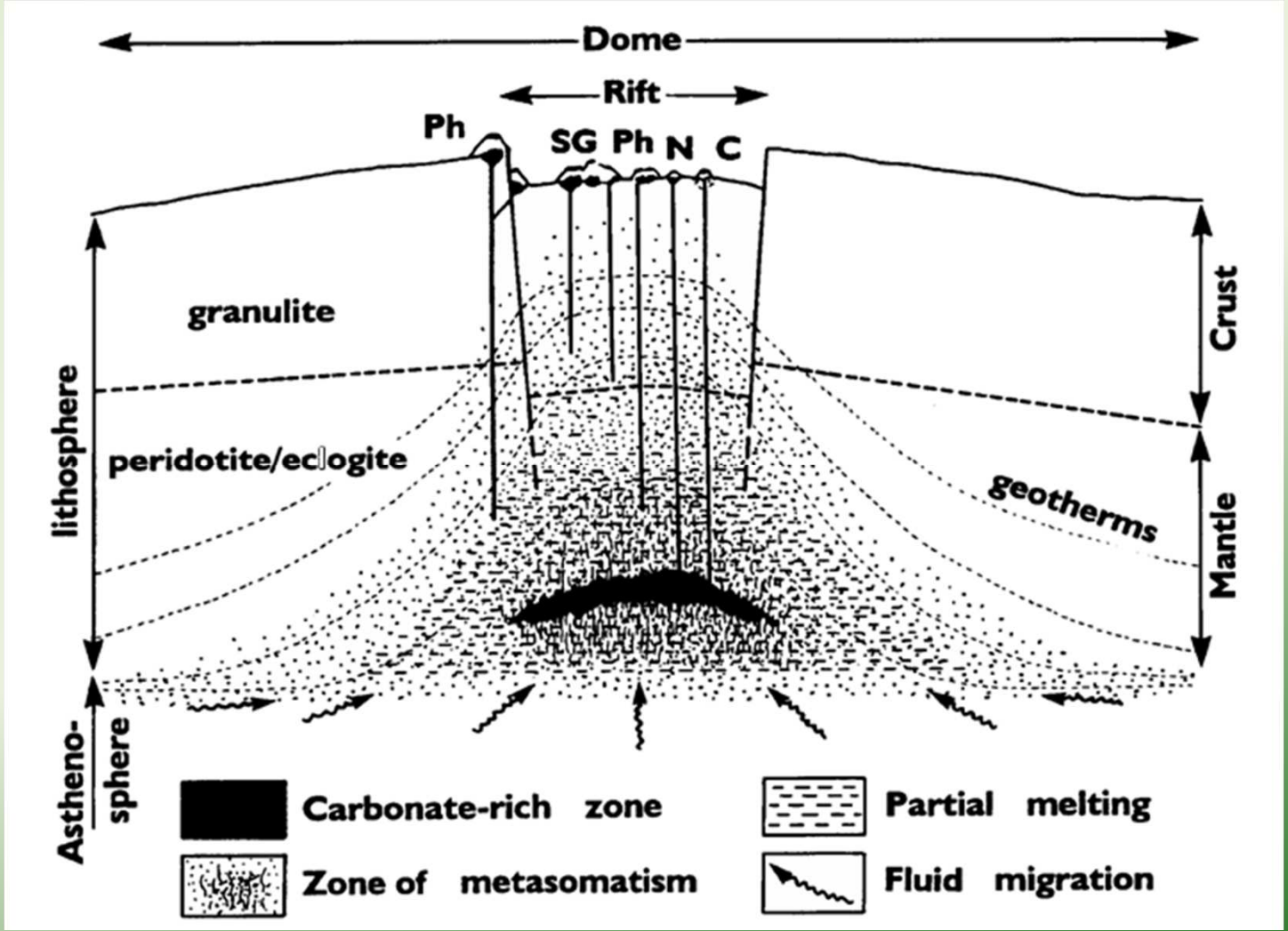
TRIGGER OF ANOROGENIC ACTIVITY (2)

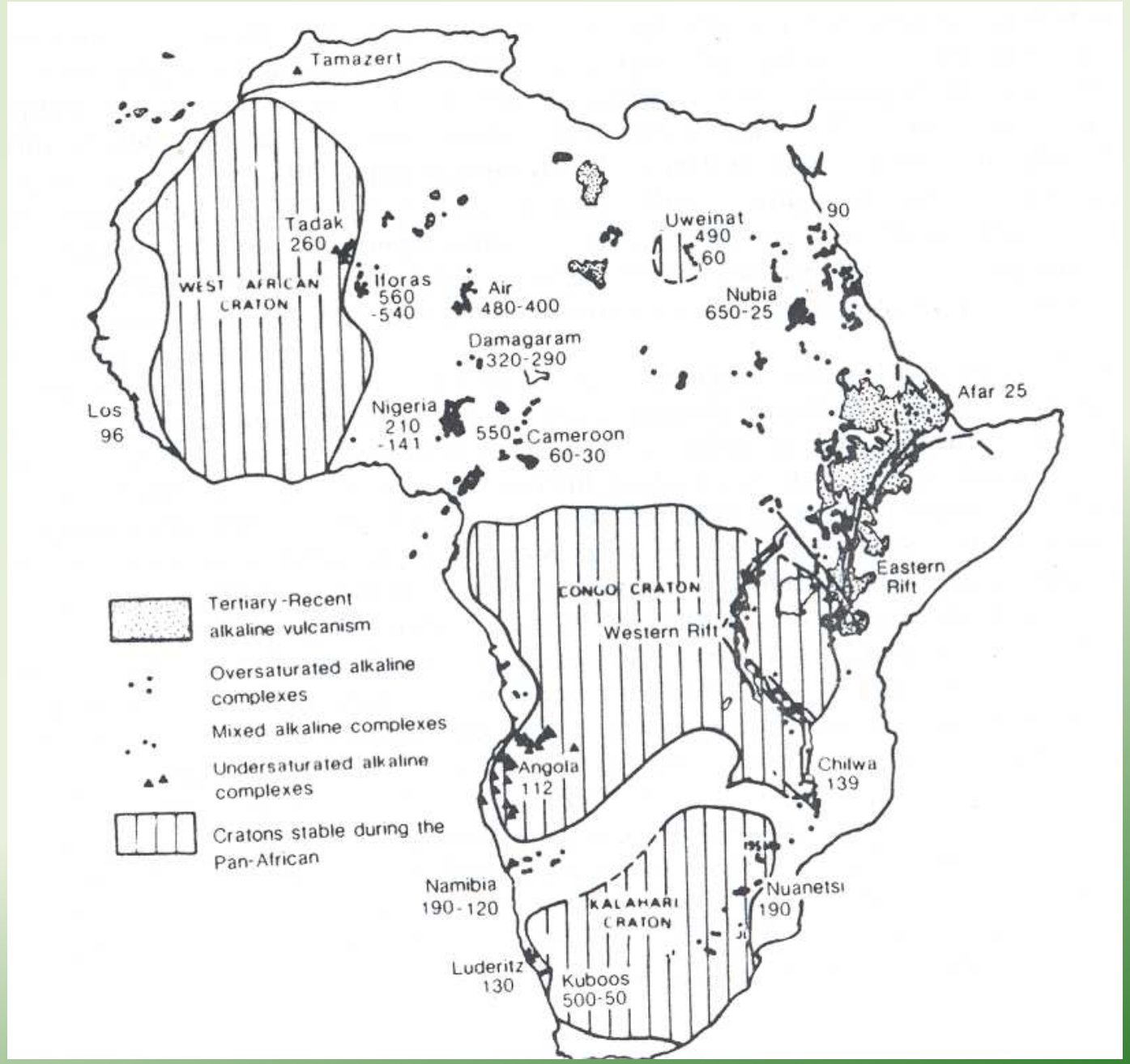
- Where the DETACHMENT also involves the crust, one obtains the association anorthosite – mangerite – charnockite – granite (AMCG suites)
- AMCG suites also arise by decompression-induced melting of the mantle, but the resulting major rock (anorthosite) is contaminated with crust. Anatexis of the lower crust is coeval, and the product (A-type granite, syenite) is contaminated with mantle
- Fertilization of the lower crust is a necessary step prior to melting

