THE AHLMANNRYGGEN GROUP, THE VIDDALEN FORMATION AND THE ASSOCIATED IGNEOUS ROCKS IN THE VIDDALEN AREA, WESTERN DRONNING MAUD LAND, ANTARCTICA

by

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Submitted in partial fulfilment of the
requirements for the degree of

MAGISTER SCIENTIAE

in the

FACULTY OF SCIENCE OF THE
UNIVERSITY OF PRETORIA,
PRETORIA

October, 1976

ABSTRACT

Nunataks within an area of approximately 3 400 km^2 between latitudes 71°50' and 72°35' south and longitudes 1°30' and 4°00' west were mapped geologically by the 12th South African National Antarctic Expedition during the summer of 1971–72. The area is underlain mainly by subhorizontal arenaceous and argillaceous sediments, extensively intruded by thick mafic sills and dykes of Precambrian age. An isolated succession comprising agglomerate, tuff and lava flows with intercalated sediments in its upper part is exposed in the east and south. A new lithostratigraphic subdivision is proposed, based on detailed investigation of field relationships combined with subsequent petrological studies and radiometric age determinations.

The oldest rocks in the area belong to the *Pyramiden Formation* which consists mostly of feldspathic graywacke and siltstone. Correlates of this formation were discovered at Kjölrabbane, Babordsranten and at Nashornet and Viddalskollen. At the latter locality the sequence is subdivided into a Lower Member, 140 m thick, deposited under low-energy, deep-water conditions, and an Upper Member, 250 m thick, which was deposited in shallower water under higher energy conditions. The overlying *Grunehogna Formation* has the widest distribution of all sedimentary formations in the area and consists of alternating persistent beds of light-coloured arenite and dark-coloured argillite. This succession is conformably overlain by the *Högfonna Formation* which is subdivided into a lower, *Borgmassivet Member,* consisting of feldspathic quartzite, shale and jasper-bearing conglomerate, and an upper, *Jekselen Member* which consists of calcareous, jasper-bearing arenaceous sediments.

All the formations mentioned above are assigned to the *Ahlmannryggen Group.* It is suggested that the *Raudberget Formation,* which is not exposed in the area investigated, is also included in this Group.

The volcanic-sedimentary succession at Tindeklypa and Istind is believed to overlie the Högfonna Formation conformably and is collectively called the *Viddalen Formation.* It is subdivided into two conformable members: a lower, *Tindeklypa Member,* some 500 m thick, which consists of agglomerate with

subordinate tuff and andesitic lava flows, and an upper, *Istind Member*, 340 m thick, consisting of alternating feldspathic quartzite, agglomerate, tuff and lava flows.

A continuous upward gradation from plutonic through hypabyssal to volcanic rock (near-surface intrusions) was detected in the 1 700 My mafic sill (*Krylen Intrusions*) at Jekselen. The lava flows in the Viddalen Formation are believed to be the volcanic equivalent of the Krylen Intrusions. Two samples of Krylen Intrusions from Jekselen and Istind were submitted for $^{40}Ar/^{39}Ar$ whole-rock age determinations. Ages of 1 339 ± 55 My and 603 ± 12 My respectively were computed, both being minimum ages resulting from complete overprinting by metamorphism.

The majority of the large mafic intrusions in the area are believed to have an age of around 1 000 My and are called *Ytstenut Intrusions.* Minor felsic intrusions are also included under this heading as they were found to represent only local remobilised differentiation products formed by the reaction between the mafic intrusions and the sediments. Two samples of Ytstenut Intrusions from Grunehogna and Ytstenut were submitted for $^{40}Ar/^{39}Ar$ whole-rock age determinations. Minimum ages of 832 ± 2 and 924 ± 4 My respectively were obtained; the latter age was regarded by the analysts as being close to the real date of intrusion.

The youngest rocks in the area are represented by minor dolerite dykes of Jurassic age and are called *Post-Ytstenut Intrusions.*

SAMEVATTENDE OORSIG

Nunataks binne 'n gebied van ongeveer 3 400 km^2 tussen breedtegrade 71°50' en 72°35' suid en lengtegrade 1°30' en 4°00' wes is geologies gekarteer deur die 12de Suid-Afrikaanse Nasionale Antarktiese Ekspedisie gedurende die somer van 1971–72. Die gebied is hoofsaaklik opgebou uit subhorisontale sandige en kleiige sedimente wat op 'n groot skaal binnegedring is deur dik mafiese plate en gange van Voorkambriese ouderdom. 'n Geïsoleerde opeenvolging agglomeraat, tuf en lawa met tussengelaagde sedimente in die boonste gedeelte is in die ooste en suide blootgestel. 'n Nuwe litostratigrafiese onderverdeling word voorgestel, gegrond op gedetailleerde bestudering van veldverhoudings, tesame met latere petrologiese studies en radiometriese ouderdomsbepalings.

Die oudste gesteentes in die gebied behoort tot die *Formasie Pyramiden* wat grotendeels uit veldspatiese grouwak en sliksteen bestaan. Korrelate van hierdie formasie is ontdek by Kjölrabbane, Babordsranten en by Nashornet en Viddalskollen. By laasgenoemde lokaliteit word die opeenvolging onderverdeel in 'n Onderste Lid, 140 m dik, afgeset onder lae-energie, diepwater toestande, en 'n Boonste Lid, 250 m dik, wat in vlakker water onder toestande van hoër energie afgeset is. Die oordekkende *Formasie Grunehogna* het die grootste verspreiding van al die sedimentêre formasies in die gebied en bestaan uit afwisselende, deurlopende lae ligkleurige sandige sedimente en donkerkleurige kleiige sedimente. Hierdie opeenvolging word konkordant oorlê deur die *Formasie Högfonna* wat onderverdeel word in 'n onderste lid (*Lid Borgmassivet*) bestaande uit veldspatiese kwartsiet, skalie en jaspisbevattende konglomeraat, en 'n boonste lid (*Lid Jekselen*) wat uit kalkryke jaspisbevattende sandige sedimente bestaan.

Al die bogenoemde formasies word by die *Groep Ahlmannryggen* ingesluit. Daar word voorgestel dat die *Formasie Raudberget,* wat nie in die betrokke gebied blootgestel is nie, ook by hierdie Groep ingedeel word.

Die vulkanies-sedimentêre opeenvolging by Tindeklypa en Istind oordek die Formasie Högfonna waarskynlik konkordant en word gesamentlik die *Formasie Viddalen* genoem. Dit word onderverdeel in twee konkordante lede: 'n onderste of *Lid Tindeklypa,* ongeveer 500 m dik, bestaande uit agglomeraat met ondergeskikte tuf en andesitiese lawa, en 'n boonste of *Lid Istind*, 340 m dik, wat bestaan uit afwisselende lae veldspatiese kwartsiet, agglomeraat, tuf en lawa.

'n Ononderbroke opwaartse oorgang vanaf plutoniese, deur hipabissale tot vulkaniese gesteentes (vlak intrusies) is waargeneem in die 1 700 Mj mafiese plaat (*Krylen-intrusies*) by Jekselen. Die lawa-uitvloeiings in die Formasie Viddalen word beskou die vulkaniese ekwivalent van die Krylen-intrusies te wees. Twee monsters van gesteentes wat tot die Krylen-intrusies behoort en afkomstig is van Jekselen en Istind is onderwerp aan $^{40}Ar/^{39}Ar$ heelgesteente-ouderdomsbepalings. Ouderdomme van onderskeidelik 1 339 $\pm$ 55 Mj en 603 $\pm$ 12 Mj is verkry; beide is minimum ouderdomme wat die gevolg is van algehele oorstempeling deur metamorfose.

Die meerderheid van die groot mafiese intrusies in die gebied word gereken 'n ouderdom van ongeveer 1 000 Mj te hê en staan bekend as *Ytstenut-intrusies*. Kleiner felsiese intrusies word ook hieronder ingedeel aangesien daar bevind is dat hulle slegs lokale hergemobiliseerde differensiasieprodukte verteenwoordig wat ontstaan het deur die reaksie tussen die mafiese intrusies en die sedimente. Twee monsters van gesteentes wat tot die Ytstenut-intrusies behoort en afkomstig is van Grunehogna en Ytstenut is onderwerp aan $^{40}Ar/^{39}Ar$ heelgesteente-ouderdomsbepalings. Minimum ouderdomme van onderskeidelik 832 $\pm$ 2 Mj en 924 $\pm$ 4 Mj is verkry; laasgenoemde ouderdom is deur die ontleders beskou as baie naby die werklike ouderdom van die intrusie te wees.

Die jongste gesteentes in die gebied word verteenwoordig deur dolerietgange van Jurassiese ouderdom en word *Na-Ytstenut-intrusies* genoem.

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I. INTRODUCTION

A. General Information

As part of the earth science programme of the 12th South African National Antarctic Expedition, geological mapping was carried out in the Ahlmannryggen and the north-eastern Borgmassivet between latitudes 71°50' and 72°35' south and longitudes 1°30' and 4°00' west. The area is bounded on the west and the east by two large north-flowing glaciers, the Schyttbreen and Jutulstraumen respectively. The area investigated is situated on both sides of the Viddalen, a 20 to 30 km wide north-east flowing contributory of the Jutulstraumen (*Fig. 1*). Twenty separate nunatak groups within this area of approximately 3 400 km^2 were thoroughly investigated and mapped on a scale of 1:25 000. During the course of this field-work, a total distance of about 1 200 km was covered, using Muskeg snow-tractors and sledges as means of transport.

A new wintering-over base was erected at Grunehogna, Peak 1285. This base is ideally situated with respect to the area investigated and undoubtedly played a major part in the success and the scope of the mapping programme which lasted from August 1971 to January 1972. The following nunataks were investigated for the first time by a South African geologist: Nashornet, Viddalskollen, Dugurdspiggen, Lyftingen, Borghallbrotet and Snöhetta.

The mountain ranges of Western Dronning Maud Land between longitudes 1° and 4° west and latitudes 71° and 73° south comprise a Precambrian sedimentary – volcanic sequence with a maximum thickness of approximately 3 000 m. This sequence had been invaded at different times by predominantly mafic intrusions and was collectively named the Ritscher Supergroup by D.C. Neethling in 1970. Neethling's latest definition and subdivision of this supergroup is given in his Ph.D. thesis (1970), and these views have up to the present time been generally accepted (*Table 1*). From the following statement in Neethling's thesis it is clear, however, that he did not regard his interpretation as being the last word as far as the stratigraphic sequence in Western Dronning Maud Land is concerned:

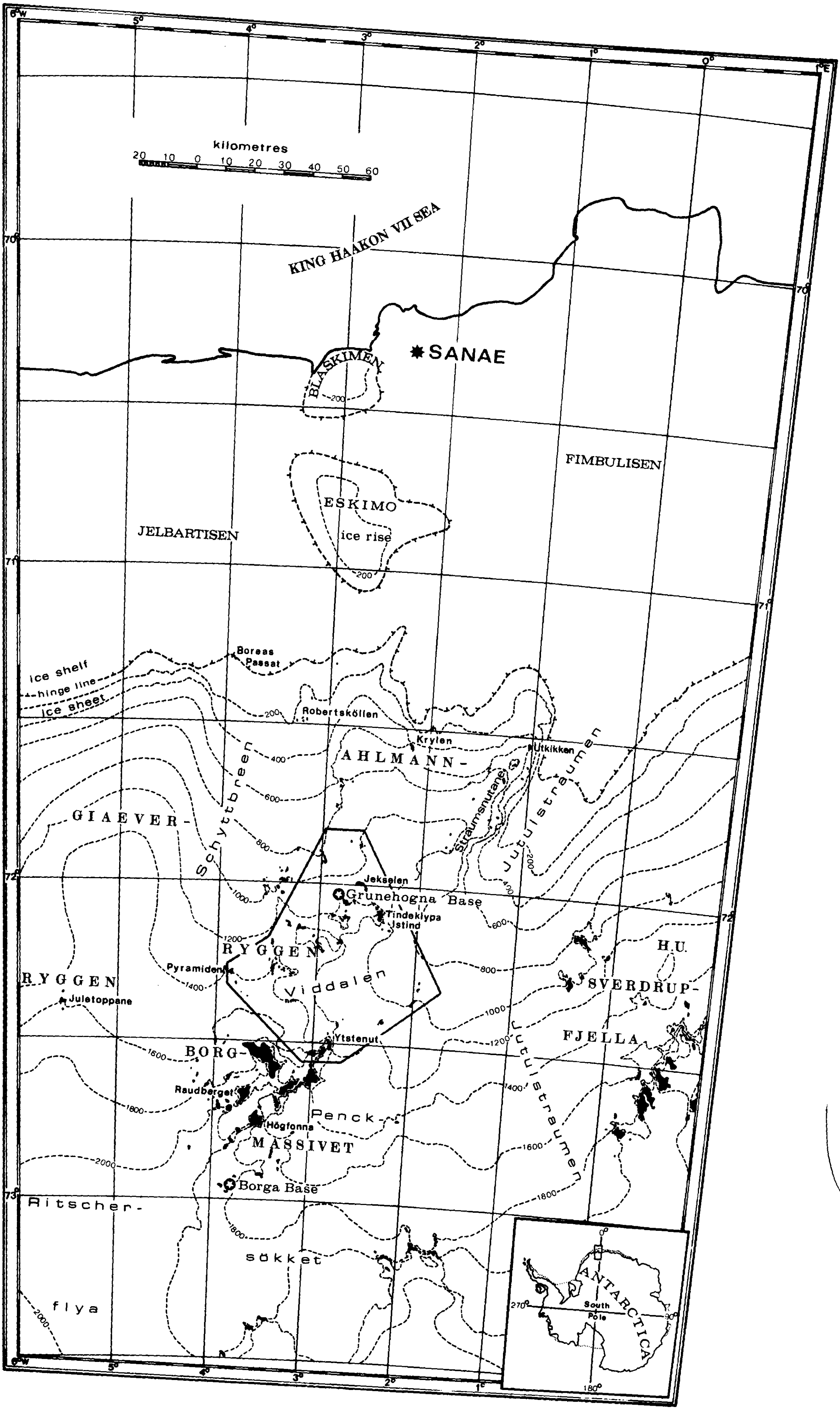

FIGURE 1. Map of part of Western Dronning Maud Land, showing the setting of the investigated area.

Table 1 – Lithostratigraphic subdivision of the Ritscher Supergroup (after Neethling, 1970)

Age	Group	Lithostratigraphic division	Thickness metres	Lithology
PRECAMBRIAN TO LATE PRECAMBRIAN (?) PALAEOZOIC (?)	Trollkjellrygg Group	Istind Formation	200	Arenite and arkose; intercalated lava flows
		Tindeklypa Formation	300	Boulder beds/pyroclastics (4 members)
		* Straumsnutane Formation	860	Altered mafic to intermediate lava flows, amygdaloidal and dense; pillow lavas and tuff (4 members)
	*Jutul Group	Jutul Volcanics	?	Altered mafic to intermediate lava
		Fassett Volcanics	c.200	
		Utkikken lava?		
	Ahlmannrygg Group	Raudberg Formation	300-500	Red bed facies sediments; arenite, argillites, polymict conglomerate and intraformational, mud-fragment conglomerate
		Högfonna Formation	650	Tuffaceous quartz arenite parted by mud-stone and subgraywacke; red beds; jasper polymict conglomerate bands; intraforma-tional mud-fragment beds
		Schumacher Formation	450	Subgraywacke, argillite and mudstone; cyclically deposited siltstone and arkose
		*Pyramiden Formation	300	Altered subgraywacke, arenite and siltstone monomict flat-pebble conglomerate

* Correlation uncertain

> "If some of these proposed subdivisions do indeed prove to be speculative, and some of them no doubt are, the proposed stratigraphic column provides a challenging framework within which future expeditions to Queen Maud Land could plan their fieldwork."

The author accepted this challenge and field observations made by himself and his colleague, Mr. A.W.W. Paterson, proved beyond any doubt that the presently accepted stratigraphic column requires a number of readjustments.

The area mapped by the author can be regarded as the key to most of the problematic stratigraphic relationships which have up to now prevented the construction of a satisfactory picture of the geological history of the area as a whole. The readjustments proposed by the author apply especially to the relative as well as the absolute ages of formations belonging to the upper part of the "supergroup". With the exception of two, all formations of the "Ritscher Supergroup" are represented in the area investigated, and as field evidence has subsequently been supported by four $^{40}Ar/^{39}Ar$ age determinations, the author feels justified in proposing a revised stratigraphic column (*Table 2*).

In doing so, it was necessary to rename and/or redefine most of Neethling's unit terms; not only to incorporate new information, but also to comply with the currently accepted South African code of stratigraphic terminology and nomenclature as based on recommendations of the International Subcommittee on Stratigraphic Classification. So, for instance, it was found that the revised lithostratigraphic subdivision of the sedimentary-volcanic rocks in Western Dronning Maud Land does not, and never did justify the designation of a rank term "Supergroup" to the succession as a whole. Furthermore, the name of the supergroup proposed by Neethling *viz.* "Ritscher", is not a geographical name and is therefore not allowed in formal lithostratigraphic nomenclature. Although Neethling derived this name from Ritscherflya, a plateau region to the south-west of the Ahlmannryggen, "Ritscher" was the name of the leader of the Neu Schwabenland Antarctic Expedition (1939), and it can consequently not be used to name a lithostratigraphic unit. Most of the stratigraphic units which were grouped under the Ritscher Supergroup have now been regrouped under a newly defined "Ahlmannryggen Group".

Table 2 – A revised lithostratigraphic subdivision of the rock units in the Ahlmannryggen and Borgmassivet

Post-Ytstenut Intrusions (191,5 ± 3,7 My)

*Straumsnutane Formation (856 ± 30 My)

Ytstenut Intrusions (1 030 ± 70 My)

Member	Formation	Intrusions
Istind Member Tindeklypa Member	Viddalen Formation	Krylen Intrusions (1 700 ± 130 My)

Member	Formation	Group
	*Raudberget Formation	AHLMANNRYGGEN GROUP
Jekselen Member Borgmassivet Member	Högfonna Formation	
	Grunehogna Formation	
Upper Member Lower Member	Pyramiden Formation	

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* Not represented in the area investigated

It is sincerely hoped that the facts presented in this thesis will not only cast light on some of the many problematic relationships in the area, but will also serve as a guide and a reference for future geologists investigating adjacent areas. However, no author who presents a theory or interpretation based on field observations in Antarctica should fail to recognise the fact that his observations were made in a hostile environment under severe climatic conditions. Failure to do so might lead to overconfidence in his statements, which in turn might discourage future investigators to criticise his work. The author therefore wishes this thesis to be regarded as just another small contribution to a better understanding of the geology of the ever-challenging continent, Antarctica.

B. Previous Investigations

Scientific work in Dronning Maud Land commenced at the end of 1939 when a German expedition under Captain Ritscher mapped the entire area topographically by means of aerial photography. The author had the privilege of meeting Mr. R.H. Schirmacher, who was one of the two pilots of this expedition, and according to information supplied by him, no geological investigations apart from aerial observation was carried out by the geologist who accompanied the expedition.

Ten years later, in 1949, the extremely well-equipped and competent Norwegian-British-Swedish-Antarctic Expedition (N.B.S.A.E.) continued the work of the first pioneers. During the course of two field seasons, the geologists of the expedition, E.F. Roots and A. Reece geologically mapped an area much larger in extent than what has been mapped by South African geologists during sixteen successive expeditions. It is obvious that not much detailed work could be accomplished during a regional survey of this nature, but the credit nevertheless goes to Roots who published the first geological map of the area in 1953 and also proposed the first subdivision of the geological formations referred to at present as the Ahlmannryggen Group.

Apart from geology, the N.B.S.A.E. also did invaluable work in the fields of meteorology, seismic determination of the thickness of the ice cover, glaciology and topographical survey. Especially the latter is of the utmost importance to South African expeditions as the series of 1:250 000 maps published by the Norsk Polarinstitutt in 1961 still forms the basis of present-day geological mapping. Field experience has proved these maps to be extremely accurate. The original names given by members of this expedition to the various topographical features, will be used in this thesis.

A Norwegian expedition established a base on the Fimbulisen in 1958, but no significant geological work was undertaken before the first South African National Antarctic Expedition (S.A.N.A.E.) took over the Norwegian base at the end of 1959. Since that date, a continuous earth science programme has been maintained during the course of sixteen successive expeditions. The following 23 geologists have taken part in the investigations up to the beginning of 1976.

V. von Brunn (1960–61); B. Butt (1961–62); D.C. Neethling (1962–63); O. Langenegger (1963–64); A. du Plessis (1964–65); W.H. Pollak (1965–66); E. de Ridder and H.A. Bastin (1966–67); J.A. Retief and C.S. Kingsley (1967–68); A.P.H. Aucamp and B.R. Watters (1968–69); L.G. Wolmarans and A.P.H. Aucamp (1969–70); H. Kahle and D. Vaclavik (1970–71); J.H. Bredell and A.W.W. Paterson (1971–72); C.L.J. Minnaar (1972–73); C.Z. van Zyl (1973–74); R.D.J. Gavshon and J.M. Erasmus (1974–75) and R.G. Heard and G.P. Meineke (1975–76).

Unfortunately, the number of geological publications which resulted from these investigations do not compare very well with the impressive list of geologists mentioned above. There are several reasons for this, the most important being failures in logistic support, especially during the early years, and loss of interest by expedition geologists after return from Antarctica. In the majority of cases, processing of data did not get further than an interim report, while much of the collected information remained hidden in field note books.

Dr. D.C. Neethling, in his capacity as co-ordinating geologist, contributed enormously, however, by publishing numerous papers amongst which an extremely comprehensive Ph.D. thesis. He also succeeded in keeping the earth science programme on an internationally competitive level by actively participating in international activities on polar research. E. de Ridder also made a valuable contribution in the form of a M.Sc. thesis on the sedimentary sequence in part of the Borgmassivet. Accounts of geological investigations in the form of short published papers have been given by Von Brunn (1964), Aucamp and Wolmarans (1970), Watters (1972), Aucamp (1972), Bredell (1973) and Van Zyl (1974).

Russian Antarctic expeditions started geological investigations in Dronning Maud Land in 1958. Although they concentrated mostly on the H.U. Sverdrupfjella to the east of the Jutulstraumen, their investigations also included parts of the Ahlmannryggen. They carried out mapping on a very regional scale (1:1 000 000), and descriptions of geological features in the Ahlmannryggen, especially as far as locality is concerned, are extremely vague. Accounts of these investigations have been given *inter alia* by M.G. Ravich and D.S. Soloviev (1966).

Previously investigations (if any) in specific areas dealt with in this thesis, will be discussed in more detail under the relevant headings.

C. Mapping Techniques

Maps on a scale of 1:250 000 compiled from oblique aerial photographs and field-work done by the Norwegian-British-Swedish Antarctic Expedition (1949–1952) and published by the Norsk Polarinstitutt (1961), were enlarged by means of a grid system to a scale of 1:25 000. These maps were used as base-maps for geological mapping. For the purposes of this thesis, however, the maps were afterwards reduced to a scale of 1:50 000. In most cases it was found necessary to alter the outlines of nunataks somewhat in order to give a more realistic presentation. In addition to these alterations, wind-scoops, blue ice-fields and moraines were added, as well as smaller outcrops which are not present on the original maps. The original 100 metre interval contours were retained, but the areas around nunataks were sketch-contoured to give a better idea of the topography. On the nunataks themselves, contours were omitted to avoid confusion with geological contacts. The only topographical features indicated on the nunataks are prominent peaks and ridges.

In order to add to the limited amount of detail that can be fitted on to plan drawings, a set of side-view drawings were compiled (at least one of each nunatak). These drawings were constructed from sketches and colour-slides taken in the field and show all geological relationships and structures as they occur in the actual outcrop. Interpolations of contacts and other features covered by snow or scree are indicated by dotted lines. Drawings of individual significant outcrops were also made to serve as an aid in the description of the geology. It is important to note that the side-view drawings are not necessarily on the same scale, as the geological maps. In the case of a complicated structure such as the south-eastern part of Jekselen, a larger-scale map was drawn in order to present more detail.

The fact must be stressed that the abovementioned is not geological mapping in the accepted sense. The only survey equipment used, were prismatic compasses to fix geological contacts and small outcrops not present on the original maps. What has been done, must therefore essentially be regarded as sketch-mapping and should be seen in the light of the abnormal conditions under which it was carried out.

The grid by means of which the maps were enlarged, also served as a system for indicating the locality of samples taken. Around each nunatak-group, a rectangular block was drawn and a "block number" allocated to it – usually the first letter of the name of the main nunatak in the group. The grid within this block was then marked with numbers from south to north and alphabetically from west to east. Each small square in the grid represents an area of 500 x 500 m and the position from which samples were taken could then be given accurately to within this area. Samples were marked accordingly, for example (J) B3/G5 would be the fifth geological sample taken from the Jekselen block and its grid position is B3. For age dating samples, the symbol α was used instead of G.

This method of marking samples was found to be extremely practical and useful and it has its main advantage in the fact that these samples can always be used by future geologists with no fear of possible misinterpretation as regards the exact locality from which they originate.

The grid system is also referred to in the description of the geology of the different nunataks, as it saves a lengthy description of the position of the outcrop under discussion.

D. Acknowledgements

Geological investigations in Western Dronning Maud Land are directed by the Antarctic Section of the Geological Survey, Department of Mines, under the aegis of the South African Scientific Committee for Antarctic Research (SASCAR). Logistic support is provided by the Department of Transport. I am indebted to these organisations for making this research possible.

I wish to express my sincere appreciation to all members of S.A.N.A.E. 12 for their assistance and moral support during the expedition. In particular I would like to thank my field companions, Messrs. A.W.W. Paterson, T.G. Schaefer, F.W. Ludik and P.H. Bennett, with whom I spent eleven months in the field and without whose co-operation geological investigations would not have been possible. A special word of thanks to my fellow geologist, Andrew Paterson, for his keen interest and numerous stimulating discussions. His companionship in the field is very much appreciated, as well as the major part he played in the final preparation of the maps and figures.

I would also like to express my gratitude to Dr. L.E. Kent, Director of the Earth Science Program, and Mr. L.G. Wolmarans, co-ordinating geologist of the Antarctic Section of the Geological Survey, for their constant interest during the expedition and the subsequent interpretation of the findings. I am also indebted to Dr. J.F. Enslin, Director of the Geological Survey, for his permission to use the data which was compiled while in his employ as a thesis.

Finally I wish to thank Professor D.J.L. Visser and Mr. C.D. Potgieter of the University of Pretoria for their guidance during the completion of this project, as well as my wife Rina for her encouragement and assistance during the preparation of the manuscript.

II. THE PYRAMIDEN FORMATION

A. General Discussion and Type Locality

This formation was named after Pyramiden, a nunatak which strikingly resembles an Egyptian pyramid, and which is situated on the eastern margin of the Schyttbreen. A succession, approximately 200 m thick, of well-bedded feldspathic graywacke and intercalated dark shale with mud-pebble conglomerate is exposed at this, the type locality. The same sequence had also been known to occur at the nunataks Sphinksen and Knallen to the immediate south and west of Pyramiden. The present investigation proved however, that the regional distribution of the Pyramiden Formation is much more extensive. The most significant finding in this connection was the discovery of a lithologically and petrologically similar sequence at Nashornet and Viddalskollen at the confluence of the Viddalen and Jutulstraumen glaciers. Seeing that detailed accounts of the sequence at the type locality have been given by Pollak (1967) and by Neethling, Kingsley and Aucamp (1968a), the present investigation at Pyramiden involved only a brief study of the sediments in order to establish a correlation with the newly discovered exposures.

The Pyramiden Formation has not yet been found in direct contact with any of the other formations in the area, and its exact position within the Ahlmannryggen Group has not been established conclusively. It is tentatively believed to represent the lowermost sedimentary sequence of the Group.

B. The Pyramiden Formation in the Nashornet-Viddalskollen area

The area under discussion comprises four nunataks (the Nashornkalvane twins, Nashornet and Viddalskollen) which are situated on a SW-NE-trending ridge at the confluence of the Viddalen and Jutulstraumen glaciers. These nunataks are separated from the rest of the Ahlmannryggen by the 20 to 30 km wide, north-east flowing Viddalen.

1. Previous Investigations

The area has previously been visited by geologists of the Norwegian-British-Swedish-Antarctic Expedition, (Roots, 1953 and 1969) and by Russian expeditions, (Ravich and Soloviev, 1966). No detailed information has, however, been published, nor have any maps been compiled of the individual nunataks.

The different views of previous authors on the subject can briefly be summarised as follows:

a. Roots, E.F.

No attempt was made to assign the sediments to any of the established formations of the "Ahlmannrygg Group" and they are described as "undifferentiated clastic rocks". All the sedimentary rocks of the northern Ahlmannryggen are classified under this heading.

b. Ravich, M.G. and Soloviev, D.S.

"In our opinion, the oldest formations exposed in the present-day erosional section include the sheets of greenstone rocks in the northeast of the region (Mount Utkinen and others) and the grayish-greenish siltstones and argillites of Mount Widdalskollen containing early Riphean algae of the Rifenites group and remains of Laminarites .....". They further imply that these rocks are overlain by the "Tindeklypa Formation", which in turn is overlain by sedimentary rocks of the "Ahlmannrygg Group".

c. Neethling, D.C.

For some reason not mentioned in the text, Nashornet is indicated on his map as a type locality of the "Trollkjellrygg Group", which is a volcanogenic sequence.

From these contradictory opinions, it is clear therefore that the age and the correlation of the rocks in the Nashornet-Viddalskollen area have given rise to a lot of confusion. This can to a large extent be attributed to a lack of information on these isolated nunataks.

The present investigation revealed a sedimentary succession with a total thickness of approximately 390 m, which had been intruded by a mafic sill, about 150 m thick. The sedimentary sequence has been subdivided on a lithological basis into two conformable members; a *Lower Member*, some 140 m thick, consisting of feldspathic graywackes and siltstones which had been deposited under low-energy, deep-water conditions, and an *Upper Member*, about 250 m thick, consisting of feldspathic graywacke, siltstone and conglomerate which had been deposited in shallower water under slightly higher energy conditions (*Table 3*).

2. The Lower Member

a. Lithology

Rocks belonging to this Member are best exposed at Nashornkalvane (peak 1016) (*Map 1* and *Fig. 2*). This is the northernmost nunatak of the group and consists entirely of sedimentary rock. A succession of approximately 140 m of well-bedded, dark brown, weathered feldspathic graywacke and intercalated dark green laminated siltstone is exposed. Individual beds vary in thickness from about 0,10 m to 3,0 m and show very good lateral continuation. Four lithologically different types of graywacke were recognised, *viz.* dark gray homogenous, light gray homogeneous, dark gray with light gray spots and faint banding, and light gray with dark gray bands. Beds of light gray quartzite up to about 0,15 m thick are present locally, but are not very persistent and pinch out laterally. Thin quartz veins and quartz joint-fillings are abundant in the lower part of the succession. Only minor epidotisation along joint planes was observed. Green copper carbonate staining is common throughout the succession, but is more conspicuous at the top of the nunatak. Small specks of disseminated chalcopyrite and pyrite are found in the graywacke, especially in the dark gray, homogeneous variety.

Table 3 – Lithological subdivision of the Pyramiden formation in the Nashornet-Viddalskollen area

	Locality	Distinctive lithological characteristics	Conditions at time of deposition	Approximate thickness (m)
UPPER MEMBER	On top of sill at Nashornet and Viddalskollen	(i) Conglomerates are abundant. (ii) Mud-cracks are present. (iii) Flow-ripples are rare, but do occur. (iv) Cross-bedding is well developed in the upper 80 m. (v) Laminated siltstone is rare. (vi) No sulphides are present.	High-energy conditions, shallow-water environment.	250
LOWER MEMBER	Nashornkalvane and below sill at Nashornet and Viddalskollen	(i) No conglomerates are present. (ii) No mud-cracks are present. (iii) Only oscillation-ripples were observed. (iv) Cross-bedding is rare and poorly developed. (v) Laminated siltstone is abundant. (vi) Disseminated copper and iron sulphides are present.	Low-energy conditions, deeper water environment.	140

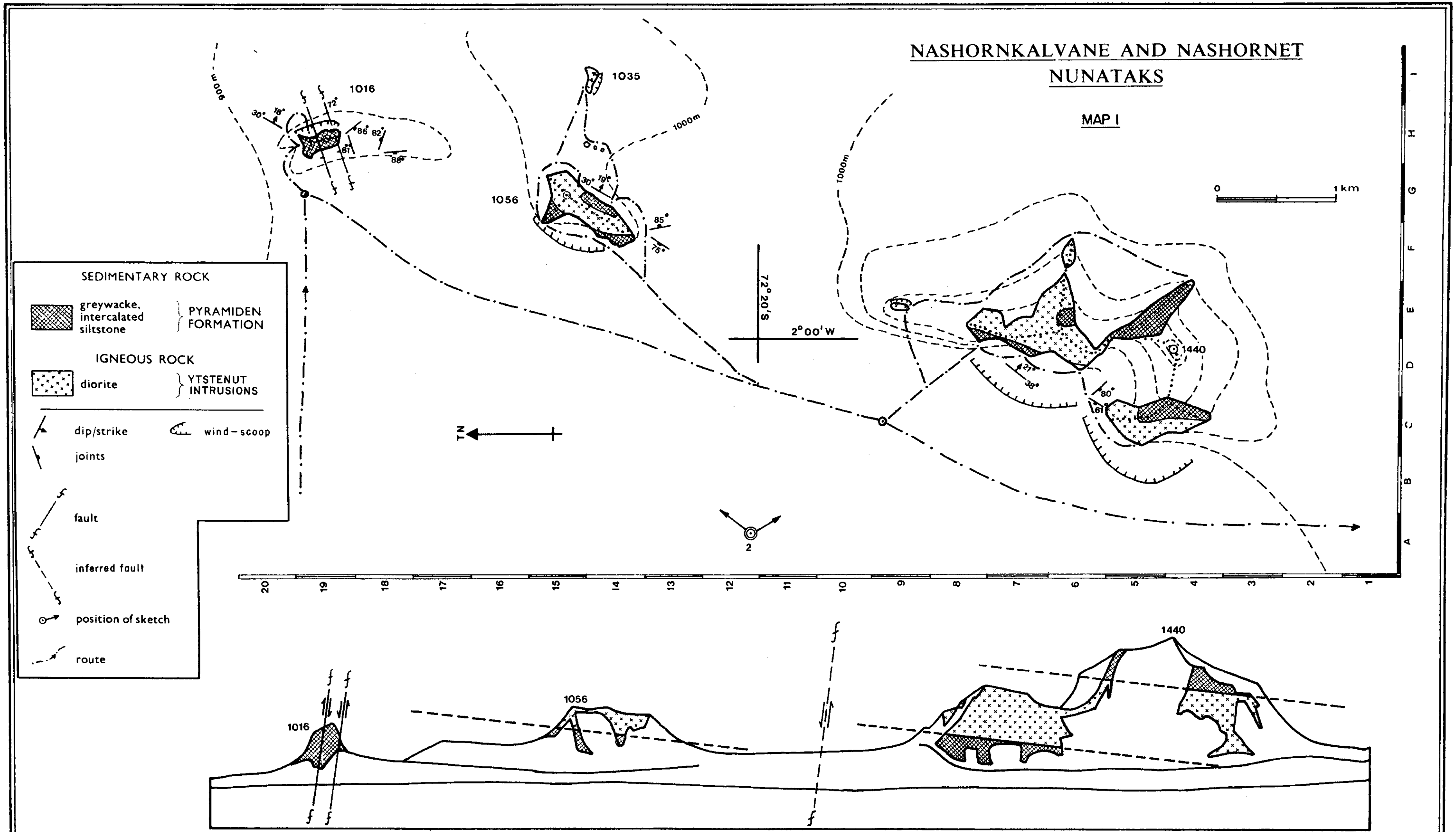

NASHORNKALVANE AND NASHORNET NUNATAKS
MAP I
0
1 km
SEDIMENTARY ROCK
greywacke, intercalated siltstone
PYRAMIDEN FORMATION
IGNEOUS ROCK
diorite
YTSTENUT INTRUSIONS
dip/strike
wind-scoop
joints
fault
inferred fault
position of sketch
route
1016
1035
1056
1440
1000m
900m
72°20'S
2°00'W
TN
2
1440
1056
1016

FIGURE 2

The scarcity of sedimentary structures and the absence of conglomerates are very characteristic of the Lower Member and serve as the main criterion by which it can be distinguished from the Upper Member. Ripple-marks are rare and only two examples were observed *in situ*. These were oscillation-ripples and so symmetrical that the paleocurrent direction could only be guessed. The strike of these ripple-marks was measured as 62° and 07° respectively.

Cross-bedding is also extremely rare and so poorly developed that the determination of paleocurrent directions is virtually impossible.

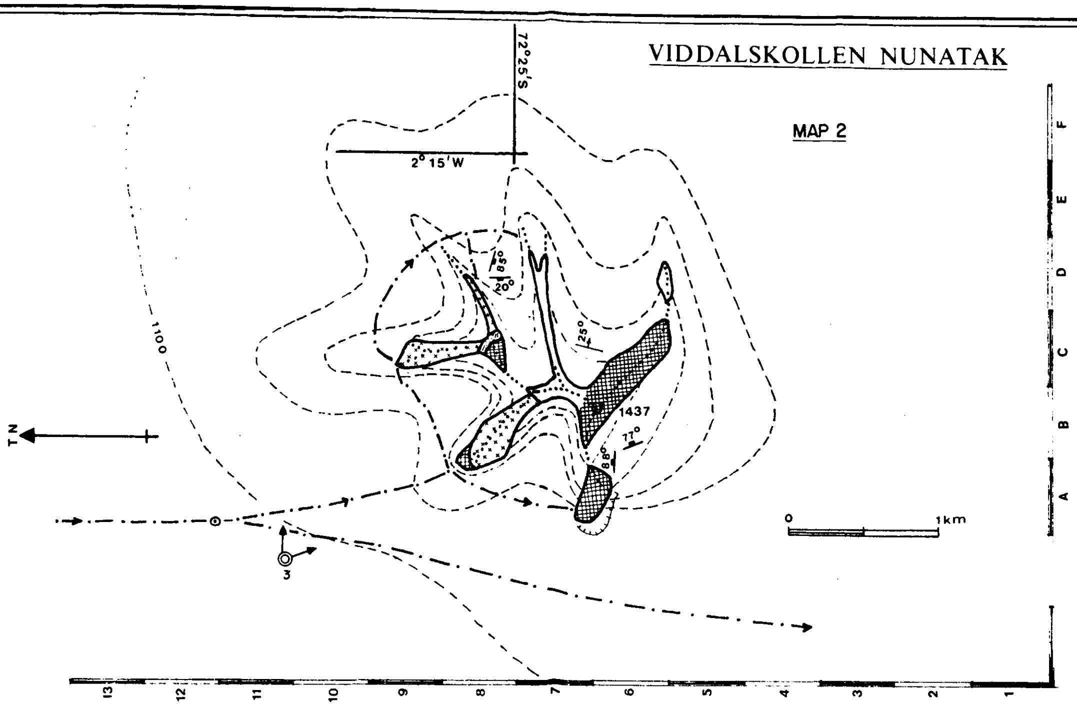
b. Metamorphism on Intrusive Contacts

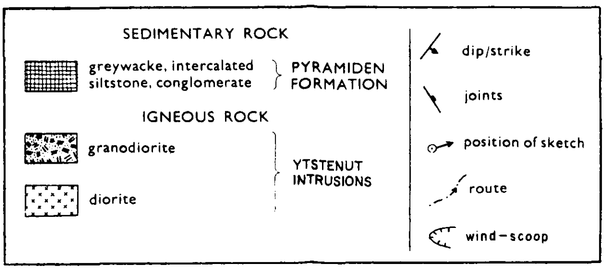
Where the Lower Member is found in contact with the lower part of the intrusive sill as at Nashornkalvane (peak 1056) and Nashornet, a definite zone of metamorphism of the sedimentary rocks was observed. For a distance of about 2 m from the contact, the siltstones had been altered to black slate and locally to dark green phyllite. The latter has a silky lustre and often exhibits undulating schistosity. Well developed pyrite crystals up to 2 mm in diameter are present in the phyllite. Quartz veins, up to 0,3 m thick, are abundant in this zone and are usually found along bedding planes in the slate. Well developed cleavage is common in the slates, but no signs of metamorphism are, however, noticeable in the graywackes, even where they are in direct contact with the sill.

