GRØNLANDS GEOLOGISKE UNDERSØGELSE
BULLETIN No. 60

THE LAYERED APLITE-PEGMATITE SHEETS OF KÎNÂLIK, SOUTH GREENLAND

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B. WINDLEY AND D. BRIDGWATER

WITH 10 FIGURES IN THE TEXT
AND 6 PLATES

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Meddelelser om Grønland, Bd. 179, Nr. 10

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BIANCO LUNOS BOGTRYKKERI A/S
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Abstract

A series of low-dipping garnet-bearing interlayered aplite and pegmatite sheets is described from Kînâlik, South Greenland. The sheets are made up of three main rock types: rhytmically layered garnetiferous aplite, megacrysts of perthite-quartz intergrowth, and pegmatite layers. The relationships between these components suggest that the sheets are the result of a single injection of magma which has segregated into a dominantly aplitic portion towards the lower margin and pegmatite towards the top. The observation that veins of pegmatite cut the aplite but not *vice versa* suggests that the pegmatite remained in a fluid state longer than the aplite. The relationship between the perthite megacrysts and the layered aplite is discussed in detail and it is suggested that while perthite and aplite were formed approximately simultaneously, in some cases the megacrysts continued to grow after the initial formation of the aplite. Recrystallisation and a partial redistribution of material after the formation of layering but before the final solidification of the body is put forward as an explanation for some of the features described.

CONTENTS

INTRODUCTION

This paper is primarily an account of the field relationships observed in the layered sheets of garnet-bearing aplite and pegmatite at Kînâlik (see fig. 1). The relationships between the aplitic and pegmatitic parts of single bodies are described in detail and their origin is discussed.

At the time that the field observations and most of the interpretations were made the literature on layered aplite-pegmatites was sparse and mainly confined to accounts in more regional pegmatite studies (e.g. Jahns and Wright, 1951; Staatz and Trites, 1955). However recent detailed descriptions by Orville (1960) and Redden (1963) together with an excellent resumé and discussion of the problem by Jahns and Tuttle (1963) suggest that these bodies are not uncommon in other pegmatite-bearing regions and have only been neglected because their significance was not understood. Since the observations were made on the Kînâlik bodies one of the writers (B. W.) has found similar features in the late Caledonian pegmatites of Loch Laggan, Scotland. Most of the details described from the Kînâlik bodies have already been noted by Orville, Redden, and Jahns and Tuttle; however, it seems worthwhile presenting them here as it has been possible to relate them to a general sequence of events in the crystallisation history of the sheets. The information gathered from the Kînâlik sheets may have considerable bearing on ideas about the crystallisation of aplites and pegmatites in general.

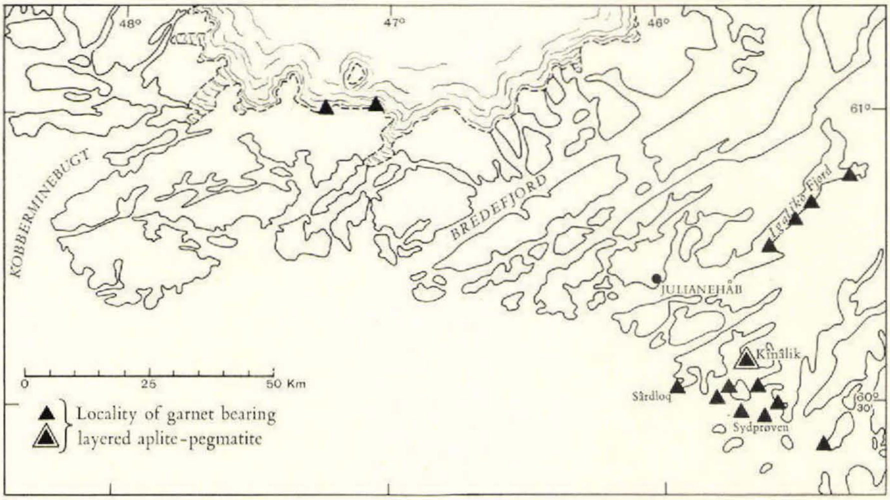

Fig. 1. Sketch map showing the distribution of garnet-bearing aplite-pegmatites in South Greenland.

HISTORY OF RESEARCH

The Kînâlik sheets were found during the general geological mapping of the area by the second author in 1961; they were revisited by both authors in 1962 and again by the second author in 1963. The interpretation of the field observations is the joint responsibility of both authors. A description and general discussion of the mode of formation of the sheets was included by the first author in a doctorate thesis submitted to Exeter University in 1963. A more general study of the aplites and pegmatites of this area of South Greenland has been made by the first author (Windley, in prep.). This has been used as a background to the specific descriptions of the Kînâlik sheets.

Layered sheets consisting of intercalated aplite and pegmatite are fairly common in South Greenland, especially in the Sârdloq area south of Julianehåb. The Kînâlik sheets however differ from the majority of these bodies because the aplitic component contains an appreciable amount of garnet, which is arranged in closely spaced parallel layers. The structures seen in these layers allow the development of the bodies to be studied in detail. Since the Kînâlik sheets were first described other garnet-bearing layered aplite-pegmatite bodies have been found in South Greenland and can be shown to have a similar developmental history. Notable localities are seen along the ice margin to the north west of Bredefjord, on the islands to the south west of Kînâlik and on the Sydprøven peninsula (D.B.); near Sârdloq village (B.W.); and on the south side of Igaliko Fjord (Berrangé, in press). These localities are marked ▲ on fig. 1. Photographs and drawings used in this paper are from the Kînâlik bodies unless otherwise specifically stated.

I. GEOLOGICAL SETTING

The Kînâlik sheets are members of widespread swarms of aplite and pegmatite formed towards the end of the Sanerutian period in South Greenland. According to BRIDGWATER (1965), the plutonic conditions prevailing during the Sanerutian period probably represent the final stages in the orogenic development of a fold belt which was formed in South Greenland between 1500 and 1900 m.y. ago.

The plutonic activity of the Sanerutian period is represented in the area surrounding the Kînâlik sheets by the following events:

a) Regeneration of a series of granites and gneisses from older granitic rocks. This regeneration took place largely without the addition of new material and represents reactivation under regional metamorphic conditions of a granitic mass which was already in place before the Sanerutian period; b) the emplacement of a series of allochthonous, generally coarse porphyritic granites (BRIDGWATER, 1963); c) intrusion of composite net-veined diorite sheets (WINDLEY, in press); d) the intrusion of basic and intermediate dykes under plutonic conditions (BRIDGWATER, 1963; WATTERSON, 1965); e) the emplacement of a series of fine-grained homogeneous granites showing contacts sharply discordant to the surrounding rocks but which contain large inclusions of country gneiss which do not appear to have been displaced.

The exact sequence of events varies from area to area in South Greenland and it is impossible to make accurate time correlations based on individual rock types within the period. Only a broad scheme of the plutonic development of the area is discernible (ALLAART, 1964). In the Kînâlik area the aplites and pegmatites are generally younger than the minor basic intrusions (c and d above) and they are thus one of the last events in the Sanerutian.

The relationship between the pegmatites and the Sanerutian granites is complex. The porphyritic allochthonous granites (b above) are associated with several pegmatite generations which are genetically connected to the granites. It is quite common to see granite veins passing both across and along the strike into pegmatites. However no regional pegmatite pattern can be seen around these granites, and the majority of Sanerutian aplites and pegmatites appear to be associated with general late plutonic conditions rather than any particular body of granite. Occasionally, concentrations of aplite and pegmatite occur either within or surrounding the fine-grained leucocratic granites (e above) and the three rock types generally occur approximately contemporaneously in the chronologies of local areas which suggests a genetic connection between them. At Kînâlik some of the pegmatites are cut and slightly dislocated by veins from one of the fine-grained granites, while other pegmatites, in particular the layered sheets described in this paper, cut and displace the fine-grained granite veins.

II. DESCRIPTION OF THE KÎNÂLIK APLITE-PEGMATITE SHEETS

1. Field relationships

Approximately 25 independent aplite-pegmatite sheets varying between one and five metres in thickness outcrop on the ice-polished lichen-free coast at Kînâlik. A large number of thinner aplite-pegmatite sheets between one centimetre and one metre are found in close association with the main bodies, and some of these can be seen to be apophyses. The country rock is a massive dioritic body of uncertain age migmatised by a coarse porphyroblastic granite thought to have been formed early in the Sanerutian period. Individual sheets are approximately planar and can be followed for a few hundred metres where they strike sub-parallel to the coast. Inland, the general direction of the bodies can be followed but their detailed structure is lost under lichen cover. Several sheets are commonly found close together and may form anastomising complexes of thin bodies which are resolved along their strike into one or two thicker sheets. The attitude of the sheets is variable; they are generally fairly flat-lying with dips between ten and fifty degrees in the north-east quadrant. Because of the low dips the strike is highly variable. The low dips also lead to outcrops of single bodies extending for a hundred metres along the coast. While this is excellent for studies of the internal structures of the sheets, it makes it difficult to show their mode of emplacement. Most of this information must be taken from apophyses given off by the main sheets. Examples of intersections between the main bodies and older planar structures within the country rocks are not common, and no cases of an intersection between an aplite-pegmatite and two non-parallel earlier structures have been seen. It is therefore impossible to prove that the sheets were emplaced by dilatation. However the converse relationship in which an aplite-pegmatite and a non-parallel apophysis displace the same older planar structure by their respective widths has been observed and suggests that the aplite pegmatites were emplaced by dilatation of the country rocks. This is supported by the majority of single intersections where the displacement of earlier structure is equal to the width of the younger structure. Occasionally the aplite-pegmatites were emplaced along small fractures, in which case the displacement of older structures need not show any simple relationship to the width of the younger body. Individual aplite-pegmatites act as single units towards earlier structures and the dilatation is independent of the local composition of the sheets at the point of intersection. This suggests that the complex internal relationships between aplite and pegmatite in the sheets are the result of a sequence of events within a single segregated intrusion rather than the result of multiple injection. This is supported by the repetition of the same relationships between aplite and pegmatite in different sheets and by the characteristic concentration of pegmatite towards the hanging wall of the bodies. Multiple sheets are quite common but the characteristic aplite-pegmatite relationships are preserved within each of the component members. Two examples of intersecting sheets in which the second was emplaced before the first had completed crystallisation have been seen in South Greenland. This phenomenon is described in detail from the aplite-pegmatites seen at Loch Laggan (B.W.). In the present paper the only structures described in detail are those developed in bodies emplaced at one time. In most cases both the aplitic and pegmatitic components of the sheets are confined within the original boundaries of the bodies; very occasionally the pegmatitic component may leave the sheet, in which case it sometimes dilates the margins or the sheet may narrow suddenly. This apparent multiple injection is discussed later on page 29.

2. Internal structure

The features described are a synthesis of the observations made from many different sheets exposed at Kînâlik. There is no reason to suggest that the sheets differ from one another in their mode of formation, although they show different stages in development.

