

GEOCHEMICAL ASPECTS OF THE EVOLUTION AND MINERALIZATION OF THE NIGERIAN MESOZOIC ANOROGENIC GRANITES

PETER BOWDEN*

ABSTRACT.—The anorogenic Mesozoic ring-complexes of northern Nigeria are composed of syenite-related granitic rocks. Field studies and geochemical evidence suggest that the peralkaline and peraluminous granites developed consecutively implying that each trend evolved its own residual mineralizing fluid. Granites with Nb-U, Zn-Sn mineralization have high initial strontium isotopic ratios but the other related granites and syenites exhibit intermediate (0.706-0.709) and low (0.704-0.706) values respectively. The geochemical data therefore suggests that sources within the mantle, lower crust and upper sialic crust have all contributed to produce the Nigerian younger granites and their mineralization.

The anorogenic Mesozoic ring complexes of northern Nigeria evolved through the early development of trachyte-peralkaline silicic volcanics mirrored at subvolcanic levels by syenite and related peralkaline granites. Isotopic measurements on two small oversaturated syenite intrusions at Zaranda and Pankshin (Fig. 1) suggest that syenitic liquids had initial ratios similar to the mantle, but that related peralkaline silicic variants from the same complexes are depleted in total Sr and have higher $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratios characteristic of the earth's crust. This variation of initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in syenite-related granitic liquids of the peralkaline spectrum has also been noted at the Shere hills, near Jos, and at Liruei (Fig. 1) and may be representative for all syenite-granite occurrences in the Nigerian younger granite province (Table I). No volcanic equivalent of biotite granite or hastingsite-biotite granite has been found in the Nigerian Younger Granite Province. It is assumed that the biotite granite trend is confined to the late magmatic hypabyssal cycle. Therefore as the magmatic cycle progressed, the granitoid liquids became less alkaline and allowed associated peraluminous biotite granites to dominate

* Department of Geology, University of St. Andrew, Fife, Scotland.