The McLelland *et al.* (2010) model explains the petrogenesis of AMCG suites

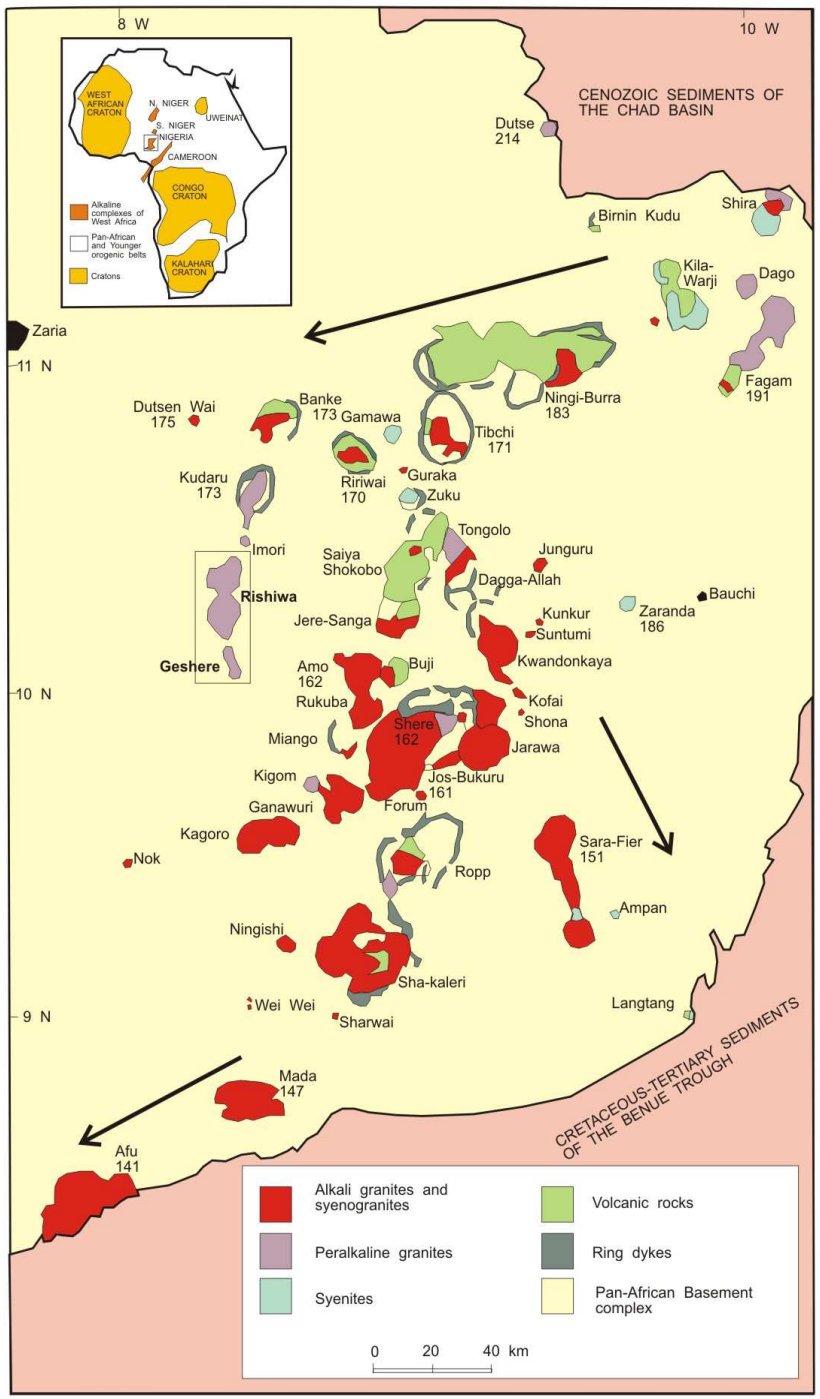


The Woolley (1987) petrogenetic model explains the variability of anorogenic products




Tamazert
Tadak
260
WEST AFRICAN
CRATON
Iforas
560
-540
Air
480-400
Uweinat
490
60
90
Nubia
650-25
Damagaram
320-290
Afar 25
Los
96
Nigeria
210
-141
550
Cameroon
60-30
Eastern
Rift
CONGO CRATON
Western Rift
Tertiary-Recent
alkaline vulcanism
Oversaturated alkaline
complexes
Mixed alkaline complexes
Undersaturated alkaline
complexes
Cratons stable during the
Pan-African
Angola
112
Chilwa
139
Namibia
190-120
KALAHARI
CRATON
Nuanetsi
190
Luderitz
130
Kuboos
500-50