The localised occurrence of the phyllites, together with the relatively undisturbed nature of the sedimentary succession as a whole, are indicative of metamorphism caused by the combined effects of temperature and pressure during the intrusion of the sill, rather than of regional dynamothermal metamorphism.

3. The Upper Member

This Member is exposed both at the southern side of Nashornet and at Viddalskollen. The better exposure is at the latter locality where an approximately 250 m thick succession was investigated. The following sequence from the base up to the summit (peak 1437) was established (*Map 2 and Fig. 3*):


VIDDALSKOLLEN NUNATAK
MAP 2
72°25'S
2°15'W
1100
1437
85°
20°
25°
77°
88°
TN
3
0
1km
A
B
C
D
E
F
13
12
11
10
9
8
7
6
5
4
3
2
1


SEDIMENTARY ROCK
greywacke, intercalated siltstone, conglomerate
PYRAMIDEN FORMATION
IGNEOUS ROCK
granodiorite
diorite
YTSTENUT INTRUSIONS
dip/strike
joints
position of sketch
route
wind-scoop

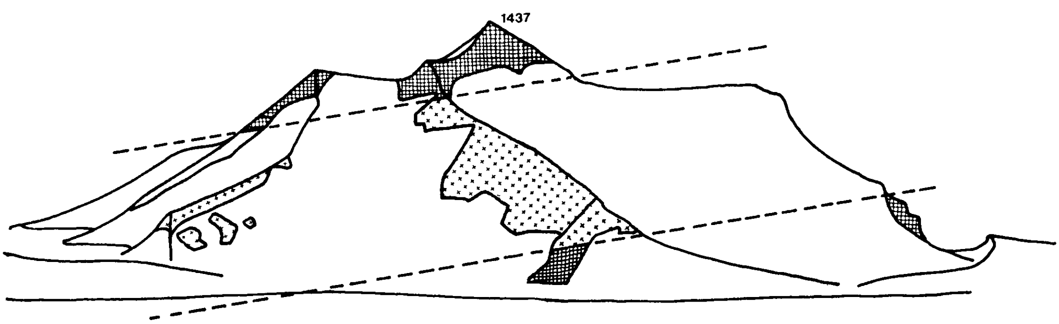

1437

FIGURE 3

Elevation above snow surface (m)	Thickness (m)	Lithological description
210–250	40	Dark gray, epidotised, banded graywacke with occasional inclusions of flat mudstone fragments. Cross-bedding is abundant and well developed.
209–210	1	Coarse-grained, epidotised graywacke containing conglomerate horizons about 10 cm thick. The pebbles consist of black slate and white vein-quartz, are fairly well rounded and up to 20 mm in diameter.
169–209	40	Dark gray graywacke with thin intraformational mud-fragment conglomerate. Cross-bedding units up to 1 m thick are conspicuous.
159–169	10	Dark gray graywacke with occasional inclusions of mudstone fragments.
157–159	2	Coarse-grained epidotised graywacke with conglomerate horizons containing well-rounded pebbles of black slate and white vein-quartz.
57–157	100	Alternating layers of dark gray homogeneous and banded graywacke with intercalated dark green siltstone. The banded graywacke is often epidotised and quartz veins are common. Closed joints (strike 17°) crossed by an open joint system (strike 142°) are often found on exposed bedding planes. Mud-cracks up to 0,15 m in diameter are abundant. Flow-ripples are rare. Green copper carbonate staining is visible locally.
7–57	50	Dark gray homogeneous graywacke with occasional quartz and slate pebbles.
5–7	2	Dark gray graywacke with intraformational mud-fragment conglomerate horizons up to 0,15 m thick.
3–5	2	Dark gray graywacke with flat, green chert pebbles up to 60 mm long.
0–3	3	Dark gray graywacke and siltstone with intraformational mud-fragment conglomerate. Epidotisation of the pebbles is common. Textures resembling "Rifenites" were found in this unit.

4. Petrology and classification

According to the classification of sedimentary rocks (Pettijohn, 1957) the arenaceous sediments of the Lower and the Upper Member fall within the feldspathic graywacke field (*Fig. 4*).

Apart from the quartz, feldspar and matrix, there is also a small percentage of rock fragments. The relative sizes of the small triangles in the Quartz-Feldspar-Matrix diagram give an indication of the percentage of rock fragments in each sample.

The feldspar is mostly untwinned albite, but a small number of clasts with albite twinning was observed. All of these have more or less the same composition (An_2 to An_{10}).

Apart from chlorite, which forms most of the matrix, the following accessory minerals were observed: calcite, actinolite, muscovite and epidote. Chert represents the "Rock fragments" fraction in the volumetric composition. The only opaque minerals detected were pyrite and chalcopyrite in rocks of the Lower Member.

The flaky chlorite crystals often penetrate the quartz grains. All the quartz and feldspar grains are angular. Maximum grain sizes in the feldspathic graywackes from both the Lower- and Upper Member are 0,1 mm for the chert grains and 0,2 mm for the quartz and feldspar grains.

5. Regional Correlation

The sedimentary succession at Nashornet and Viddalskollen is correlated with the Pyramiden Formation on account of striking lithological and mineralogical similarities. Comparisons were made from hand specimens, personal investigation of the Pyramiden Formation at the type locality, descriptions by previous geologists (Pollak, 1966; Neethling, Kingsley and Aucamp, 1968a) and from thin section analyses.

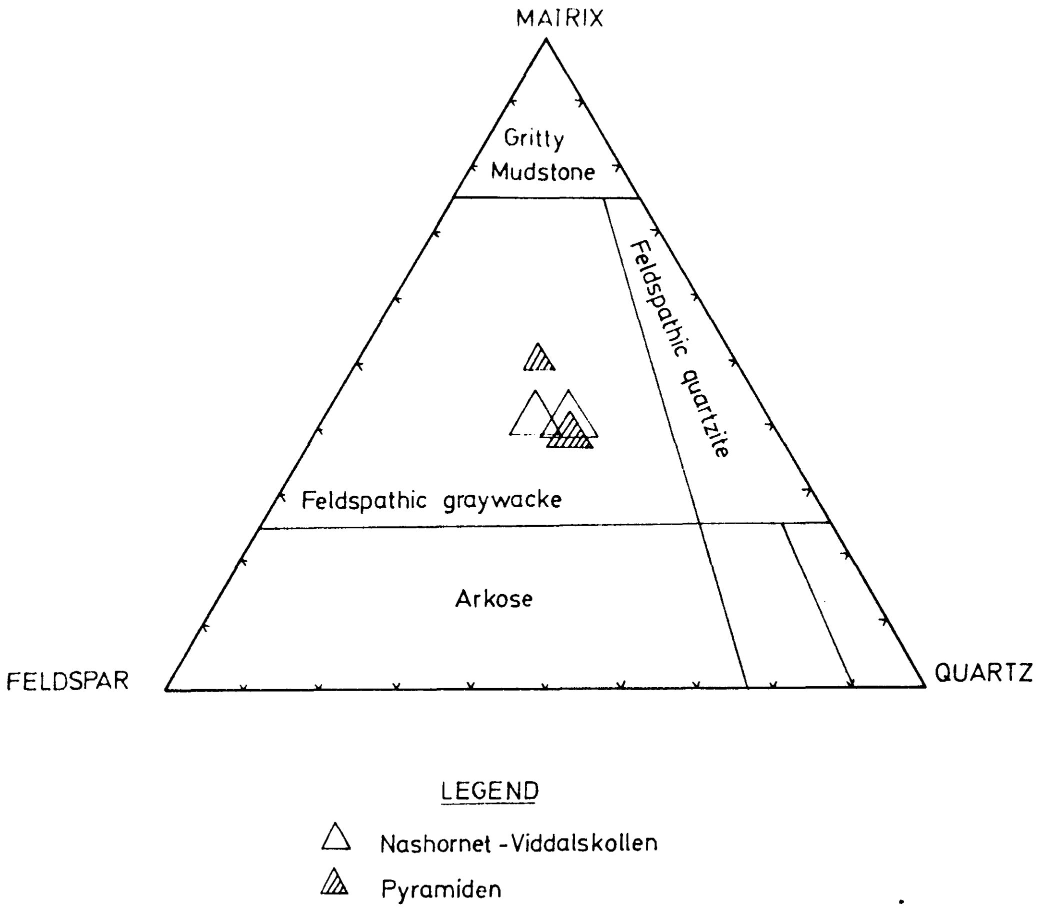


FIGURE 4. Triangular diagram (after Pettijohn) showing volumetric composition of Nashornet - Viddalskollen arenites in relation to that of arenites from Pyramiden

a. **Lithology**

Distinctive lithological features common to both the Nashornet-Viddalskollen sediments and the Pyramiden Formation at the type locality are:

(i) The rock types are mainly feldspathic graywacke and siltstone.

(ii) Sedimentary structures are scarce.

(iii) The presence of pyrite and chalcopyrite (only in the Lower Member at Nashornet and Viddalskollen).

(iv) The frequent occurrence of monomict, mud-fragment intraformational conglomerates (only in the Upper Member at Nashornet and Viddalskollen).

(v) The presence of chert in the arenaceous rocks.

(vi) The occurrence of light-coloured quartzite bands.

b. **Petrology**

Common features are:

(i) Arenaceous rocks from both localities can be classified as feldspathic graywackes (*Fig. 4*).

(ii) The composition of the feldspar grains is virtually the same. (An_{4-10} for Pyramiden and An_{2-10} for Nashornet).

(iii) Chlorite is the most abundant ferromagnesian mineral and is present as flaky crystals in the matrix.

(iv) The accessory minerals are the same: calcite, augite, actinolite, muscovite and epidote.

(v) Rocks from both localities had been subjected to greenschist facies metamorphism (Barrovian-type facies series – Winkler, 1967). They most probably belong to the quartz-albite-muscovite-chlorite subfacies.

(vi) Maximum grain sizes in the arenaceous rocks are 0,2 mm for the feldspar grains and 0,3 mm for the quartz and chert grains (Pyramiden); and 0,1 mm for the chert and 0,2 mm for quartz and feldspar grains (Nashornet).

(vii) Poor sorting and rounding of the grains are characteristic.

(viii) The material for both successions was derived from a granitic source located to the west. Pebbles of granite were observed in the sediments at Pyramiden.

Modal analyses were done on four representative arenaceous samples from Nashornet and Pyramiden. On each thin section 1 000 counts were made, using a Swift automatic point counter (*Table 4*). The data were plotted on a Quartz-Feldspar-Matrix diagram for comparison (*Fig. 4*). As can be seen from the relative sizes of the small triangles, the Pyramiden rocks contain a few per cent more rock fragments than those from Nashornet. This is most probably due to the larger average grain size of the chert in the Pyramiden rocks.

6. Conditions of Deposition

Deposition started off with the filling of a deep basin where low-energy conditions prevailed. The scarcity of sedimentary structures and the presence of sulphides in the Lower Member are indicative of quiet sedimentation under deep-water, reducing conditions. The basin filled gradually and in the later stages periodical drying out and subsequent flooding took place. The Upper Member was deposited under these conditions of increased energy in the basin.

The sediments were most probably derived from a granitic provenance located to the west. This deduction is based on:

a. The high percentage of angular quartz and albite (An_2–An_{10}).

b. The presence of granite pebbles up to 20 mm in diameter in sediments of the Pyramiden Formation at the type locality.

c. Measurements of cross-bedding and ripple-marks gave a paleocurrent direction varying between ENE and SSE (74^o to 152^o).

d. A slight decrease in average grain size from Pyramiden in the west to Nashornet and Viddalskollen in the east.

7. Structure

a. Faults

No large-scale faulting was observed. The only faults found in outcrop were two parallel east-west-striking normal faults which cut through the central

Table 4 – Volumetric composition of arenaceous rocks from Nashornet and Pyramiden

	NASHORNET		PYRAMIDEN	
Sample No.	(N) H19/G2	(N) D7/G14	(P) J14/G1	(P) J14/G3
Quartz	22,5	31,3	28,9	24,5
Feldspar	24,7	29,2	23,3	28,1
Matrix	49,3	37,4	37,9	38,8
Rock fragments	3,2	1,6	8,8	8,0
Opaque	0,3	0,5	1,1	0,6
I.C.*	126	129	109	114

* I.C. = Identity change

and the southern part of nunatak 1016 at Nashornkalvane (*Map 1* and *Fig. 2*). The fault planes dip approximately 80° to the north and total displacement is only about 2 m. Slight monoclinical folding occurs on the downthrow side of the northernmost fault.

b. Dips of strata

The general dip of the sedimentary succession is between 18° and 25° ESE. A very slight change in the attitude of the beds was observed going from north to south along the nunatak range. In the northern part (Nashornkalvane), the shallowest dips were encountered (18° to 20°) and the direction of dip is more southeasterly, (strike 30° to 42°). Towards the south the dips get steeper and the strike changes to between 14° and 18°. The steepest dips were measured in the extreme south of the range at Viddalskollen, (24° to 25° east-south-east). Local deformation along intrusive contacts causes dips of as much as 45°.

c. Joints

Joints are well developed in the entire area in both sedimentary rocks and intrusive sill. A total of 65 joint measurements were taken and plotted on a rose diagram (*Fig. 5*). Although the number of measurements is very limited, three prominent joint directions are revealed, *viz.* N–S, NE–SW and E–W. The N–S trend seems to be the best developed and corresponds with the strike direction of the Jutulstraumen in this area. The strike direction of the Viddalen is displayed by the north-east – south-west trend. Both these glaciers are believed to follow lines of intense pre-glacial tectonic activity. These two trends (northerly and north-easterly) also correspond with two of the three major structural trends recognised by Neethling for the Ahlmannryggen (Neethling, 1970). The east–west direction appears to be more localised and coincides with the strike direction of the two parallel faults in the northern part of the area.

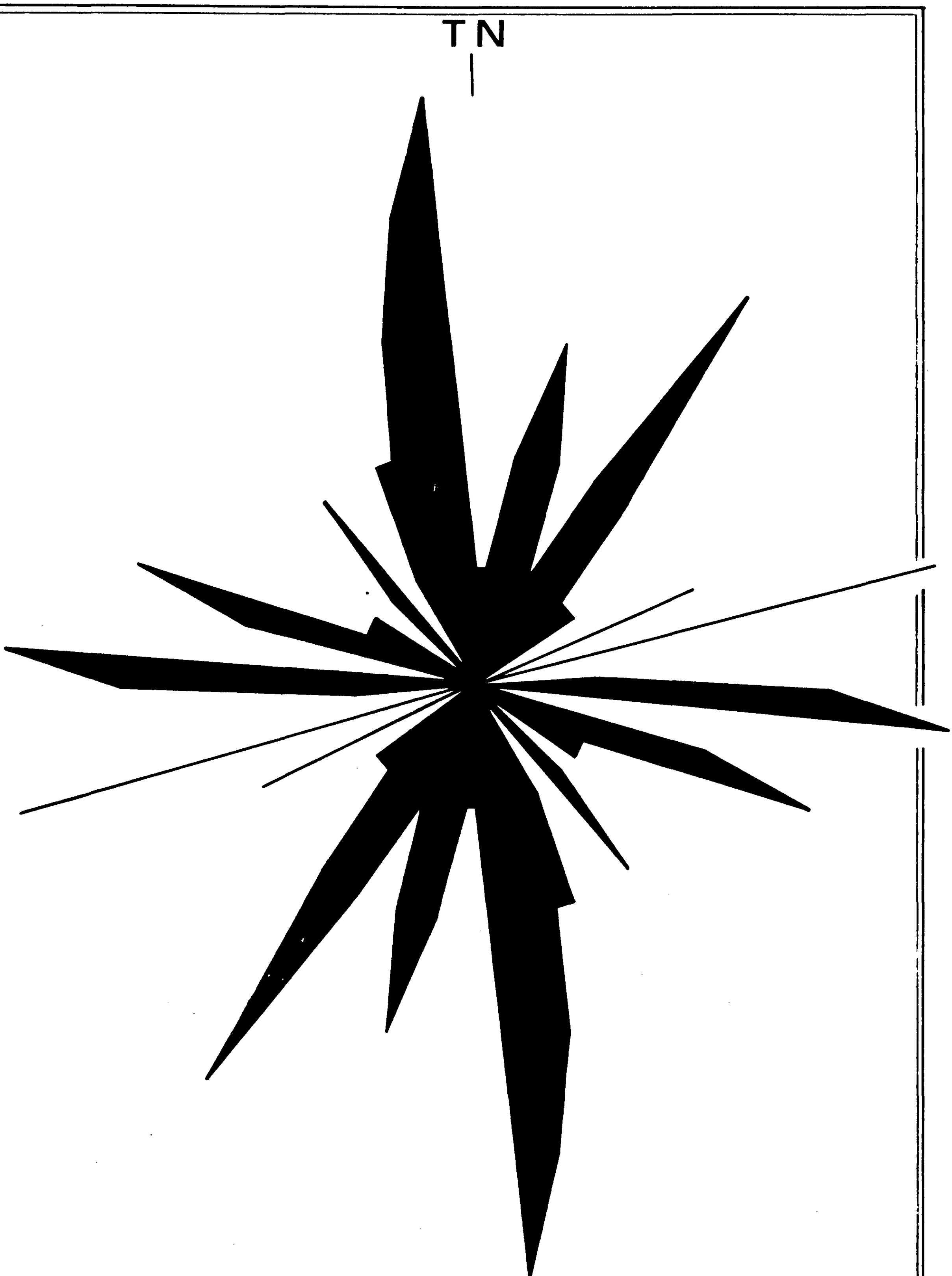


FIGURE 5. Rose diagram of joints in the Nashornet - Viddalskollen area

C. Correlates of the Pyramiden Formation at Other Localities

1. Kjölrabbane, peak 1611

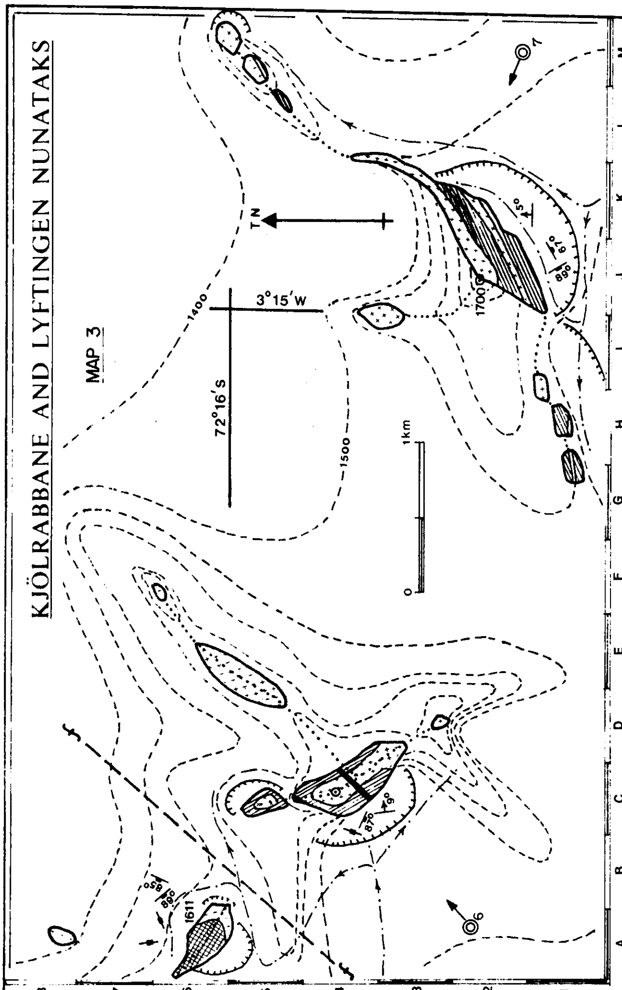
A succession of approximately 30 m of feldspathic graywacke with intercalated mud-fragment conglomerate is found on top of an intrusive sill at this locality (*Map 3* and *Fig. 6*). It is impossible to distinguish these sediments from those at the type locality in hand-specimen or in thin section. A normal fault with downthrow on the south-eastern side is inferred to account for the anomalous relative positions of sediments belonging to the Pyramiden and Grunehogna Formations at peak 1611 and the nunatak to the south-east.

2. Babordsranten

At this locality, an approximately 80 m succession of sediments identical to those at Kjölrabbane peak 1611, is exposed on the eastern side of the nunatak. The sediments have been intruded by a mafic dyke which dips to the south-east (*Map 4* and *Fig. 8*). The predominant sedimentary rock types are banded and homogeneous feldspathic graywackes, with subordinate dark shale. Monomict mud-fragment conglomerate is common in the homogeneous feldspathic graywacke horizons. Pebbles are very flat (1 to 2 mm thick), well rounded and range in size from about 2 mm to 50 mm in diameter. The presence of these flat-pebble conglomerates, which are so characteristic of the sediments at Pyramiden, leaves little doubt that the sedimentary succession at Babordsranten is also a correlate of the Pyramiden Formation.

The sediments are epidotised, but not as much as those at Viddalskollen. Thin quartz veins are abundant and malachite staining is common along joints.

Flow-ripple-marks strike between 118° and 52° and indicate a source-area located between SSW and SE. This is anomalous as it differs from the normal west to east or north-west to south-east paleocurrent directions measured in rocks of the Pyramiden Formation at other localities. It is, however, to be expected that fluctuations in current direction will take place during the shallow-water conditions under which these sediments were deposited.



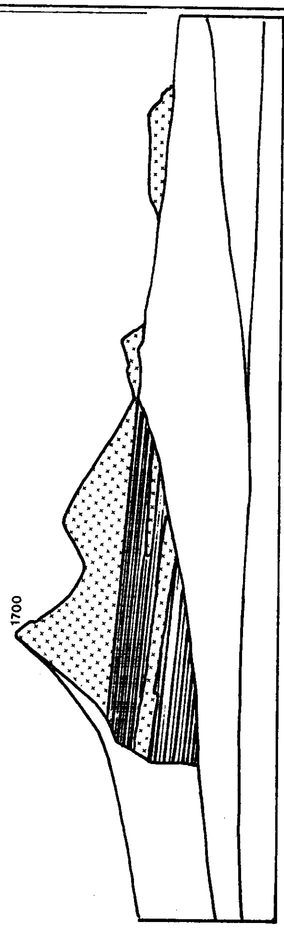


FIGURE 7

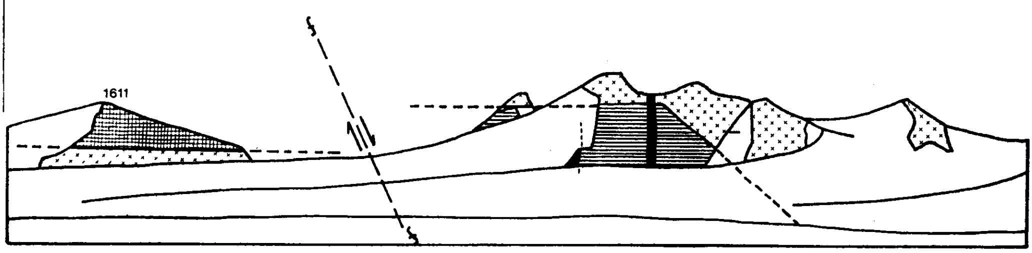
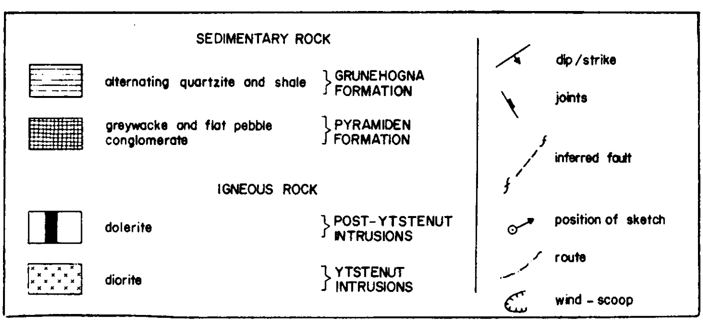
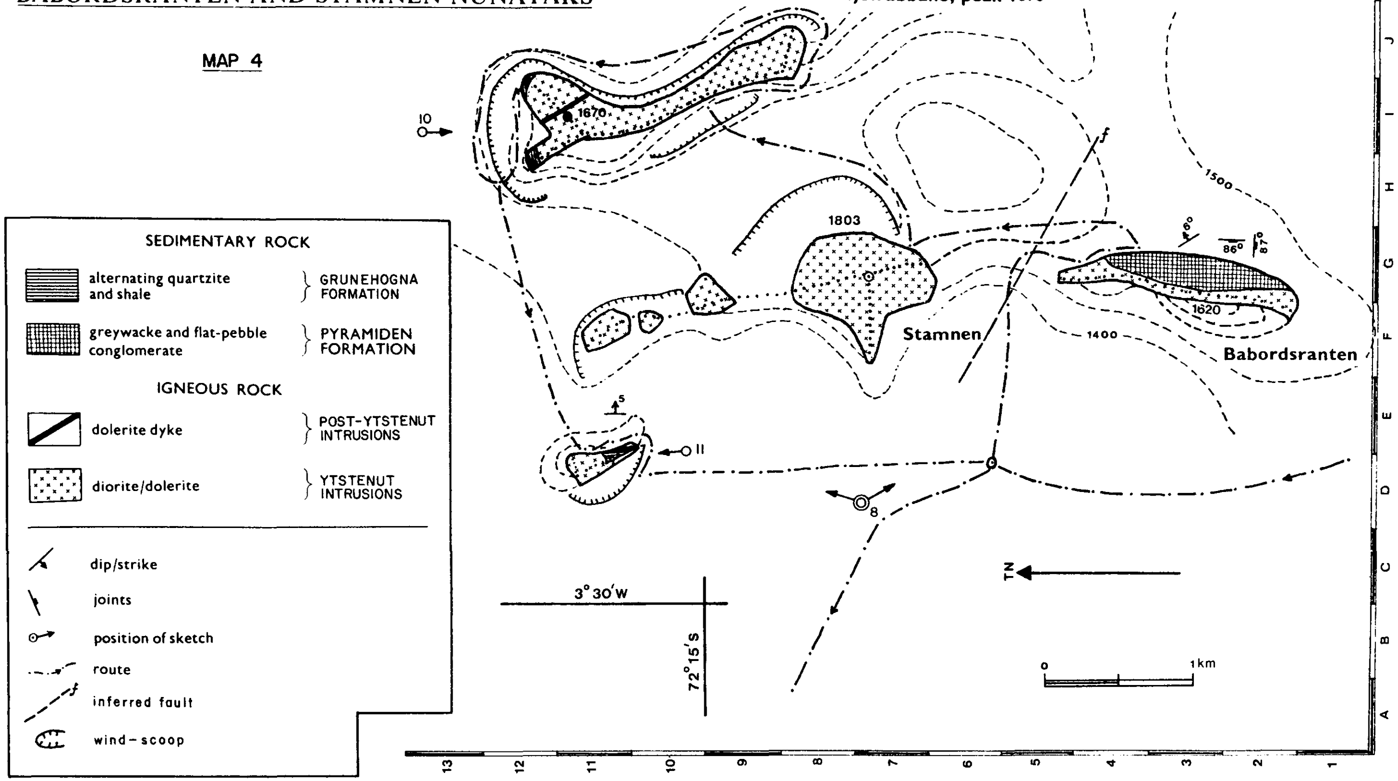


FIGURE 6



BABORDSRANTEN AND STAMNEN NUNATAKS



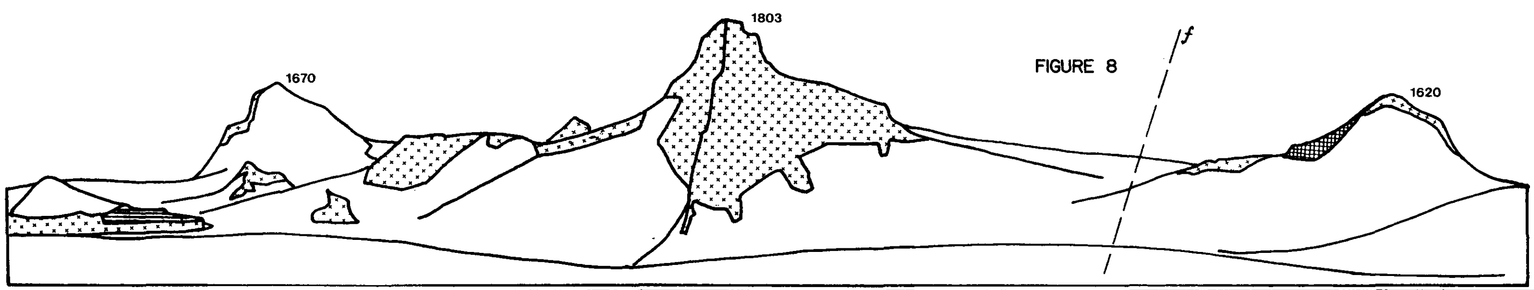


FIGURE 8

The average dip of the beds is 6^{o} east-north-east, which differs from the general south-easterly dip of the strata in the rest of the Ahlmannryggen. This can be attributed to the transgressive nature of the intrusion which must have caused local tilting of the beds. The usual manner of intrusion of the larger sills in the rest of the area is concordant.

III. THE GRUNEHOGNA FORMATION

A. General Discussion and Type Locality

This formation has up to now been known as the "Schumacher Formation" and the name was derived from Schumacherfjellet, a prominent nunatak in the north-western part of the Ahlmannryggen (Neethling, 1970). The nunatak owes its name to Nils Jørgen Schumacher, one of the meteorologists of the Norwegian-British-Swedish Expedition, and as the formation has therefore, strictly speaking, been named after a person (Schumacher) and not after the geographic locality (Schumacherfjellet), the use of the term "Schumacher Formation" is not feasible in formal lithostratigraphic nomenclature. The easiest solution to this problem would seem simply to change the name to "Schumacherfjellet Formation". However, since Neethling's visit to Schumacherfjellet in 1962, subsequent investigations have proved that the "Schumacher Formation" is much better exposed in other parts of the Ahlmannryggen, and the relatively small exposure at Schumacherfjellet can definitely no longer be regarded as the type locality of this stratigraphic unit. While it has therefore become necessary to change the name of this formation to comply with formal lithostratigraphic nomenclature, it was considered appropriate to use an entirely new name which is derived from the location of the stratotype. It has been found that the most typical and significant exposure of this formation is at the Grunehogna group of nunataks ($72^{o}02'$ S, $02^{o}48'$ W). Although thicker successions are found at other localities in the Ahlmannryggen, the occurrences at Grunehogna are stratigraphically the most significant because of a well exposed conformable relationship with the overlying Borgmassivet Member of the Högfonna Formation. The author therefore proposes the term Grunehogna Formation for all those sedimentary rocks in the Ahlmannryggen which have up to now been grouped under the "Schumacher Formation".

The Grunehogna Formation is, as far as distribution is concerned, by far the most predominant sedimentary formation exposed in the area investigated.

A minimum thickness of 450 m was estimated by Neethling for sediments belonging to this formation. Its characteristic macroscopic appearance in the form of alternating persistent beds of light-coloured arenite and dark-coloured argillite, makes the Grunehogna Formation the most easily identifiable formation in the Ahlmannryggen.

Lithologically the Grunehogna Formation comprises well-bedded orthoquartzite with alternating siliceous siltstone in the lower part of the sequence and arkosic quartzite with alternating mudstone in the upper part. Although conglomerates are usually conspicuously absent in this formation, some rare well-rounded mudstone pebbles were observed in the upper part of the sequence at Lyftingen (Van Zyl, *pers. comm.*, 1974).

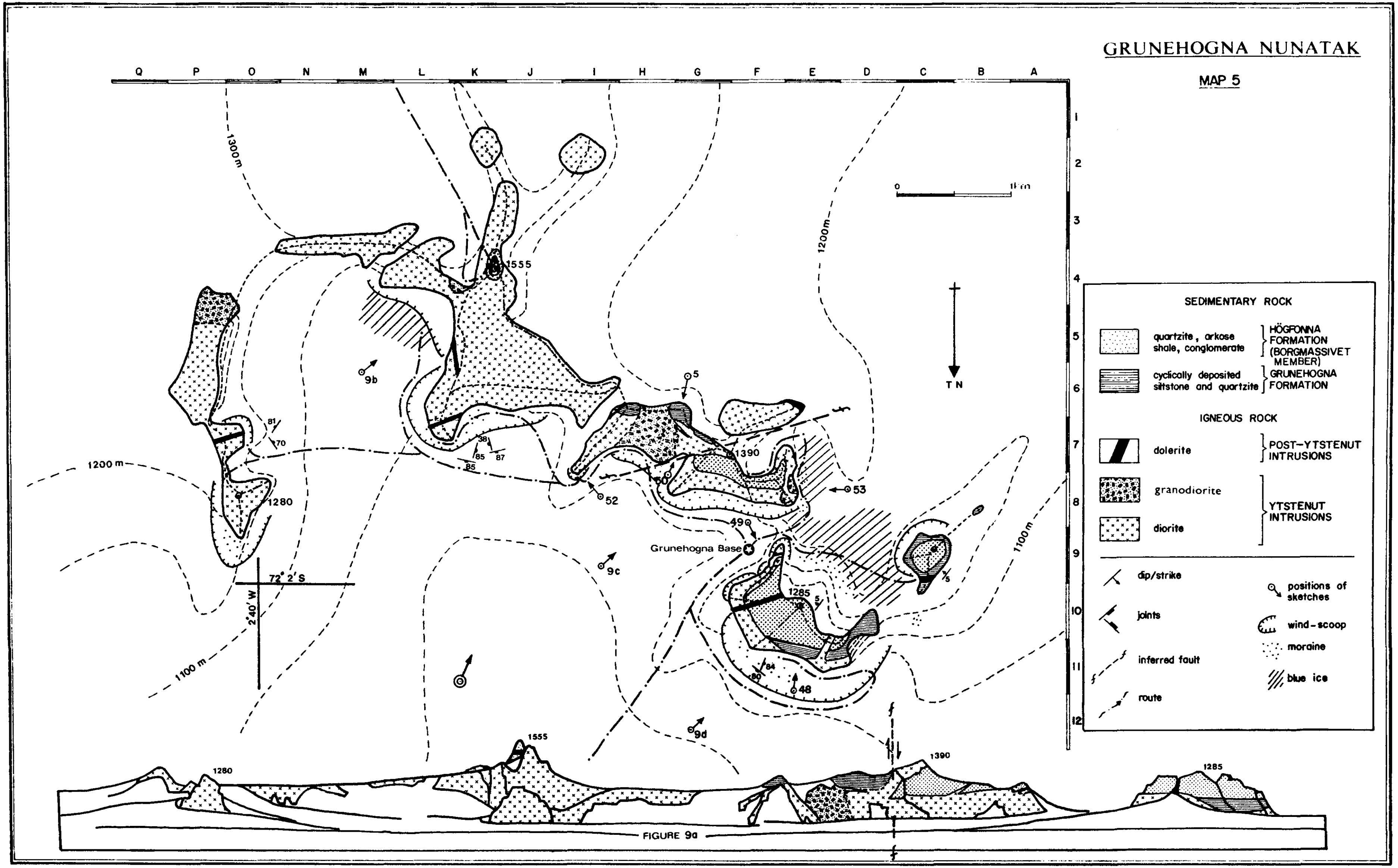
The base of the Grunehogna Formation is nowhere exposed in the Ahlmannryggen or the Borgmassivet and its contact with the supposedly underlying Pyramiden Formation has not yet been proved in outcrop. Although the uppermost few metres of the succession at Pyramiden somewhat resemble the Grunehogna Formation in general appearance, they lack the typical lateral continuity of bedding and are consequently not correlated with the Grunehogna Formation. The top of the Grunehogna Formation is however clearly exposed at the type locality.

B. Distribution

1. Grunehogna

a. Peak 1285

This is the northernmost nunatak of the Grunehogna complex and rises to a height of approximately 185 m above the general snow surface (*Map 5* and *Fig. 9a* and *9d*). In the wind-scoop on the northern side, another 30 to 40 m of rock is exposed. Sediments belonging to the Grunehogna Formation form the lower 90 m of the 200 m thick sedimentary succession which is present on top of a differentiated intrusion. Although no signs of an unconformity between the Grunehogna and the overlying Högfonna Formation could be detected, the contact between these two formations is so clear that it can be detected from a distance of several kilometres. The exposure of this contact is, apart


GRUNEHOGNA NUNATAK
MAP 5
Q P O N M L K J I H G F E D C B A
1 2 3 4 5 6 7 8 9 10 11 12
0
1 km
TN
1300 m
1200 m
1200 m
1100 m
1100 m
72° 2' S
2° 40' W
1555
1390
1280
1285
9b
9c
9d
5
52
53
49
48
Grunehogna Base
FIGURE 9a
SEDIMENTARY ROCK
quartzite, arkose shale, conglomerate
HÖGFONNA FORMATION (BORGMASSIVET MEMBER)
cyclically deposited siltstone and quartzite
GRUNEHOGNA FORMATION
IGNEOUS ROCK
dolerite
POST-YTSTENUT INTRUSIONS
granodiorite
diorite
YTSTENUT INTRUSIONS
dip/strike
joints
inferred fault
route
positions of sketches
wind-scoop
moraine
blue ice

NORTH-EAST SIDE OF GRUNEHOGNA NUNATAK

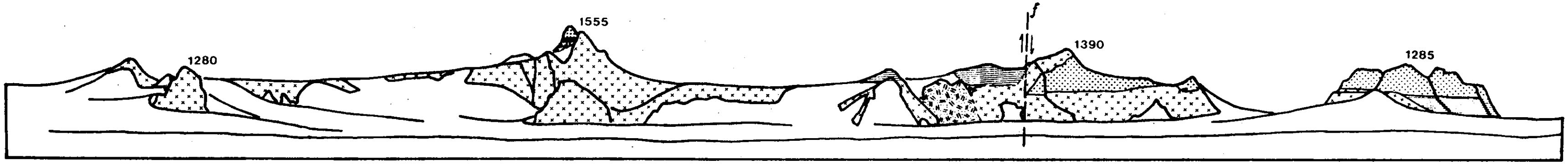


FIGURE 9a

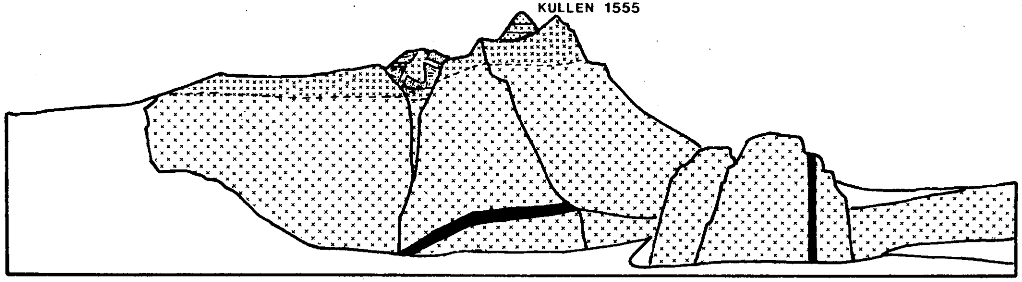
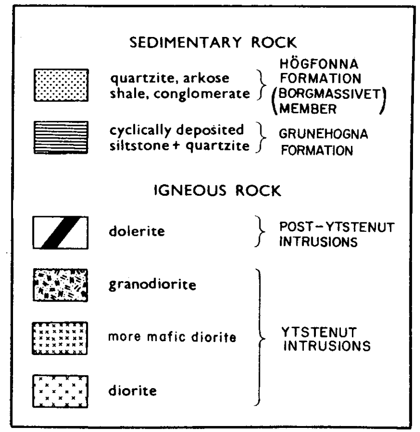


FIGURE 9b



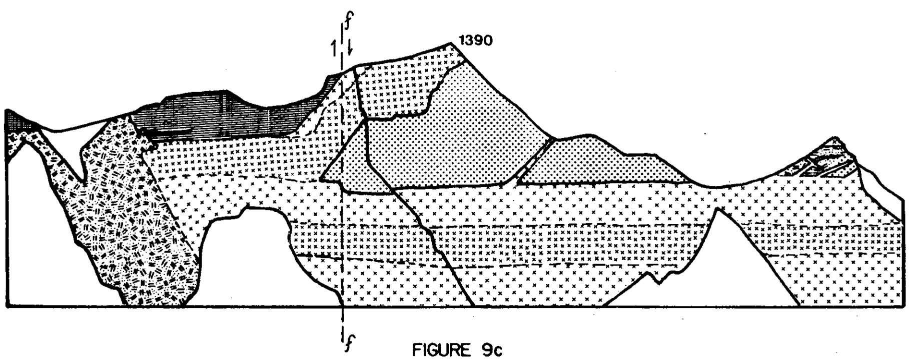


FIGURE 9c

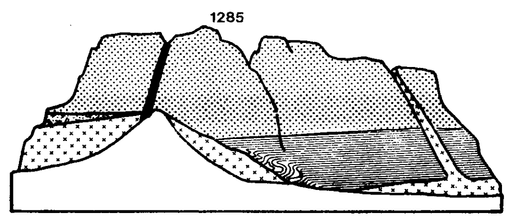


FIGURE 9d

from being a welcome sight to the geologist, also a remarkable coincidence if it is borne in mind that the base of the actual mountain is covered by some 500 m of ice.

