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En omfattende geologisk rapport som dveler lite ved erts-mineraliseringer .

Ni innhold i bekkesedimenter er forklart som silikatnikkel knyttet til Fayalittinnholdet i Olivin.

Ksund

FOR FALCONBRIDGE NIKKELVERK A/S

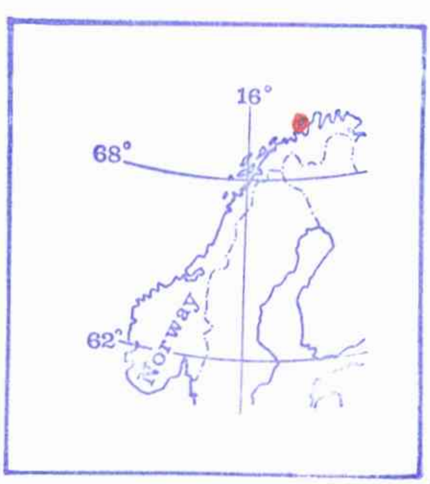
A/S SULFIDMALM

PROJECT 905-16

REPORT ON THE NORDRE BUMANDSFJORD ULTRAMAFIC INTRUSION - WITH A GENERAL BACKGROUND TO THE SEILAND GABBRO PROVINCE.

BY

PROFESSOR BRIAN A. STURT



A/S SULFIDMALM

INTER-OFFICE MEMORANDUM

Date: March 23rd, 1973

To: Falconbridge Nikkelverk A/S

cc: A. M. Clarke, H. T. Berry,
B. A. Sturt, H. A. Rosenqvist

From: J. B. Gammon

Subject:

905-16, Seiland Gabbro Province, Report No. 228/72/16.

Please find attached a report from Prof. Brian Sturt concerning the Seiland gabbro province of western Finnmark. The introductory remarks summarize the general geological features of this area in a very concise and useful fashion. A general review of known information with emphasis on basic and ultrabasic intrusive phases then follows. The report concludes with a detailed description of the Nordre Bumandsfjord ultramafic intrusion which was investigated by Sturt during the 1972 field season. No sulphide concentrations of economic significance have yet been encountered. Appended to the report are geological maps of SW and SE Seiland and of Sørøy.

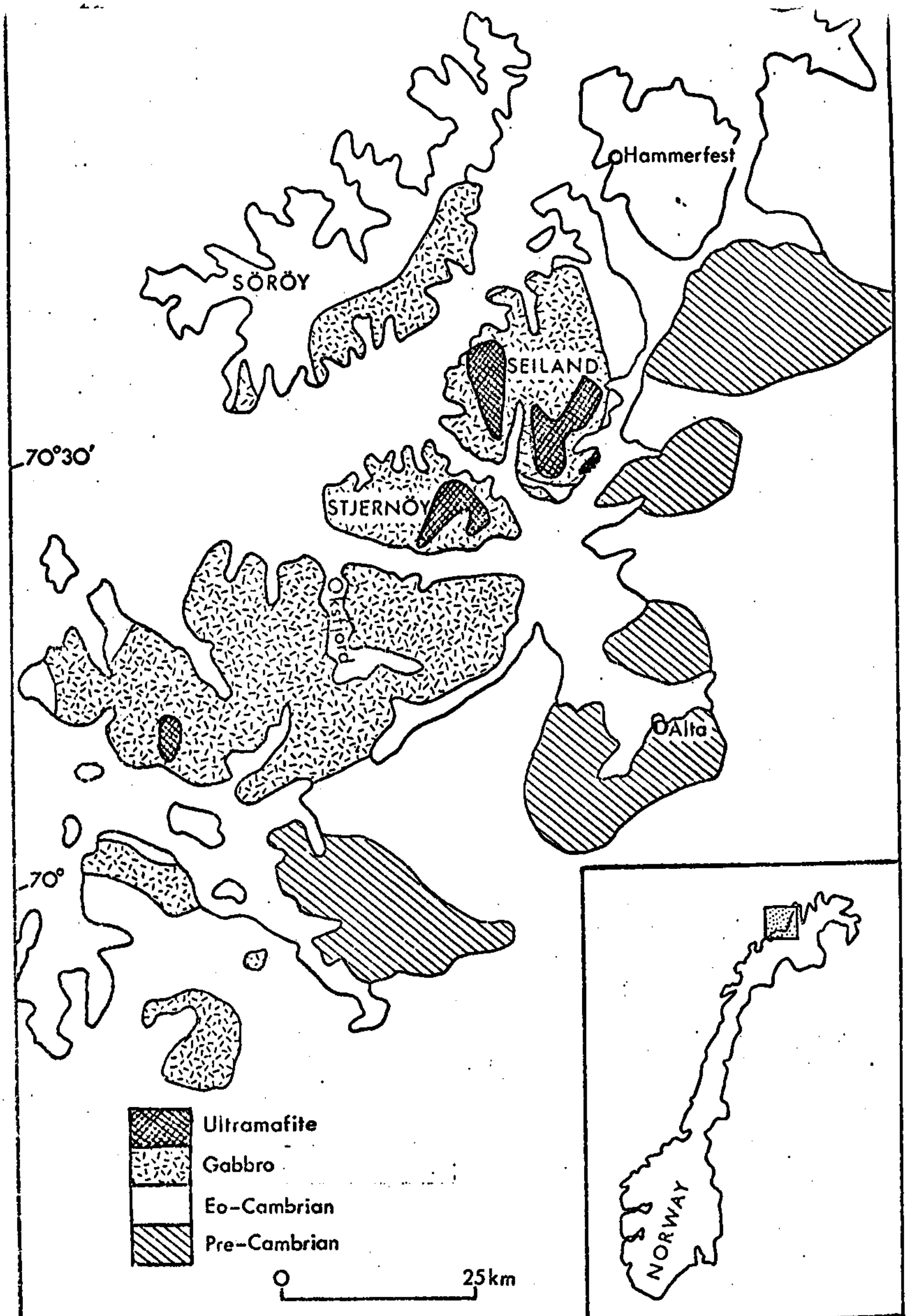


Fig. 1 General pattern of distribution for mafic and ultramafic rocks in the Seiland Province

I GENERAL BACKGROUND TO SEILAND GABBRO PROVINCE

1. Introduction to the general features.

The Seiland Gabbro Province occupies a region of approximately 4000 km^2 in the coastal region of West Finnmark and N. Troms, and includes the islands of Sørøy, Seiland, Stjernøy and the Øksfjord peninsular (Fig. 1). Although situated about 75 km west of the main Caledonian thrust front, the province borders on several tectonic windows in which the pre-Cambrian Rapais suite is exposed, situated beneath a thrust allocthonous Caledonian metasedimentary/metaigneous complex. The very low-grade sediments and green schists of these windows have a comparatively simple deformation pattern (Reitan 1963), and contrast markedly with the complexly deformed and metamorphosed rocks of the overlying thrust complex. It is indeed possible that the whole of the Seiland Gabbro Province is underlain by a fairly shallow thrust representing the westward extension of this major dislocation. This is certainly indicated by the regional geometry of the geological units, and from the regional gravity studies by Brooks (1970).

The Seiland Gabbro Province forms a distinctive petrologic unit within the Scandinavian mountain chain with respect to both the volume and variety of mafic and ultramafic rocks emplaced during the orogenic development of the region. The magmas from which the gabbroic rocks have crystallised range from quartz-normative tholeites to alkali basalt types, and seperated intrusions derived from such different magmas are to be found. In addition to the gabbroic rocks considerable volumes of ultramafic rocks have been emplaced ranging in composition from dunite, divene pyroxente, wherlite and Pheotzolite. The ultramafic rocks either form individual plutons or arefound as facies within layered gabbro plutons. The northern part of the Seiland province is also distinctive for the widespread occurrence of synorogenic alkaline rocks-nepheline-syenites, alkali-syenites, jaquparangites, and carbonatites.

One of the major features of the mafic/ultramafic rocks of this syn-orogenic suite is their commonly layered character, where features of rhythmic, gravitational and cryptic layering can be ascertained. This feature is one which gives considerable similarities to bodies emplaced into nonorogenic environments viz. Skaergaard, Bushveld, Stillwater, Muskox etc. which have been taken to represent standard models for such intrusions both in terms of petrologic development and of tectonic setting. There have been a considerable number of earlier accounts of these rocks e.g. Barth (1926-1953, 1961), Krauskopf (1954), Heier (1961) and Oosteroom (1954, 1955, 1963). To these authors the position of such rock-types in the central part of the caledonian orogene presented problems which they felt could not be explained on a standard petrologic model, and they arrived at the consensus opinion that the genesis of the mafic rocks involved the metamorphic/anatectic transformation of a series of interbedded lavas, tuffs and sediments under conditions of granulite facies regional metamorphism.

Since approximately 1960, however, the truly igneous nature of these rocks has been appreciated due to work in the northern part of the Province directed by the writer (Stumpfl & Sturt 1963 , Sturt and Ramsay 1965, Sturt 1970, Robins B. 1970, Speedyman 1967, Sturt 1971 a,b, Sturt and Taylor 1972, Robins 1972, Gardner 1972) and in the southern part of the province due to work directed by Prof. P. Hooper (Univ. of Oregon - formerly Univ. Coll. Swansea) - (Ball et al 1963, Hooper and Gronow 1970, Hooper 1971 a,b, Bennett 1971). The proof of the original igneous character of these rocks can be judged in two independent manners.

1. In relation to the form, petrology and internal features of the intrusions themselves.

2. Due to the recognition of well-developed contact metamorphic aureoles about the intrusive body. In this last respect the aureoles are not always perfectly preserved owing to the overprinting effects of ensuing deformation and metamorphism (See Sturt & Taylor 1972).

2. Tectono/Metamorphic setting of the Gabbro Province.

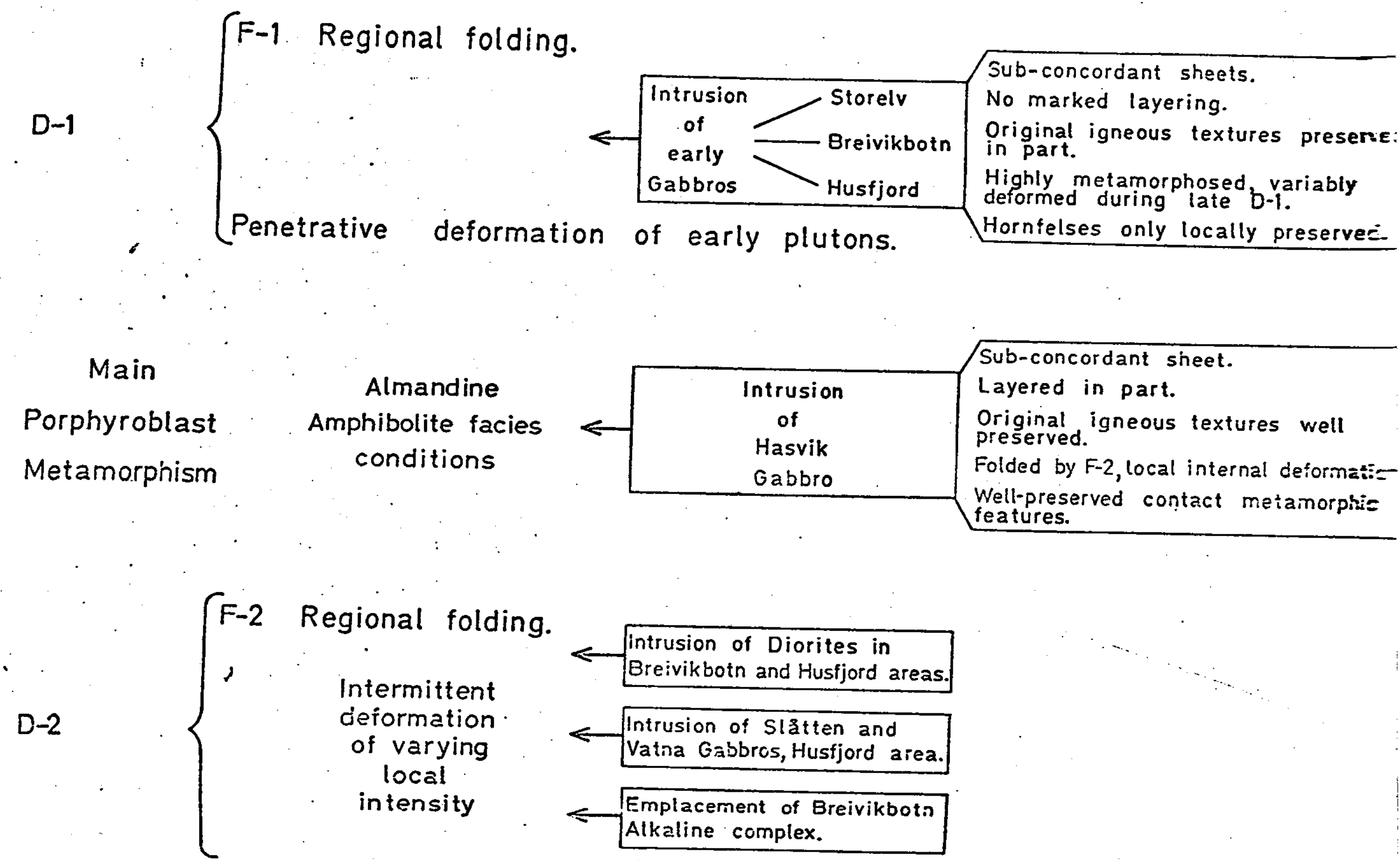
The envelope to the Gabbro Province comprises a thick sequence of Eo-Cambrian/Cambrian metasediments of dominantly shallow water type. The sequence comprises thick psammites, semi-pelites, pelites, limestones and calc-silicates. Several local successions have been established and can be correlated with what must now be regarded as a standard for the region on the island of Sørøy (Ramsay 1971, Roberts 1967, Sturt et al. 1967) of : -

	Stratigraphic Unit	Lithologic Type
Top	Hellefjord Schist Group	Metagreywacke/Pelite
	Åfjord Pelite Group	Graphitic Pelites
	Falkenes Marble Group	Marbles/Calc-silicate schists
	Storelv Schist Group	Semi-pelitic/pelitic schists
Base	Klubben Psammite Group	Psammites/pelitic schists

The age of the Falkenes Marble Group can be determined as lower Middle Cambrian on the basis of the finding of archaeocyathids (Holland and Sturt 1971), implying that the whole succession is Eo-Cambrian - Cambrian in age. An upper age limit can be assigned to the stratigraphic succession on the basis of both K/Ar and Rb/Sr radiometric age determinations on the metamorphic rocks (Sturt et al. 1967, Pringle and Sturt 1969, Pringle 1971, Pringle and Roberts 1972), showing thct the orogenic metamorphism occurred between 530 my and 496 my. This naturally implies that the mafic/ultramafic complex of the Seiland Gabbro Province is coeval with those of Aberdeenshire, and Connemara emplaced into the Dalradian metamorphic complex of Scotland and Ireland respectively.

The metasedimentary and metaigneous rocks of the Seiland Province are variably affected by the late Cambrian/early Ordovician metamorphism of the region.

Fig. 2 Sequence of pluton emplacement – Söröy.



