islands and peninsulas. Furthermore some of these folds are rootless, and are best described as giant intrafolial folds. Two axial directions appear to dominate – N–S roughly horizontal, and ESE with low plunge. The folds with N–S axes are generally overturned towards west, while the ESE folds are overturned towards both north and south. The age relationships between these folds are still uncertain; there are indications that the axial direction may change the level.

Whatever the age relationships between the various folds, it is now evident that the Proterozoic, post-Marmorilik Formation, tectonics of the area are very complicated. A distinctive sequence of amphibolite, augen gneiss, biotite gneiss and augen biotite schist has been traced over about 1250 km² in the north-east part of the area. This sequence overlies an infolded remnant of the Marmorilik Formation, a situation which requires at least 30 km of lateral transport of the marker sequence. Both the Marmorilik Formation and the marker sequence have been subsequently involved in tight folds with N–S axes and overturned to the west. One of us (M.C.A.) has collected material for a study of what effect this Proterozoic deformation has had on the Rb-Sr isotopic system.

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Archaean ultramafic rocks with relict spinifex textures in the Umanak area, central West Greenland

J. Christian Knudsen

Conspicuous olivine and serpentine textures were found in a number of ultramafic bodies in the Umanak area while it was being mapped on a scale of 1:20 000. The rocks in the area mapped by the writer are mainly a suite of quartzo-feldspathic gneisses (Pulvertaft *et al.,* this report) in which there are distinct amphibolite-dominated supracrustal horizons which enable the major structures of the area to be recognised. The structure which dominates the area is a large recumbent/reclined fold plunging ESE at a low angle and closing to the NNE.

Isoclinal folds belonging to an earlier phase, and late open folding have also been recognised in the area.

The chief rock types found in the supracrustal horizons are diopside amphibolite, garnet amphibolite, anthophyllite-cordierite-quartz rock, pelitic gneisses and sillimanite quartzites with minor amounts of anthophyllite, green mica, and cordierite. The ultramafic rocks form isolated pods and lenses up to 100 m thick within the supracrustal horizons. These are thought to be boudins derived from originally more continuous ultramafic bodies (fig. 11 and later). Because of their relatively greater resistance to erosion the ultramafic rocks form small topographic highs. Their weathered surfaces have a characteristic reddish brown colour. The mineral parageneses in the ultramafics vary with the degree of alteration and deformation, but the main constituents are usually serpentine, olivine, tremolite, pyroxene, chlorite, carbonate, magnetite, ilmenite and pyrrhotite.

A map of the most interesting ultramafic body and its immediate environs is shown in fig. 11. This occurrence is in the closure zone of the large ESE-plunging recumbent/reclined fold, which may account for the better state of preservation of primary relationships and textures in this locality. The sequence of rocks from bottom to top (south to north) is as follows:

Max. *c*. 60 m of amphibolites of varying composition.
Max. *c*. 70 m of ultramafic rock.
c. 2 m of biotite-amphibole gneiss.
c. 1.5 m diopside, carbonate and hornblendite layers.
c. 0.5 m biotite-amphibole-sillimanite gneiss.
c. 1.5 m ultramafic rock.
c. 2.5 m biotite-garnet-sillimanite-quartz rock.
c. 1.5 m ultramafic rock with spinifex textures.
Max. *c*. 10 m amphibolite with diopside-rich layers.
Max. 25 m cordierite-quartz-anthophyllite rock.
Min. 50 m of diopside amphibolite.

In the main ultramafic body there are four major layers which show conspicuous grooves on weathered surfaces where elongated serpentine aggregates or olivine blades have been etched out (fig. 12). It has been possible to follow these layers along strike over the whole length of the body, even though the layers are locally stretched and deformed, and have lost their characteristic texture. At each end the layers are cut off abruptly against the surrounding layered amphibolite, which lends support to the view that the isolated pods of ultramafic rock are boudins of bodies which were once more continuous. Small lenses of carbonate and calc-silicate are common and, as indicated on the map, there are also two layers of carbonate up to 3 m thick and extending up to 100 m along strike parallel to the grooved layers.

Grooved weathered surfaces due to etching of elongated aggregates of serpentine and olivine have also been observed in the other ultramafic bodies shown in fig. 11, and in ultramafic bodies in other amphibolite-dominated supracrustal horizons. However, due to deformation, the distribution of such textures within these bodies is less well understood.