THE YOUNGER GRANITES OF NIGERIA: DISTRIBUTION



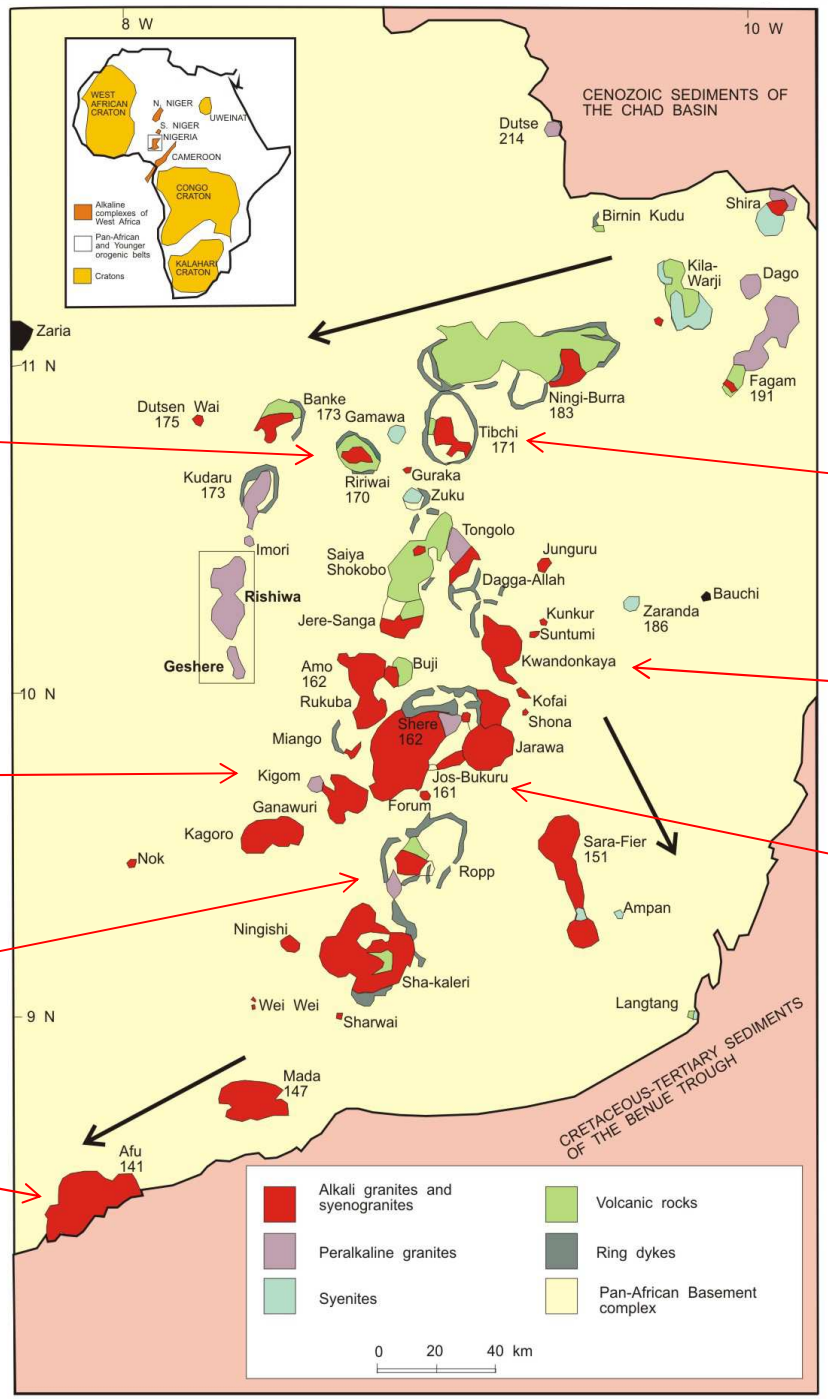
THE YOUNGER GRANITES OF NIGERIA: DISTRIBUTION

