

SHORTER COMMUNICATIONS

ANORTHOSITES AND ASSOCIATED ROCKS OF TAMIL NADU SOUTHERN INDIA

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Introduction: In the state of Tamil Nadu there are known at present five occurrences of anorthosite, commonly associated with basic and ultrabasic rocks (Fig. 1); the aim of this paper is to review their style of occurrence, characteristic features and probable mode of origin. It is our contention that these rocks may belong to a suite formed by similar igneous processes, and that they may be used as stratigraphic markers. Hopefully it may prove possible in the future to use these and similar rocks as a means of delineating an anorthosite-basic-ultrabasic tectonic belt through the charnockite-gneiss province of southern India.

As extremely similar rocks are present in several high-grade Archaean terrains on other continents, it will be useful to summarise recent data on their main features and mode of origin with a view to comparing them with the rocks of Tamil Nadu.

Type and Origin of Similar Rocks in other Continents: Archaean anorthosites and associated rocks occur in several continents as conformable layers in hypersthene-bearing charnockitic and retrogressive or progressive hornblende-biotite gneisses which are older than about 3000 m.y. (Windley, 1973). They appear to be best developed in the Archaean craton of the North Atlantic region (Bridgwater, Watson and Windley, 1973), and especially in West Greenland (Windley, 1969) where there are exposed on the present erosion surface at least 1500 km of layers as measured along their strike. They range in width mostly up to 2 km, reaching 6-8 km rarely, but are often thinned to only a few metres and may even be reduced by fragmentation and migmatitisation to rows of inclusions in the gneisses.

The Fiskenaeset complex, which is at present being studied in great detail by the Geological Survey of Greenland (Kalsbeek and Myers, 1973), has a folded strike length of at least 500 km (single layers can be followed along strike for 80 km), and contains a complete upward succession from ultrabasic rocks, through gabbros and leucogabbros to chromite-layered anorthosites (Windley, Herd and Bowden, 1973). One of the most distinctive units is a hornblende leucogabbro with a marked cumulate texture outlined by plagioclase megacrysts (Myers, 1973). In spite of the fact that the rocks have been metamorphosed to a granulite or amphibolite grade, many primary igneous features are well preserved, such as cumulate textures, grading and layering. The igneous differentiation trend of the sequence is still intact (Windley *et al*, 1973), as well as cryptic chemical variations through individual mineral species such as plagioclase (An_{80-96}), olivine, orthopyroxene, hornblende and magnetite (Windley and Smith, 1974). In other words, there is abundant evidence that these rocks formed in a differentiated layered igneous complex. A final important structural point is that the stratigraphy of many layers is often repeated showing that they themselves are isoclinal.

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Elsewhere in West Greenland anorthositic layers in the gneisses are not chromite layered, they lack the complete stratigraphy of the Fiskenaesset complex, but they are commonly associated with hornblende leucogabbros with the same diagnostic cumulate texture as in the Fiskenaesset leucogabbros. In many areas the layers have been extensively fragmented and so occur as inclusions in gneisses and late amphibolite facies retrogression has commonly caused a decrease in the An content of the plagioclase, which may reach as low as 30. Although it was once considered by Sorensen (1955) that some calcic anorthosites in West Greenland may have formed by recrystallisation of calcareous sediments, the more detailed recent evidence clearly points to an igneous origin for this suite of rocks.

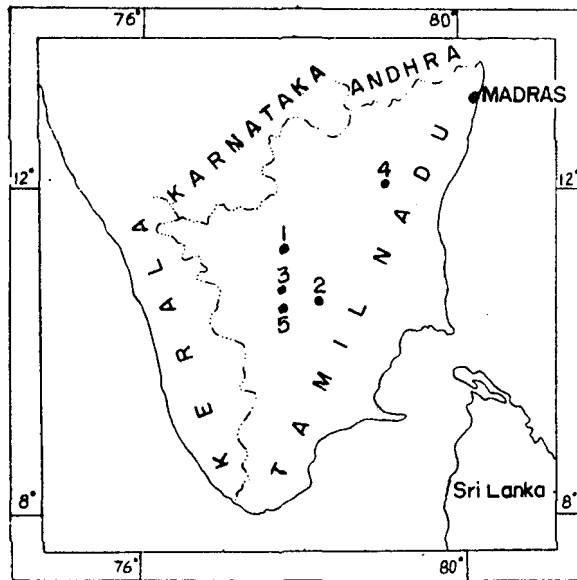


Figure 1. Anorthosite occurrences in Tamil Nadu, India.

