Bergvesenet

Postboks 3021, 7002 Trondheim

Rapportarkivet

Bergvesenet rapport nr	Intern Journal nr	Internt arkiv nr	Rapport lokalisering	Gradering
BV 2232				Fortrolig
Kommer fra ..arkiv	Ekstern rapport nr	Oversendt fra	Fortrolig pga	Fortrolig fra dato:
Sulitjelma Bergverk A/S	"522300002"			

Tittel
Geology of the Alta Kvënangen window (Kvaenangen side).

Forfatter	Dato	Bedrift
GAUTIER A.	1975	Sulitjelma Gruber A/S

Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad

Fagområde	Dokument type	Forekomster
Råstofftype	Emneord	

Sammendrag

Geologiske undersokelse av Alta - Kvënangen vinduet i Nordtroms og Vestfinnmark. Generell skildring av berggrunnen, detaljerte petrografiske beskrivelser av de forskjellige bergartene i grunnfjellet og Raipas -dekket. Metamorfose, geokjemi og geokronologi grundig diskutert. Mulighetene for mineraliseringer vurderes som sma. Del av doktorarbeide. Skyvedekke. Tektonikk.

522.300.002

A/S Sulitjelma Gruber
N-8230 SULITJELMA Norge

No. Copy

GEOLOGY OF THE ALTA-KVAENANGEN WINDOW (Kvaenangen side)

N.-Troms and W.-Finnmark, Norway
Regional mapping to the scale 1/50.000

Field work: summer 1974 and 1975

André M. GAUTIER
Licencié ès sciences géologiques et minéralogiques
Dpt. de minéralogie
Université de Genève
13 r. des Maraîchers
CH-1211 GENEVE 4
Sveit - Switzerland

November 1975

A/S SULITJELMA GRUBER
N - 8230 SULITJELMA NORGE

GEOLOGY OF THE ALTA - KVÆNANGEN WINDOW (Kvæ nangen side)

N - Troms and W-Finnmark, Norway

Regional mapping to the scale 1/ 50.000

Field work : summer 1974 and 1975

André M. Gautier
Licencié ès sciences géologiques
et minéralogiques (= B. Sc.)
Université de Genève/Dept. Minéralogie
13, rue des Maraîchers
CH - 1211 GENEVE 4
Sveits - Switzerland

November 1975

Content

Content | Page

Content | Page

Content

I Introduction

I. INTRODUCTION

1.1. LOCATION

The area of interest is located approx. between 69°45' and 70°N, 21°50' and 22°45 ' E, and is partly in the Kvaenangen herald (N-Troms) and partly in the Alta herald (W.-Finnmark).

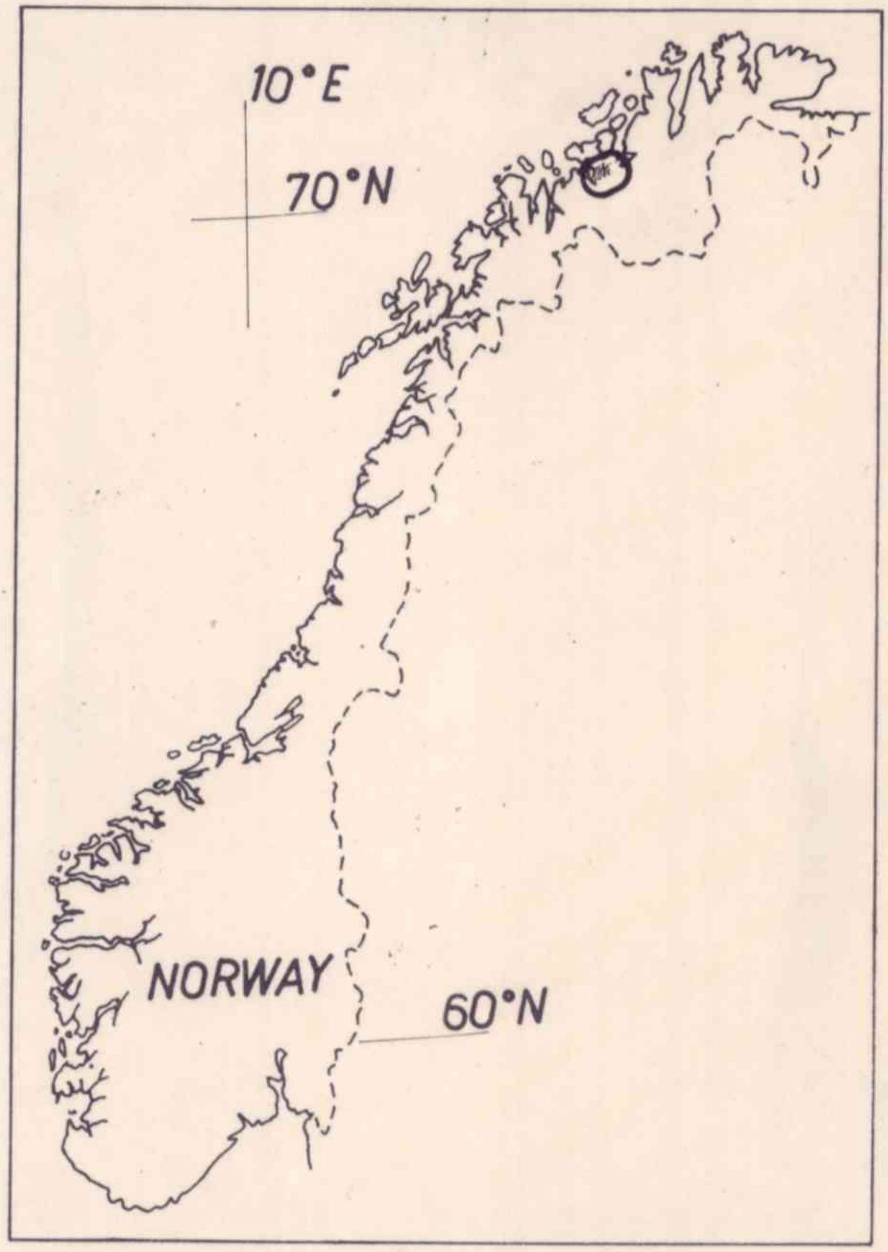
The area is inhabited, except the coastal zone. The road E 6 is following this coastal zone. The only "localities" are: Badderen (shop "Samvirkelag" for food and first need goods, petrol, post office, telephone and a workshop), Burfjord (shops, petrol, post office, telephone, medical center, inns-gjestgiveri, ...). Apart from the international E 6 road, there are some smaller roads leading to Kviteberg (7,5 km. from Burfjord), to the upper part of Burfjorddalen (6 km from Kåsen, with the non-recommended--by-car possibility to cross a rotten bridge) to reach the top of Middavarre, 500 m high; then 3,5 more km to Dorras, on the shore, 5 km from the E 6; there is also a cart track in Badderelvdalen. It is possible to drive as far as 7 to 8 km with a moped.

The access to the field is very limited with these roads. Apart from walking - which might be difficult because of river-crossing (that might take up to one walk-day), the best way to reach the field is the floatplane, when the lakes are icefree (several possibilities from Alta).

The lakes where a landing is possible, are Flintvan (EC 495485, 550 m) Djupvatnet (EC 510460, 570 m), Baddarjavri (EC 555410, 558 m), Nikkelnob'baljav'ri (EC 555460, 675 m), Storelvvatnet (EC 5550505, 634 m), Holmvatna (EC 620555, 531 m) , no name (EC 575538, 606 m), Oag'gujav'ri (EC 665510, 472 m).

The tree limit reaches 300 m in the shade of the wind. There are some huts near a lake, very well situated for fishing, but not for a regional geological mapping, excepted at Djupvan. For this reason, as soon as the field is out of reach from the road, it is necessary to make camps of several days.

I B



1.1.2. TOPOGRAPHY

West from the E 6 road between Burfjord and Badderen, there is Riiddevarre, with tops up to 460 m to the South (lille R.) and 700 m to the North (store R.)

East from this line there are several parallel ridges, North-South oriented, very uneven, with tops up to 700 - 800 m and the valley of Flintvan (550 m). Further East, the ridge of Blåfjellet is between 600 - 867 m high. Tho big "cuts" East-West are dividing the area from the E 6 road to here; there are the rivers Burfjordelva and Badderelva.

After Blåfjellet, there is a zone with softer relief, but up to 800 - 915 m.

To the E N E of Storelvvatnet, the steep ridge of Didnoirhar'ji is 998 m high.

To the E of this latter mountain, there are some deep valleys, approx. N- S, an uneven area again, to the mountain of Fiskartind (Oag'gučåkkat), 844 m high and the lake Oag'gujav'ri.

The zone more E and NE is described in another work by ourselves: a) field report of the N-E part of the Alta- Kvaenangen tectonic window, Elkem Spigerverket, 1971, b) geological map Alta 1834 I 1/50.000 (description in preparation), NGU.

1.1.3. OUTCROPS

The outcropping might be described as good. When out of the wooded areas, the structures can be followed easily on air photos.

The bottom of the valleys and also the quite flat area are covered with rather important amount of morainic material, which has the tendency to mask the soft formations, when not covering everything!.

Generally, the rock has a weathering crust, oxydation crust, up to 1/2 cm thickness. Even more, the rock is covered by lichens, whose thickness varies from some tens of mm. to some cm. But anyway, these two facts are enough to mask completely the petrography, the limits between rock-types.

The rock is often broken, with lots of joints whose surfaces are weathered, rusted, or with a chloritic coating. It might be difficult to get a good hand-specimen with a fresh cut.

From good, the outcrop conditions are getting very bad when considering detail structures such as pillow-lavas in a fine-grained greenstone, or as gradded beddings, cross beddings, in banden rocks.

Glacial streaks might also mask primary features of the rock.

1.1.4. CLIMATE

Generally the snow disappears at the beginning of June in low areas; some zones, covering important surfaces, might be snow-covered during all summer.

The melting of snow causes strong flood of the rivers, so that there are many river-crossing problems for the geologist.

Snowfall might occur at any moment in summer time. Temperatures range from $5^{\circ}C$ (or less) up to $30^{\circ}C$ within a few hours.

The wind may be very strong. It happens that it is very strong in altitude and inexistant in the valley, causing an irregular gradient of pressure that should be taken into consideration when using an altimeter.

According to floatplane pilots, wind up to 50-60 kt/h are not uncommon. When the observatorium of Sukkertoppen was still operating at the beginning of the century, winds up to 60 m/s have been measured.

The summer 1974 was rather favourable concerning the snow-conditions; the consequence of a winter with little snow and a warm wave at mid-June was that the area was free of snow. Our field experience from previous years indicates that such case is seldom.