The etched elongated grooves represent two different kinds of texture in the ultramafic bodies:

(1) Radiating spinifex (Nesbitt, 1971) or randomly oriented olivine (Donaldson, 1974) as seen in fig. 12. This is the commonest type in the area. The etched blades of serpentine or

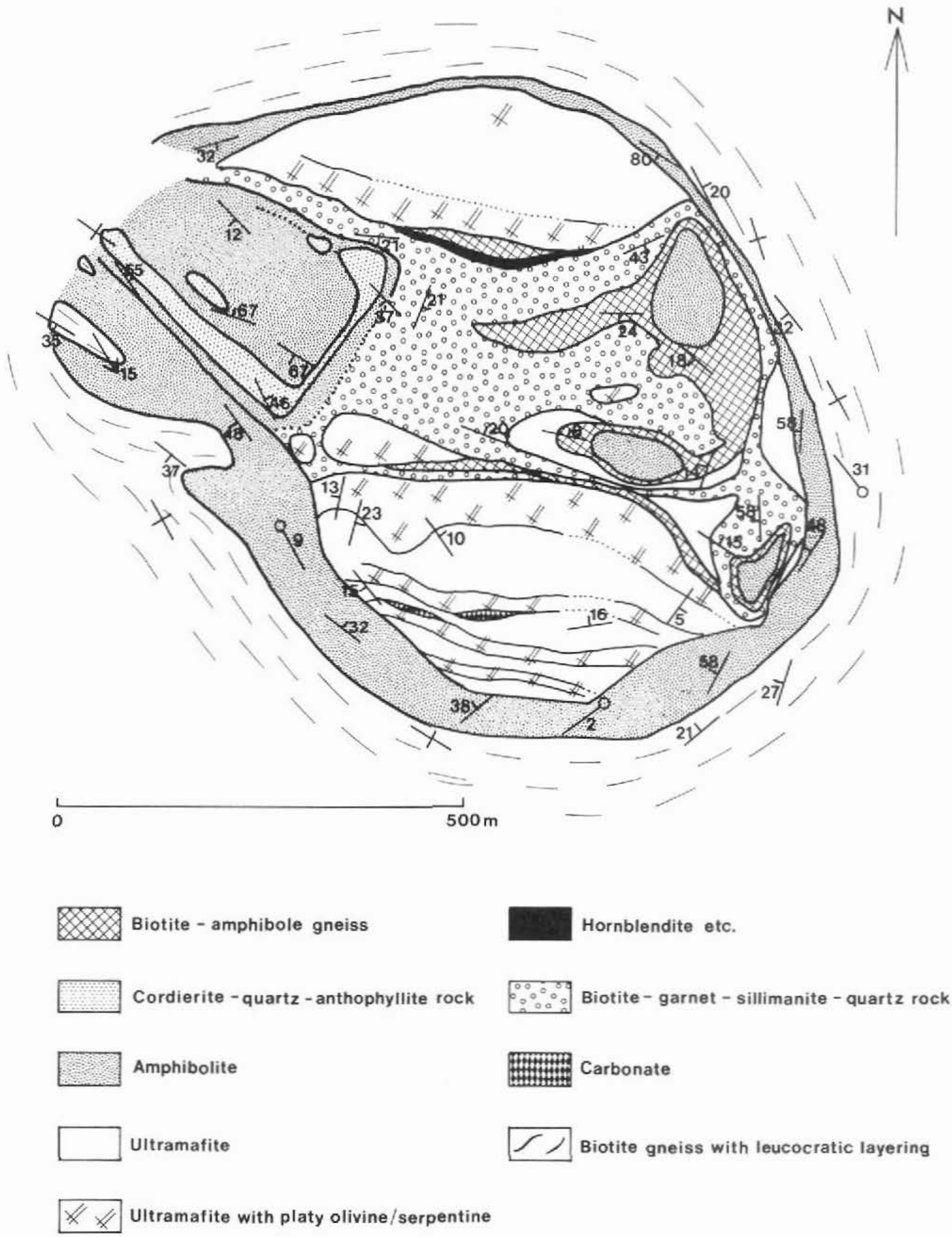

Fig. 11. Sketch map to show the field relations of the ultramafic rocks, the associated supracrustals and the country gneiss.

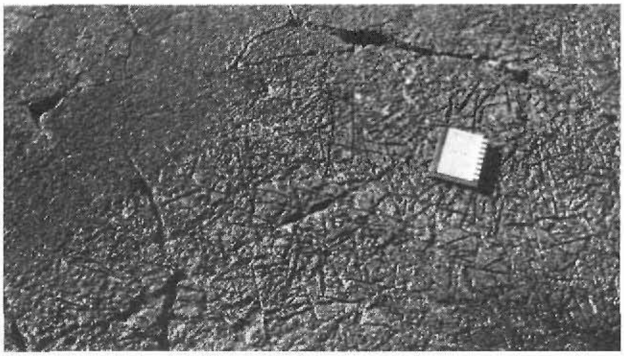

Fig. 12. The randomly oriented type spinifix. In the upper left part of the picture the texture is probably destroyed by deformation.

olivine vary from a few centimetres up to 50 cm long and are apparently randomly oriented.