Sn, Zn, Nb, U

Mo

Nb, Sn

Nb, Sn

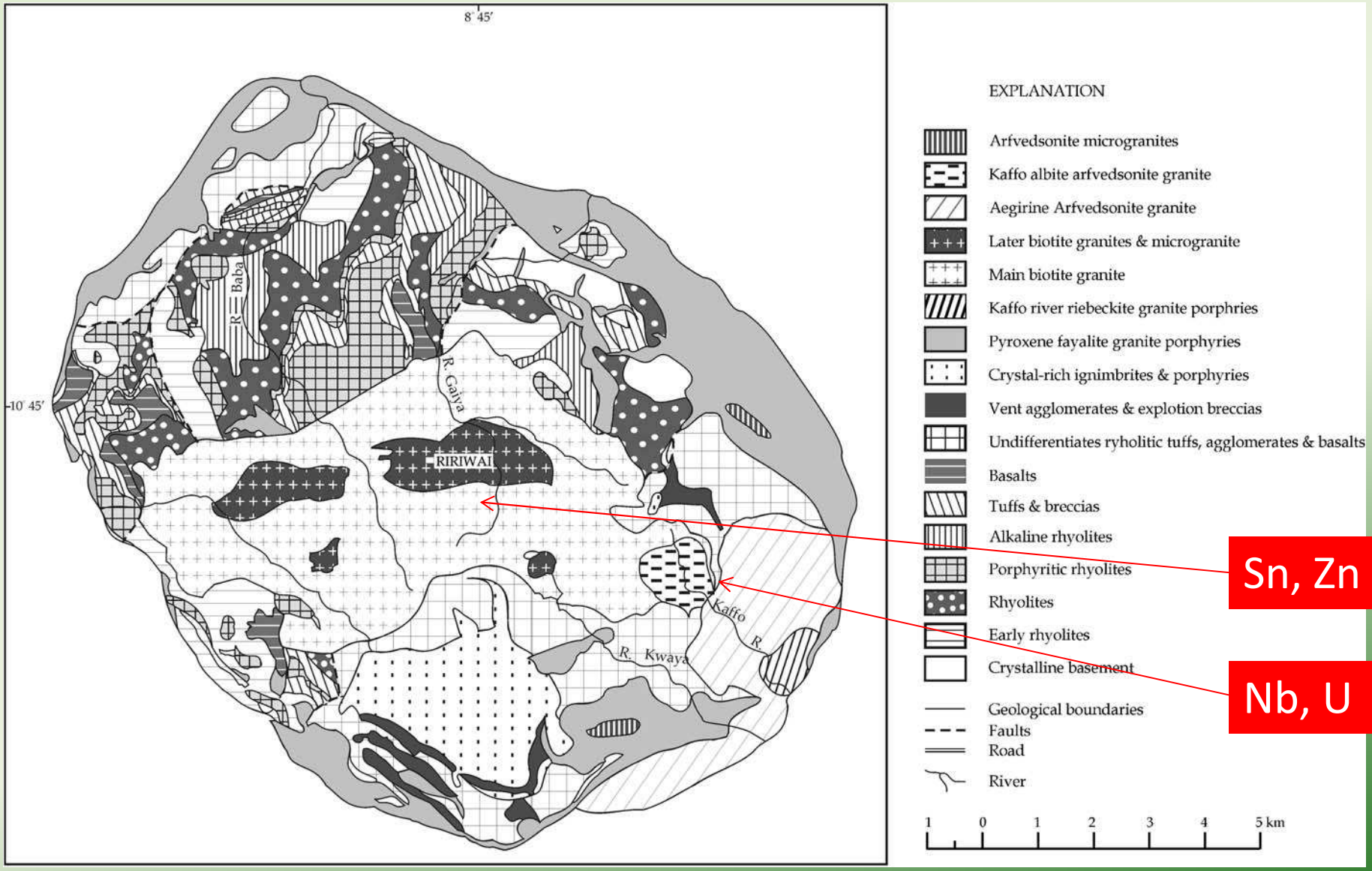


Sn

Be

Sn

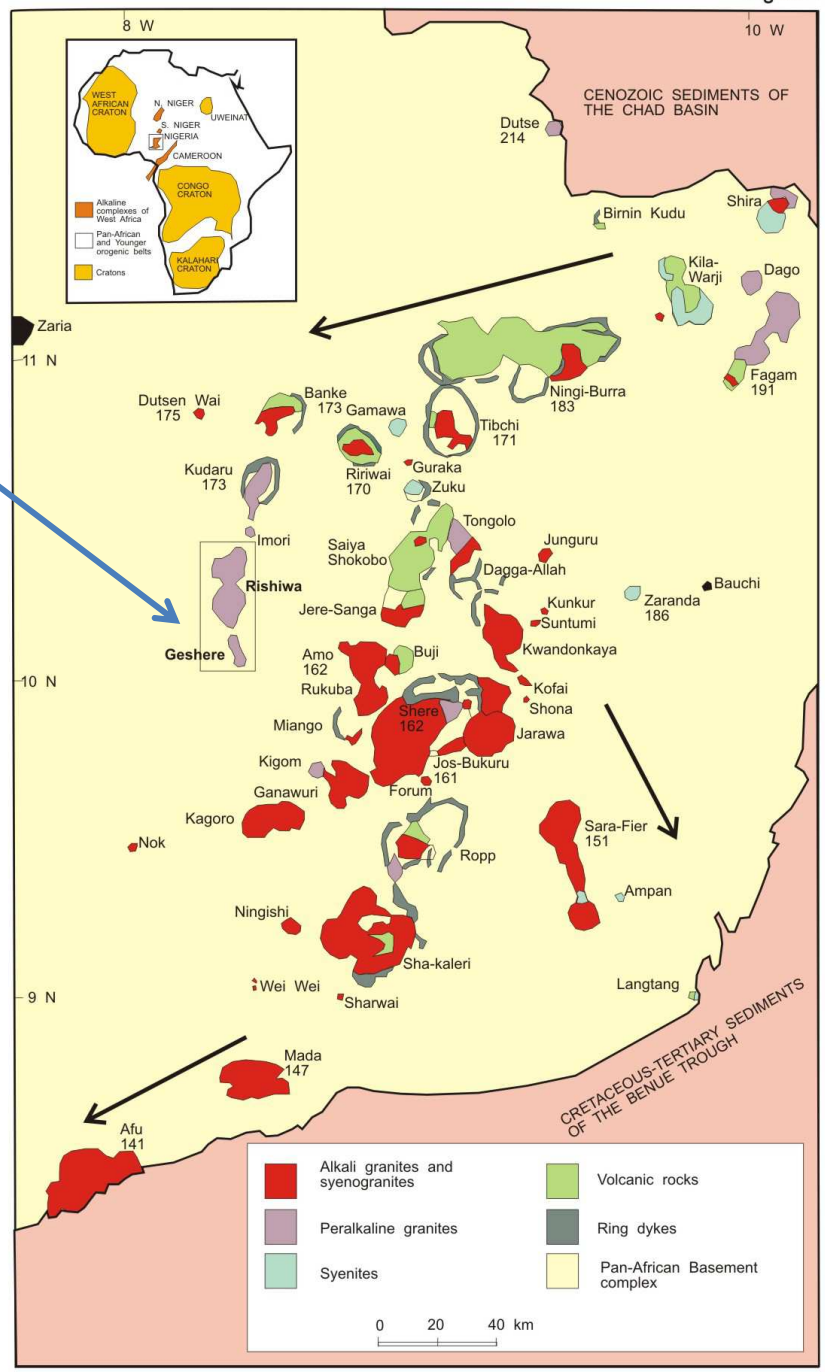
The RIRIWAI Complex



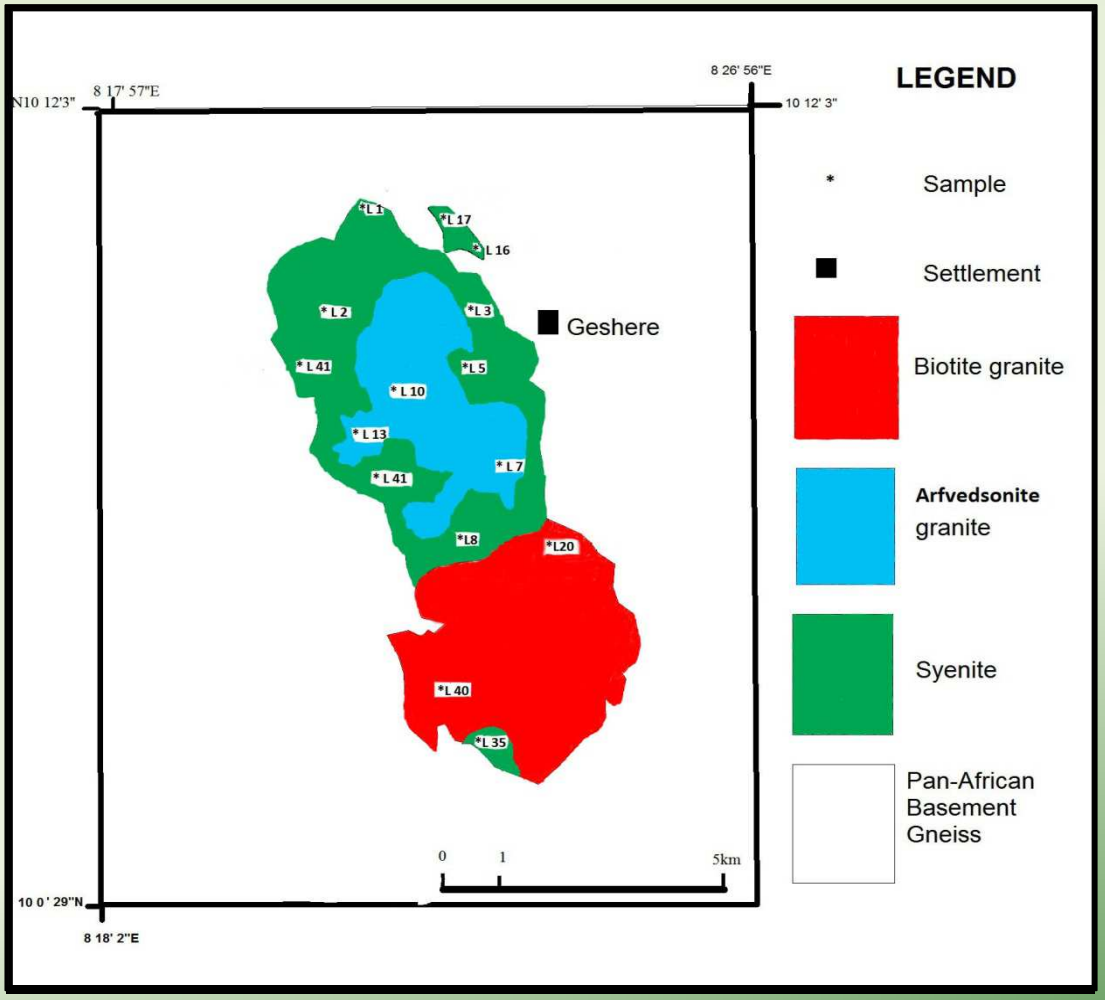
Ogunleye et al. (2006)