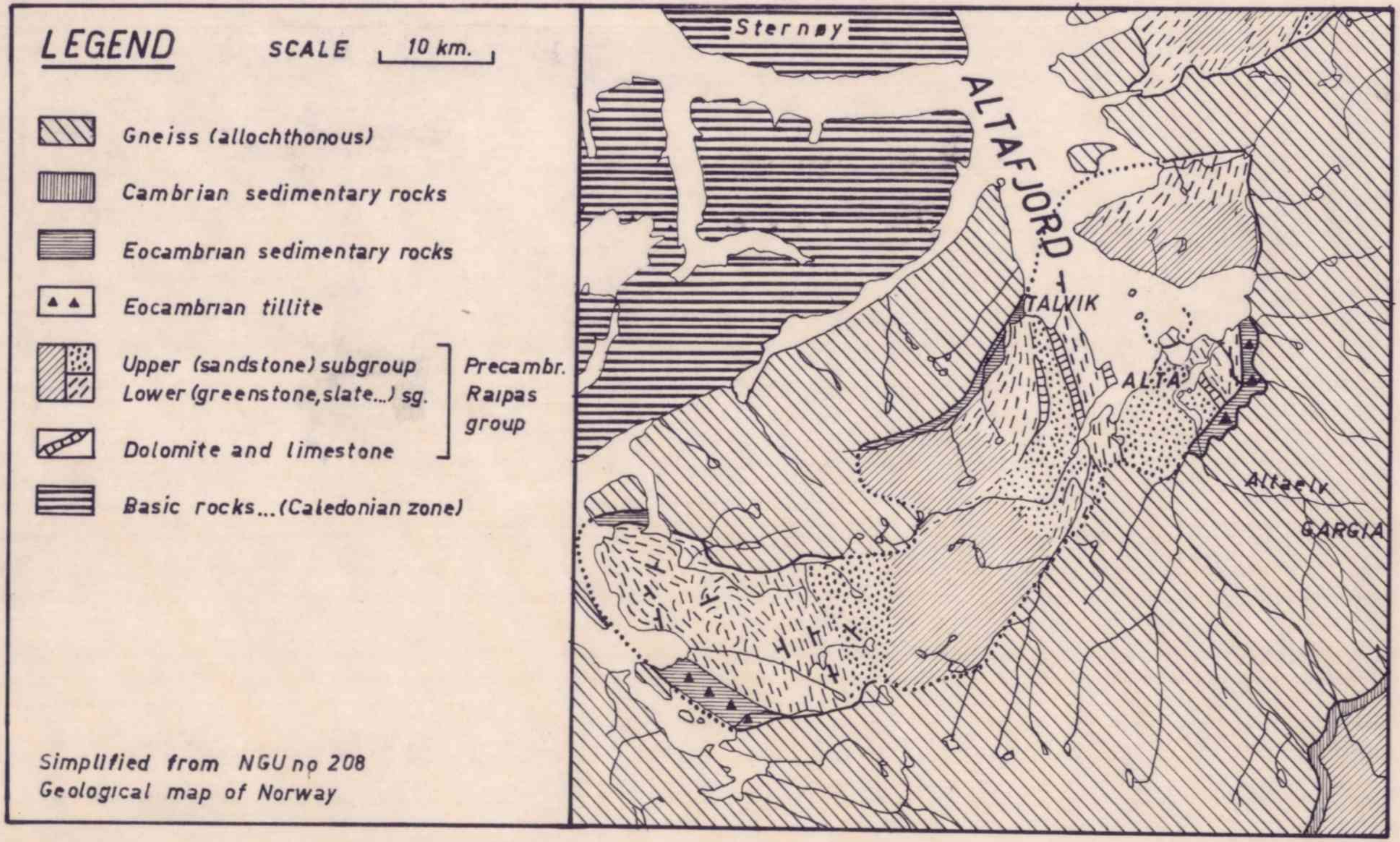
In 1975 the situation was very unusual, much more unpleasant in terms of working conditions: at mid-June the whole field above 400 m was still snow-covered and the lakes were frozen, excepted in a zone of 2-3 km from the shore of the fjord. Mid-July the lakes were still frozen above 400 m and crossable some tens of meters higher. End-July even big lakes such as Storelvan (634 m) were still frozen. Baddervan (575 m) was free of ice, with important floating ice. Nikkeluob'baljav're (675 m) was frozen, except a small zone of some tens of meters on one side, and a very strong ice on the other side.

The ice broke after a heavy storm and rain on August 6th. The lakes we found above 800 m kept frozen all the summer.

The snow cover was important too. End June / beginning July it was very strong on slopes to the E (50 - 80%) and 20-50% on slopes to the W (above 400 m). Later, the snow melted, but important zones still remained covered, at the foot of cliffs or on the bottom of the valley.

Big tunnels up to some meters high were taking shape above the streams and rivers flowing under the snow, forming dangerous snow-bridges, invisible until they were broken. This fact represented an additional danger for the work.

End of August some snowfalls happened above 700 m. At the beginning of September there was a period of 4 days of windstorm and snowfalls above 570 m.


LEGEND
SCALE 10 km.
Gneiss (allochthonous)
Cambrian sedimentary rocks
Eocambrian sedimentary rocks
Eocambrian tillite
Upper (sandstone) subgroup
Lower (greenstone, slate...) sg.
Precambr. Raipas group
Dolomite and limestone
Basic rocks... (Caledonian zone)
Simplified from NGU no 208
Geological map of Norway
Sternøy
ALTAFJORD
TALVIK
ALTA
Altaelv
GARGIA

1.2. GEOLOGY

1.2.1. General geology of the W part of the Alta-Kvaenangen window.

The fig.p. I F, modified and enlarged twice from the geological map of Norway (1/1.000.000) shows the general geological outlines. The numerous Caledonian "nappes" (allochthonous gneisses) have been grouped together.

There are 3 main tectonic units, from the bottom to the top: 1) the basement, 2) the autochthonous, and 3)the allochthonous.

1- The Precambrian basement, called Raipas group, is divided into 2 sub-groups:

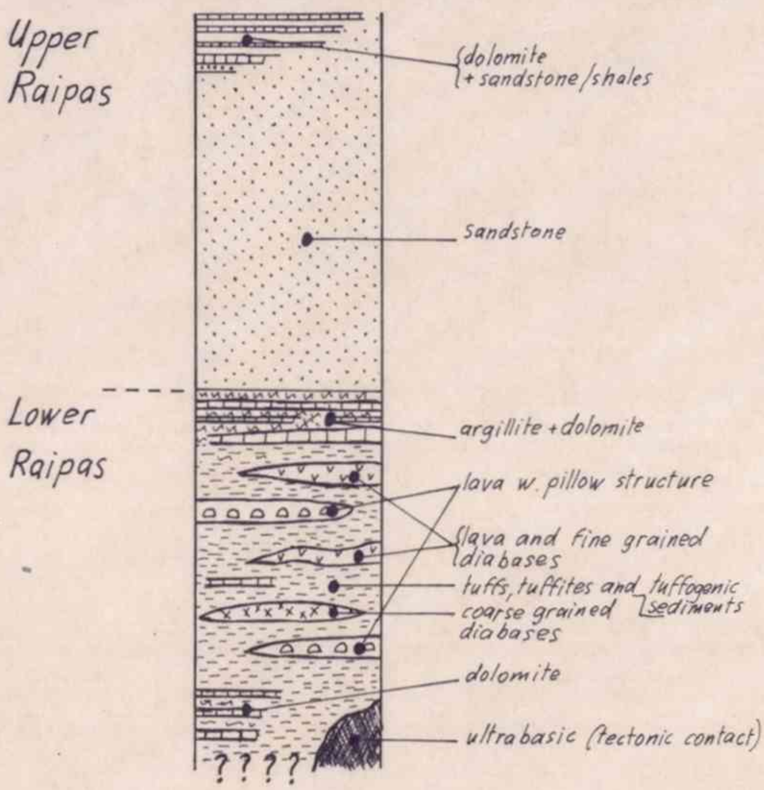
- the Lower Raipas subgroup, consisting mainly of a folded sequence of volcanic and volcano-sedimentary rocks: metadiabases as sills, lava streams, often with pillow-lava structure, exceptionally with columnar jointing, with basaltic composition, sometimes with a spilitic tendency, associated with tuffs, tuffites and tuffogenic sediments, and also some pelitic or carbonate layers. There is in one place an ultrabasic outcrop (serpentinised lherzolite).

- the Upper Raipas subgroup, consisting mainly of a thick sequence of sandstone ± quartzitic and a formation of interbedded dolomite and greywacke and shales.

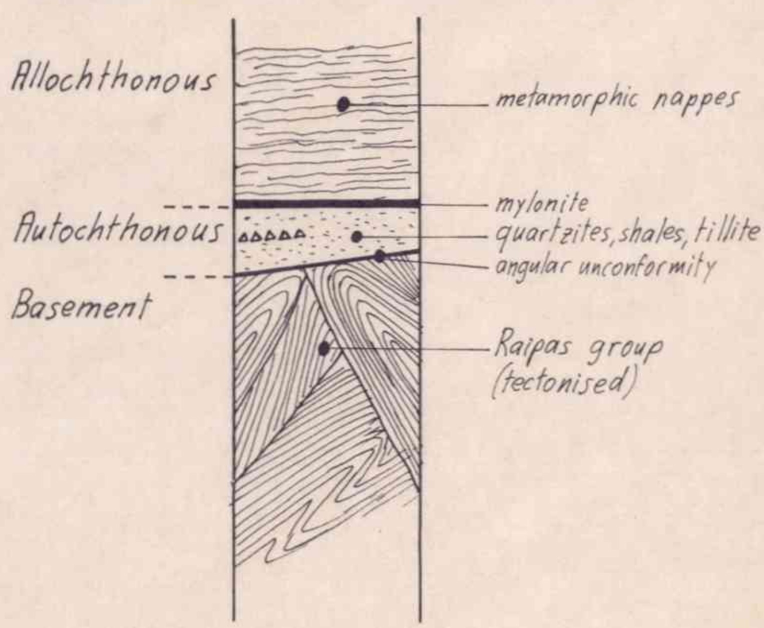
2- The autochthonous (sensu stricto) consists mainly of white, bluish etc. quartzites, with some shales, tillite layers, etc. Around Alta, where it has been studied in detail, it is divided into 2 distinct groups:

Alta-Kvaenangen window
Geological and tectonic outlines

Stratigraphy of the Raipas Group (without scale)



Tectonic pile (without scale)



-the Bossekop group (late Precambrian), mainly white quartzite, laying with an angular unconformity on the basement;

- the Borras group (eo-cambrian), characterised by a tillite and different shales and quartzite, slightly unconformable on the Bossekop group.

It is not possible to correlate the typical stratigraphy in Alta with the autochthonous rocks all around the window.

3. The allochthonous. The latter is made of all the Caledonian nappes.

1.2.2. Previous work.

During the last century the area has been studied. (Russeger, 1841), (Pettersen, 1874), (Reusch, 1890).

In 1915 a first stratigraphy has been established for the precambrian formations of Alta, called Raipas group (Holtedahl 1915, 1918).

At the same time, a geological map and a report were written about the mining district of Alta & Kåfjord and Kvaenangen (Zenzen 1915), to the scale 1/100.000 and 1/50.000, and this already for Sulitjelma Gruber! In this report there is reported the presence of numerous lavas with pillow structures, but without tectonic interpretation.

More recently, a rough surveying was done in the Talvik-Kåfjord area (Geukens & Moreau 1958). This publication is useless. Another survey was undertaken at Riiddevarne and Klubben close to Burfjord. (Milnes and Ritchie, 1962). This publication is useless too, at least in the Precambrian.

A detailed mapping around Alta has been done, in correlation with the tillites met in other localities in Finnmark (Føyn, 1963).

A general surveying of the window has been done to the scale 1/50.0(in 1965. This work is mainly a photo interpretation and should be considered as such, with too much extrapolation and geological borders following a "reingjerde" .....

On the other hand, apart from published papers, several investigations, more specific and located on small surfaces, and some drillings, have been done at different periods on and around the old mines of Kvaenangen.

The paragenesis of the old mines of Raipas, on the Alta side, have been studied in detail (Vokes, 1956).

The area of the old copper mines of Kåfjord was a diplom subject for two students (Mørk, 1969; Stacke 1970).

The area of Bergmark anticline (Badderen) has been studied in 1970 for Bleikvassli Gruber (we have not seen the report).

We have personnally done the geological mapping to the scale 1/50.000 ofthe E and NE part of the Alta-Kvaenangen window (Alta side), this for Elkem Spigerverket (geological map Alta 1834 I, NGU 1973 Zwaan & Gautier).

In 1972, part of the window was mapped in Kvaenangen for Sulitjelma Gruber (S. Laux). Unfortunately the interpretation and the tectonic conclusion did reveal wrong.

The allochthonous units (Caledonian nappes) have been mapped between Alta and Kvaenangen in 1971, 1972, 1973 by NGU (K. B. Zwaan)

In 1974 a study of Quaternary geology was done for the evaluation of gravel, sand and economically valuable construction material(NGU).

During these last tens of years, a geological mapping of the precambrian window of Komagfjord, between Altafjord and Hammerfest (Reitan 1963), of the Altenes window, on the N- side of Altafjord (NGU, Fareth 1974) has been done.

In 1975 the autochthonous and allochthonous around the window, especially North of it, was done by NGU (Inge Bakke and Zwaan) to complete the 1/250.000 Noreisa mapsheet. During a one-month-work for NGU, we personnally mapped the autochthonous between Badderen-Kjaekan and the Bergmark area. Some soil sampling has been done around Cedar mine by Mr. Grammeltvet .