(2) Plate spinifex (Nesbitt, 1971) as seen in fig. 13. Here the olivine or serpentine occurs as sets of parallel thin plates up to almost a metre long. As seen in fig. 13, the different sets are randomly oriented and form complex interlocking patterns and the platy type here grades into the randomly oriented type. The sets end abruptly at the margin of the layer.

At present only thin sections of the randomly oriented type have been examined. In these the olivine blades are fresh and each blade is in optical continuity across the whole area of the thin section, but the blades are not skeletal. Instead grain boundaries are jagged against the adjacent tremolite, and there are inclusions of idioblastic tremolite, subidioblastic magnetite, and carbonate in the olivine. Thus it appears that the olivine as seen today is not truly magmatic, although it could have formed by recrystallisation *in situ* of primary quench olivine, with preservation in the main of the primary magmatic texture. Alternatively both the olivine and the texture might be metamorphic (Oliver *et al.*, 1972; Evans & Tromsdorff,

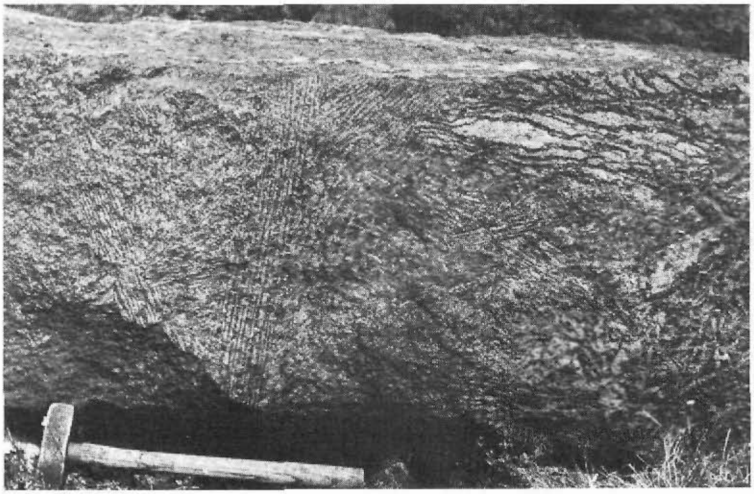

Fig. 13. Large sets of plate spinifex. A gradation to the randomly oriented type is seen in the lower right part of the picture.

1974). "It is clear that both pseudomorphed spinifex textures as well as similar-looking but metamorphic textures may occur" (Schau, 1977, p. 341).

As already indicated by the terminology used in the description of the textures of elongated aggregates of serpentine and olivine, these show a marked overall similarity to textures described from less deformed and metamorphosed areas with ultrabasic extrusive or hypabyssal rocks in other parts of the world (Viljoen & Viljoen, 1969; Nesbitt, 1971; Arndt *et al.,* 1977) and also to textures in plutonic ultrabasic intrusives (Donaldson, 1974). According to Donaldson it is not possible to distinguish between extrusive and intrusive ultrabasics on the basis of spinifex textures alone. It remains to be considered if there are any other grounds for favouring an extrusive or an intrusive origin for the Umanak ultramafic rocks.

Although there are variations in the size of the aggregates of serpentine and olivine blades and sets of plates, it has not been possible to establish any consistent pattern in these variations that could be related to way-up, as has been possible in komatiitic extrusives in less deformed areas (Arndt *et al.,* 1977). No pillow structures have been observed in the Umanak ultramafic rocks. On the other hand the occurrence of the Umanak ultramafics within supracrustal sequences in close association with metasedimentary rocks such as pelitic gneisses and quartzite, and the intercalation of carbonate within one layered ultramafic body, suggest that the ultramafics themselves might be of supracrustal-extrusive origin. Alternatively they could be portions of high-level sills, but the general setting rules out a deep-seated intrusive origin.

The question as to whether the ultramafics described here originated as flows or high-level sills is of only secondary importance. The main conclusion to be drawn is that the textures in these rocks point clearly to crystallisation from an ultramafic silicate melt. Geochemical investigation is planned to find out if this melt was of komatiitic composition.

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