The succession comprises alternating cream-coloured quartzites and dark-brown to black siltstones and mudstones. Mud-cracks and cross-bedding are found only in the uppermost 3 m of the sequence. The general dip of the beds is between 4^o and 6^o to the south-east.

Intensive folding of the Grunehogna sediments may be observed all along the transgressive contact of the intrusion on the northern side of the nunatak (*Fig. 9d*). The largest fold is a recumbent isoclinal fold with an amplitude of approximately 6 m. Numerous fan-folds are developed, but on a smaller scale (amplitude about 1 m). All the folds are of the parallel (concentric) type and the layers are continuous, with no breaking or displacement along the folds. The strike of the fold axes is difficult to determine as the folds are only exposed on a near-vertical cliff. It can, however, be assumed to be parallel to the strike of the intrusion, i.e. 27^o and more or less horizontal. The force which caused the folding must have acted in the form of two components; one parallel to the contact, causing the downbending, and a vertical one from beneath that caused compression. For the sediments to have been so intensively and plastically deformed, they must either have been of a much less brittle nature at the time of intrusion, or they must have been subjected to a prolonged period of high temperature and slow, constant pressure.

For a distance of about 20 m from the contact, the quartzitic beds are partly granitised or invaded by thin granodiorite veins. (Granitisation of the sedimentary rocks in the area will be discussed in more detail at a later stage). Minor occurrences of hematite were observed along joints in the folded sediments just above the contact.

b. Locality C9

This small unnamed nunatak to the south-west of Peak 1285 needs special comment because of the excellent exposure of Grunehogna sediments as well as their contact with the overlying Högfonna Formation (*Map 5*).

The lower 2 to 3 m of the exposed Grunehogna succession consists of dark-brown to black siltstone. Approximately 20 m below the Grunehogna–Högfonna contact, thin cream-coloured quartzite beds appear, but the darker-coloured argillaceous rocks are still predominant. The quartzite beds gradually become thicker towards the top of the succession until they reach a thickness of about 1 m just below the contact. Mudstone beds are only a few centimetres thick at this level. The succession is therefore siltstone, siltstone with minor pure quartzite, and feldspathic quartzite with minor mudstone beds. This, together with the occurrence of flow-ripples and cross-bedding towards the top of the sequence, suggest an uplift of the provenance area, which resulted in a faster inflow of more arenaceous material during the later stages of deposition. These conditions continued and became more prominent during deposition of the Högfonna Formation. Occasional drying up of the floor of the basin during the last stages of Grunehogna deposition is indicated by the occurrence of mud-cracks in the upper part.

From the limited number of measurements on cross-bedding and flow-ripples, it was determined that the provenance area was located to the west and the north-west. Measurements taken on both sides of the Grunehogna–Högfonna contact indicated the same flow direction.

A mudstone bed containing a high percentage of specularite is present about 15 m below the Grunehogna–Högfonna contact. This bed is very persistent, but only 50 to 60 mm thick.

c. Peak 1390

As can be seen in *Fig. 9c*, Grunehogna sediments at this locality have an abnormal relationship to a succession of Högfonna sediments in that the two formations lie at the same elevation. To have reached its present position, the Grunehogna succession must have been displaced upwards through a vertical distance of at least 100 m. This could either have been accomplished by a pre-intrusive reverse-fault (of which no signs are visible at present) or by the intrusion itself. Down-faulting of the Högfonna beds is unlikely, as they occur at the same elevation as the exposure at Peak 1285 (*Fig. 9d*).

2. Lyftingen

At the main nunatak (Peak 1700) a 120 m thick succession of sedimentary rock belonging to the Grunehogna Formation is capped by a mafic sill (*Map 3* and *Fig. 7*). The sequence comprises typical well-bedded alternating mudstone and quartzite. The thickness of individual beds varies from a few centimetres (mudstone) to about 1 m (quartzite). Slight epidotisation is common in the light-coloured beds. Specularite is present locally along joints in the mudstone. The presence of mud-cracks and the thin-bedded nature of argillaceous rocks indicate that this succession constitutes the upper part of the Grunehogna Formation. The lower contact of the overlying intrusion must be at approximately the same stratigraphic level as the original Grunehogna – Högfonna contact.

The attitude of the beds is very constant and measurements at various localities indicate dips between 5^{o} and 6^{o} north (strike 92^{o}).

Smaller exposures of Grunehogna sediments are also present at nunataks to the west and north-east of Peak 1700 (*Map 3*).

3. Kjölrabbane

At the unnamed nunatak to the south-east of Peak 1611 (locality C4, *Map 3*), a 50 m thick succession of typical Grunehogna sediments is exposed (*Fig. 6*). Cross-bedding in the upper part of the exposure indicates a paleocurrent direction from west to east. The dip of the beds varies between 8^{o} and 10^{o} east, (strike 353^{o}). This differs markedly from the northerly dip of the strata at Lyftingen, only 3 km distant. Although emplacement of the larger intrusions must have determined the present attitude of the sedimentary successions to some degree, subsequent structural control is clearly displayed in this area. Strike directions of the strata are approximately parallel to predominant joint directions as well as the general trend of the nunatak ranges.

At the northern side of Peak 1670, the largest nunatak in the Kjölrabbane group, two wedge-shaped inclusions of Grunehogna sediments have been preserved within the mafic intrusion at the same elevation on a near-vertical cliff (*Map 4*, localities J12 and H12). Similar sediments also crop out at the base of this nunatak immediately below the inclusion at H12. A side-view drawing of these exposures is presented in *Fig. 10*. Intensive small-scale folding of the sediments can be observed locally along the intrusive contacts.

A 20 m succession of alternating quartzite and mudstone, which undoubtedly belongs to the Grunehogna Formation, is exposed at the southern part of a small nunatak approximately 2 km north-west of Stamnen (*Map 4* and *Fig. 8*). Bedding planes dip at an angle of 5^{o} to the east, with the strike parallel to the general trend of the nunatak range Babordsranten – Stamnen – Styrbordsknattane – Ovenuten. As can be seen in *Fig. 11*, this succession has been preserved on top of a concordant offshoot from a near-vertical dyke which cuts across the sediments on the northern side.

4. Styrbordsknattane and Ovenuten

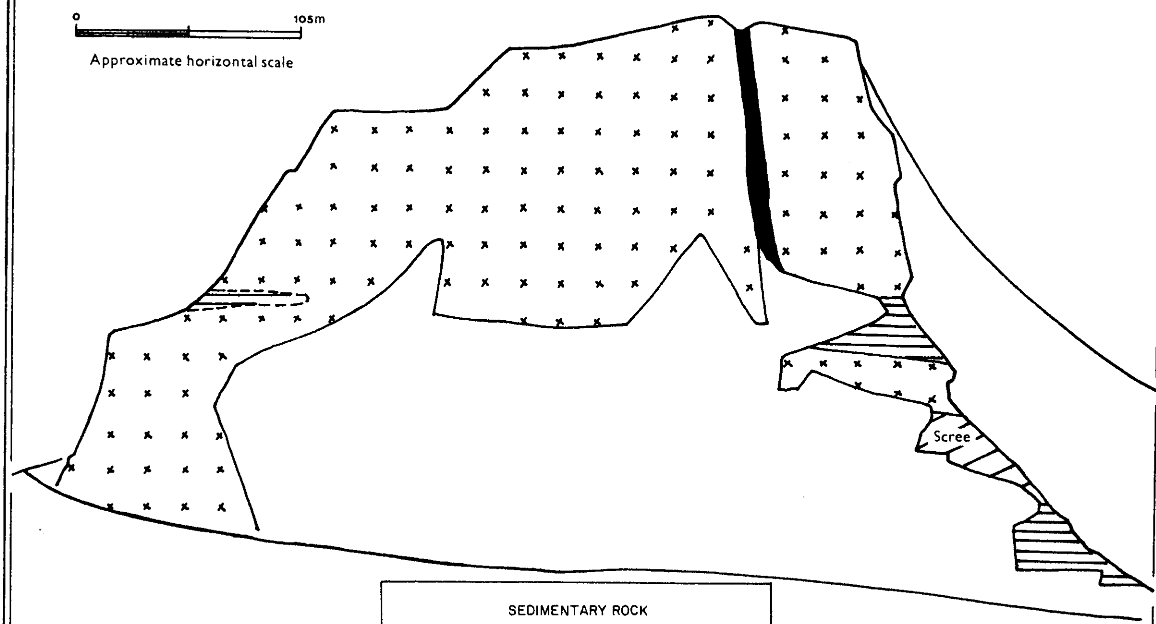
The only outcrop of sedimentary rock at Styrbordsknattane is a succession of typical Grunehogna sediments at Peak 1400 (*Map 6*, locality E2).

At Ovenuten, a 280 m thick succession of sediments belonging to the Grunehogna Formation is exposed. The sediments have been invaded by various concordant and discordant branches of the same intrusion (*Map 6* and *Figs. 12, 13* and *14*). The largest outcrop of sedimentary rock is found at Peak 1579 where a large wedge of Grunehogna sediments has been preserved between two intrusive bodies. It is very interesting to note the manner in which these two bodies were emplaced. As can be seen in *Fig. 13*, the larger upper sheet is transgressive for the greater part, except in the north-east where it follows the bedding plane. The lower intrusion follows exactly the opposite path. This phenomenon could be explained in terms of lithostatic pressure as follows: The larger intrusion, having been emplaced first, followed the path of least resistance by intruding horizontally at a certain level until it reached a point where the lithostatic pressure of the overlying sedimentary cover was sufficiently low to allow the magma to cut its way across the strata. The lower intrusion, having a smaller mass, required at first less energy to intrude transgressively. When it reached a point immediately below

FIGURE 10

NORTHERN SIDE OF

KJÖLRABBANE, PEAK 1670



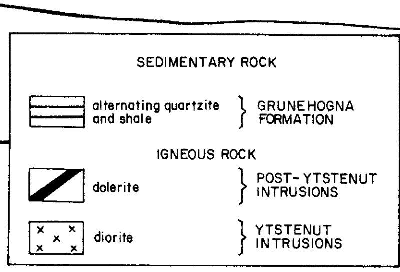
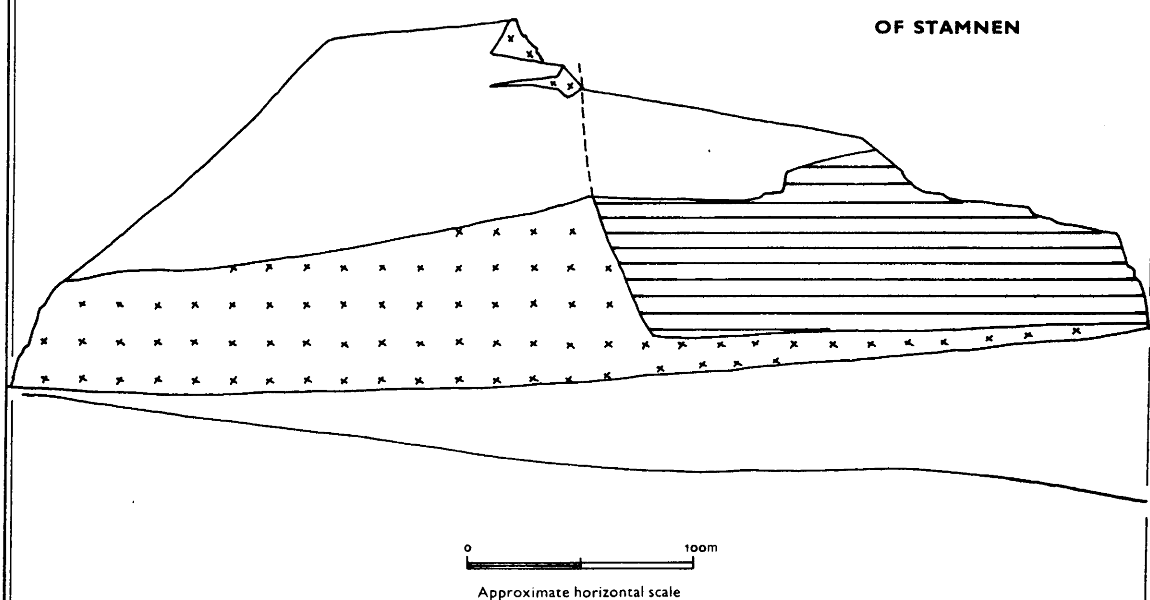


FIGURE 11

NUNATAK 2KM NNW

OF STAMNEN



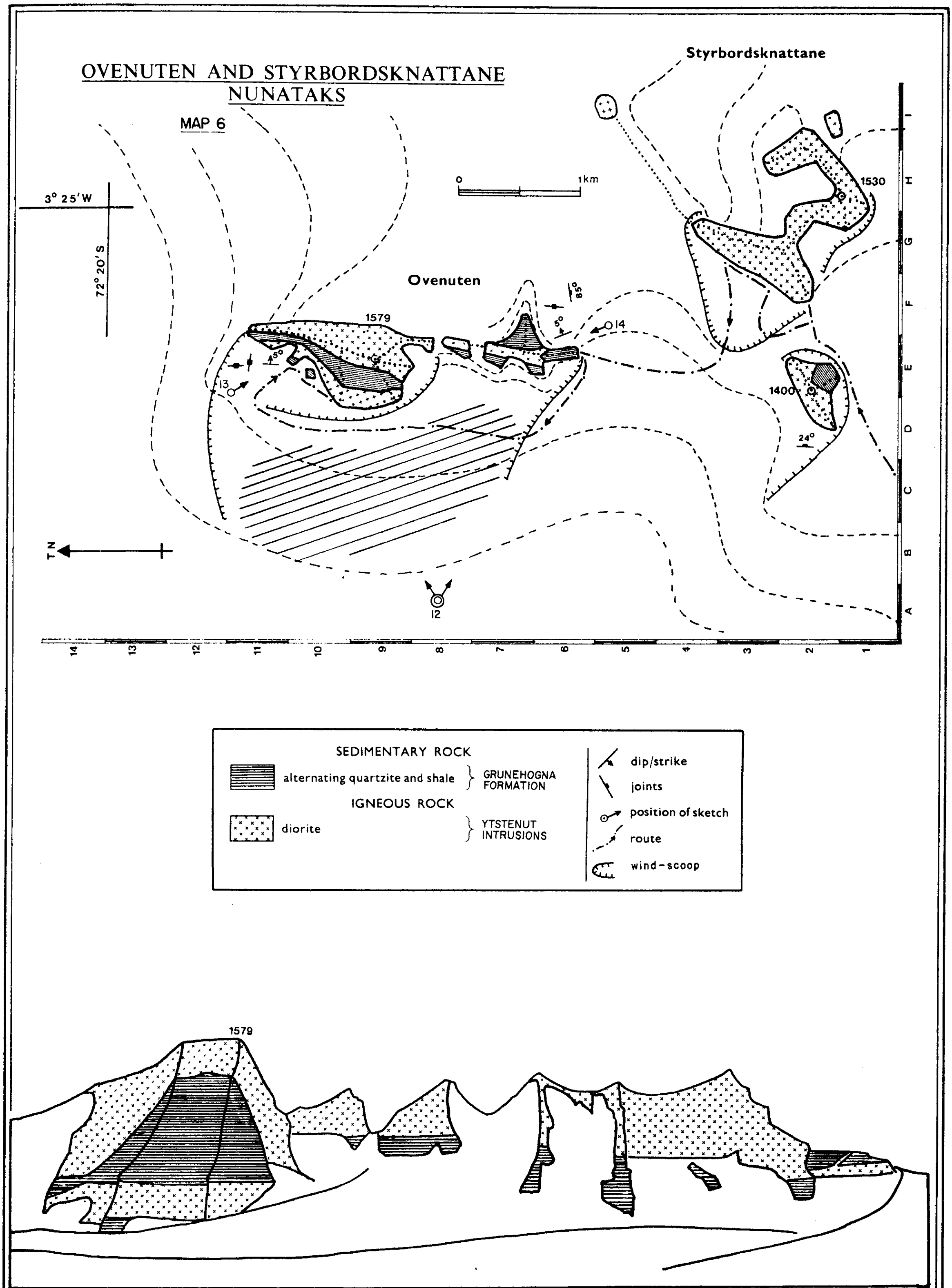
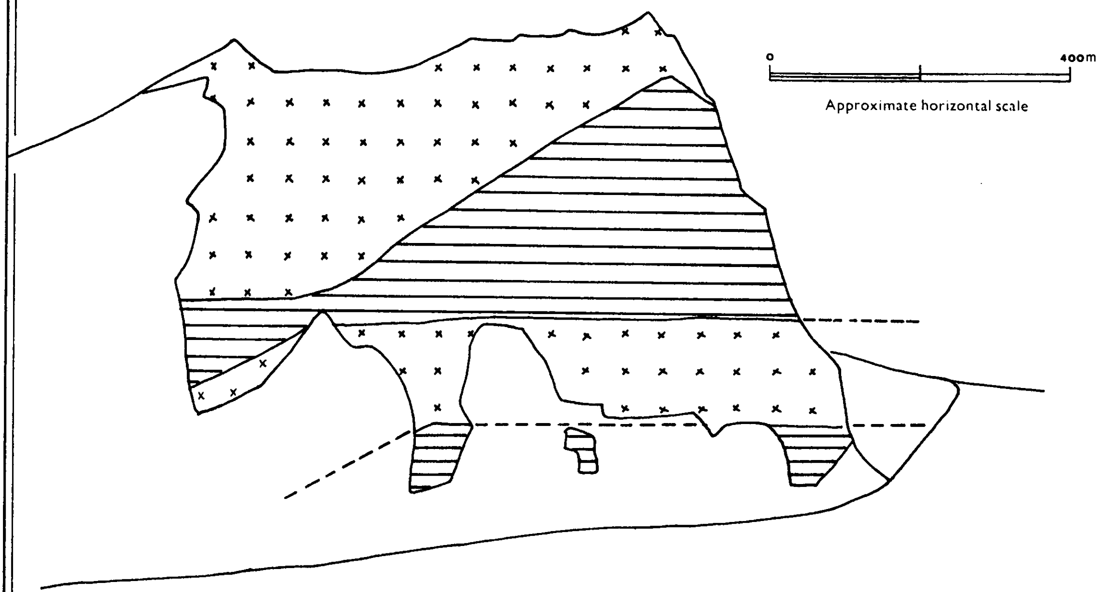

OVENUTEN AND STYRBORDSKNATTANE
NUNATAKS
MAP 6
Styrbordsknattane
Ovenuten
3° 25'W
72° 20'S
0
1km
1579
1530
1400
SEDIMENTARY ROCK
alternating quartzite and shale
GRUNEHOGNA FORMATION
IGNEOUS ROCK
diorite
YTSTENUT INTRUSIONS
dip/strike
joints
position of sketch
route
wind-scoop

FIGURE 12

FIGURE 13

NORTH-WEST SIDE OF OVENUTEN



SEDIMENTARY ROCK

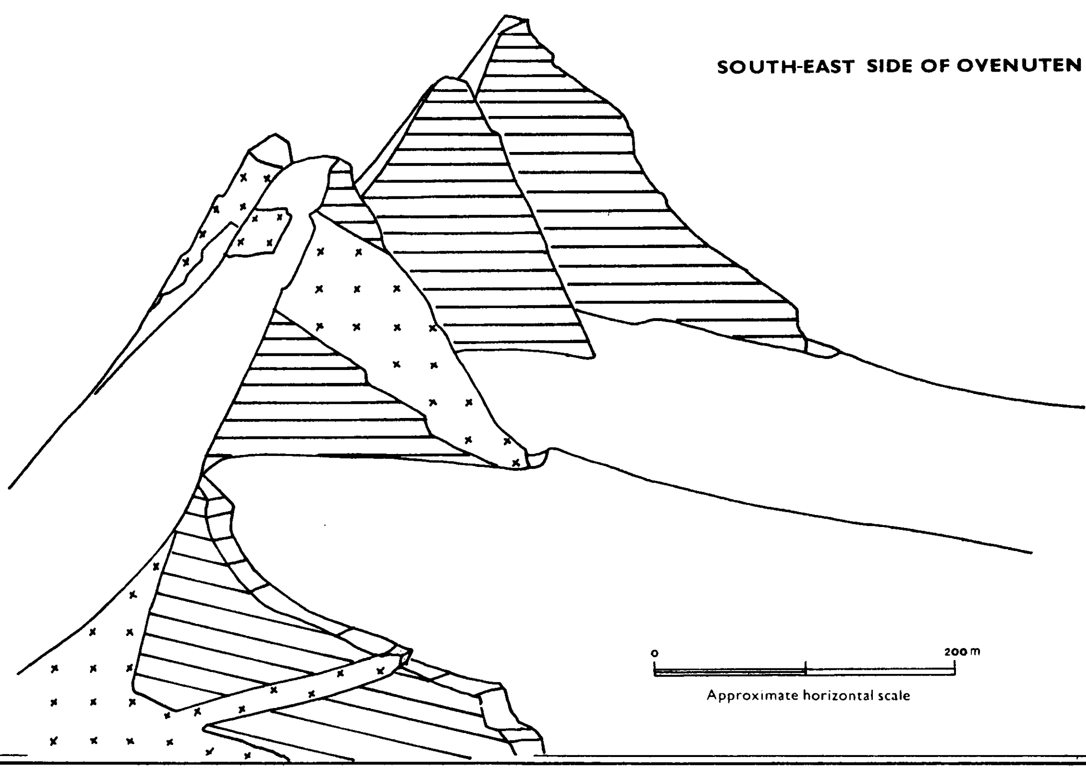
alternating quartzite and shale — GRUNEHOGNA FORMATION

IGNEOUS ROCK

diorite — YTSTENUT INTRUSIONS

FIGURE 14

SOUTH-EAST SIDE OF OVENUTEN



the already emplaced upper sheet, however, the combined pressure of the overlying sedimentary and intrusive rock caused it to deviate into a horizontal direction.

The attitude of the beds varies from 5^{o} east-north-east (strike 159^{o}) in the south (locality E6) to 5^{o} east (strike 02^{o}) at the base of Peak 1579. Paleocurrent direction as obtained from cross-bedding measurements is in a direction between 11^{o} and 43^{o}. The presence of cross-bedding as well as occasional mudflows indicate that this succession belongs to the upper part of the Grunehogna Formation. Fine black dendrites are common on bedding planes of quartzites low down in the sequence.

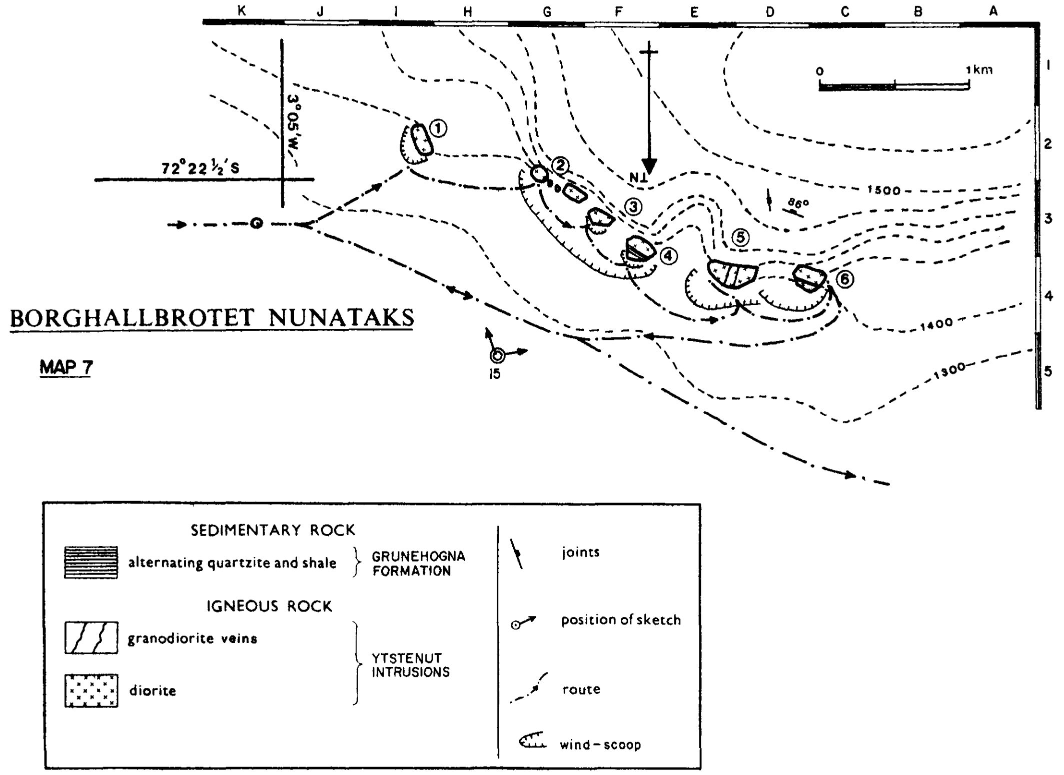
5. Other Smaller Occurrences of the Grunehogna Formation

a. Borghallbrotet

The southernmost extension of the Grunehogna Formation in the investigated area was encountered at this extraordinary range of outcrops which consists essentially of a row of north-facing, near-vertical cliffs forming an escarpment about 100 m high (*Map 7* and *Fig. 15*). Ice from the southern side of the escarpment is pushed over the cliffs and avalanches, consisting of huge blocks of blue-ice falling over the edges, is a frequently observed phenomenon.

The only exposure of sedimentary rock is at outcrop no. 4 (*Fig. 16*). An 8 m thick succession of sediments is found near the top of the exposure. It consists of a 3 m thick bed of cream-coloured quartzite at the base, followed by 5 m of alternating dark argillite and light-coloured quartzite. The succession is bounded at the top and the bottom by mafic intrusive rock.

This small exposure of Grunehogna sediments is also significant as far as the structural history of the area is concerned. The occurrence of sedimentary rocks of the same formation at the same elevation on either side of the Viddalen glacier (at Lyftingen in the north and Borghallbrotet in the south) tends to support the theory that the Viddalen is a pre-glacial graben structure.



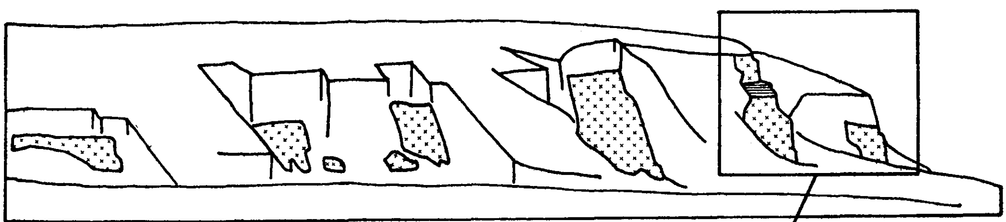


FIGURE 15

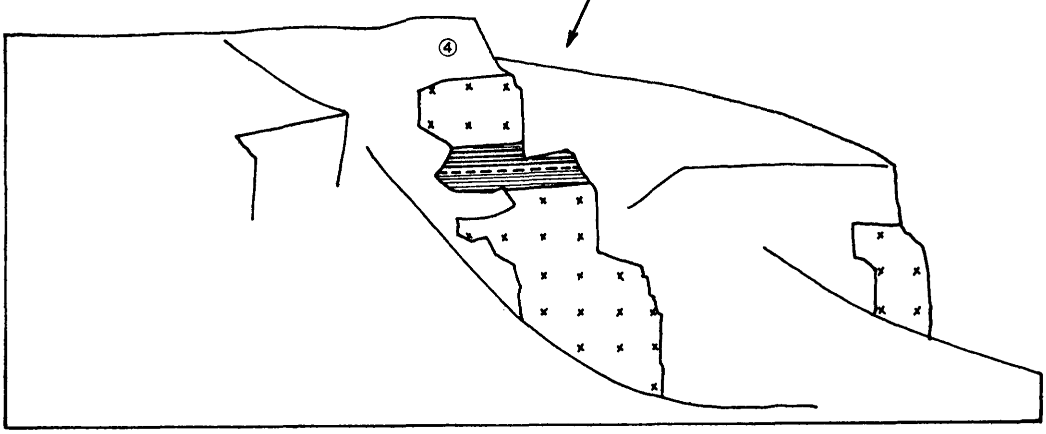


FIGURE 16

b. Vesletind

A 20 m thick succession of Grunehogna sediments is capped by a concordant mafic intrusion at Peak 1520 between Hornet and Vesletind (*Map 8* and *Fig. 19*).

6. Occurrences of Grunehogna Formation Outside the Area Investigated

According to Van Zyl (*pers. comm.*, 1974), Grunehogna sediments dipping 4^{o} to 5^{o} to the east and south-east are found in the north-western part of the Ahlmannryggen at the following localities: Flarjuvnutane, Klumpane and the north-western side of Flarjuven.

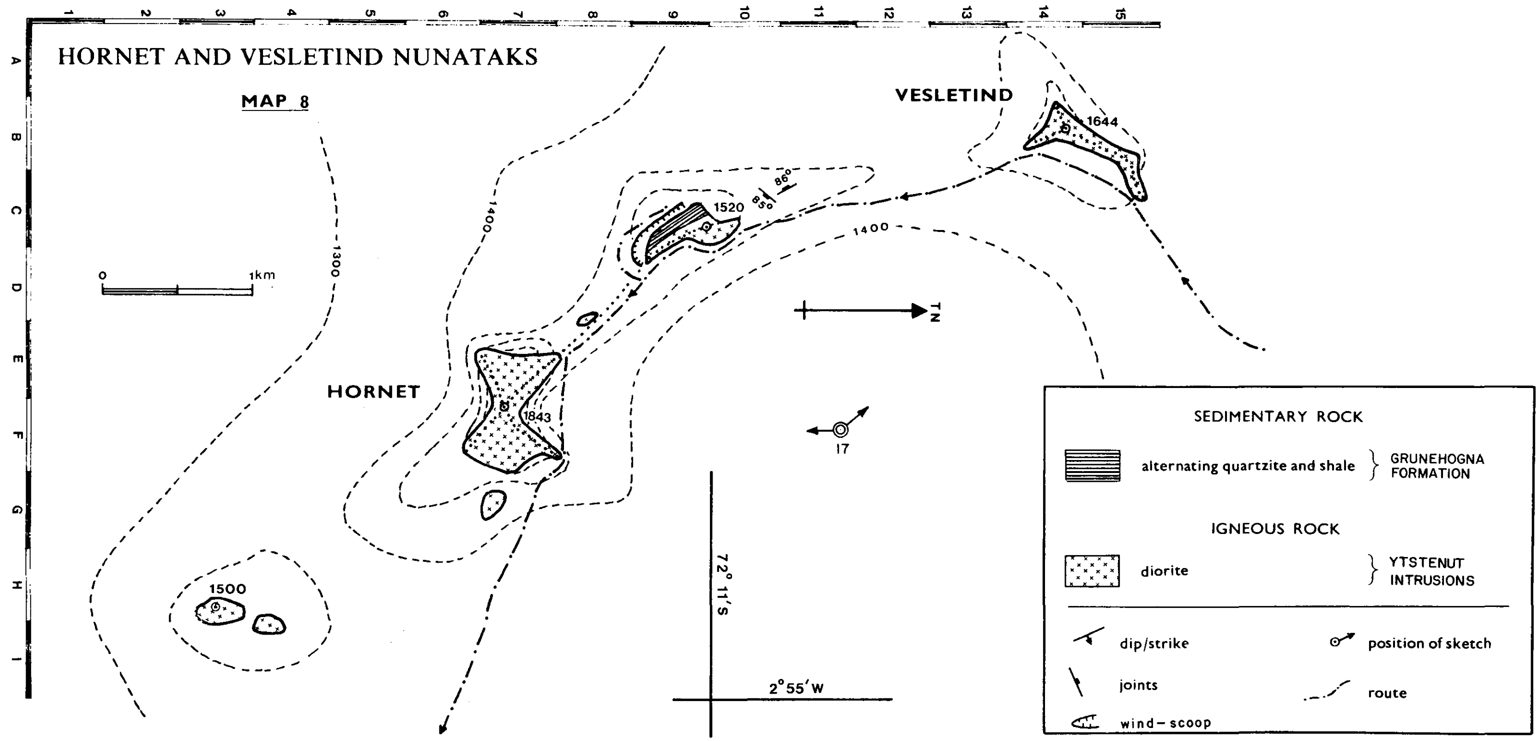
Sediments belonging to the Framryggen Formation (De Ridder, 1970) which are exposed at Framryggen and other smaller outcrops in the western Borgmassivet, may also be included in the Grunehogna Formation (Neethling, 1970). Lithological comparison as well as microscopic examination support this correlation undoubtedly.

C. Conditions of Deposition

Deposition of the Grunehogna Formation commenced under low-energy conditions which persisted up to the closing stages of sedimentation when a slight increase of energy set in. This slight increase in energy of sedimentation constitutes the beginning of a long period of higher-energy conditions which continued during, and reached its peak at the end of deposition of the overlying Högfonna Formation.

The absence of sulphides and the presence of iron oxides in the form of hematite and specularite indicate deposition in shallow water under oxidising conditions. Occasional drying up of the floor of the basin must have taken place during the final stages of Grunehogna sedimentation to account for the presence of mud-cracks in the upper part of the succession.

Source-material was derived from a provenance which was located along the southern and north-western margin of the depositional basin. The first material to be


HORNET AND VESLETIND NUNATAKS
MAP 8
VESLETIND
1644
1520
86°
85°
1400
1300
0
1km
TN
HORNET
1843
17
1500
72° 11'S
2°55'W
SEDIMENTARY ROCK
alternating quartzite and shale
GRUNEHOGNA FORMATION
IGNEOUS ROCK
diorite
YTSTENUT INTRUSIONS
dip/strike
position of sketch
joints
route
wind-scoop

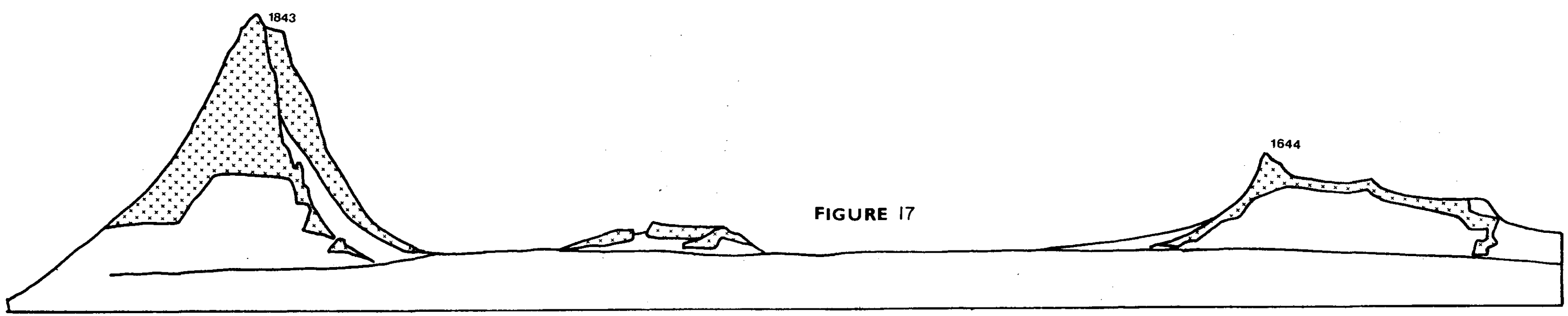

1843
1644

FIGURE 17

FIGURE 18

SNÖHETTA SEDIMENTARY OUTCROP C13

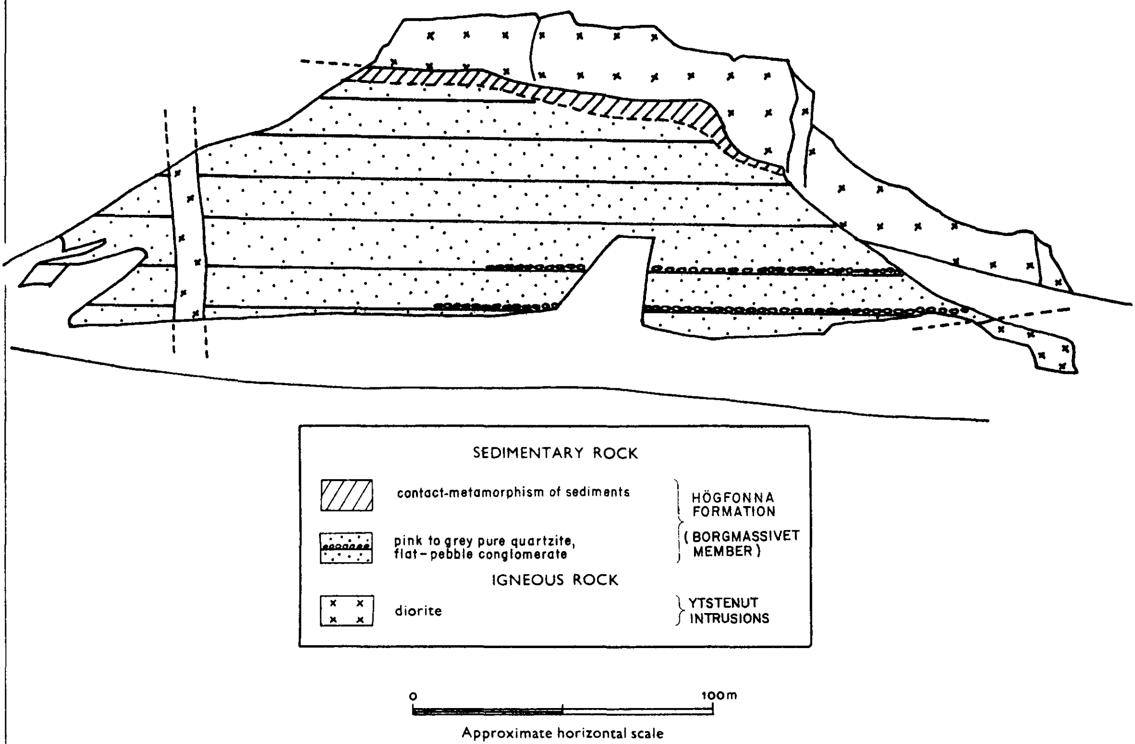
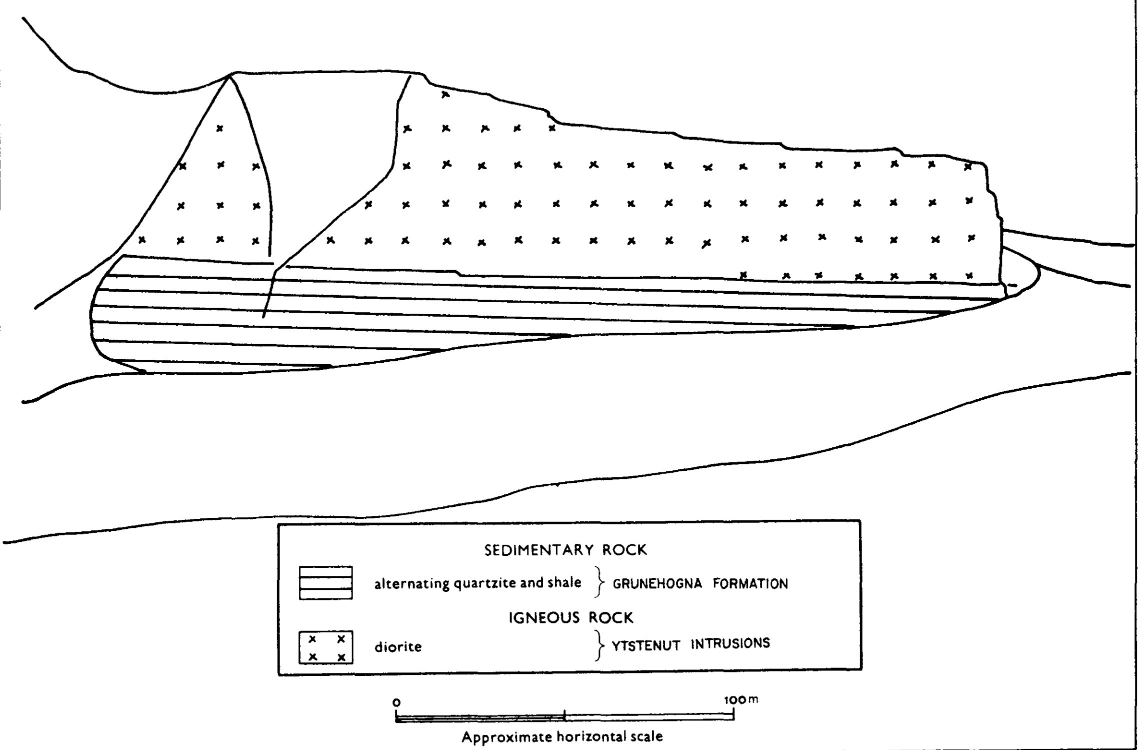


FIGURE 19

HORNET SEDIMENTARY OUTCROP AT PEAK 1520



transported was argillaceous matter derived from weathered portions of the source-rocks. Subsequent erosion in the provenance area led to removal, transportation and deposition of increasing quantities of arenaceous material. As sedimentary structures in adjacent argillite and arenite beds indicate the same paleocurrent direction, the alternating nature of these rock types is most likely due to sorting during transportation and differential settling under quiet conditions.