A. Major divisions

The layered aplite-pegmatites consist of three lithologically separable components:

i. aplite;
ii. quartz-felspar intergrowth and perthite megacrysts;
iii. pegmatite as distinct units.

The terms aplite and pegmatite are used in a purely relative sense in this paper to contrast the coarse-grained rock types (average grain size considerably over 1 cm) with the medium- and fine-grained units. The aplites themselves show considerable variation ranging from rocks with an average grain size under 1 cm to rocks with an average grain size under 1 mm. The proportions of the three components vary from body to body and along the strike within the same body so that in the extreme case a sheet may vary from solid aplite at one outcrop to solid quartz-felspar intergrowth in another. Sheets which are predominantly aplite in one exposure may give off apophyses which are predominantly pegmatite and *vice versa*. In general there is a tendency for the aplite to be concentrated towards the lower margins and the pegmatite towards the upper margins of the sheets.

The bodies show a crystallisation sequence in which aplite was the dominant early rock type while pegmatite was the last. Alternating units of the three components form the overall layered structure seen in most outcrops of these bodies. This coarse layering runs approximately parallel to the contacts (see Plate 1). There is a general increase in the coarse quartz-felspar intergrowth and pegmatitic components towards the hanging wall. Locally the quartz-felspar intergrowth forms irregular masses which are discordant to the general structure. Massive intergrowth of this type often contains apparently undisturbed inclusions of aplite. The pegmatites send out veins which cut both the intergrowth and the aplite. Large perthite megacrysts with intergrown quartz are found within the aplites where they interrupt the simple planar layered structures. The perthite megacrysts are locally concentrated into distinct layers, in which case they may become indistinguishable from the quartz-felspar intergrowth layers.

Vertical sections through many of the low-dipping sheets show a concentration of pegmatite on the hanging wall. The low relief presents too limited sections for it to be ascertained whether there is a similar increase in the proportion of pegmatite when an individual body is traced up-dip. However it seems likely that such a vertical variation in the proportions of aplitic and pegmatitic components might occur and would explain the compositional variations seen in adjacent sheets. This possibility is illustrated in fig. 2. If an overall variation with height is present, then it is meaningless to give bulk analyses of specimens taken at the present erosion level. Random sampling of all the sheets exposed at Kînâlik might give a bulk composition of the initial material emplaced provided that there is no regional variation in composition with depth. Sampling for such compositional studies would require blasting and drilling on the ice-smoothed surface which was beyond the scope of the present study.

B. Description of components

i. Aplite

The aplite is a medium- to fine-grained granitic rock consisting essentially of quartz, plagioclase, microcline, and a little scattered garnet,

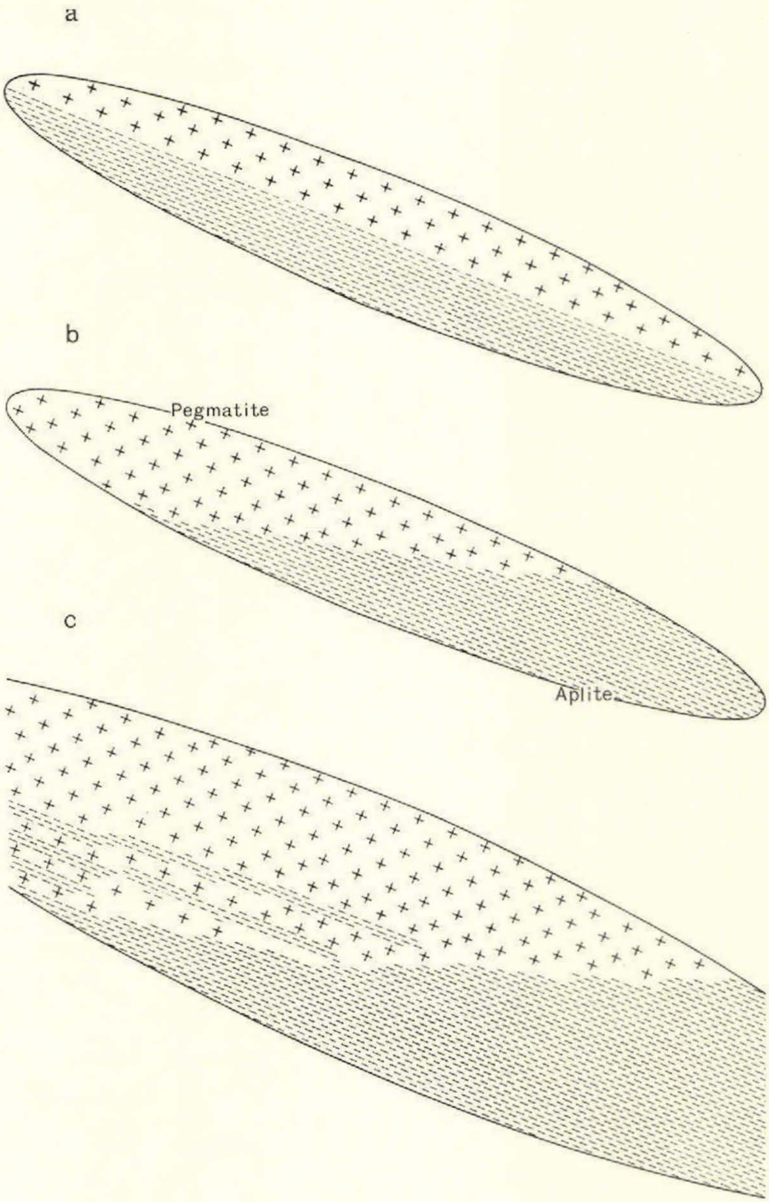

Fig. 2. Idealised diagrams showing the distribution of aplite and pegmatite in gently inclined sheets. All three diagrams are of cross-sections of the sheets at right angles to the strike. Diagram **a** shows a sheet in which the segregation of aplite and pegmatite took place towards the lower and upper margins respectively. In this case sampling at regular intervals across any section of the sheet will provide a reasonable estimate of the bulk composition. Diagram **b** shows a sheet in which there has been some concentration of pegmatitic material up-dip as well as towards the upper margin. In this case sampling at any random section provided by the present erosion surface will not give a true estimate of the bulk composition of the sheet. The vary-

biotite and opaque iron oxides. The rock has a sugary texture in hand specimen and is generally slightly pinkish in colour due to the garnet and probably some rust staining caused by oxidation of the iron-bearing minerals.

a. Simple aplite layering

The most noticeable feature seen in the aplitic components of these sheets is well-developed layering, a general view of which is shown in Plate 1. The layering varies both within the same body and from body to body, the example illustrated in Plate 1 being the most perfectly preserved seen at Kînâlik. However the features described from one body can usually be found at least partially preserved within any of the other sheets.

The layers consist of alternating laminae of granitic aplite which show considerable variation in grain size and composition from layer to layer. The aplite layers vary in width between 5 mm and 5 cm, and average 15 mm. The variation in composition from layer to layer makes it impossible to give meaningful modal analyses of the aplites without statistical sampling. The proportion of each of the three main minerals, quartz, plagioclase and potash felspar varies in layer to layer from less than $10\,^0/_0$ to over $90\,^0/_0$ of the total. The majority of the aplite layers are markedly richer in plagioclase than the coarser-grained rocks found in the Kînâlik sheets. The grain size often gives an approximate guide to composition, as layers rich in potash felspar are coarser grained than other aplite layers.

Individual layers are remarkably constant in character and may be followed along their strike for several metres. The stratified appearance seen in these rocks in the field is emphasized by thin layers of garnet-rich aplite or solid garnet rock varying between 0.5 mm and 4 mm thick separating the normal aplite layers. Because of their distinctive mineralogy these thin layers of garnet-rich aplite stand out from the normal aplite and therefore provide excellent "marker horizons" which can be used to show the effect of later processes modifying the original simple layering. Plate 2a shows a polished specimen of the simplest type of layering seen in the aplite pegmatites; in general, individual layers are approximately planar, the garnet layers showing slight crenulations and discontinuities. The aplite surrounding the garnet-rich layers is often

ing proportions of aplite and pegmatite seen in the Kînâlik sheets may be due to this process. Note that the layering in the aplite follows the lower surface. Diagram c shows a detail of the contact between aplite and pegmatite towards the upper part of a sheet. Early-formed, layered aplite has been partially replaced by pegmatite, which was concentrated up-dip as the body solidified. The numerous examples seen at Kînâlik, where relics of aplite are surrounded by pegmatite, may be due to this process (see Plate 5a).

whiter than the surrounding rock. In the specimen illustrated the garnet-bearing layers can be seen to be irregularly spaced; four or five layers occur within two centimetres while the next aplite band is four centimetres thick and contains both disseminated garnet and faint discontinuous lines of garnet crystals. This non-uniform distribution of the garnet layers is also seen on a larger scale (see Plate 1). The aplitic portion of the sheets is divided into alternating units up to a metre wide of aplite rich in garnet layers and aplite poor in garnet layers. Careful examination of the units poor in garnet layering shows that these contain thin discontinuous layers of garnet parallel to the layering in the units above and below. Some of the local lack of layering in the aplites may be primary, due to greater dissemination of all constitutents throughout the layers, or due to secondary processes described later.

Most of the layering is parallel to the walls of the sheets and may follow minor variations in the form of the contacts even when the layering is some distance in towards the centre of a body. If a sheet divides, individual layers can generally be traced into one of the branches. This need not necessarily be the largest branch or that nearest to the attitude of the body before branching. In some sheets the layering may divide where the sheet branches, the layers nearest to the margin following the branch while the inner layers continue along the main body. Individual garnet layers are not seen to branch; the only exception to this occurs when secondary layering cuts discordantly through the simple layers as described on page 26. At the junction between two sets of layering, which occurs when two branches each with its concordant layering meet, one set of layers becomes dominant and the second set becomes diffuse and irregular.

b. Secondary modifications to simple layering

Fold structures

Occasionally some of the layers show simple monoclinal folds which persist throughout the width of the body. Not all the layers take part in this folding and sometimes there is a confused area where two sets of layering should meet. The folding appears to be a secondary process either formed by some recrystallisation after the initial formation of the aplite or formed by slumping possibly before the complete consolidation of the layers. Plate 3a shows a confused area in aplite layering together with a late pegmatite vein, the emplacement of which was apparently controlled by the fold structure.