THE YOUNGER GRANITES OF NIGERIA: DISTRIBUTION

Location of the Geshere complex



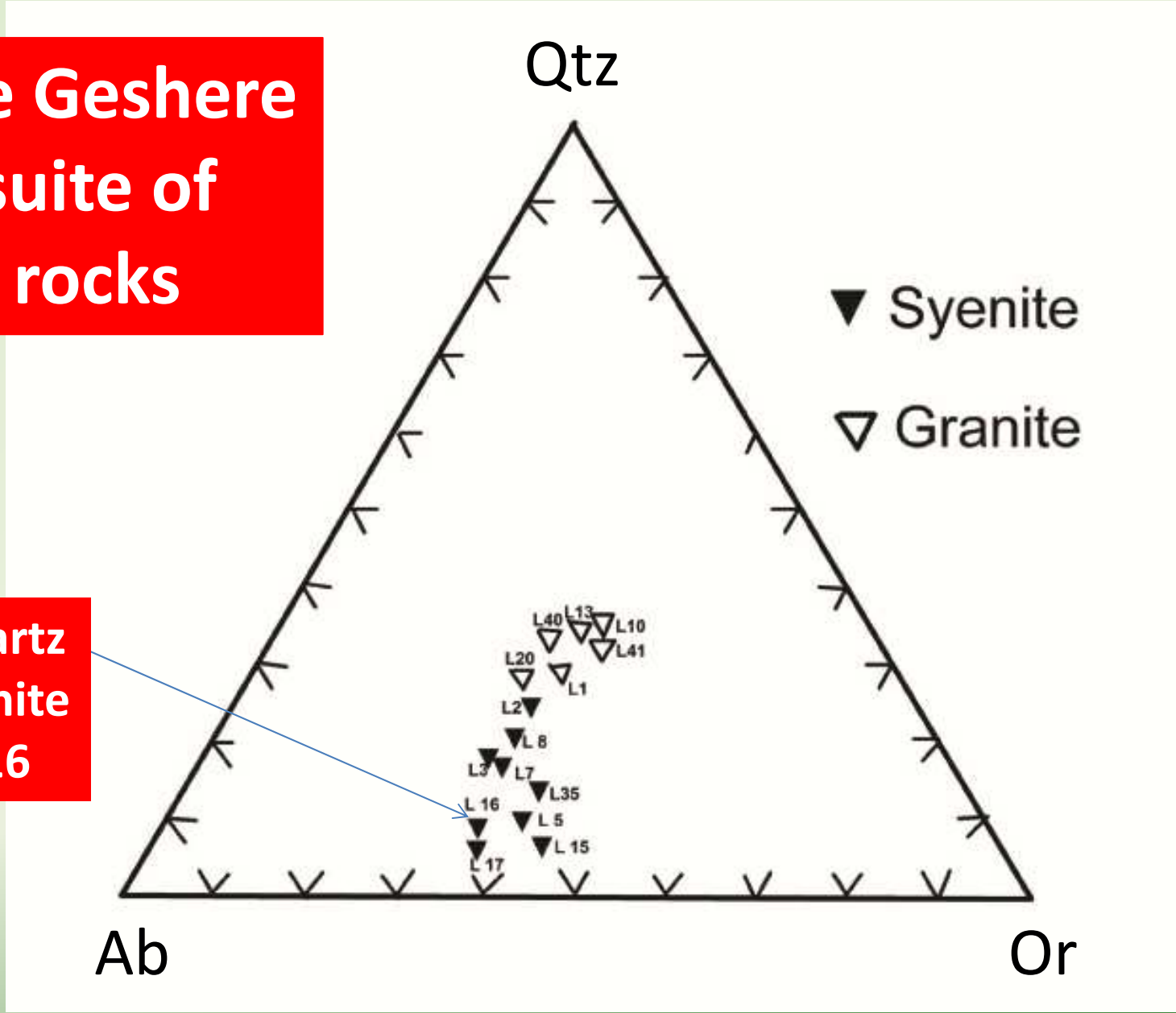
THE GESHERE SYENITE–PERALKALINE GRANITE COMPLEX