IV. THE HÖGFONNA FORMATION

A. General Discussion and Type Locality

The Högfonna Formation was originally named and defined by De Ridder (1970). The name is derived from Högfonna, a nunatak located in the north-eastern part of the Borgmassivet, which is also considered as the type locality. De Ridder defined this formation as being "... the jasper-bearing conglomeratic sedimentary sequence exposed in the central part of the Borg Massif ...". For the purpose of his localised study in the Borgmassivet, De Ridder divided the formation into a Lower and an Upper Member "... on the basis of local red beds and tuff in the upper part of the formation". Subsequent investigations revealed, however, that the Högfonna Formation is not only confined to the Borgmassivet, but is also present at various localities in the Ahlmannryggen, up to as far north as Nils Jørgennutane. Red beds as well as ash particles have also been discovered low down in the Högfonna Formation at Grunehogna (Aucamp, 1972). It seems therefore that although De Ridder's subdivision might have been justified for the Borgmassivet, it does not apply for the area as a whole. Furthermore, a lithologically different correlate, which is believed to constitute the upper part of the Högfonna Formation in the Viddalen area, was found to occur at Jekselen and Tindeklypa.

In view of these recent findings, the author would like to redefine and propose a new two-fold subdivision for the Högfonna Formation, *viz.*:

1. A *Borgmassivet Member,* which will include all sedimentary rocks assigned by De Ridder to the originally defined Högfonna Formation, as well as all lithologically similar rocks found in the Ahlmannryggen; and

2. A *Jekselen Member,* which includes all dark-gray to buff-coloured arenaceous, jasper-bearing, calcareous sedimentary rocks occurring in contact with the volcanic equivalent of the 1700 My Krylen Intrusions and the Tindeklypa Member of the Viddalen Formation at Jekselen and Tindeklypa.

As the Borgmassivet Member has been dealt with in detail by various authors (De Ridder, 1970; Neethling, 1970; Aucamp, 1972), no attempt will be made to enlarge upon the characteristics of this unit. Only the distribution in the investigated area will be discussed and some interesting features described. The Jekselen Member will, however, be dealt with in more detail; not only because it is a newly introduced unit of the Högfonna Formation, but also because of its critical position in the stratigraphic sequence of the area as a whole.

B. The Borgmassivet Member

1. Grunehogna

This is the only locality in both the Ahlmannryggen and the Borgmassivet where the base of the Högfonna Formation is exposed. At Peak 1285 and the small nunatak immediately to the south-west, a 110 m thick succession of sedimentary rocks belonging to the Borgmassivet Member overlies the Grunehogna Formation conformably. The succession comprises brown to dark gray feldspathic quartzites and shale, interbedded with mud-fragment and jasper conglomerates. Mud-cracks, mud-flows and cross-bedding are present in abundance. Much more lateral variation may be observed than in the well-bedded Grunehogna Formation. This difference between the two formations gives rise to a very clear contact noticeable from quite a distance (*Fig. 9d*). On the northern cliff of Peak 1390 (*Fig. 9c*), at an elevation of between 1220 and 1300 m, a large wedge-shaped occurrence of sedimentary rocks belonging to the Borgmassivet Member can be observed. The sediments are bounded at the bottom and on the southern side by mafic intrusive rock (Ytstenut Intrusions). Similar sedimentary rocks are also exposed at Kullen Peak. At this locality, the sediments had been invaded by thin transgressive and concordant offshoots from the main mafic sill (*Fig. 9b*), and especially the lower part of the succession had been intensively granitised. (Granitisation of the sedimentary rocks in the area will be discussed at a later stage).

As is the case with all exposures of the Borgmassivet Member in the area investigated, the attitude of these beds at Grunehogna is near horizontal (dips between 4^{o} and 6^{o} south-east).

2. Dugurdspiggen

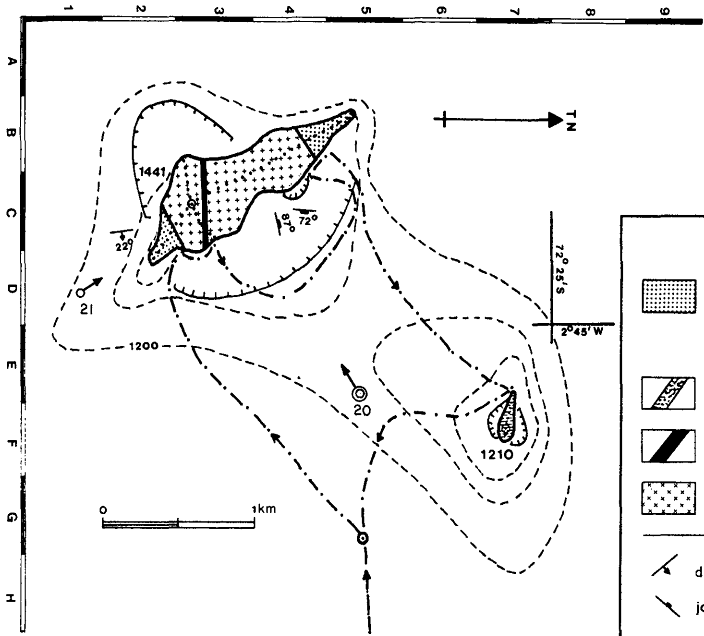
As no record exists of any previous investigations at this nunatak, the sedimentary succession (which as a whole belongs to the Borgmassivet Member) was studied in more detail.

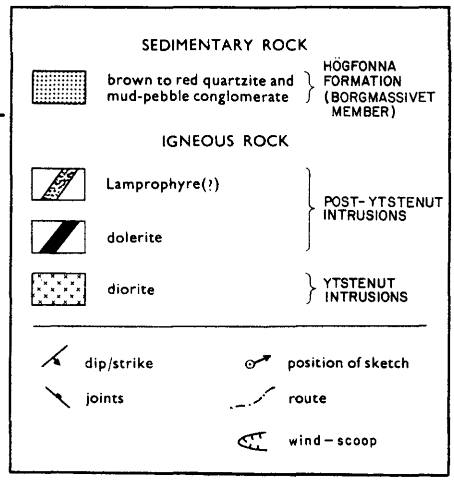
The main nunatak is approximately 1,6 km long and sedimentary rock is exposed on the southern and northern sides (*Map 9, Fig. 20*). The two exposures do not differ from each other lithologically and the total sequence is as follows:

Elevation above snow surface (m)	Thickness (m)	Lithological description
25–95	70	Predominantly reddish-brown feldspathic quartzite with subordinate brownish-gray feldspathic quartzite containing small grains of red jasper. The brownish-gray variety gradually disappears towards the top, while the intensity of the red colour increases. The uppermost 5 m of the succession consists of brick-red quartzite with conspicuous gray circular and oval structures displayed on bedding planes.
5–25	20	Dark brownish-gray feldspathic quartzite containing small grains of red jasper. Mud-pebble horizons are common, as well as intercalated beds of reddish-brown, fine-grained quartzite up to 0,5 m thick.
0–5	5	Dark brown fine-grained feldspathic quartzite.

DUGURDSPIGGEN NUNATAK

MAP 9





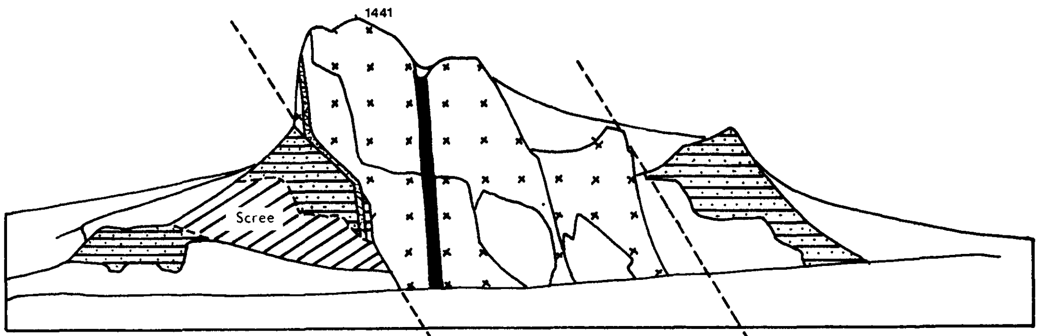


FIGURE 20

NORTH-EASTERN SIDE OF DUGURDSPIGGEN

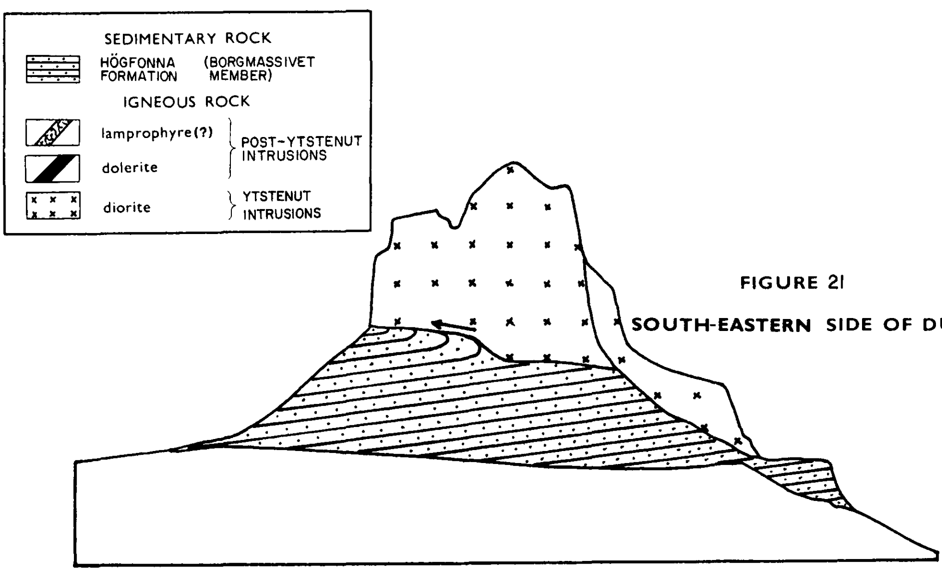


FIGURE 21

SOUTH-EASTERN SIDE OF DUGURDSPIGGEN

A striking feature of both sedimentary exposures at the main nunatak is the bleaching of the red quartzites along the contact with the large mafic dyke. For a distance of up to 40 m away from the contact, these sediments are gray to buff in colour before changing (laterally) into the normal red colour.

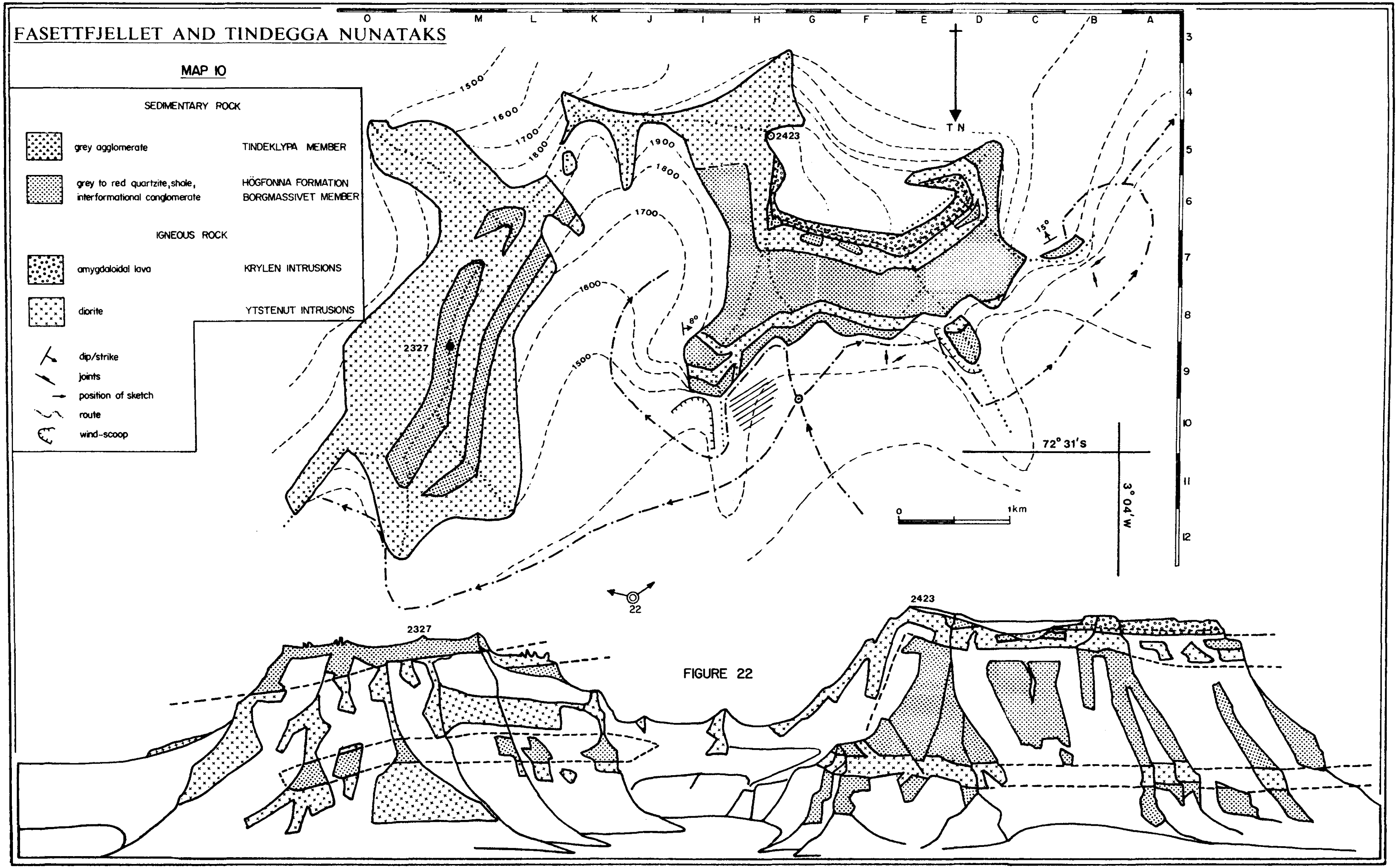
At Nunatak 1210 (locality F7), a total thickness of 60 m of brick-red quartzite with minor intercalated mudstone is exposed.

The average dip of the succession is 22^{o} east (strike 352^{o}). This attitude of the beds can mostly be attributed to the effect of the intrusion which cuts through the succession at an angle of approximately 45^{o}. In some places close to the contact, the beds are tightly folded *(Fig. 21).* Fold axes strike approximately 102^{o}. Paleocurrent direction as obtained from the measurement of mud-flows is from south-west to north-east. (Average strike of the flows 132^{o}).

3. Fasettfjellet and Tindegga

Detailed mapping in this area was carried out by Bastin (De Ridder and Bastin, 1968) as well as by Aucamp and Watters (Watters, 1969). The present investigation supports the work done by these geologists, but a new map was compiled on which quite a few alterations have been made (*Map 10, Fig. 22*). The main difference between the new map and the older one is in the extent of the various rock types.

These two nunataks are typical examples of the large blocky, flat-topped mountains in the Borgmassivet. They both rise to a height of about 800 m above the general snow surface. The southern and western sides are completely ice-covered up to the top and investigations were mainly concentrated on the northern cliff at Fasettfjellet. The nunataks consist mainly of a succession of sedimentary rock (Borgmassivet Member) some 400 m thick, intruded by mafic sills and dykes (Ytstenut Intrusions) and capped by agglomerate and lava (Tindeklypa Member). Features not mentioned by previous geologists are joint fillings of calcite which are common in the upper red quartzites and which are frequently associated with small amounts of specularite. The dip of the beds vary


FASETTFJELLET AND TINDEGGA NUNATAKS
MAP 10
SEDIMENTARY ROCK
grey agglomerate
TINDEKLYPA MEMBER
grey to red quartzite, shale, interformational conglomerate
HÖGFONNA FORMATION
BORGMASSIVET MEMBER
IGNEOUS ROCK
amygdaloidal lava
KRYLEN INTRUSIONS
diorite
YTSTENUT INTRUSIONS
dip/strike
joints
position of sketch
route
wind-scoop
O N M L K J I H G F E D C B A
3 4 5 6 7 8 9 10 11 12
T N
1500
1600
1700
1800
1900
2423
2327
72° 31'S
3° 04'W
0
1km
22
2423
2327
FIGURE 22

from 13° to 16° south-east (strike 58°). Sedimentary structures are abundant throughout the succession and indicate a paleocurrent direction from south-east to north-west.

4. Ytstenut

No previous investigations at this nunatak have been reported. The nunatak consists essentially of a succession, approximately 500 m thick, of light gray to red quartzites which have been intruded by transgressive mafic bodies (*Map 11, Figs. 23, 24, 25*). Sediments throughout the succession are well indurated and are further characterised by an absence of conglomerate horizons. The following general sequence was established:

Elevation above snow surface (m)	Thickness (m)	Lithological description
250–500	250	Dark-brown to gray, fine- to medium-grained quartzite containing abundant grains of red jasper. This unit is characterised by distinct banding of the brown and gray colour types. Lateral blending into a dark red quartzite of the same texture was observed at the top of the mountain at locality C15. Cross-bedding is well developed and indicate an average paleocurrent in direction 266°.
150–250	100	Dark-brown to gray, fine- to medium-grained, vaguely banded quartzite containing abundant grains of red jasper.
100–150	50	Light-gray, medium- to coarse-grained quartzite.
0–100	100	Greenish-gray, fine-grained massive quartzite.

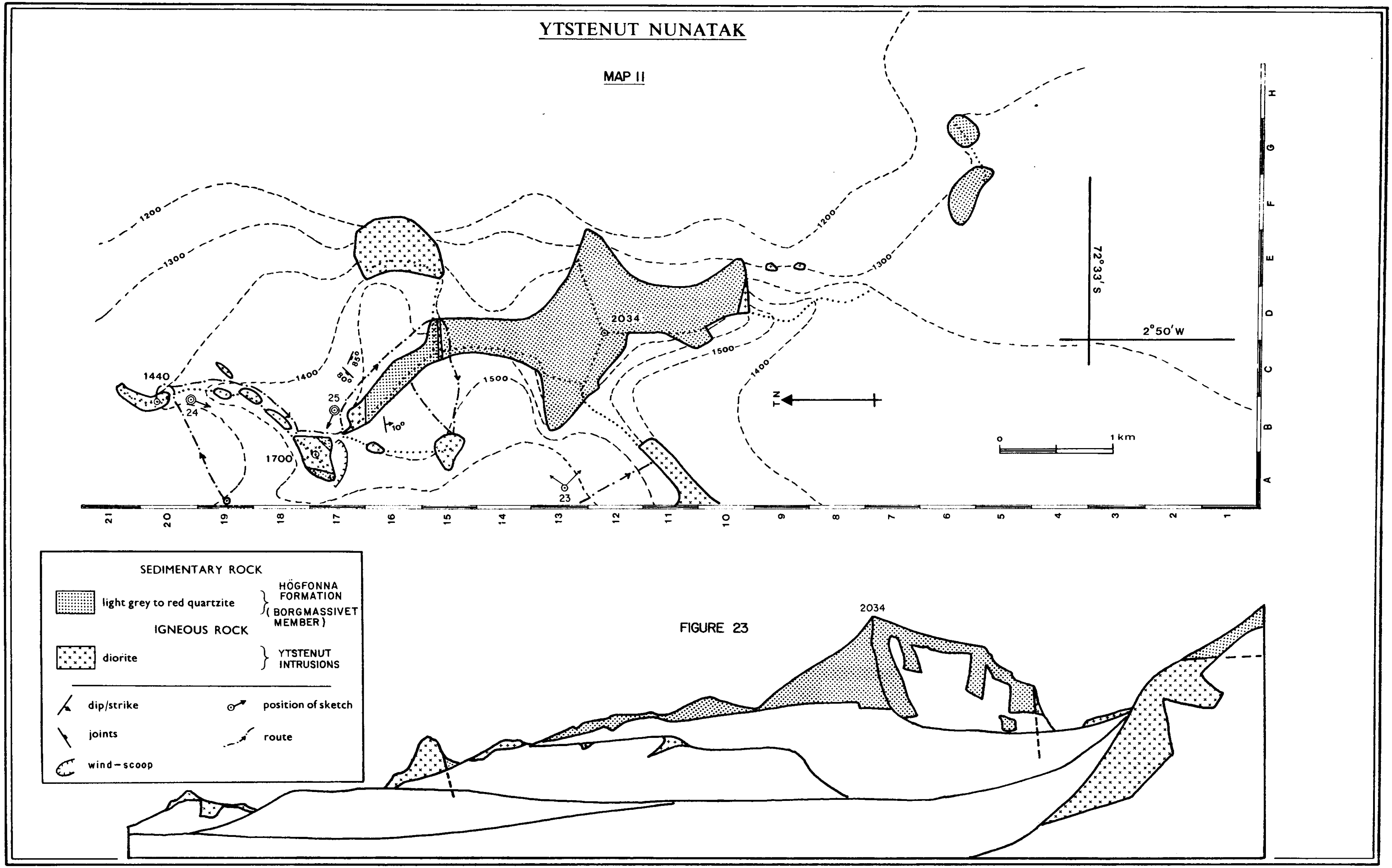

YTSTENUT NUNATAK
MAP II
1200
1300
1400
1500
1440
1700
2034
24
25
23
80°
85°
10°
72°33'S
2°50'W
T N
0
1 km
A
B
C
D
E
F
G
H
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
SEDIMENTARY ROCK
light grey to red quartzite
HÖGFONNA FORMATION
(BORGMASSIVET MEMBER)
IGNEOUS ROCK
diorite
YTSTENUT INTRUSIONS
dip/strike
position of sketch
joints
route
wind – scoop
2034

FIGURE 23

FIGURE 24

NORTH SIDE OF PEAK 1700

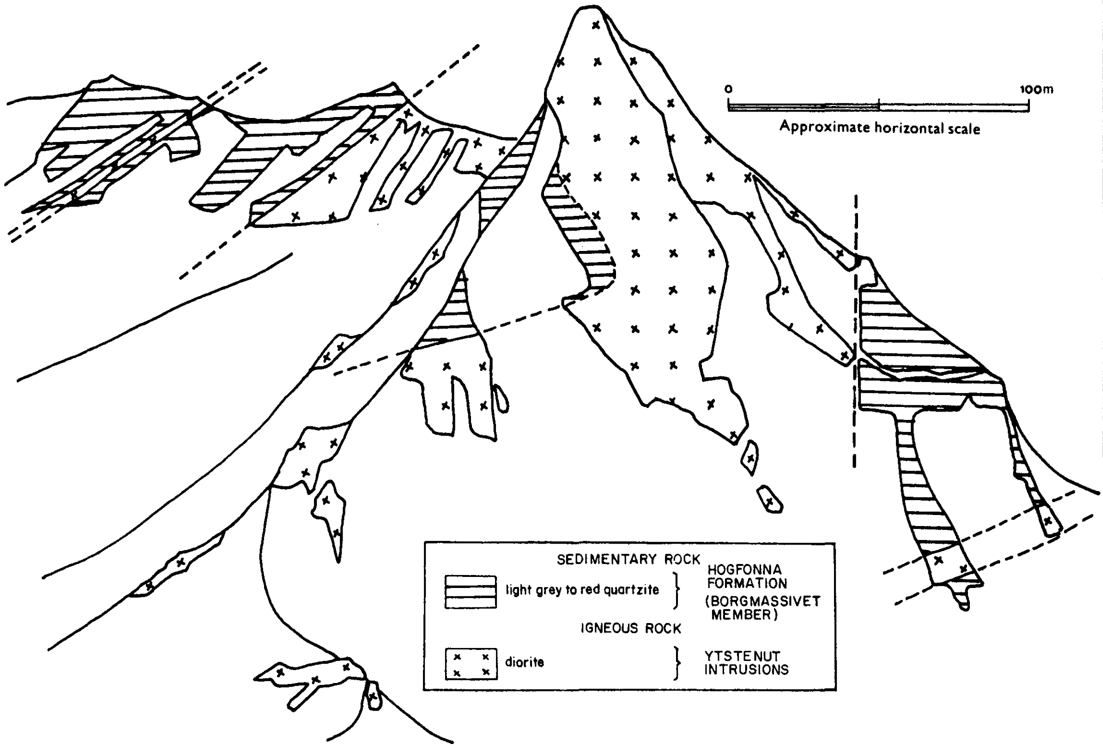
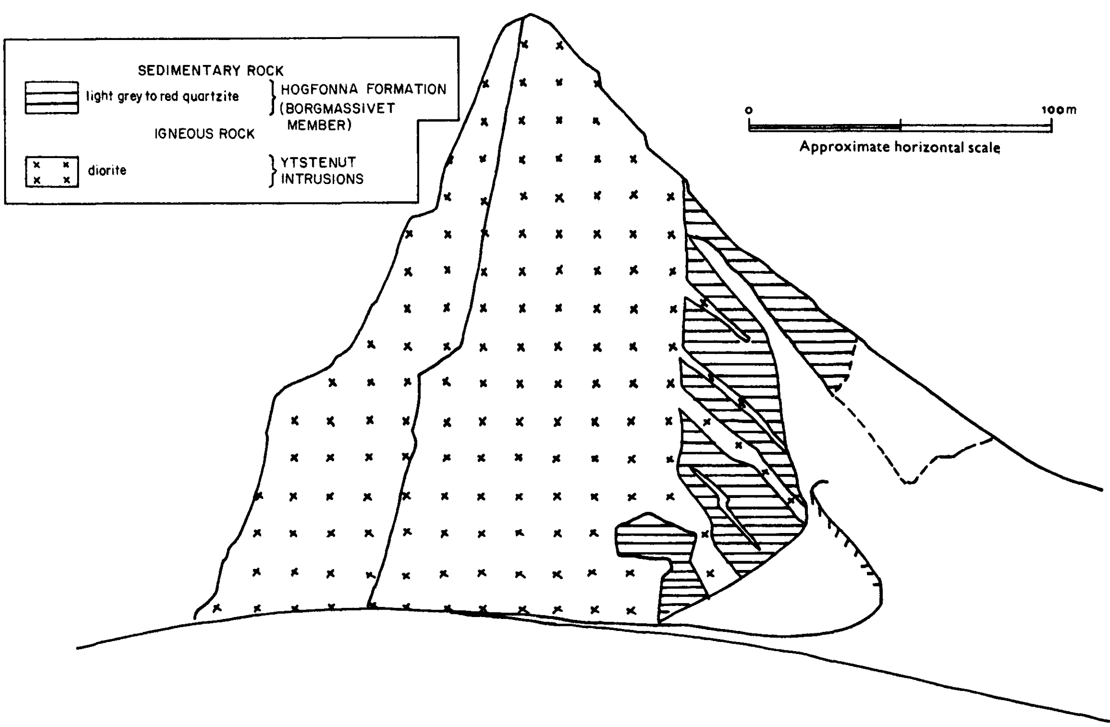


FIGURE 25

SOUTH-EAST SIDE OF PEAK 1700



The dip of this succession is fairly constant (8^{o} – 10^{o} to the north) except for a very shallow symmetrical syncline (fold axis striking east-west) which can be observed on the eastern face of the southern part of the main nunatak (locality D10). This deformation is due to an intrusion, the upper contact of which is just visible above the snow surface immediately to the south.

The sedimentary rocks at Ytstenut are correlated with the Borgmassivet Member on account of their indurated nature and the presence of jasper. The absence of conglomerates and argillaceous material is, however, an anomalous feature.

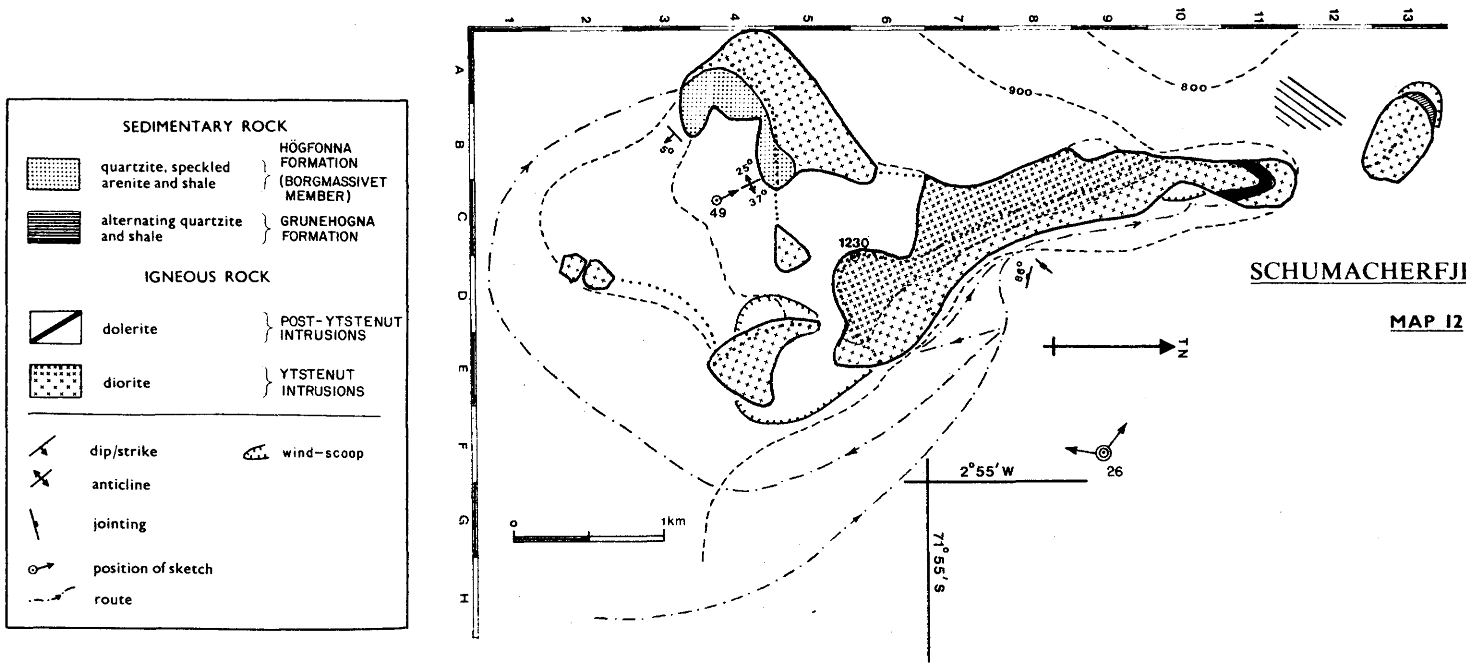
5. Schumacherfjellet

A succession, approximately 30 m thick, of sediments belonging to the Borgmassivet Member is exposed on the southern side of this nunatak (*Map 12, Fig. 26*). These sediments have been investigated by Neethling (1964) and by Aucamp (1968, field notes). No maps of the nunatak have however, been compiled.

The sediments range from a reddish-brown speckled arenite at the base to brown and gray quartzite with intercalated mudstone and shale horizons near the top. Small grains of jasper are abundant in the arenaceous rocks. The general dip of the succession is approximately 5^{o} to the south-east. Right at the top of the succession however, (locality C4), a small anticline was observed (*Fig. 28*). The fold axis is approximately horizontal and strikes 342^{o}. The two limbs of the fold dip 37^{o} east and 25^{o} west respectively. The amplitude is about 2 m. Part of the mafic sill intrudes the anticline on the western side and the deformation of the sediments was undoubtedly caused by this intrusion. It is very unlikely that this localised small anticline can be attributed to a mid-Paleozoic orogeny as proposed by Vaclavik and Kahle (1971).

6. Liljequisthorga

Accounts of previous investigations at these nunataks have been given by Butt (1962) and Pollak (1967). No maps have been compiled.


SEDIMENTARY ROCK
quartzite, speckled arenite and shale
HÖGFONNA FORMATION (BORGMASSIVET MEMBER)
alternating quartzite and shale
GRUNEHOGNA FORMATION
IGNEOUS ROCK
dolerite
POST-YTSTENUT INTRUSIONS
diorite
YTSTENUT INTRUSIONS
dip/strike
wind-scoop
anticline
jointing
position of sketch
route
SCHUMACHERFJELLET NUNATAK
MAP 12
900
800
1230
49
26
TN
2°55′W
71°55′S
0
1km

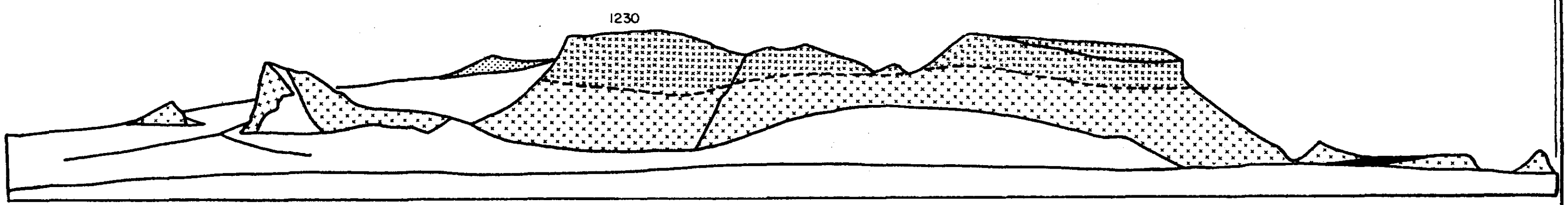

1230

FIGURE 26

FIGURE 27

EAST SIDE OF GÖSTAPIGGANE

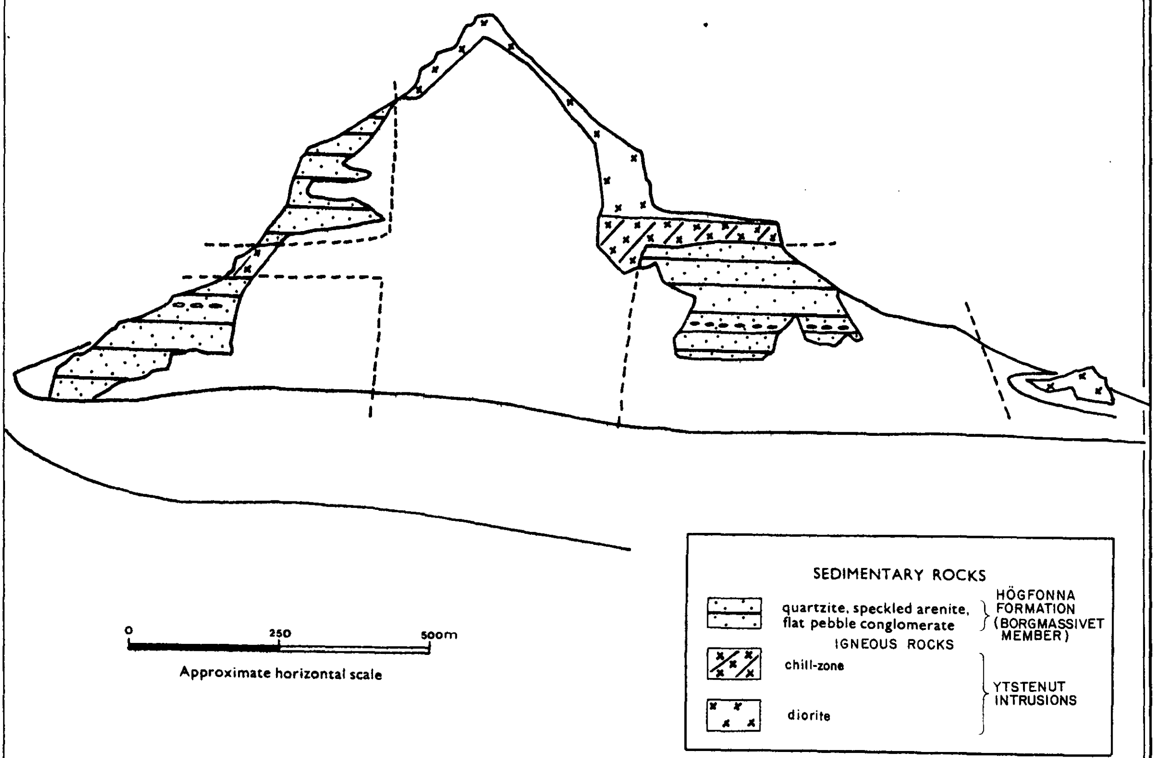
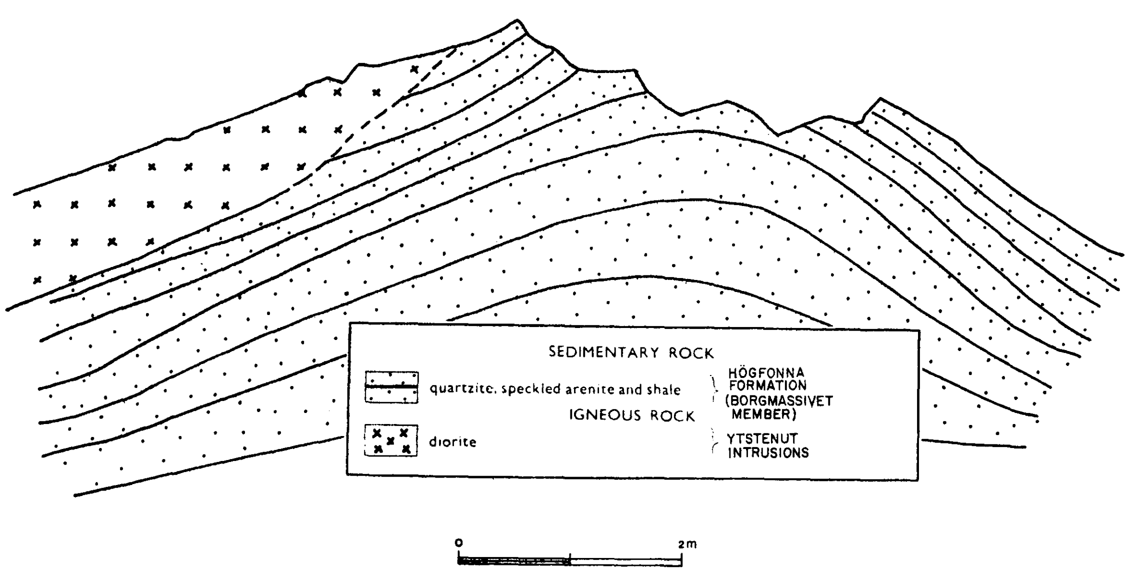


FIGURE 28

ANTICLINE IN HÖGFONNA FORMATION ON SOUTH-WESTERN SIDE OF SCHUMACHERFJELLET



Sedimentary rocks are exposed only at the eastern part of the complex (Göstapiggane) (*Map 13, Figs. 27* and *29*). According to Paterson (Bredell and Paterson, 1972), the sediments (which are all correlated with the Borgmassivet Member) differ in lithology from outcrop to outcrop and no definite sequence could be established. On the southern side of the main nunatak quartzites similar to those found at Ytstenut were encountered. No argillaceous rocks or jasper-pebble conglomerate horizons were observed. Jasper is however a common constituent of the quartzites.