Paired layers

Figs. 3 and 4, which are details of the layering in the aplite seen in Plate 1, show that many of the garnet-rich layers are paired and contain a central core of leucocratic material. In some cases this central core is

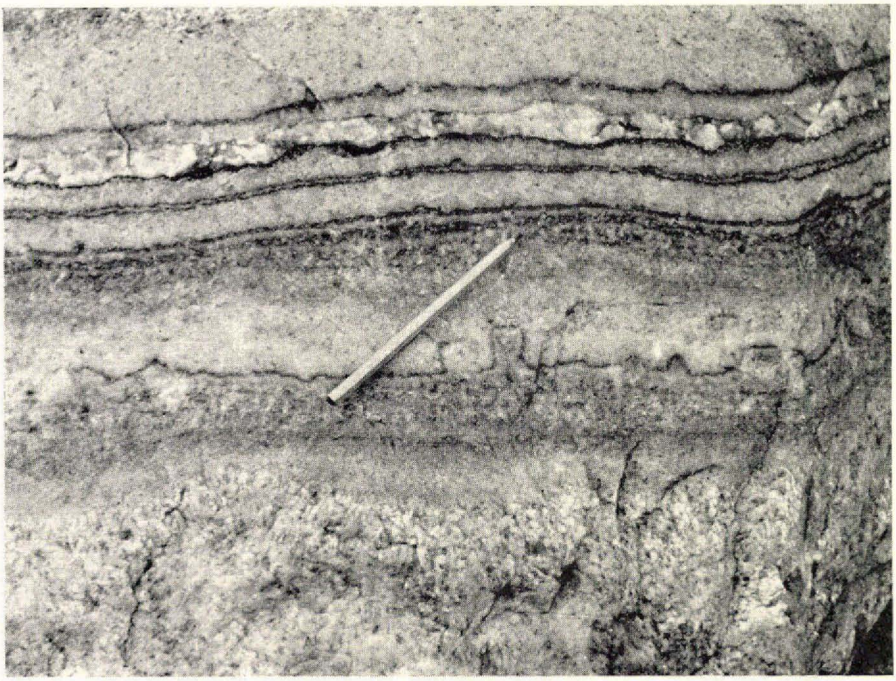

Fig. 3. Detail of layering within the aplite. Note the high proportion of paired garnet-bearing layers. A perthite-rich, coarse-grained layer is prominant at the top of the photograph. Eyed structures surrounding small perthite megacrysts are seen below the pencil. A concordant layer of quartz-felspar intergrowth is seen at the bottom of the photograph.

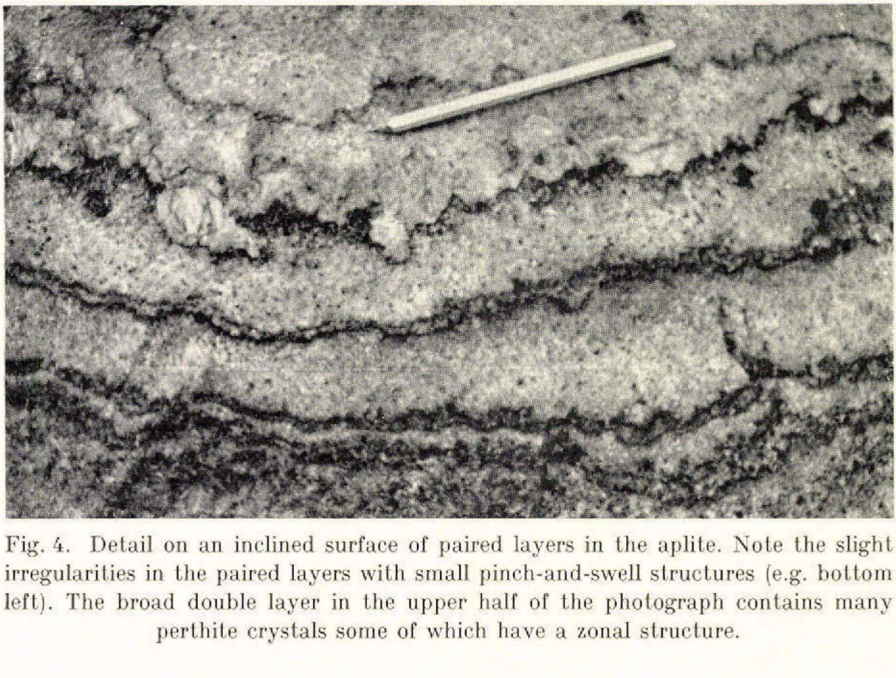

Fig. 4. Detail on an inclined surface of paired layers in the aplite. Note the slight irregularities in the paired layers with small pinch-and-swell structures (e.g. bottom left). The broad double layer in the upper half of the photograph contains many perthite crystals some of which have a zonal structure.

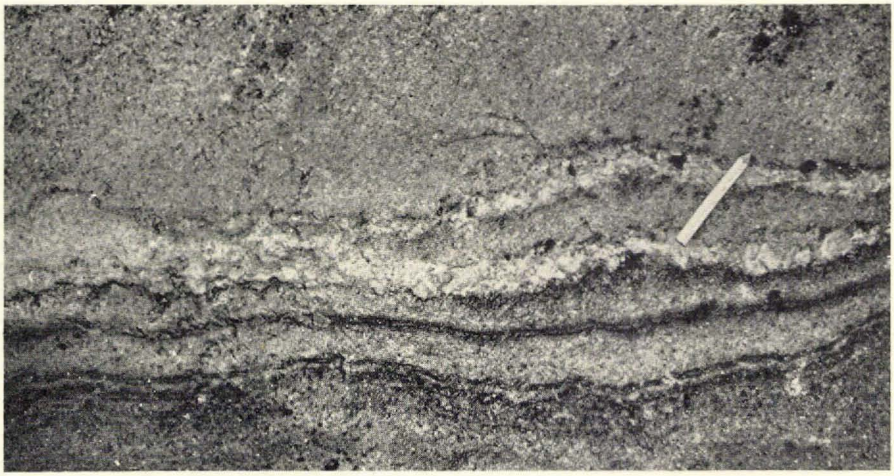

Fig. 5. Detail of a branch in a paired layer with a central core containing coarser material than the host aplite. When traced laterally, the branches thin out and resemble the thin paired layers seen at the bottom of the photograph.

over a centimetre wide and can be seen to consist of grains of perthite filling the whole width of the vein; in other cases the paired layers are less than 0.5 cm apart and the central core is indistinguishable in the field from the surrounding aplite. Some of the wider paired units can be traced laterally into thinner paired layers. The paired layers can be traced for several metres conformably with the normal aplite layering. Two examples in which the perthite core to a paired layer divides into two, each limb with its own paired garnet rim, have been noted (fig. 5). These are the only examples where the paired layers are at all discordant to the normal layering in the aplite and might possibly represent late veins of pegmatite similar to those described on page 23. Occasionally the central perthite core becomes irregular resulting in the structure seen at the top of fig. 4, where one of the garnet rims is more pronounced than the other. The paired layers may be restricted to one particular aplite unit in the body. They are not restricted to the main sheets; some of the ten centimetre apophyses, consisting nearly entirely of unlayered aplite, contain central paired layers with a slightly coarser core.

Sutured layers

Some of the sheets, which do not show the rhythmic layering so well developed as the example illustrated in Plate 1, have thin garnet-quartz layers within fine-grained aplite which contains a few, scattered quartz-felspar intergrowths. These garnet-quartz layers are slightly coarser grained than the host aplites and might be termed micropegmatite layers. The most noticeable difference between these layers and the simple garnet-rich layers described above is their form, which is highly convoluted, with downward-facing, open loops and upward-facing, crenulate loops. The layers show a remarkable superficial resemblance to ammonite sutures (Plate 3b). The sutured layers run broadly parallel to the contacts of the body although they do not follow individual irregularities as closely as the simple layers. Some closely spaced examples of the sutured layers develop loops at corresponding points along their length in which case the enclosed aplite layers have sinuous, parallel margins. In general however, there is little agreement between two neighbouring sutured layers and the enclosed aplite thickens and thins irregularly.

Detailed examination of the sutured layers shows that the upward-facing crenulate loops contain larger grains of quartz and are thicker than the other parts of the layers. Further, the centres of the upward-facing loops commonly contain quartz-felspar intergrowths similar to the early stages in the development of the quartz-felspar megacrysts described on page 20. The crenulations in the upward-facing loops are commonly formed by prominent quartz blebs which form part of the garnet-quartz layer and the quartz-felspar intergrowth from the centre of the loop. Occasionally the upward-facing loops are particularly strongly developed and become detached from the main layer. In this case the layers may break or they may form "eyed domes" of the type described on page 19 and shown in Plate 3c.

ii. Quartz-felspar intergrowth and perthite megacrysts

The coarse-grained intergrowths between quartz and felspar which form a major constituent of the Kînâlik sheets can be discussed under three headings:

a. Concordant layers of formless quartz-felspar intergrowth.

b. Diffuse masses of quartz-felspar intergrowth with discordant, gradational contacts against the other components.

c. Perthite megacrysts.

a. Concordant layers of formless quartz-felspar intergrowth

Plate 1 shows five, main, concordant layers of coarse-grained quartz and felspar alternating with the layered aplites. These layers consist of a rather featureless intergrowth of plagioclase and microcline both with a graphic intergrowth of quartz rods, the orientation of which is controlled by the felspar crystallography. The proportion of the two felspars present is unknown; on some weathered surfaces pink microcline appears to be more abundant than the buff-coloured plagioclase, but this need not be a general rule. The proportion of quartz and felspar varies considerably even within one crystal and several of the felspars show a zonal structure with alternating layers of quartz-rich and quartz-poor intergrowth. Similar changes can be seen within individual felspar crystals where there is a change in size or orientation of the quartz rods. The felspar crystals forming the intergrowth layers commonly reach over ten centimetres in diameter, are approximately equidimensional and generally show no preferred orientation. Some of the broader layers of intergrowth show a central zone in which quartz and felspar form separate crystals and the distinction between these layers and the pegmatitic component of the sheets described on page 23 is purely arbitrary. Similarly, there is no rigid distinction between layers of intergrowth and layers formed by the preferential concentration of the perthite megacrysts described in (c) below. The intergrowth layers show a variety of relationships with the aplites. Many of the intergrowth layers appear to have formed approximately contemporaneously with the simple layering in the aplite and there is commonly a transitional zone between an intergrowth layer and the adjacent aplite in which the garnet layers are diffuse and poorly defined. Locally, the intergrowth layers may thicken, in which case the aplite layers above them form gentle, concordant swells. Some of the concordant intergrowth layers are linked to discordant veins of pegmatite or intergrowth, which shows that they were formed after the surrounding aplite. In the left hand photograph of Plate 1 the concordant layers of intergrowth at the bottom of the sheet may be seen to be later than the surrounding aplite, as they are connected to a vertical vein of coarser material cutting the layered aplite above. However intergrowth layers branching from the same vertical vein near the top surface of the same body can be seen to be earlier than the aplite lying conformably on their upper surface.