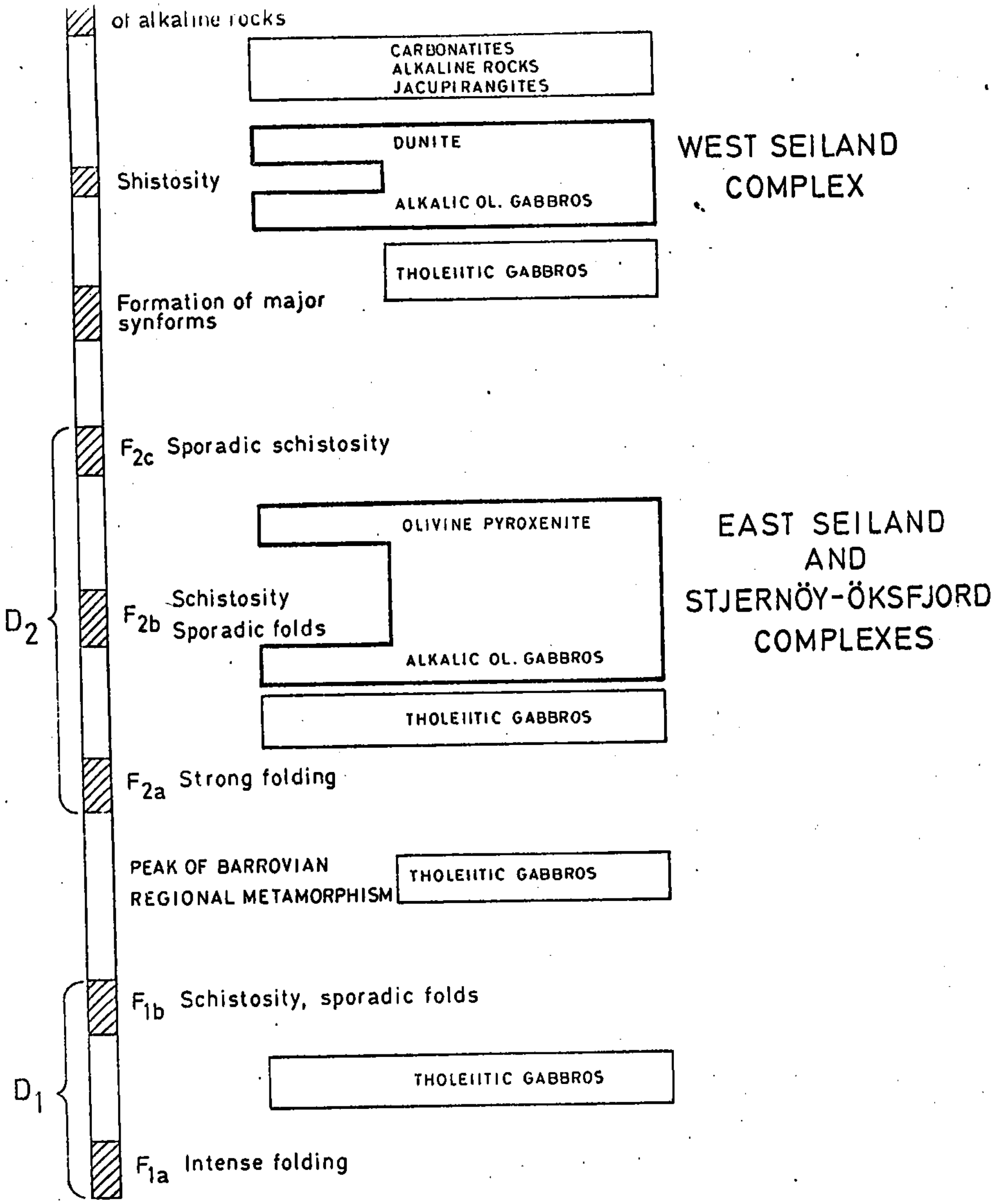


Fig. 3 Sequence of Mafic and Ultramafic rocks, on Seiland, Stjernøy and Øksfjord.

Generally there would appear to have been two major deformation stages broadly synchronous with the metamorphism during this orogenic period. These major deformation stages are responsible for the production of the regional fold patterns. Essentially the early deformation period D-1 has produced large scale fold structures varying from fairly modest overfolds to the widespread inversion of strata in giant recumbent folds as indicated by Pearson (1971) in the Kvaenanger region of N. Troms. The second major deformation stage (D-2) was responsible for the production of the more obvious macroscopic folds developed in the region and are generally of more simple tectonic style than those previous. The tectonic development of the region is however, much more complicated than the simplified statement presented above, each of the major deformation stages includes a complex of strains and are themselves polyphasal and progressive.

Studies of the regional metamorphism all indicate that the maximum conditions of metamorphism occurred between the two main deformational episodes and declined progressively during the second of these periods. The metamorphic grade shows some variation from the fringes to the central parts of the Seiland Province, though in the main conditions of high amphibolite facies were reached over the greater extent of the region. It is not proposed here to give more than this brief introductory statement to the tectono/metamorphic development of the metasedimentary envelope to the Gabbro Province as many well-documented accounts of the details are readily available.

When we turn to the igneous rocks of the province, and consider their relation to the tectono-metamorphic evolution of the orogene, certain features are immediatel apparent which show differences in the interpretation of mafic and ultramafic rocks in an orogenic environment to many interpretations which have been made in the Scandinavian Caledonides. It can be demonstrated that the mafic/ultramafic igneous activity in the region spans the entire orogenic development, that such rocks have been emplaced at successive intervals during the tectono/metamorphic evolution of the Province. (Figs. 6a & 6b.)

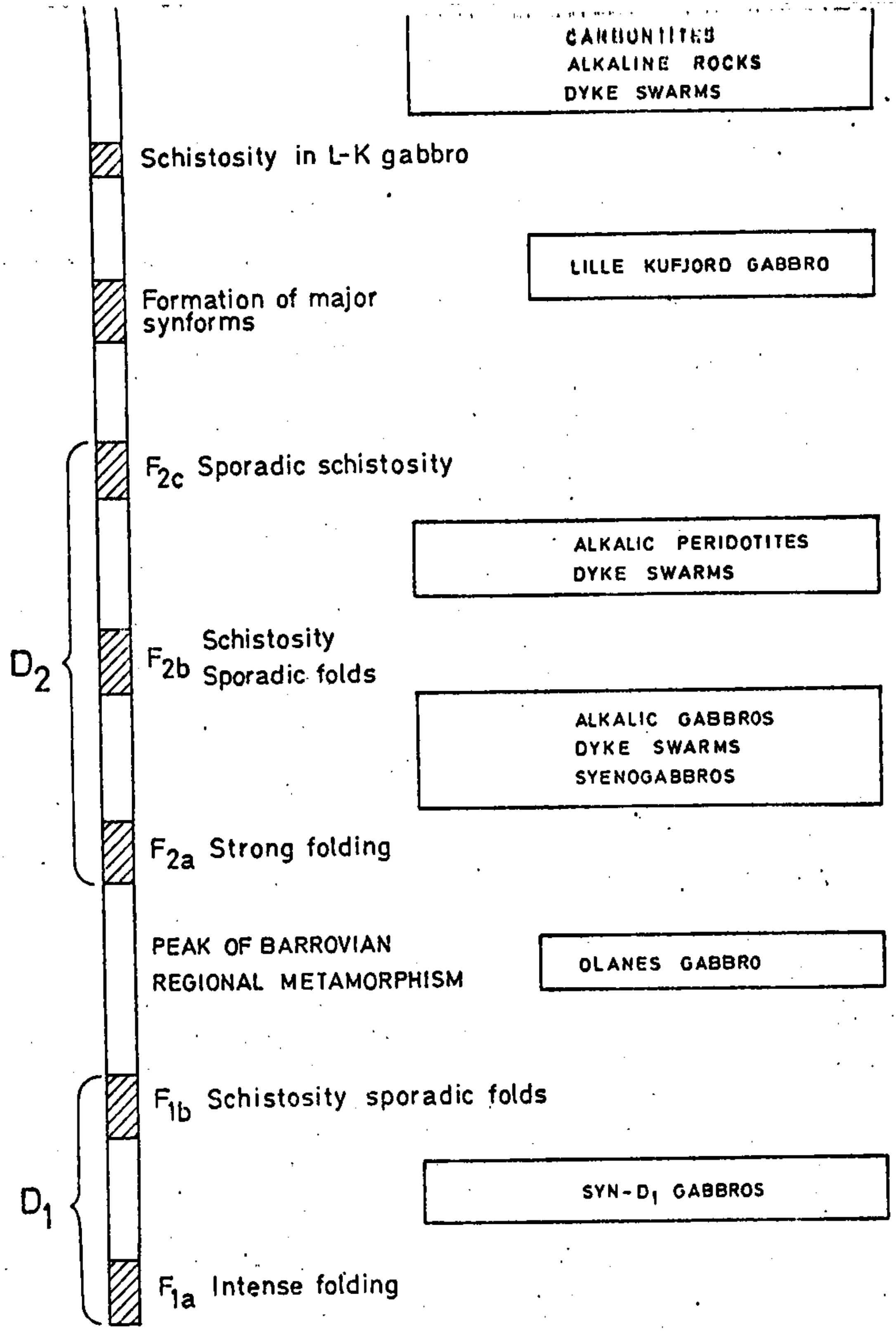


Fig. 5 **Sequence of igneous emplacement South Seiland.**

Figs. 2 & 3 show the sequences of mafic/ultramafic rock emplacement during the orogenic evolution of the province, and it can be readily appreciated that major mafic and ultramafic plutons were emplaced during D-1, in the interval between the major deformation episodes and during D-2. The igneous rocks of the region as a result display tremendous variation of metamorphic and defomational fabrics, and variably presesved primary igneous textures, fabric and mineralogy. Generally it is true to state that the later intrusions in this sequence preserve more faithfully the original igneous features than those earlier in the sequence. Of particular interest in this context is the intrusive sequence of S. Seiland worked out by Robins (1971). Here Robins demonstrates (Fig. 3&5) that major igneous plutons were emplaced successively during the orogenic development of the region. The maximum of igneous activity occurring during and perhaps overlapping the second major deformation (D-2). The remarkable feature of these southern Seiland plutons is that each was deformed with the development of foliation before the emplacement of the next pluton in the sequence.

Robins (1971) demonstrates that although primary textures are abundant in the later members of the intrusive sequence, metamorphic textures & mineralogies prevail in the early intrusives. Indeed all the intrusive rocks have undergone metamorphiem in amphibolite facies. This probably implies that the normal criteria governing the distribution of the sulphide phase in unmetamorphosed mafic and ultramafic rocks cannot be upheld, and that considerable migrations and redistribution of constituents have taken place.

2. General Petrology

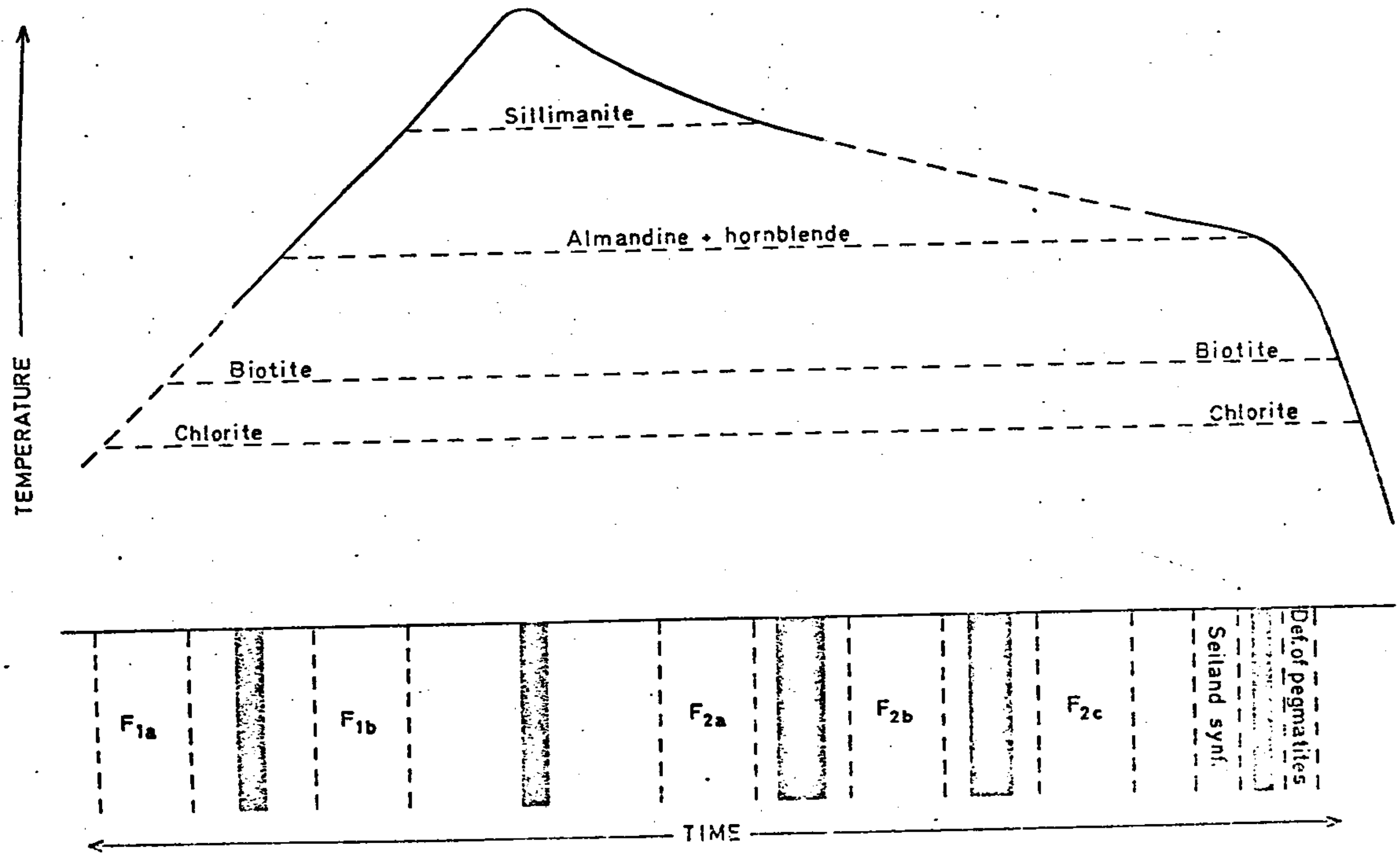
It is possible to view the mafic/ultramafic rocks of Seiland under 3 groups (see Fig. 5)ie.

Syn D-1

Interkinematic

Syn D-2

Fig. 6a Timing of metamorphism and igneous emplacement S. Seiland.



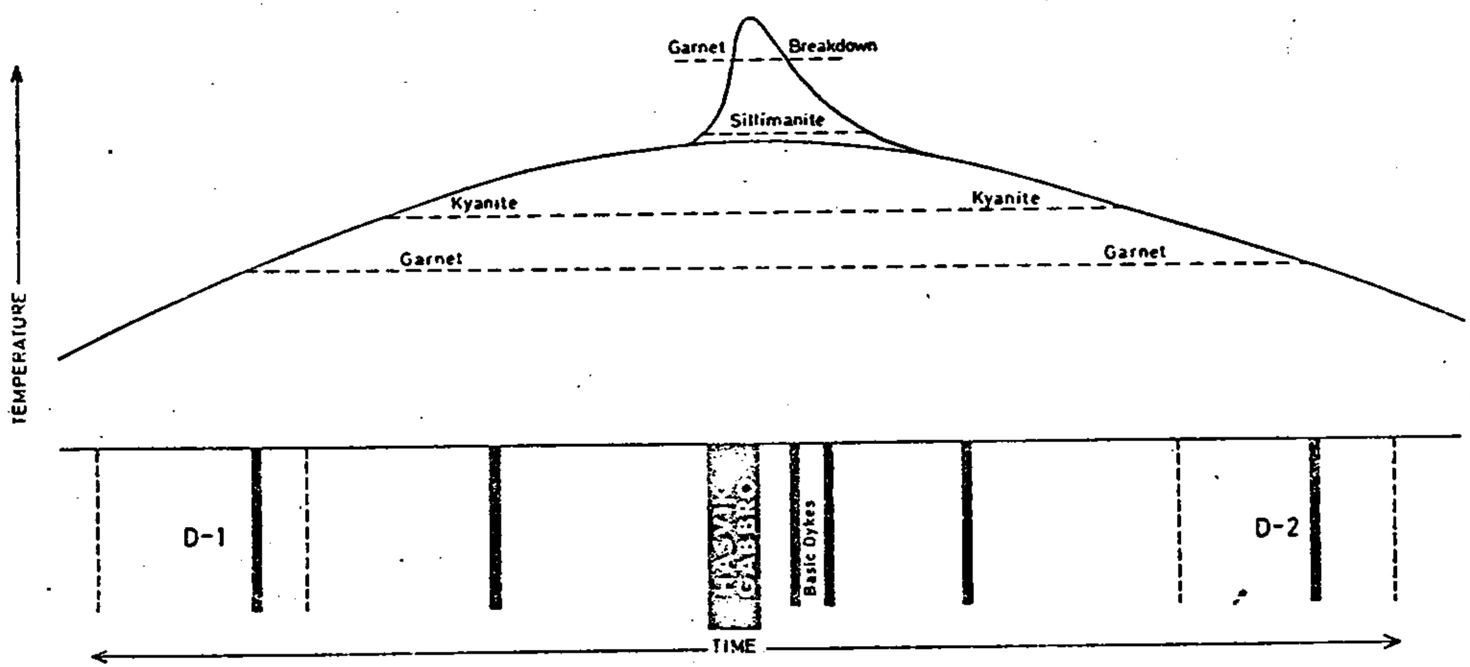


Fig. 6b Timing of metamorphism and igneous emplacement, Sørøy.

Syn D-1 Intrusives

It is possible to show as indicated in the introduction that the D - 1 phase of deformation in fact comprises a complex of strains, and is indeed polyphasal in type. This is particularly well evidenced in terms of the syn - D 1 intrusives, where the gabbros are seen to cut through major fold cores (Fig. 6), preserve minor fold structures as relicts within their aureoles and become themselves strongly deformed by strains which have similar orientation. Details of the analysis of such a situation is given in the appended paper by Sturt & Taylor 1972.

