Geochemistry of the Malene metavolcanic amphibolites from Ivisârtoq: significance to the Archaean stratigraphy of southern West Greenland

R. P. Hall

One of the most fundamental unresolved problems of tectonic modelling of the Archaean craton of West Greenland is the interpretation of the magmatic environment in which the ubiquitous Malene-type supracrustal rocks were formed and the relationship of these rocks to the pre-existing Amîtsoq (*c.* 3750 m.y.) sialic crust in the Godthåbsfjord region at the centre of the craton. The Amîtsoq gneisses are a complex of polyphase, pegmatite banded, tonalitic to granitic rocks and the Malene supracrustals are dominated by metavolcanic amphibolites associated with metasedimentary layers and ultrabasic bodies (Bridgwater *et al.,* 1976). The present large scale intercalation of major Malene supracrustal and Amîtsoq gneiss units is clearly the result of an early phase of thrusting (Bridgwater *et al.* 1974; Hall & Friend, 1979). However, whether the juxtaposition of the two suites originated from a cover-basement relationship or was purely tectonic in origin has been open to speculation.

If the Amîtsoq granitic (*sensu lato*) gneisses formed an early Archaean continental crust through which the Malene metavolcanic amphibolites were originally injected to form a cover-basement relationship, then numerous basic feeder dykes should be preserved within the Amîtsoq gneisses. Since abundant metamorphosed basic dykes *are* a characteristic feature of the Amîtsoq gneisses (McGregor, 1973), these rocks (the Ameralik dykes) can obviously be postulated as feeders to the Malene metavolcanics in the Godthåbsfjord region. (cf. Chadwick & Coe, 1976; Beech & Chadwick, 1980). The field relationships in this region have led several workers to tabulate the intrusion of the Ameralik dykes and formation of the Malene supracrustal rocks as consecutive stratigraphic events (Bridgwater *et al.,* 1976; Hall & Friend, 1979; McGregor, 1979; Coe, 1980), but there is no definite field evidence to suggest or disprove their consanguinity. Hence, the chemistry of the Ameralik dykes and Malene metalavas is fundamental in determining whether or not the two are genetically related and thus, whether or not the Malene rocks were deposited onto the pre-existing Amîtsoq sialic crust.

Metavolcanic amphibolites form a major component of the Malene supracrustal suite (McGregor, 1973; Friend & Hall, 1977). Their volcanic origin and sub-aqueous deposition is clearly suggested by the abundance of well preserved pillow structures (Bridgwater *et al.,* 1976; Hall, 1980). They form a chemically variable suite which ranges in character from komatiitic to primitive tholeiitic and their closest present day analogues are ocean floor basalts. There are only minor chemical differences between the metavolcanic rocks of the Ivisârtoq area in the core of the Amîtsoq gneiss terrain, and those of the Ravns Storø supracrustal belt in the southern Fiskenæsset region which are remote from the Amîtsoq gneisses (Hall, 1980; Friend *et al.,* in press). However, the chemistry of these supracrustal amphibolites is significantly different from that of the Ameralik dykes (Gill & Bridgwater, 1979).

The Ameralik dykes are relatively more evolved tholeiites, having higher concentrations of alkalis, Fe, Rb, Zr and Ti and lower Mg, Cr and Ni values (figs 21 and 22). These

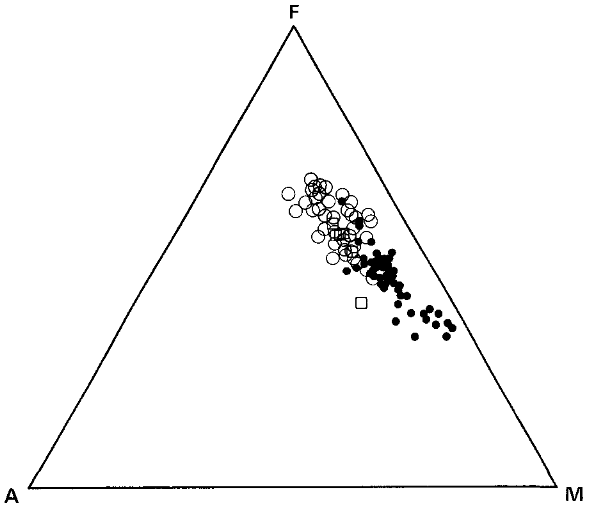

Fig. 21. AFM plot of Malene metavolcanic amphibolites from Ivisârtoq (dots) and Ameralik dykes from the Godthåbsfjord – Isua region (open circles) showing the chemical difference between the two stratigraphic groups. The open squares represent six new analyses of Ameralik dykes from Ivisârtoq (other Ameralik data from Gill & Bridgwater, 1979). The Ameralik dykes are clearly more alkali and Fe-rich reflecting their more evolved tholeiitic character relative to the primitive tholeiitic and komatiitic Malene metavolcanics (Hall, 1980).