b. Diffuse masses of quartz-felspar intergrowth

Some of the aplite-pegmatite sheets are made up of quartz-felspar intergrowths from wall to wall at one outcrop, while farther along the strike the same body contains considerable layered aplite. There is commonly a transitional zone in which irregular patches of aplite are found within the intergrowth. The aplite patches are usually elongated parallel to the margins of the bodies and they may contain garnet layers which run concordantly with the elongation. In many cases individual garnet bands can be traced through several, separated patches of aplite which are completely surrounded by coarse intergrowth, (as far as can be seen on a plane surface). Islands of aplite surrounded by quartz-felspar intergrowth are one of the commonest features observed in the composite pegmatites in the area around Sârdloq and have been extensively studied by WINDLEY (in prep.). Plate 5a shows an example from an island to the south-west of Kînâlik. The same body shows local areas of garnet layering preserved near the lower contact. The internal structure of these diffuse masses of quartz-felspar intergrowth is identical to that of the concordant layers described in (a) above. In bright sunlight individual felspar crystals up to twenty centimetres in diameter are seen packed together in an apparently random fashion. Several of the quartz-felspar intergrowth bodies contain euhedral garnets up to ten centimetres in diameter which are also intergrown with quartz.

c. Perthite megacrysts

Nearly all the layered aplite-pegmatite bodies from Kînâlik contain megacrysts of potash felspar intergrown with quartz. Similar megacrysts of plagioclase felspar have not been observed. In the simplest case the megacrysts are randomly distributed as isolated crystals throughout the aplite, each megacryst extending over several layers within the aplite. In some of the bodies the megacrysts are preferentially developed within certain of the aplite layers generally below a prominent garnet-bearing band. If the megacrysts become dominant within a particular layer, they may interfere with one another, and masses of intergrowth similar to those described in (a) and (b) above result (Plate 2b). When not seen *en masse*, the megacrysts have a characteristic form controlled by the crystallography of the felspar. Typical megacrysts are cone-shaped with a rectangular cross section and domed upper surface. The long axis of the cones, which corresponds to the "a" crystallographic axis of the felspar, is oriented at right angles to the layering in the aplite (Plate 2c). Vertical sections of megacrysts show wedge-shaped crystals with the thin end always pointing downwards, even in the upper parts of sheets. This is in contrast to the descriptions published by Orville, Redden and Jahns and Tuttle, who describe megacrysts which either increase in diameter towards the centre of the body or show no preferred orientation. This asymmetry is probably associated with the flat-lying nature of the Kînâlik bodies and is considered to be of genetic importance. Similar observations have been made by Berrangé (in press) from the layered aplite-pegmatites in Igaliko Fjord. The megacrysts range from a few centimetres along the "a" axis to fifty centimetres. The larger crystals are often more idiomorphic and show a more consistent orientation at right angles to the aplite layering. In planes cut parallel to the aplite layering the megacrysts appear either as sections of rounded domes surrounded by a ring of garnet arched up by the megacryst (Plates 3c and 4a) or as euhedral crystals with garnet-rimming concentrated on two faces. This difference in form is due to the plane of section, cross sections close to the top of the megacrysts showing the rings, while those lower down show rectangles (Plate 4b). The preferential distribution of megacrysts within certain aplite layers can be seen in horizontal section as a concentration of rings on one surface and rectangular crystals on the next (Plates 3c and 4c). In horizontal section the megacrysts have been found to reach eighteen centimetres along one side.

The megacrysts show rhythmic variations in the distribution of quartz intergrowths which gives rise to a banded structure as seen in Plate 2c. This structure is due to changes in the proportions of quartz and felspar and in the size of individual quartz blebs, and resembles annual growth rings in wood. In vertical section the banding has a gently arcuate form parallel to the upper surfaces of the megacrysts and is thus approximately parallel to the layering in the aplites. Twin planes running along the length of the megacrysts do not seem to have any affect on the banded pattern. In horizontal section the rhythmic variations are generally parallel to the margins in the outer parts of the crystals but become more rounded towards the crystal centres (Plate 4b). This is thought to be due to the direction of growth of the megacrysts, the rounded, central zones representing the original, dome-shaped top of the megacryst at an earlier stage in development.

d. Relationship between the perthite megacrysts and the layered aplites

The interrelationship between the megacrysts and the layered aplites is one of the most important features studied in the Kînâlik sheets, as it gives considerable evidence about the crystallisation history of the bodies. STAATZ and TRITES, ORVILLE, REDDEN, and JAHNS and TUTTLE have all described features similar to those seen at Kînâlik, although there is no agreement about their significance. For purposes of comparison these features have been compiled in fig. 6. Two aspects of the relationships of the megacrysts have to be considered; those between the megacrysts and the aplite as a whole and those between the megacrysts and the garnet layering in the aplites.

The aplite forms the host rock to the megacrysts, generally surrounding them completely. Some individual megacrysts contain inclusions of aplite which are oriented randomly within the crystals, cutting off the rhythmic quartz banding. As far as can be seen, the aplite included within the megacrysts is identical to that outside and has not been disturbed by its inclusion. Commonly thin aplite layers are found associated with the finer rhythmic bands within the megacrysts. These thin aplite layers may contain trains of minute garnet crystals which give the banding a slightly pinkish tinge. Some of the garnet trains are continuous with the garnet layering in the surrounding aplite and may be interpreted as phantom layers similar to those illustrated by REDDEN in his fig. 91 (see fig. 6). These phantom layers are generally rather diffuse and are commonly broader than the garnet layers in the adjacent aplite. Other

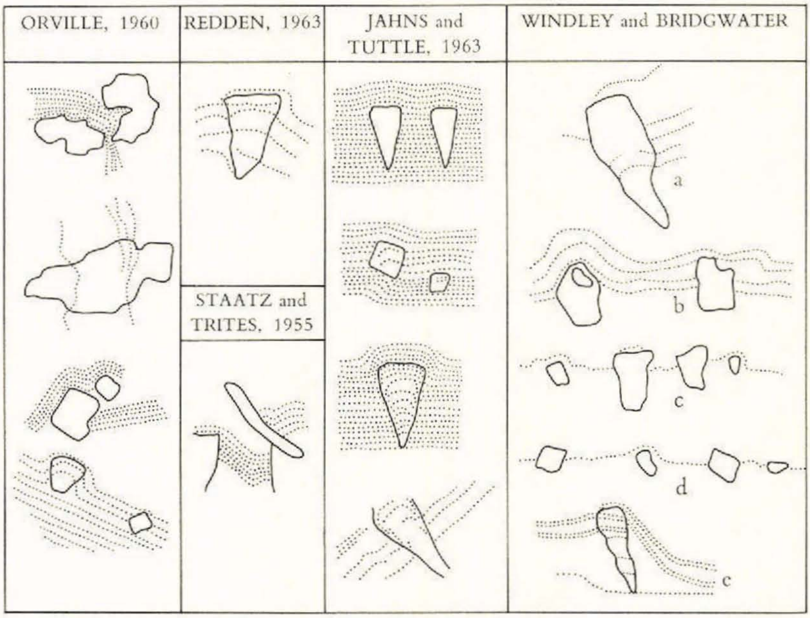

Fig. 6. Compilation diagram showing variable relations between potash felspar megacrysts and surrounding layered aplite from different authors.

bands of garnet within the megacrysts are not continuous with the layering in the surrounding aplite and appear to be an integral part of the megacryst structure formed at the same time as the bands of quartz described above. It seems important to distinguish between these two types of garnet layering within the megacrysts, since the first can be used as evidence to suggest the relationship between the megacrysts and the surrounding aplite. From fig. 89 in Redden's paper it appears that some of Redden's phantom layers are similar to the second case described above and are equivalent to the structure illustrated in Plate 2c of this paper. An interesting example, suggesting that some of the layering within the perthite megacrysts is not derived from garnet layering in the aplites, is seen in fig. 6e (drawn from a photograph by Berrangé). The megacryst shows five, distinct layers, only two of which are associated with layering in the surrounding aplite.

The garnet-rich layers in the aplites show a variety of relationships to the megacrysts which are illustrated in figs. 6 and 7.

a) The garnet layering may pass through the megacrysts without deflection but with apparent recrystallisation, so that the garnets are no longer completely in an aplitic host (fig. 6a).

b) The garnet layering may be partially deflected or arched by a megacryst and then pass through it as in (a) above (fig. 6e).

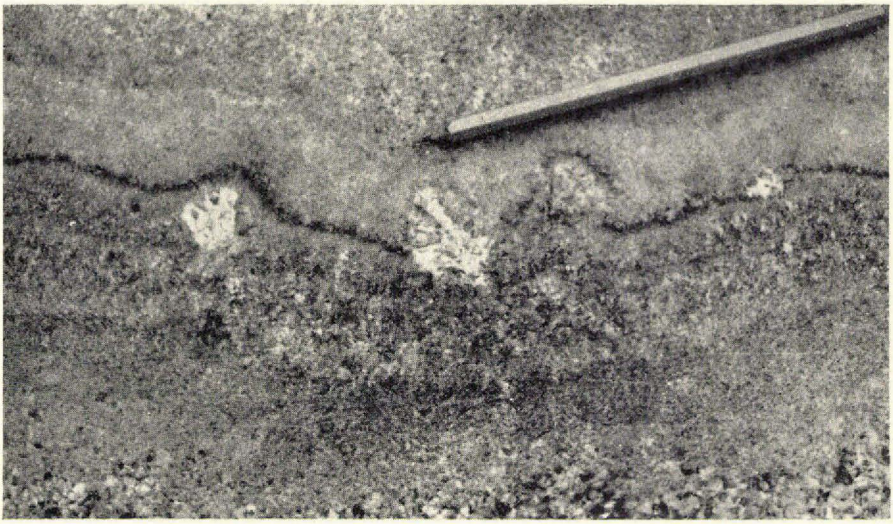

Fig. 7. Small megacrysts set in an aplitic host. Note the preferential distribution of the megacrysts in one particular layer and the variable relationships between the megacrysts and the overlying, garnet-rich layer. The intergrowth between quartz and felspar making up the megacrysts is clearly visible.

c) The garnet layering may be truncated by the megacryst without deflection (fig. 6d).

d) The garnet layering may be partially deflected by the megacryst and then truncated (fig. 6b).

e) The garnet layering may be deflected around the top of a megacryst with or without recrystallisation and the formation of sutures (figs. 6b and 6c).

f) Garnet layers may become completely recrystallised and the garnet-forming material reprecipitated around the megacryst or even within fractures in the megacrysts (Plate 4b).

Furthermore, any one megacryst may show different relationships to different layers, so that at its base it either truncates the layers or the layers pass through it without deflection, while at its top the layers dome over it (fig. 6b). Commonly, the first layer to pass over the top of a megacryst is sutured and shows a complex relationship with the intergrowth of quartz within the megacryst, while the following layers are simple, smooth domes. In general, the felspathic component of the megacrysts projects farther into the layer above than the quartz.