Robins (1971) has distinguished two principal phases of deformation under D 1 (i.e. F 1a - F 1b) and considers that an interkinematic interval existed during a series of intrusions of gabbroic and to a minor extent ultramafic magmas occurred. These gabbros occur as fringes around the main ultramafic centres of Seiland as relatively thin sill like bodies see (Fig. 7).

In general structural terms Robins (1971) shows that the mafic/ultramafic complex of E. Seiland is in a great synclinal structure, which he terms the Seiland Syncline. This is essentially a boat -shaped fold with a steep plunge at both southern and northern extremities. The core of this syncline is occupied by the extensive Melkvann peridotite which is shelled by gabbroic sheets of varying petrographic character and age relation. This Seiland Syncline is considered by Robins to be extremely late in the sequence of structural events, and to be intimately related to the evolution of the ultramafic/mafic complex in terms of its origin. The structure being of late D - 2 development.

1). Hønseby Gabbro

This represents the largest of the syn-F1 gabbro bodies on the island of Seiland. It occurs in the NW region of the mafic/ultramafic province and is at its maximum development south of Kårhamn, the gabbro stretches from the coast through Hønseby and eventually through to the N.E. coast of the island. The gabbro is tholeitic in character and contains both clino and ortho-pyroxene. According to Worthing (1970) few traces of igneous texture are preserved within the Hønseby Gabbro and much of the body is dominated by amphibolite facies metamorphic textures and mineral assemblages.

Typically the Hønseby gabbro is present as an amphibolite varying from foliated to non-foliate varieties. The more mafic members are often strongly garnetiferous. Occasional peridotite/tractolite lenses are found within the body forming boudinage masses. Jackson mapping the region south of Kårhamn finds extensive evidence of granulite facies metamorphism in the rocks of the Hønseby Gabbro due to the effects of the syn - D 2 alkali gabbro of N.W. Seiland, and the Bumandsfjord Pluton.

2). Hammeren Gabbro Complex of Eastern Seiland

This is a complex of sills and dykes of gabbroic which form a broadly concerdant lit-par-lit injection complex involving gabbro and psammitic metasediments which occurs in an extensive strike-parallel belt in eastern Seiland.

The rocks of this group are often strongly foliated with the development of metamorphic/tectonite fabrics. In some places however it is possible to find relict areas in which primary igneous textures and mineral assemblages have been retained. Here the gabbros can be seen to be "two-pyroxene" types with both bronzite -hypersthene in the orthopyroxenes and diopsidic augite as the clinopyroxene. Occasional examples of exsolution lamellae of orthopyroxene in clinopyroxene have been recorded by both Worthing (1970) and Robins(1971). The primary igneous plagioclase appears to be in the range An_{50-60}. The constant presence of orthopyroxene in the assemblage and the occasional examples of exsolved lamellae of o.p. in clinopyroxene indicate that they crystallised from a tholeitic magma. The gabbros frequently exhibit ophitic - sub-ophitic textures.

As indicated the syn-D - 1 gabbros have generally metamorfic textures and mineralogies being composed essentially of hornblende biotite and plagioclase. The latter mineral being more normally as shape orientated and highly deformed crystals or as a polygonal grain mozaic within lenticular areas which define a flaser texture with a composition An_{30-36} typical of amphibolite facies assemblages. The rock types varying from massive amphibolites to hornblende schists.

In S. Seiland , ultramafic dykes are associated with syn- D -1 gabbroic material in the Olderfjord area. They are all with metamorphic fabric and assemblage and consist of a cummingtonitic amphibole, moderately sepertinized olivene with accessory green spinel. These generally bear a late D - 1 foliation.

Interkinematic Gabbros (D1 - D2)

The only interkinematic (D1 - D2) gabbro recognized on Seiland is the Olanes Gabbro (Fig. 7). The following description is summarized from Robins (1971). The Olanes Gabbro is a sheet like body fairly thin on the east side of St. Kufjord (i.e. $<$ 500m) but rapidly increases in thickness west of the fjord to $>$1000m. This body is essentially a concordant body with its margins paralleling the pre-existing D-1 schistosites. The gabbro is highly contaminated and contains many rafts and lenses of metasedimentary material. To the west of Store Kufjord the body is layered and leuco-gabbro is the dominating rock type.

Mineralogically the Olanes gabbro is typically tholeiitic, with an abundance of hypersthene-ferrohypersthene over clino pyroxene. This tholeiitic trend is emphasised in the dioritic members where freequartz is present. Where original igneous textures are preserved they are commonly ophitic or sub-ophitic.

Again the predominating feature is the pervasive amphibolite facies recrystallisation of the rocks, partly during the strong deformation during D-2. One feature that deserves mention here is the way in which the Olanes Gabbro in contact with the subsequent Lille Kufjord mass is contact metamorphosed in granulite facies. This recrystallisation preduces an annealied mozaic of plagioclase and both clino-and orthopyroxene.

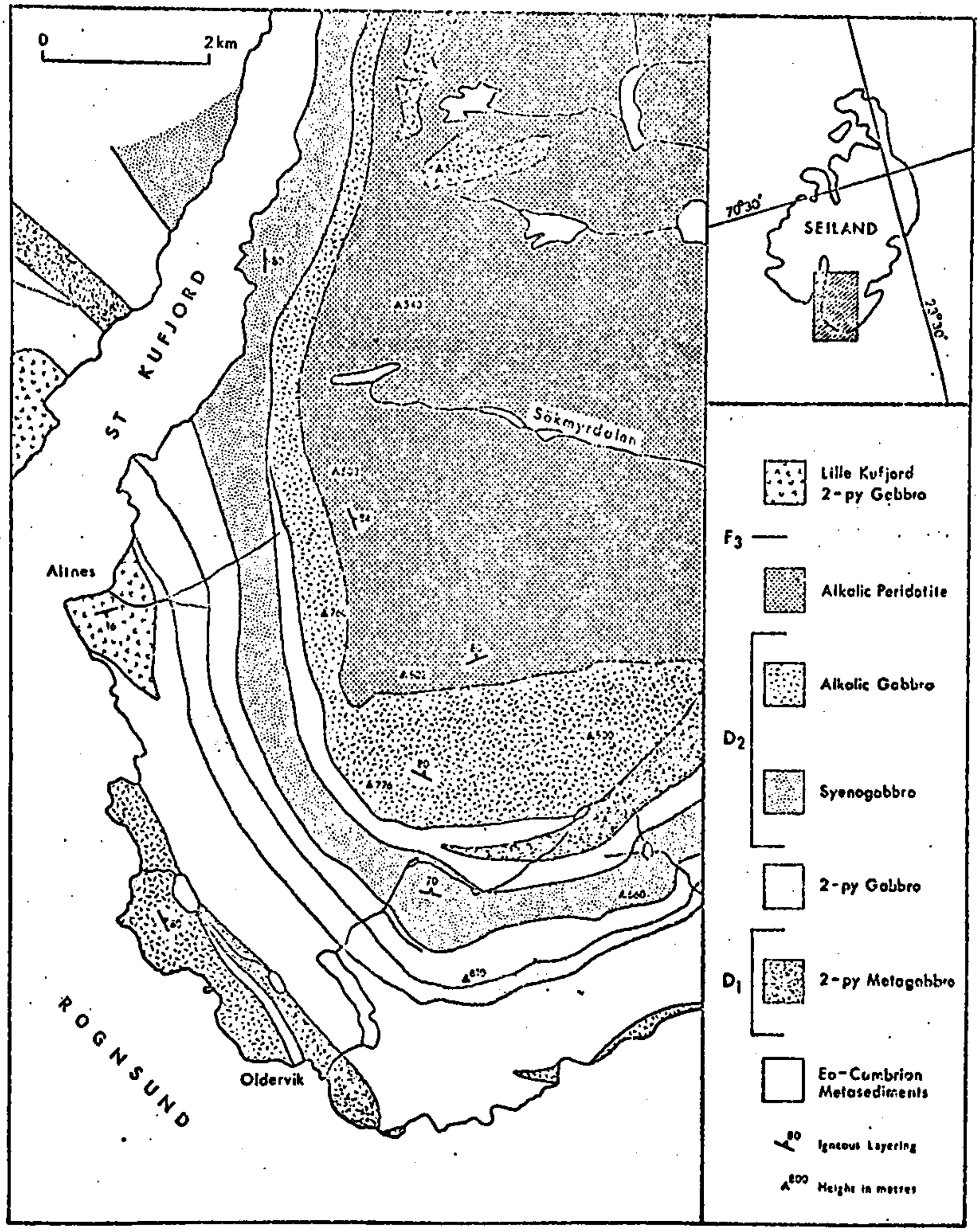


Figure 7

The distribution and age-relations of the Caledonian igneous rocks of southern Seiland, northern Norway.

The Syn-D2 Intrusives of Seiland

The rocks intruded during the protracted D-2 deformation period are extremely varied in their petrology and generally fall into five petrographic groups: -

(i) SYENOGABBROS

(ii) ALKALIC OLIVENE GABBROS

(iii) THOLEIITIC GABBROS

(iv) ULTRAMAFIC ROCKS

(v) ALKALINE ROCKS

It is proposed here to present a concise statement concerning each of these units and then to give a more detailed account of the Western Seiland Ultramafic Complex. (The Burnandsfjord Ultramafic), investigated in some detail during the summer of 1972.

(i) SYENOGABBROS

Gabbroic rocks associated with syenitic differentiates crop out over fairly extensive tracts of S. Seiland (Fig. 7). Two main bodies have been located on S. Seiland.

a) The most extensive body stretching from the head of Store Kufjord to Store Kjernevika.

b) A much less extensive body extending NW from between the head of Store Bekkarfjord and Olderfjord.

These gabbros are occasionally divene bearing, but the major volume is an olivene-free facies with rare layers of a perthositic rock-type. The contacts of the syeno-gabbros are commonly indistinct with the upper and lower boundaries showing a sheeted interlayering of psammitic or quartzitic metasediment with sills of fine-grained two-pyroxene gabbro. Such boundaries are highly suggestive of a permissive type of magma emplacement.

The syeno-gabbros are invariably more or less strongly deformed, though in many places the gross features of the primary structues remains clear. Generally the tectonic foliation is parallel or sub-parallel to the primary layering. At many localities the layering has been cross-cut by dense swarms of dykes and sheets which have been strongly deformed along with the host . Indeed this may have poceeded to such an advanced degree that it is now difficult, in many cases, to distinguish between primary igneous layerin and deformed sheets of intrusive mafic or ultramafic material.

In general terms there is a lower zone of olivene-free border facies, succeeded by a zone of layered olivene gabbro (often troctolitic) and thence to a thick upper zone which is olivene-free and containing occasional perthositic layers. The mineral assemblages within the olivene-bearing rocks do not include alkali feldspar, though this mineral is present as an accessory in most of the other varieties. In many of the rocks it is obvious that alkali feldspar forms part of the cumulate assemblage.

As the result of metamorphism much alteration of pyroxene to hornblende and biotite has occurred, also the feldspars frequently have been recrystallised to polygonal grain mozaics: in such cases the plagioclase has assumed a composition compatable with amphibolite facies conditions i.e. An_{28-35} as apposed to An_{45-65}.

The constant association of orthopyroxene with olivene and clinopyroxene in particular facies of the syenogabbros implies that the parental magma had tholeiitic affinities. The presence of olivene-bearing rocks, which must be considered cumulates, in the basal part of the succession at Svensenes, and the lack of any evidence of ever-saturated differentiates higher in the sequence, suggests that the parental magma was undersaturated to the extent of the presence of normative olivene. Thus it is considered thet the parent magma was an olivene tholeiite. The syeno-gabbros, show successions which resemble those within the Insch intrusion of Aberdeenshire (Wager & Brown 1968), and the Kiglapait intrusion of Labrador (Morse 1969). Both these bodies show, in contrast to normal tholeiitic intrusives, the development of saturated syenitic differentiates during the latest stages of crystallization.

(ii) THE ALKALIC OLIVENE GABBROS

Distinctly layered olivene gabbros form a number of small, but formerly much more extensive, bodies in S. Seiland. Internally, they exhibit a characteristic variety of typers of layereing and distinct often coarse-grained textures. The largest of these bodies is at or near the contact of syeno-gabbro and the Melkvann peridotite (Fig. 7), and numerous inclusions and large rafts of alkalic gabbro are now located in the peridotite body.

Although these alkalic gabbros are very distinctive in the field, their main distinguishing feature is in fact a mineralogical one, which is reflected in the chemistry of the rocks. The alkalic olivene gabbros contain only a single primary pyroxene - a salite rich in alumina and containing appreciable titanium. The pyroxene is distinctive in thin-section, its purplish colour and slight pleochroism being probably a function of TiO_2 content, and the aluminous nature is demonstrated by the extremely common occurenc of exsolution lamellae of green spinel. Exsolution of orthopyroxene has not been observed. The undersaturated nature of the pyroxene is reflected in normative assemblages by the constant presence of nepheline.

The chemistry and mineralogy of the alkalic olivene gabbros is such that they must be considered as the crystallisation products of an alkali olivene basalt magma. It would also appear that the major layered gabbro described by Oosteroom (1963) from E. Stjernøy is of the same type as the smaller alkalic gabbro bodies of S. Seiland. This body which extends onto northern Øksfjord Krauskopf (1954) reaches a thickness of the order of 7 km. Naturally this gives a certain uniqueness to the province as major layered intensions stemming from alkal-basalt magmas are scaresly recorded in the literature.

The gabbros of this group are often distinctly layered bodies and is mainly of the following types: -

a) An accretionary layering including harrisitic layering. This type is most strongly developed in the border facies.

b) Cumulus layering.

c) The dominant layering which consits of rather irregular layers which are individually distinct from adjacent layers e.g. compositions such as leucocratic olivene gabbro, periodotite and mafic olivene gabbro which have sharp, though irregular contacts with each other.

Of particular interest in the alkalic gabbros are the pegmatitic zones in which spectacular crescumulate developments are to be found (Robins 1972).

Petrographically the alkalic gabbros show a range in composition from ultramafic to leuco-gabbro layers. The mineralogy is fairly simple consisting of a primary igneous assemblage of clinopyroxene, plagioclase (An_{62-85}), olivene and accessory spinel, oxides and sulfides. Secondary metamorphic effects are seen in relation to the solid-state plagioclase + olivene reaction to produce symplectic growths of mainly orthopyroxene and spinel. Indeed the only occurrence of orthopyroxene in these rocks is as a result of this reaction. Hornblende and biotite occur extensively but are always metamorphic products. According to Robins there are fairly frequent concentrations of magnetic oxide minerals in the alkalic gabbros, and he considers that these are the probable cause of the steep magnetic anomalies shown on the N.G.U. map.

The main geochemical feature of these alkalic gabbros is their deficiency in silica, reflected by the constant presence of olivene and nepheline in the normative assemblages. Late stage differentiates associated with these alkalic gabbros have not been distinguished yet, but in view of the undersaturated nature of the gabbroic rocks they might be supposed to be feldspathoidal types which may be represented in the province by the numerous nepheline syenites and litchfieldites.

(iv) ULTRAMAFIC ROCKS

Peridotitic rocks form two major bodies in Seiland.

a) The Melkvann peridotite in S. Seiland

b) The Bumandsfjord Pluton in W. Seiland and as a number of minor bodies in the region. The Bumandsfjord pluton will be discussed seperately at the end of this general account.

The Melkvann Peridotite crops out over a large area in the central regions of the island, forming a generally low-lying tract. The northern border of the peridotite is generally located at the base of the mountains which form a ring around most of Seilandsjøkel. The structurally lower part of peridotite, reinforced by large xenoliths of alkalic olivene gabbro, forms the high plateau of Tverfjell. Almost the entire area of the Melkvann body is, according to Robins, occupied by various types of peridotitic rocks with olivene gabbros and metagabbros only occurring in marginal zones contaminated by the host gabbros or in the vicinity of enclosed gabbro xenoliths: Robins finds that the clino pyroxenes of both the peridotites of E. Seiland and the alkalic gabbro are similar in composition, which inducates to him that they are thus both alkalic in character.

According to Robins there is definite evidence of rhythmic layering within the Melkvann body. The orientation of this layering indicates that the peridotite was emplaced as a sub-horizontal sheet and subsequently rotated into its present position during the growth of the Seiland Synform. Since it occupies the core-zone of the synform, the Melkvann peridotite has a general lopolith-like form, although this shape is a secondary expression of the tectonic pattern. Peridotites mainly olivene pyroxenites occupy the whole thickness of the Melkvann which is up to 3 km in thickness.