From 1972 to 1975, Sulitjelma has proceeded with the stream-sediment geochemistry of the window.

We should mention that many old mining reports from the XIX and beginning of the XX centuries might be found in the archives of N.G.U.

1.3. OLD MINING AREA.

The Alta-Kvaenangen window is well-known for its old mines.

On the Kvaenangen side, the old mines are:

Middavarre		EC 460542	
		EC 468536	
Bergmark anticline :	Sedars	EC 472475	
	Kisgangfjellet	EC 457450 (area)	
	Ruk'sesčárro	EC 429472	
		EC 429480	

Apart from these mines, we found some exploration works, trenches, shafts, tunnels ..e.g. in the "canon" between Riiddevarrevatnet and Fjellbukta (EC 352556), on the left side of the stream, or at Randberg, on the shore (area of EC 332595).

The last tentative of evaluation and production of the mineralisation, except the recent and probably last exploration works (see previous work) have been done in Middavarre before World War II.

Sand and gravel are worked out here and there at a small scale for local use.

1.4. SURVEY : WHY AND HOW

1.4.1. Geological motives

The only "general" map - except some local surveyings - of the precambrian window is the geological map of Norway, scale 1/ 1.000.000 (!!!.), which is useless for the problems of regional geology.

Mines were in production at the end of the XIX and at the beginning of the XX century, in Raipas (Alta), Kåfjord, Kvaenangen. Further North, in the Komagfjord tectonic window, there is a new copper mine since a few years (Reppafjord). There is another new mine in Bijjovagge (with an uncertain future due to the actual economic conditions ,.....) on the other side of the Caledonides, in precambrian formations, which are similar - if not the sames- as in the window.

It seems from all these facts that the Precambrian might contain mineralisations.

It was important for this reason to have more detailed tectonic and stratigraphic knowledges and this for two reasons:

- to try to find a "similar" control with the former mines
- to interpret the geochemistry results (stream-sediments method) of sampling done since 1972 up to now, The preliminary results of the geochemistry are not yet known.

The present work was therefore the logical continuation of the work done on the Alta side of the window for Elkem Spigerverket during summer 1971 and 1972 (the latter work being our Ph. D. subject, University of Geneva, and being the main material for the precambrian part of the new geological mapsheet Alta 1834 I, 1/50.000 NGU).

1.4.2. Field work

Summer 1974

Our basis was in the boarding school of Burfjord, from 15.6. to 30.9.1974.

We mapped alone from 15.6. to 8.8. the area West of the vertical coordinate (N-S) line EC 430, including the mountains Hiddevarre, Daumanstind, Rastufjellet, Grönlifjellet.

Starting August 8th, we got the help of an assistant, Mr. John Harrisson, geologist, who - after a short period of introduction in this volcano-sedimentary area - showed himself as a great help and a good friend.

We mapped first, walking from the road, the Badderelva valley, Middavarre (- in collaboration with Mr. Per Bøe, "ammanuensis" from NTH, who was carrying out some personal researches on the mineralisations).

The mapping of the inland has been done with the help of the floatplane (two camps of 5 days each, one at Flintfjellet, EC 500480, one at Holmvatna, EC 621551).

After these two camps, the weather became very bad(cold, rain, stormy wind ...) especially on the high plateaus, preventing an efficient work to be done there. For this reason we started with the mapping of the N-part of Ĉaikavarre (EC 460500), and also Lille Blåfjellet (EC 500525), that we could reach daily from the top of Middavarre (it is possible to drive to the latter top, but not recommended at all for the vehicle). This way of doing was the only one to save time and to map, in spite of the daylight getting shorter every day. Due to the weather it was irrealistic to try to establish a camp in the working area.

The field work ended at the end of September with snow storms.

We think that the end of the field work in this area should be around 15th to 20th September for future work.

Mr. Jan Fr. Holten, Box 75, 9501 Alta, was the pilot of the (A-flight licence) floatplane, and used to take off from Storelvdalen/Alta. Despite the fact that we consider him as a good pilot, we would counsel to fly with professional pilots for field work: he happened to forget appointments.

If a very detailed work has to be done later in the Middavarre area or even as far as Fiskervatnet (EC 490540), or in the Bergmark anticline area (EC 460470), we can agree with and emphasize the proposition of S. Laux in his report about the use of mopeds.

For the two camps we used two small bivuac tunnel tents (one roof), which were just enough, the weather conditions being not too hard during these camps.

Summer 1975

From the 15th of June to the 15th of July we were mapping the authocthonous units between Badderen and Kjaekan, and also the Bergmark anticline area which was claimed by other mining companies. This work was ordered by NGU (cooperation A/S Sulitjelma Gruber - N. G. U.). During this time we had our base at the boarding school of Burfjord.

From the 15th of July we were working for A/S S. G.
We had the chance to get as field assistant Mr. Arfinn Johansen from Øksfjordbotn (geology student in Tromsø, 1st. year). His interest for the mountains around his homeplace , for the geology and also his "local" knowledges (e. g. for the shopping before every camp) were of a great help for our work, which was very difficult this summer due to the weather.

After some working days in Badderen (Uldaidvarre, EC 435445) we moved to Alta, where we could stay in the house of Mr. Dahlen of Norsk Nefelin (to the 27th of August). Later on, we found a room with a friend.

We established the following camps from Alta by floatplane (sea-plane):

22. VII. - 26. VII.	:	Fiskervan (Oag'gujav'ri) EC 656523
30. VII. - 7. VIII.	:	Baddervan (Nikkeluøb'baljav'ri being frozen . .) EC 556422.
14. VIII. - 22. VIII.	:	Lake West of Holmvan EC 575536
5. IX. - 9. IX.	:	Djupvan EC 511464 (cabin with fuel oil stove).

We mapped the area of Sedars Gruve (EC 470480) and the end of the Bergmark anticline, walking from Burfjorddalen and bivouaqing.

The experience teached us that 1 1/2 - 2 days are necessary to prepare a camp, including planning the food, the shopping - especially in Alta where we have to go from one end of the city to the other, to find everything we need - . . . the repairing of the equipment damaged during the previous camp, the preparation of the "mapping strategy" on the air photos, ordering the plane, etc.

The flights were done by Norwing (Alta airport). We had some problem at the beginning due to a new office man. On the other hand the pilots have been very helpful and cooperating.

Camp: each of us had at disposal a 2-men bivouac tunnel tent, with one roof (Fjellteltet tunnel-enkelt, Hell Sport, Trondheim). They reveal to be real "wind channels", the wind blowing through the big ventilation openings.

During the first camp we tried to put the 2 tents in front of each other, with approx. 1 - 1, 2 m between them, and with a plastic sheet as shelder to cook between the two tents. This method should be developped with a proper tent cloth. Our plastic sheet has been teared by a wind blow ....

After this experience, we could use an ordinary mountain tent for two persons, "doppelt". We used only the external tent, whose borders joining the ground were loaded with stones, this as kitchen tent and wind shelter. It was then possible to have a higher temperature inside the shelder with the help of 2 candles and a butane lamp; the cooking was less heroic but it was possible to warm the food.

We had problems with the butan cookers: they were working very badly because of the cold weather.

The use of the kitchen tent improved the cooker's working too.

For a similar work we would advise in the future the use of 3 tents (or 2 tents with a shelder in between), but the tents should be models with 2 roofs, as we were working sometimes nearly in " late winter" conditions.

II Petrography

II. PETROGRAPHY

2.1. UPPER UNITS

2.1.1. ALLOCHTHONOUS (metamorphic caledonian nappes).

Not mapped.

We have to mention here a nappe, which is not present in the type -profile of the Alta area (Alta mapsheet 1834 I). This nappe is made of a quartzitic sandstone, rather dark, but whose weathered surfaces have a grey-beige colour. On one hand the weathered surfaces might look like some light coloured autochthonous quartzites. On the other hand, as fresh sample, this rock looks like some greywacke of the Upper Raipas (see below). In the triangle between Djupvan, Baddervan and Storelvan one can find this nappe as megascopic "coating" on the Upper Raipas Sandstone, with an important quaternary cover on both of them. It might be very difficult, even impossible by dark cloudy weather or with the sun low on the horizon, to distinguish this nappe from the Upper Raipas sandstone.

2.1.2. AUTOCHTHONOUS (late precambrian & eocambrian).

The autochthonous is made mainly of massive quartzite, white to bluish, pinkish, greyish white, sometimes rusty. A basal conglomerate might be observed sometimes. These quartzites are interbedded in places with schistous layers of different colours and sometimes with one or more tillite layers. The autochthonous is mapped by NGU.

These units are important on our mapping as border of our working area.

2.2. BASEMENT (Raipas Group)

This basement is divided into 2 subgroups.

2.2.1. Subgroup of Upper Raipas

2.2.1.1. Dolomite interbedded with sandstone and shales

This formation is similar to the one mapped in Luovusvarri, Stokkstadfjellet (Alta mapsheet 1834 I), coord. 755555.

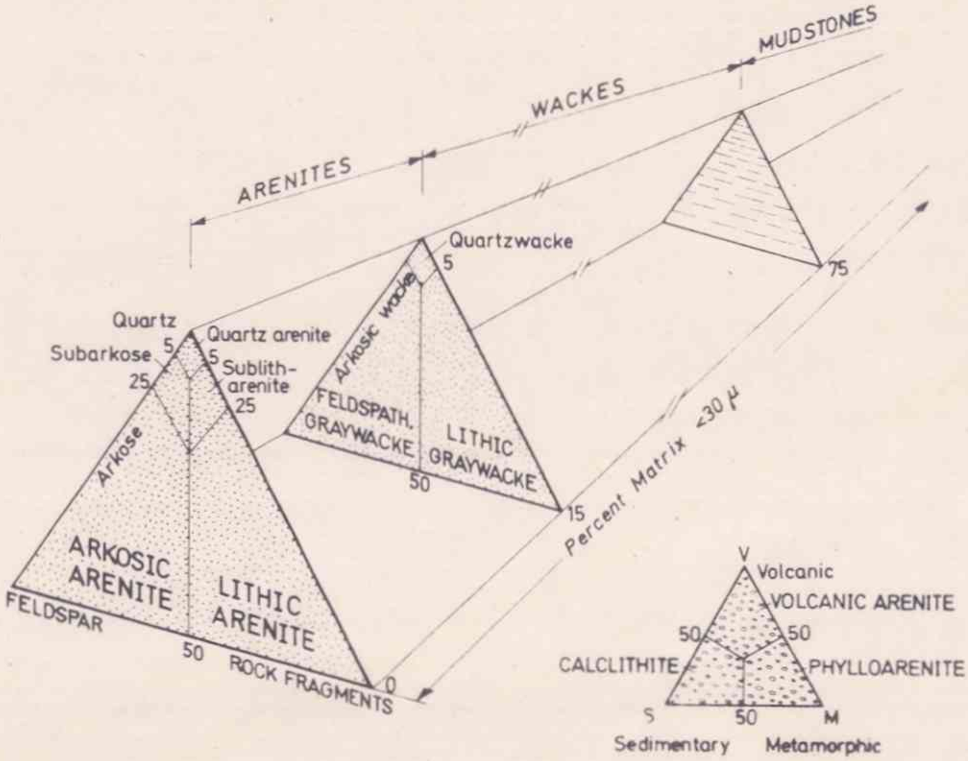
There is an interbedding of dolomite beds and greywacke to greenish schist-wacke. This dolomite has a light colour in fresh section, pinkish, whitish or purple. The weathered colour is light brown. This formation might not be recognized on medium to low slopes, the dolomite forming a negative relief and being covered by moss, lichens, etc. and id seems that there is only greywacke.

Small cliffs or crevices (joints) perpendicular to the strike let discover these dolomite layers.

The main outcrop of this formation is on Midda<u>varri</u> (EC 530490) - do not confuse with Midda<u>varre</u> (EC 470540). There is a thick layer (10 - 20 m) of quartzite at the bottom, forming a wall in the landscape when the dip increases. Over the quartzite, there is a first thick layer of dolomite, very characteristic in the landscape, with a light yellowish brown colour. (We put this basal dolomite layer as an individual layer on the map, and another colour for the whole rest of the formation).