A megacryst may affect several of the layers above it, the domes dying out gradually away from the megacryst. Megacrysts rarely affect layers below them and in the few cases where this has been observed the effect is less than at the top of the same megacryst (Plate 5b). One case of suturing has been found at the base of a megacryst. In bodies where the growth of megacrysts is particularly marked, the garnet layering becomes completely broken up and appears as a series of discontinuous domes either capping or within individual megacrysts (Plate 2b). These discontinuous bands of garnet-bearing aplite are quite common within many of the late Sanerutian quartz-felspar intergrowth pegmatites in South Greenland, suggesting that the processes described from Kînâlik are widespread.

iii. Pegmatite as distinct units

The pegmatitic component of the sheets is concentrated on the hanging wall in the same way as the layers of quartz-felspar intergrowth and a distinction cannot always be made between the two rock types as there is every gradation between them. The pegmatite consists of discrete crystals of quartz, perthite and plagioclase as major minerals with minor amounts of biotite, garnet, muscovite, magnetite, allanite and a little beryl. An intergrowth between quartz and felspar and more rarely between quartz and some of the accessory minerals occurs but is not typical. Several of the pegmatites forming integral units within the layered bodies show a typical zonal structure with medium-grained margins of quartz and felspar as individual crystals, intermediate zones of quartz-felspar intergrowth, and a central zone of quartz and felspar as large separate crystals. Occasionally, there is considerable vein quartz with free-floating felspar concentrated near the centre of these zoned units. The vein quartz may break through the zoning and cut other units in the layered body. Magnetite and allanite are concentrated in the inner part of these zoned pegmatite units. Garnet and biotite are more common towards the outer zones and are generally coarser grained than those in the aplites. Muscovite occurs as a late mineral with a very uneven distribution; it frequently "spears" earlier-formed felspar.

General relationships between the pegmatites and the other components

Most of the pegmatite layers are parallel to the margins of the bodies and more or less conformable with the layering in the aplites. However, the pegmatites show many more irregularities than the other, main components of the sheets; individual pegmatite layers thicken and thin and show gross changes in composition with the centres of the thicker parts full of quartz. In contrast to the simple layering in the aplites, the pegmatites commonly branch (Plate 5c), in which case at least one of the branches becomes unconformable to the main layering in the body. Because of the asymmetric distribution of the pegmatite near the top of the body, most of the discordant veins of pegmatite run

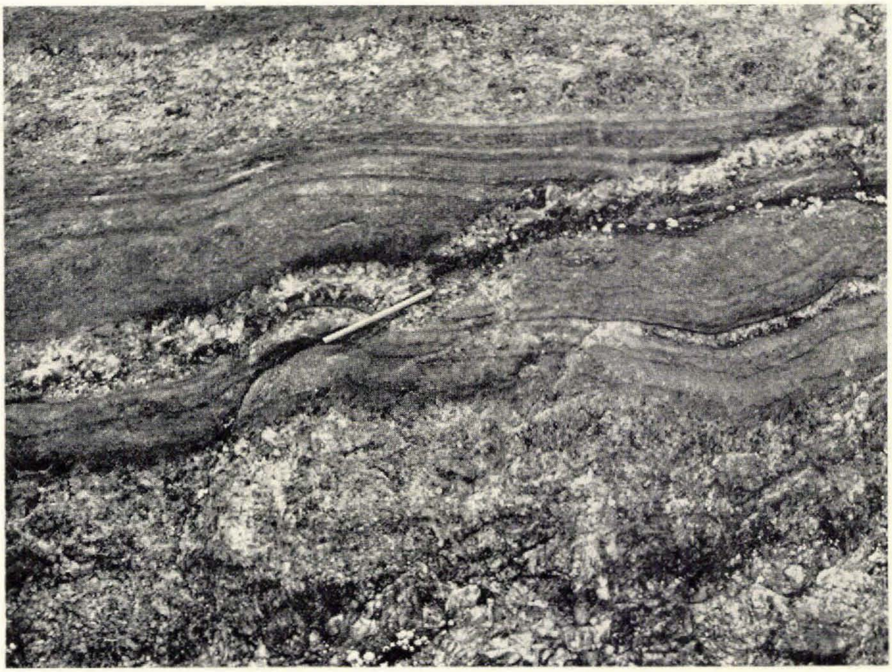

Fig. 8. Late, discordant, pegmatite vein cutting layered aplite along a small fracture. Note the conformable layers of quartz-felspar intergrowth at the top and bottom of the picture. The lower intergrowth-layer shows a slight zonal structure with more discrete crystals of quartz and felspar in the centre of the layer (bottom right hand corner of the photograph). The late pegmatite vein is locally concordant with the aplite layering and it sends several thin apophyses into the aplite.

downwards into the layered aplites, where they commonly become concordant (fig. 8). Smaller branches may arise from the first set of pegmatite veins and cut the aplites either above or below them. This is in apparent disagreement with Redden's description of the pegmatites of layered bodies of the Black Hills, where the pegmatites always run outwards from the centres of the bodies cutting the earlier-formed layered aplites. However this seems to be another case in which the flat-lying attitude of the Kînâlik sheets has distorted the normal relationships, so that the pegmatite concentration near the top of the sheets is equivalent to the common coarse-grained and pegmatitic zones in the central parts of vertical dykes described by other writers. Some of the pegmatites may pass outside the parent body into the surrounding country rock. The general layering of the aplites has exerted some structural control on the formation of the pegmatite veins, as discordant branches commonly swing into concordant layers a little way away from their parent pegmatite layer. These pegmatite "sills" die out along their strike. Plate 6a shows a small sheet with an upper pegmatite unit and a lower aplite

Fig. 9. Local development of aplite with garnet-rich layers near the upper surface of a sheet. Note that the garnet layering follows the irregularities of the pegmatite lenses.

unit. The aplite contains five, thin pegmatite bands each of which passes into a garnet layer along its strike.

Detailed relationships between the pegmatites and the other components

The most important generalisation which can be made about the relationship between the pegmatites and other structures in the Kînâlik bodies is that the pegmatites are always the last rocks to crystallise. This is seen in a variety of ways, the most common of which is the large number of veins and apophyses that the pegmatites send into the earlier rocks. Similarly, although many of the larger pegmatite units are concordant with the general layering, they cut small features in the rock surrounding them, such as the felspar megacrysts. Many of the pegmatite veins are emplaced along fractures, which displace the earlier layering by an amount several times the width of the pegmatite veins and which continue for some way in the aplite after the pegmatite has died out. Most of the fractures do not continue outside the layered bodies and seem to have formed as the result of internal stresses during the last stages of crystallisation. A few of the fractures pass into the country rocks and may be due to other causes. Occasionally the fracturing becomes so intense that the earlier layering within the body is completely disrupted. Plate 6b shows a mass of quartz-felspar intergrowth with disoriented felspars containing garnet banding. The intergrowth has been brecciated and then veined by undisturbed pegmatite. In one body on a small island to the south east of Sydprøven the phase of movement separating the formation of the late pegmatite from the quartz-felspar intergrowth was so intense that the quartz rodding in the intergrowth was deformed and recrystallised parallel to the plane of shearing. In this case the dominant movement was parallel to the margins of the sheet. In many of the sheets the garnet-loops over the top of megacrysts are asymmetrical with the steep limb on one side, suggesting movement parallel to the walls of the body. The pegmatites of the same sheets are undeformed.

The emplacement of the pegmatites is commonly associated with some recrystallisation of the surrounding rock. The most noticeable feature is the formation of garnet borders to the pegmatite veins which cut discordantly across the earlier, simple garnet layering (Plate 6c). The recrystallised garnet margins to the pegmatite veins are often coarser-grained than the simple layers and the garnets are more widely spaced. Rather irregular bands of garnet are also found within finer-grained areas surrounded by the pegmatite. Some of these can be seen to be relics of simple garnet banding in aplite which has been replaced by pegmatite. Other garnet layers have apparently formed approximately contemporaneously with the pegmatite phase and follow the upper surface of individual pegmatite lenses (fig. 9). This suggests that local formation of garnet-bearing aplite persisted right to the final stages of crystallisation of the sheets, although the main aplite phase was early in the crystallisation sequence of the sheets.

III. INTERPRETATION OF THE FIELD OBSERVATIONS

The structures preserved in each of the Kînâlik sheets are the result of differentiation and segregation of single injections of granitic magma (see page 10). There is no evidence to suggest that the initial magma from which individual sheets were formed was other than homogeneous when it was emplaced. Thus the complex relationships between the various components within the sheets provide a detailed record of the sequence of crystallisation in thin granite bodies under the influence of temperature and chemical gradients. Although the features described from Kînâlik give considerable evidence about the sequence of events within the sheets, the significance of each of the features is open to several interpretations.

1. General sequence of events

The three, main components of the Kînâlik sheets; layered aplite, quartz-felspar intergrowth and pegmatite represent in turn the dominant rock types formed in the three stages of crystallisation of the bodies. The description does show however that there has been some temporal overlap of these three stages. The spacial relationships between aplite and pegmatite in these flat-lying sheets suggest that aplite formed along the lower margins while pegmatite formed in the upper part of the bodies (fig. 10). The detailed relationships between aplite and pegmatite suggest that the major part of the aplite was formed before the solidification of the pegmatite. This is most convincingly shown by the pegmatite veins which cut the aplite, whereas no aplite veins have been seen cutting the pegmatite. No vertical differentiation has been seen in any of the steeply-dipping apophyses, these showing a similar sequence to the low-dipping parent bodies but with the last-formed components concentrated in the central zones. Most of the apophyses consist dominantly of one rock type and possibly show the approximate composition of the remaining magma at the time at which they were given off from the main sheets.

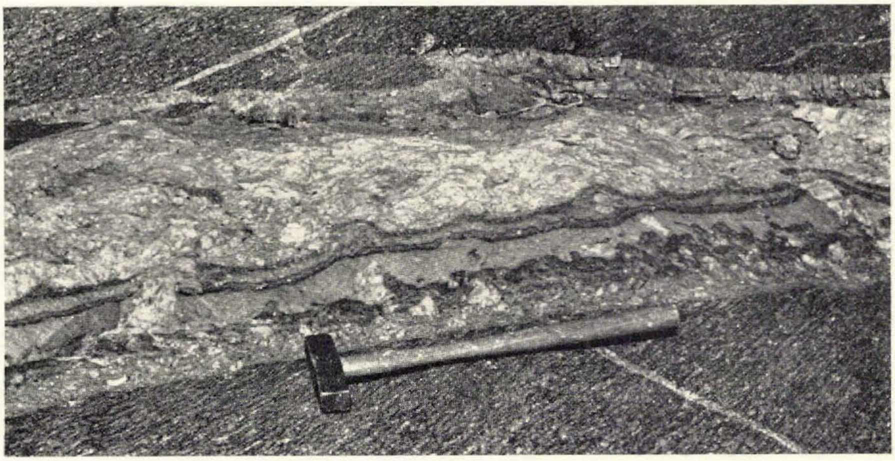

Fig. 10. A low-dipping sheet on the south side of Igaliko Fjord. Note the concentration of pegmatite towards the upper margin and the paired, garnet-bearing layers in the aplite. The preferential direction of growth of the perthite megacrysts is well seen. The sheet differs from those at Kînâlik as there is a well-marked, marginal development of medium to coarse-grained material. Photo G.G.U., J. BERRANGÉ.