The Melkvann intrusion has the variable development of a tilaiitic border facies near the contacts with the alkalic gabbros. The presence or absence of this border facies is directly related to the availibility of alkalic gabbro material and Robins postulates that the feldspar content of the rocks of this facies "was derived by both mechanical and chemical incorporation into the peridotite magma from the alkalic gabbro wall rocks or xenoliths". Although having an overall tilaiitic composition, the border facies is occasionally layered and involves a variety of rock types ranging in composition from peridotites to rare leucogabbros. Even at such outcrops, however, mafic divene gabbros (Tilaiites) are dominant. Much of the layering appears to be due to variations in the amount of interstitial plagioclase. Such layering has been termed matrix layering (Dunham 1965) to distinguish it from the layering produced by variations in the relative proportions of the cumulus phases. Robins considers that laterally inconstant layers of leucogabbro represent rocks in which the plagioclase can be considered to be of cumulus origin. The author has however observed similar border zones to other ultramafic bodies in the region and considers the layering here to represent a flow/fluxion structure which results in the parallel streaking of xenoliths etc. If not perfectly exposed this could well be mistaken for primary igneous crystallization layering.

The internal facies of the Melkvann body is according to Robins description composed of relatively homogeneous rock types: olivene pyroxenites being dominant and forming large tracts, though dunites, wehrlites, cortlandites and rare olivene gabbros are represented. Thereis little evidence of primary igneous layering except in the smaller Happofjell peridotite, on the north side of Store Kjernvik, where olivene-pyroxenite adcumulates are developed. Rhythmic layering is also sporadically present on Tverfjell, where units comprising dunite or wherlite and olivene pyroxenite show both normal and reverse grading. Much of the layering marked within the Melkvann peridotite on the reconnaisance map of Seiland by Barth (1953) in fact proves to be a secondary structure produced by swarms of gabbroic and ultramafic dykes.

According to Robins the rocks of the internal facies have, in some places, been transformed during later episodes of metasomatism. This is apparently well marked in the area around Steinfjellvann and that forming the Søkmyr valley. In the former area (Steinfjellvand) the olivene pyroxenites are cross-cut and netveined by dunitic rocks which show graduational contacts with the hosts - this metasomatism is attributed to a silica deficient relatively anhydrous fluid. In the Søkmyr valley, on the other hand, the olivene pyroxenites are densely dissected by replacive hornblende-rich veins and veinlets. These are regarded as ultramafic fenites developed from peridotitic paleozome, around intrusive jacupirangite dykes.

The internal facies of the Melkvann peridotite has also been intruded by dykes, locally forming dense swarms, involving rock types similar to the olivene pyroxenite host, olivene gabbros, hornblende gabbros, nepheline syenites, carbonatites and very rarely granitic pegmatites. The dykes occupy dominantly the east-west master-joints whith post-date the deformation of the body during the formation of the Seiland Synform.

Petrography and Chemistry of the Melkvann Body.

On the basis of their mineralogies Robins finds it difficult to seperate the rocks of the Melkvann (and Happofjell) ultramafics from the alkalic olivene gabbros. The main points are as follows: -

(1) Both contain clinopyroxenes that are optically identical and show the same excolved phases.

(2) In neither case is primary orthopyroxene crystallized from the melt or exsolved from the clinopyroxene phase.

(3) The plagioclase compositions are similar.

The textures of some of the peridotites show a variety of cumulate features and it would appear that these rocks are typically adcumulates and heterodcumulates. The textures of most of the peridotites are not distinctive, the exact relationships between olivene and pyroxene in the olivene pyroxenite commonly being obscure. Hornblende and less commonly biotite form distincty poikiloblastic crystals enclosing many olivene crystals, and are due to metamorphic replacement of the primary clinopyroxene. Occasionally plagioclase is poikilitic being the result of adcumulus growth. The feldspar in the olivene pyroxenites is however usually interstitial.

In some instances spinel-free coronas are developed at olivene/plagioclase grain boundaries involving the formation of clinopyroxene. Robins interprets this as suggesting an olivene-melt reaction producing clinopyroxene instead of the orthopyroxene typical of such a reaction in tholeitic magmas. If this is correct it is importance in indicating the trend of differentiation of the peridotite magma. It would be expected that the possbile differentiates would be an olivene-poor or feldspathic pyroxenite possbily with concentrations of apatite and ore minerals. Such rocks have not been detected in the ultramafic bodies, but may be represented in the province by the small bodies of jacupirangites.

The chemistry of the peridotites indicates that they should be considered as alkalic in type, being strongly undersaturated. This latter being reflected in the presence of nepheline and even leucite and larnite in the normative assemblage. These two minerals only appear in the normative assemblages of the olivene-pyroxenites reflecting the undersaturated character of the modal clinopyroxene.

Robins concludes that the ultramafic rocks, crystallised from an ultramafic magma with a composition represented by about 55-65% clinopyroxene + 30-25% olivene with the balance as hornblende, plagioclase, spinel and ores. The border facies being produced by the contamination of this magma by alkalic gabbro material derived from the wall rocks. The olivene-pyroxenite magma was also at a sufficiently high temperature to produce the partial fusion, and in some cases complete fusions of xenolithic gabbroic material. The ultimate origin of the olivene pyroxenite appears to represent the progressive fusion of a zone within the peridotite mantle, with the extraction of melts in the order alkali basalt $\rightarrow$ olivene pyroxenite $\rightarrow$ wehrlititic dunite.

Post D-2 Intrusives

Lille Kufjord Gabbro

A good general discription of the Lille Kufjord Gabbro is given in Oosteroom' (1955) account which is readily available. In the brief additional statement on this body by Robins (1971) a few additional points of interest can be noted: -

(1) The internal facies falls into 2 distinct types

a) The north-western strongly layered type.

b) The south- eastern weakly layered type.

The boundary of the two types roughly coinciding with the eastern face of Kufjordtind.

(2) According to Oosteroom the layering of type a) has two components:

(i) a small scale layering involving layers of diverse composition - superimposed on

(ii) Repetitive megalayering comprising units up to 150 m thick

The latter are apparently zoned from dominantly peridotitic compositions showing sharp contact against the rocks beneath to leucooratic gabbro at the top. At least 4 such zones are present in the Lille Kufjord section.

(3) The S.E. layered facies has many features reminiscent of the interior of the Skaergaard intrusion.

(4) There is variably a distinct border facies with accretionary layering.

(5) On the basis of his observations Robins concludes that the Lille Kufjord intrusion was emplaced in two stages: -

a) The intrusion of the N.W. facies as a sub-horizontal sill, with the megaunits representing successive magmatic injections. This was followed by rotation and tilting and

b) Injection of a further body of magma to produce the S.E. Facies, followed by further tilting.

(v) THE ALKALINE ROCKS

It is not proposed to describe these rocks here. General accounts are found in Heier (1961), Oosteroom (1963), Sturt and Ramsay (1965), Ramsay and Sturt (1970) and Robins (1972).

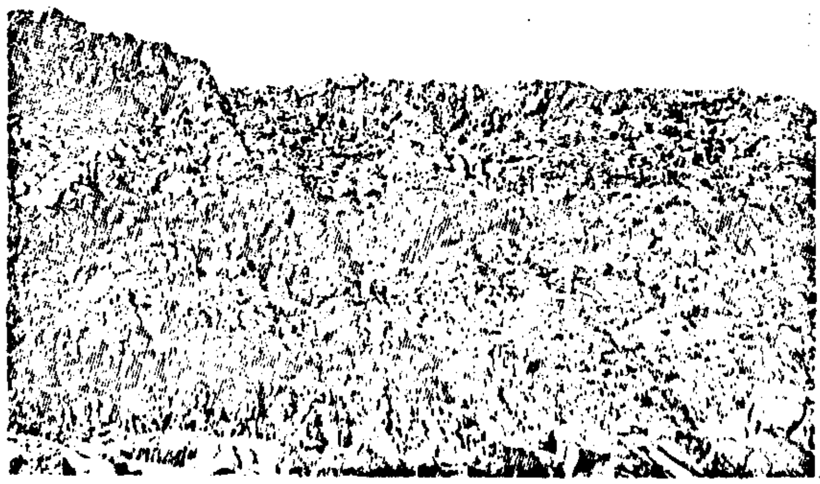


Photo 1 Northern Contact of Bumandsfjord Ultramafic with layered gabbro. Note detached rafts of gabbro in ultramafic.

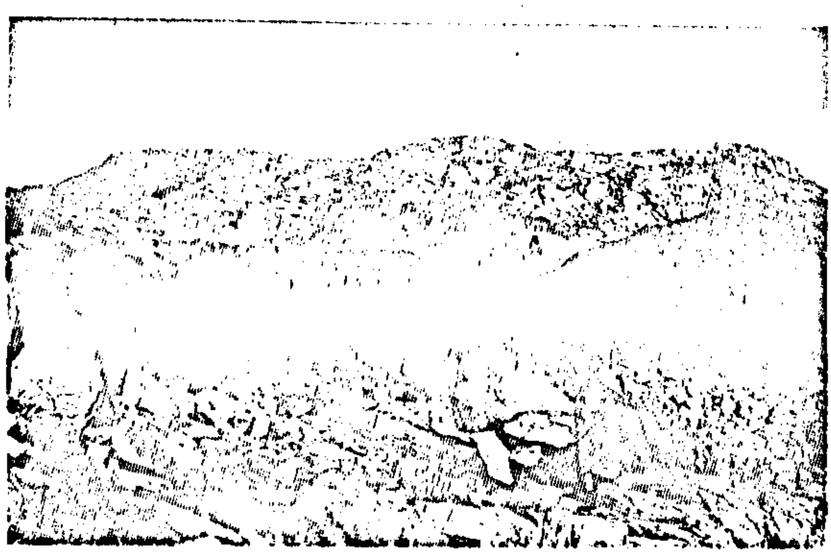


Photo 2 Dykes and sheets of ultramafic intruding marginal metagabbro.

Photo 3 Dyke of ultramafic intruding wallrock gabbro.

THE BUMANNSFJORD ULTRAMAFIC PLUTON

The general form of the Bumandsfjord pluton is shown on the map (Fig.). It is seen to have a rounded plan with a tapering southern extremity which passes into an intricate dyke and sheet complex in the region of Ubivann. The mapping this summer has established the details of the northern and western contacts and the southern extremity was mapped during the summer of 1969. The boundary of the eastern contact of the pluton has not been mapped in detail but has been put in approximately by binoculars from the highest point of W. Seiland and by indications from the air photographs.

The ultramafic body is seen everywhere at its contacts to be an intrusive body. This is particularly well marked from the northern boundary region where the ultramafic is emplaced into a layered gabbro body, with well-marked layering which has a comparatively low angle of dip. Here the transgressive intrusive nature of the ultramafic body can be studied both in terms of the large and small scale phenomena. In the former case large detached pendants and rafts of the country rock have founded into the ultramafic (Photo 1) and substantial sheets and dykes of the ultramafic transgress into the roof and wall-rock (Photo 2, 3). Along the northern contact it is quite clear that the margin of the ultramafic body has a fairly steep northerly dip i.e. between 45-70° as opposed to the wall-rock gabbros which have a moderate southerly dip. The dip of the contact is variable as can be particularly well seen to the east of Søndre Bumandsfjord where the contact varies from near vertical to near horizontal (See map) and it can be seen that a pronounced swarm of dykes and sheets of ultramafic material is concentrated in the roof and sidewall above convex bulges in the contact. On the large scale the body thus shows many of the features of a stock-like mass which has been forcibly emplaced into its surroundings. At the southern extremity of the body where it tapers off into a complex tail, there is virtually a transition from ultramafic with many inclusions of country rock with many dykes and sheets of ultramafic material.

There are three major field distinctions that can be made in relation to the Bumandsfjord pluton: -

Photo 4 Dunitic ultramafic with xenoliths of layered gabbro. Note way in which xenoliths break-up.

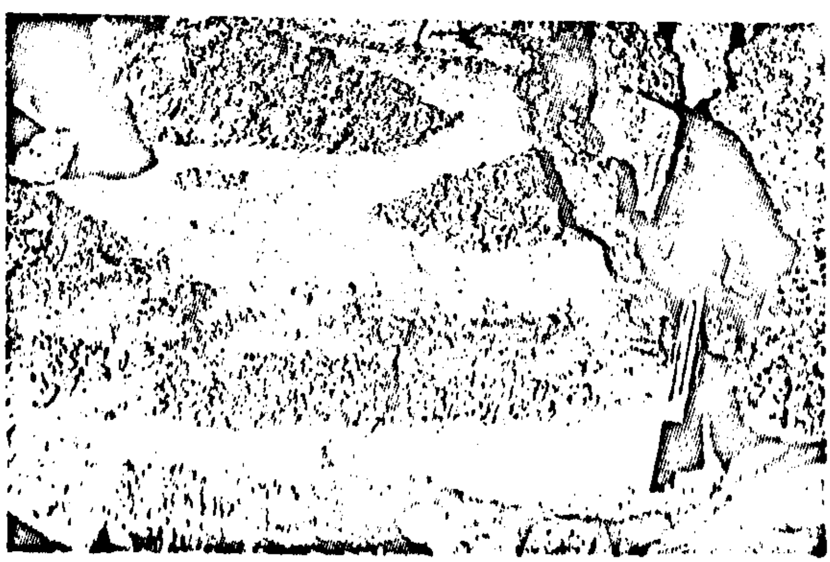


Photo 5 Close-up of same locality as (4).

(1) Border Zone Facies, this is found along the western, northern and eastern boundaries and is a zone replete in xenoliths where considerable contamination of the ultramafic has taken place.

(2) Interior Facies, this occupies the interior of the body and represents a zone where considerable melting of xenolithic gabbroic material has taken place.

(3) The Southern Facies, here the pluton tails off into a major dyke and sheet complex.

Before discussing the different facies of the pluton in detail it is necessary to make a brief statement regarding the general petrologic nature of the ultramafic. The primary magmatic crystallisation product of the intrusion show a certain variablity from dunite through olivenite to olivene pyroxenite. These various types do not appear to have any particularly marked pattern of areal distribution and at the level of exposure the intrusion does not appear to be layered. Although this brief statement would seem to indicate an inherent simplicity in the composition of rocks in the pluton, in detail the pattern is much more complex. The simplicity of mineral assemblage only applying to the primary crystallisation products from the ultramafic magma.

It may here be stated that the Bumandsfjord intrusion is superbly exposed and the various aspects of field relations can be studied in very great detail from sea-level to heights of over 1000 m . This enable both a good three-dimensional appreciation of the form of the body to be made and of the details of relationships within and without the pluton.

(1) BORDER ZONE FACIES

The border zone of the intrusion is replete with xenoliths of varying size of country rock gabbro and develops facies showing consederable amounts of contamination by this xenolithic material. The contamination in the northern region is generally by material derived from the neighbouring alkalic gabbro (Photos 4, 5, 6, 7, 8 , 9).

i.e. a contamination producing a facies of feldspathic peridotite relatively rich in clino-pyroxene.

Before engaging in a general discussion of the problems of this Border Zone, the best general impression can perhaps be gained from a number of abstracts of actual field descriptions from the writers notebook: -

3)[X] The ultramafic here is very dunitic. However, there are swirling zones rich in feldspar, sometimes also with a fair amount of pyroxene. These zones are in some instances connected, though in many others they form distinct but isolated patches. In the latter instance well recongnisable xenoliths of gabbro are to be observed showing marked fritting indicating that the feldspar and pyroxene of the surrounding patch is in fact of xenocrystic nature and produced by the physical break-up of xenoliths.

7) This is an exceptional locality for observing the break-up of xenoliths into an essentially dunitic host. The ultramafic here contains gabbro xenoliths of fairly varied composition and it can be seen that the areas rich in leucogabbro xenoliths, these break-up ultimately into dominantly feldspar xenocrysts which produced a plagioclase-peridotite local facies. Melanocratic gabbro and pyroxenite xenoliths on the other hand break-up to give a pyroxene-rich contamination of the ultramafic producing plagioclase-pyroxene peridotites and olivene-pyroxenite.

X Numbers refer to field locality numbers shown on map.

20. Have mapped in a flat lens-shaped raft of layered gabbro some 200m x 30m, in which the banding dips approximately 20°E - strike 142°. The gabbro is very well-layered and is cut by dykes and sheets of dunitic ultramafic. These sheets and dykes vary from being "clean" to being packed with clinker-like xenoliths. The xenoliths vary from small rounded xenoliths 1-2 cm in diameter to individual xenocrysts of plagioclase and pyroxene, and larger thin slabs of wall-rock in the process of breaking up into such little xenoliths and xenocrysts. Many of the sheets that penetrate the layered gabbro are "clean" except at their margins where feldspar and pyroxene xenocrysts have been fritted from the wall-rock into the dunite.