1. Sittampundi, 2. Kadavur, 3. Chinnadharapuram,
4. Mamandur, 5. Oddanchatram.

In the Scourian gneisses of Scotland there are many small anorthositic-basic-ultrabasic inclusions that contain relict igneous structures (Bowes, Wright and Park, 1964). The largest anorthosite is in the Rodil Complex, a conformable lens in gneisses (Dearnley, 1963). A layer about 13 miles long and 0.5 km wide has recently been discovered by Davis (1974) near Scourie; it has a succession from ultrabasics through gabbros and leucogabbros with a small amount of anorthosite at the top. All these are regarded by the authors concerned as metamorphosed and deformed remnants of layered igneous complexes.

The granulite-to-amphibolite facies gneisses of the Limpopo belt of southern Africa contain at least 100 km strike length of folded conformable layers that consist of anorthosites and leucogabbros with the diagnostic cumulate texture (Söhngge, 1945; van Zyl, 1950). A strong retrogressive metamorphism has caused zoning of most plagioclases, but a recent geochemical survey reveals that most of the rock differentiation is preserved and that the hornblendes retain some igneous cryptic chemical

variations (Hor *et al*, in prep.). The anorthosites are both chromite layered and corundum bearing and thus resemble the Sittampundi anorthosites. Although Bahnemann (1970) thought that the anorthosites might be recrystallised calcareous sediments, the evidence of the chromitite layering and the relict rock and cryptic fractionation trends indicate that the rocks belong to a meta-igneous suite.

The Sakeny anorthosites in Malagasy also appear to belong to the group of rocks under consideration (Boulanger, 1959).

The Tamil Nadu Rocks: Within the dark hypersthene-bearing gneisses (charnockites) and grey hornblende-biotite gneisses (migmatitic gneisses) there are conformable layers of anorthosite and associated rocks at Sittampundi, Kadavur, Chinnadharapuram, Mamandur and Oddanchatram.

Sittampundi, Salem District: In recent years this complex has been studied by Nehru (1955), Subramaniam (1956a), Naidu (1963), and Ramadurai and Sankaran (1970). The complex consists of chromite-layered anorthosites with minor gabbros and ultrabasic rocks. It was regarded by Subramaniam (1956a) as a layered igneous body later subjected to high-grade regional metamorphism, but Naidu (1960, 1963) reinterpreted it as a group of recrystallised calcareous sediments.

We have recently reinvestigated the complex and discovered that it contains a primary igneous stratigraphy which passes upwards from rare pyroxenites, through gabbros, to anorthosites overlain by clinozoisite anorthosites; in the north-east of the area the clinozoisite can definitely be used as a stratigraphic marker mineral. The way-up of the succession is not just based on a priori geochemical grounds, but on the fact that the complex has a repeated stratigraphy, like the Fiskenaasset Complex, indicating that the present layer in the gneisses has the shape of an isoclinal anticline (Ramadurai and Sankaran, 1970). Thus the lower ultrabasic rocks occur in the core of the structure and are flanked by the younger anorthosites. The anorthositic rocks have many alternating plagioclase- and hornblende-rich layers up to about 10 cm thick, which we regard as modified igneous layers. We also place importance on the chromitites (which are up to 6 m thick) in the anorthosites as evidence of an igneous origin for this rock suite.