The formation of the overall, layered structure of the sheets was controlled by gradual concentration of potash felspar and quartz at the top of the bodies. The most reasonable explanation for this is the rise of volatiles towards the top of the sheets (JAHNS and TUTTLE, 1963, p. 90). It is suggested that the first stage of solidification was represented by the crystallisation of the lowest layers of garnet-bearing, plagioclase-rich aplite along the bottom of the sheets. General crystallisation continued upwards until the volatile concentration was high enough to cause the formation of concordant, coarse-grained layers of intergrowth. Some of the residual was locally intruded along cracks formed in the aplite below, which had solidified slightly earlier, to form intergrowth. Aplite formation began again above the concordant intergrowth layers either due to the depletion of the residual magma in a particular component or possibly due to the periodic loss of volatiles from the body. The alternation of aplite and intergrowth layers was repeated several times during the formation of the larger sheets and resulted in the large-scale layering seen in Plate 1. There was a gradual increase in the proportion of intergrowth and pegmatite towards the upper surface of the bodies. It also seems quite likely that the upward migration of volatiles carrying quartz and potash felspar occurred "up dip", and this may explain the many instances in which early-formed aplite has been replaced by late intergrowth. It is suggested that the marked segregation of potash felspar and quartz under the influence of the upward movement of volatiles resulted in an abnormal crystallisation trend in which potash felspar and quartz were the last major minerals to solidify. The fracturing of the earlier, crystallised components in the sheets was possibly caused by the concentration of volatiles as an independent phase at approximately the same time as the main formation of pegmatite. The pegmatites utilised the fractures and thus have intrusive features against the earlier-formed rocks. Locally, the late-formed pegmatites were intruded outside the original confines of the body.

The local accumulation of pegmatite and its intrusion into the already-solidified, lower, aplitic parts of the sheet gives the impression of multiple intrusion in some outcrops. Diagnostic features of multiple intrusion, such as dilatation of one component of the sheet by a later phase, are commonly observed. However, if the bodies are considered as a whole, then these effects are seen to be local and do not prove that the sheets were formed by the separate emplacement of two magmas. The characteristic accumulation of pegmatite along the upper surface of the sheets suggests that these rocks were genetically connected with the remaining components in the sheets and were not the result of multiple injection.

The sequence of events described from the flat-lying Kînâlik sheets shows some similarities to those described from normal, vertical, zoned pegmatites in which a fine-grained, marginal zone is followed by a quartz-felspar, intergrowth zone surrounding a central core of coarse-grained pegmatite with free-floating felspar. In the case of the low-dipping sheets at Kînâlik this general case has been modified by the differential effect of gravity, which allowed the preferential accumulation of some of the later components towards the top of the body. This segregation probably began early in the crystallisation of the sheets and explains the formation and preservation of aplite along the lower surface.

2. Detailed interpretation of the internal structures

A. The formation of the simple layering in the aplites

The thin, continuous, simple layering in the aplites is one of the most difficult features to explain. The relationship of the layering to the perthite megacrysts and the discordant pegmatites shows that it was formed early in the crystallisation history of the bodies, but the mode of formation is far more problematical. Ideas on the formation of the layering can be divided into two: a) the layering was formed by rhythmic crystallisation at the interface between the magma and the first-solidified portion of the sheet; b) the layering was formed by a rhythmic redistribution of material within rocks which were at least partially solidified. There is nothing to prove which of the two processes caused the layering in the Kînâlik aplites, as there is no direct evidence about the composition or texture of the first rock to crystallise from the granitic magma. No primary flow textures of the type described by JAHNS and TUTTLE (1963, p. 82) have been observed in the Kînâlik sheets. In the following account the simple layering is assumed to be primary, since it is the earliest feature seen and there is no evidence that secondary processes played a role in its formation. However recrystallisation and redistribution of material are common in the crystallisation history of granitic rocks and were a major factor in the later stages of the development of the Kînâlik sheets. This might suggest that at least some of the features seen in the garnet layering developed within the partially solidified aplite parallel to the crystallisation surface. Although the mechanics of layer formation in the aplites are unknown, the following field observations suggest some of the conditions which controlled its formation.

i. The layering develops parallel to the walls of the sheets whatever their attitude. Because of their asymmetrical development the layers are generally parallel to the lower wall; however in steep or vertical apophyses the layering is controlled by both walls. The latter suggests that the rhythmic accumulation of heavy minerals under the influence of gravity is not an important factor in the layer formation of these bodies.

ii. The layering is developed from the outer wall inwards, generally from the lower wall upwards. This can be shown by the effect of minor irregularities within the layers such as the doming over the top of early formed megacrysts (see p. 19). The layering was not formed at the same time throughout a sheet and although the general scheme of layered aplite—quartz-felspar intergrowth—pegmatite holds, local patches of layered aplites were formed late in the sequence. In these cases the layering is parallel to the surface of the rock which solidified before its development. This suggests that the layering was controlled by the attitude of the solid-liquid interface, although it need not imply that the two were coincident.

The most reasonable explanation for the type of layering seen in the Kînâlik sheets would seem to be that put forward by JAHNS and TUTTLE on p. 87, when they suggest that the layers were formed by rhythmic crystallisation under the influence of alternating super- and under-saturation in the main constituents of the magma. Such an explanation, although more generally applicable to crystallisation at a solid-liquid interface, could equally well occur within a crystal mush, in which there was sufficient diffusion taking place to allow local "build up" of particular components, provided that some overall gradient were present.

B. The formation of paired garnet layers in the aplite

The paired layers described on page 14 are a common feature in the aplites. With rare exceptions, they show a striking conformity with the simple garnet layering. The two types of paired layers, those less than 0.5 centimetre wide and those with prominent perthite cores, are regarded as having formed in a similar way, because they pass from one to the other along their strike. The relationships between the paired layers and the felspar megacrysts are the same as those between simple layers and megacrysts, showing that they were formed at approximately the same time as the simple layering and are thus early in the crystallisation sequence in the sheets. However it is difficult to explain why the unit garnet-perthite-garnet should occur with such regularity if the paired layers are regarded as a chance sequence of supersaturation in the magma. It is also impossible to explain the rare occurrence of branching perthite layers, each limb with its own garnet sheath, unless the rock surrounding the perthite was already solid at the time of formation. It seems more likely that the paired structures grew within a solid medium or crystal mush and were caused by the chemical expulsion of garnet-forming material during the growth of the central perthite layer. The garnet rims would then be analogous to "basic fronts" along the margins of replacement pegmatites. It seems likely that the majority of the perthite centres were initiated by the crystallisation of a thin layer of material rich in potash felspar during the formation of the simple garnet layering. The potash felspar layers would thus be strictly conformable to the simple layering in the aplite and are now represented by the thin layers of aplite surrounded by paired garnet layers. After the initial formation of these layers, potash felspar continued to diffuse through the semisolidified crystal mush and was precipitated round the incipient perthite layer. This process drove out the local garnet-forming constituents of the surrounding aplite probably by a process of resorption and reprecipitation in the interstitial liquids of the crystal mush. The garnets were re-formed along the margins of the perthite grains and formed the typical double bands seen in fig. 3. The formation of branches such as the example illustrated in fig. 5 was probably controlled by slight dislocations within the partially solidified aplite surrounding the perthite layers. Migration of potash felspar along the discordant planes of weakness led to the formation of perthite layers and redistribution of the garnet of the host rock to form "basic fronts". This is especially well illustrated in Plate 4b.

C. The formation of perthite megacrysts

Three, main view points have been expressed in modern literature about the relationship between the formation of the simple layering and the development of the perthite megacrysts, which occur in bodies similar to those at Kînâlik. STAATZ and TRITES (1955) proposed that the megacrysts projected above the layered aplite surface, acting as buttresses to the crystallising fluid. ORVILLE (1960) suggested that the megacrysts were either later than the layering or at least they continued to grow after the solidification of the surrounding rock. REDDEN (1963) and JAHNS and TUTTLE (1963) suggested that the megacrysts and layering were essentially contemporaneous. The divergence of viewpoint expressed is due to differences in interpretation rather than differences in evidence.

The Kînâlik bodies show features similar to those described by the above authors and a case could be made for any of the viewpoints, if one set of features were given more prominence than the other.

The apparent incompatibility of the evidence from Kînâlik might suggest that there is more than one period of megacryst formation, with some crystals formed slightly before, some contemporaneously with the aplite layers adjacent to them, and others formed after the initial solidification of the aplite. However, examples are found in the Kînâlik sheets similar to that illustrated by REDDEN in his fig. 93 in which a single megacryst shows different relationships to layering at different points along its length. It is difficult to explain the gentle arching of garnet layers in the aplite above and not below megacrysts unless the latter projected above the crystallisation surface. However, it is equally difficult to explain the inclusions of aplite within the upper parts of megacrysts unless aplite was already solidified when the megacryst was formed. This is especially true when the included aplite contains garnet layers in line with garnet layers in the host aplite.

The writers suggest that the most reasonable explanation for these phenomena is that the megacrysts started to form at approximately the same time as the layering in the aplite but continued to grow after the initial solidification of the surrounding rock. The different relationships between the megacrysts and the aplite layering could be explained as due to purely local variations in the rate of growth of the two rock types.

Orientation of the megacrysts

The preferred orientation of the felspar megacrysts as described on page 19 suggests firstly that the most favourable direction of crystal growth was at right angles to the walls of the body and thus parallel to the growth direction of the aplite layering, and secondly that perthite crystals oriented with their "a" axis at right angles to the aplite layering grew at a faster rate than randomly oriented, perthite crystals. This need not imply that the perthites were formed at exactly the same time as the aplite layering, nor that the perthite growth took place at a crystal-liquid interface. It does however suggest that the same processes, which controlled the formation of the layering of the aplites, also controlled the growth of perthite and it is thus likely that the two events were approximately contemporaneous.

Formation of the sutured garnet layers

The sutured garnet layers are intimately connected with the formation of felspar megacrysts, and ideas about their formation depend on the particular viewpoint held on the mode of formation of the large perthite crystals. There are two main possibilities:

a) The sutured layers represent an irregular development of the normal, primary layering in which the megacrysts in the centres of the upward-facing loops originally projected above the surface of the crystallising aplite. The suturing would then represent the formation of a simple layer on a highly irregular surface.

b) The suturing represents the effect of megacryst growth on normal layering. The layering was displaced probably by a process of resorption and recrystallisation, analogous to the formation of the garnet-rich borders to the perthite layers in the paired bands described on page 14.