At locality O12 the sedimentary succession comprises brick-red quartzite and dark-brown mudstone. A distinctive flat-pebble conglomerate horizon (about 0,2 m thick) is present a few metres above the snow surface at this locality.

At locality K9 the quartzites are light pink to light gray in colour and mudstone horizons are more abundant. Ripple-marks and mud-cracks are fairly common. A lithologically similar sequence is also exposed at locality L11, as well as at the two low ridges to the south of Göstapigane (not indicated on Map 13 – see *Figs. 30* and *31*).

The average dip of the sediments at Göstapiggane is 6^{o} with the strike varying between 18^{o} and 48^{o}. At the low ridges to the south however, dips of between 14^{o} and 20^{o} south-east were measured.

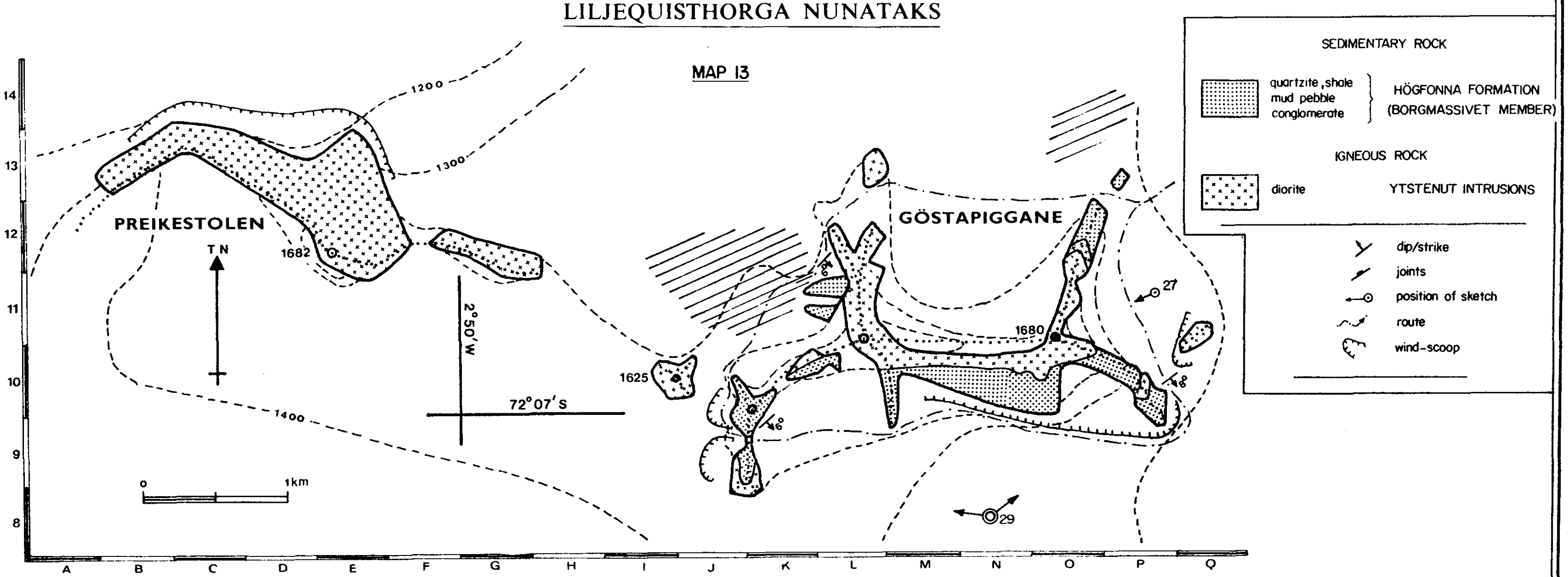
7. Nils Jørgennutane

These nunataks had previously been investigated by Neethling (1964) and by Aucamp (1968, field notes). No maps were compiled.

The distribution of the sedimentary rocks (Borgmassivet Member) is indicated on *Map 14* and *Fig. 32*. Sediments are best exposed on the northern side of Nunatak 1080. The following sequence was established:

LILJEQUISTHORGA NUNATAKS

MAP 13



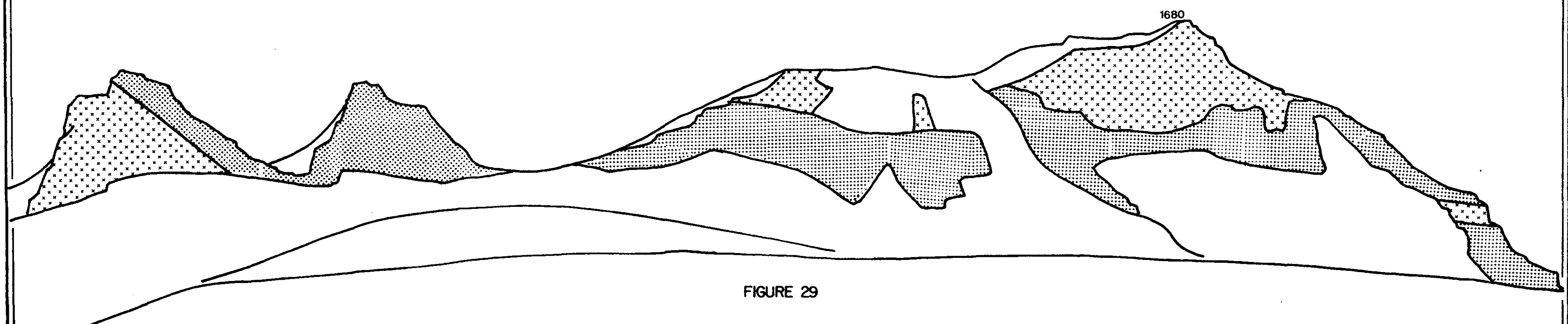


FIGURE 29

FIGURE 30

LOW RIDGE TO SOUTH OF GÖSTAPIGGANE

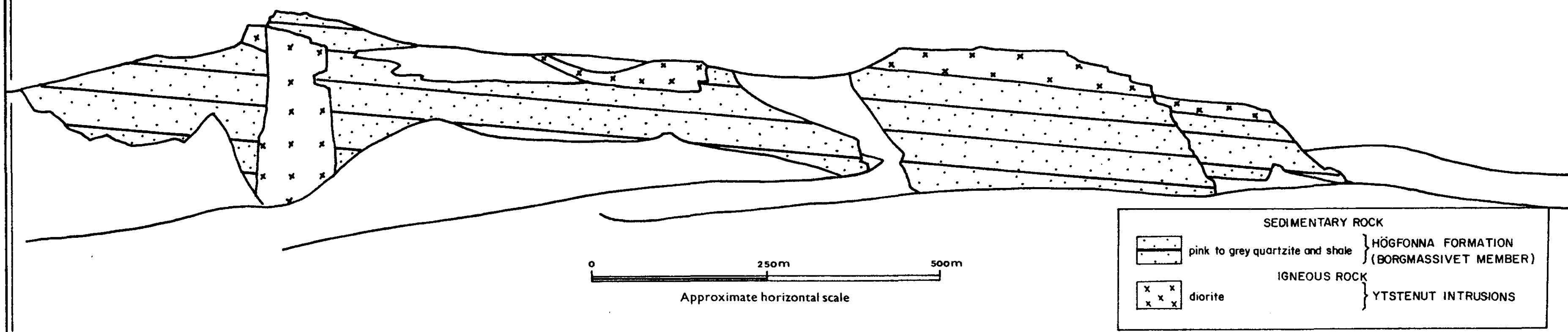
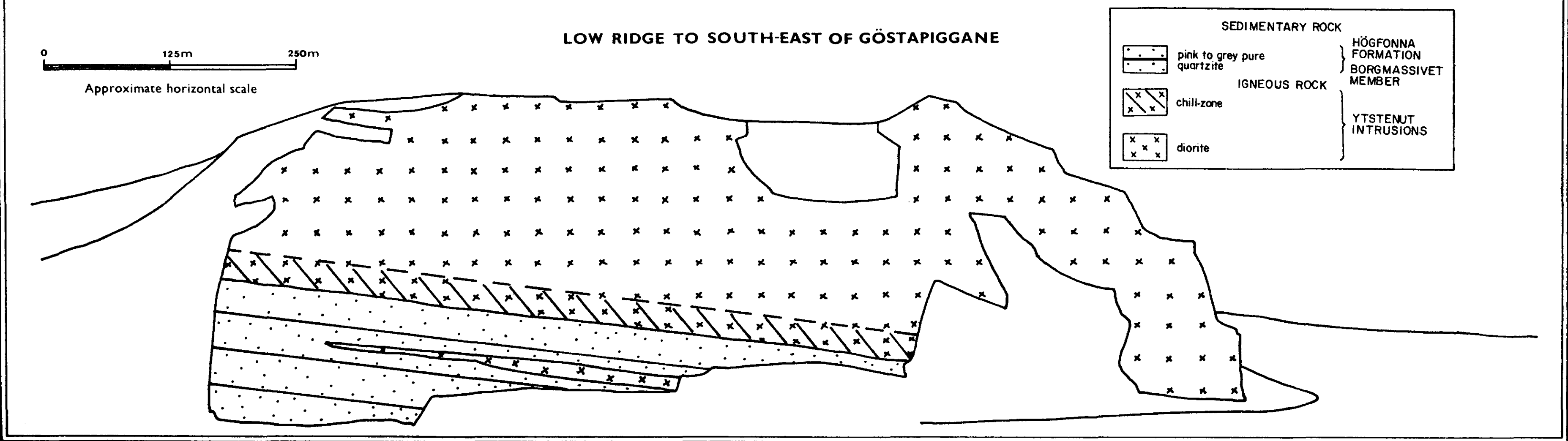


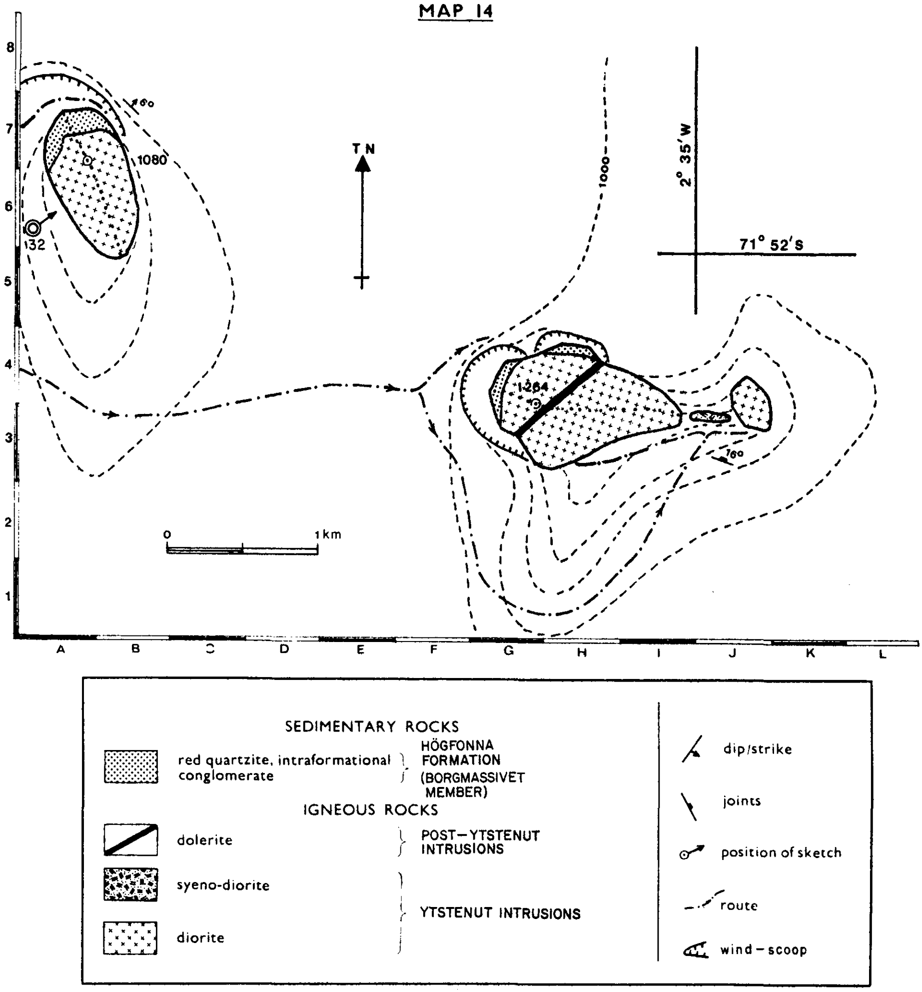
FIGURE 31

LOW RIDGE TO SOUTH-EAST OF GÖSTAPIGGANE



NILS JØRGENNUTANE

MAP 14



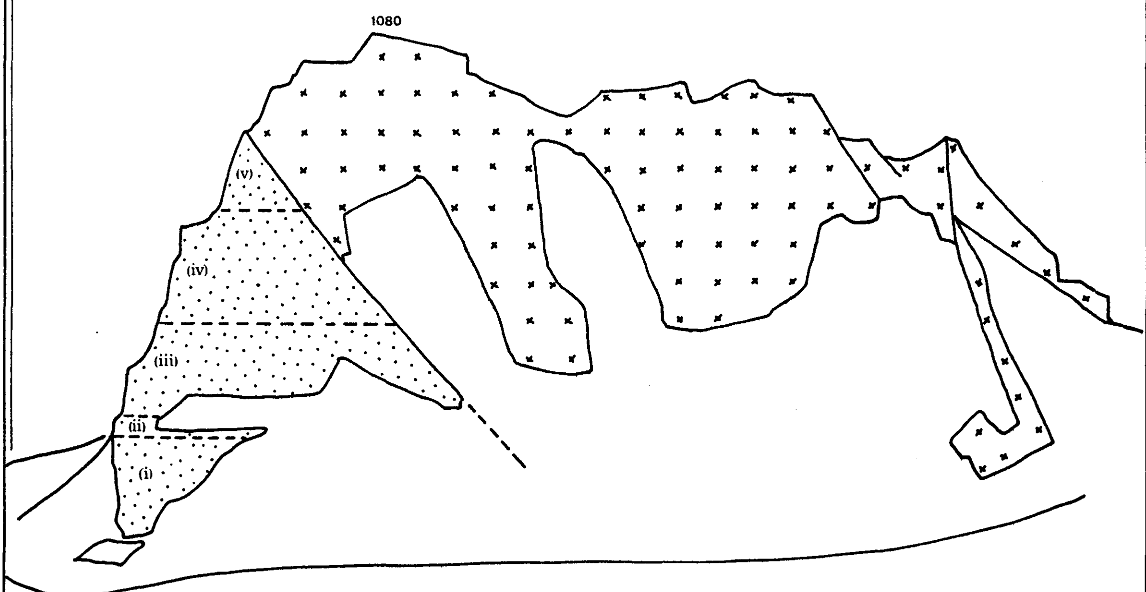


FIGURE 32

NUNATAK 1080

Elevation above snow surface (m)	Thickness (m)	Lithological description
36–51	15	(v) Light-coloured, pinkish gray quartzite (yellow to green on weathered surfaces)
21–36	15	(iv) Dark gray, vaguely banded quartzite containing red jasper.
11–21	10	(iii) Dark reddish-brown, fine-grained quartzite; well-bedded with thin laminae which are darker or lighter coloured than the rest of the sediment. Specularite is often found as thin layers or in small spherical structures and is invariably associated with epidote.
10–11	1	(ii) Pink fine-grained quartzite with intra-formational mud-pebble conglomerate. The conglomerate bands are severely epidotised. This horizon is very conspicuous and persistent.
0–10	10	(i) Identical to the succession occurring between 11 and 21 m.

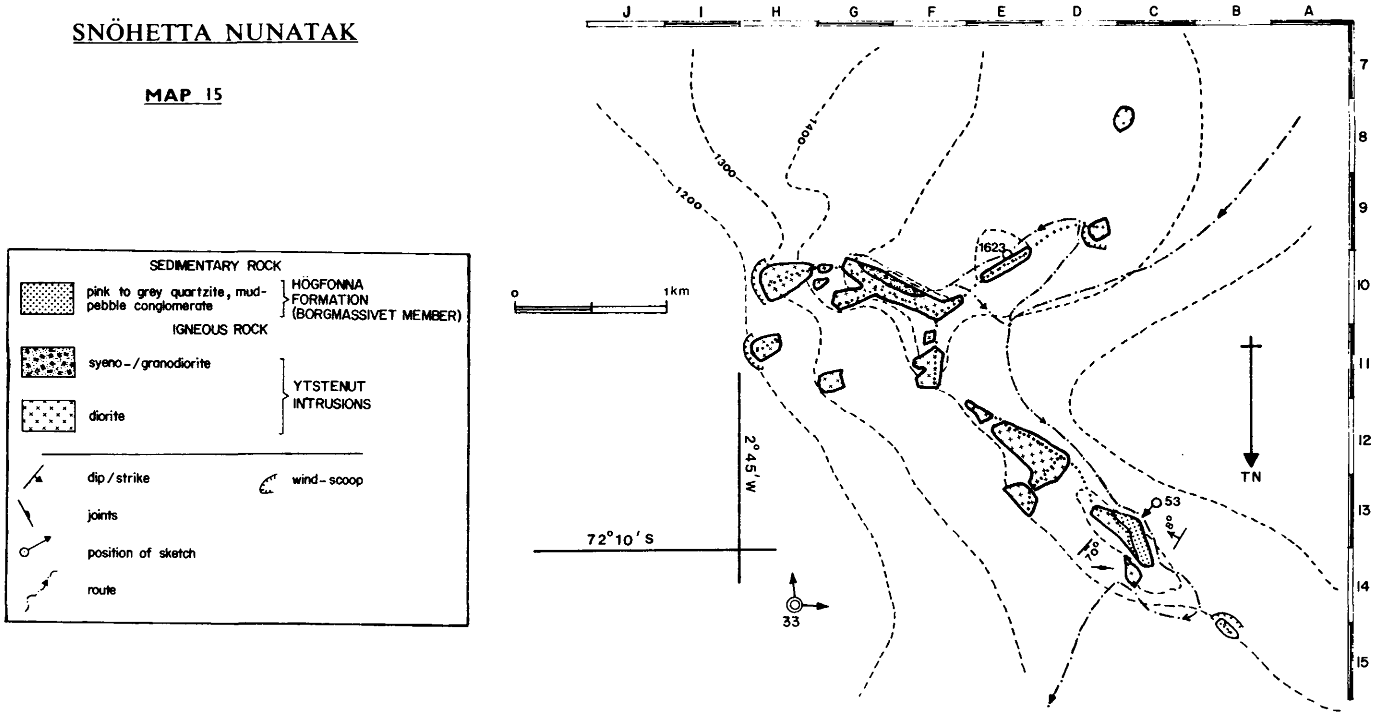
A similar sedimentary succession is also exposed at the eastern and northern sides of the main nunatak (1264). The general dip of the strata is 6^{o} north-east (strike 132^{o}).

8. Snöhetta

No previous investigations at this nunatak have been reported. As can be seen from *Map 15* and *Fig. 33*, the nunatak is almost completely covered

SNÖHETTA NUNATAK

MAP 15



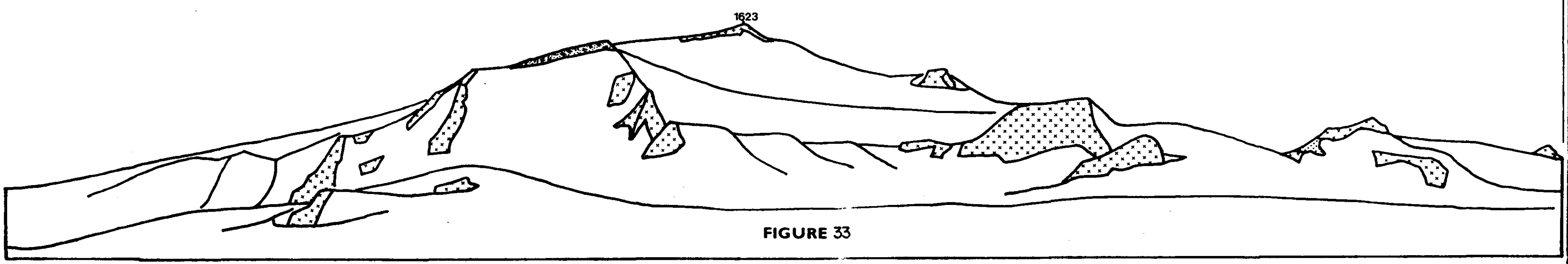


FIGURE 33

by snow and outcrops are few and isolated. The only exposure of sedimentary rock is at locality C13 (*Fig. 18*). According to Paterson (Bredell and Paterson, 1972), the 25 m thick succession of sediments is bounded at the top and bottom by mafic sills. The succession consists mainly of light gray to pink quartzite. Two distinct mud-pebble conglomerate horizons are found near the base of the outcrop. The general dip of the beds is 8° south-east (strike 30°).

9. Jekselen

This nunatak has previously been investigated by Neethling (1964) and by Vaclavik and Kahle (1971). No detailed mapping was done. In the view of Vaclavik and Kahle's revolutionary interpretation of the geology of the area as based on observations made at Jekselen, it was decided that a detailed re-investigation of this nunatak was essential. In short, these two geologists postulated that the sedimentary rocks in the area are Palaeozoic to Mesozoic in age and should be correlated with the Beacon Supergroup. According to them, these rocks had not been intruded by the mafic sheet (dated as 1700 ± 130 My by Allsopp and Neethling, 1970), but were deposited on the erosional surface of the sheet. Special attention was therefore paid to outcrops on which their assumptions had been based.

Two lithologically and structurally different sedimentary groups are exposed at the south-eastern part of the nunatak. Both belong to the Högfonna Formation, the one to the Borgmassivet Member (which will be described below) and the other to the Jekselen Member (which will be discussed under the appropriate heading).

At locality G4 (see *Map 16* and *Fig. 34*), an estimated thickness of 25 m of undisturbed subhorizontal sediments is exposed (*Fig. 35*). This outcrop closely resembles the wedge-shaped sedimentary occurrence at Peak 1390, Grunehogna (*Fig. 9c*). Both these outcrops are at the same elevation and their relationship to the mafic rock is identical. The lower contact is slightly undulating and the undulations cut across individual beds (*Fig. 35*) which makes the possibility of it being an erosional contact highly unlikely. On the south-eastern side, a large transgressive body cuts across the sediments at an angle of 85° to the south-east in exactly the same way as at Grunehogna. No brecciation is found along this contact.

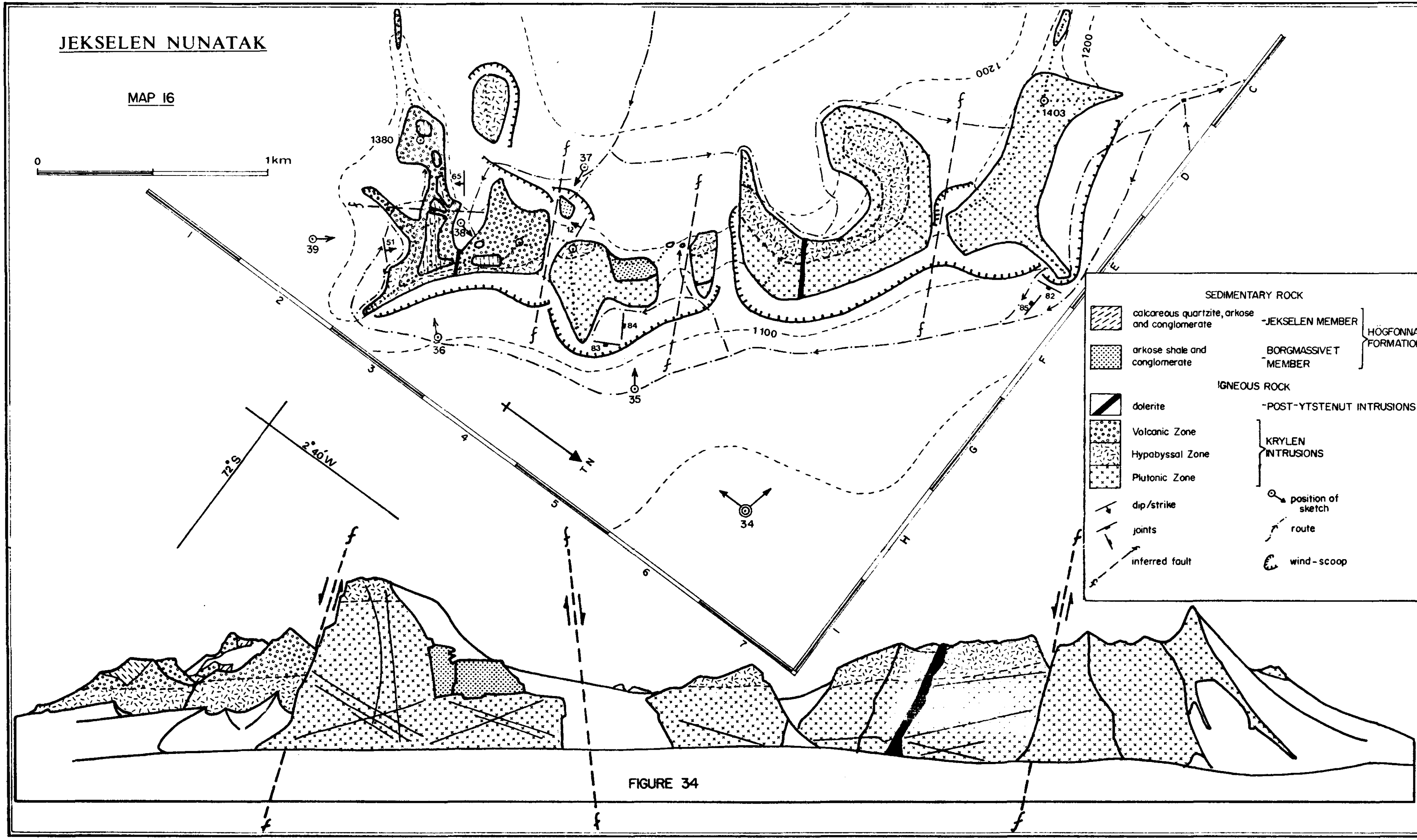

JEKSELEN NUNATAK
MAP 16
0
1km
1380
1403
1200
1100
65
51
12
82
85
83
84
39
38
37
36
35
34
72°S
2°40'W
N
1
2
3
4
5
6
7
C
D
E
F
G
H
SEDIMENTARY ROCK
calcareous quartzite, arkose and conglomerate
-JEKSELEN MEMBER
arkose shale and conglomerate
BORGMASSIVET MEMBER
HÖGFONNA FORMATION
IGNEOUS ROCK
dolerite
-POST-YTSTENUT INTRUSIONS
Volcanic Zone
Hypabyssal Zone
Plutonic Zone
KRYLEN INTRUSIONS
dip/strike
joints
inferred fault
position of sketch
route
wind-scoop

FIGURE 34

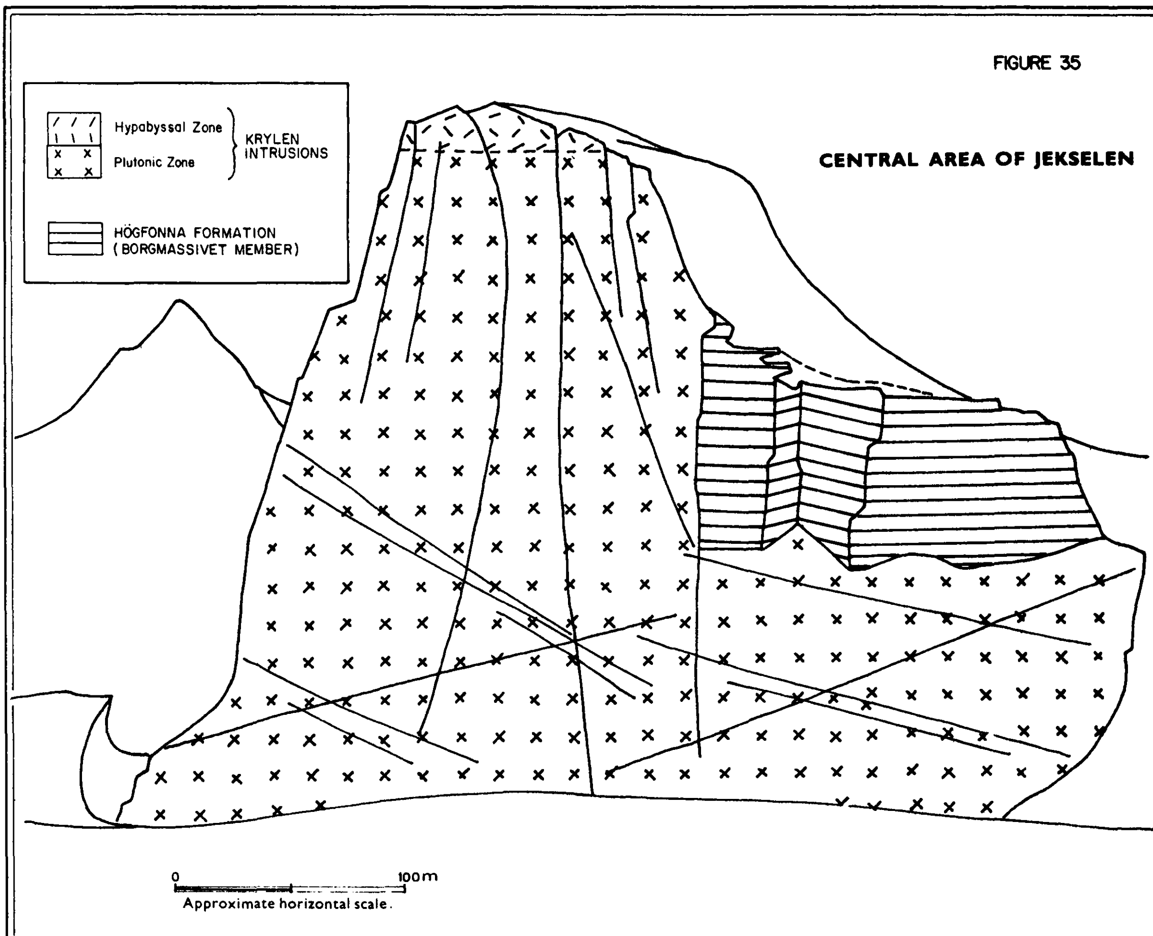


FIGURE 35
CENTRAL AREA OF JEKSELEN
Hypabyssal Zone
Plutonic Zone
KRYLEN INTRUSIONS
HÖGFONNA FORMATION (BORGMASSIVET MEMBER)
0
100m
Approximate horizontal scale.

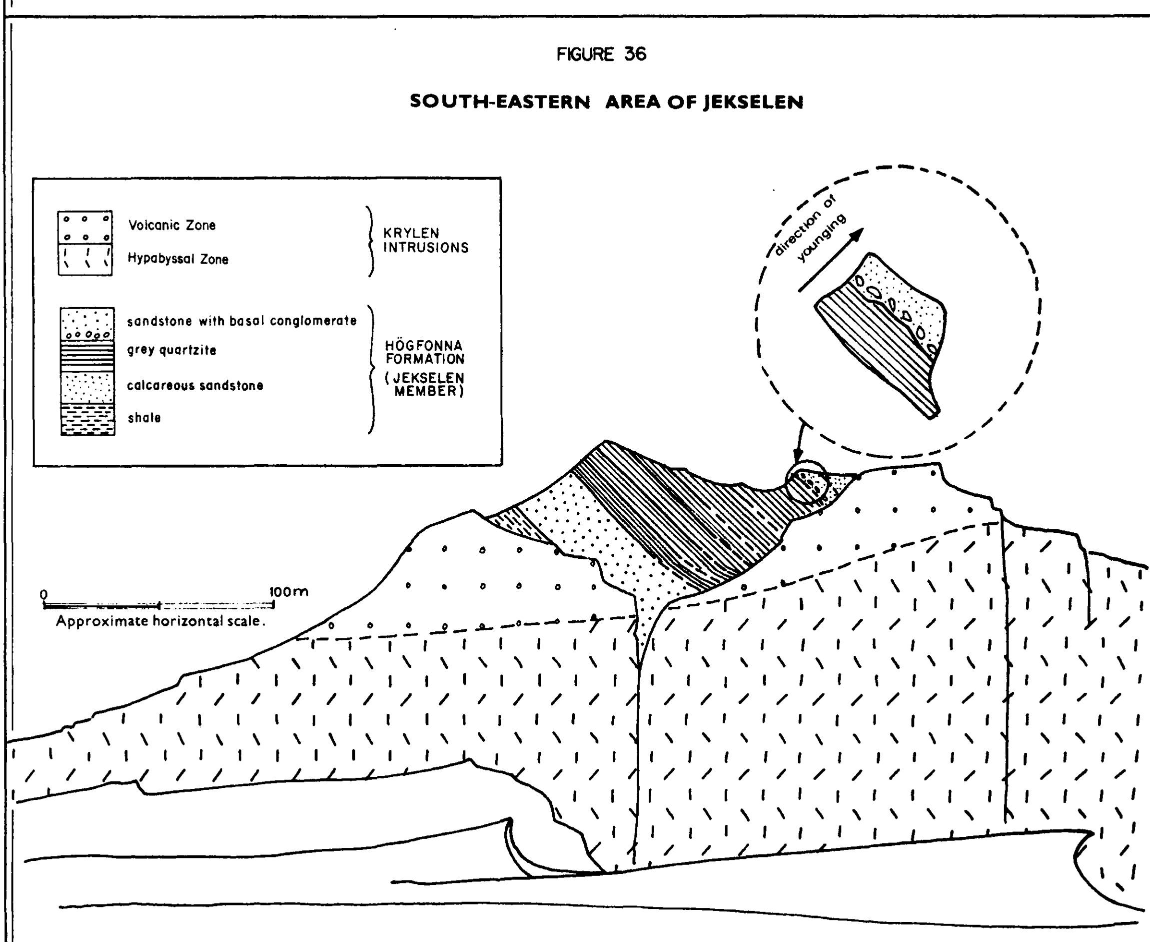


FIGURE 36
SOUTH-EASTERN AREA OF JEKSELEN
Volcanic Zone
Hypabyssal Zone
KRYLEN INTRUSIONS
sandstone with basal conglomerate
grey quartzite
calcareous sandstone
shale
HÖGFONNA FORMATION (JEKSELEN MEMBER)
direction of younging
0
100m
Approximate horizontal scale.

No evidence for a large downward displacement of the sediments could be found as suggested by Neethling (1964). A brecciation zone, which most probably gave rise to this theory, is present at the base of the nunatak but approximately 20 m south-west of the contact line. Absolutely no lateral change in the composition of the mafic rock on either side of the contact line and the brecciation zone could be detected. As the mafic intrusions in the Jekselen area show a definite, easily detectable, vertical change in texture and composition, any large displacement would bring two different types in contact with each other. This, together with the fact that similar cross-cutting relationships are very common in the rest of the Ahlmannryggen, suggest a normal intrusive, rather than a tectonic relationship between the sediments and mafic rock at Jekselen.

The abovementioned sedimentary succession closely resembles sediments of the lower part of the Borgmassivet Member as they occur at Grunehogna. The sediments are mainly dark-brown to gray quartzites with intercalated dark-brown to reddish-brown mudstone. The latter frequently contains mud-cracks and ripple-marks. Grains of red jasper are common in the arenaceous rocks. Disseminated chalcopyrite and pyrite can be observed in hand-specimen. On account of the presence of these sulphides, this succession was at one stage considered to be a correlate of the Pyramiden Formation (Neethling, 1970). The presence of jasper, which is characteristically absent in the Pyramiden Formation, rules out this correlation.

An almost identical succession of subhorizontal sediments crops out just above the snow surface on the south-western side of the nunatak at locality G3–4 (*Fig. 37*). The average strike is 77^{o} and the dip 10^{o} south south-east. Ripple marks and mud-cracks are abundant and flow directions indicate a source area located to the north and the north-west (between 308^{o} and 352^{o}). These sediments differ from those exposed on the north-eastern cliff in that they are darker in colour and have a baked appearance. Slight epidotisation is evident throughout the outcrop. Unfortunately the contacts with the igneous rock are totally obscured by snow and scree.

