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Anorthosite—first occurrence in Nigeria and relevance to Younger Granite genesis

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SUMMARY. Plagioclase crystal fragments and a block of anorthosite occur in small basaltic dykes on the Jos Plateau. The anorthosite is unusual, for the feldspar is labradoritic, but the interstitial mineralogy is granitic rather than basic, displaying granophyric intergrowths in places. The anorthosite is probably not an intermediate stage in fractionation from a basic parent magma towards granite, since over 95 % of this large province is granitic and the volume of basic magma required would be prohibitively large. Nor did it develop as an intermediate stage in fractionation from a salic parent magma, e.g. syenite, because the plagioclase is too calcic to have crystallized from a syenitic melt. Basic to intermediate dykes are numerous though volumetrically insignificant in the Younger Granite province. The anorthosite may be related to the evolution of small volumes of basaltic magma, which had little to do with Younger Granite magmatism.

ANORTHOSITIC intrusions occur in the ring complexes of the 'Younger Granite' province of Aïr in Niger. Black (1965) regarded them as part of a postulated differentiation sequence from basaltic magma through to peralkaline granites: plagioclase cumulates removed alumina from the melt, thus raising the alkali:alumina ratio, so that later liquids evolved through alkali syenites to aegirine- and riebeckite-bearing granites with alk:al $\approx$ 1. Another line of descent led from the basaltic parent through fayalite-bearing pyroxene-amphibole syenites and granites to aluminous biotite granites with alk:al $\approx$ 1, by separation of mafic phases. The Aïr province is petrochemically almost identical to the Nigerian Younger Granite province, the chief difference being in the relative proportions of peralkaline and biotite granites, outcrops of which cover respectively 45 % and 3 % of the total area of intrusive complexes in Niger, and 12 % and 56 % respectively in Nigeria (Black and Girod, 1970).

A volumetrically insignificant but ubiquitous component of the Nigerian province is dykes ranging from dolerite through syenodolerite to microsyenite in composition, emplaced at several stages throughout the period of Younger Granite intrusion (Buchanan *et al.*, 1971). A small group of basic dykes occurs north of Jos, in the Delimi river gorge where it cuts through the western end of the long, narrow, arcuate Rafin Jaki ring dyke (fig. 1), a late member of the Younger Granite province. The dykes are irregular and sinuous, with complex cross-cutting relationships, and enclose fragments of basement gneisses. There are two kinds, one aphyric, the other containing plagioclase crystals up to 2 or 3 cm long, which are sometimes concentrated along the central portions. One of the feldspar-bearing dykes contains a large block of anorthosite (fig. 2) consisting almost entirely of tabular euhedral plagioclase crystals

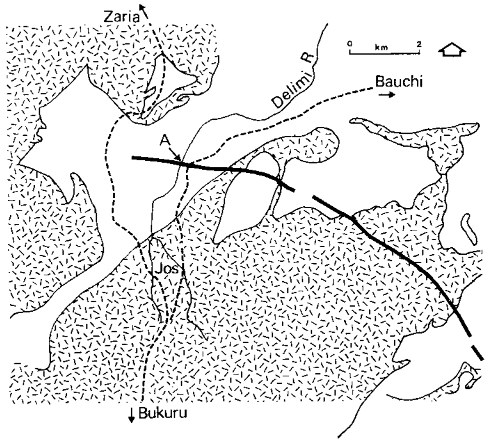
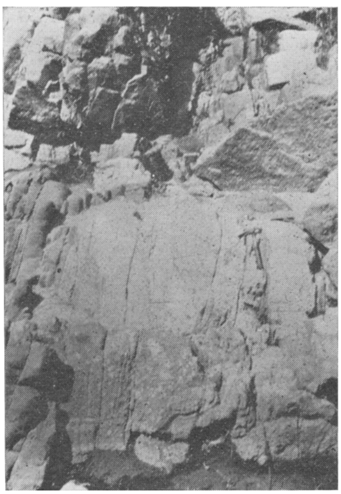
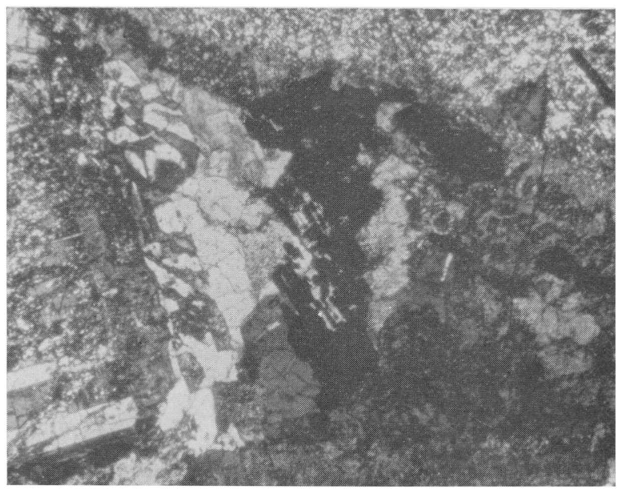


FIG. 1. Simplified geological map (after Buchanan *et al.*, 1971), to show cross-cutting relationships of Rafin Jaki ring dyke (black) to other members of Younger Granite province (stippled; boundaries within individual complexes not shown). Basement gneisses, blank. Anorthosite locality, A.