The eastern margin of the raft is quite a sensation, here it has been penetrated, prised and broken-up by what is essentially a "clean" dunite. Within this dunite, however, one can trace all stages of xenolith break-up into small xenoliths and xenocrysts. Entire blocks of gabbro of varying composition and texture, of which the margins can still be traced, have obviously yielded at grain-boundaries and at boundaries between a number of grains (multi-grain boundaries). The spaces thus produced have been filled with a dunitic matrix. That this did not occur in an entirely static environment is shown by the way in which such small xenoliths and xenocrysts have been streamed in the dunite magma giving rise to a marked fluxion structure.

Walking around this group of outcrops gives an indication of how virtually every petrographic variant of the ultramafic, in the border zone, in the entire Bumandsfjord region could have been produced by a mechanism of assimilative contamination of an essentially dunitic melt by the enclosed gabbro fragments.

These three quotations from the writers field notebook give a considerable impression of many of the general features of this contact border facies. The ultramafic showing considerable variation owing to the variable degree of assimilation and contamination. The particular facies developed depending upon the relative abundance of the various gabbro compositions held as inclusions and rafts. In the majority of exposures it is possible to find evidence confirmatory of an assimilation/contamination origin for the feldspathic and feldspar-pyroxene rich facies of the ultramafic. However, there are some exposures in which the degree of assimilation and contamination is so complete, that the origin of the rock-type connot be adduced from the individual outcrop. In the country-rock away from the northern margin many dykes and sheets of the feldspathic peridotite facies are to be observed cutting the layered gabbros. These it is considered represent a mobile portion of the marginal contamination facies, and frequently such dykes contain many small xenoliths and obvious xenocrysts bearing similar relations to those described from localities 3, 7 and 20. J.B. Jackson mapping north of the northern margin of the Bumandsfjord Ultramafic, has established the existence of similar dykes and sheets of feldspathic peridotites up to 3 km north of the main body, he also has mapped a series of small plugs which have diatreme form, with steep sided margins and which are crammed with variably orientated xenoliths. The matrix of these small bodies is dunitic . The observations of Jackson would appear to confirm the writers observation that this northerly contact has a moderate northward dip, and extends for a considerable distance beneath the surface.

A part from the fluxion banding mentioned earlier, the border facies possesses no layered structure. This fluxion banding is developed sporadically, in some places well-developed as in the contact zone between Nordre and Søndre Bumandsfjord and in others poorly developed or absent. An interesting observation of this structure was made at loc. 24, at the contact of the ultramafic with the sidewall gabbro. Here the ultramafic was found to have a pronounced fluxion banding where the contact is concordant to subconcordant, and that this banding is absent where the contact is sharply transgressive.

As can be expected from the previous descriptions the petrography of the ultramafic is this border facies shows considerable variation from virtually pure dunites to olivenites and olivene pyroxenites which represent original magmatic crystallisation products or at the most, in the latter case, slightly contaminated varieties. As the degree of assimilation increases,feldspathic peridotites and feldspar bearing olivene pyroxenites are produced which show a considerable range in the respective proportions of the essential minerals present i.e. olivene, clinopyroxene, orthopyroxene, plagiocalse, amphibole, spinel, oxides and sulphides. The primary pyroxene in these rocks is dominantly a clinopyroxene though orthopyroxene is also present as a primary igneous phase.

The plagioclase, however, has not been in equilibrium with its surround and spectacular synanatectic coronas are developed between plagioclase and olivene and less commonly between plagioclase and clinopyroxene. The plagioclase composition is usually in the range An_{60-72}, which corresponds to that of the surrounding gabbroic rocks. It is difficult to be totally categoric as to whether or not plagioclase is ever present as a primary magmatic phase within the intrusion. There is much dunite and olivenite where plagioclase is entirely absent, and where plagioclase is present a xenocrystic origin can very often be proved.

The plagioclase + olivene corona reaction is one that produces essentially orthopyroxene and spinel . The gross form of the corona is of a zone of orthopyroxene seperating the olivene from the plagioclase; occasionally the orthopyroxene is accompanied by clinopyroxene and infrequently this zone is entirely of clinopyroxene. In such coronas spectacular vermicular growths between pyroxene and green spinel and plagioclase and green spinel are characteristically developed. The texture being strongly reminiscent of myrmekite. Infrequently vermicules of clinopyroxene accompaning spinel in plagioclase/spinel symplectites. In some instances this fabric has been partially to completely recrystallised with a polygonal mozaic structure formed where the spinel is present as discrete grains. It is considered that these corona structures have been formed during the cooling of the ultramafic and represent essentially sub-solidus reactions. The absence of garnet in the corona assemblage implies that the pressures of metamorphism where moderate in the region and probably between 7 and 11 kilobars only.

A pale brown (in thin-section) to orange brown amphibole is often present in the mineral assemblage and electron-microprobe analysis indicates it to be one rich in the Tschermakite molecule. The amphibole is seen to usually be secondary after pyroxene, but in some of the dykes intruding the sidewall country rock it is sometimes present as part of the primary assemblage, probably attesting to a concentration of valatites in such situation. The olivene is remarkably fresh, even in this border zone, and is but rarely slightly altered to serpentinite minerals. The olivene often shows signs of recrystallisation into polygonal grain mozaics, due most probably to substained heat from the still crystallizing central parts of the intrusion. Perhaps the most remarkable feature

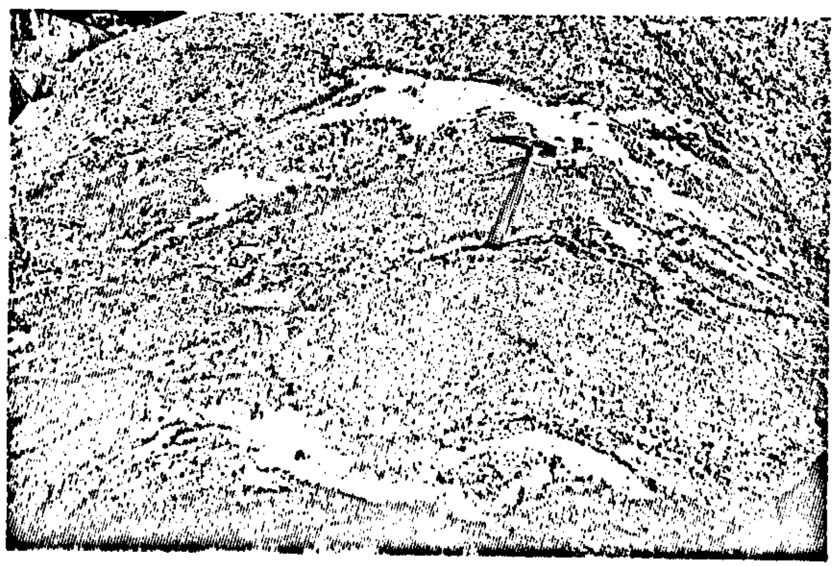


Photo 10 Gabbro - migmatite produced by high-temperature anatexis in wall-rock gabbro. Northern margin of Bumandsfjord ultramafic.

of the body is shown by the composition of olivenes in this marginal zone. Some 16 compositional determinations of olivene have been made by a variety of methods: - 2V determination, X-ray diffraction, electron microprobe and wet chemical. The results of these are extremely consistent and in a number of cases more than one techniqe has been employed giving a range Fo_{58}-Fo_{73}. This indicates olivene compositions in dunitic rocks of abnormally low forterite content. Three olivene determination have been made from the central region of the intrusion and these are in the range Fo_{64-70}. The implications of this are probably most important and bear on the probable initial temperatures of the dunitic melts and indicating a considerably lower maximum melt temperature than has been taken for the forsterite rich dunites.

Sulfide minerals are present in most specimens from the border zone but usually only as a few scattered tiny grains, and no concentrations more than about 0.5% (visual estimate only) have been recorded. A full account of the occurrence of sulfides will be given by Helge Fischer of Hamburg University.

One of the remarkable features of the Bumandsfjord pluton is found in the degree that anatexis or partial melting of gabbroic rocks has been occasioned by the extremely high temperatures of the ultramafic body. Such anatectic melts are developed both from the wallrock gabbros and from the innumerable rafts of gabbroic material which occur within the pluton. In places near the contact the layered gabbro takes on a markedly migmatitic appearance, where partial melting has caused a disruption of the banding giving more diffuse patterns to the rock. Textural changes produced cause the gabbroic rocks to assume the appearance of veinites, nebulites etc. This is well illustrated in Photo 10 where the gabbro has developed a veinitic to nebulitic pattern where anatectic veins of more leucocratic character occur irregularly in a more melanocratic matrix, disrupting the structure of the latter. In many other cases in the Border Zone parallel sided veins and net-veins of leucogabbro emanate from included rafts of alkalic gabbro to intruded the host ultramafic, such veins of dykes of anatectic material can sometimes be traced for several tens of metres from the source gabbro raft. A more detailed account of the anatectic phenomena will be given in the following section.

Photo 6 Break up of pyroxene rich gabbro xenolith in dunitic ultramafic.

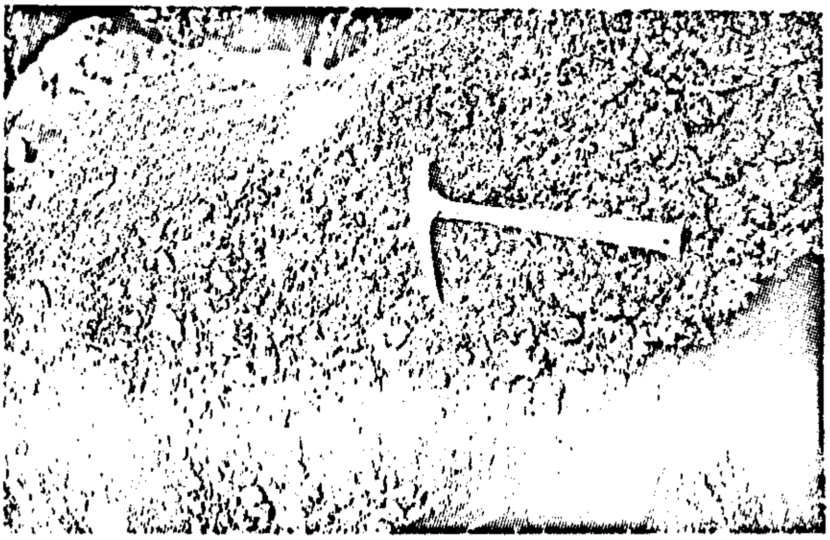


Photo 7 Break up of feldspar rich gabbro xenolith into smaller xenoliths.

Photo 8 Xenoliths broken down to xenocrysts and xenocrystic aggregates of pyroxene and feldspar in dunitic matrix.

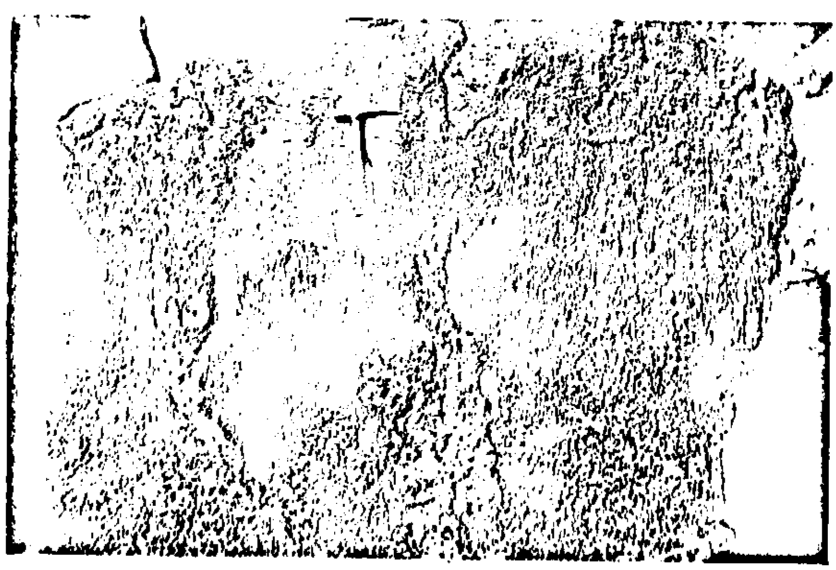


Photo 9 Contamination of ultramafic to produce feldspathic peridotite by xenolith break-up.

(II) THE INTERIOR FACIES

No clear boundary is to be drawn between the central part of the intrusion and the Border Zone Facies described earlier, but two major differences are to be detected:

a) There is a considerable increase in the amount and type of anatectic phenomena from margin to centre of the intrusion.

b) There is a corresponding decrease in xenolith break-up to xenocrysts, which produces the contamination facies of the border region.

The main primary ultramafic rocks of the Interior Facies are identical with those of the border facies i.e. dunite, olivenite and olivene pyroxenite, these rocks are indeed more abundant and plagioclase bearing facies less common. The most remarkable difference in this Interior Facies is the behaviour of the included metagabbro rafts. These no longer show the well-developed and easily recognised primary igneous textures and layering which still characterise the equivalent rocks of the border zone. Considerable recrystallization has occurred within these rafts with growth of pophyroblasts of pyroxene and hornblende, and there is a considerable development of irregular pegmatitic material. The pegmatitic material occurs as irregular patches growing without control by the igneous banding of the gabbro raft, or irregularly along or approximately along the pre-existing banding. In both cases the net effect is to obscure the former primary igneous texture of the rock. Perhaps the most striking feature of the rafts in this interior zone is essentially the change from the regular, well-preserved, primary igneous layering (of the Border Facies) to a rock in which the banding is highly irregular, taking on swirling and contorted patterns. When the contact between such rafts and the containing ultramafic is examined in detail, sheets of similar irregularly banded gabbro are seen to emanate from the raft and penetrate the surrounding peridotite. Also many anatectic veins of varying composition originate in the rafts and penetrate, often for consideralbe distances into the ultramafic. The first of these secondary intrusive phenomena results from a bulk mobilization of the material of the gabbro raft, due to the build-up of small quantities of anatectic melt which occur throughout the body of the rock.

Presumably when this reaches a certain critical value the material of the raft loses its coherence and is capable of re-injection into the surrounding ultramafic, through a process of plastic flourage. The second instance of the discrete anatectic veins refers to the formation and accumulation of pockets of anatectic melt with in the raft, which as the result of pressure-differentials are driven out of the raft, into joints forming in the surrouding ultramafic and crystallize in discrete dykes, sheets and net-veins. To give a distinctive account of their field relationships it is proposed to present a series of shortened descriptions from the writers field note-bbok (locality numbers refer to those on the locality map).

The following description represents the authors observations on a region of ½kmradius to locality (42): -

The whole region on entering the plateau from the route up from loc. (41) gives a general picture of a series of gabbro rafts of varying dimensions included within the ultramafic. The ultramafic cuts such rafts in dyke and sheet-like penetrations, and a wide variety of recrystallization, mobilization and anatectic phenomena can be observed in relation to the rafts. At the same time it is possible to observe features of assimilation of gabbroic material with consequent contamination of the host ultramafic material. To clarify the individual features it is proposed to discuss the various rock units in turn: -

(I) Character of the Gabbro Rafts.

These are very numerous, and at first sight give the impression that one is dealing with an area made up principally of layered gabbro. However, any development of gabbroic material is always completely surrounded by ultramafic rock, and where there is deep dissection this is seen to be a three-dimensional feature. The gabbro is also shot through by many dykes and sheets of ultramafic rock, and indeed many large areas between the gabbro rafts are entirely occupied by ultramafic rock. The original nature of both the layering and textures of the layered gabbro have suffered extensive modification as the result of engulfment in the ultramafic magma, but these will be detailed later. Ignoring such subsequent modifications, for the time being, the layered gabbro is seen to be virtually identical with that described from the northern margin of the ultramafic pluton. The original igneous layering was obviously well developed, and there are well-preserved relics of inch-scale layering, and graded gravitationally stratified layering. In contrast to the gabbro of the northern margin, however, the layering of the rafts is essentially horizontal; this probably as the result of the bouyancy effect of the host ultramafic magma. In small cross-cutting dyke and sheet-like bodies of ultramafic the orientation of layering in the contained xenoliths may be quite random. The gabbro in the rafts is essentially a pyroxene-plagioclase rock, though olivene bearing facies are not rare.

(II) Character of the Ultramafic.

This is essentially similar to that of the Border Facies i.e. a dunitic peridotite which has undergone considerable contamination by the assimilation of gabbroic material. Excellent examples are profuse where xenolith break-up into xenocrysts and xenocrystic aggregates can be observed on virtually all scales. Further sheets and dykes of "clean dunite" traverse certain facies of the gabbro with relatively little contamination, this being particularly the case in fine-grained gabbro facies.