FIGURE 37

HORIZONTAL SEDIMENTS IN AREA G3

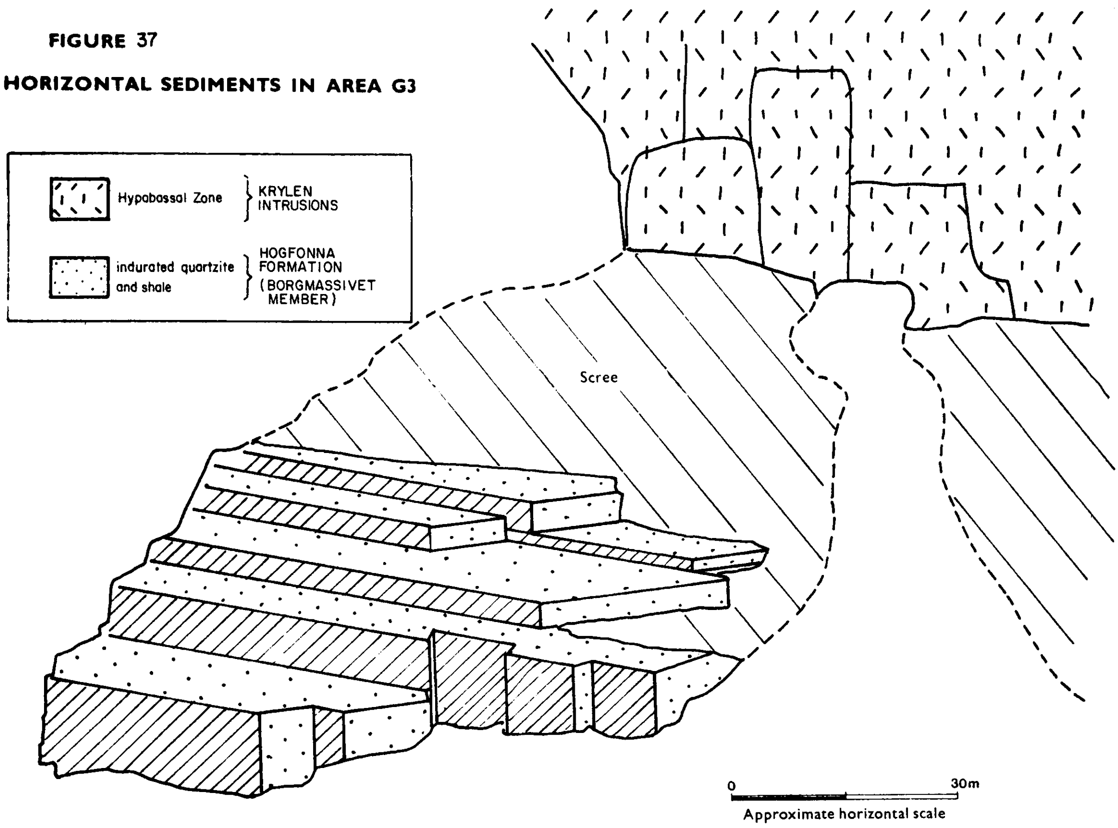
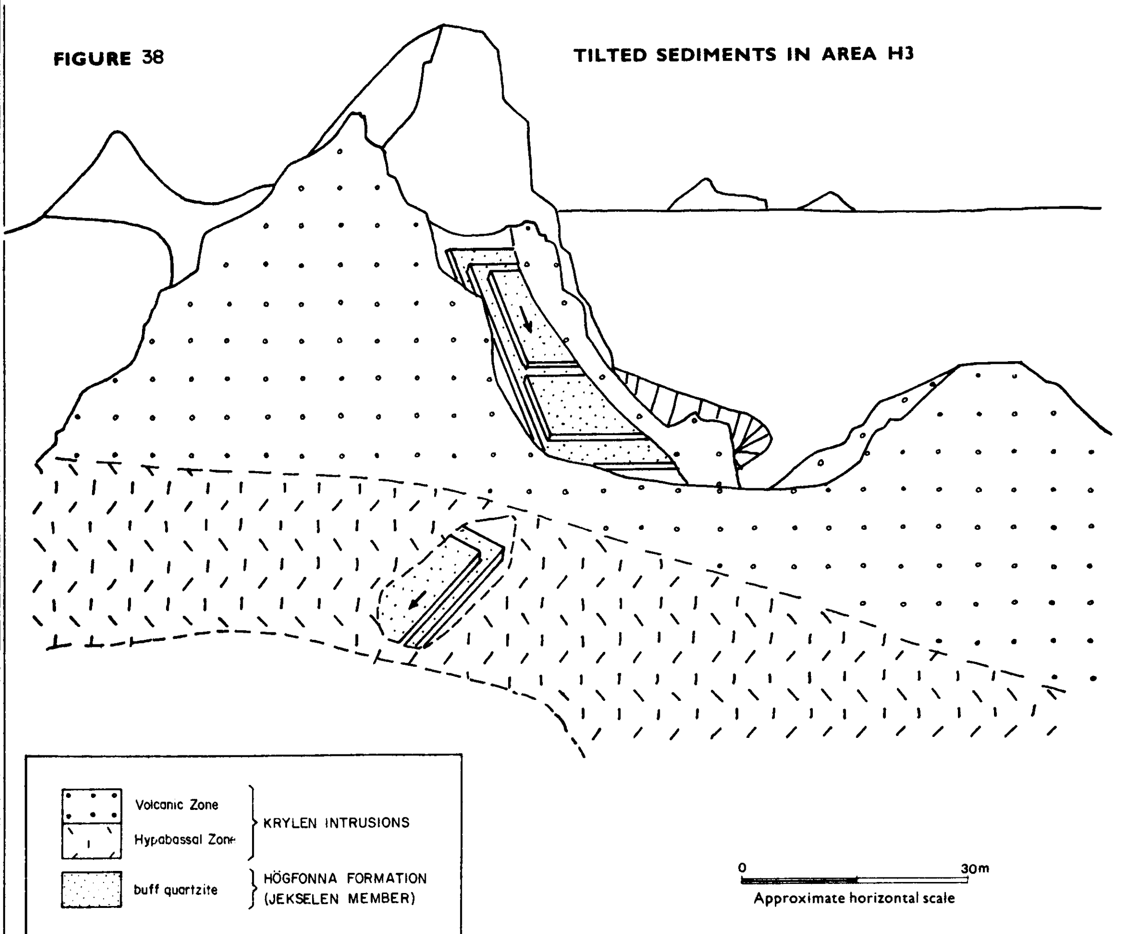


FIGURE 38

TILTED SEDIMENTS IN AREA H3



C. The Jekselen Member

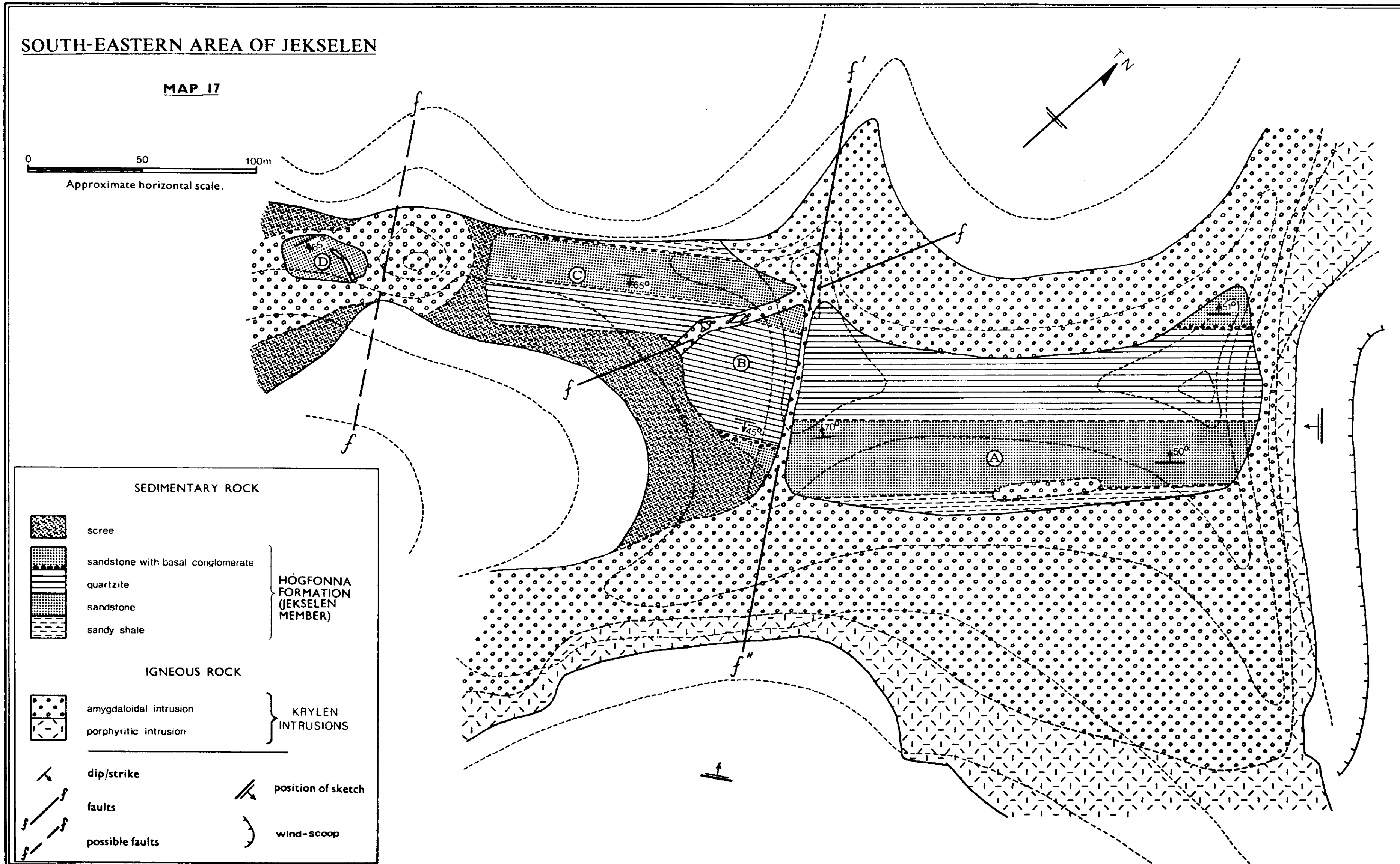
1. Jekselen

At this, the type locality, sediments belonging to the Jekselen Member are confined to the south-easternmost part of the nunatak; south-east of the north-east-trending fault indicated on *Map 16*. (Localities H3 and H2). They occur typically as isolated patches within the mafic rock and invariably dip at angles of 36^{o} or more.

The largest of these exposures was found to be structurally very interesting and was investigated and mapped in detail. *Map 17* is a sketch map on scale 1:2 500 of this outcrop, indicating the structure and main beds of the sequence. *Fig. 36* is a side-view sketch of this outcrop as it is exposed on the north-eastern cliff and shows the structure described as an "... isoclinally folded succession of sediments ..." by Vaclavik and Kahle (1971). This succession was carefully investigated and sampled as indicated on the sketch. The direction of younging was found to be normal, i.e. from bottom to top in the succession. In spite of a number of beds which are very suitable for use as marker horizons, absolutely no duplication of beds is found in the sequence. This rules out any possibility of isoclinical folding.

The sequence is as follows:

Elevation above intrusive contact (m)	Thickness (m)	Lithological description
74,15–80,15	6	Coarse-grained buff-coloured sandstone containing grains of red jasper and minor amounts of calcite.
74–74,15	0,15	**Polymict** conglomerate resting unconformably on a slightly undulating erosional surface. The conglomerate consists of angular to subrounded pebbles of red jasper, green chert, white quartz and fragments of dark


SOUTH-EASTERN AREA OF JEKSELEN
MAP 17
0
50
100m
Approximate horizontal scale.
T N
f
f'
f''
A
B
C
D
65
65°
45°
70°
50°
51°
SEDIMENTARY ROCK
scree
sandstone with basal conglomerate
quartzite
sandstone
sandy shale
HÖGFONNA FORMATION (JEKSELEN MEMBER)
IGNEOUS ROCK
amygdaloidal intrusion
porphyritic intrusion
KRYLEN INTRUSIONS
dip/strike
faults
possible faults
position of sketch
wind-scoop

		greenish-gray quartzite in a matrix of buff-coloured sandstone which contains grains of red jasper and small amounts of calcite. Pebbles vary in size from 2 to 30 mm.
59–74	15	Dark, greenish-gray, fine-grained quartzite containing calcite as small inclusions and along joints and bedding planes.
24–59	35	Scree.
22–24	2	Dark greenish-gray calcareous quartzite containing light-coloured spherical calcite concresions, 2 to 5 mm in diameter. In some places the calcite has been removed through weathering, giving the rock a porous appearance.
12–22	10	Greenish-gray to buff-coloured, calcareous sandstone with numerous angular, flat mudstone fragments, as well as inclusions of calcite and occasional slightly rounded pebbles of dark brown quartzite. Mudstone fragments attain lengths of up to 10 cm, but are of the order of 1 to 2 cm on the average. Calcite inclusions vary in shape and size. (Very small to 2 cm in diameter).
2–12	10	Intensely sheared buff-coloured calcareous sandstone with dark-brown mudstone fragments and calcite inclusions up to 1 cm in diameter.
0–2	2	Cream-coloured and light-gray to greenish-gray sandy shales containing minor amounts of calcite concentrated along fractures.

As is indicated on *Map 17* and *Fig. 39*, the sedimentary exposure consists of four outcrops separated by transgressive amygdaloidal dykes. The sequence described above is that of outcrop A where the strike is 42° and the dip 50° north-west. Sediments of outcrops B, C and D dip almost exactly in the opposite direction, with the dyke between A and B separating the two structurally different types. In outcrop B the sediments strike 54° and dip 45° south-east. The dyke which separates outcrops B and C is approximately 2 m wide and contains several rotated boulders (up to 1 m in diameter) of sedimentary

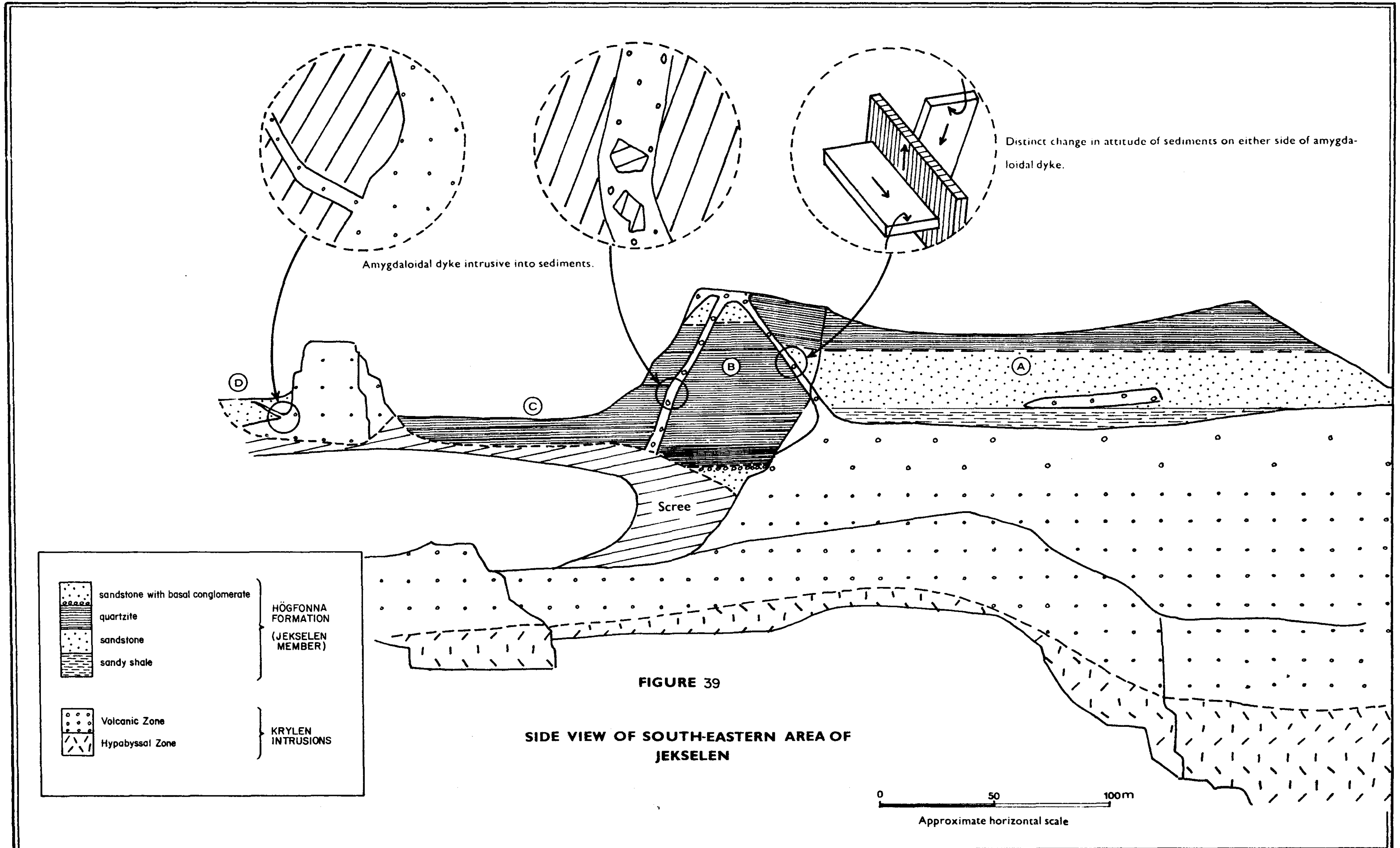


FIGURE 39

SIDE VIEW OF SOUTH-EASTERN AREA OF JEKSELEN

rock. There is no lithological change in the sediments on either side of this dyke, but the beds in outcrop C have a slightly different attitude (Strike 50°, dip 65° south-east). Outcrop C consists mainly of buff-coloured sandstone with small inclusions of calcite. Many of these inclusions have regular, symmetrical shapes in the form of short cylinders approximately 5 mm in diameter and were at first thought to be coral fossils. Subsequent microscopic investigations proved, however, that they are not of organic origin. Just above this zone of pseudofossils, a horizon 5 cm thick, of almost pure calcite was found, containing small cubic crystals of limonite. Ripple marks are rare and only one example could be found in situ, by means of which it was determined that the bedding is normal and not overturned.

The same buff-coloured sandstone is exposed at outcrop D, but again there is a change in attitude (Strike 17°, dip 65° east-south-east).

Structurally, these sediments can therefore be divided into two main parts; a north-westerly and a south-easterly dipping sequence. This is believed to have been caused by differential pressure during intrusion at relatively shallow depths. (See discussion in Chapter VI). The sedimentary succession broke along f'f''and tilted independently in opposite directions. Secondary faulting took place in the south-easterly-dipping beds, causing minor local disturbances. Andesitic magma, which has been proved to be the volcanic (near-surface) equivalent of the Krylen Intrusions, moved in along all the fault-zones.

The only other outcrops of sediments belonging to the Jekselen Member were found at locality H3 (*Fig. 38*). The larger of these two outcrops is right at the top of the nunatak and consists of 2 m of buff-coloured sandstone with 1 m of dark-gray quartzite at the top. The beds dip at 36° north-east and strike at 152°. Minor folding is present in the sediments on the contact with the amygdaloidal intrusion. Although the succession as a whole is calcareous, calcite is markedly more concentrated in a zone, approximately 15 cm wide, along the contact. A smaller outcrop in the form of a small isolated patch of sedimentary rock surrounded by the amygdaloidal intrusion, was found lower down on the south-western slope of the mountain. It consists of the same buff-coloured sandstone as the larger outcrop, but becomes quartzitic in places where intensive small-scale folding occurs.

2. Tindeklypa

An assemblage of rock types, remarkably similar to that at the south-eastern part of Jekselen, is present at Nunatak 1390, the northernmost exposure of the Tindeklypa range (*Map 18*, locality A19). On the north-western side of this nunatak, which is situated about 5 km south-east of Jekselen, a succession, 50 m thick, of Jekselen Member sediments is exposed. Two to three metres of buff-coloured sandstone is found at the base and the rest of the succession consists of pink to brown quartzite containing abundant grains of red jasper. There is a gradational relationship between the two rock types and the distinction is based only on slight differences in colour and induration. Dendrites are common on the bedding planes of the quartzites. Ripple-marks and occasional cross-bedding were observed throughout the sequence. Flow direction as indicated by the ripple-marks, was from west to east. The general dip of the strata is 10^{o} to 15^{o} to the north-west, but it increases towards the contact with the amygdaloidal intrusion (*Fig. 41*). A rotated xenolith of quartzite (approximately 30 cm in length) occurs in the intrusive rock just next to the contact. As indicated in *Fig. 41*, a few metres of quartzite is also exposed right at the top of the nunatak.

At the northernmost of the small outcrops between nunataks 1390 and 1599, an inclusion of buff-coloured quartzite is found within the amygdaloidal intrusion. This exposure is approximately 5 m thick and 10 m long.

Apart from the exposures mentioned above, Jekselen Member sediments are also present abundantly as larger and smaller inclusions within the Tindeklypa Member of the Viddalen Formation (Chapter V).

D. Conditions of Deposition

Deposition of the Högfonna Formation took place under predominantly high-energy conditions in a shallow-water, oxidising environment. Unlike the Pyramiden and Grunehogna Formations, no significant changes in depositional conditions took

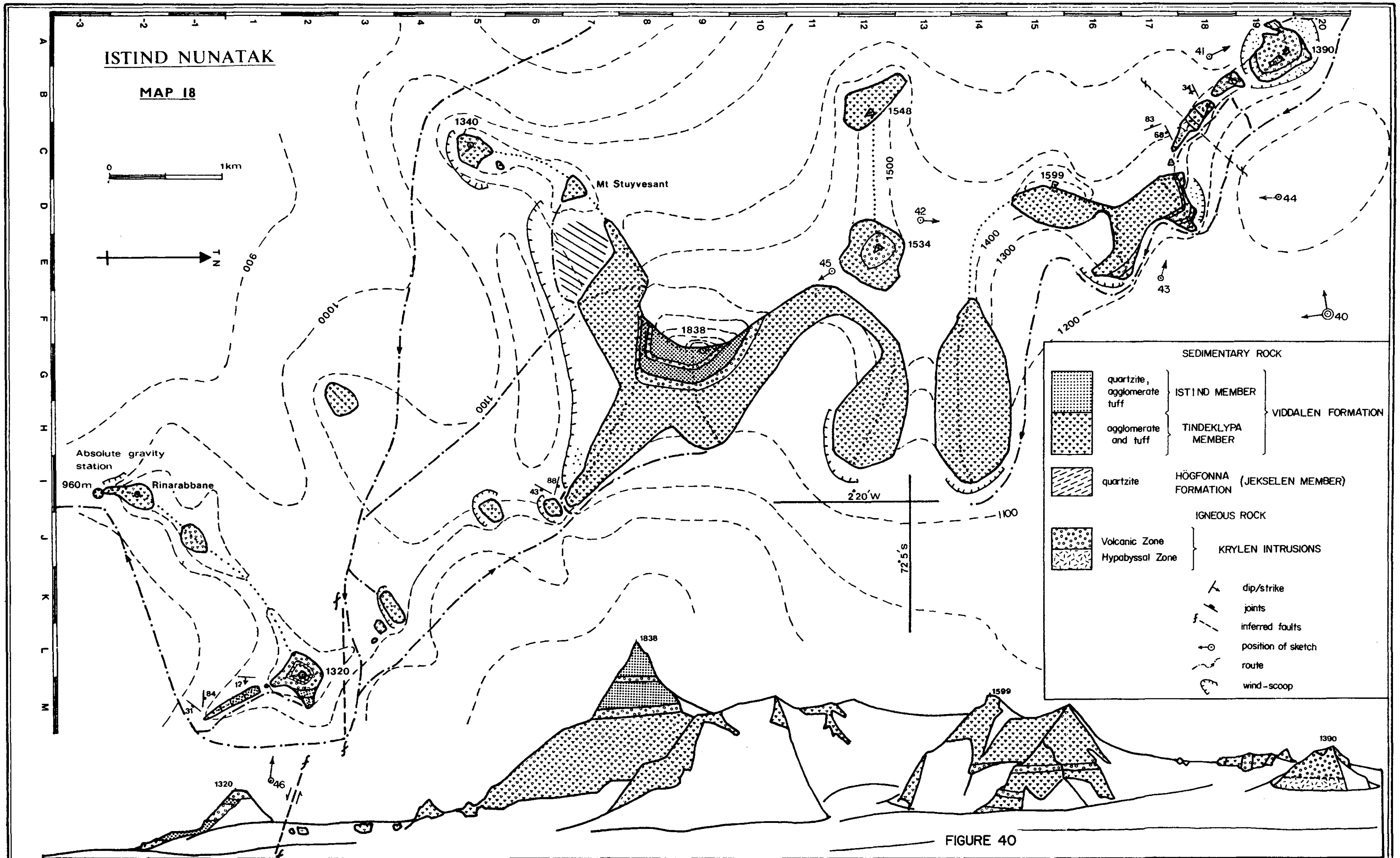

ISTIND NUNATAK
MAP 18
0 1km
TN
Absolute gravity station
960m
Rinarabbane
1340
Mt Stuyvesant
1548
1534
1500
1838
1599
1390
1320
900
1000
1100
1200
1300
1400
2°20'W
72°5'S
SEDIMENTARY ROCK
quartzite, agglomerate tuff
ISTIND MEMBER
agglomerate and tuff
TINDEKLYPA MEMBER
VIDDALEN FORMATION
quartzite
HÖGFONNA FORMATION
(JEKSELEN MEMBER)
IGNEOUS ROCK
Volcanic Zone
Hypabyssal Zone
KRYLEN INTRUSIONS
dip/strike
joints
inferred faults
position of sketch
route
wind-scoop

FIGURE 40

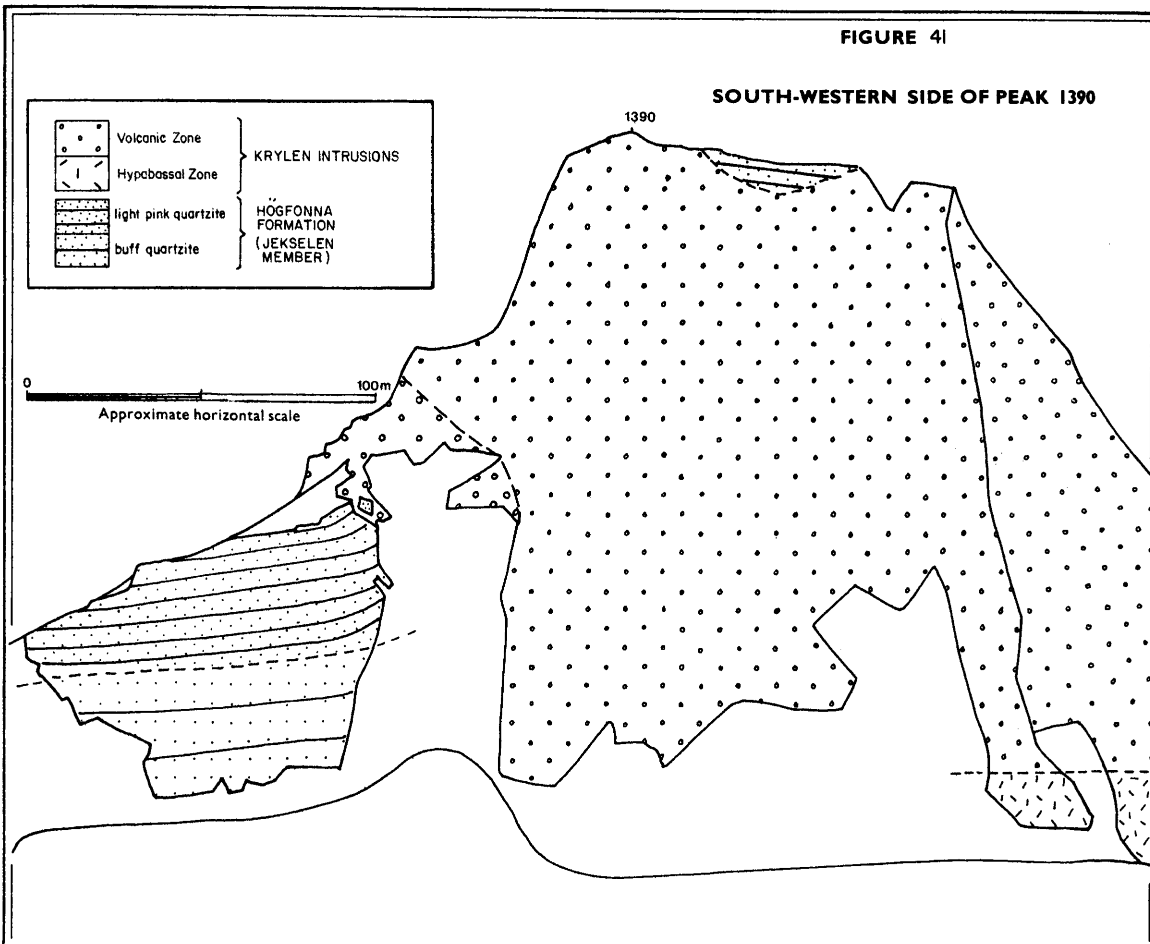


FIGURE 41

SOUTH-WESTERN SIDE OF PEAK 1390

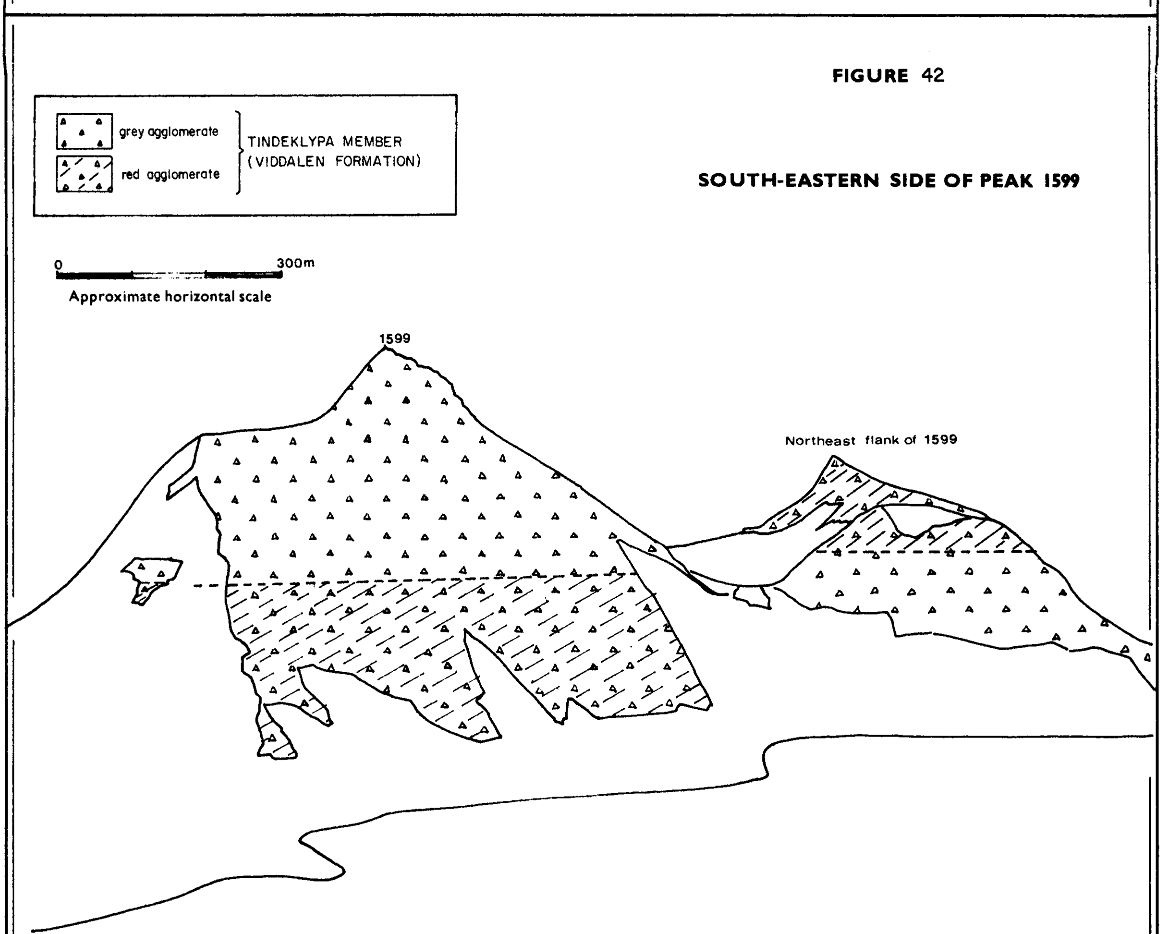


FIGURE 42

SOUTH-EASTERN SIDE OF PEAK 1599

place during Högfonna times. Sporadic volcanic activity in the source-area commenced during the early stages of Högfonna deposition (ash particles low down in the Borgmassivet Member, reported by Aucamp, 1972), and gradually spread to within the depositional basin during deposition of the upper part of the Borgmassivet Member (well developed tuff bands – De Ridder, 1970).

Calcareous sediments belonging to the Jekselen Member were deposited in the north-eastern part of the basin shortly prior to large-scale volcanism which replaced sedimentation in the eastern Ahlmannryggen, while deposition of red beds (Raudberg Formation – De Ridder, 1970) was taking place farther to the south.

Volcanic and tectonic activity in the vicinity and within the depositional basin resulted in relatively unstable conditions compared with those under which the pre-Högfonna formations had been deposited. The influence of these conditions is mainly displayed by the typical lateral discontinuity of beds, the abundance of sedimentary structures such as cross-bedding and ripple-marks, and the inconsistency of paleocurrent direction. Measurements of cross-bedding and ripple-marks indicate that, during Högfonna times, the depositional basin received material from a provenance located within a wide arc of 268° (between 84° and 352°). This differs markedly from the provenance arcs of 190° and 124° for the Pyramiden and Grunehogna Formations respectively.

V. THE VIDDALEN FORMATION

A. Definition and Type Locality

The author wishes to introduce the Viddalen Formation to replace the presently used stratigraphic units "Tindeklypa Formation" and "Istind Formation" as defined by Neethling (1970). The newly defined Viddalen Formation will include all the agglomerate, tuff and penecontemporaneous lava as well as the shallow-water sediments with intercalated agglomerate, tuff and lava flows, which occur at the Tindeklypa-Istind range of nunataks at the confluence of the Viddalen and Jutulstraumen glaciers. Exposures of similar rock types at Fasettfjellet and Grasteinen are considered to be correlates of this formation.

On the basis of the presence of non-volcanic sediments in its upper part, the Viddalen Formation is subdivided into two conformable members, *viz.*:

1. A basal *Tindeklypa Member*, some 500 m thick, which consists predominantly of agglomerate with subordinate tuff and penecontemporaneous lava; and

2. An upper *Istind Member,* approximately 340 m thick, comprising alternating feldspathic quartzite, agglomerate, tuff and lava flows.

The necessity for abandoning the "Tindeklypa Formation" and "Istind Formation" as two separate formations will be clear from the discussions and the descriptions that follow; the main reasons being the close relation in time which was found to exist between these rocks and the underlying sedimentary formations, and the observed fact that the relation between the "Istind Formation" and "Tindeklypa Formation" is not one of angular unconformity as suggested by Neethling (1970).

B. Discussion of Previous Investigations

Ever since the discovery of this isolated sedimentary - volcanic sequence in the eastern part of the Ahlmannryggen, geologists have been confused as to the origin of these rocks and their relationship to the monotonous subhorizontal sedimentary sequences and intrusive sheets in the rest of the area.

E.F. Roots, who as member of the N.B.S. Antarctic Expedition (1949–52), was the first geologist to visit the Tindeklypa area, made no attempt to group these rocks into a separate stratigraphic unit and classified them under the heading "undifferentiated clastic rocks" (Roots, 1969).

Since the second South African expedition (1961–62), ten South African geologists, representing eight different expeditions, have investigated the Tindeklypa - Istind area (Butt, Langenegger, Bastin, Pollak, Watters, Vaclavik and Kahle, Bredell and Paterson, and Van Zyl). Neethling, who attempted the enormous task of compiling the sometimes extremely contradictory and confusing findings of the first five geologists, could with the information available to him, not possibly hope to succeed in giving a satisfactory account of the stratigraphic relation of these rocks to other units within his "Ritscher Supergroup". The following statement from his thesis indicates that Neethling himself is clearly not very satisfied with his final interpretation:

"The Istind sediments and the Tindeklypa Formation, and the Straumsnutane Volcanics could therefore have a much closer relation in time to the upper part of the Ahlmannrygg Group and the Jutul Volcanics than what would seem to be suggested by their relative radiometric ages" (Neethling, 1970).

After the first investigation of the area, a glacial origin for the "Tindeklypa Formation" was advanced (Butt, 1962; Neethling, 1964). This idea has since then rightfully been abandoned in favour of a volcaniclastic origin. In his thesis, Neethling describes the Tindeklypa Formation as unconformably overlying red arkose and comprising "... a massive conglomerate-boulder bed deposit with occasional sedimentary interbeds indicating a regional east-southeasterly dip of $5^{o} - 50^{o}$ in places". This "formation" is in turn unconformably overlain by the subhorizontal "Istind Formation". Together with the Straumsnutane Formation (andesitic lavas with an age of 856 $\pm$ 30 My), the "Tindeklypa and Istind Formations" are assigned to the socalled "Trollkjellrygg Group". The existence of a pre-Trollkjellrygg lava is also inferred, based on lava "pebbles" found in the "conglomerate" and an outcrop of lava present below the "Tindeklypa Formation" as reported by Butt. This lava ("Jutul Volcanics") is assigned to a separate stratigraphic unit, *viz.* the "Jutul Group" which is considered to be intermediate in age between the "Ahlmannrygg" and "Trollkjellrygg Groups".

As was mentioned previously, Russian geologists who visited this area expressed views which are in direct contradiction with Neethling's model. They regard the "Tindeklypa Formation" as forming the base of the sedimentary successions which are found farther to the west (Ravich and Soloviev, 1966). In the author's opinion, this erroneous impression was created when these investigators approached the area from the east during a reconnaissance survey, noted some reddish sediments overlying massive agglomerate at Istind Peak, and immediately correlated these sediments with reddish sediments which they subsequently observed farther to the west and the south.

C. The Tindeklypa Member

1. Distribution

Except for relatively minor occurrences at Fasettfjellet and Grasteinen, rocks belonging to this member are confined to the Tindeklypa nunataks south of Nunatak 1390 and at the base of Istind Peak. The base of the Tindeklypa Member is nowhere exposed and the estimated total thickness of 500 m should be regarded as a minimum value. A total thickness of 300 m proposed by Butt (1962) for the "Tindeklypa Formation" is considered an under-estimation, which is most probably due to the fact that there were no reliable base-maps available at that time.

a. Small Outcrops Between Nunataks 1390 and 1599

The northernmost exposure consists of lava with small quartz amygdales at the base (the same as at Nunatak 1390). This grades into lava with bigger amygdales (1 to 2 cm in diameter) towards the top where an inclusion of Jekselen Member sediments is found within the lava. Further to the south, red, gray and yellow agglomerate rest directly on the amygdaloidal lava (*Fig. 44*). The

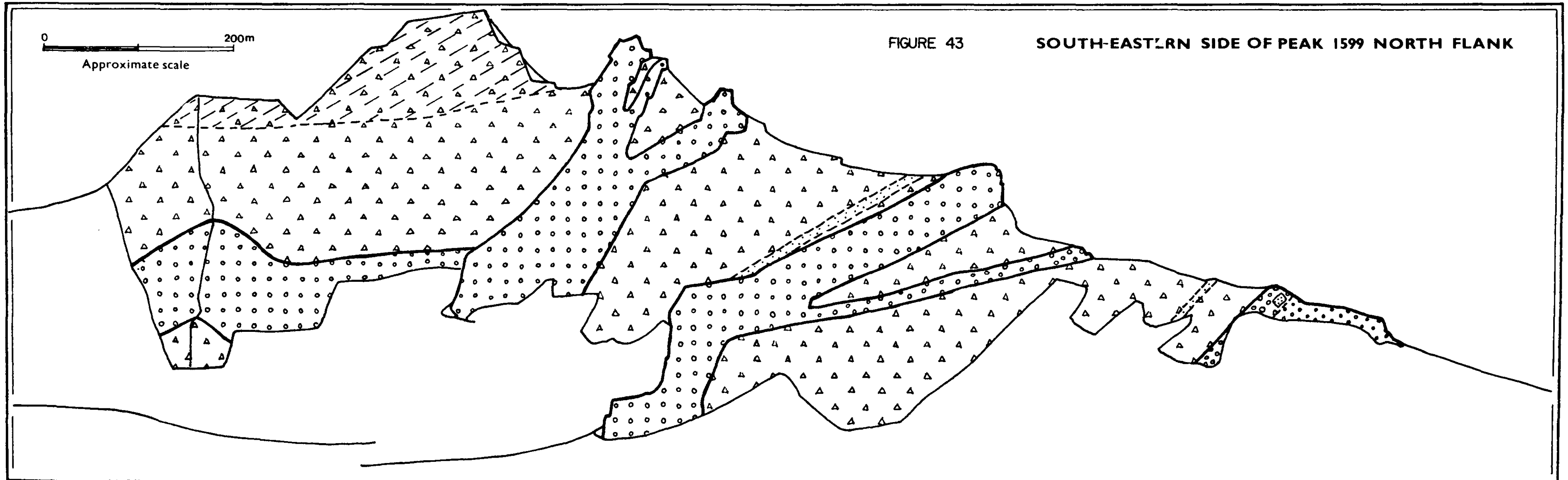


FIGURE 43 SOUTH-EASTERN SIDE OF PEAK 1599 NORTH FLANK

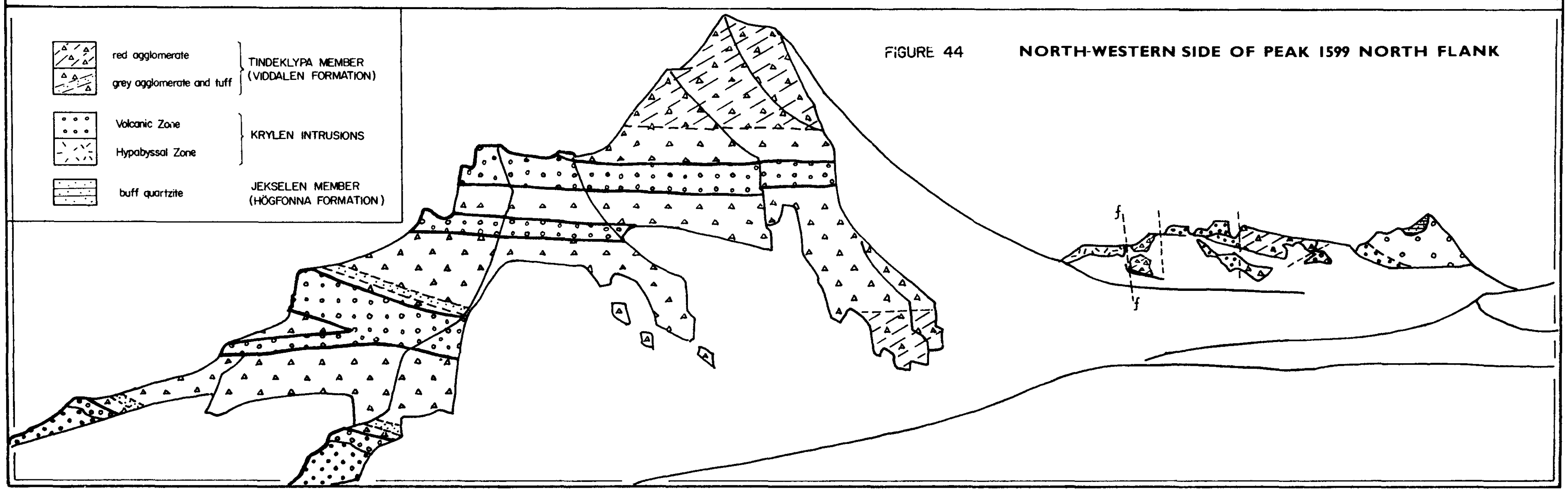


FIGURE 44 NORTH-WESTERN SIDE OF PEAK 1599 NORTH FLANK

yellow type is found only in the vicinity of thin lava flows which are connected with the main underlying flow. The agglomerate at this locality consists of angular fragments of dark-green argillite (up to 1 cm long) in a fine-grained quartzitic matrix. Joints are well developed in the agglomerate, but bedding is vague. The average strike is 64^{o} and the dip 34^{o} to the south-east. Flows of lava with big quartz amygdales (1 – 2 cm) are present in the agglomerate and contain sedimentary inclusions varying in size from a few centimetres to about 5 m. The sediments range from a buff-coloured sandstone to a grayish green well-indurated quartzite. Exactly the same sediments were found as isolated patches within the agglomerate on the saddle at the top of the outcrop. All these sediments originally belonged to the Jekselen Member.