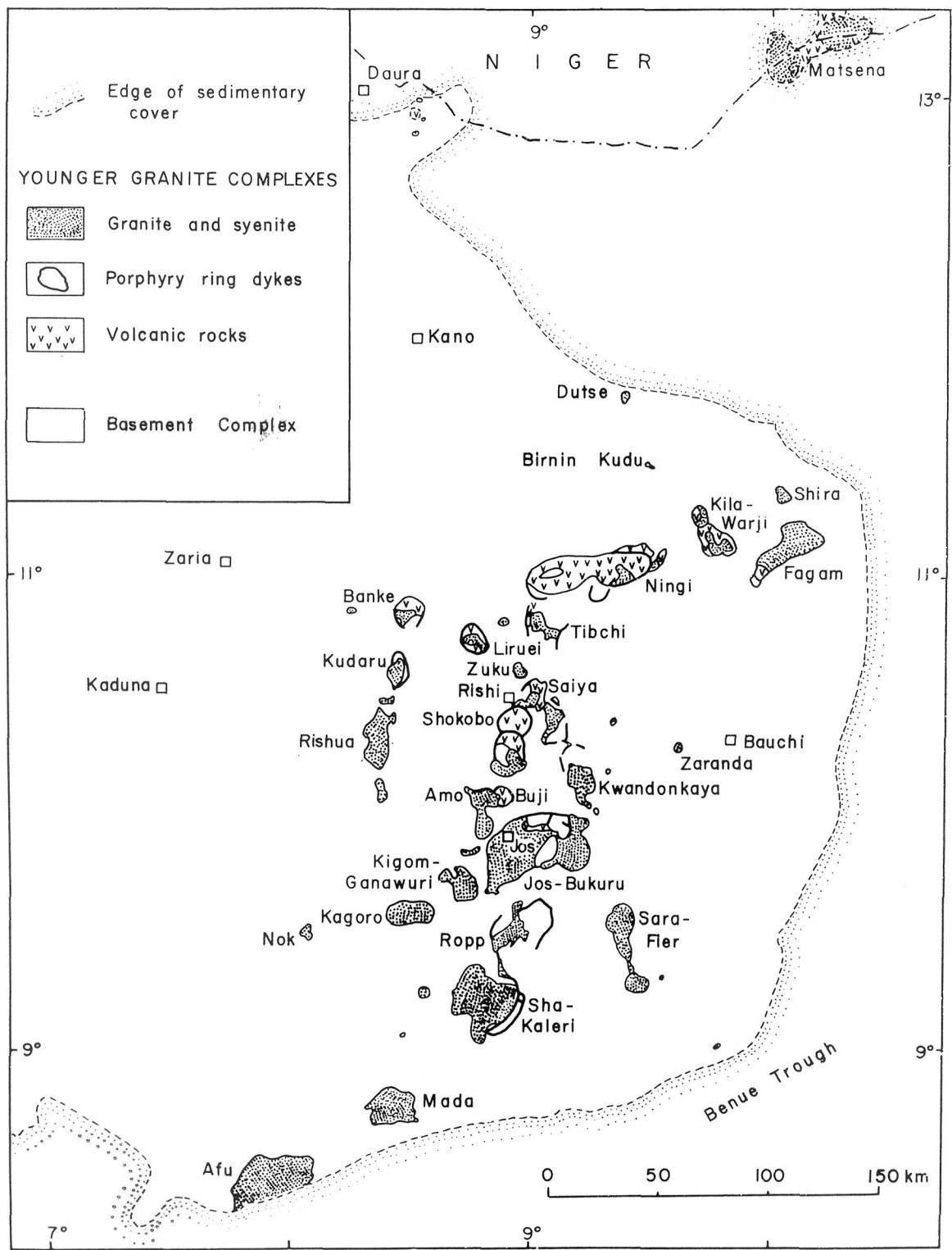


FIG. 1

Location map of the Nigerian Mesozoic ring complexes showing their distribution and principal rock types. Two petrogenetically related but considerably older centres at Daura and Matsena are depicted in the region of the Niger border

TABLE I

Averaged initial strontium isotopic ratios for the syenite-related peralkaline granite trend, Nigeria

	$^{87}\text{Sr} / ^{86}\text{Sr}$ (initial)
Syenite	0.705
Quartz syenite	0.706
Fayalite granite	0.707
Arfvedsonite-riebeckite granite	0.708
Albite-riebeckite granite (mineralized)	0.752

and end the magmatic cycle. The coarse grained biotite granites have consistently low $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in the range 0.706-0.709, but mineralized biotite granites have considerably higher initial strontium ratios (Table II).

The isotopic evidence suggests that a substantial crustal contribution was introduced at some stage during the development of residual fluids either through exchange with country rocks, assimilation or partial melting during the intrusion of syenitic parent magmas to high levels in the crust (van BREEMEN *et al.*, 1975).

TABLE II

Averaged initial strontium isotopic ratios for the biotite granite trend, Nigeria

	$^{87}\text{Sr} / ^{86}\text{Sr}$ (initial)
Hastingsite-biotite granite	0.707
Biotite granite	0.709
Albite biotite granite (mineralized)	0.730

The petrogenetic evolution of the Nigerian younger granites has been widely discussed by numerous authors (see for example, TUGARINOV *et al.*, 1968; BUCHANAN *et al.*, 1971; MACLEOD *et al.*, 1971; BOWDEN and TURNER, 1974). It is generally accepted that the petrographic and geochemical criteria

supports the view that the younger granites are of magmatic origin. It is also accepted that there is peralkaline trend responsible for the formation of arfvedsonite-riebeckite granites from a syenitic parent magma, and a contrasting aluminous biotite granite trend which may have evolved from a similar syenitic source rock. Although it was originally thought that both peralkaline and peraluminous trends evolved simultaneously by divergent differentiation (JACOBSON *et al.*, 1958), recent work has shown that the initial alkaline granite trend was completed in its entirety before the later biotite granite trend developed.

This suggestion eliminates one of the major obstacles to the concept of divergent differentiation and further proposes that the peralkaline and peraluminous trends were not concurrent but consecutive. The implication of this proposal is that each trend develops its own residual mineralizing fluid.

PERALKALINE GRANITES

In the peralkaline granites there was one period of mineralization essentially related to recrystallization and the introduction of albite. It is considered that a high agpaitic coefficient maintained miscibility in the albite-rich ore fluids between silicate and aqueous phases to low temperatures so that mineralizing components continually accumulated together and prevented widespread precipitation of ore minerals. This fluid rich in fluorine albitized and modified the peralkaline granites causing new mineral growth in the sub-solidus and the crystallisation of uraniferous pyrochlore. High initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (up to 0.752) in pyrochlore-bearing albite-rich peralkaline granites suggest a substantial late-stage sialic crustal contribution to the late magmatic fluids.

PERALUMINOUS GRANITES

If, however, the high agpaitic coefficient could not be maintained, silicate and aqueous fluid phases would have separated resulting in substantial ore formation. This process appears to have occurred in the peraluminous biotite granites. A pre-joint autometamorphic mineralization dispersed columbite, thorite and xenotime into the uppermost parts of biotite-granite cupolas. This early phase of mineralization during the cooling and consolidation of the granite was subsequently followed by a post-joint replacement mineralization with the metasomatic introduction of cassiterite, minor wolfram, and abundant sulphide minerals into crystalline host rocks along cooling joints, fissu-

res, veins, and ring fractures. The degree of albitization in the mineralized biotite granites is far less intensive than in the peralkaline granites, but the proportion and variety of ore minerals is far greater. The initial $^{87}\text{Sr}/^{86}\text{Sr}$ isotopic ratios for mineralized biotite granites (0.72-0.73) whilst still reflecting a crustal contribution are not as high as in the strongly albitized peralkaline granites.