(III) Subsequent history of the Gabbro Rafts after incorporation in the Ultramafic Magma.

This can be viewed under a number of headings.

A. Xenolith break up

Already described in detail from the Border Facies.

B. Textural Changes

(i) Of Layering

In many cases the typical igneous layering of the gabbro can be traced into a diffuse structure, which can at best be described as a migmatitic layered gabbro. Here the previously regular banding takes on swirling patterns and internal discontinuities occur where locally some layers cross others. Irregular patches and veins of a more feldspathic fraction have developed and the latter have fairly random orientations traversing through the surrouding layering. Thus the gabbroic rocks have the appearance of fairly typical migmatites with the formation of veinitic and nebulitic facies. Often when examining this zone, the whole rock is seen to have been mobilized and to intrude the surrounding ultramafic as dykes, sheets etc. Sometimes these have straight-parallel margins, in other instances they have curved trends. Often they join up, together giving the appearance of a net-vein complex.

In the body of the layered gabbro rafts there is in general an irregularly blotchy recrystallisation of the gabbro, eventually leading to an obliteration of the layered structure.

(ii) Pegmatization

Within the layered material of the rafts coarse post-layering pegmatization is to be abundantly observed. The composition of the pegmatites is variable: -

Hornblende - Plagioclase (Biotite).

Hornblende - Plagioclase - Pyroxene (Biotite).

Pyroxene - Plagioclase - Hornblende (Biotite).

Pyroxene - Plagioclase (Hornblende).

Pyroxene - Olivene - Plagioclase (Hornblende).

In addition a number of minor phases are present e.g. apatite, oxides and small quantities of pyrrohtite etc. The size of the pegmatite minerals can be up to 25 cm as in the case of some hornblende crystals.

The pegmatites are develpped in a variety of manners i.e. : -

a) As irregular to ovoidal patches within the layered gabbro, which swamp and obscure several layers. Indeed at the margins of such patches individual crystals grow across several layers.

b) As elongated lensoidal developments along the layering, where the pegmatitic material has been controlled in its form by the pre-existing layering attitude. In many of these examples, where the gabbro has a fairly delicate layered structure preserved, the pegmatic development can be observed to extend through quite a number of individual layers.

c) Less common developments at the contacts between ultramafic and raft, where the pegmatitic material has formed at the expensesof the gabbro. Such pegmatite is most frequently developed at the contact between ultramafic and the mobilized layered gabbro described under β - (i). Irregular patches of pegmatite, usually hornblenderich, are developed within such mobilized gabbro. Both types represent a post-mobilization recrystallization.

C. Mobilizates (anatexites)

These have a variety of forms, and it is obvious that a range exists in the mineralogical and hence chemical compositions of such mobilizates,

(i) Bulk mobilization of fine/medium grained layered gabbro (see B - (i). This is a very abundant type of mobilizate, and in addition to those characters described earlier, it should be added that these intrusions often bear marked flow-banding, in which flow folds can be quite common.

(ii) A common anatexial vein material is pegmatite. This often is present in straight-parallel sided dykes and sheets, which tend to form rectilinear net-vein patterns within the ultramafic. Such dykes can frequently be traced for several tens of metres from the source gabbro raft. In all cases, where they can be followed to the contact between ultramafic and gabbro raft, they are seen to emanate from the latter and to merge imperceptibly into the matrix of the gabbro where it is itself strengly pegmatized or migmatitic.

(iii) A medium-grained aphanitic feldspar-rich anatexite, which cross-cuts the ultramafic in, usually, straight parallel-sided dykes or sheets. One such dyke 20 cm thick was traced for over 50 m from the source gabbro raft with little change in thickness. In this dyke olivene was observed, in places, to grow as elongated crystals from the sidewalls of the dyke towards its centre. The consistency of thickness of this dyke, the aphanitic nature of the rock and the growth relations of olivene attest to the highly fluid melt which must have been transported along the dyke. These dykes are mainly play-pyr-oliv (hbl.) and are observed to stem directly from medium-grained aphanitic gabbro. (Photos 11, 12).

(iv) Total mobilization of med / coarse grained gabbro. This occurs in a number of localities near the ice. Such mobilizates comprise a streaky textural coarse-medium grained gabbroic rock which contains a large number of xenoliths (inclusions) of

a) various types of gabbroic rock - particularly of aphanitic fine /medium grained material and pegmatite.

b) ultramafic - both of "clean dunite" and of the various contamination products. The ultramafic blocks are usually angular. They are sometimes cracked open and veins of gabbro mobilizate penetrate the blocks.

This observation shows that the gabbroic material had considerable mobility after much of the ultramafic was solid - this is also shown by the next point:

c) blocks of fine-grained basic dyke material. In one example the contact between dyke and ultramafic was preserved in included block.

Photo 13 Anatectic veins stemming from gabbro raft, and cutting ultramafic. Note that gabbro raft is also cut by ultramafic sheet.

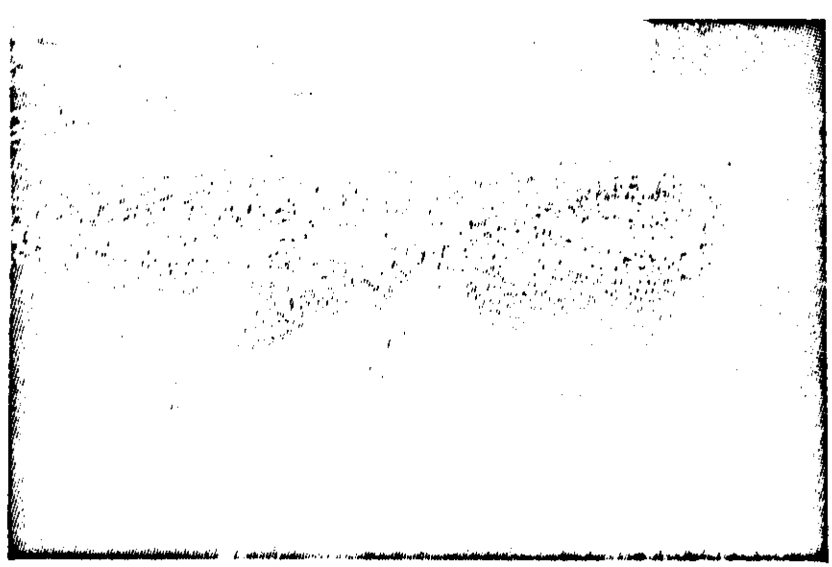


Photo 14 [illegible]

The mobile phase is observed to intruded both peridotite and other types of gabbro raft. In many cases the ultramafic cuts gabbro in the same locality that it is cut by gabbro mobilizate.

(IV) Basic Dykes

Although no measurements of trends were taken, the dykes are much more random in direction than those observed in the outer parts of the pluton. It would appear that there are in fact several stages of d ke injection during the cooling history of the body. This is to be seen where many examples of dykes occur torn-up into blocks within the mobilized gabbroic material. There are also many examples of subsequent dyke-sets with more regular trends and straight parallel sided aspects.

Observations from locality 50

From (49) to (50) have been traversing mainly ultramafic with many, many gabbro rafts. For the first part of the traverse much evidence of contamination of the ultramafic material by the assimilation of broken-up xenolithic material is to be observed. Approaching locality 50 however, there is a vast increase in the amount of anatexial phenomena, and all the rafts take on a migmatic material.

At locality 50 it would appear that the gabbroic xenoliths and rafts have totally ceased to exist as coherent bodies and have been capable of flow in virtually any direction. A plethora of anatexitic veins of varying composition are given off from the rafts and intrude the ultramafic usually as straight parallel sided dykes, sheets and net-veins. The banding in the gabbro takes on swirling patterns and small gabbro rafts and detatched peridotite blocks are taken up as included material. Those mobilized gabbro rafts are observed to cut each other at random and to obviously have acheived a high degree of fluidity. (Photos 13, 14).

An account will now be given of the details of the phenomena in this region: -

I Ultramafic

This occurs mainly as a pyroxene - plagioclase bearing peridotite. Much evidence is still to be seen for the assimilation of gabbroic material, but often the facies is fairly homogeneous. Areas however do exist where the ultramafic is still dunitic i.e.: -

a) As sheets and dykes cutting gabbro rafts particularly where the gabbro is of the finer-grained variety. Here the dykes and sheets are cross-cutting and show evidence of xenocryst and xenolith plucking from the sidewall rock.

b) As xenolithic blocks in the pyroxene-plagioclase bearing peridotite. The blocks may be rounded, oroidal, sub-angular or angular.

c) As xenoliths in mobilized gabbro where the ultramafic occurs as angular to sub-angular blocks.

The pyroxene-feldspar bearing peridotite facies often occurs as xenoliths in the mobilized gabbro as angular, sub-angular, rounded, ovoidal or lenticular blocks. In some cases the mobilized gabbro and the pyroxene-feldspar bearing peridotite together develop swirling banded patterns. In such cases the junctions between the two members are often diffuse and the appearance of the rock indicates that both elements have been involved in the flourage pattern.

In places about this locality a variety of the ultramafic that has not been yet recorded elsewhere in the intrusion occurs. This is a pyroxene-hornblende-feldspar bearing peridotite which has a distinctive mottled appearance due to the presence of large poikiloblastic hornblende. The hornblendes may be up to 10cms across and impart a spectacular texture to the rock.

II Anatectic Veins

These are developed in profusion, intruding the peridotite and can always be traced to stem originally from the gabbroic material. They vary in texture and type from: -

Photo 15 Pegmatitic patches developed in gabbro raft as result of anatexis.

a) Medium grained aphanitic gabbro which has a dominating plagioclase, feldspar content. These vary in composition from feldspar-pyroxene, feldspar-pyroxene-olivene to feldspar-olivene rocks

b) Pegmatitic veins essentially composed of plagioclase-hornblende ($\pm$ biotite), though pyroxene and olivene bearing variants also occur.

The anatectic veins, dykes and sheets are generally straight parallel-sided bodies which often form a rectilinear net-vein pattern in the peridotite. When traced into the source gabbro sheet (raft) they are always observed to merge into the texture of that sheet. However, they may cut other gabbro rafts and streaks or even other anatectic veins. At the margins of the feldspar-rich aphanitic anatectic veins there is usually a thin dark zone (1 - 3mm) composed of pyroxene-spinel symplectite. This latter is presumably the result of reaction between the olivene of the host peridotite and the plagioclase of the intrusive vein. Similar rims are developed at plagioclase olivene interfaces in the divene-bearing veins.

At the contact of the pegmatitic veins there is often a pronounced black margin made up of hornblende crystals.

III The Gabbro Rafts

a) Non-mobilized material

Between (49) and (50) many discrete gabbro rafts are to be observed, these often have sharp margins with the enclosing ultramafic. Penetration of the rafts by dykes and sheets of both "clean dunite" and pyroxene-feldspar peridotite are frequent. Appraaching loc (50) major changes are observed in the ultramafic/gabbro relations. The gabbro takes on a characteristically migmatitic appearance with a progressive destruction of the original igneous layered features, textures etc. by patch irregular recrystallization, the production of diffuse feldspar-rich veins, pegmatitic patches, streaks etc. (Photo 15).

Anatexis is seen to have occurred on a profound scale (see II) and often apophyses of identical texture stem from the gabbro raft and intrude the neighbouring ultramafic; here the layering or banding takes on swirling forms and complex patterns of flow folds are developed in some instances.

It is possible in places to see very advanced stages in the mobilization of the material of such gabbro rafts, where the apophyces of raft material intrude all surrounding rocks in dyke-like form carrying xenoliths of ultramafic, coarse gabbro, gabbro pegmatite etc. The latest of such dyke phases developed have sometimes a cataclastic texture and with a well marked though swirling fluxion banding generally parallel to the dyke margin.

b) Mobilized Gabbros.

Perhaps the most spectacular feature of this (50) region is the way in which all gabbroic material in the rafts may eventually exhibit at total loss of coherence, and the entire raft acts as a mobile material which is capable of flow through an essentially more brittle peridotite surround. Dykes and sheets, both of straight parallel sides and of irregularly curving and swirling form, are to be observed. The gabbro in such re-intrusions has a vastly different appearance to that of the rafts in the border zone. They exhibit a crude gneissic banding which contains

(a) lenses and irregular patches of pegmatite

(b) Pegmatite developing along the banding

This banding may be essentially parallel to the margins of the sheet, but in other cases takes on swirling patterns within the sheet resulting from flow folding. Such sheets cut sharply through the peridotite and in several examples xenoliths of gabbro in the ultramafic are observed to be cut by such sheets (Fig. 14). Innumerable cases occur where mobilized gabbro sheets cut one another with dilational offset (Fig. 14). In other examples the mobile gabbroic material forms a crude net-vein pattern in the ultramafic, with the gneissic internal banding swirling from one trend to the

Photo 11 Anatectic dyke of anorthositic gabbro cutting contaminated peridotite.

Photo 12 Net vein complex of anatectic leucogabbro stemming from gabbro [illegible]

other (Fig.   ). Many anatectic veins can be seen to have been given off from such sheets and to extend for many metres into the peridotite. Such veins are commonly pegmatitic.

In some instances thin schlieren of peridotite are observed within the sheets. These often appear to merge into the host and take on the same swirling flow patterns.

These two detailed accounts of localities within the interior facies give a picture of the type of situation which obtained during the cooling history of the body. In bulk the included gabbroic material in the body must be in the order of 30-50% of the total exposed volume of the intrusion.

It is obvious that with the degree of mobilization that occurred in this interior facies of the pluton that there must have been considerable potential for the migration of the sulfide phase. In no places were any significant concentrations of sulfide minerals found, though sulfide was rather more noticeable in association with the mobilized gabbro rafts than in many other instances. In no cases, however, was a sulfide content more than a fraction of a percent up to perhaps a maximum of 1% seen. A more detailed account of the opaque minerals will however be presented by Mr. Fischer.

III The Southern Facies

This is distinguished from the Border Zone Facies and the Interior Facies in relation to its more complex relationships with the enveloping country rocks. Here in this region east of Baardfjord the character of the country rocks is much more varied than in the previously described parts of the pluton. The country rocks include a number of gabbroic varieties, and also a range of metasedimentary rock types. The gabbroic rocks in the marginal zone have all undergone granulite facies metamorphism and have a partially developed superimposed amphibolite facies assemblage shown by the growth of hornblende from the pyroxene-granulite fabric. The metasediments are all affected by the granulite facies metamorphism and include semi-pelites, pelites, impure psammites, pure quartzites, and calc-silicates. The former sedimentary parentage of the first three types is now little in evidence they are thoroughly recrystallized into granulite facies assemblages and show abundant evidence of anatectical melting with widespread mobilization of the anatexite. This is particularly obvious where the metasediments are cut by basic dykes, and these latter are seen to be backveined by anatectic dykes, sheets and veins emanating from the surrounding country rocks. In many cases the metasediments are observed to have undergone a widespread process of "dioritization" where the metasediments take on the appearance of a massive streaky textured igneous rock with many schlieren of more resistant, quartzite, pelite, calc-silicate and basic dyke lenses.

The relationships between the gabbroic rocks and the metasediments is also more complex and there appear to be serveral sheets of gabbro of differing age relations. However, as the result of the pervasive granulite facies recrystallisation the detailed relationships and sequence are extremely difficult to unravel. It is though obvious that the ultramafic of the Bumandsfjord pluton is the latest major igneous event post-dated only by mafic and ultramafic dykes swarms and sporadic pegmatite dykes of nepheline syenitic and granitic compositions.

Relations of the Ultramafic

As is to be seen from the map of the region the clearly demarcated pluton of the northern part of the area has less distinct contact relationships in its southern extremity. Here there is a transition from ultramafic containing many gabbro rafts, to country rock containing many dykes, sheets and veins of ultramafic material. It is fairly obvious that the pluton is tapering to a narrow body at its southern end, but it would also appear that the roof of the body is plunging southwards beneath the cover. This latter feature is indicated by the great incidence of dykes, sheets etc. of ultramafic south of the main body.