Farther south, the agglomerate stops abruptly against a body of lava, about 20 m wide, which dips steeply to the north. This lava has an aphanitic texture and contains relatively few small quartz amygdales. South of the lava, a few metres of red agglomerate is exposed. The contact between this agglomerate and the porphyritic mafic rock (see Chapter VI) which forms the southernmost outlier, is obscured by ice and a normal fault with a downthrow on the northern side is inferred to account for this sudden change in rock types (*Fig. 44*).

b. Nunatak 1599

Especially the north-eastern flank was investigated in detail (*Figs. 43* and *44*). A grayish green fine-grained lava is exposed at the base (locality D18), containing small spheroidal quartz amygdales as well as short needle-like crystals (pigeonite). This lava grades into a dark green aphanitic variety with big (1–3 cm) amygdales of quartz and calcite. Angular boulders of light-gray quartzite are present as inclusions within the latter horizon.

The rest of the nunatak consists mainly of agglomerate with irregular lava flows up to 10 m thick. The agglomerate is generally greenish-gray to gray in colour, but becomes brick-red towards the summit. Two well-bedded greenish-gray tuff horizons, about 3 m thick, are found below and just above the second major lava flow (*Figs. 43* and *44*). They form sharp contacts with the agglomerate and have a very persistent lateral extent. The lower horizon strikes 30° and dips 27° south-east, while the upper one strikes 161° and dips at 31° to the north-west.

Small isolated patches of buff-coloured sandstone (a few metres across and dipping steeply in various directions) were observed on the eastern slopes of the nunatak. These sedimentary inclusions attain larger dimensions than the average inclusions in the agglomerate, and although they undoubtedly originally belonged to the Jekselen Member, they should in cases like these be regarded as forming part of the Tindeklypa Member.

Where the snow surface is lower, especially at the southern and south-eastern parts of the nunatak, a red agglomerate is exposed at the base (*Fig. 42*). The general sequence of the agglomerate is therefore red at the base (lowermost exposed part), gray in the middle and red at the top. All the lava flows in this area are confined to the gray agglomerate which has a total thickness of about 250 m. The author can definitely not support Neethling's subdivision of the "Tindeklypa Formation" into four "conformable members" (Neethling, 1970).

c. The Main Tindeklypa Nunataks

The two large nunataks which strike east-west immediately north of Istind Peak consist entirely of red and gray agglomerate. No lava flows were observed at this locality.

d. Istind Peak

The lower 400 m of this, the second highest peak in the Ahlmannryggen, consists of massive gray agglomerate which are devoid of any lava flows.

e. Nunatak 1320

Agglomerate belonging to the Tindeklypa Member makes up the lower 75 m of this nunatak (*Fig. 46*). The following threefold subdivision was established (from the base upwards):

FIGURE 45

NORTHERN SIDE OF ISTIND PEAK 1838

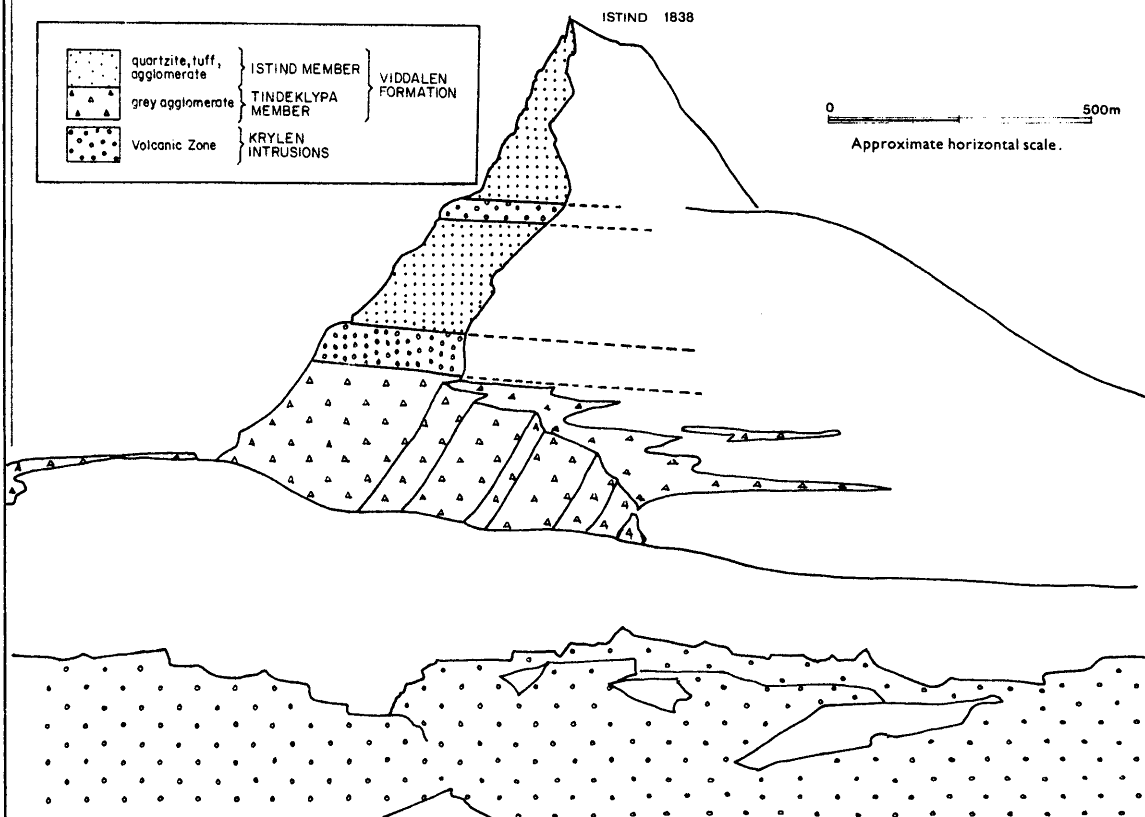
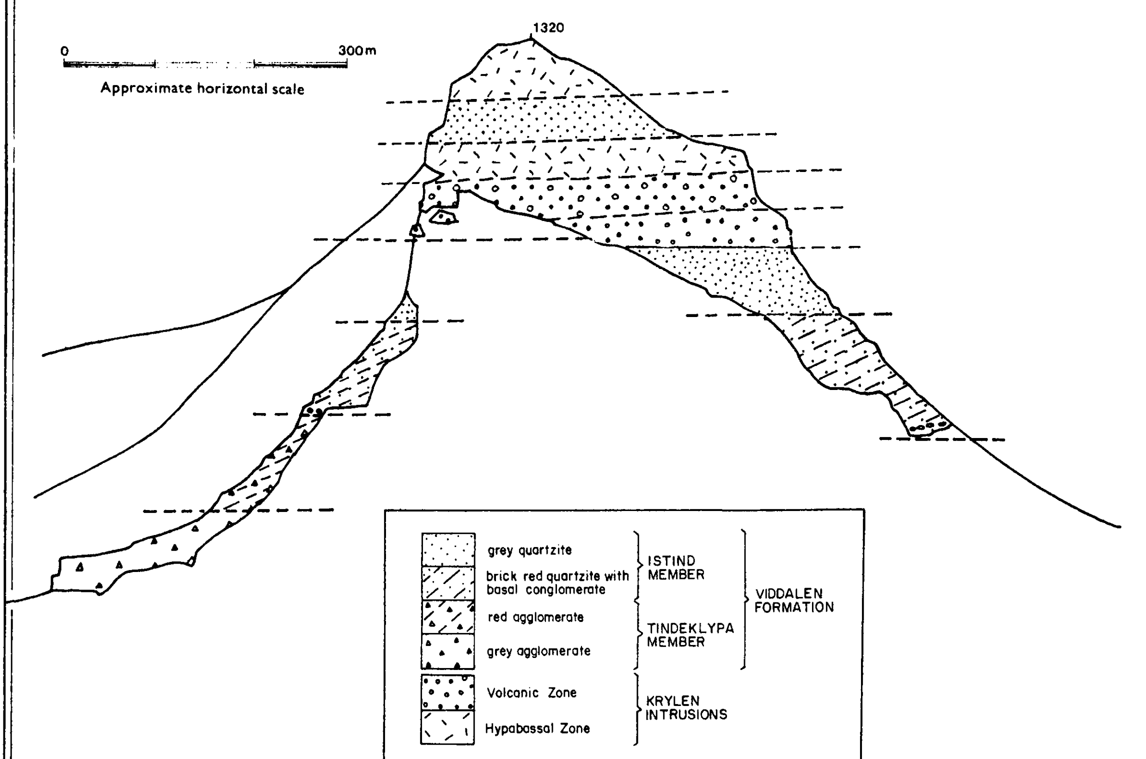


FIGURE 46

EASTERN SIDE OF NUNATAK 1320



i. Agglomerate containing angular sedimentary inclusions up to 20 cm long in a dark-gray matrix (10 m).

ii. Agglomerate with smaller inclusions in a greenish-gray matrix (25 m).

iii. Agglomerate consisting of small (up to 1 cm) dark-green argillaceous fragments in a brick-red, fine-grained matrix (40 m). This agglomerate is identical to that described at locality B18.

The two small nunataks to the south-west of 1320 consist entirely of gray agglomerate. Small pyrite crystals were observed in the matrix of the agglomerate, but these occurrences are extremely rare.

f. Correlates of the Tindeklypa Member

According to De Ridder (1970), the Högfonna Formation at Fasettfjellet is overlain by "a sequence of volcanic breccias, tuffaceous sediments, tuffs and a thick lava flow." Neethling (1970) collectively termed these rocks the "Fasett Volcanics" which he included in the "Jutul Group". However, he indirectly implied that the "Fasett Volcanics" is a correlate of the "Tindeklypa Formation", which according to him belongs to the "Trollkjellrygg Group"! Talking about the "Tindeklypa Formation", he says: " ... its association with red bed clastics and interbedded tuff in the Fasettfjellet region seem to favour a volcaniclastic origin".

These extremely contradictory views in Neethling's thesis fit in perfectly with the new stratigraphic column as proposed by the author. Both the "Jutul Group", the "Tindeklypa Formation" and the "Istind Formation" are now grouped together in one stratigraphic unit, the Viddalen Formation. The relative stratigraphic position of the "Fasett Volcanics", as well as their close lithological similarity to the lava and agglomerate in the Tindeklypa area, leaves little doubt that these rocks belong to the Tindeklypa Member. A possible correlation with the Istind Member can not be excluded, although the absence of intercalated sediments at Fasettfjellet tends to oppose such a possibility.

Van Zyl (1974) reported a sequence of agglomerate and lava at Grasteinen (approximately 20 km north-east of Tindeklypa) which, according to his description is a definite correlate of the Tindeklypa Member.

2. The Nature of the Inclusions in the Agglomerate

All the inclusions are angular and show no definite orientation. There is absolutely no sorting and inclusions ranging in size from small microscopic fragments to large angular boulders, several metres in diameter, are found side by side. Although most of the inclusions form sharp contacts with the matrix, the contacts of some are diffuse. About 90 per cent of the inclusions are of sedimentary origin and they also, on the average, attain larger dimensions than the relatively small number of igneous clasts which were observed. The latter inclusions can all be correlated with the plutonic and hypabyssal phases of the Krylen Intrusions and no recognisable inclusions of extrusive igneous rock were observed. A list of the different types of inclusions and their possible correlates in pre-Viddalen formations is given in *Table 5*.

Smaller inclusions present in lesser quantities are: red jasper (up to 2 cm in diameter), chert, calcite and black shale as well as other inclusions which are too altered to be identified. At locality D7 an epidotised mud-pebble conglomerate was found as an inclusion, as well as a porphyritic mafic rock, identical to the middle part of the Jekselen sill. These two inclusions were undoubtedly derived from the Borgmassivet Member of the Högfonna Formation and the Hypabyssal Zone of the Krylen Intrusions respectively. As can be seen in *Table 5*, all the pre-Viddalen sedimentary formations are represented in the form of inclusions in the agglomerate of the Tindeklypa Member.

3. The Matrix

A characteristic feature of the matrix is that microscopically, it closely resembles the macroscopic appearance of the agglomerate as a whole. It consists mainly of unsorted angular to subrounded quartz grains which in turn are embedded in a finer argillaceous matrix. No volcanic material such as glass

Table 5 – Inclusions of sedimentary rock in the agglomerate of the Tindeklypa Member and their correlates in the Pre-Tindeklypa formations

INCLUSIONS IN THE AGGLOMERATE OF THE TINDEKLYPA MEMBER		CORRESPONDING CORRELATES IN THE PRE-TINDEKLYPA FORMATIONS		
Sample No.	Description	Sample No.	Locality	Stratigraphic unit
(I)B18/G28	Buff-coloured, massive quartzite	(J)H4/B34	Jekselen	Jekselen Member (Högfonna Formation)
(I)I7/G8	Pink, massive quartzite	(I)A19/G5	Nunatak 1390 (Tindeklypa)	Jekselen Member (Högfonna Formation)
(I)I7/G10	Light-green indurated quartzite	(Y)B17/G4	Ytstenut	Borgmassivet Member (Högfonna Formation)
(I)K3/G14	Reddish-brown massive quartzite	(Ni)A7/G1	Nils Jørgennutane	Borgmassivet Member (Högfonna Formation)
(I)I7/G11	Black massive siltstone	(K)J1/G1	Lyftingen	Grunehogna Formation
(I)I7/G12	Dark gray, banded graywacke containing small pyrite crystals	(N)H19/G2	Nashornet	Pyramiden Formation

shards or ash particles were observed. Accessory minerals occurring in subordinate quantities are: alkali feldspar, calcite, pyrite and magnetite. In the author's opinion, the most acceptable explanation for the absence of volcanic material in this particular case is the theory put forward by Geikie (1897). He suggested that the agglomerate produced during the first efforts to establish an eruptive vent would contain little or no truly volcanic material, and it would consist merely of fragments of whatever happened to be the rocks through which the eruptive orifice had been drilled. A striking example quoted by Geikie is the Sepulchre Mountain in the Yellowstone National Park where the lower breccias, which are the product of the Electric Peak volcano, attain a thickness of about 150 m and are composed of fragments of Archaean rocks which underlie younger formations.

D. The Istind Member

1. Relation to the Tindeklypa Member

In contrast with the underlying Tindeklypa Member, the Istind Member also includes quartzites and shales of non-volcanic origin. The presence of these sediments, together with the more frequent occurrence of lava flows in the Istind Member, are the only features which distinguish the two members from each other. In general, the Istind Member comprises alternating red and gray agglomerate (identical to that of the Tindeklypa Member), lava flows, red, gray and buff quartzites and subordinate tuff and shale. The fact should be stressed that there is no unconformity between the Istind and Tindeklypa Members as suggested by Neethling (1970). Although the degree of eruptive violence decreased during deposition of the Istind Member, thus allowing more quiet lava outflows and even shallow-water sedimentation, there is no evidence that the continuity of events had ever been interrupted for a significant period of time. Van Zyl (1974), who made a detailed study of the succession at Istind Peak, is also of the opinion that the "Istind Formation" is a "mere upward continuation of the Tindeklypa Formation" and that the term Istind "Formation" should be abandoned.

2. Distribution

The Istind Member has an even more limited distribution than the Tindeklypa Member. It is confined to Istind Peak where a thickness of about 340 m of strata is exposed and to Nunatak 1320 where a succession, 215 m thick, has been recognised as a correlate of this Member (*Fig. 46*).

3. Stratigraphy

The following sequence for the Istind Member was established at Nunatak 1320:

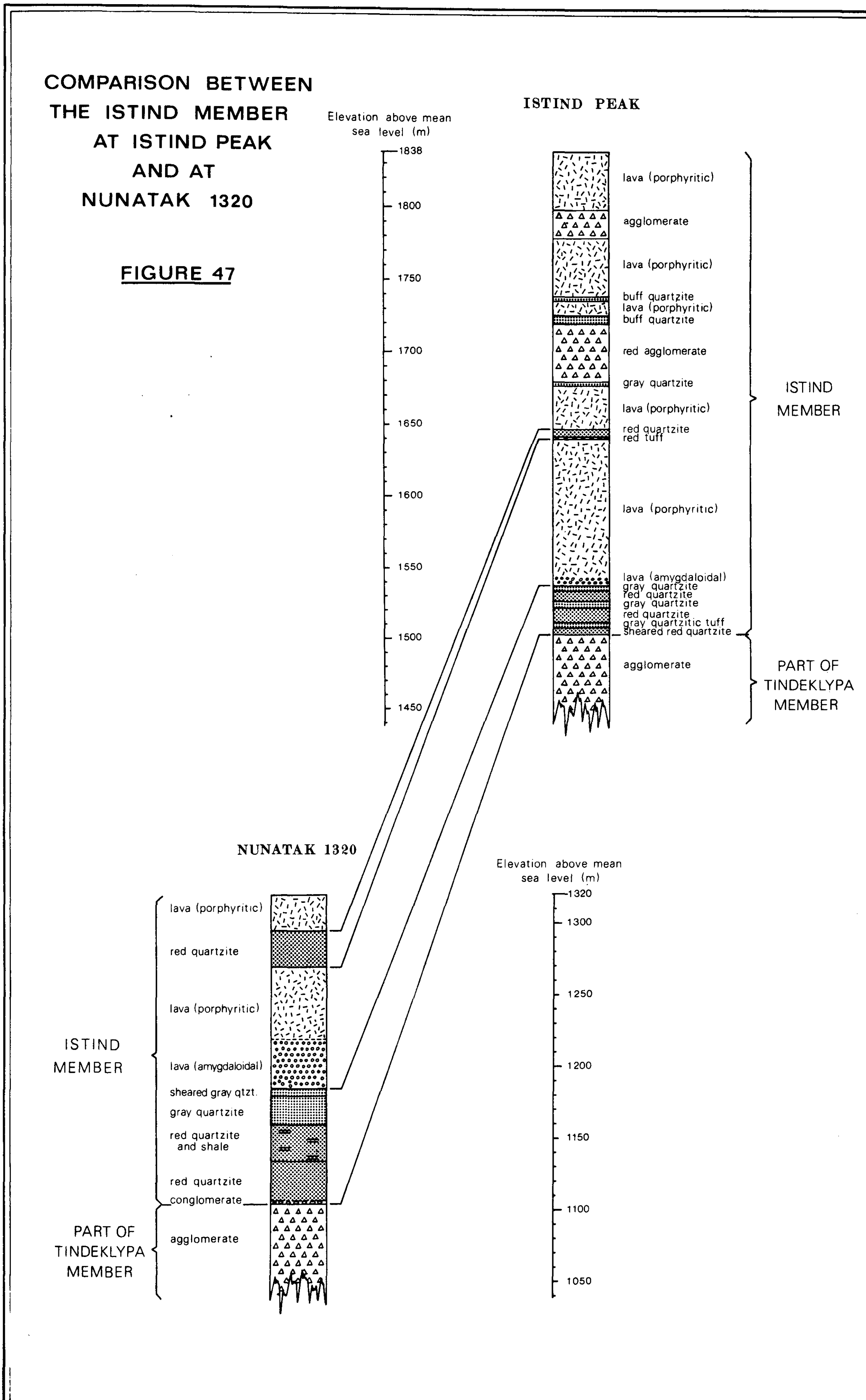
Elevation above snow surface (m)	Thickness (m)	Lithological description
266–291	25	Dark green andesite with pigeonite phenocrysts up to 1 cm long.
241–266	25	Red quartzite (mainly scree).
191–241	50	Dark green andesite with pigeonite phenocrysts up to 1 cm long. Calcite and epidote are developed along fractures. Small pyrite crystals were observed locally.
156–191	35	Dark green andesite with quartz amygdales up to 2 cm in diameter.
155–156	1	Greenish gray andesite with small (1–2 mm) quartz amygdales.
150–155	5	Intensely sheared red quartzite.
130–150	20	Dark brownish gray quartzite, containing small grains of red jasper.
105–130	25	Dark red quartzite and shale with abundant flow ripple-marks and mud-cracks. Cross-bedding is present but is not well developed. Direction of transport was from the north (between 171° and 174°). The general strike of the beds is 020° and the dip 12° to the east.
77–105	28	Fine-grained red quartzite and intercalated red shale with flow ripple-marks and occasional mud-cracks.
75–77	2	Conglomerate, containing well-rounded pebbles of red jasper and gray quartzite (up to 7 cm in diameter).

Fig. 47 shows the correlation between the succession at Nunatak 1320 and the thicker, more complete succession compiled by Van Zyl for Istind Peak. The only difference between the author's interpretation and that of Van Zyl, is that the latter regards the igneous rocks in the sequence as being intrusive sills and not lava flows as proposed by the author. The author bases his interpretation on the fact that although sedimentary xenoliths (the same as those which are found as inclusions in the agglomerate) are commonly present in the lava, no fragments of the actual agglomerate were observed. This means that these igneous rocks were either not intrusive at all, or intrusion took place shortly after deposition of the agglomerate at a stage when the latter had not yet been solidified. The difference in opinion on the nature of these igneous rocks does, therefore, mainly concern the interpretation of the mechanism, and not so much the relative ages between the igneous and the volcaniclastic rocks.

An important fact established by Van Zyl is that the boundary between the Formations previously referred to as the Tindeklypa and Istind Formations is not the lower subhorizontal lava flow (*Fig. 45*) as proposed by Neethling (1970), but the first sediments actually appear some 37 m below this level. As the presence of sedimentary rocks is the only lithological feature which distinguishes the Istind Member from the Tindeklypa Member, the base of the former is regarded as being the base of the first sedimentary layer in the Viddalen Formation. According to this definition, the total exposed thickness of the Istind Member is 336 m, which is for some unknown reason less than Neethling's figure of 350 m for the Istind Formation.

E. The Origin of the Viddalen Formation and its Relation to the Ahlmannryggen Group

The proposal for a volcaniclastic origin for the Tindeklypa agglomerate is accepted and supported by the author (Neethling, 1970). This idea should, however, now also be extended to incorporate a large part of the Istind Member which contains much more agglomerate than has been known previously. The agglomerate is believed to have formed during explosive eruptions which accompanied tectonic movements while the Jutulstraumen and Viddalen troughs were formed. These violent explosive eruptions were periodically interrupted by quiet outpouring of lava.


COMPARISON BETWEEN THE ISTIND MEMBER AT ISTIND PEAK AND AT NUNATAK 1320
FIGURE 47
ISTIND PEAK
Elevation above mean sea level (m)
1838
1800
1750
1700
1650
1600
1550
1500
1450
lava (porphyritic)
agglomerate
lava (porphyritic)
buff quartzite
lava (porphyritic)
buff quartzite
red agglomerate
gray quartzite
lava (porphyritic)
red quartzite
red tuff
lava (porphyritic)
lava (amygdaloidal)
gray quartzite
red quartzite
gray quartzite
red quartzite
gray quartzitic tuff
sheared red quartzite
agglomerate
ISTIND MEMBER
PART OF TINDEKLYPA MEMBER
NUNATAK 1320
lava (porphyritic)
red quartzite
lava (porphyritic)
lava (amygdaloidal)
sheared gray qtzt.
gray quartzite
red quartzite and shale
red quartzite
conglomerate
agglomerate
ISTIND MEMBER
PART OF TINDEKLYPA MEMBER
Elevation above mean sea level (m)
1320
1300
1250
1200
1150
1100
1050

During the formation of the Tindeklypa Member, explosive eruptions predominated and lava flows are relatively few in number and are steeply inclined. Inclusions also attain their largest dimensions in this Member. The underlying sedimentary formations served as the main source of material for the formation of the agglomerates. Inclusions of mafic intrusive rock resembling the Krylen Intrusions probably originated from deep-seated sills which had already solidified when the eruptions took place, while inclusions of lava reported by Butt (1962) could have been taken up in the agglomerate by new, alternating eruptions which brought up material from already existing agglomerate and intercalated lava flows.

Volcanic activity ceased for short periods while the Istind Member was being formed and shallow-water sediments were deposited during these intervals. Lava flows in this Member all have a subhorizontal attitude, indicating relatively stable conditions. The eruptive energy increased again during the last stages of deposition of the Istind Member, but never reached its former violence.

Judging from the angular and ill-sorted nature of the inclusions in the agglomerate, it is doubtdul whether this material was ever transported over any significant distance. Volcanic activity was most probably concentrated along fissures parallel to the Jutulstraumen, which explains the restricted but linear distribution of volcaniclastics at Fasettfjellet, Tindeklypa-Istind and at Grasteinen. The steeply dipping sediments of the Jekselen Member which are found associated with amygdaloidal intrusions at Jekselen, indicate the westernmost boundary of this volcanic episode.

The Viddalen Formation has nowhere been found in contact with any other formation, and its relative position with respect to the Ahlmannryggen Group can therefore only be derived by indirect means. In order to accomplish this, the following lines of reasoning could be followed:

1. The first and most obvious indication regarding the stratigraphic position of the Viddalen Formation, is the variety of rock types represented as inclusions in the agglomerate. It has already been mentioned that all the different sedimentary formations, from the Pyramiden Formation to the Jekselen Member of the Högfonna Formation are represented in the agglomerate. This, however,

Formation is reported to have the same relation to the Högfonna Formation at Högfonna Nunatak (De Ridder, 1970). It follows thus that the "Raudberg" and Viddalen Formations are contemporaneous. (Although the "Raudberg" Formation is nowhere exposed within the area investigated, the author wishes to suggest the name Raudberget Formation, as the latter is the proper geographical name of the type locality as described by De Ridder).

5. Conclusions: Shortly after deposition of the Jekselen Member of the Högfonna Formation about 1 700 My ago, the volcanic activity of which signs already appeared low down in the Högfonna Formation, reached its peak in the Ahlmannryggen area. In the north, igneous activity was restricted to the intrusion of thick mafic sheets, while at Jekselen signs of near-surface intrusions can be observed. At Tindeklypa and Istind eruption of agglomerate and lava took place, while at the same time sediments belonging to the Raudberget Formation were being deposited in the more quiet areas farther to the south in the Borgmassivet.

VI. IGNEOUS ROCKS OF VIDDALEN AND POST-VIDDALEN AGE

It is quite evident from the enclosed maps and figures that the sedimentary sequence of the Ahlmannryggen Group has been invaded on a large scale by predominantly mafic intrusions. As a matter of fact, it is a rare exception to find a nunatak in the Ahlmannryggen area which comprises only sedimentary rock. With the exception of the lava flows which are found in (and which form part of) the Viddalen Formation, all the igneous rocks in the Ahlmannryggen and Borgmassivet post-date the Viddalen Formation. A sample of biotite granite collected by Soviet expeditions from Annandagstoppane (6^{o} W, $72^{o}30'$ S) in the Giaeverryggen represents the only igneous rock of pre-Ahlmannryggen age known in the vicinity. This sample was dated at 3060 $\pm$ 80 My by means of the whole-rock Rb-Sr method (Halpern, 1970) and also represents the oldest rock yet reported from Antarctica. As these granites are not exposed anywhere within the area investigated, they will not be dealt with in this thesis.

Neethling (1970) recognised the following groups of igneous rocks for the Ahlmannryggen area:

A. **Jutul Group**. (Age and correlation uncertain).

1. Utkikken lava.
2. Jutul Volcanics.
3. Fasett Volcanics.

B. **Borg Intrusions**. (Age circa 1 700 My).

C. **Jørgen Intrusions**. (Age circa 1 000 My).

D. **Trollkjellrygg Group**. (Correlation problematic).

1. Straumsnutane Formation. (Age circa 800 My).
2. Tindeklypa Formation.
3. Istind Formation.

E. **Mafic and ultramafic dykes and minor sills**. (Age unknown).

Field relationships supported by additional radiometric age determinations in strategic regions enabled the author to simplify Neethling's subdivision to a large extent. The following geochronological subdivision is proposed:

A. **Krylen Intrusions.** (Age circa 1 700 My).

These intrusions also have a volcanic equivalent (forming part of the Viddalen Formation) and include Neethling's "Jutul Group", part of his "Borg Intrusions" as well as the lavas in his "Tindeklypa" and "Istind" Formations.

B. **Ytstenut Intrusions.** (Age circa 1 000 My).

In this unit are incorporated the greater part of Neethling's "Borg Intrusions" as well has his "Jørgen Intrusions".

C. **Straumsnutane Formation.** (Age circa 800 My).

D. **Post-Ytstenut Intrusions.** (Age circa 190 My).

Since a fair amount of mineralogical, petrological and petrochemical work has already been done by previous investigators (especially Neethling and Von Brunn) on the igneous rocks of the Ahlmannryggen area, the author restricted his studies mainly to field relationships and aspects directly related to the relative position of the igneous rocks within the geological history of the Ahlmannryggen Group and the Viddalen Formation.

A. The Krylen Intrusions.

1. Definition

The Krylen Intrusions will, by definition, include all igneous rocks, plutonic as well as hypabyssal and volcanic rocks, which were emplaced or extruded circa 1 700 My ago. These rocks are younger than the lower part of the Ahlmannryggen Group (up to, and including the Högfonna Formation), equal in age to the upper part of the Ahlmannryggen Group (Raudberget Formation), and form part of the Viddalen Formation.

The Krylen Intrusions correspond in age with the "Borg Intrusions" as defined by Neethling (1970), but differ completely as far as regional distribution and relationship to the upper part of his "Ritscher Supergroup" are concerned. Seeing that "Borg" is strictly speaking not a geographic name and that the intrusions in the Borgmassivet have been proved to be some 700 My younger, the author thought it feasible, in order to avoid confusion, to abandon the term "Borg Intrusions" altogether. The name "Krylen" is derived from Krylen Nunatak ($71^{o}32'$ S, $2^{o}10'$ W) where the first age of circa 1 700 My was obtained in Western Dronning Maud Land (K-Ar age of 1 650 My by McDougall, 1967).

2. Distribution

As a result of the close lithological and mineralogical resemblance between the Krylen and Ytstenut Intrusions, the exact distribution of these rocks is not known at present. The nature of the inclusions in the Tindeklypa Member of the Viddalen Formation suggests, however, that the majority of the mafic intrusions in the area is of post-Viddalen age, i.e. younger than circa 1 700 My. At the present stage, therefore, the author considers rocks only from areas where radiometric age determinations have proved the age to be circa 1 700 My, as belonging to the Krylen Intrusions. Within the area investigated, the Krylen Intrusions are known to be represented at only two localities: Jekselen and the Tindeklypa - Istind area. Outside the area investigated, rocks of this age have been proved to exist at Krylen and at Utkikken.

a. Jekselen

The existence of circa 1 700 My old volcanic rocks was recognised by Neethling and was based partly on a model age of 1 760 My obtained for altered lava from Utkikken (Eastin, *et al.*, 1970), and partly on the presence of lava "below" the Tindeklypa Formation at Tindeklypa. Neethling made special provision for these rocks in his stratigraphic column and combined them in his "Jutul Group". The relationship of these lavas to plutonic rocks of similar age was, however, never established until the author and his colleague, Mr. Paterson, discovered a continuous upward gradation from plutonic through hypabyssal to volcanic rock at Jekselen nunatak. This discovery proved to be of great significance and can be considered as being the key to many of the puzzling relationships which had been reported elsewhere in the area.

A total of approximately 300 m of igneous rock belonging to the Krylen Intrusions is exposed at Jekselen. During several traverses up the nunatak, a definite vertical variation in composition and texture was detected. The following sequence was established: (A summary of the sequence is given in *Table 6*. All names of plutonic rocks are in accordance with the classification and nomenclature as recommended by the IUGS Subcommission on the systematics of Igneous Rocks - Streckeisen, 1974).

It should be noted that the term "volcanic" as used below is not regarded as a synonym for "extrusive", but it refers to near-surface intrusions which are included in the volcanic class as described by Turner and Verhoogen (1951) and as defined in Glossary of Geology (1973).

(i) Plutonic Zone

The greater part of Jekselen nunatak (*Fig. 34*) is composed of coarse- to medium-grained intrusive rock which, judged from its texture, must have crystallised under plutonic conditions. A striking feature of this zone is the frequent banding which can be observed as a result of variations in composition. The lighter-coloured bands (granodioritic in composition) vary in width from a few metres to about 15 cm and are horizontal and undeformed. Only minor displacement of the bands was observed along joints. The upper and lower contacts of these granodiorite bands with the more mafic variety (quartz monzodiorite) are sharp. Lenses of epidote are commonly found throughout the zone, as well as joint-fillings consisting of quartz, calcite and epidote. Green copper carbonate staining and small amounts of limonite are frequently associated with these fillings.

The most common constituent of the granodiorite is plagioclase (andesine), which is present as subhedral grains, quite often exhibiting ophitic and subophitic textures with clinopyroxene. Quartz is sometimes present as small clusters showing undulose extinction, but the bulk of this mineral is present as micrographic inter-

Table 6 – Summary of the plutonic-volcanic sequence of the Krylen Intrusions as exposed at Jekselen

Approximate thickness (m)	Zone	Subzone	Characteristic textural features	Rock type
80–100	Volcanic Zone	Volcanic Contact Subzone	Large calcite amygdales in an aphanitic matrix	Quartz andesite
		Main Volcanic Subzone	Small quartz amygdales in a fine-grained matrix	Quartz andesite
8–10	Hypabyssal – Volcanic Transition-zone		Combined occurrence of small quartz amygdales and small pigeonite phenocrysts	Porphyritic quartz andesite
100	Hypabyssal Zone	Upper Quartz Dioritic Subzone	Small pigeonite phenocrysts in a fine-grained matrix	Quartz diorite
		Lower Quartz Monzodioritic Subzone	Large pigeonite phenocrysts in a fine-grained matrix	Quartz monzodiorite
10–15	Plutonic – Hypabyssal Transition-zone		Sparsely distributed large pigeonite phenocrysts in a medium-grained matrix	Quartz monzodiorite
100	Plutonic Zone		Coarse- to medium-grained texture	Quartz monzodiorite with bands of grano-diorite

growths with alkali feldspar which is present as euhedral to subhedral grains of orthoclase perthite. The mafic minerals (in order of abundance) are clinopyroxene, orthopyroxene and hornblende.

The quartz monzodiorite basically contains the same mineral constitutents as the granodiorite; the main difference being the larger percentage of mafic minerals in the former. Most of the feldspars are extremely saussuritised and in some specimens hardly recognisable. Some of the pyroxene crystals are partially replaced by hornblende. Other recognisable alteration products of the pyroxenes are fibrous uralite and talc.

(ii) Plutonic – Hypabyssal Transition-zone

Following directly on top of the typical plutonic zone, but without any sharp boundary, there is a relatively thin transition-zone (10–15 m thick) within which porphyritic crystals of pigeonite start appearing.

Rocks of this zone still have a quartz monzodioritic composition and except for the sparsely distributed bladed pigeonite crystals which are approximately 0,5 m across and up to 10 mm long, these rocks are identical to those of the Plutonic Zone.

(iii) Hypabyssal Zone

The porphyritic texture gradually becomes more dominant until the bladed crystals of pigeonite occupy about 30 per cent (by volume) of the rock. These crystals are scattered evenly throughout the rock and have no preferred orientation.

The Hypabyssal Zone can be subdivided into a lower quartz monzodioritic subzone and an upper quartz dioritic subzone, each about 50 m thick, and with a gradual transition between them. In hand-specimen, rocks from the two subzones can easily be distinguished by the size of the porphyritic crystals. The lower subzone contains larger porphyritic crystals (8–10 mm long), while in the upper subzone these crystals are markedly smaller (2–4 mm long).

The matrix of rocks from the Hypabyssal zone is fine-grained, compared with the medium- to coarse-grained nature of rocks from the Plutonic Zone.

Apart from the porphyritic pigeonite, the most conspicuous mineralogical difference between the Hypabyssal and the Plutonic Zones is the complete absence of orthopyroxene and amphibole in the former.

(iv) Hypabyssal – Volcanic Transition-zone

As in the case of the Plutonic and Hypabyssal Zones, the Hypabyssal and Volcanic Zones are also separated by a transition-zone. The characteristic feature of this transition-zone (5–10 m thick) is the combined occurrence of textures typical of both hypabyssal and volcanic rocks. Small spheroidal quartz amygdales (1–8 mm in diameter) start appearing at the base of this zone, but the small porphyritic pigeonite crystals still dominate the texture. Gradually the amygdales become more abundant and the porphyritic crystals decrease in number until they disappear completely. The upper contact of the zone is taken where traces of the porphyritic texture are not visible any more in hand-specimen.

Representative samples indicated a quartz dioritic composition, i.e. the same as the upper subzone of the underlying Hypabyssal Zone. As a result of their amygdaloidal texture, however, rocks from this zone should rather be termed porphyritic quartz andesite.

(v) Volcanic Zone

The greater part of this zone, 80–100 m thick, consists of rock which is similar in general appearance to that of the underlying transition-zone. The porphyritic texture is, however, characteristically absent. Small spheroidal quartz amygdales in a fine-grained matrix are the dominant macroscopic textural features of this part which is here termed the Main Volcanic Subzone.

At the contacts with sediments of the Jekselen Member, however, the vesicles are much larger (up to 70 mm in diameter) and filled with calcite. In this latter case, where the volcanic rocks are usually present as transgressive bodies along fault-zones in the sediments (*Fig. 39*) the matrix is aphanitic and dark grayish green in colour. This part of the zone is termed the Volcanic Contact Subzone.

According to mineralogical composition, rocks from both subzones can be classified as quartz andesites.

The volumetric and chemical compositions of the different zones of the Krylen Intrusions at Jekselen are given in *Tables 7* and *8*.

b. Tindeklypa – Istind area

Except for the Plutonic and Plutonic – Hypabyssal Transition-zones which are not exposed, the sequence as observed for the Krylen Intrusions at Jekselen is also developed along the Tindeklypa – Istind range of nunataks. The most complete exposure is at Nunatak 1390 (*Fig. 41*) and at the small outcrops between this nunatak and Nunatak 1599 (*Fig. 44*). Farther to the south along the Tindeklypa range, only the Main Volcanic and Volcanic Contact Subzones are developed. They are present as alternating flows (or penecontemporaneous intrusions) within the agglomerate and are here considered to form part of the Tindeklypa Member of the Viddalen Formation (*Figs. 43* and *44*). At Istind Peak and Nunatak 1320 the Krylen Intrusions are again represented in the form of the Hypabyssal and Volcanic Zones found as concordant flows (or penecontemporaneous sills) within the sediments and agglomerate of the Istind Member (*Fig. 47*).

c. Fasettfjellet

The amygdaloidal lava which caps this nunatak and overlies agglomerate and tuff (Viddalen Formation) as well as sediments (Högfonna Formation) is considered by the author to be a correlate of the Volcanic Zone of the Krylen Intrusions (*Fig. 22*).