The upper part of this formation contains much less dolomite layers as the lowest part. On another hand, the greywacke is grading to a schistous wacke, light green with sedimentary figures that might be confused with some layers of tuffites of the Lower Raipas (see below).

This formation is probably the top of the subgroup of Upper Raipas, and thus outcrops as middle of the synclines.



Classification of terrigenous sandstones (modified from Dott 1964,fig.3)
Pettijohn,Potter & Siever (1972) (p.158)

Pettijohn,Potter & Siever 1972
Sand and sandstone

Springer Verlag

2.2.1.2. Greywacke (sandstone with some argillaceous layers.)

This sandstone is grey-greenish at the bottom of the formation, getting grey higher up and is finally blue-purple on the top.

It is very homogenous, massive. From thin sections studied on the Alta side it should be classified as lithic greywacke (Pettijohn, etal. 1972). It is possible to observe sedimentary figures such as ripple-marks, cross beddings, etc., with sometimes more argillaceous layers on some meters thickness. In places there are some layers with fossile traces, some of them as concentric structures of 1-2 cm of diameter. According to Mrs. Siedlecka (NGU) there are not stromatolites (personal discussion Aug. 1975).

This sandstone appears as dark-green rocks in the landscape. Very often the surface weathering is masking sedimentary structures, and schistosity. As fresh sections, these structures can hardly be seen - if they can ... The best outcrops are surfaces bleached by snow.

It is difficult and time consuming to look after these sedimentary structures to resolve the detailed structures, as the study of the outcrop is so bad. Such a work in detail is useless in that these sandstones have no economic value.

2.2.2. Subgroup of Lower Raipas

2.2.2.1. Argillite (shales)

This rock is dark grey, sometimes claret and has a little luster, rather schistous. It might grade to a lithic wacke.

In one locality we found a layer of argillite containing a rather important number of "septarian nodules" (cf. dictionary of geological terms, of Dolphin), this e.g. at coord. EC 480520 (West of Blåfjellet).

2.2.2.2. Black schists

Several rock types might be designated as "black schists":

- tuffs, tuffites or even argillites impregnated with black and/or rusted oxydation products (probably oxydation of sulfides). When the original rock type is recognized, it is mapped under its original name.
- often one can observe a black schist zone of some dm. at the contact of different rock types, with greenstones (lavas or sills). We think these are either contact metamorphism phenomenons or zones sheared and oxydised, due to the difference in the rock-competence during the tectonic movements.
- a black and massive rock, schistous, heavy, probably mineralised, with lots of rusted surfaces on it and around the outcrop, e.g. in Kisgangfjellet in the Bergmark anticline (EC 456456). This rock has been designated "graphitic schist" in some earlier works. Up to now and as far as we know no analyse has been done to check if there is C (carbon) or not. For detail work it should be checked of the colour and the weight is not due to iron oxyde.
- finally, a black rocktype too, schistous, sometimes phyllite-looking, sometimes crushed in thin plates. This type of schist seems to us to be very important for the tectonic. In fact we find such rocks as "joints" between volcano-sedimentary monoclinal units, and very often have very irregular forms in cross sections, like wedges e.g., or locating thrust faults. These cross sections etc. might be observed in valleys perpendicular to the tectonic structures. (see chapter "tectonic")

We do not think that this rock type is characteristic of a definite stratigraphic layer. It seems that this is the result of a tectonic "grinding" of several sedimentary or tuffogenic rocks. We sometimes found lime zones grey to black coloured isolated in these black schists.

2.2.2.3. Carbonate rocks (dolomite - limestone)

These rock types are forming mainly negative relief in the landscape due to their high solubility, often filled by quaternary deposits.

Under this heading we mapped different rock types:

- massive dolomite, white on fresh sections, light brown on weathered surfaces, containing often veinlets and nodules of quartz, chert ....
- banded dolomite, slaty, (1/2 to 1 cm for one slate). These two first described dolomites occur often together.
- dolomite made of a whole of spherulitic or pisolitic like elements, of various size, from some mm to the cm. The matrix is of the same composition as the elements. The colour is faintly greenish grey. (e. g. at coord. EC 372538).

West and South of the mountain of Riddevarre there are some scapolite bearing dolomite as cristals of 3-4 mm in cross section and 1-2 cm long. The outcrop West of Riddevarre has been described by Milnes & Richtie, 1962.

The dolomite zone of the Bergmark anticline, some tens of meters W of point of coord. EC 456456 contains very numerous octahedrons of magnetite, some 1/10 of mm in size.

There are also some small dolomitic or lime layers, never thicker than some meters, very irregular (lenses ??) and thus not mappable as such. cf. e. g. "tuffs/tuffites w. dolomite lenses."

2.2.2.4. Basaltic tuffs, tuffites and tuffogenic sediments.

The volcano-sedimentary formations show important variation on short distances. It is not possible for this reason to map in detail and separately the different types of tuffs, tuffites, etc. For the same reason the term includes sometimes rocks more pelitic (tuffogenic sediments), thin lime layer in tuffs/tuffites, and also some green and greenish black schist associated with tuffs/tuffites.

The term tuff, tuffite and tuffogenic sediment is described here according to the work of Blokhina & al., 1959. These authors established a classification for the ancient clastic rocks and might be shortened as follows:

Pyroclastic rocks Tuffs and volcanic breccias	Tuffite	Tuffogenic sedimentary rocks
Uniform composition: tuffs Non uniform composition: agglomerate tuff	Predominantly pyroclastic mat. $> 50\%$ sedim. mat. $< 50\%$	Pyroclastic mat. $< 50\%$ Sedim. mat. $> 50\%$

This formation is showing sometimes good polarity (way up, sedimentary facing) usable for tectonic, such as cross bedding, gradded bedding, or the angle between the stratification and schistosity.

These rocks are forming generally negative relief in the landscape. When the dip is high they have a tendency to outcrop as "schists".

- Banded rock: this rock shows a banding of light green and dark green bands (sometimes even greenish black) on fresh cuts. On bleached surfaces the light green bands are getting whitish and the dark bands light green.

  The thickness of an individual band is of a magnitude of 5 mm, but might reach 2-3 cm. The size of the grain is small up to invisible (aphanitic).

This rock type might show cross bedding and/or gradded bedding, sometimes on a few cm only.

The first appearance of this rock type is similar to glacial "varve".

- Agglomerate tuffs: these tuffs look very brecciated, with elements from some mm to sometimes some cm, these elements being metabasalt or metadiabase.

In places these tuffs/ tuffites are getting more pelitic or sedimentary (greywacke), but it is not possible to fix an accurate limit. We indicate this transition on the map with a special mark (see legend of the map).

2.2.2.5. Basaltic tuff and tuffite with dolomite lenses

We wanted to indicate some small carbonate layers, which are laying within tuffs/tuffites, but their small thickness and their lack of extent being such, that they were not mapable individually at the 1/50.000 scale.

2.2.2.6. "Greenstones": Introduction

Some definitions:

	GB use	USA use
fresh rock with a basaltic composition and ophitic texture	dolerite	diabase
idem, but metamorphised	diabase	metadiabase

We are taking the American use in consideration.

We distinguished 2 main groups of greenstones:

- the coarse grained metadiabases (or "metagabbro" after the use of Canadian field geologists, considering only the appearance of a hand specimen and not the occurrence, as sill, dyke or pluton . . .)
- the medium to fine grained greenstones named "fine grained metadiabases" or "metabasaltes".

  Pillow-lavas belong to this group.

For all these "greenstones", except when the occurrence is very clear (pillow-lava or other typical volcanic feature, or when the intrusive character is certain), there is always a doubt: sill or lava flow?

A sill might intruse in consolidated rocks, or in non-consolidated and still water-saturated sediments; a lava flow (submarine or subaeral) might be massive. The distinction between sill and lava is a problem in many cases. (This is a general problem in ancient volcanic area cf. H. Furnes in the Solund area).

No typical intrusive contact feature has been determinated safely, as the contacts are very often masked by talus, or are strongly weathered. . . .

We shall mention that the sediments close to these lava-flows or sill are very often crushed on the contact; this is due to the competence difference during the tectonic movements.

According to the great lateral extent of most of the greenstone levels and their regularity, we do presume that they are massive lava flows, and probably submarine, without pillow-lava formation.

In the field, these rocks are brownish russet on weathered surfaces, dark green to light on some polished or bleached surfaces. The weathered crust (surface) and the lichens (and moss in some cases) might mask completely the surface look of the rock, so far that it happens to go over a rock boundary without noticing it.

2.2.2.6.1. Coarse grained greenstone ("metagabbro")

They are characterized by a meta-pphitic to meta-intersertal texture. How a sample looks like might differ, depending on the degree of ouralitisation, saussuritisation...

Generally one can observe on some weathered surfaces the net of albite microlites due to a differential etching for every mineral type.

2.2.2.6.2. Coarse grained greenstone with basaltic tuffs/tuffites etc. layers

This symbol on the map has been used to indicate coarse grained greenstone layers (or sills) separated by tuffs, tuffites or tuffogenic layers, which were too small to be put on the map 1/50.000, but characteristic on air photos and easy to follow in the field.

2.2.2.6.3. Metabasalt (except pillow-lava)

These are fine to medium grained metadiabases, some showing (with a lens) a fine meta-ophitic to meta-intersertal texture.

Except in the case of compact lava flow or sill (cf. 2.2.2.6), we found some characteristic volcanic features:

- pipe vesicles : when a lava stream flows over a wet substratum (subaerial or low depth submarine volcanism) the formed stream rises into the lava flow, with a considerable force, forming "pipes". Two adjacent channels might meet each other, forming an inverted "Y". This is assumed to be a "facing" figure (Shrock, Mc Donald). The Middavarre and surrounding area up to Daumanstind area exhibit very good outcrops with this feature (EC 471539, EC 413513), On the top of Middavarre (point "f" on the sketch of Middavarre, see below) there is a lava surface "filled" with holes, their average ∅ being between 2-5 mm. In places some holes attain 1 cm ∅ . In vertical sections to this lava surface, one observes the pipe vesicles along their length; some of them have been refilled by several secondary minerals. Others remain empty, as hand samples resemble a coarse screen made of lava.

- columnar basalt

Mainly in Middavarre, and also in a few other localities surfaces with polygonal nets with a " diameter" of 10 - 30 cm might be observed. They reveal themselves to be lava flow with columnar jointing. The trenches of the old mines in Middavarre let see these columns in a 3-dimensional view. The texture of the lava is fine to medium grained. Up to now, this mountain was regarded by economic geologists as a gabbro pluton, according to the appearance of a hand specimen, this gabbro explaining the presence of the mineralisation .....

There, there are in fact basaltic lava flows with columnar jointing in sandwich between tuffs, tuffites and pillow-lavas.

In Blåfjellet (EC 500530 - 490490) one can observe onion-like weathering of the columns, forming curved slices up to 10 cm thick, perpendicular to the axis of the column. (These slices should not be confused with the " cup and saucer" jointing also present in the columns of some localities.)

It should be notices that all these described volcanic features, and also the pillow-lava (cf. next paragraph are absolutely sure, and are very fresh-looking, as good as they might be observed in modern volcanic area, such as Island or Italy e. g.

We can also mention that we observed in places the bottom of lava flow, seen from below. They had the typical "pahoehoe" look.

2.2.2.6.4. Metabasalt with pillow -lava structure

It is now recognized that pillow lavas have been formed beneath water or at least in swampy and water-saturated grounds. Much research, some very recent, has contributed to understanding their mode of formation.

The criteria for the identification of pillow-lavas and their distinction from pahoehoe are quite well defined. (Vuagnat 1946, Rittmann 1958, Vuagnat & Pustaszeri 1965, Moore et al. 1971, Mc Donald 1972 ....)

The pillow-lavas are very common in the Lower Raipas sub-group. They also have a very important extent: many layers might be followed from one to the other side of the window (about 10 km, N-S, perhaps even more). Due to the partly isoclinal folding and complicated tectonic along a E-W profile, it is not possible to guess their extent along the folding direction. They are generally occurring as complex flow: only the bottom or the top of a lava stream has such a structure; the rest of the stream consisting of massive lava; or a pillow-lava layer occurs between lava layers (with or without pillows) with a tuff/tuffite in-between.