Mapping by Shehu S. Magaji, 2010

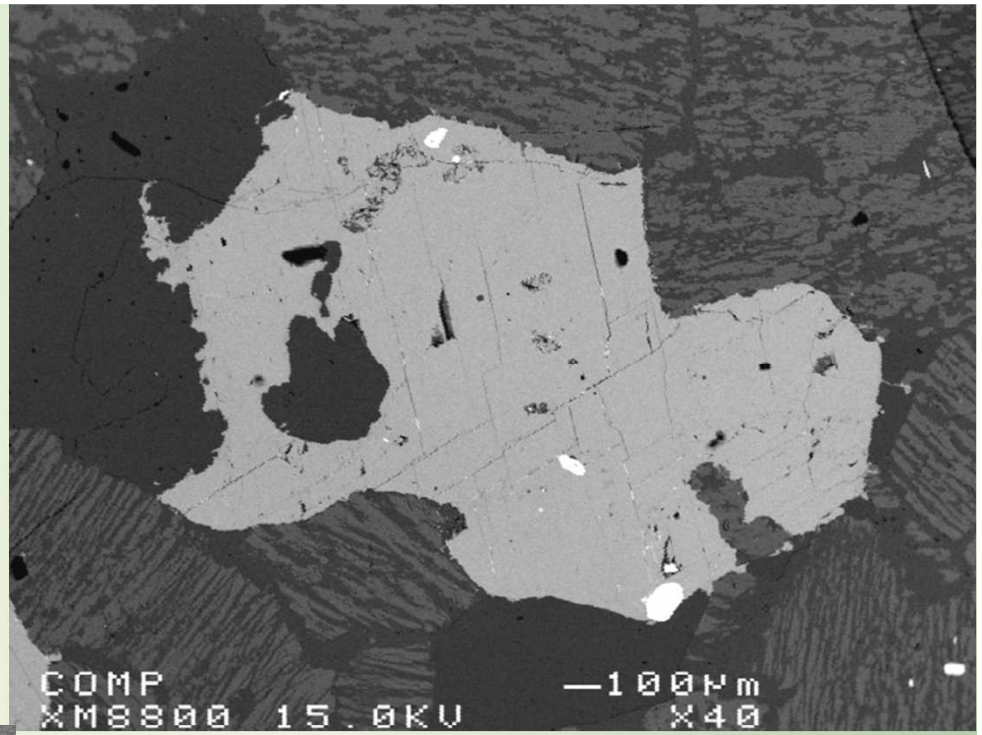
Arfvedsonite granite, Rishiwa complex

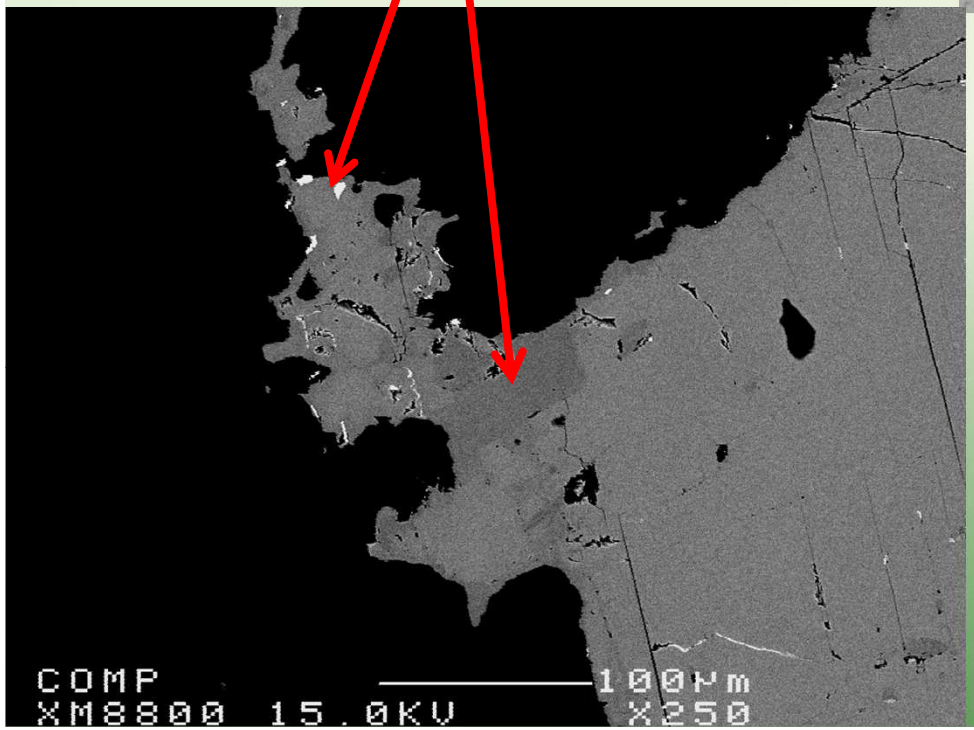
The Geshere suite of rocks



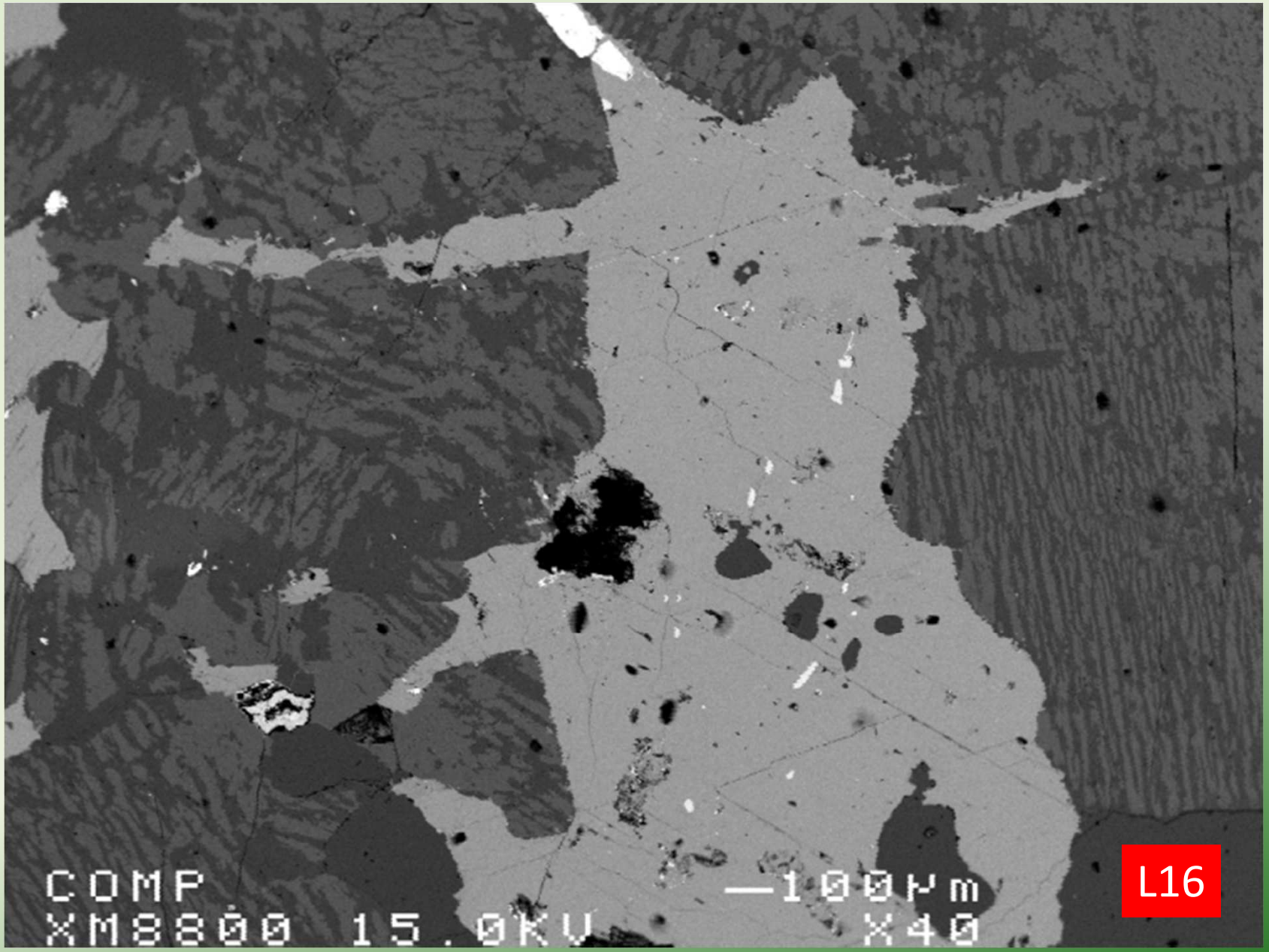
Quartz syenite L16

Very minor development of secondary arfvedsonitic amphibole (in situ fluid-induced replacement of the primary amphibole)