FIGS. 2 and 3: FIG. 2 (left). Large anorthosite block (centre), smaller fragments, and plagioclase crystals in one of the larger basic dykes, Delimi River Valley. Line shows boundary of dyke. Hammer length about 30 cm. FIG. 3 (right). Granophyric intergrowths of quartz and turbid feldspar interstitial to sericitized calcic plagioclase crystals (relatively unaltered plagioclase visible in lower left). Skeletal oxide to right of the intergrowth. Crossed polars. Vertical picture length represents *c.* 1·5 mm.

up to 3 cm in largest dimension, with some signs of preferred orientation (this may be a cumulate texture).

Petrography of the anorthosite. The large unzoned and patchily sericitized plagioclase crystals, forming over 95 % of the rock, have well-developed Carlsbad-albite twinning, from which extinction angle measurements gave compositions ranging from An_{58} to An_{65}. Small dark interstitial patches seen in hand specimen contain chiefly quartz, with lesser amounts of very turbid alkali(?) feldspar, in places displaying granophyric intergrowth (fig. 3) also biotite, opaque oxide, green-brown amphibole, epidote, apatite, and chlorite.

Petrography of the basic dykes (cf. Buchanan *et al.*, 1971). Dykes containing the large feldspar crystals are fine grained and so heavily altered that only calcic plagioclase laths (0·1–0·5 mm), chlorite, sericite, biotite, and tabular iron oxide are identifiable in the body of the rock. Numerous 0·1–0·5 mm amygdales are rich in biotite, chlorite, and feldspar(?) needles and almost invariably have a core of quartz. The large feldspar crystals in these rocks are identical to those in the anorthosite, and show signs of physical abrasion and rounding, but no chemical reaction rims were observed.

Dykes without large feldspars retain a recognizable doleritic texture, despite extensive alteration. Plagioclase is sericitized and clinopyroxene has been altered to fibrous actinolite. There is some biotite, chlorite, and plentiful iron oxide, and the amygdales are composed chiefly of calcite and chlorite, sometimes with a little quartz.

Significance of the anorthosite. The Aïr anorthosites are both more extensive (379 km^2, Black and Girod, 1970) and more 'normal' than the small Nigerian occurrence. They contain coarse labradorite/andesine, olivine (Fa_{35}), titanaugite, amphibole, and biotite. If these were cumulates from the alkaline gabbros, which are found in a few of the intrusive complexes, they could have contributed to development of some of the strongly alkaline salic rocks, as suggested by Black (1965) and proposed also by Bridgewater and Harry (1968) for generation of salic members in the Gardar province (Greenland). However, the volume of basic rocks is very small (2 % in Niger, 1 % in Nigeria) and they do not grade into syenites and granites of the intrusive complexes. In Niger and Nigeria, moreover, granites and rhyolites occupy respectively 75 % and 95 % of the total area of Younger Granite outcrop. Gravity measurements (Ajakaiye, 1970) have determined that granitic rocks in the intrusive complexes extend down to at least 10 to 12 km in Nigeria, and there is no reason to suppose the situation is different in Niger. The total exposed area of granitic rocks in Nigeria is more than 5000 km^2, which means more than 50 000 km^3 of granitic magmas, not including the substantial volcanic superstructure, the remnants of which still cover some 1200 km^2.

If this volume of granite were to represent 5 to 10 % of acid residua from a differentiating basic magma at depth, then the Jos Plateau area of Nigeria would have to be underlain by at least 5×10^5 km^3 and perhaps as much as 10^6 km^3 of depleted basic rocks deep in the crust. Such a volume would be encompassed by a slab approximately 220 km square and between 10 and 20 km thick, and the Younger Granite province would be the site of a substantial crustal depression, rather than a broad plateau area with a sizeable regional negative gravity anomaly (Ajakaiye, 1970).

Current thinking on the origin of West African Younger Granites inclines more to the thesis of Bailey and Schairer (1966), that the parental magma was of syenitic composition, evolving by fractionation or crustal contamination, or both, into the variety of granite types encountered (MacLeod *et al.*, 1971; Black and Girod, 1970; Wright, 1970). Separation of plagioclase from a syenite parent would deplete residual melts in alumina and lead to development of peralkaline granites. Separation of mafic phases, especially fayalite and pyroxene, would produce the aluminous biotite granites. The Rafin Jaki anorthosite block might represent part of a feldspar cumulate formed in this way, for its interstitial mineralogy is granitic rather than gabbroic. However, the unzoned labradoritic plagioclase of the anorthosite is much too calcic to have separated from the syenites, which contain zoned feldspars no more calcic than An_{40}.

Conclusion

The available evidence makes it likely that the anorthositic block and calcic plagioclase fragments in the Delimi river dyke are related to the fractionation history of a small batch of basaltic magma generated independently of the main Younger Granite magmatism (cf. McLeod *et al.*, 1971). The 'granitic' mineralogy of the interstitial material, which contrasts so strongly with the basic plagioclase, can be ascribed to the influence of the residual silica and water-rich fluids that were responsible for the alteration in the basaltic host rocks.

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