fundamental chemical differences indicate that the Ameralik dykes cannot represent feeders to the Malene metavolcanics. The major element chemistry of the two suites is clearly distinguished by the statistical discriminant major element functions F1, F2 and F3 as defined by Pearce (1976). Plots of F3 against F2 and F1 against F2 values suggest that the Malene rocks coincide with the empirical, statistically defined field of ocean floor basalts while the Ameralik dykes fall in the low-K tholeiite quadrant (fig. 23). It is possible that the Ameralik dyke rocks represent merely more highly differentiated, later fractions of the Malene magma. However, since so few of the Malene metavolcanics have compositions comparable with the Ameralik dykes, the preservation of earlier, more primitive phases solely as metavolcanics and the later more evolved phases as the feeder dykes is considered to be pleading a special case.

Since the Ameralik dykes could not have fed the Malene metavolcanics, it follows that the latter could not have originally been erupted through the Amîtsoq 'continent'. In addition, the similarity of the Malene metavolcanics of the inner Godthåbsfjord region (Hall, 1980) with those from the remote Ravns Storø belt (Friend *et al.,* in press) and the overall resemblance of both these suites to ocean floor tholeiitic assemblages support the hypothesis that the Amîtsoq sialic basement of the Godthåbsfjord region and the Malene supracrustal rocks were originally discrete and were juxtaposed tectonically by thrusting (Hall & Friend, 1979). Since Ameralik dykes are not recognised in the Malene suite in inner Godthåbsfjord, the intrusion of these dykes is considered to be a separate and earlier phase of basic magmatism. Thus, the separation of the Ameralik dykes from the Malene supracrustal rocks in numerous published stratigraphic tables (Bridgwater *et al.,* 1976; Hall & Friend, 1979; McGregor, 1979; Coe 1980) appears to be a real geological separation.

A dilemma still remains as to the nature of the Amîtsoq 'continent'. It is difficult to imagine how such a sialic crust *stable* enough (cf. Moorbath, 1976) to undergo extensive crustal dilation and associated injection of abundant Ameralik dykes, could be deformed