Kadavur: According to Subramaniam (1956b) the complex consists of gabbros overlain by anorthosites and it has the shape of a conformable synclinal layer in the gneisses; however Saravanan (1963) and the writers found little central anorthosite. The most important feature of the body in our opinion is that it consists of a hornblende leucogabbro with a very distinctive cumulate texture outlined by plagioclase megacrysts. This rock is identical to the cumulate leucogabbros in the Limpopo and Fiskenaasset Complexes and associated with the other Greenland anorthosites. It has a considerable variation in grain size; in some localities the plagioclases are about 1 cm across, in others they reach at least 10 cm. The centres of many plagioclase megacrysts are dark and consist of single large crystals, which have been partially recrystallised around their borders to a fine-grained granular aggregate of white plagioclase granules. The megacrysts are in all stages of recrystallisation, some being well preserved, others being almost totally recrystallised. The important feature to note is that the outline of the megacrysts is unaffected by advanced stages of recrystallisation which takes place only within them with the result that the diagnostic igneous cumulate texture is easily discernible in the present metamorphic rocks. In our opinion these megacrysts are not metamorphic porphyroblasts and we do not ascribe to the view that the rocks are migmatised amphibolites (Saravanan,

1963). The complex occurs in a low deformation zone within the gneissic terrain with the result that the syncline has an open form and the cumulate plagioclase megacrysts are undeformed by simple or pure shear.

Subramaniam (1956b) concluded that the Kadavur Complex was an Adirondack-type anorthosite-gabbro. However, from the first author's experience the rocks are totally unlike any of the main components of the Proterozoic complex in the Adirondack Mountains of New York State. In spite of the fact that the leucogabbros contain minor haemo-ilmenite (M. K. Bose, personal communication) we see no reason to conclude that these rocks have more structural, stratigraphic or chemical affinities with the Adirondack-type anorthosites and gabbros than with the Archaean types found elsewhere in Tamil Nadu or on other continents.

Chinnadharapuram, Trichy District: In the charnockitic gneisses of this area there are several metamorphosed ultramafic layers and lenses up to about 100 m across that consist largely of dunite, peridotite and pyroxenite (Srinivasan and Kanishkan, 1973). One body is bordered by corundum-rich anorthosite about 1 m wide that is similar to the corundum anorthosites of the Sittampundi Complex. No detailed account exists of these bodies, but there seems every reason to believe that the ultramafic rocks were originally of igneous origin. The bodies now form tectonic relicts in the gneisses.

Mamandur: Murthy (in press) has described anorthosites associated with metamorphosed basic and ultrabasic rocks at Mamandur in the South Arcot district and suggested that they are of igneous origin. In petrological investigations Ramanathan (1972a, b) found that the plagioclases have an anorthite content ranging from 55–98%, and the garnets consist largely of the grossular-andradite molecules. Because these mineral compositions differ from those in the Adirondack anorthosites and resemble those in metamorphosed limestones, Ramanathan (op. cit.) and Saravanan and Ramanathan (1973) concluded that the Mamandur 'anorthosites' are recrystallised sediments. However it is fair to say that the plagioclases and garnets are not unlike those in the Sittampundi Complex, which Subramaniam (1956a) considered to be of meta-igneous origin.

Oddanchatram: In the gneisses of the Oddanchatram area of the Palni district there is a hornblende anorthosite layer (with An_{50-65} plagioclase) that is about 5 km thick and at least 16 km in extent (Narasimha Rao, 1963, 1964; Lakshminarayanan, 1974). The meta-anorthosite has an An_{45-65} plagioclase and subordinate hornblende and it contains lenses and layers of meta-norite. Narasimha Rao considered the rocks to belong to an intrusive complex of the Adirondack type (Buddington, 1960); Lakshminarayanan (1974) disagreed with the Adirondack comparison, but did conclude that the suite was of intrusive origin.

Discussion: In our opinion in Tamil Nadu State there has in the past been too much emphasis in interpreting anorthositic rocks either as recrystallised calcareous sediments or as metamorphosed Adirondack-type anorthosite complexes; we propose alternatively that they would be better understood as metamorphosed and deformed relicts of early Archaean layered anorthositic igneous complexes. They certainly appear little different from the Archaean meta-igneous bodies in Greenland, Scotland and southern Africa.