Many of the petrologic features of the pluton are identical with those previously described, and the writer will not repeat such descriptions. However, one difference is fairly marked. This is that the ultramafic is almost entirely of the plagioclase-pyroxene peridotite, with variable proportions

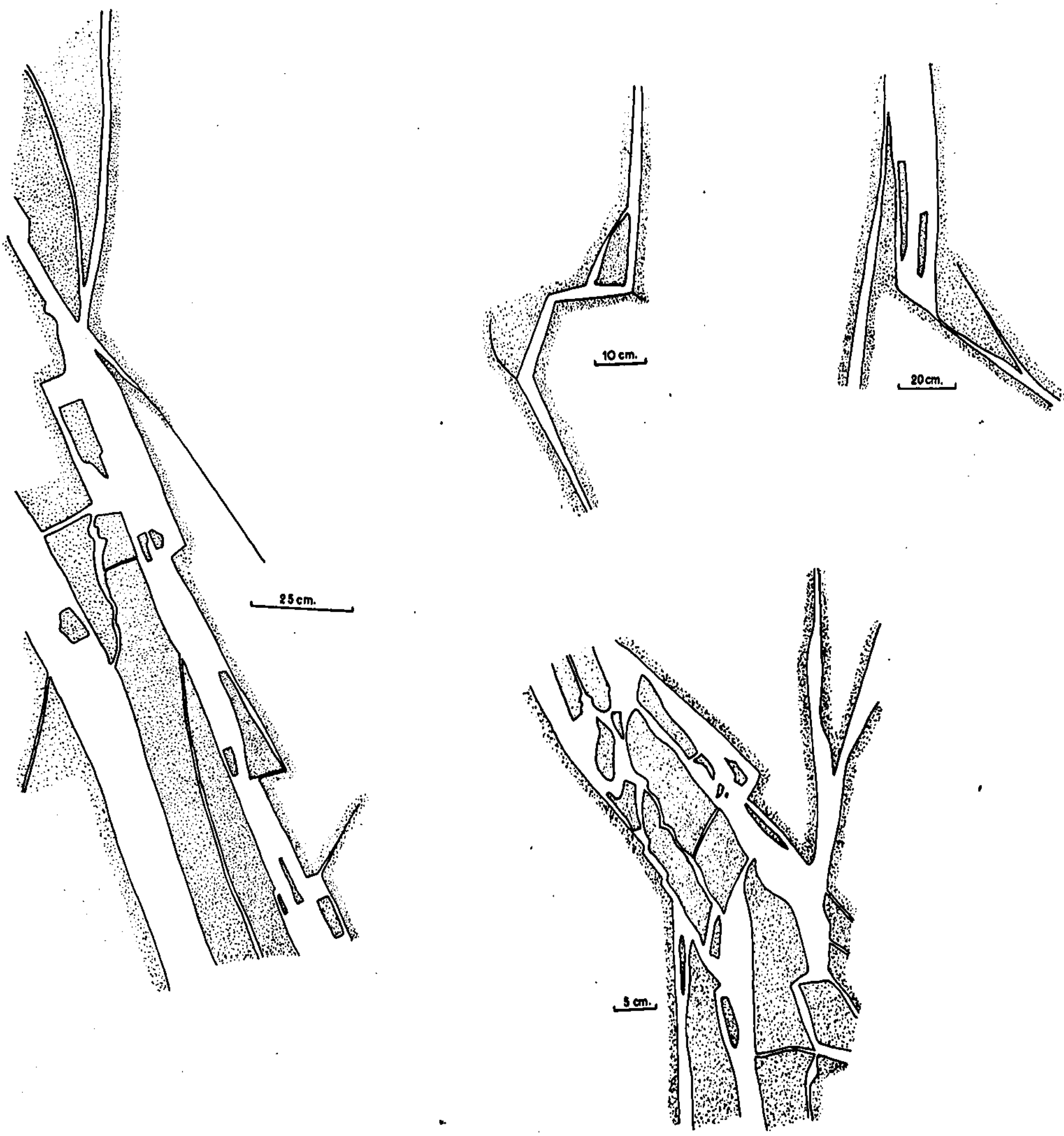


Fig. 9 Ultramafic dyke and vein complex in wall rock

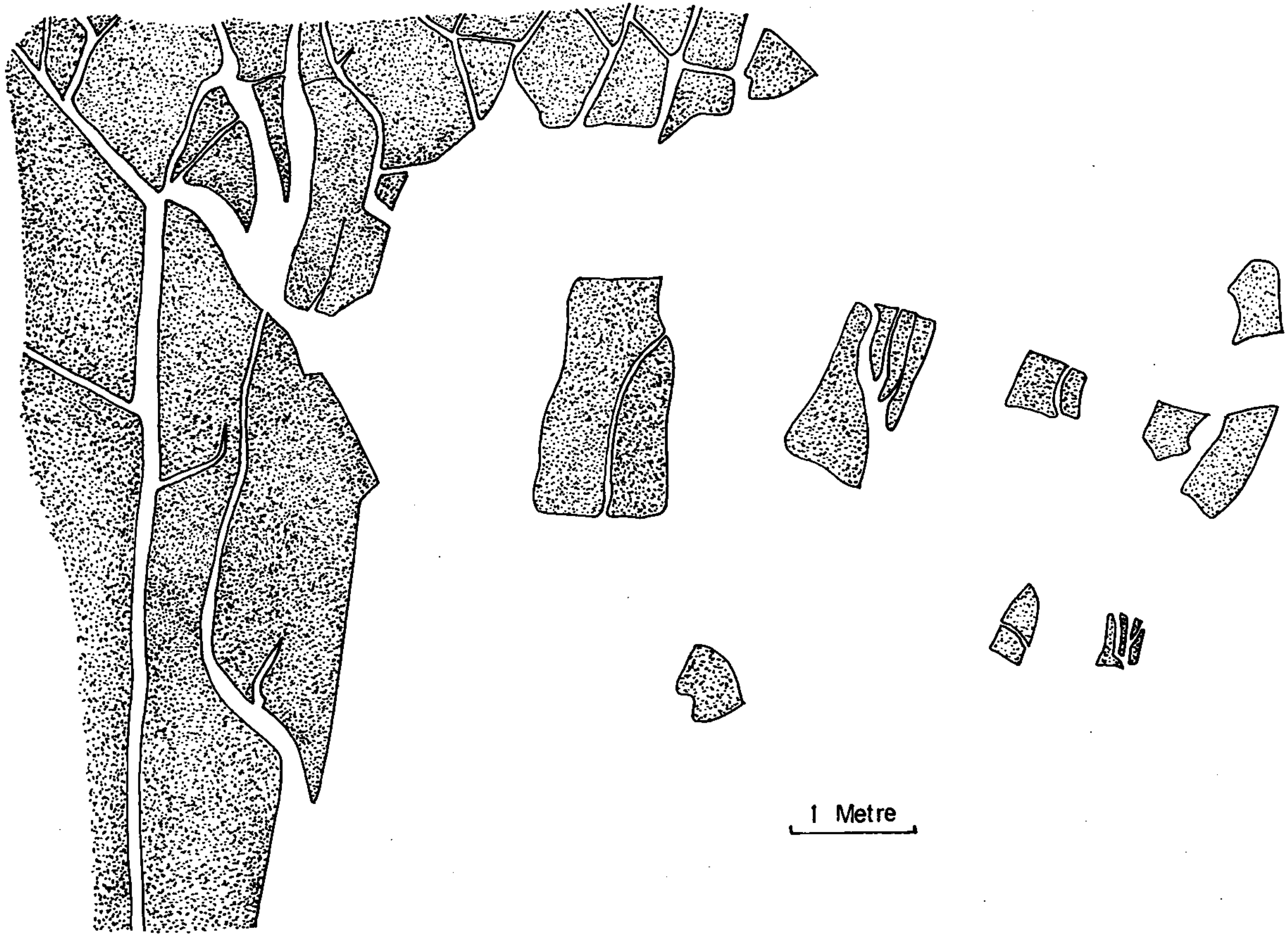


Fig. 10 Margin of ultramafic complex with wall rock gabbro. Note (1) detached blocks of wall rock
(2) Dyke and vein complex of ultramafic in wall rock.

of the three principal minerals i.e. olivene-pyroxene-plagioclase. Pure dunites or olivenites are much less abundant and only usually seen as: -

a) Small dykes cutting the pyr-plag-peridotite

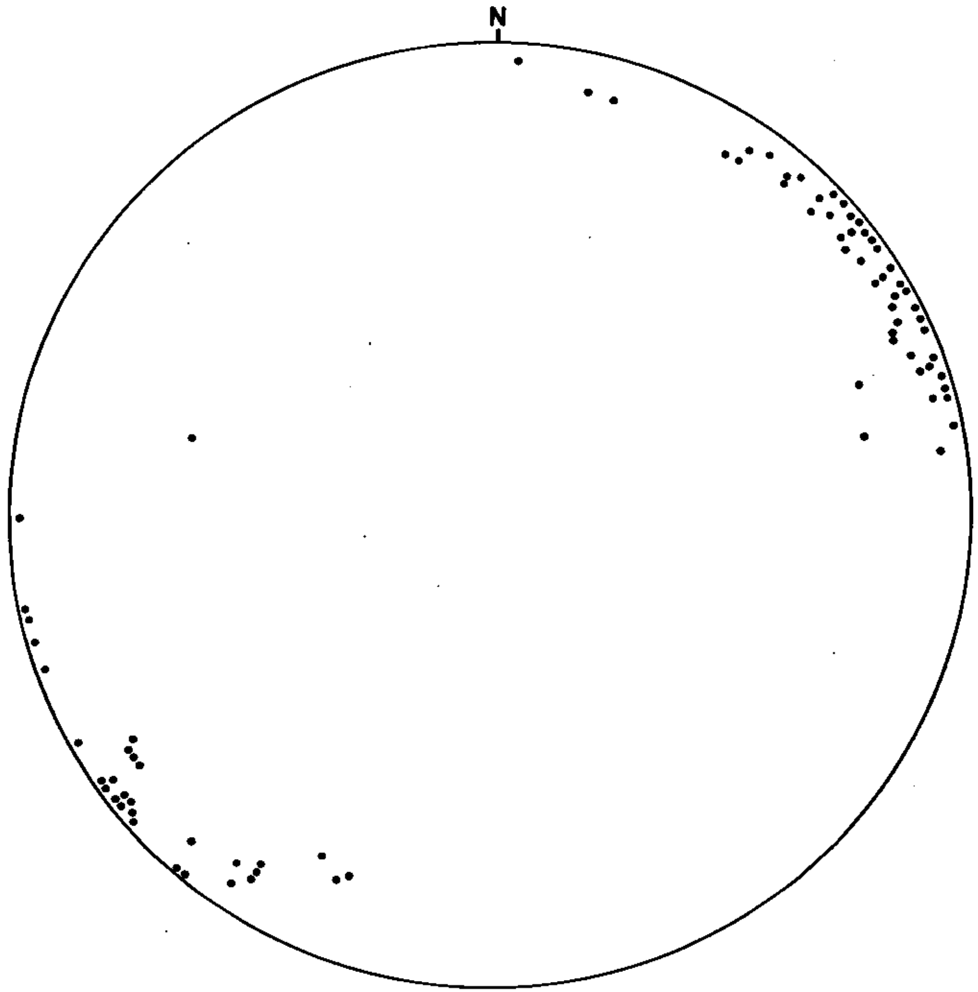
or b) Small xenoliths, usually rounded, in the peridotite.

Evidence is seen sporadically of xenolith break-up, of the type described earlier in this report, but generally such features are not common.

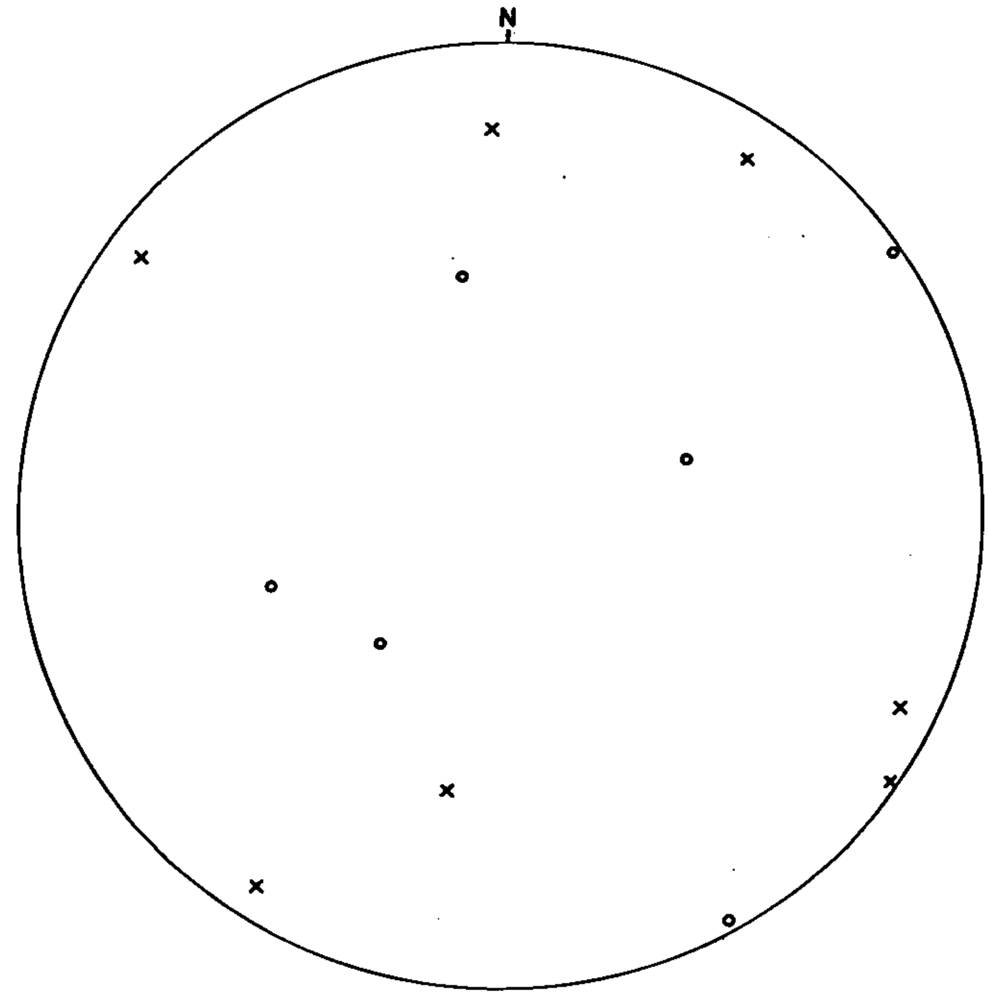
The dyke and sheet complexes of peridotite invading the country roof and wall rocks are very spectacular (Fig . 9) and must indicate that the peridotite magma possessed high fluidity not unlike that of completely molten basalt. Fig. 10 gives an impression of the way in which part of the roof and sidewall of the body has been smashed open by the prising action of the ultramafic magma to form a dyke and sheet complex, and how angular blocks of the country rocks have been detached and stoped to form xenoliths in the ultramafic material. A consideration of Figs. shows that many delicate intrusion features, produced by the penetration of the ultramafic magma, are preserved. These include dilatational heaving of the sidewalls of dykes, and significantly hair-veins of peridotite (often less than 1 cm in thickness) which penetrate along cracks in the gabbro, often stemming from the angular inflexions of dilatational points. It is also possible to see that the gabbro xenoliths within the main body of ultramafic are extrensively cracked open and penetrated by often delicate reliculate patterns of peridotite veins.

One remarkable facies of the ultramafic is observed, to the west of Ubivann, where the peridotite has penetrated the metasedimentary sequence. Here lenses of pure quartzite abound as inclusions, and have a brilliant lilac-blue colour. Thin sections reveal that the quartz contains many small needles of rutile which are probably responsible for the prominent blue coloration.

No noteworthy concentrations of sulfides were observed in the ultramafic or in the margining country rocks, though the ultramafic contains traces of visible sulfide in most localities. Similarly the gabbroic rocks have small disseminations of sulfides more sporadically developed.



Basic Dykes in Bumandsfjord Pulton
81 Observations



× Fracture Cleavage
o Alignment of xenoliths

Fig. 11 Structural observations from Bumandsfjord Pluton

IV The Post-Peridotite Dyke Complex

In the region of the Bumandsfjord Pluton there is a very considerable volume of basic, ultramafic and pegmatitic dykes. These are of variable age-relationships and complex in detail. They can be divided into two major age-groups i.e.

a) Pre-Bumandsfjord Pluton

b) Post-Bumandsfjord Pluton

In the extensive zone of hornfelsing around the Bumandsfjord pluton the first set can be easily recognised where anatectic melting of the hornfelses produces back-veining of the dykes. However, further away from the pluton margin the age differences are less easy to decypher. The post-pluton dykes, however, have their greatest concentrations within the pluton, and represent a late expansion of the pluton. The dykes are of variable composition and include peridotite, dolerite, hornblendite and feldspar-dolerite porphyries. It will be seen from Fig. 11 that the dykes although somewhat variable in trend are essentially a NW-SE to NNW-SSE swarm of nearly vertical sheets. At a number of localities where continuous surfaces were exposed estimates were made of the total volume occupied by the dykes in order to give some idea of the degree of linear volume expansion occurring during dyke emplacement.