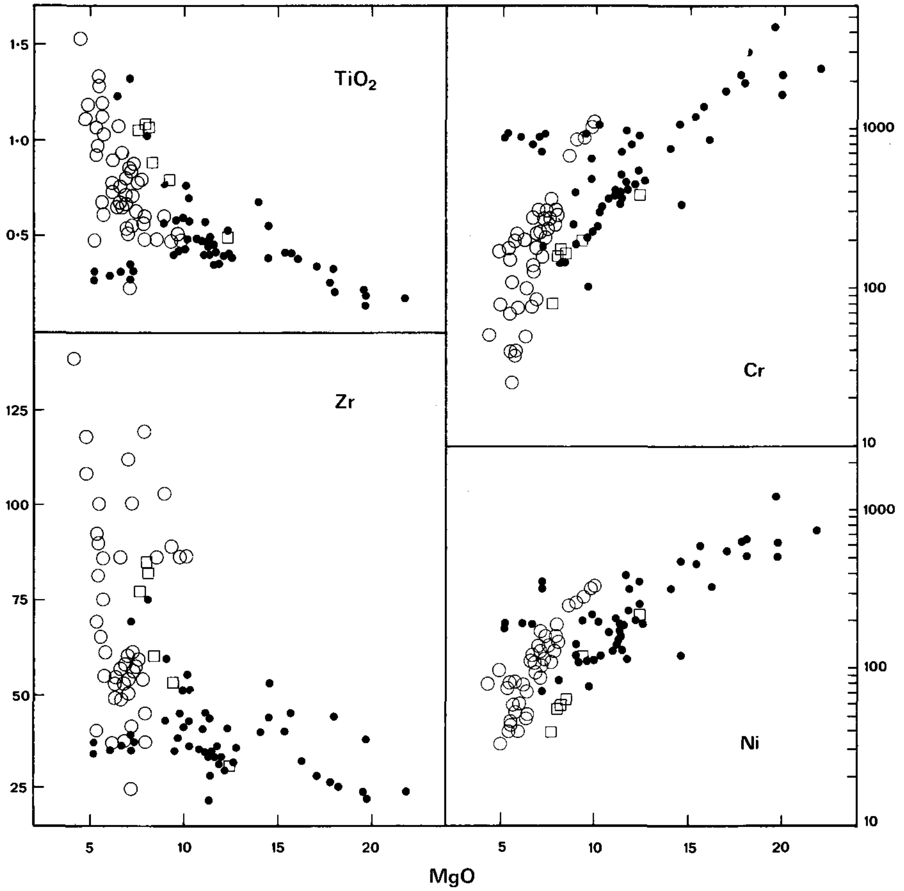

Fig. 22. Plot of TiO_2 (wt %), Zr, Cr and Ni (ppm) against MgO (wt %) for Malene metavolcanic amphibolites and Ameralik dykes (symbols as for fig. 21). The two stratigraphic groups are chemically distinct with respect to these elements, with only a small degree of overlap between them.

subsequently by at least two major phases of very large scale folding (Hall & Friend, 1979). The wavelength and amplitude values of these structures (up to 30 km) suggest that these rocks must have reached a depth compatible with partial melting although the isotopic chemistry strongly contradicts this structural evidence (Moorbath, 1977). A model involving the collision of thin oceanic and sialic 'plates' may be more suitable to explain the development of such large scale thrust and fold structures than one invoking the existence of a pre-existing 'stable continent'.

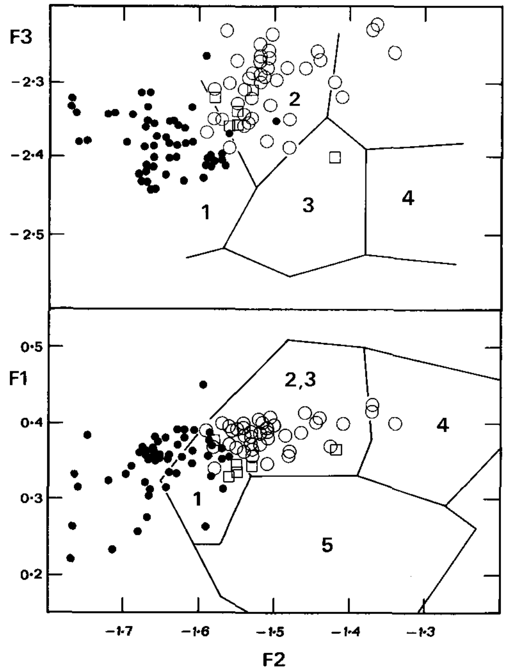

Fig. 23. Plot of major element chemistry functions F3 against F2 and F1 against F2 (Pearce, 1976), showing the mutual discreteness of the Malene metavolcanics and Ameralik dykes (symbols as for fig. 21). The statistically defined fields separate 1: ocean floor basalts, 2: low-K tholeiites, 3: calc-alkali basalts, 4: shoshonites and 5: within plate basalts.

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Department of Geology,
Portsmouth Polytechnic,
Portsmouth PO1 3QL,
U.K.

Investigations on amphibolite facies orthogneisses, amphibolites and leucogabbros on Akugdlerssuaq, inner Godthåbsfjord

A. P. Nutman

Two weeks of June 1981 were spent examining the amphibolite facies orthogneisses, amphibolites and leucogabbros of Akugdlerssuaq, inner Godthåbsfjord (fig. 24). This area was visited by V. R. McGregor during the helicopter reconnaissance mapping programme of Godthåbsfjord in 1976 (Allaart *et al.,* 1977). McGregor observed a sharp, concordant contact between a layered complex of amphibolite, leucogabbro and anorthosite and a unit of banded gneisses, considered to be predominantly Amîtsoq. The area was revisited in 1981 for more detailed study of the relation between the orthogneisses and layered complex. Equal emphasis was placed on mapping at a scale of approximately 1:20 000, detailed study of selected outcrops and sampling for geochemical and isotopic studies.

Geological divisions

The area can be divided into five zones, zone I being the lowest and zone V the highest (fig. 24). Zones I to III were examined in more detail than IV and V.

Zone I comprises multiphase pegmatite banded biotite-hornblende tonalitic-granodioritic gneisses. Subconcordant intrusive sheets of schlieric pegmatitic gneiss and of grey gneiss occur locally. More massive grey tonalitic gneiss units within the banded gneisses may be a distinct phase. Pods of amphibolite, ultramafic rocks and quartz-rich rocks within the banded gneisses form less than 5 per cent of the zone. Most of the amphibolite is fine grained