This formation is one of the most important of the area: it gives good polarity criterons and this on long distance, and in all the parts of the mapped area (not like the sedimentary structures such as cross bedding etc. that might be seen well only in rare localities and on short distances). For this reason, they are important to resolve the tectonic and the field geologist should not be afraid to spend lot of time on these outcrops to find a proper section in the lava stream for way up determination.

Due to the surface weathering of the rock the pillow-lava structure might not appear at the first look. In the window the presence of pillow-lavas should be suspected every time a fresh cut of a rock shows a light green colour and a very fine grain. But it is not possible to describe more: the recognition of this rock type is a matter of personal experience and should be practiced in the field from well-known and described outcrops.

The pillow-lavas are generally well jointed and separated from each other by what is the glassy crust, of about 1-2 cm thickness. Sometimes, in the interstice between two pillows, calcite or chert is found. The dimension of the cross section ranges from about 15 cm in diameter (once we found one with 5 cm ∅) to 1,5 - 0,7 m, but most of them are between 20 to 50-70 cm.

Pillows in the window are showing no tectonic deformation except in one zone in Store Riiddevarre.

Three dimensional, the pillows appear as elongated sausages, the cross section of which changes very quickly, from a circular to a flattened form, and with all the "classical" sections such as "beau", " balloon", with one or several stems.

Lengthwise, these "sausages" can be tortuous, showing sometimes a "bulbous growth". Sometimes they fork into two parts, thus showing the direction of the stream (Vuagnat & Pustaszeri, 1965). It is even possible to find pillow-lavas whose crust has been perced (probably due to internal lava pressure) and from which new pillows have been formed.

The formation of pillow-lavas from an active lava flow has been filmed in close-up under water by Moore in Hawaii during these last few years, and this mode of pillow birth is observed and lasts a few seconds only.

The internal structure of the pillow-lava of the window is the following from the outside to the middle, on a cut and polished surface:

A dark crust (meta-hyaloclastic matrix) is followed by a thin and lighter (in colour) variolitic zone. The varioles are some tens of mm in diameter. Further, there is a zone (or rim) of amygdules and they appear as dark blue to black dots. This zone is about 1 cm. from the pillow border and is about 1 cm thick too. (This zone is characteristic for all the pillows of the window, except for one layer, where, instead of the amygdules zone, the 2-3 first cm. are filled with very small amygdules, more numerous and much less visible).

There are sometimes some disseminated amygdules in the pillow too. From the amygdules rim to the center of the pillow, the green pillow matrix is speckled by chloritization. These speckles are in irregular zones, but more or less disappearing in the pillow center. It is already possible to observe a very fine intersertal texture, sometimes intersertal divergent, this with a single lens. It should be noticed that metamorphic transformations such as albitisation, chloritisation, saussuritisation, have the tendency to mask the original texture.

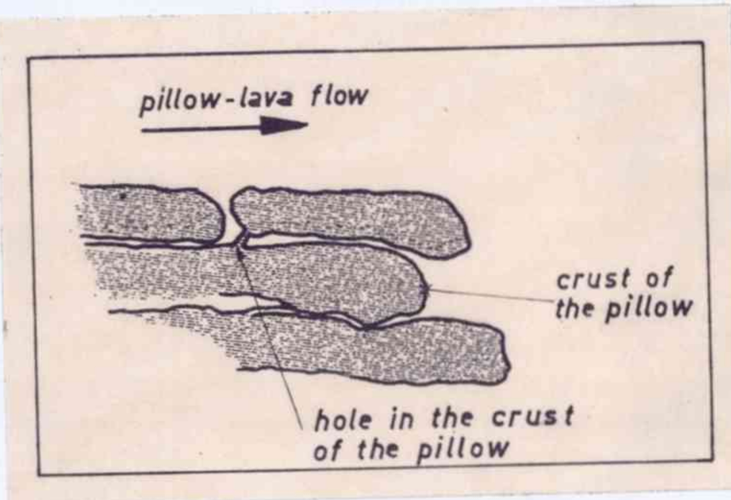
The weathered surface (outcrop) of the pillow-lava is greyish brown to russet, whilst the bleached sections of pillows (due to the snow) are light green. In the latter case, the amygdules and the "glassy" crust appear whitish and have a positive relief on the surface. It happens too that the vacuoles only are to be found, when the filling(mainly chlorite) of the amygdules has disappeared.

Some pillow breccias occur, associated with the pillow-lavas. The pillow fragments are about 1 dm wide, in a fine metahyaloclastic matrix. Bedding and sorting are completely lacking. The pillow fragments are easily recognized by their crust and their amygdule zone (pillow border). This kind of breccia is called " broken pillow breccia" by Carlisle 1963.

We consider that these pillow-lava streams (or flows) are the most important elements for the understanding of the tectonic and stratigraphy of the precambrian window. Further, we present a map of Middavarre for an excursion for the geologist who wants an introduction in these volcanic features.

2.2.2.6.5. Fine to medium grained metadiabase with interbedded tuff layers.

As in 2.2.2.6.2. this symbol has been used to mark some levels of tuffs/ tuffites that cannot be mapped individually due to their small size, but characteristic on air photo and easy to follow in the field, and whose direction (position) is useful to show the structural features.

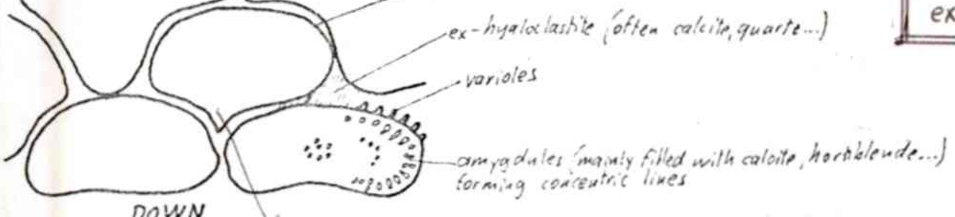


It is possible to observe the mode of formatiom of a pillow-lava along the river Gammeelva : the crust of the pillow has been pierced (probably due to the internal lava pressure) and a new pillow has been formed from this hole.It is an evidence that pillows are primarily interconnected and are not isolated bags (=pillows...).
Cf. recents papers about submarine volcanism and the film of Tepley & Moore.

NOTICE ABOUT PILLOW-LAVA

We called pillow-lava only rocks showing clearly some characteristic elements of the pillow-structure

Field report 1971
for Christiania Spigerverk
(Alta area)
extract ...



Every time it was possible, we used the pillow to determine the position of the serie (normal or up-side down)

Generally the pillows formations have a reddish brown weathering color (when looking all the mountain). Fresh sections might be dark green, even without visible structure !

2.2.2.6.6. Metadiabase "interbedded"(?) with marble "layers".

We found in a single locality, as elongated hillock (EC 355610 - EC 373602) a medium/ coarse grained metadiabase alternating with coarse grained carbonate (marble). The melanocrate minerals (dark) are elongated along the structural direction. On cross sections, one recognize a blasto-ophitic structure, with lots of veinlets and epidote zones.

The marble occurs as bands of 30 - 50 cm thickness (sometimes 10 cm only) with a "layer" every 2 to 10 meters. As for all the carbonate layers, these are difficult to localize on smooth slopes. They are easy to be seen on vertical joint surfaces perpendicular to the structure. The dip is about 40° to the NE and is getting steeper to the South (to 60 - 70°), where the frequency of the marble is increasing (one zone every 2 m). When observing the marble zone on the cliff surface, it seems that there is some "boudinnage". The metadiabase seems to have been deformed, elongated (tectonically); this is well observed along the foot of the cliff.

There is a little problem with this outcrop: does it belong to Lower Raipas or already to the autochthonous (this latter containing tectonized greenstone lenses in the Kvaenangen area)?.

The position of this outcrop along the border of the window and the fact that this rocktype occurs nowhere else didn't give us the opportunity to resolve this problem.

2.2.2.7 Ultrabasic

We found outcrops of a meta ultrabasite, probably a partly seppentinised, tectonised and metamorphised lherzolite in a " tectonic zone" as a geological "scar", in a single zone, following Blåfjellet to the W, emerging out of quaternary deposits. (EC 487531)

The weathered surface of this rock is orange-rusty coloured, with lots of serpentine veinlets running in all directions.

On fresh cut this very light grey-greenish rock seems to be monomineral, made of tabular cristals of approx. 2 mm size. In fact we can observe serpentinised pyroxenes and (?) olivine in thin section (see ch. 3).

This rock is the only ultrabasic met in the window, from Kvaenangen to Alta.

The closest outcrops around this ultrabasic body are black schists. Our hypothesis about the role of these schists seems to be confirmed.

This ultrabasic body disappears to the South, in the direction of the Flintvan.

II T

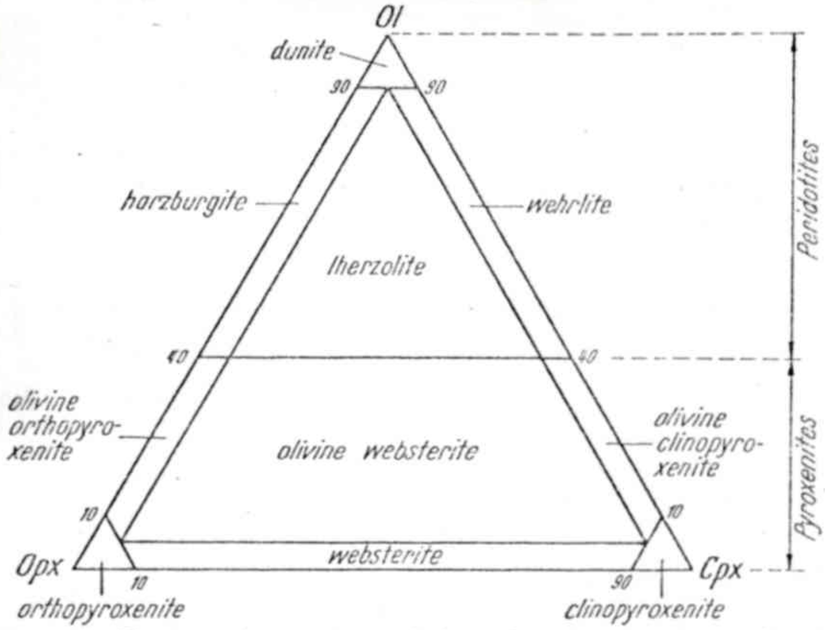


Fig. 2. Classification and nomenclature of ultramafic rocks. Ol + Opx + Cpx + Hbl (+ Bi + Gar + Sp) ⩾ 95; Opaque minerals ⩽ 5.

Fig. 2a. Ultramafic rocks composed of olivine, orthopyroxene, and clinopyroxene.