Ferro-richteritic amphibole (primary) in quartz syenite L16 crystallized from a femic interstitial melt left over after massive crystallization of 1) alkali feldspar, and 2) quartz


COMP
XM8800 15.0KV
100μm
X40
L16

The Geshere Complex

- Current work on this complex (Magaji *et al.* 2011) reveals an unusual degree of enrichment in IRON, and an unusual depletion in MAGNESIUM, such that the Mg# is 0.5 (on a scale of 100!); “reverse” differentiation results
- Mücke (2003) favored partial melting of the iron formations in the basement to explain the exceptional degree of Fe enrichment and of Mg depletion

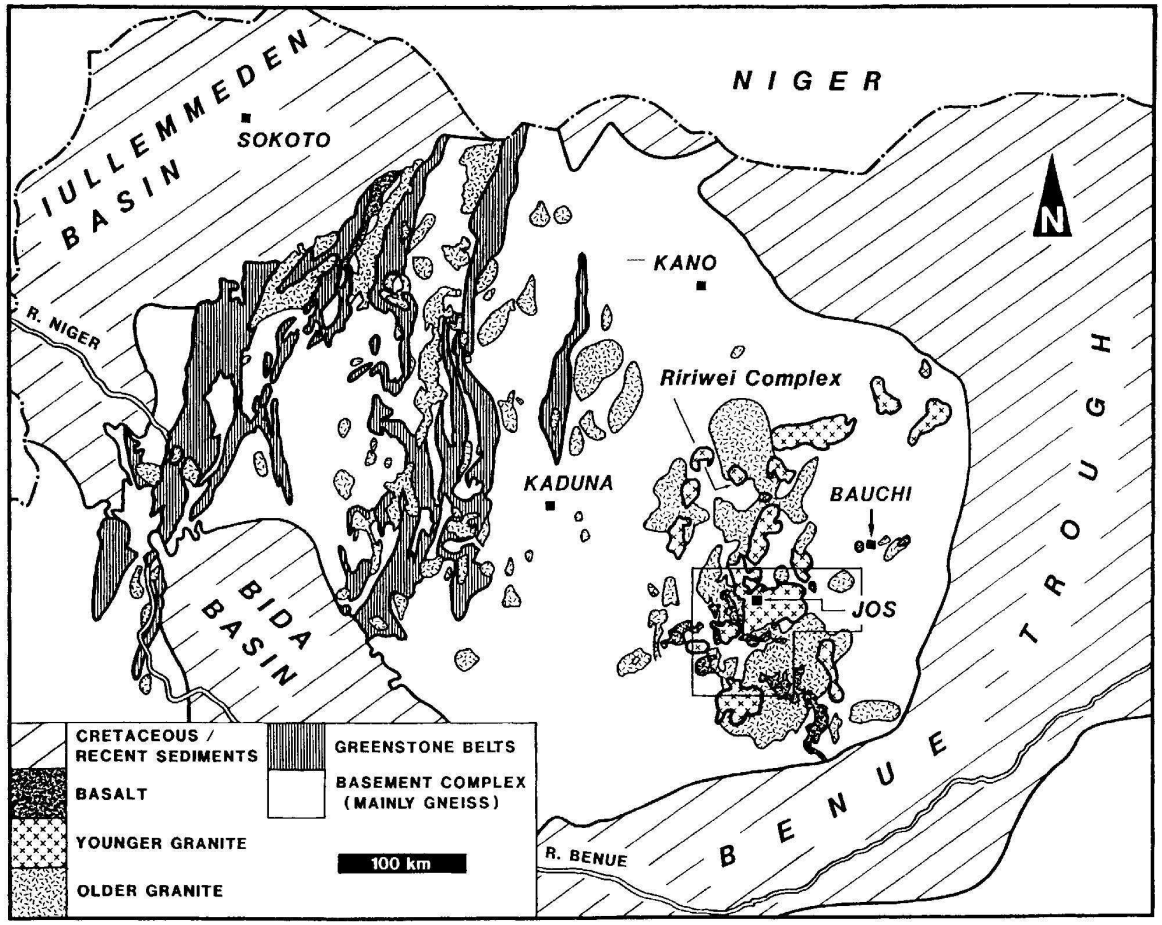


Fig. 1. General geology of northern and central Nigeria showing the distribution of the Jurassic Younger Granites within the Precambrian basement complex including the greenstone belts (containing iron-formations) and the Older Granites of Pan-African age. Marked area is shown in Fig. 2.

Mücke (2003)

The scenario in Mesozoic times…

- No evidence of BIF inclusions in the A-type plutons. On the other hand, anorthosite xenoliths have been found, as have Pl xenocrysts in basaltic dikes in the Rishiwa complex
- In Nigeria, detachment of the lower crust and lithosphere began 400 Myr after the Pan-African orogeny. The Woolley (1987) model kicks in, and rising H_2O–CO_2 fluids cause a fertilization of the basement complex