The method of approach here is simple. The thickness of dyke normal to its walls, dip and strike of dyke and the thickness of internening ultramafic were all recorded. The data being shown in the following manner.

Dyke Measurement Station 4 - Locality No. 39. (thickness in metres)

	Peridotite	Dyke	Dyke orientation
	0.29	0.12	148°/85°W
	1.20	0.18	160°/70°E
	0.28	0.12	168°/69°W
	0.52	0.15	164°/vert
	3.80	0.31	165°/85°W
	0.62	0.31	156°/vert
	0.25	0.09	147°/vert
	1.70	0.02	156°/80°W
	0.08	0.02	155°/80°W
	0.17	0.18	155°/vert
	0.54	0.23	161°/86°W
	0.26	0.51	154°/82°W
	0.54	0.12	154°/vert
	0.99	0.82	164°/vert
	0.12	0.22	165°/vert
	3.93	0.08	169°/vert
	0.12	0.17	171°/84°W
	2.68	0.02	150°/vert
	3.71	0.02	164°/vert
	2.70	0.65	168°/vert
	0.11	0.74	168°/vert
TOTAL	24.61	5.08	

% Linear expansion $\frac{C_1 - C_0}{C_0} \times 100 = \frac{5.08}{24.61} \times 100 =$ 20.65%

Similar measurements were taken at localities (4), (13), (37) and (41) with the following results: -

	% linear volume expansion
Loc. (4)	38.8%
Loc. (13)	27.3%
Loc. (37)	38.2%
Loc. (41)	24.3%

It must here be stated that these represent stations chosen at random, and possibly biased towards prominent dyke development especially perhaps at localities (4) and (37). The reason for presenting this data is however two-fold

(a) It gives some idea of the type of dyke concentration

(b) It provides a field method for the rapid estimation of the volume of rock occupied by minor dyke phases, which could be of value in terms of estimation of tonnage etc.

The dyke measurements come entirely from the marginal zone of the pluton and show the regular pattern pertaining in the NW border zone. No such studies have as yet been carried out in other parts of the pluton. It has been shown earlier (p.32) that in the Interior Facies of the pluton that the dykes have less regular trends, and indeed in some instances have been involved in the flowage consequent on the mobilization of gabbro raft material. This implies that the dyke-swarm is occupying fractures formed during the cooling of the pluton.

Apart from the mafic and ultramafic dyke swarm there are a few small dykes of granite pegmatite in the northern part of the pluton and of nepheline syenite pegmatite in the southern part of the body.

V Deformation of the Bumandsfjord Pluton

In relation to the broad synformal structure indicated for southern Seiland by Robins, the Nordre Bumandsfjord Pluton is intruded into the western limb of this structure completely post-dating its formation. There is little evidence that the rocks of the pluton have undergone any strong penetrative deformation. A closely spaced jointing occurs sporadically within the pluton and this in places is developed into a fracture cleavage. Only a few measurements of this cleavage have been made (Fig. 11) and these show no particular directional trends.

The most deformed rocks in the pluton are in fact the subsequent dyke phases which infrequently have a strongly developed mylonitic foliation parallel to their margins or occasionally a cross-cutting fracture cleavage. The maximum deformation is seen in the dykes of nepheline syenite pegmatite, which can have completely cataclastic fabrics where the rocks are milled down to banded porphyroclastic mylonites. Within such dykes several phases of folding of this mylonitic banding can often be observed. The deformation is essentially confined to the interior of the dykes with the exception of a zone no more than a few centimetres wide, in the margining peridotite where a mylonitic foliation is developed. The concentration of deformation within the dykes is a consequence of the strength differential between the stronger wall-rock peridotite and the weaker dyke material. It is apparent that the folding of the mylonitic layering is due to simple shear operating during the deformation with resultant rotational strain causing this localized folding within the dykes. The folding is entirely a consequence of strain concentration at these sites, and the repeated folding is independent of the folding phases to be observed in the metasedimentary envelope.

Apart from these features the only other indications of deformation are small faults zones with only minor displacements and little associated brecciation. No mineralization of note has been recorded from these small fault-zones.

VI The Contact Metamorphic Effects of the Bumandsfjord Pluton

Much has already been stated in the main body of this report of the high-grade granulite facies metamorphism which has affected the rocks surrounding the pluton and the rafts of gabbro and metasediment within the body. These can be summed up as follows: -

(a) The rafts of gabbro within the ultramafic have undergone widespread recrystallization to granulite facies assemblages. Partial melting of gabbroic material has been an important process, producing a wide variety of anatectic phenomena which have been described in detail earlier.

(b) Similar features are seen in the contact zone of the envelope gabbroic rocks, though naturally the extremes of temperature encountered within the pluton were nearer reached and the anatectic phenomena are not so developed as those within the rafts. In the outer parts of Søndre Bumandsfjord part of the highly deformed Hønseby Gabbro occur within the aureole of the Bumandsfjord pluton and is here converted into a two-pyroxene garnet granulite. It would appear that the contact metamorphic effects of the pluton extend for a considerable distance from its margin, but in rocks of gabbroic composition it is difficult to be precise in ascribing limits to the contact phenomena.

(c) Perhaps the most remarkable effects of the contact metamorphism are to be observed in the Bumandsfjord area in the metasedimentary rocks of the local envelope. These as previously mentioned are thoroughly recrystallized into granulite facies assemblages, and anatectic phenomena are developed to an extra-ordinary degree. This latter is particularly well to be observed in the shore-sections along the northern side of Baardfjord where it can be seen that selective melting of layers within the sequence with consequent mobilization has produced a great complexity in the rock relationships. Considerable flourage of partially melted material has occurred, essentially along the layering which has produced a streaking and flattening of the rocks by a process which can best be described as Flow- Flattening.

It would appear that the emplacement of the ultramafic into its country rock envelope produced a number of changes in this envelope: -

(i) Changes in the mineral associations as a consequence of the superimposed temperature gradient - which was also responsible for:

(ii) Widespread anatexis with partial melting and mobilization of many of the metasedimentary rock types.

(iii) Strong extension of this envelope as a result of the great volume change engendered by the emplacement of this intrusive pluton.

Thus when one considers these features collectively, it is possible to appreciate the extension -flouwage - flattening effects occurring in this contact zone responsible for the remarkable deformation features present in the rocks.

This subject, however, is not of great moment for the report except to explain the appearance of the rocks at Baardfjord, and perhaps to emphasise the high temperatures engendered by the Bumandsfjord Pluton. It is however, important as a lead in explaining the way in which the incoming magma was able to provide space for the crystallizing pluton by causing great extension with lateral flouwage of the surrounding rocks.

CONCLUSIONS

The main body of this report has attempted to indicate many of the principal geological features of the mafic and ultramafic rocks of the island of Seiland. They represent a remarkable assemblage of rocks emplaced into a deep zone in a developing orogenic belt. One which in fact was undergoing high grade metamorphism and intermittent deformation during the evolution of the igneous complex.

The range of gabbroic rocks stemming from a variety of basaltic magmas, presumably evolving through partial melting of mantle material at varying depths within the mantle and emplaced into an actively developing orogenic belt present a problem which finds few if any precise analogues in the geological literature. In addition account must be taken of the large volumes of ultramafic rocks in the province which have apparently crystallized from ultramafic magmas, and the abundant presence of alkaline rocks such as nepheline syenites and carbonatites. Not only is the range of petrographic types extreme, but also many of the internal features of the plutons themselves are unusual in such a tectonic setting. For example the extremely well developed features of layering in not only the gabbroic but also in the ultramafic rocks (e.g. the Reinfjord Ultramafic Body).

As has been indicated earlier no major concentrations of sulfide minerals have been discovered during the writers investigations of the Bumandsfjord Pluton although minor amounts of sulfides are seen in most specimens of the peridotite. This would at first seem to be at variance with the results of the stream-sediment geochemistry of Sulfidmalms associates (Foldal Verk) which show promising Ni/Cu anomaly patterns in many parts of the area. However, this variance can probably be the result of a number of contributory factors: -

a) The physical nature of the streams sampled. These are in fact all fast-flowing streams with bare rock or boulder courses, which at time of high precipition and/or a high degree of snow-melting become ranging torrents. The writer has checked on a number of the sampled streams and finds that the sediment occurs in small pockets, where the heavier mineral fraction has been effectively concentrated by panning-action.

b) The possibility that part of the stream sediment nickel anomaly is resultant upon silicate nickel in olivene. Recent experimental work indicates that silicate nickel has a highest potential with increased Fayalite content in olivene. It will be remembered here that the olivenes in the Bumandsfjord peridotite have abnormally high fayalite-contents for such rocks.

c) That there are localized concentrations of sulfides not located in the course of the present investigation.

In conclusion the writer must state that he sees no reason for the apparent paucity of sulfides in many of the mafic and ultramafic rocks of the Seiland Province. Indeed the assay-results obtained by H. Rosenqvist from the Reinfjord Peridotite and the Olderfjord Norite in N. Troms show that promising locations are present in the region. Whether or not more areas with a reasonable degree of mineralization occur in the region can only be established as the results of further investigations.

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EXPLANATION
THE CALEDONIAN PLUTONIC HISTORY
DEFORMATION of alkaline rocks
Alkaline rocks; Carbonatite
Fenites
GROWTH of major SYNFORM
LILLE KUFJORD GABBRO (Tholeiitic)
F2c
Dunite
Olivine pyroxenite
Tilaiitic facies
ALKALIC PERIDOTITE
D2
F2b
ALKALIC OLIVINE GABBRO
2-pyroxene gabbro
Olivine-bearing facies
SYENOGABBRO (Tholeiitic)
F2a
PEAK of REGIONAL METAMORPHISM
OLANES GABBRO (Tholeiitic)
D1
F1b
METAGABBRO (Tholeiitic)
F1a
GABBRO - age relations unknown
Intrusive metalimestone
METASEDIMENT - mainly psammite
SYMBOLS
C Carbonatite dyke(s)
L Litchfieldite dyke(s)
B Biotite magnetite syenite dyke(s)
Sh Shonkinite dyke(s)
Ja Jacupirangite dykes
Db Dunite breccia dyke
Metasomatic dunite
Xenolith rich areas
Syenogabbro with perthosite layers
Schistosity, foliation
Rythmic layering
Rythmic layering and schistosity
D2 fold axis
Younging direction
BOUNDARIES
Definite
Inferred
Conjectured
SCALE
0 1 2km
N
ODDNINGSFJELL
Kasfjordelven
Olderfjorddalen
OLDERFJORD
REVNEFJELL
L. Bekkarfjord
Storfjell
Storholm
STORE BEKKARFJORD
Melkelven
MELKEVANDENE
STEINFJELL
ELVENES
Svensenes
Kvitberg
Birgitbergfjell
Klubnes
Altnes
Graddalsting
TVERFJELL
St. Kjervik
Kjervik
Seibugt
OLDERVIKVAND
Skarvvd
Skarvbugt
Skarvbergnes
Grandnes
Hakstabben
Oldervik
ROGGSUND
Geology of SE SEILAND
W-Finnmark
AFTER B. ROBINS 1971
Scale 1:20 000
A/S Sulfidmalm
2-228-72-16
Map sheet

KEY:

Strike and dip of

a) Foliation in
I metasediments
II streaky diorite
III diorite gneiss
IV gabbro gneiss
V leucogabbro

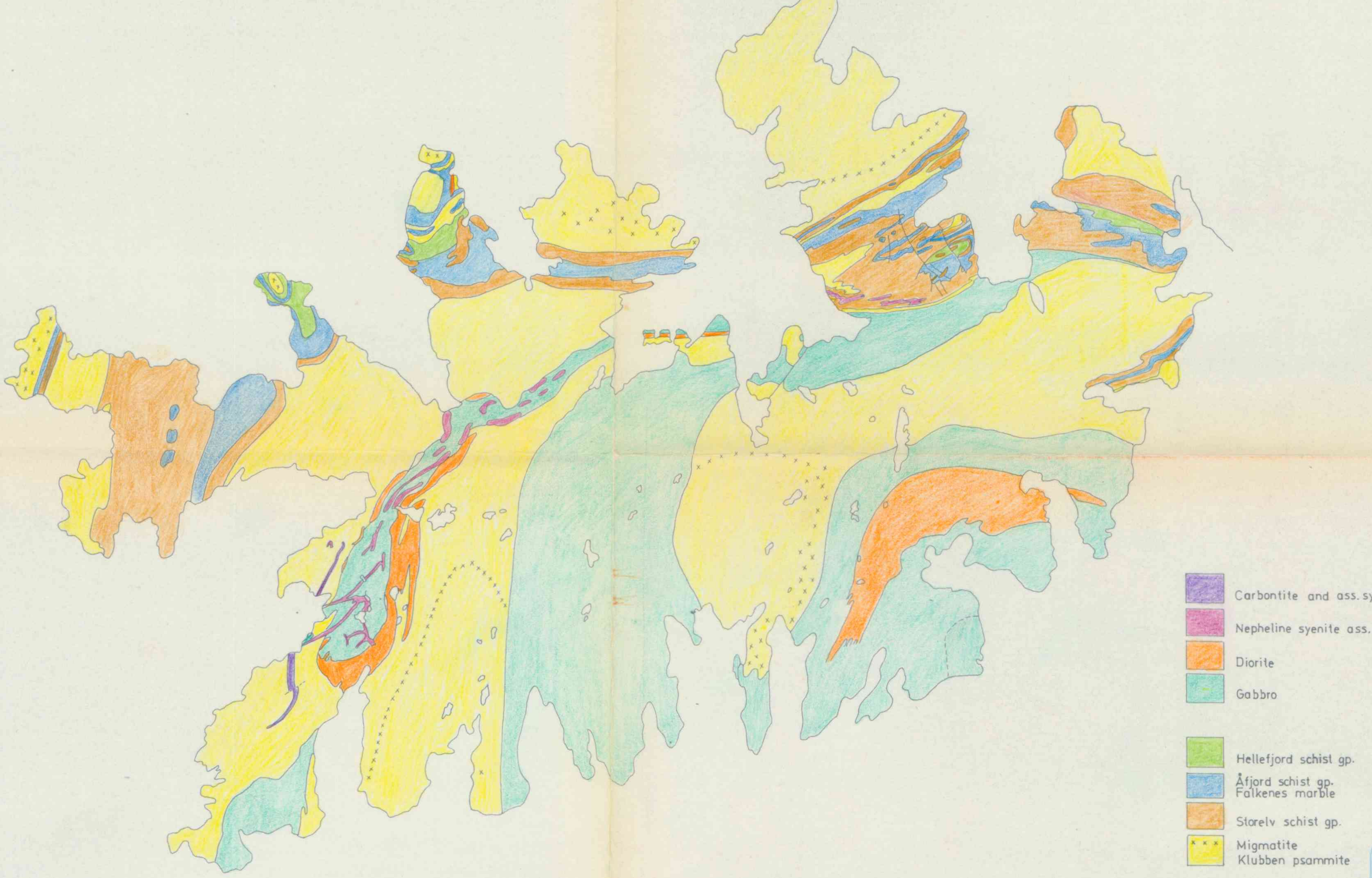
b) Layering in layered gabbro
I "in situ"
II rafts in peridotite

Strike and dip of cleavage in some peridotites

- Carbonatite
- Nepheline syenite pg.
- Perthosite
- Peridotite (somewhat contaminated) containing many rafts and streaks of layered gabbro
- Peridotite containing many rafts mainly of dioritic metasediment with blue quartzite.
- Peridotite
- Layered gabbro
- Coarse leucogabbro, poorly foliated
- Contaminated gabbro, foliated in part
- Foliated gabbro (on coast resemble layered gabbroic gneiss)
- Dioritic gneiss
- Dioritic metasedimentary hornfels with blue quartzite
- Calc-silicate hornfels
- Psammitic hornfels
- Streaky diorite.

Geology of SW SEILAND Preliminary map	SCALE approx. 1: 15 000	OBS. Sturt	Speadyman
		DRAW.	
		TRAC. BL	2-73
		CHK. HaR	2-73
A/S SULFIDMALM	MAP NO. 1-228-72-16		
	MAP SHEET		

A.s Termkopi. 3000. A 1. E 9 gl. 10-71. Sentrum Trykkeri.



Geology of Sørøy WEST - FINNMARK	SCALE 1:125.000	OBS.	
		DRAW.	
		TRAC. BL	2-73
		CHK.	
A/S SULFIDMALM	MAP NO. 3-228-72-16		
	MAP SHEET		

A.s Tørrkopi. 2000. A 2. E 9 gl. 10-71. Sentrum Trykkeri.