The following points are relevant to the origin of the Tamil Nadu rocks:

- 1) The anorthosites are commonly accompanied by layers of marble (of presumed sedimentary parentage), magnetite quartzite and banded iron forma-

tion. It seems very unlikely that calcareous sediments would change into such different metamorphic rocks as marbles and anorthosites in the same area and at the same time.

Particularly confusing is the fact that the anorthosite complexes are in places (Fiskenaesset, Limpopo) actually bordered by marbles, quartzites and BIF of obvious meta-sedimentary origin and may even contain inclusions of them. But this should not be construed as evidence of a sedimentary origin for the anorthosites. It seems more likely that the anorthositic complexes (or parent magmas) were emplaced into a sedimentary pile.

2) Too much reliance should not be placed on mineral assemblages and compositions in assessing the origin of rocks of this type. The Archaean anorthosites are in places (usually where best preserved) so calcic that An_{80-95} plagioclases and grossular-rich garnets, plus other calc-silicates such as hornblende, diopside, epidote and scapolite are to be expected and so these sorts of minerals cannot be said to be unequivocally diagnostic or definitive of a metamorphosed calcareous sediment.

3) The Adirondack-type anorthosites belong to a Proterozoic igneous suite emplaced about 1700–1200 m.y. ago in two tectonic belts, extending across the North Atlantic Shield and Gondwanaland (Herz, 1969; Bridgwater and Windley, 1973). No complexes of this type in Archaean terrains have been found isotopically to have an Archaean age. Comparison has largely been made with Adirondack-type bodies because at the time of publication details of the Archaean type were not available to authors.

4) Recent work in West Greenland (Bridgwater *et al.*, 1973; McGregor, 1973; Bridgwater *et al.*, 1974) suggests that it has taken at least 1000 m.y. to build up a high-grade gneissic terrain, this involving in particular the inter-thrusting of rock units (gneisses, sediments, volcanics and plutonics) of several different ages. Thus only tectonic remnants (lenses and discontinuous layers) of the more resistant rock units like igneous complexes will be found today in the gneisses.

Naidu (1960) thought that the inter-bedded nature of the rocks disproved an igneous origin and that the whole gneissic terrain represented an in situ recrystallised supracrustal pile. However this conformability would be better considered to be of tectonic origin; cover basement or continental-oceanic rocks have been inter-thrusted or inter-folded to give rise to a tectonic stratigraphy.

In this discussion too much emphasis tends to be placed on the more exotic anorthositic rocks compared with the leucogabbro, gabbros and ultramafics. It is clear that where these rocks are best preserved they belong to each other in layered stratiform-type igneous complexes, usually with an upward stratigraphy of ultramafics-gabbros-anorthosites. The deformation of the complexes is such that any part or combination of parts of the succession may be preserved in the gneisses, e.g. just ultramafics or gabbros, or both. Thus in Tamil Nadu besides the anorthosites consideration should be taken of the ultramafic/gabbroic remnants and in this way it may be possible to demarcate tectonic belts through the gneissic terrain marked by the presence of these meta-plutonic slices. Of course it may well be impossible to inter-relate genetically isolated occurrences of these rocks, although geochemical data might be useful.

Acknowledgements: The first author (BFW) acknowledges a research grant from

the Natural Environment Research Council, London, which enabled him to visit Tamil Nadu, and we are both grateful to the Director General, Geological Survey of India for permission to carry out the expedition and to publish this paper; and to Dr. M. V. N. Murthy, who was in charge of the Tamil Nadu Circle, G.S.I., at that time, for support of the expedition. The first author also wishes to thank many Indian geologists in Madras for their kindness and cooperation during his visit.

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ACID CHARNOCKITE (METASOMATIC) NEAR SIVASAMUDRAM, KARNATAKA STATE

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Introduction: Since the term 'charnockite' was first introduced by Holland for the hypersthene granite in South India, considerable research has been carried out on various aspects of this rock as also its variants. The term was extended by Holland (1900) to 'charnockite series' to include other genetically related types from acid to ultrabasic composition on the contention that they were of magmatic origin. Some workers, however, considered these rocks in India and abroad to be of magmatic origin subsequently metamorphosed in view of the granulitic or gneissic fabric