SOURCE AND ORIGIN

The anorogenic younger granites of Nigeria vary in age from 200 Myrs in the north to 140 Myrs in the south (Fig. 2). There were therefore sequentially intruded at high levels into the Precambrian 'Basement', and many of the ring complexes at the present erosional levels began life as chains of volcanoes during the Mesozoic. The younger granite group represents an episode of continental mid-plate magmatism during Upper Triassic to Upper Jurassic times in Nigeria (BOWDEN *et al.*, 1976). However despite the frequency of

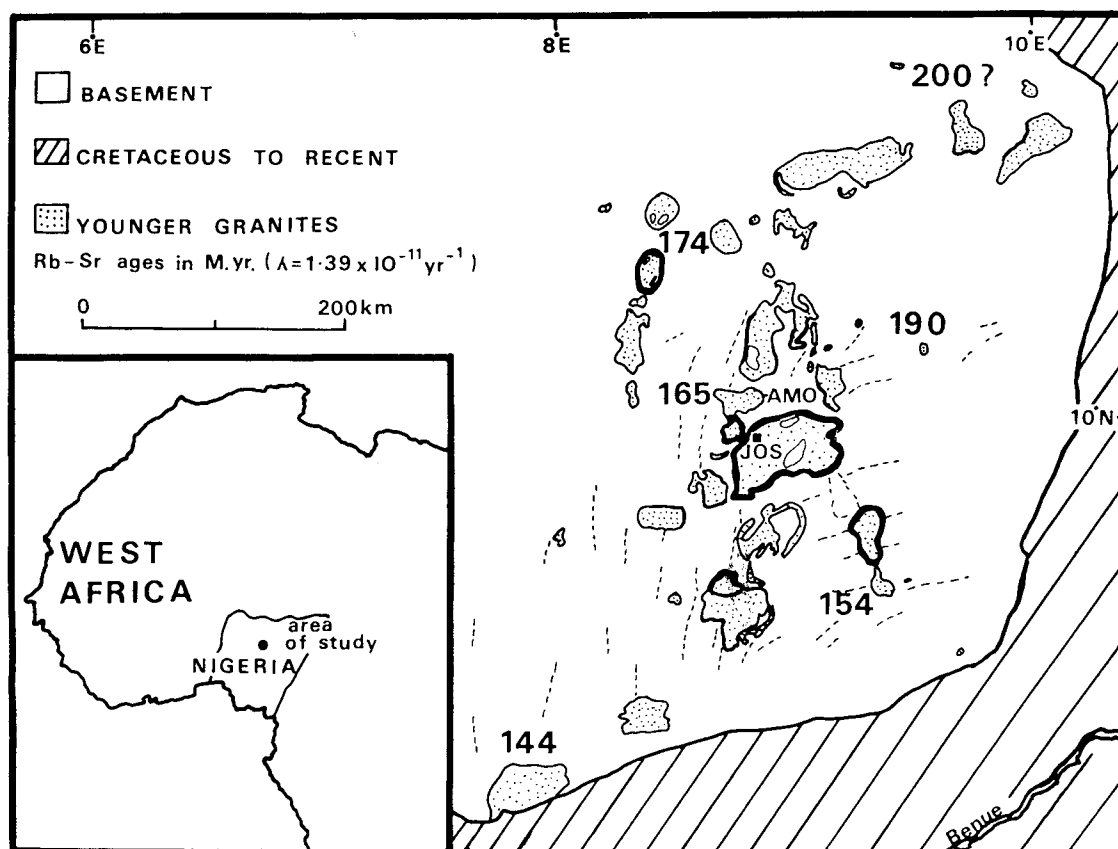


FIG. 2

Sequential age trends for some Nigerian Mesozoic granites

intrusions and number of complexes it appears that the evolution and mineralization processes discussed above were repeated over 40 times during a 50 Myr cycle. Wherever the source of the metals for mineralization may have been situated it must have withstood repeated tapping and must have been an inexhaustable supply of niobium and uranium, zinc and tin.

From the isotopic evidence there are three groups of strontium initial ratios to explain in terms of source and origin of the magmatic liquids and their residual mineralizing fluids i.e. low ratios (0.704 - 0.706) in parental syenites which are close to mantle values; intermediate ratios of 0.706 to 0.709 in most coarse grained granites, and high ratios (0.721 to 0.752) in mineralized granites. We therefore have isotopic evidence for contributions from the mantle, lower crust and sialic upper crust. When this data is examined in conjunction with other geochemical evidence it appears that material from all *three* sources has been utilised to produce the varied and exotic geochemical features of the Nigerian Mesozoic anorogenic granitoid rocks.

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