Neither of the two ideas can be proved and it is possible that both processes occurred. However several observations suggest that the second is the most likely explanation in the majority of cases. The intricacy of the convolutions in the quartz-garnet layers as they loop over the top of the megacrysts suggests a closer relationship between the growth of the megacrysts and the garnet layers than would be expected by the chance formation of a garnet-rich layer on the top of a highly irregular surface. Many of the loops are dumb-bell shaped in three dimensions with the bases narrower than the tops. If the garnet layering crystallised onto a surface which was already solid then the megacrysts must have projected from the surface as cones with only the thin ends "buried" in the aplite below. This mode of formation seems reasonable to the writers, but is not demonstrable in the sutured layers of the Kînâlik sheets.

If it is accepted that the suturing could be caused by the growth of felspar megacrysts with a redistribution of garnet-forming material continuing after the initial crystallisation of the aplite, some of the less complex loops seen where garnet layers dome over the top of felspar megacrysts might also have formed in a similar manner. This means that the most important criteria, suggesting that the aplite layers which arch over the top of megacrysts are later than the megacrysts, need no longer be valid, since the arching could have been caused by a secondary process. It seems that the most reasonable approach is to take each example separately. Some arches such as those illustrated in Plate 5b certainly appear to have formed by the crystallisation of garnet layers on a pre-existing surface, whilst more complex arches such as those illustrated in Plate 3c may have originated by a redistribution of the garnet-forming material.

The idea that some of the textural features described from granites are due to processes which occurred after the initial solidification of the rock has come into favour in the last decade (see, for example, STONE and AUSTIN, 1961). One of the main chemical and textural changes in these processes, which took place after the solidification and before the final consolidation, is the recrystallisation of a relatively fine-grained rock into a coarse-grained rock which is often accompanied by the redistribution of the material to form potash felspars. It would seem highly probable that such processes are common in granitic pegmatites, where the accumulation of volatile material is generally thought of as higher than normal and thus the tendency for migration of potash felspar correspondingly high.

Secondary effects due to the formation of massive quartz-felspar intergrowth

The presence of apparently undisturbed relics of layered aplite (p. 18) within some of the sheets, which are composed almost entirely of quartz-felspar intergrowth, suggests that some of the intergrowth masses must have formed by *in situ* replacement of the aplite, and are thus not strictly comparable with the conformable intergrowth layers. Whether there was any change in the bulk composition of the rock, when this occurred, is not certain, as both aplite and intergrowth consist of the same three minerals. It is possible that the massive intergrowth was locally formed directly from aplite by recrystallisation in the presence of volatiles accumulated in the upper portions of the sheet (see fig. 2c).

Secondary effects due to the emplacement of the late pegmatite veins

The pegmatite veins which cut through the earlier structures were generally emplaced along fractures in already consolidated rocks. However, many of the pegmatite veins show an appreciable effect on the adjoining rocks. Chief among these effects are modifications to the aplite layering. There is commonly a confused area in the garnet layering close to the pegmatite veins suggesting that the aplite was recrystallised in a zone adjacent to the veins. Garnets resorbed during this recrystallisation were deposited as "basic fronts" along the margins of the cross-cutting pegmatites. Generally, these new garnet layers are discordant to the original structure, but where the pegmatite veins locally become sills, the new garnet formation may emphasis the original layering (fig. 8).

CONCLUSIONS

This paper is based almost entirely on field descriptions of the relationships between the various components within the Kînâlik sheets. Petrological details and the discussion of chemical problems have deliberately been kept to a minimum as a rigorous programme of sampling is necessary before embarking on a full petrographical study.

From the field relationships described it is suggested that two interacting processes were jointly responsible for the structures seen in the Kînâlik sheets; a general, upward movement of potash and silica resulting in a pegmatitic, upper part of the sheets, and a crystallisation sequence with aplite as the dominant early product and pegmatite as the dominant late product.

The processes which can be seen to have occurred in the Kînâlik sheets suggest that these bodies are of great potential geochemical interest as they give considerable insight into the crystallisation of a granitic magma.

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Færdig fra trykkeriet den 2. oktober 1965.

PLATES

Plate 1

General view of the main aplite-pegmatite sheet at Kînâlik. The sheet is approximately four metres thick at this point, only the upper two metres being illustrated in the photographs. The major divisions into aplite and pegmatite are easily visible. Note that the rocks forming the skyline, which is very close to the top of the body, are coarser grained than average and do not show the finely layered structures so well. Many of the pegmatite layers, which on first sight appear to be concordant, can be seen to wedge out in the aplite or to join discordant veins. The layering in the aplite is generally concordant to the margins of the body and in a few places it can be seen to arch over structures lower down in the sheet, suggesting that the main direction of crystallisation was from the bottom upwards. This is particularly well seen in the centre of the left hand photograph where layering in the aplite arches over a lens of pegmatite. Note that paired, garnetiferous bands are concentrated in one particular unit of aplite (in the centre of the right hand photograph). Some of these paired bands change along their strike due to thickening and thinning of the central perthite core. In the centre of the left hand photograph there is a near-vertical, discordant pegmatite vein which transects and in places offsets both the layered aplite and conformable pegmatite layers.

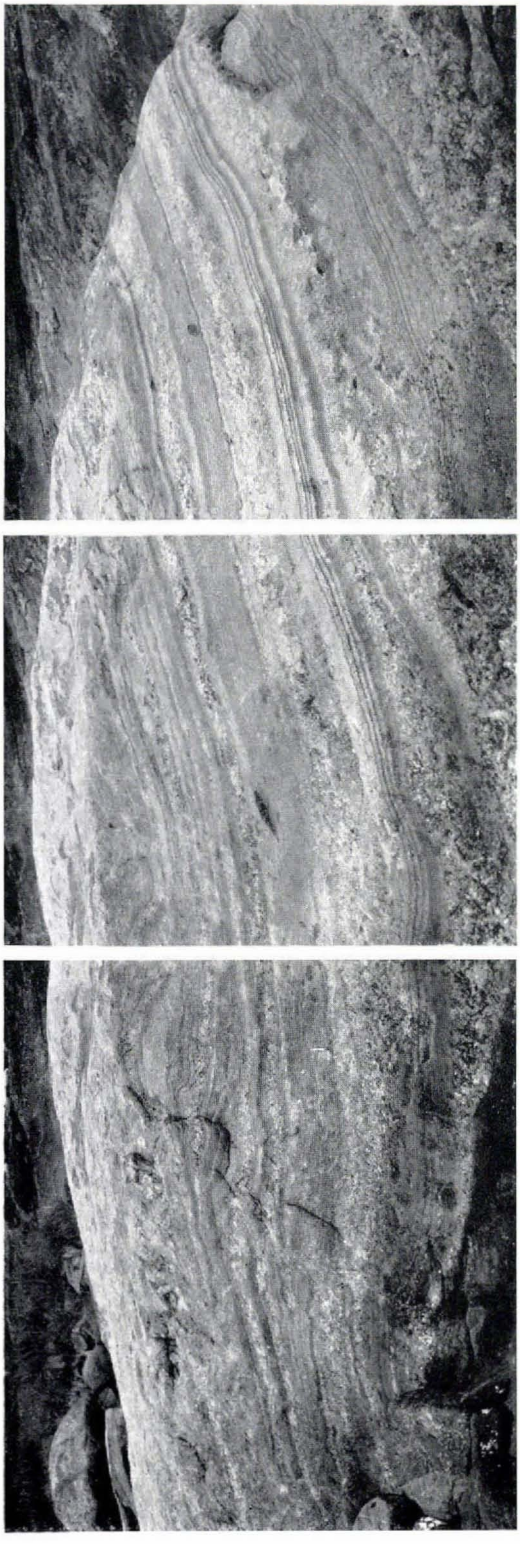


Plate 2

a

Detail of layering in aplite seen on a polished surface. The section measures 11 cm from top to bottom. Note the variation in thickness of the layers and the differences in grain size from layer to layer. Garnets are concentrated in layers in the aplite but some occur in the pegmatite near the bottom of the photograph.

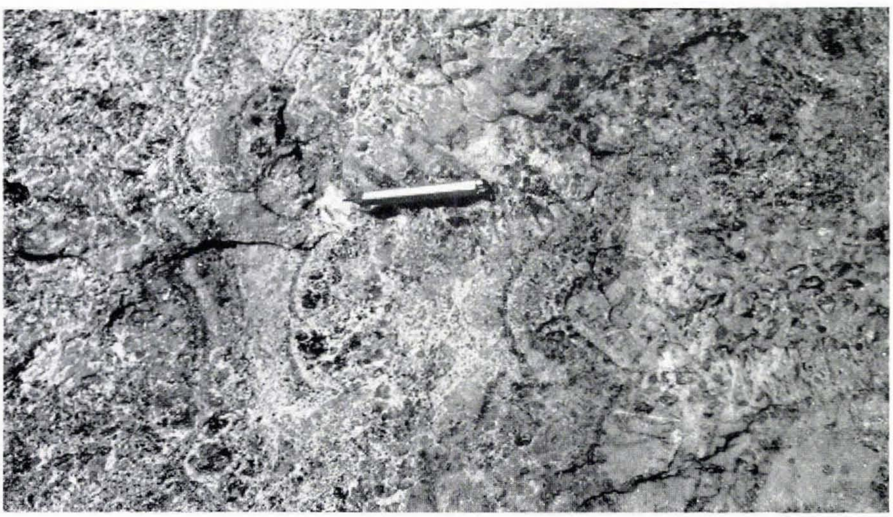
b

Closely-packed perthite megacrysts each of which is intergrown with quartz. Note the discontinuous, garnetiferous aplite layers capping some of the megacrysts. The dominant elongation of the felspar crystals at right angles to the layering is well marked.

c

Vertical section of a single perthite megacryst. Note the cone shape with the broad end uppermost, the clearly defined twin plane and the rhythmic variation in the quartz intergrowth. The coin measures 2.5 cm in diameter.