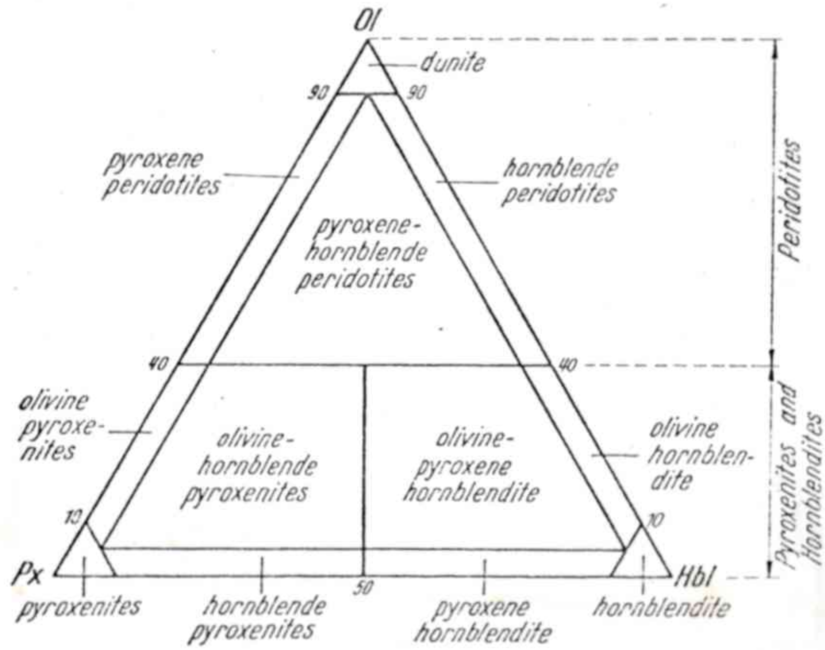


Fig. 2b. Ultramafic rocks that contain hornblende.

from IUGS Subcomission on the Systematic of Igneous Rocks
Classification and Nomenclature of Plutonic Rocks, Recommendations p155

Classification of Ultrabasic rocks (cf 2.2.2.7)

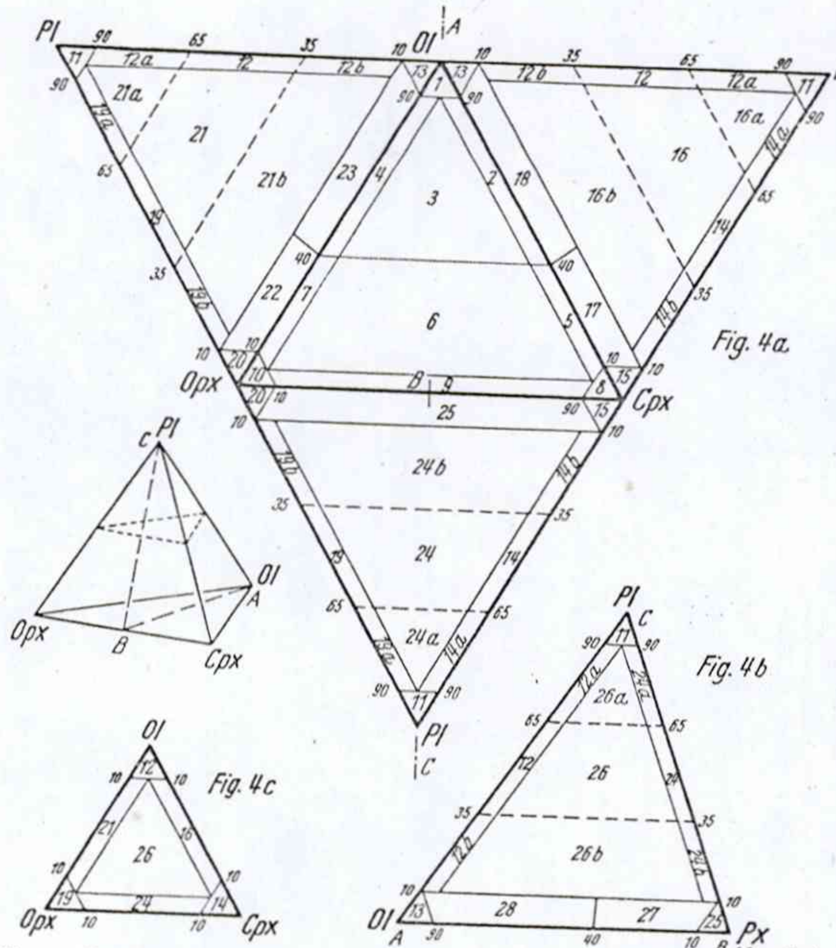


Fig. 4. Classification and nomenclature of gabbroic and ultramafic rocks in the tetrahedron plagioclase — orthopyroxene — clinopyroxene — olivine.
a) Faces of the tetrahedron.
b) Section of the tetrahedron along the line A—B—C.
c) Section of the tetrahedron parallel to the basis ol-opx-cpx at 50 percent plagioclase content (representative for plagioclase contents of 10—90 percent).

Charnockitic Rocks

The Subcommission has not yet agreed on a scheme for the classification of charnockitic rocks, so recommendations for these rocks are deferred to a later time. The charnockitic rock suite consists mainly of hypersthene-bearing rocks of the QAP triangle.

Color Index

The Subcommission suggests using the *prefixes mela-* and *leuco-* to designate the more felsic and mafic types of each rock group, in comparison with normal types. Fig. 6 shows tentatively the leuco- and mela-types of each rock group. The prefixes leuco- and mela- precede the root name: e.g., biotite leucogranite, hornblende-biotite melagranodiorite, biotite leuco-quartz diorite, mela-olivine gabbro, mela-nepheline diorite, nepheline-bearing melasyenite, etc.

As muscovite, apatite, primary carbonates, etc. are considered commonly as felsic minerals, color index M′ is defined as follows:

$$M' = M - (\text{muscovite, apatite, primary carbonates, etc.}).$$

Rocks may also be grouped according to color index into *leucocratic* (M′ = 0—35), *mesocratic* (M′ = 35—65), *melanocratic* (M′ = 65—90), and *ultramafic* rocks (M′ = 90—100).

Explantation to Fig. 4 (p. 158).
1 dunite (olivinite)
2 wehrlite
3 lherzolite
4 harzburgite
5 olivine clinopyroxenite
6 olivine websterite
7 olivine orthopyroxenite
8 clinopyroxenite (diopsidite, diallagite)
9 websterite
10 orthopyroxenite (enstatitite, bronzitite, hypersthenite)
11 anorthosite (plagioclasite)
12 troctolite (a = leuco-, b = mela-)
13 plagioclase-bearing dunite
14 gabbro (a = leuco-, b = mela-)
15 plagioclase-bearing clinopyroxenite
16 olivine gabbro (a = leuco-, b = mela-)
17 plagioclase-bearing olivine clinopyroxenite
18 plagioclase-bearing wehrlite
19 norite (a = leuco-, b = mela-)
20 plagioclase-bearing orthopyroxenite
21 olivine norite (a = leuco-, b = mela-)
22 plagioclase-bearing olivine orthopyroxenite
23 plagioclase-bearing harzburgite
24 gabbronorite (a = leuco-, b = mela-)
25 plagioclase-bearing websterite
26 olivine gabbronorite (a = leuco-, b = mela-)
27 plagioclase-bearing olivine websterite
28 plagioclase-bearing lherzolite

Classification of Ultrabasic and Basic rocks [II u

III Metamorphism
Geochemistry
Geochronometry

III. METAMORPHISM, GEOCHEMISTRY and GEOCHRONOMETRY

3.1. Metamorphism (from thestudy of thin sections)

3.1.1. Introduction

Most of our (meta-) diabases have a primary ophitic or intersertal texture. The recrystallisation during the metamorphism did not affect the same way all the rocks. Some of them still exhibit rather fresh primary textures (blasto-ophitic or blasto- intersertal), some others recrystallised textures (grano-nematoblastic).

The effects of the metamorphism are as follows:

- The plagioclase have been transformed in albite;
- The augite are partly or completely ouralitised (actinolite).
- Actinolite crystals did grow in all directions and everywhere, and also epidote

  Some zones in actinote have darker outlines and cleavage border. This is due to the formation of hornblende, showing variation increasing of the metamorphism, to the upper part of the greenschists facies; this is confirmed by the apparition of biotite.

3.1.2. Usual parageneses and metamorphism grade

Some parageneses found in the basic sequence are :

- albite/ augite/ ouralite/hornblende/ leucoxène/biotite/carbonate
- albite/ chlorite/ epidote/ quartz
- albite/Ti-augite/ ouralite/ chlorite/ epidote/ leucoxène/apatite
- albite/ augite/ chlorite/ actinolite/ leucoxène.

In some cases the leucoxène (from ilmenite) is disseminated in very small grain and in such a way that the optical determination of the thin section is getting impossible.

In the pelitic sequence (also in the tuffs/tuffites etc.) there are some neocrystallisations of idiomorph crystals of tourmalin, interpenetrating the neighbour minerals. (Schorlite).

All these parageneses indicate that the rocks of the window belong to the greenschist facies, and that there is a little variation in the metamorphism to the highest part of the facies.

3.2. CHEMISTRY (main oxydes)

3.2.1. Introduction

It has been established from the microscopical study of thin sections that the meta-volcanites of the window are roughly metabasaltics (- metagabbroic).

This fact is confirmed by chemical analyses. We plottet the results of analyses from the N-NE side (Alta-side) of the window (number 1 - 11, marked on the diagrams with circles) with the results from the Kvaenangen side of the window, to show a full view of the window's chemistry. The results W of Oag'gujav'ri have the number 12-22 and are marked with full squares on the diagrams.

The results are monotonous. On the Alta side there is a tendency to spilitisation.

The analyses have been made on:

- pillow-lavas (border and center)
- fine grained metadiabase
- coarse grained metadiabases
- tuffs/ tuffites

3.2.2. Data from the rocks on the Kvaenangen side of the Alta-Kvaenangen window .

GEOCHEMICAL ANALYSES (X-Ray fluorescence)
****

DEPARTMENT OF PETROLOGY, U.G.

DONNEES NORDIQUES

Diagram number	SPECIMEN (Locality)	SIO2	TIO2	AL2O3	FE2O3	FEO	MNO	MGO	CAO	NA2O	K2O	P2O5	H2O-	H2O+	CO2	SUM OX.
12	1128	49.11	0.95	13.39	3.13	11.39	0.29	6.02	8.92	2.77	0.40	0.18	0.00	2.43	0.23	99.21
13	1265	46.60	1.47	14.18	3.42	11.51	0.22	6.84	8.24	3.80	0.37	0.19	0.00	3.63	0.19	100.66
14	1333	47.11	1.40	13.66	3.79	11.66	0.28	6.43	10.35	2.26	0.10	0.16	0.00	2.15	0.29	99.64
15	1365	45.69	1.15	13.75	4.54	9.22	0.18	5.03	11.34	2.52	0.13	0.15	0.00	3.54	2.97	100.21
16	1175	49.06	1.33	12.39	3.51	11.36	0.20	6.42	8.90	2.76	0.64	0.19	0.00	2.64	0.16	99.56
17	1180	47.33	1.05	12.43	2.50	7.95	0.22	13.19	13.37	0.16	0.10	0.16	0.00	1.62	0.46	100.54
18	1289	49.14	1.08	14.04	3.30	9.77	0.22	6.82	10.11	2.13	0.11	0.13	0.00	2.60	0.10	99.55
19	B1183	48.92	0.96	11.96	2.55	9.97	0.19	9.82	9.32	2.23	0.01	0.14	0.00	3.25	0.39	99.71
20	C1183	49.48	0.95	11.94	2.40	9.81	0.19	9.61	8.50	2.72	0.01	0.15	0.00	3.25	0.51	99.52
21	B1185	45.93	1.03	14.19	2.92	10.64	0.25	9.81	8.89	1.60	0.06	0.17	0.00	3.83	0.21	99.54
22	C1185	46.79	0.97	12.51	3.08	11.00	0.28	10.63	9.23	0.90	0.03	0.17	0.00	3.57	0.21	99.37

No sample	Coordinates	Rock type	Texture	Minerals
12	EC 401542	diabase	ophitic (coarse)	albite+actinolite+hornblende+biotite+augite(ouralit.)+chlorite+leucoxene
13	EC 435550	lava	opacity (leucox)	epidote+chlorite+leucoxene+ ???
14	EC 342552	diabase	nematoblastic & tectonised	actinolite+hornblende+epidote+albite ;the crystals are bent
15	EC 464533	tuff/ tuffite	banded	epidote+leucoxene+biotite+actinolite+tourmaline+calcite+plagio(no further determ.possible)
16	EC 409581	diabase	intersertal (meta-)	albite+epidote+ouralite(actin)+hornblende+leucoxene±biotite
17	EC 461540	lava (columnar)	ophitic-like but the net is not made of feldspars	albite+epidote+actinolite+leucoxene
18	EC 334602	diabase	ophitic (coarse)	albite(w.inclusions)+actinolite+hornblende+epidote+chlorite+leucoxene
19	EC 462531	pillow [illegible] (border)	variolitic &meta-intersertal	actinolite+epidote+chlorite+albite+leucoxene+quartz±biotite
20	"	pillow (center)	blasto-intersertal	actinolite+epidote+chlorite+albite+leucoxene+quartz±biotite
21	EC 342541	pillow (border)	variolitic &meta-intersertal	actinolite+epidote+chlorite+albite+leucoxene+quartz±biotite
22	"	pillow (center)	blastointersertal	actinolite+epidote+chlorite+albite+leucoxene+quartz±biotite
ultrabasic (no analyse)	EC 485530	ultrabasic	serpentinised &completely tectonised	tremolite+clinochlore+antigorite+phantom of olivin in tremolite phantom of pyroxen (pseudomorphosed in amphibol)+leucoxene+opaques lines showing old crystals borders

