15 *The Younger Granites*

SUMMARY

The Younger Granite ring complexes of West Africa extend from Aïr to Cameroun and range in age from Palaeozoic to Tertiary. They are dominated by granites and are emplaced in Pan African basement rocks, on 'swells' bordering sedimentary basins.

The complexes probably represent the root zones of ancient volcanoes of the type characterised by caldera collapse. Early stages of magmatic activity involved the eruption of large volumes of rhyolitic ignimbrites. Further eruptions occurred along more or less circular ring faults. Magma subsequently solidified in these fractures and formed marginal ring dykes of granite porphyry that define the outer limits of some complexes. Inside the peripheral ring fracture, a variety of mainly granitic rocks was emplaced, both as massive ring dykes and as more or less cylindrical stocks and bosses. The ideal pattern is one of concentric intrusions, becoming progressively younger towards the centre, but many complexes depart from this ideal.

The dominant granites of the complexes range from peraluminous to peralkaline in composition and they are associated with smaller amounts of syenite, gabbro and anorthosite. Some of these magmas originated in the upper mantle, but the overwhelming preponderance of granite suggests that there was a contribution from crustal melting also.

Regional tectonic controls on emplacement of the complexes remain a matter of speculation. On the local scale, emplacement of individual complexes must have been controlled by basement fracture systems, but these are not easily identified.

The Younger Granites of Nigeria in particular are famous for their tin (cassiterite) mineralisation, which is mainly associated with the biotite granites. These rocks also contain significant quantities of the niobium-rich mineral columbite as an accessory. Most of the workable deposits of cassiterite and columbite are in alluvial concentrations. The peralkaline granites also contain accessory uranium-bearing minerals, which probably provided the primary source for the sedimentary uranium deposits of Niger.

15.1 Introduction

The numerous ring complexes collectively termed the Younger Granites are now found along a nearly 1500 km long belt in areas of Pan African basement uplift surrounded by sedimentary basins that achieved their main development in the Cretaceous (cf. Fig. 13.1a). The Younger Granites have been studied in most detail in Nigeria, partly for their intrinsic interest, providing comparative data for study of similar formations elsewhere in the world, but mainly because in the early 1900s they were recognised as the source of rich alluvial cassiterite deposits that had long been known to exist on and around the Jos Plateau (Sec. 15.5).

Detailed field mapping of the ring complexes has demonstrated a consistent succession of magmatic activity from volcanism to plutonism associated with the emplacement of mainly granitic melts at high levels in the crust. The most striking petrographic feature of the whole province is the overwhelmingly acid nature of the rocks and the uniformity of rock types found in all areas. Over 95% of the rocks can be classified as rhyolites, quartz–syenites or granites, with basic rocks forming the remaining 5%. Many of the rocks have strongly alkaline to peralkaline compositions, others are aluminous to **peraluminous**.

Initial stages in development of the complexes involved extrusion of vast amounts of acid lavas, tuffs and ignimbrites, now only partly preserved as a result of subsidence along ring faults. Almost everywhere these rhyolitic rocks directly overlie the metamorphic basement, which means that the Younger Granites were emplaced in uplifted areas that were undergoing erosion. Granitic **ring dykes** are the major component of most complexes, ranging from 5 km or less to over 30 km in diameter, and varying in plan from the polygonal to circular or crescentic, and through more irregular shapes to simple stocks and bosses. Some complexes have a broadly concentric pattern, indicating that the activity was confined to one area, but others have overlapping rings, because the centre of activity migrated with time.

In most Younger Granite complexes, both volcanic and intrusive rocks are confined to roughly circular areas bounded by ring dykes or ring faults. The volcanic rocks were downfaulted in great collapse structures that formed calderas at the surface. The volcanics are fairly well stratified and they are tilted to varying degrees, as a result partly of sagging and fault drag accompanying caldera collapse and partly of emplacement of later granites. Although the volcanics probably once extended well beyond the present limits of the complexes, they are now only preserved in these downfaulted regions. Virtually all traces of their former extent outside the caldera walls have long since been eroded away. Even where ring complexes have no associated volcanics at all, this is probably because they have been removed by erosion rather than because they were never erupted. The ring dykes were probably emplaced by mechanisms involving underground **cauldron subsidence**, though as the intrusive forms are quite varied other processes of intrusion must also have been involved. An important feature of several complexes is the occurrence of **screens** of crystalline basement rocks between successive granitic intrusions.

15.2 Evolution of the complexes

Figure 15.1 shows the likely sequence of evolution of the Younger Granite complexes, in highly simplified and abbreviated form. Eruption of the volcanic components probably followed a pattern broadly similar to that found in modern calderas, and two main stages can be recognised.

15.2.1 Eruption of early rhyolites
Where significant volumes of volcanics are preserved, the succession generally commences with layered sequences of rhyolites, **ignimbrites** and welded tuffs, bedded air-fall tuffs, agglomerates and occasional basalts and trachytes.

Most of the early rhyolites are typical ignimbrites or welded tuffs, with original fragmental textures obscured by welding and later devitrification and recrystallisation. Many lack any sign of fragmental textures, and may be lavas. Compositionally, the early rhyolites consist of quartz and alkali feldspar phenocrysts in a fine-grained devitrified ground mass.

Little is known of the pre-caldera structures formed by these early effusions, but the dominance of ignimbrites suggests that they may have been plateaux or very flat shield volcanoes. The surface activity must have been preceded by the formation of a magma chamber high in the crust (Fig. 15.1). This caused crustal doming and so promoted development of the ring fracture that controlled surface caldera collapse. Evidence for pre-caldera doming is found in the **cone sheet** swarms round a few complexes, and circular lineaments visible on satellite photographs round others. The cone sheets are normally thin curved intrusions of felsite or granophyre, dipping inwards at angles of between 30° and 60° and projecting to a focus some 5 km below the present surface.

15.2.2 Eruption of later rhyolites
Massive porphyritic rhyolites up to several hundred metres thick and xenolithic in places, overlie the bedded volcanics of the early rhyolites in several complexes. They probably represent caldera-filling eruptions and appear to occur in two main forms: (a) crystal-rich ignimbrites or welded tuffs, often banked up against caldera walls and erupted as ash flows from the ring fracture which controlled the surface caldera collapse and underground cauldron subsidence (Fig. 15.1), and (b) massive bodies representing original highly viscous magma extruded as thick flows and dome-like masses (**tholoids**). The later rhyolites are all crystal-rich, with abundant quartz and alkali feldspar phenocrysts.

It is possible that the main phase of caldera subsidence was initiated during this eruptive episode. The high phenocryst content of the later rhyolites indicates that the magma had reached an advanced stage of crystallisation within the subvolcanic reservoir. This probably contributed to the build-up of gas pressures that initiated the large ignimbrite eruptions. The resultant partial evacuation of the magma chamber started the process of collapse and the formation of a surface caldera. The ring fracture which now formed the main pathway for eruption of the magma, probably as a **fluidised system**, was widened by the violent nature of the eruptions. It subsequently became filled with the relatively gas-poor and more viscous ring dyke porphyries described in the next section. The amount of caldera subsidence can be estimated from the thickness of volcanics preserved in Younger Granite complexes, and it was of the order of 500 to 1000 m.

Post-caldera eruptions are known in some modern calderas, but either these did not occur in the West African complexes or their products have since been lost through erosion. In any case the igneous activity often shifted sideways, so that renewal of volcanism on sites of previous collapse may have been relatively uncommon. Clastic sediments are preserved in a few