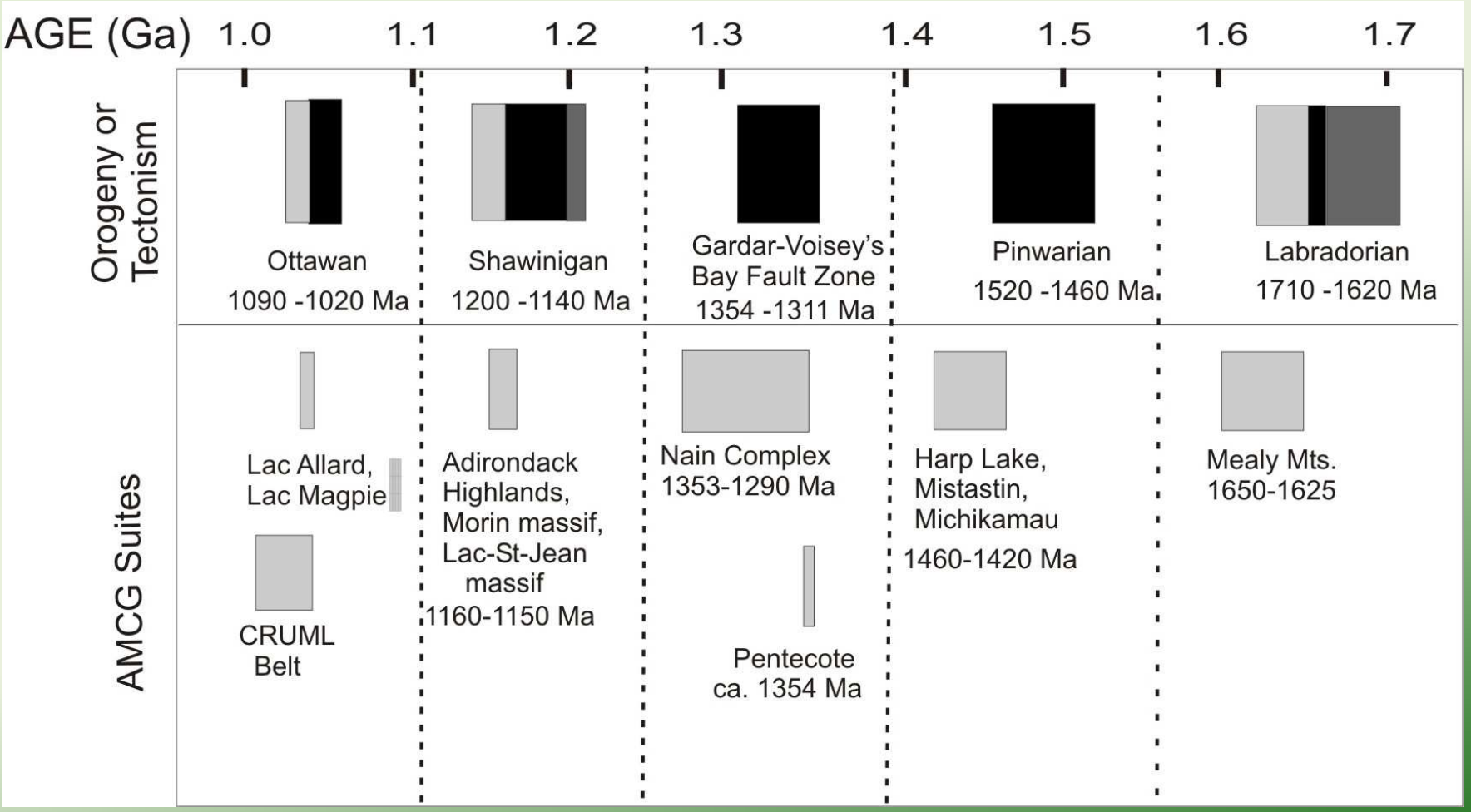
The scenario in Mesozoic times… (2)

- Metasomatize the orogenic (calc-alkaline) granitic rocks, the anorogenic suites, both part of the Pan-African cycle, the Paleoproterozoic iron formation, THEN partially melt
- Where the precursor was already Fe-enriched, the metasomatic overprint followed by partial melting explain well the observed geochemical anomalies

Now back to the Grenville Province

- Where delamination and gravitational collapse of an orogen occur soon after an important collision, the change in tectonic setting can be rapid, possibly in less than 5 Myr
- The Grenville orogen marks the locus of repeated collisions, each followed by a period of anorogenic activity, *i.e.*, repeated emplacement of AMCG suites

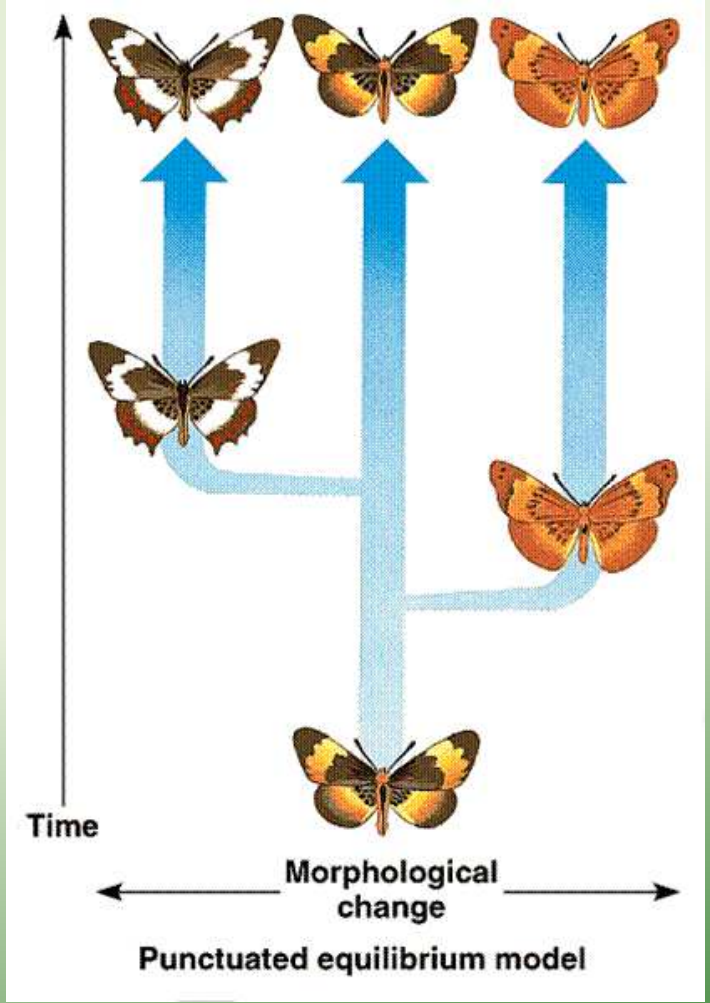
Punctuated anorogenic activity in the Grenville Province of eastern Canada



McLelland et al. (2010, Fig. 7)

As in the case of our butterflies…..

1) Cases of punctuated anorogenic activity are not uncommon
2) Where the precursor is itself an anorogenic suite, the second step of fenitization at the source will lead to anomalous enrichments and depletions
3) Direct tie-in to considerations of economic potential : why are some complexes promising and others not?



Tony Mariano's burning question

- Tony is a consulting geologist who spent his career evaluating anorogenic complexes for REE, Nb, Be, among others, in Nigeria and 87 other countries
- He once asked me: How does one know which pluton will be mineralized, in a petrographic province like the Nigerian Younger Granites?
- I hope that with my background information, I have presented the beginnings of an answer; of course, much remains to be done to be more specific

In particular…

- Detailed studies of petrography, mineralogy, geochemistry…
- Tied in with geochronology, including information on inherited cores in zircon
- Acquisition of stable and radiogenic isotopes to evaluate the respective roles of crust and mantle
- An open mind about open systems


Danke
schön!