c


b

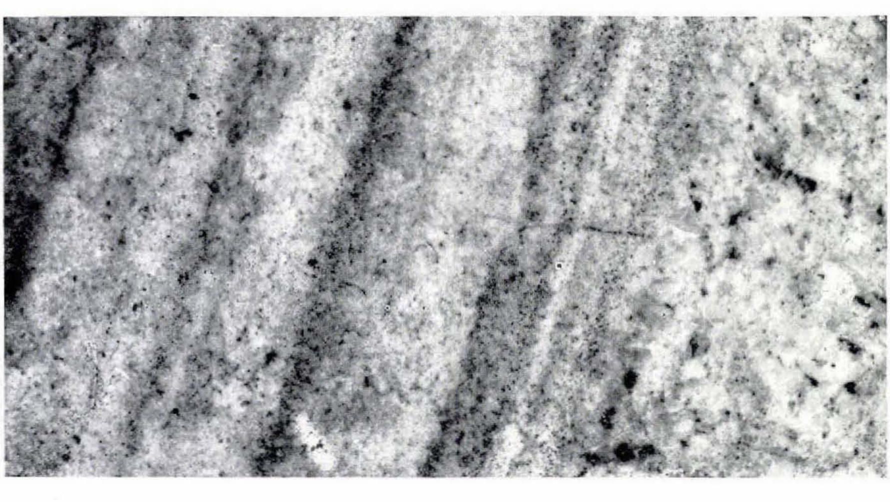

a

Plate 3

a

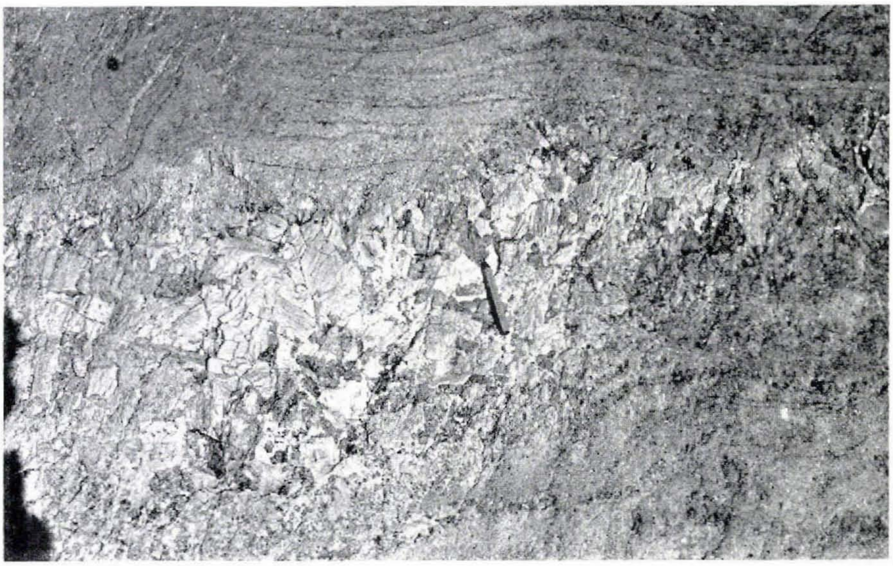
Discordant pegmatite composed of distinct crystals of quartz and felspar cutting layering in an aplite. Note the irregularities in the layering in the top left hand corner of the photograph where there appears to have been some slumping or recrystallisation after the layering was first formed.

b

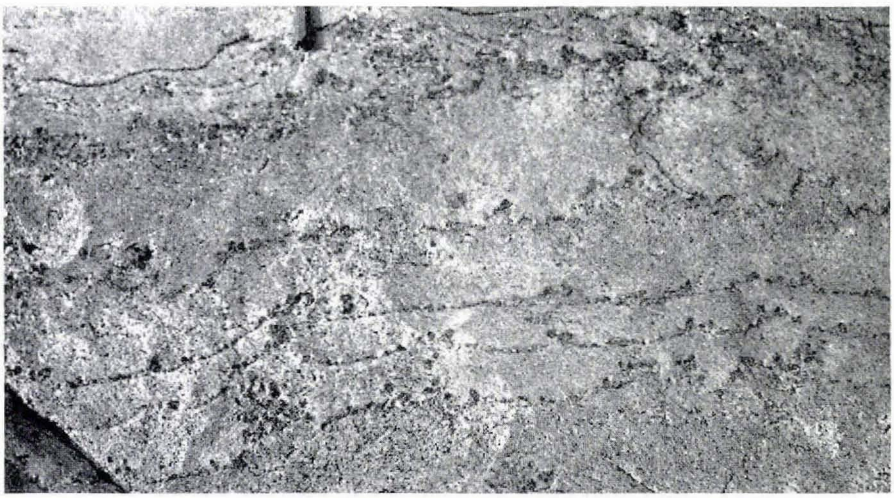
Aplite with sutured layers of coarser garnetiferous material. Some of the upward-facing loops such as those in the lower left hand corner of the photograph contain perthite megacrysts with pronounced quartz blebs forming an intergrowth with the felspar. Other loops do not appear to contain megacrysts at least on the present erosion surface. The section illustrated is approximately 20 cm from top to bottom.

c

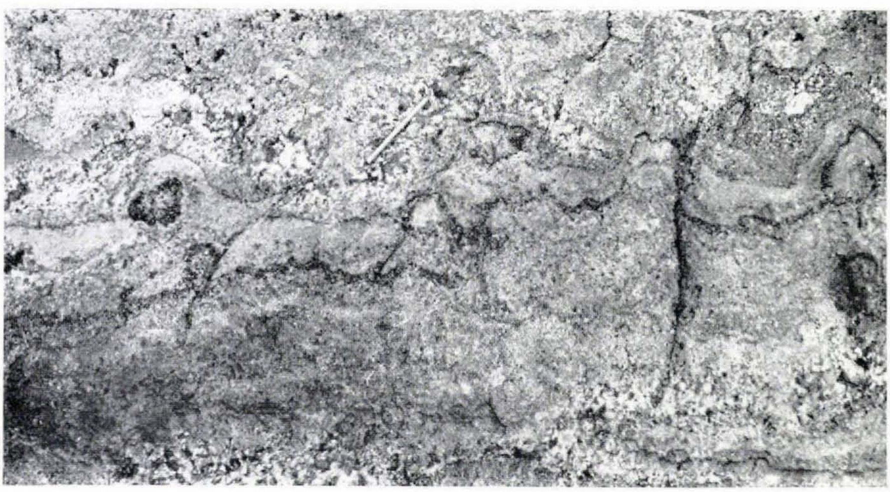
Detail of top surface of megacryst-rich layer. Note the convolutions in the garnetiferous layers as they dome over the top of megacrysts. The layer of coarse-grained, quartz-felspar intergrowth at the top of the photograph is slightly discordant to the garnetiferous layer just below. The plane of section is subhorizontal, the layering in the aplite dipping away from the observer at approximately 10°.



a



b



c

Plate 4

a

Top of one of the megacrysts seen in Plate 3c. Note the irregular form and the way in which the garnet-rich layers follow the upper surface of the megacryst. The coin is 1.8 cm in diameter.

b

Horizontal section of a megacryst at a lower level than the one illustrated in 4a. Note the concentration of garnet-rich aplite on the top and right hand edges of the crystal. The zonal distribution of the quartz intergrowth within the megacryst is parallel to the margins of the crystal. Towards the centre the intergrowth (marked by a line of garnet inclusions) is less regular and may represent the domed upper surface of the megacryst at an earlier stage of growth.

c

Preferential distribution of megacrysts with rectangular outlines on a horizontal surface (contrast Plate 3c). This is thought to be caused by the formation of megacrysts in distinct layers within the aplite; a horizontal section will therefore show megacrysts at approximately the same stage in development.

a

b

c

Plate 5

a

Upper part of a low-dipping aplite-pegmatite sheet on a small island to the south west of Kînâlik. Note that the aplite occurs as long, irregular masses within the coarse intergrowth of quartz and felspar. Internal structures within the aplite are continuous from one fragment to another, although separated by pegmatite.

b

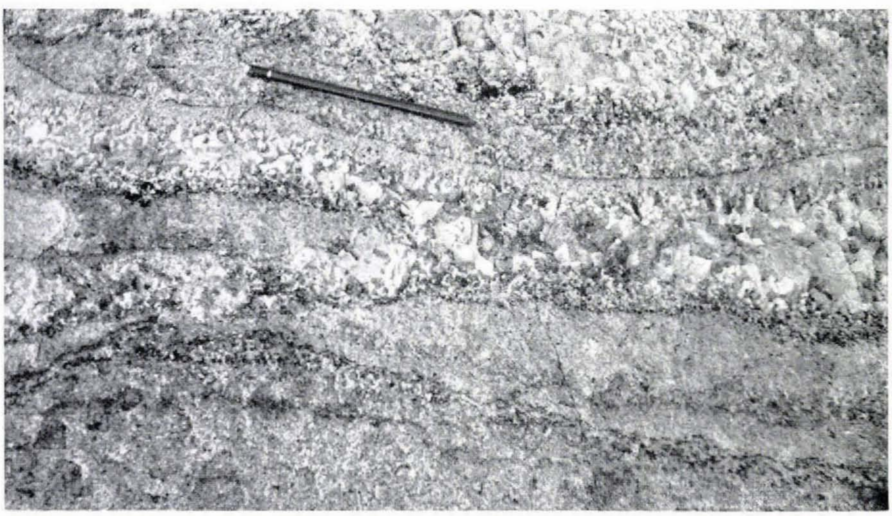
Perthite megacryst with a small inclusion of aplite (directly under the lower end of the pencil). Note the strong arching of the garnetiferous layers over the top of the megacryst and the relatively weak arch at the base. It is thought that in this example the megacryst projected ahead of the crystallising aplite. The indentation in the layer below the megacryst was probably caused by consolidation of the rock after the formation of the megacryst and the layers above.

c

Branching vein of pegmatite in a banded aplite. Note that the garnet-rich layer above the pegmatite vein is concordant while layering below is offset by the vein.

a

b



c

Plate 6

a

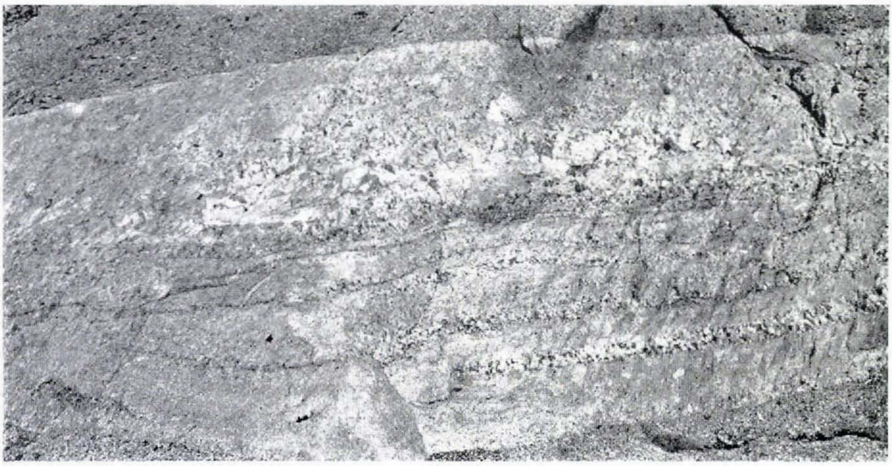
A 1 m wide sheet at Kînâlik with coarse-grained material concentrated in the upper half of the sheet. Note the thin, concordant, pegmatite layers in the aplitic lower half. Some of these thin pegmatites change along their strike into garnet layers in the aplite.

b

Horizontal section of a breccia of quartz-felspar intergrowth set in a matrix of pegmatite. The intergrowth fragments show faint internal structures which are discontinuous from fragment to fragment. This suggests that they were disrupted before the formation of the surrounding pegmatite.

c

Small pegmatite vein cutting and displacing garnet-layered aplite. Note that the pegmatite is surrounded by a thin layer of garnetiferous rock, which is also discordant to the general layering in the body.



a

b

c