III

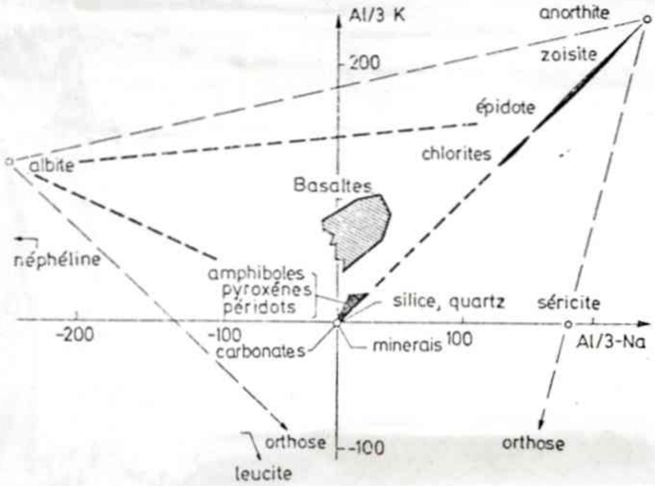


Fig. 2. Diagramme Al, Na, K. Domaine des basaltes et champ des associations spilitiques

from: "Spilites and Spilitic Rocks" p. 44

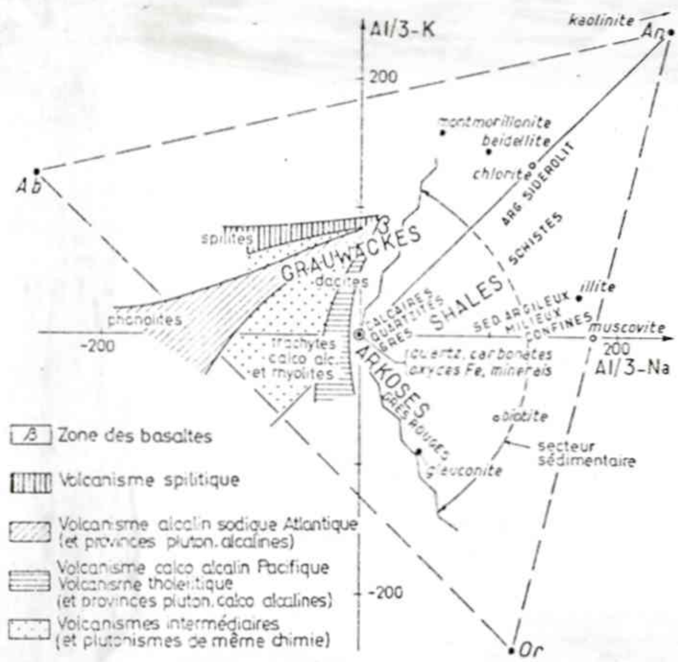


Fig. 1. Diagramme Al, Na, K. Disposition générale des associations volcaniques. Leur opposition par rapport aux associations sédimentaires. D'après H. de la ROCHE (1968)

from: "Spilites and Spilitic Rocks" p. 40

Explanation of the diagram (cf. 3.2.3.1)

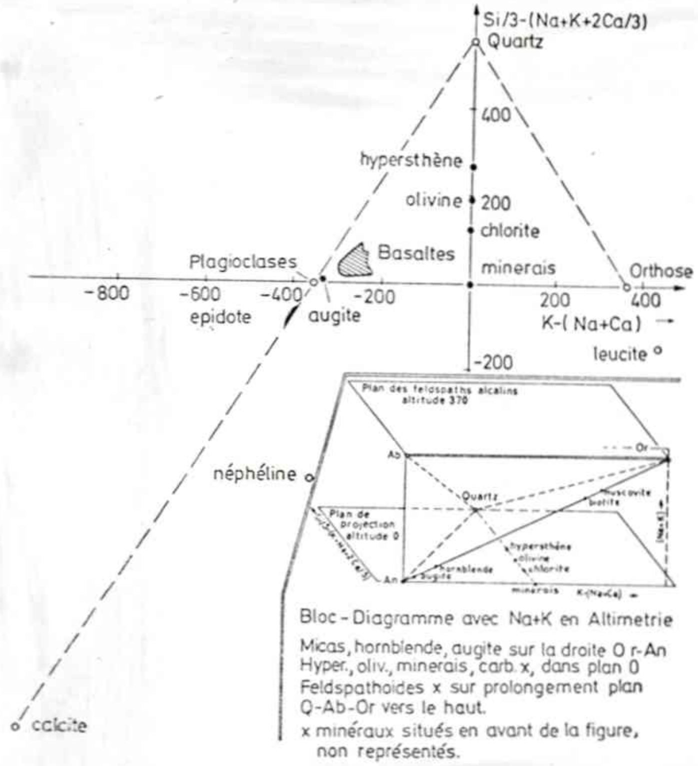


Fig. 7. Diagramme Si, K, Na, Ca. Domaine des basaltes et champ des associations spilitiques

from:
"Spilites and Spilitic Rocks" p. 48

Explanation of the diagram (cf 3.2.3.1)

3.2.3. Diagrams

3.2.3.1. Diagram $\left(\frac{Al}{3} - K\right) = f\left(\frac{Al}{3} - Na\right)$ and

$$\frac{Si}{3} - \left(Na + K + \frac{2}{3} Ca\right) = f\left(K - (Na + Ca)\right)$$

These diagrams, established by H. de la Roche, G. Rocci and Th. Juteau 1974, allow to put in evidence and to show the specific character of basalts and spilites, better than the classical diagrams, such as Harkey, Niggli, Peacock, Jung, Kuno, Murata .....

The parameters have been calculated with the number of milliatomgram in 100 grams.

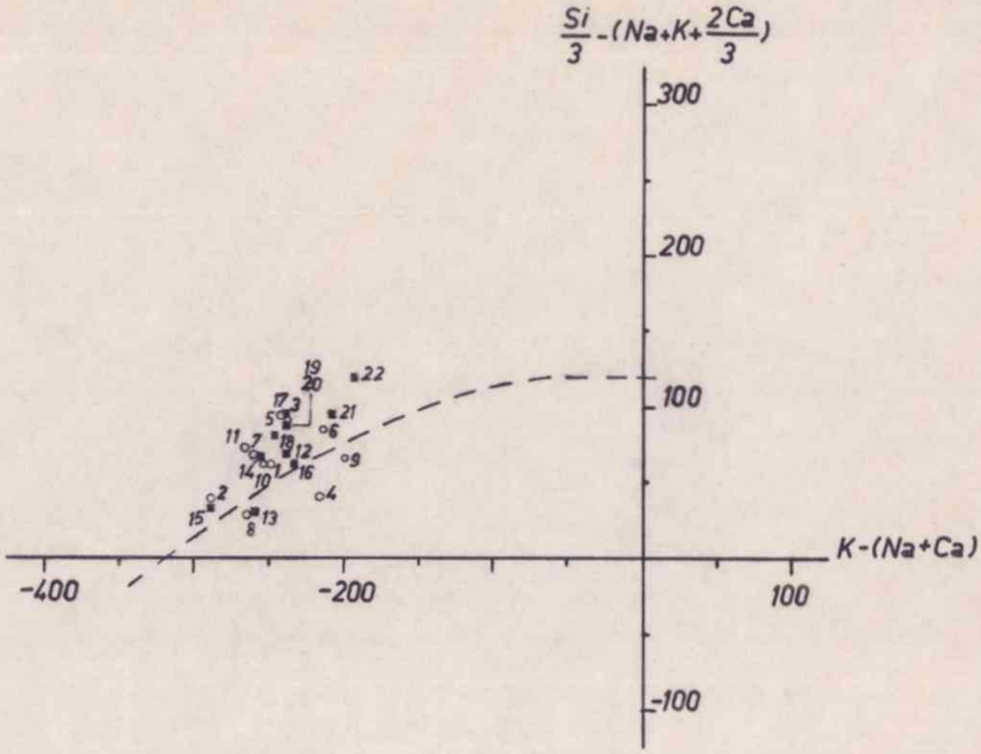
3.2.3.1.1. Diagram $\left(\frac{Al}{3} - K\right) = f\left(\frac{Al}{3} - Na\right)$

This diagram shows the differential " behavour" of the alcalis compared to alumina; it is possible to distinguish the "sedimentary" weathering" ("dégradation sédimentaire") from the igneous differenciation ("différenciation ignée").

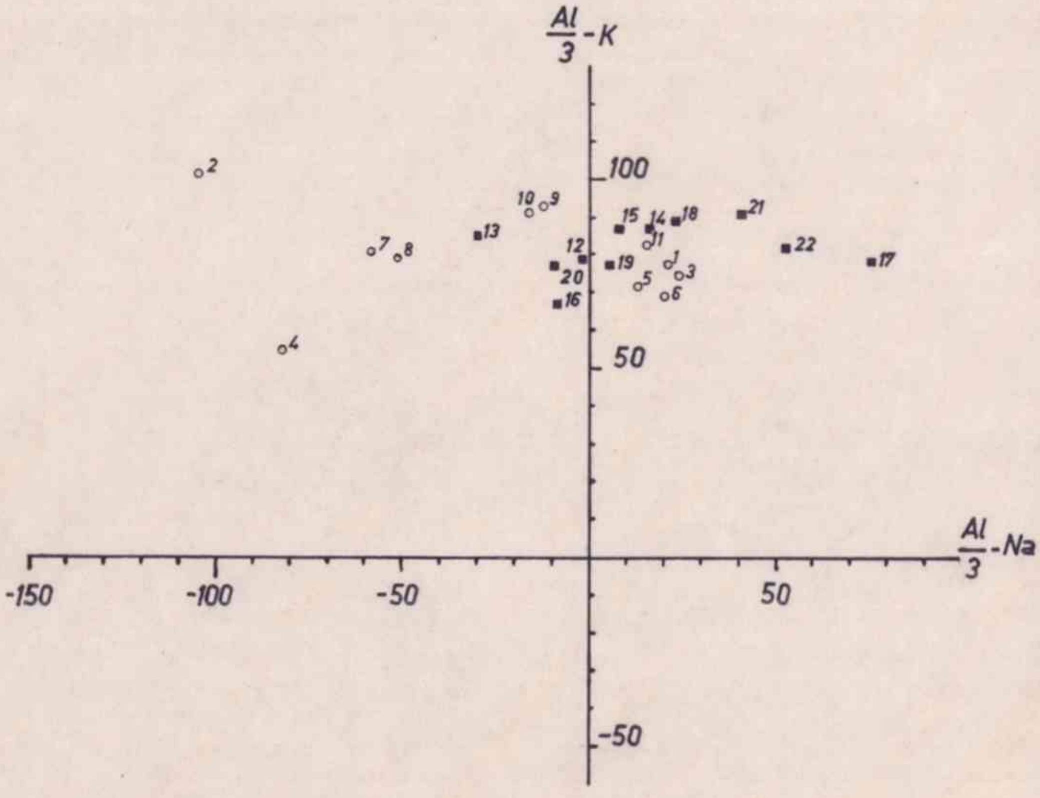
In fact, part of the rocks of the window are in the basalt field, the other one being in the spilitic field.

3.2.3.1.2. Diagram $\frac{Si}{3} - \left(Na + K + \frac{2}{3} \cdot Ca\right) = f\left(K - (Na + Ca)\right)$

The interesting fact with this diagram is that the vector showing the transition anorthite → albite is projected on the diagram as a very short line, that might be assimilated as a spot. This latter fact allows to avoid mistakes, in the case of modal analysis e. g., due to a too high albite content in spite that the basic grade of the rock did not change in the case of spilitisation and metamorphism



$\frac{Si}{3} - (Na + K + \frac{2Ca}{3})$
300
200
100
-100
K-(Na+Ca)
-400
-200
100



$\frac{Al}{3} - K$
100
50
-50
$\frac{Al}{3} - Na$
-150
-100
-50
50

One observes that the rocks of the window are grouped together, showing no tendency of differentiation along one of the classical igneous serie.