Table 7 — Average volumetric composition of the different zones of the Krylen Intrusions at Jekselen

Zone	Subzone	Quartz	Alkali feldspar	Plagioclase	Orthopyroxene	Clinopyroxene	Amphibole	Opaque	Matrix	IC
VOLCANIC ZONE	Volcanic Contact Subzone	6,3	0,0	48,9	0,0	21,3	0,0	0,0	23,5	124
	Main Volcanic Subzone	9,1	0,0	46,7	0,0	20,6	0,0	0,0	23,6	96
HYPABYSSAL — VOLCANIC TRANSITION-ZONE		4,4	0,0	35,4	0,0	34,4	0,0	1,7	24,1	82
HYPABYSSAL ZONE	Upper Quartz Dioritic Subzone	7,2	4,4	40,4	0,0	32,1	0,0	5,7	10,2	102
	Lower Quartz Monzodioritic Subzone	9,0	10,3	40,0	0,0	26,2	0,0	0,0	14,5	112
PLUTONIC — HYPABYSSAL TRANSITION-ZONE		9,7	9,8	35,4	0,0	23,7	0,0	3,8	17,6	108
PLUTONIC ZONE	Granodiorite	27,2	12,5	33,6	2,1	8,1	1,3	3,3	11,9	75
	Quartz Monzodiorite	10,7	9,7	33,6	3,5	16,8	5,8	5,3	14,5	100

Table 8 – Chemical composition of some of the zones of the Krylen Intrusions at Jekselen

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	Cr_2O_3	Mn_3O_4	H_2O^+	H_2O^-
VOLCANIC ZONE (Main Volcanic) Subzone)	52,73	15,11	2,41	6,58	7,28	7,36	2,68	0,45	0,64	0,06	0,05	0,15	3,40	0,44
HYPABYSSAL – VOLCANIC TRANSITION-ZONE	53,58	15,19	3,52	6,23	5,97	7,10	1,76	2,16	0.84	0,09	0,03	0,16	2,77	0,33
HYPABYSSAL ZONE (Upper Quartz Dioritic Subzone)	54,02	14,87	2,66	6,81	5,81	8,85	1,66	1,14	0,81	0,08	0,03	0,16	2,59	0,34
HYPABYSSAL ZONE (Lower Quartz Monzo-dioritic Subzone)	53,94	14,72	0,88	8,12	5,67	8,07	2,56	1,15	0,81	0,07	0,03	0,15	2,77	0,60
PLUTONIC ZONE (Quartz Monzodiorite)	56,46	14,79	2,76	6,95	3,33	7,56	2,45	1,87	1,05	0,11	0,01	0,15	2,36	0,21
PLUTONIC ZONE (Granodiorite)	61,44	12,55	2,65	7,81	1,41	5,03	2,40	2,75	1,32	0,18	0,01	0,14	1,88	0,38

(Analysts: National Institute for Metallurgy)

3. Mode of Emplacement of the Krylen Intrusions

The mechanism of emplacement of the Krylen Intrusions in the Jekselen-Istind area could briefly be visualised as follows:

A large body of magma of andesitic composition entered the overlying sedimentary succession along the western margin of the Jutulstraumen trough, which was at that time in the process of being formed. Initially, while the lithostatic pressure was still high, intrusion and crystallisation of the magma took place in a normal plutonic manner, resulting in a rock exhibiting typical plutonic texture and with typical intrusive relationships to the surrounding sediments. Intrusion most probably took place by means of a combined mechanism of stoping and assimilation of the sedimentary rocks. In this regard it is important to note that under these initial plutonic conditions, the surrounding sediments were not noticeably disturbed; even in places where the intrusion cut at steep angles across the bedding (*Fig. 35*). This latter phenomenon could also be regarded as being indicative of the fact that the emplacement of large intrusions of this kind is a very slow and lengthy process.

At a certain stage during the intrusive episode, however, the physical conditions governing crystallisation started to change significantly to give rise to a texturally different type of rock. Increasing tectonic activity in the upper crust combined with the progressive uprise of the magma resulted in a decrease of lithostatic pressure which in turn led to more rapid crystallisation which gave rise to porphyritic texture. (The Hypabyssal Zone). Although the need for the recognition of an intermediate (hypabyssal) class of igneous rocks is considered to be "doubtful" by Turner and Verhoogen (1951), the author is of the opinion that in this particular case where porphyritic rocks occupy such a definite intermediate position in space between mineralogically and chemically closely related rocks with typical plutonic and volcanic textures, use of the term "hypabyssal" is undoubtedly justified.

Judging from the thickness of the Hypabyssal Zone, intermediate temperature and pressure conditions must have prevailed for a considerable period before further changes in these environmental conditions once again took significant effect on the texture of the crystallised product. By this time, the magma must have reached a level close to surface where tectonic fracturing of the crust provided vents for rapid pressure release and uprise of the magma, resulting in accompanying undercooling, increase in viscosity and the formation of vesicular textures (The Volcanic Zone).

The part of the magma which extended into the vents as such was subjected to even lower pressure and vesicular textures are therefore better developed in these parts. Although having a cross-cutting relationship to the country-rock, these vent-fillings therefore exhibit the same textures as a lava which extruded on surface (The Volcanic Contact Subzone).

4. The Age of the Krylen Intrusions

The first suggestion of an age of the order of 1 700 My for intrusive rocks in Dronning Maud Land came from K-Ar isotopic age measurements on hornblende from the intrusion at Krylen. The actual age obtained was 1 650 My (McDougall, 1967). This high age was, however, considered to be somewhat doubtful until in 1970 an age of 1 700 $\pm$ 130 My was established by the Rb-Sr method on four whole-rock samples from Jekselen (Allsopp and Neethling, 1970). This age is interpreted as being the actual date of emplacement of the intrusions.

Bowman (1971) determined a Rb-Sr age of between 1 190 and 1 280 My on one whole-rock sample of the lava at Fasettfjellet. As mentioned earlier, this lava can, according to field relationships, be correlated with the Volcanic Zone of the Krylen Intrusions, and Bowman's ages are therefore regarded by the author as representing minimum values, probably resulting from overprinting during metamorphism.

In order to support the relationships established by the author for the different zones of the sill at Jekselen, a whole-rock sample from the Main Volcanic Subzone was submitted to Geological Dating Services for determination of $^{40}Ar/^{39}Ar$ age spectra. A minimum age of 1 339 $\pm$ 55 My was computed (Bredell, 1973). According to the analysts, the extensive replacement of the original minerals by epidote and chlorite, the clouding of feldspar with clay and

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consent of the Legislative Council and House of Assembly thereof, as follows:

Schedule No. 1 of Ordinance 18, 1844, repealed.

I. The said first schedule, or schedule No. 1, appended to the said Ordinance No. 18, 1844, is hereby repealed.

Schedule to this Act No. 1 substituted.

II. The schedule to this Act marked No. 1 shall be deemed and taken to be in room and stead of the schedule aforesaid hereby repealed, and the said Ordinance No. 18, 1844, shall be construed with reference to the schedule to this Act as if it were the schedule to the said Ordinance.

Agents purchasing at public sales to name their principals.

III. As often as any immovable property shall be sold by public sale the auctioneer shall before or at or forthwith after the knocking down of the hammer or other closing of the bidding for any lot ascertain from the bidder for whom he purchases, and if such bidder shall profess to purchase for some person other than himself then the auctioneer or his assistant shall in case the purchase so disclosed shall be approved of take down in writing the name of such bidder and of the purchaser for whom he purchases, and until the name of the purchaser, whether the bidder himself or some one else for whom he purchases, shall have been taken down in writing there shall be no sale to any person; and the lot, notwithstanding that the hammer may have been knocked down, may be again put up to competition: Provided that it shall not be necessary that the name of the person for whom any bidder shall be purchasing shall be announced publicly to the by-standers, provided it may be made known to the auctioneer and be by him or his assistant taken down in writing as aforesaid.

Bidders refusing to say for whom they buy may be deemed themselves the purchasers.

IV. Should any bidder whose bid shall have been accepted by the auctioneer refuse to declare when called upon so to do by the auctioneer after the knocking down of the hammer for whom such bidder purchases, it shall be lawful for the auctioneer to treat and consider such bidder as being himself the purchaser, and such bidder shall in such case be deemed and taken to be to all intents and purposes the purchaser; or the auctioneer at his election may treat such bidding as null and void and proceed afresh as if it never had been made: Provided that the auctioneer having once made his election either to treat such bidder as the purchaser or to proceed to sell afresh shall not be at liberty afterwards to alter such election.

Bidder naming a principal without authority from him in writing to be personally liable to transfer duty.

V. If in any case any bidder should give in as aforesaid the name of some person as his principal, who shall be taken down as aforesaid as the purchaser and who shall afterwards refuse to accept the property purchased in his name, then unless the bidder shall produce a sufficient authority in writing from such alleged principal authorizing such bidder to make such purchase for such principal the bidder shall himself (without prejudice to other questions between the parties) be liable to pay transfer duty: Provided however that such bidder paying transfer duty shall recover the same

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over from his principal in case he shall succeed in proving that such principal did in fact give him authority to make the purchase in dispute.

No auctioneer to take down any purchaser as purchasing "q.q."

VI. No auctioneer shall take down in regard to any lot the name of any person as purchasing in the manner commonly called and written "q. q.," or receive in any form the name of any person as purchasing any lot for an unnamed principal; and any auctioneer contravening this section of this Act shall incur and be liable to any penalty not exceeding twenty-five pounds.

When alleged principal refuses the property the alleged agent may take it without paying any second transfer duty.

VII. If in any case the person whose name shall have been given in and taken down as the purchaser of any property shall deny that he gave authority for the making of such purchase, or if for any other reason such person shall decline to accept such purchase and the agent or alleged agent shall be willing to take such property for his own individual account, and the vendor shall consent thereto, no transfer duty shall be payable upon the sale or alleged sale to the alleged principal; but only single transfer duty as if the sale had been made *ab initio* to the alleged agent in his individual capacity, and the solemn declarations by law required to be made shall be altered in the manner indicated in the forms marked A and B to this Act annexed.

In private sales all agents must name their principals.

VIII. Every private sale or sales made otherwise than by auction in regard to which the purchaser shall not profess to purchase for himself in his individual capacity shall be wholly null and void, unless at the time of the making and completion thereof the name of the principal for whom the purchase is made shall be disclosed and inserted in the note or memorandum in writing, if any, which may be made in regard to such sale.

The 5th and 7th sections of this Act to apply to private sales.

IX. The provisions of the fifth and seventh sections of this Act relative to purchases at public sales by agents for alleged principals shall extend and apply, *mutatis mutandis*, to purchases made by agents for alleged principals at sales not being public sales.

Sales may in case no consideration have passed be rescinded and transfer duty shall be remitted.

X. When and as often as any contract of sale upon which transfer duty shall be payable shall be by mutual consent of the vendor and the purchaser cancelled and rescinded before transfer made, without any part of the purchase money having been paid or any valuable consideration given or promised by or on behalf of the purchaser for the purpose of obtaining the consent of the vendor to such cancellation, the transfer duty upon such sale shall be remitted: Provided that the vendor and the purchaser or their agents shall make in reference to such cancellation solemn declarations, which shall be in substance in the forms marked C and D to this Act annexed: Provided also that the Governor may, in case from death or other cause any vendor or purchaser shall be unable to make such declaration, dispense with the declaration of such vendor or purchaser.

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Sales declared void by legal process not to be chargeable with transfer duty.

XI. When and as often as any contract of sale upon which transfer duty shall be payable shall be set aside or declared or made void by the judgment of any competent court, the transfer duty upon such sale if unpaid shall not be payable, and if paid shall be returned.

When purchasers cannot be discovered and no purchase money has been paid declaration may be altered.

XII. When and as often as it shall be made to appear to the Governor of the colony by any person who shall have sold any property upon which sale transfer duty shall be payable that the purchaser of such property cannot be discovered within the colony, or has left the colony without taking transfer and without paying any part of the purchase money, and that such vendor is unable to obtain or enforce the fulfilment of the contract, it shall be lawful for the said Governor to permit the vendor aforesaid, in case he shall sell the said property over again, to make the necessary alteration in the form of the solemn declaration to be made by him in reference to such second sale: Provided that nothing herein contained shall alter or affect the law in reference to the respective rights or remedies of such vendor and such purchaser in regard to such first or original sale.

Form of solemn declaration in regard to certain of the foregoing cases.

XIII. In the case of a fresh or second sale of any property which was included in any such sale as in the tenth, eleventh, and twelfth sections aforesaid mentioned, the solemn declaration to be made by the vendor in regard to such fresh or second sale shall be altered in the manner indicated in the form marked E to this Act annexed.

Before whom declaration to be made.

XIV. The several declarations mentioned in this Act shall be made before such persons respectively as are or shall be by law entitled to attest declarations of sale and purchase for the purpose of transfer duty, and any person who shall wilfully and corruptly make and subscribe any declaration in this Act mentioned knowing the same to be untrue in any material particular shall be deemed to be guilty of the crime of contravening this section of this Act, and shall upon conviction thereof suffer such punishment as shall be by law provided for the crime of perjury.

What declaration to be made in case of rescinded sale.

XV. When and as often as any sale in regard to which transfer duty shall have been paid but no transfer given shall be cancelled and rescinded by mutual consent of the vendor and purchaser it shall be lawful for the Governor, upon being satisfied that no portion of the purchase money has been paid nor any valuable consideration given or promised for or in respect of such cancellation, to permit in regard to any fresh or second sale by the same vendor of the same property the declaration to be made by such vendor to be altered so as to conform to the fact; and such declaration shall be in substance in the form marked E to this Act annexed.

Transfer duty to be payable upon transfers for religious, charitable, educational, municipal, and the like purposes.

XVI. And whereas remissions of transfer duty are virtually grants of money, and grants of money made in an inconvenient form: Be it enacted that from and after the commencement and taking effect of this Act no transfer duty shall be remitted upon any sales made to any person or persons for religious or charitable or educational uses or purposes, or upon sales made to municipal commissioners for municipal uses or purposes, or upon sales made to harbour improvement boards for harbour improvement purposes, or generally upon any sales whatever except sales in regard to which the transfer duty if paid would be paid directly from and out of the colonial revenue.

Surviving spouses taking over the joint estates to pay no transfer duty.

XVII. And whereas surviving spouses who had been married to their deceased spouses in community of property frequently take over by appraisement or some similar arrangement, or by purchase at public sale from the executors or heirs of the deceased, the immovable property of the joint estate: And whereas the rule in regard to the payment of transfer duty by such surviving spouses requires to be declared and established: Be it enacted that no surviving spouse shall be chargeable with any transfer duty upon a purchase or taking over by appraisement or other mode of acquiring any of the immovable property of the joint estate, and that every such surviving spouse, if a widow, may have such property standing registered in the name of her deceased husband registered in her own name in her individual capacity without the payment of any duty.*

Construction of terms

XVIII. In the interpretation of this Act, the word "Governor" shall mean the officer for the time being administering the government, and any word importing the singular number or masculine gender shall be understood to include several persons and things as well as one person or thing and females as well as males, unless there be something in the subject or context repugnant to such construction.

Act when to commence.

XIX. This Act shall commence and take effect from and after the promulgation thereof.

Schedule No 1.

A. When any person appearing upon the records of the deeds registry to be a joint owner of any property shall purchase that property he shall not be charged with duty upon that proportion of the purchase money which represents his individual share or interest.

B. Any person being a descendant of any deceased person and who would be the heir, or one of the heirs *ab intestato* of such deceased person, who shall, being entitled as an heir or legatee in the estate, purchase or take over the immovable property in the estate or any part thereof, shall not be chargeable with duty upon so much of the purchase money or value of such property as represents his share, considered as or as if an heir *ab intestato*; and the husband of any such heir or legatee, or the tutor, curator, or authorized agent or trustee of any such heir or legatee, purchasing

* Repealed by section No. 7 of Act 7 of 1858.

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for and in the name of such heir or legatee shall be deemed and taken to be such heir for the purpose of this exemption.

C. Any heir or legatee of any deceased person, being such a person as has been above described under letter B, who shall require to have any of the immovable property inherited by him from the deceased, or by the deceased legated or prelegated to him, removed from the name of the deceased into his own name, shall not be chargeable with duty upon the amount of his share in the property so to be transferred in case or supposing that the deceased died intestate.

D. Every surviving spouse, being either the sole or a joint heir *ex testamento* of his or her deceased spouse, shall for the purpose of the exemption provided as aforesaid under letter C be regarded as if an heir *ab intestato* of the deceased spouse.*

E. When any surviving spouse shall have been instituted as sole and universal heir of the first dying spouse, which first dying spouse shall leave children him or her surviving, such children shall respectively be entitled (unless wholly and lawfully disinherited) to the exemptions provided as aforesaid under letters B and C, precisely as if they together with the surviving spouse had been instituted joint heirs of the deceased.

F. The husband of any female to whom he shall be married in community of property may have any property standing in the Deeds Registry Office in the unmarried name of such female removed into his own name without the payment of any duty.

G. As often as the owner of any immovable property, being a husband or intended husband, or being an intended wife, or being the parent of a husband or wife or of an intended husband or intended wife, shall agree or determine to vest such property in a trustee or in trustees for the purpose of thereby making a provision for the support of the marriage, or for the wife or intended wife, or for the children of the marriage, transfer of such property may be made to such trustee or trustees without the payment of any duty: Provided that this exemption shall only extend to cases in which no consideration other than an intended marriage or natural love and affection for or towards both or one or other of the spouses or the children of their marriage shall be given to the owner of the property proposed to be vested in trustees upon the trusts aforesaid or upon trusts of the like nature.

H. In every case in which any one person shall by the records in the Deeds Registry Office appear to be merely a trustee for any other person, whether the latter shall be a minor or a major or under coverture or not, the property so held in trust may be removed from the name of the trustee to that of the other party being entitled to have it so removed without the payment of any duty.

I. In every case of voluntary or compulsory partition between joint owners of immovable property all changes in the records of the deeds registry required for the due registration of the separate shares to be held by each in severalty shall be made without the payment of any duty.

J. Any person being a descendant or a surviving spouse of any person who shall by will or otherwise have burthened any immovable property with the entail of *fidei commissum* in regard to such descendant or surviving spouse, so that the latter shall be

* Repealed by section 7 of Act No. 7 of 1858.

entitled only to a life or other limited interest in such property, may have his title to such limited interest recorded in the Deeds Registry Office without the payment of any duty.

K. Any person claiming free property in remainder after the expiration or extinction of any previous *fidei commissum* burthening such property may, in case such person be a descendant within the fourth degree of the person imposing such *fidei commissum*, have the said property registered as his own in the Deeds Registry Office without the payment of any duty.

FORM A.

I, A B, do solemnly and sincerely declare that I sold to C D, as the agent or alleged agent of E F, on the —— day of ———, 185—, and not before, the property following, namely (here describe the property), for the sum of £——; and I declare that the said E F has declined to accept the property, and that the said C D has signified his willingness to take the same to and for his own individual account for the said sum of £——, neither more nor less: And I further declare that I am not to receive any valuable consideration other than the said sum of £—— for or in respect of the alienation of the said property: And I further declare that the said C D, as the agent or alleged agent of the said E F, is the only person who has ever purchased the said property, and that I never sold the same to any other person than in manner aforesaid to the said C D, who with my consent and by virtue of the Act in that behalf provided takes over the property aforesaid as his own: And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the Ordinance No. 6, 1845, entitled "Ordinance for substituting Declarations in place of certain Oaths, and for the suppression of voluntary and extra-judicial Oaths and Affidavits."

(Signed) A B

Declared before, &c.

FORM B.

I, C D, do solemnly and sincerely declare that I did, in the name of E F, purchase from A B, on the —— day of ———, 185—, and not before, the property following, namely (here describe the property), for the sum of £——; and I declare that the said E F has declined to accept the said property, and that the said A B has consented and agreed that I shall take over the said property as the purchaser thereof for the sum of £——: And I further declare that I have not, nor has any person to my knowledge on my account given, nor is there by me or on my behalf to be given, any valuable consideration of any kind whatever for or in respect of the alienation to me of the said property other than the sum of £—— aforesaid: And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the Ordinance No. 6, 1845, entitled "Ordinance for substituting Declarations in place of certain Oaths, and for the suppression of voluntary and extra-judicial Oaths and Affidavits."

(Signed) C D

Declared before, &c.

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Form C.

I, A B, do solemnly and sincerely declare that I sold to C D, on the —— day of ———, 185—, the property following, namely (here describe the property), for the sum of £——; and I declare that I have never received any sum of money or other valuable consideration from the said C D on account of the said purchase:* And I further declare that I have consented and agreed with the said C D to cancel by mutual consent the said sale, which sale was on the —— day of ———, 185—, cancelled accordingly: And I further declare that I have not received nor am I to receive from the said C D or any other person any money or other valuable consideration for or in reference to my consent to the cancellation of the said sale: And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the Ordinance No. 6, 1845, entitled "Ordinance for substituting Declarations in the place of certain Oaths, and for the suppression of voluntary and extra-judicial Oaths and Affidavits."

(Signed) A B

Declared before, &c.

Form D.

I, C D, do solemnly and sincerely declare that I bought from A B, on the —— day of ———, 185—, the property following, namely (here describe the property), for the sum of £——; and I declare that I have never given to the said A B any sum of money or other valuable consideration on account of the said purchase:† And I further declare that I have applied to the said A B to consent to cancel the said sale, which sale hath accordingly been cancelled by mutual consent: And I further declare that I have not given nor am I to give, nor has any person on my behalf to my knowledge given, nor is any person to my knowledge to give any money or other valuable consideration for or in reference to the cancellation of the said sale: And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the Ordinance No. 6, 1845, entitled "Ordinance for substituting Declarations in the place of certain Oaths, and for the suppression of voluntary and extra-judicial Oaths and Affidavits."

(Signed) C D

Declared before, &c.

Form E.

I, A B, do solemnly and sincerely declare that the sum of £—— is the full and entire purchase money for which I have sold (here describe the property) to E F; and I declare that I sold the same to the said E F on the —— day of ———, 185—, and not before; and that I am not to receive any other valuable consideration for or in respect of the alienation of the said property: And I do further declare that the only person other than the said E F to whom I ever sold the said property, or who at any time

* Should any interest have been received upon the purchase money, add the words "except certain interest upon the said sum."

† Should any interest have been paid upon the purchase money, add the words "except certain interest upon the said sum."

purchased the said property from me, was C D, to whom I sold the same on the — day of ——, 185— : And I further declare that the said sale to the said C D has been cancelled by mutual consent, and that the transfer duty thereupon has been remitted: (Or in regard to section 11, "and I further declare that the said sale has been set aside by a judgment of the Supreme Court bearing date the — day of ——, 185—, pronounced in a suit wherein —— was the plaintiff, and —— was the defendant:" or in regard to section 12, "and I further declare that the said C D has, to the best of my knowledge and belief, left the colony," "or cannot be discovered within it" as the case may be, and that he has not paid me any part of the purchase money agreed to be paid, and that I have received from his Excellency the Governor the permission herewith annexed to make this special declaration.) And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the Ordinance No. 6, 1845, entitled "Ordinance for substituting Declarations in the place of certain Oaths, and for the suppression of voluntary and extra-judicial Oaths and Affidavits."

(Signed) A B

Dated before, &c.

In cases of exemption claimed under and by virtue of the 15th section of this Act, the above form shall be altered by changing the word "remitted" into the word "paid."

No. 16—1855.] AN ACT [June 8, 1855.

To Provide for the Organization of the Inhabitants of the several Divisions of this Colony for the Internal Defence of their respective Divisions.

Preamble.

WHEREAS it is expedient to make provision for enrolling and organizing the able-bodied inhabitants of this colony for the protection of life and property within their respective divisions: Be it enacted by the Governor of the Cape of Good Hope, with the advice and consent of the Legislative Council and House of Assembly of the same:

Field-cornets to frame lists of persons liable to burgher duty.

I. Within three months after the promulgation of this Act the several field-cornets throughout the colony shall make out a list containing the names of all the male residents in their respective field-cornetcies between the ages of twenty and fifty years, distinguishing those who are hereinafter exempted from liability to service under this Act.

Who exempt from burgher duty.

II. All persons disqualified for service as burghers by bodily or mental infirmity, all ministers of religion, judges, resident magistrates, all teachers in private schools, and

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constables, all persons serving in any of the military or naval departments of Her Majesty or in the civil service of this colony or in the service of the Honourable East India Company, and all merchant seamen under articles, shall be exempt from serving in the burgher force under this Act, except with their own consent.

How lists to be framed where no field-cornets

III. In any municipality for which no field-cornet is appointed the duties devolving upon that officer under this Act shall be executed by the commissioners of such municipality, with the exception of the municipality of Cape Town, within which the duties devolving upon the divisional councils and field-cornets under this Act shall be executed by the commissioners and wardmasters of the said municipality.

How claims to exemption to be made in cases of age or infirmity.

IV. In every case in which exemption may be claimed on account of bodily or mental infirmity the party so claiming shall be required to furnish a competent medical certificate, and if he claim it on account of age but cannot certify on affidavit nor afford proof of the validity of his claim, the decision of his liability to service shall rest with the divisional council of his division.

Should field-cornet neglect civii commissioner to make out the list.

V. If any field-cornet should neglect to make out the list as hereinbefore mentioned and to furnish it to the divisional council of his division within the time specified, or shall furnish an imperfect list, it shall be the duty of the civil commissioner of the division to make out or to perfect the said list as the case may be.

Duty of divisional council on receiving list.

VI. Every such divisional council shall forthwith upon the receipt of such list cause a copy thereof to be affixed at or near all churches or other places of religious worship, and also at the residence of each field-cornet and at each court-house within the division and at the place of meeting of such council as aforesaid, and shall cause a notice to be served on or at the residence of each person on the list of the day on which the said council will hold a court for the purpose of hearing objections to such list, which day shall not be sooner than two weeks nor later than four weeks after the day of affixing the aforesaid copy at the place of meeting of the said council.

Divisional council to hold a meeting for correcting each list.

VII. Upon the day and at the place so notified the divisional council shall hold a meeting, at which it shall on due proof by declaration or affidavit correct all errors in such list, either by adding the names of persons liable to service which may have been omitted therein or by striking out from the list of those so liable the names of any persons entitled to be exempt; provided that such meeting may be adjourned from day to day until all questions as to the correctness of the list are determined; and provided that the decision of such divisional council shall be final.

What officers to belong to the burgher force and how to be elected.

VIII. The burgher force to be enrolled under this Act shall be officered by field-captains, one of whom shall command the burghers enrolled in each field-cornetcy, and of a commandant

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in each division, who shall command all the force enrolled therein; and all such officers shall be elected as hereinafter enacted; provided that if two or more companies be called out and assembled together and the field-commandant be not present, the field-captains then present shall out of their number elect one to act as provisional field-commandant during the absence of the field-commandant.

Field-captains how to be elected.

IX. Upon the completion of such lists as aforesaid each field-cornet shall by notice served on or at the residence of each person on the said lists fix a day, not to be later than one month after the date of such completion, on which the burghers of his field-cornetcy shall assemble, at a place to be by him appointed in such notice, to elect a field-captain and a deputy to act in the absence of such field-captain for such field-cornetcy; provided that such election shall be decided by a majority of burghers belonging to the said field-cornetcy then present and that notice of the names of the field-captains and their deputies so elected be forthwith transmitted by the chairman of such meeting to the divisional council.

Field-commandant how to be elected.

X. Within one month after the election of the field-captains and their deputies as hereinbefore provided they shall assemble, on a day to be fixed by the divisional council, and shall elect their field-commandant.

Field-commandants, &c., how long to remain in office.

XI. All field-commandants, field-captains, and deputy field-captains elected as above provided shall serve for three years or until other persons be elected in their stead in the manner above provided for their first election, and shall be then re-eligible. If any field-captain or deputy field-captain at any time decline to serve he shall give notice thereof to the field-commandant of his division, and if any field-commandant so decline to serve he shall give notice thereof to the divisional council, who shall respectively proceed in the same manner as above provided to the election of the successor of such officer.

By whom and how the burgher roll of each division to be framed and burghers to be called out in their order.

XII. Within one month after the election of the field-commandant that officer shall assemble with the field-captains and (with the assistance of the field-cornets) shall frame a roll of the burghers of the division, placed in the order in which they shall be called out for service in such division and all burghers shall be called out in consecutive order according to such roll; and no burghers shall be called out a second time for service in such division except with their own consent until all the other burghers on the said roll have been called out; provided that any person considering himself aggrieved by the position of his name on the aforesaid roll may appeal to the divisional council, who shall decide on such appeal.

On completion of burgher roll every burgher to receive notice of his number.

XIII. Upon the completion of such roll as aforesaid the field-commandant shall furnish a copy thereof to the divisional council of his division, and the said council shall cause a

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notice to be addressed to every burgher in his division, in which shall be stated the number of his name on such roll.

Burgher roll to be triennially revised.

XIV. Every such roll shall be revised at the expiration of every three years in the same manner as is above provided for its original formation.

How names to be annually struck off and added to the burgher roll.

XV. Every field-cornet shall within the first month of each year furnish to the divisional council of his division a list of all burghers who have died or have passed the age of fifty, or have ceased to reside in his field-cornetcy during the preceding year, together with a list of all persons liable to serve as burghers who have reached the age of twenty, or have taken up their residence during the same period in his field-cornetcy; and unless such latter persons prove their claim to exemption before the divisional council their names shall be added by the said council at the end of the roll; and the names of all such former persons shall be erased from the roll by the said divisional council.

Where no divisional council who to perform its duties.

XVI. If in any division no divisional council shall be in existence the civil commissioner of such division assisted by any two justices of the peace shall do all acts required in this Act to be done by the divisional council; and all lists required to be furnished to the divisional council shall be furnished to the civil commissioner: Provided always that nothing herein contained shall be construed to exclude the commissioners and wardmasters in their respective municipalities from performing the duties imposed on them in the third section of this Act.

Governor may call out so many of the burghers as he may consider necessary.

XVII. Whenever it shall be necessary for the defence of any division of the colony or for the protection of life and property therein, the Governor or the officer administering the government of the colony may by proclamation call out the burgher force of such division or such part of the said force as he may consider necessary, for service within the said division, and not elsewhere except with their own consent.

Proceedings in the case in which the Governor shall call out the burghers.

XVIII. Upon the receipt of such proclamation or in the event of an emergency the civil commissioner shall give notice thereof to the field-commandants and to the field-captain or captains whose companies it may be necessary to call out, who shall thereupon proceed to call out in such manner as they may deem best the required number of burghers in the order in which they stand upon the roll of the division, and shall at the same time appoint a time and place at which the burghers of their respective field-cornetcies shall assemble therein; and if it be required to summon a general assembly of the burghers of the division or the burghers of more than one field-cornetcy the civil commissioner shall in his summons to the field-commandant and field-captains signify at what time or times and in what place or places the several companies shall meet for the service required of them.

Officers or burghers making default when called out to forfeit any sum not exceeding £3.

XIX. Any commandant, field-captain, deputy field-captain, or burgher who having received due notice of his liability to serve and having received due notice of his having been

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called out to serve on any occasion shall absent himself without a lawful cause for his absence, or shall withdraw himself before permission to that effect be given by some competent authority, or shall refuse or wilfully neglect to obey any lawful command of the Governor or any officer duly authorized by the Governor, or in the case of a field-captain or burgher the lawful orders of his superior officer, shall upon conviction before the divisional council of his division be liable to a fine not exceeding three pounds, which shall be recoverable by summary process in the court of the resident magistrate and shall be appropriated to the maintenance of the burghers called out and serving under the provisions of this Act.

Pay of officers and burghers.

XX. Each commandant, field-captain, deputy field-captain, and burgher when called out into active service and acting within his division shall receive rations for himself and forage for his horse if mounted, or in lieu thereof the following sums per diem, viz.:

If mounted	4s. 6d.
If not mounted	2s. 0d.

Widows of burghers and burghers permanently injured to be pensioned.

XXI. The widow of any burgher who may be killed in action and any burgher who may receive during his service any wound or injury permanently injurious in its consequences shall receive a pension or allowance of not less than one shilling per diem and not exceeding seventy pounds sterling per annum, the amount whereof shall be fixed by the Governor, subject to the approval of Parliament.

Burgher losing horse, &c., to be compensated.

XXII. Every mounted burgher whose horse shall be killed or carried off by or abandoned to the enemy or be destroyed to prevent the same falling into the enemy's hands, or who shall while on active service suffer loss by the enemy of saddle, gun, or accoutrements, shall be paid the value of the same at the time of the loss thereof; such value to be certified by the commandant of the force to which the burgher belongs.

Equipments of burgher force how to be obtained.

XXIII. When the burgher force of any division or any part thereof is called out for active service, the field-commandant or the field-captains or deputy field-captains of the several wards of such division are authorized to require from those who possess them such wagons, horses, mules, oxen, and gear, together with such provisions, forage, or other necessaries, as shall be needed for the service of such force; and every inhabitant shall be bound to render obedience to such requisition: Provided that with reference to such requisition the aforesaid officers shall conform to the instructions which they may have received from the civil commissioner of the division to which they belong.

How equipments to be paid for.

XXIV. When any articles as aforesaid shall be so obtained the officer obtaining the same shall justly estimate the value thereof, and shall give a certificate certifying that he has obtained from ——— the articles in question and

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that the same are fairly worth £——; and the civil commissioner shall on presentation of such certificate, if acquiesced in by the owner and not appearing to him excessive in value, proceed to pay the sum stated in such certificate; or shall grant to such owner a certificate payable on demand for all sums under twenty pounds, and for all higher sums either payable on demand or redeemable by Government within a period not exceeding two years, which certificate shall be transferable by cession and secure the said amount with legal interest if not payable on demand from the date of purchase to the date on which such certificate shall be paid: Provided that if the value placed on such article be deemed excessive or if the late owner shall object to the same as being inadequate the question may be referred to the divisional council, which shall cause such inquiry to be made as it shall see fit into the just and fair value of such articles, and the said divisional council thereupon shall affix such value as it may deem just and fair; and its decision thereon shall be final; and all articles so obtained shall be the property of Government and shall when no longer required be disposed of under such regulations as may be appointed.

Governor may provide arms for burghers who have not arms.

XXV. The Governor or the officer administering the government may in each division take such measures as may be deemed expedient for providing at the public expense arms for such burghers as may not possess arms of their own, and for the due preservation and custody of all public property provided for the use of the burgher force.

Costs of this Act to be borne by the general revenue.

XXVI. The cost and charge of carrying out this Act shall be defrayed out of the general revenue of this colony.

No. 1—1856.] AN ACT [June 4, 1856.

For Preventing the Spread of Contagious or Infectious Diseases.

Preamble.

WHEREAS it is expedient in case any contagious or infectious disease of a fatal or dangerous character should break out or appear amongst the inhabitants of this colony that stringent and immediate measures should be taken to prevent the spread thereof: Be it enacted by the Governor of the Cape of Good Hope, with the advice and consent of the Legislative Council and House of Assembly thereof, as follows:

Governor may declare this Act in force in towns or other localities.

I. In case any contagious or infectious disease should break out or appear in any of the towns or villages or other localities of this colony it shall be lawful for the Governor thereof, by proclamation to be published in the Government Gazette, to declare this Act in force in such town or village or other locality, and such other towns, villages, or other

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localities as the said Governor shall deem needful and describe.

Act to remain in force until withdrawn by proclamation.

II. As often as any such proclamation as aforesaid shall be published as aforesaid this Act shall be thereupon in force in the place or places described in such proclamation, and shall remain in force therein until such proclamation shall by some other proclamation to be so issued as aforesaid be withdrawn.

Magistrate may by notice put the Act in force until proclamation can be issued.

III. If any such disease as aforesaid shall break out or appear in any town or village other than Cape Town or some town or village in the Cape district it shall and may be lawful for the resident magistrate having jurisdiction in such town or village, by a written or printed notice posted at his office and in any other way in which public notices are usually published in such town or village, to declare this Act in force within such town or village, and thereupon this Act shall be forthwith in force therein precisely as if such notice aforesaid were a proclamation of the Governor: Provided that every resident magistrate issuing any such notice shall without delay report his proceeding to the said Governor in order that such a proclamation may be published as in the first section mentioned, after the publication of which proclamation the notice aforesaid shall, *ipso facto*, become null and void.

Proclamation to supersede such notice.

Powers of municipality in respect of this Act when enforced.

IV. As often as this Act shall be in force in any town or village which shall be a municipality it shall be lawful for any two commissioners or any two wardmasters of such municipality, or for one commissioner accompanied by one wardmaster, or for any two inhabitants who shall produce an authority in writing signed by the secretary or town-clerk of the municipality purporting to be so signed by order of the commissioners authorizing the said inhabitants by name to aid in carrying into effect the provisions of this Act, accompanied by a medical practitioner in case there be one resident within five miles of the town-house or office of the municipality, to demand entrance into any dwelling-house, building, or habitation within such municipality, and in case entrance shall not be afforded to use or cause to be used all necessary force to effect such entrance, and to visit every room, closet, and apartment therein, and if they shall find in such house any person labouring under the contagious or infectious disease in regard to which this Act shall have been put in force in such municipality and who shall not be under medical treatment by some medical practitioner they shall cause such person to be removed with all possible care and all proper speed to any hospital or building open for the reception of such patients, in order that such person may be properly treated for the disease and may not communicate it to others: Provided that any medical practitioner resident as aforesaid who shall without lawful cause refuse when called upon by any two such persons as aforesaid to

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accompany them for any such purpose as in this section mentioned shall be liable to a fine not exceeding ten pounds; and provided that every medical practitioner accompanying any such persons for any such purpose shall be entitled to his reasonable fee for so doing, such fee in case of dispute to be fixed by the Governor aforesaid.

Filth and other noxious matter to be removed from houses, &c.

Defective drainage, &c., to be remedied.

V. If any such persons as in the last preceding section mentioned shall discover in any house or building which they shall examine or in any yard, out-house, or other place belonging thereto any accumulation of offensive or noxious matter, refuse, dung, or offal, or any foul or offensive drain, privy, or cesspool, it shall be lawful for such persons to require the occupant of the premises or place in which such noxious, foul, or offensive matter or thing shall be forthwith to do or cause to be done what shall be needful to put such premises as far as may be into a wholesome state; and in case such occupant shall refuse or neglect forthwith so to do then the said persons so visiting the said premises as aforesaid may cause to be done what shall be needful for the purpose aforesaid, and the costs and charges of so doing shall be a debt due by the occupant of such premises and may be recovered by such persons by action in any competent court: Provided that as often as such occupant shall not be the owner then the owner shall also be liable, and both the owner and the occupant may be sued together in the same action, the one of them paying the other to be discharged: Provided however that nothing herein contained shall extend to alter or affect the mutual responsibility of such owner and occupier as between themselves, which shall be determined by the nature of their contract and the circumstances of the case.

Liability of owner and occupier.

Overcrowding of dwellings to be prevented or remedied.

VI. Should any such persons as aforesaid in their examination of any house, room, or other place discover or ascertain that so many inmates are crowded together in such insufficient space as evidently to expose them to the ravages of the disease which shall be then in question it shall be lawful for such persons so examining to require that so many of the said inmates as shall be plainly in excess of the number which such house, room, or other place can safely accommodate shall remove to some other fitting place, and the persons so to remove shall be selected by arrangement between such inmates themselves, and failing that, by the decision of such persons so examining as aforesaid, after hearing the parties concerned; and in case the inmates who shall be required to remove shall not be themselves provided with any place approved of by such persons so examining as aforesaid as a fitting place, then it shall be lawful to require them to remove to some building or place which shall be provided by the municipality for the reception of parties so circumstanced: Provided that no charge shall be made for the use by any such parties of such lastmentioned building or place.

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In case inmates refuse to remove.

VII. If any such inmate as aforesaid shall upon request of such persons so examining as aforesaid refuse to remove either to some fitting place selected by himself or to the building or place provided as aforesaid for the reception of such individuals, it shall be lawful for the resident magistrate of the district (and in regard to Cape Town, for either the resident magistrate of Cape Town or the judge and superintendent of police of Cape Town) to cause such inmate to be brought before him and upon proof that the request aforesaid to remove was reasonable and necessary to commit such inmate to prison, unless and until he shall consent to remove either to some fitting place selected by himself or else to some building or place provided as aforesaid by the municipality: Provided that if he should so consent before imprisonment he shall not be imprisoned, and that upon so consenting he shall, if in prison, be liberated.

Where there is no municipality duties of magistrate.

VIII. In any town, village, or other locality in which this Act shall be put in force, not being a municipality, it shall be lawful for the resident magistrate of the district to nominate and appoint by any writing under his hand so many of the inhabitants as shall appear to be necessary and who shall be willing to serve to aid in carrying into effect the provisions of this Act, and any two such persons shall possess in regard to such town, village, or locality the same powers and authorities which might under the fourth section of this Act be lawfully exercised within a municipality by any two of the persons in the said section mentioned: Provided that in regard to any town, village, or locality not being a municipality the resident magistrate aforesaid shall should it be necessary so to do provide some building or place to be used as a public hospital and some other building or place for the reception of persons whom it shall be necessary to remove from overcrowded rooms or houses; and the provisions of the fourth and sixth sections of this Act shall respectively extend and apply to such buildings or places respectively: And provided that such persons as in this section mentioned need not to be accompanied by a medical practitioner.

In case of small-pox.

IX. Any two of the persons authorized under this Act to aid in carrying into effect the provisions thereof in any town, village, or other locality in which this Act shall have been put in force by reason or on account of the appearance of small-pox may require any person within such locality to give proof that such person has been vaccinated, and if any person who shall not give proof of having been vaccinated shall refuse to allow himself to be vaccinated it shall be lawful for the resident magistrate of the district (and in regard to Cape Town for either the resident magistrate of Cape Town or the judge and superintendent of police of Cape Town) to cause such person to be brought before him, and in case such person shall fail to prove that he has boen vaccinated and yet shall refuse to allow himself to be vaccinated

Proof of vaccination required.

In case of refusal to be vaccinated.