The dotted line on the diagram indicates the limit between tholeiitic (above) and alcaline (under) series.

The tholeiitic character of the window appears clearly.

3.2.3.2. Diagram FMA (total iron oxyde, MgO, total alkalies). This diagram shows the " monotony" of the rocks of the window, and the very tholeiitic composition of the columnar basalt of Middavarre (no. 17).

3.2.3.3. Diagram $CaO / Na_2O / MgO$

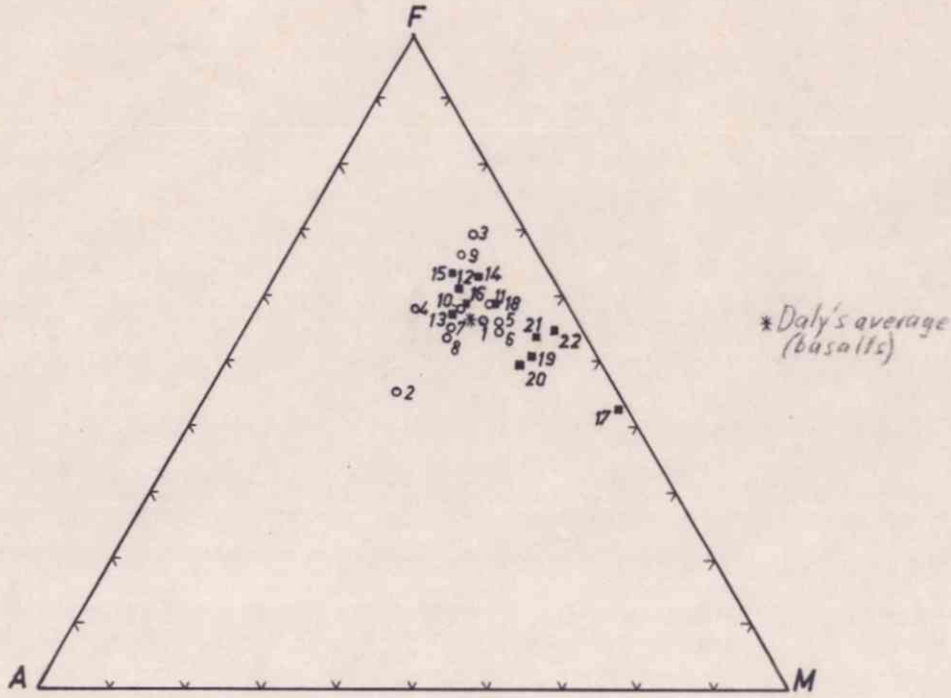
This diagram shows the decreasing CaO to the benefit of Na_2O in the spilites. The rocks of Kvaenangen are in the tholeiitic area.

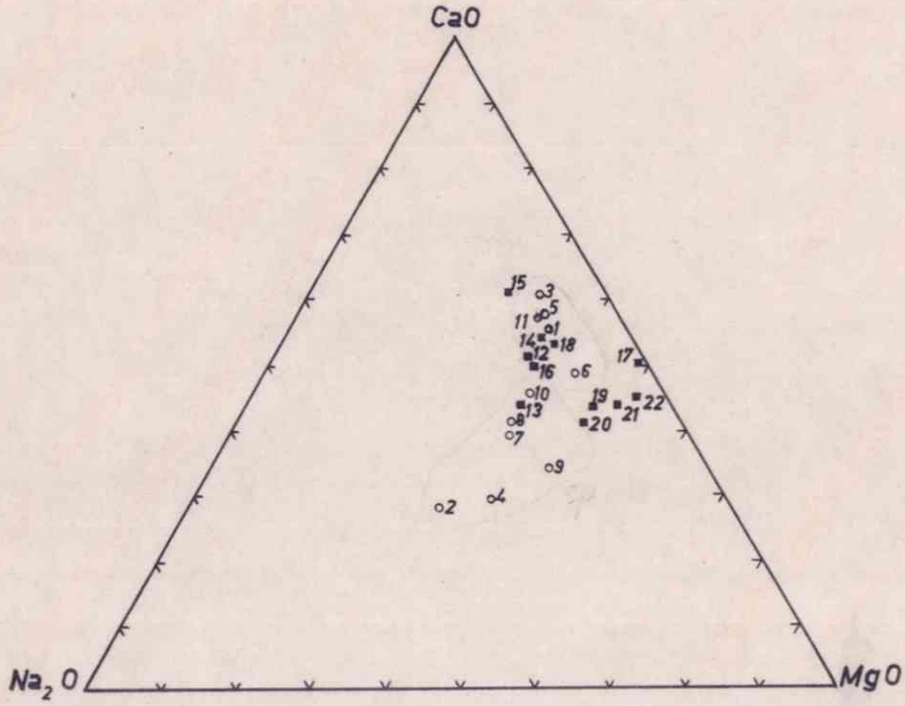
3.2.3.4. Diagram $CaO / Na_2O / K_2O$

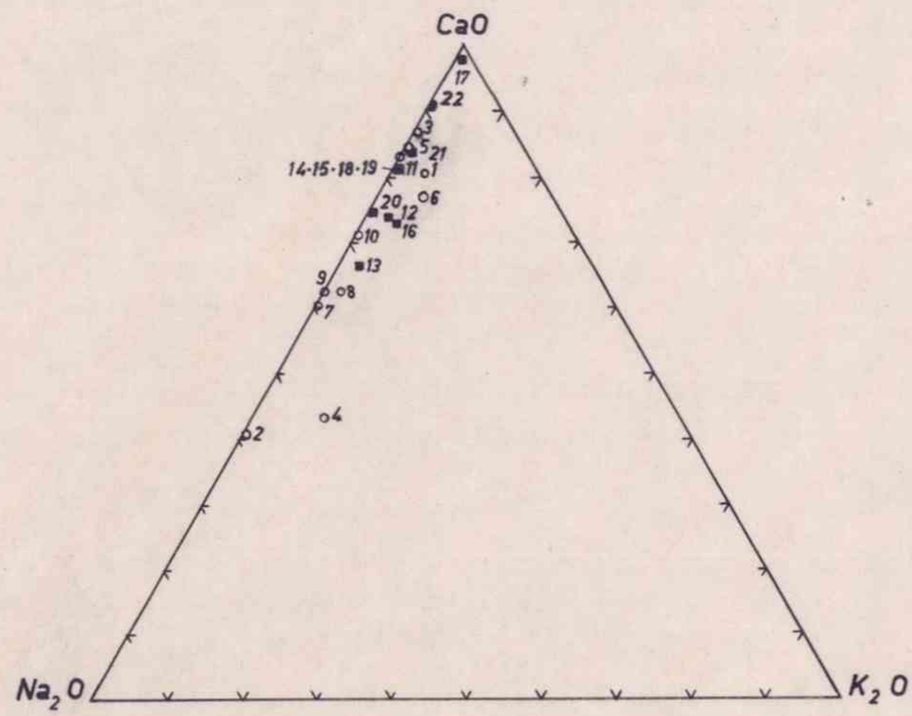
This diagram shows the very low content in K_2O.

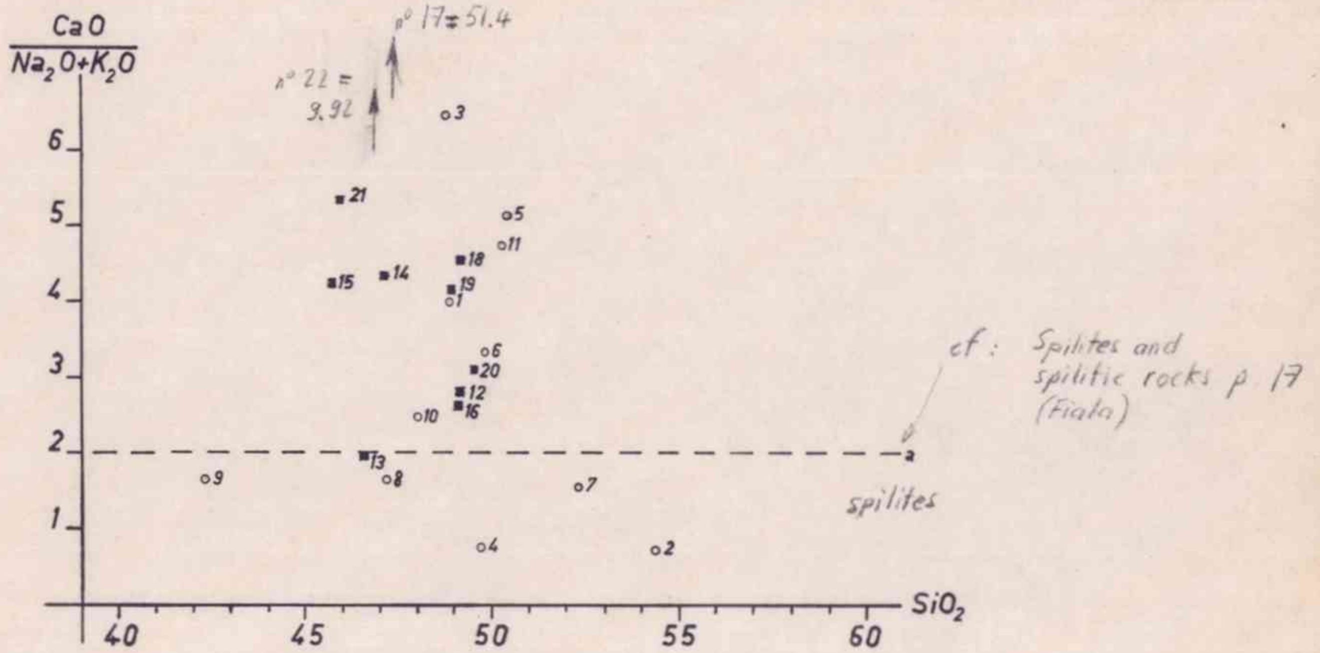
3.2.3.5. Diagram $\frac{CaO}{Na_2O + K_2O} = f(SiO_2)$

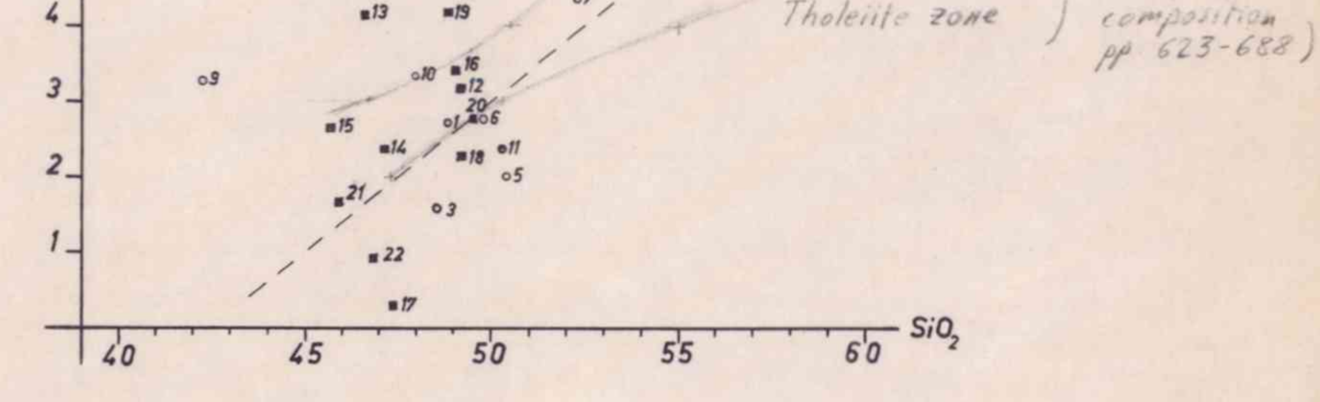
It is possible to put a limit in this diagram for the spilites. Fiala 1974 (in "Spilitic rocks") proposes $CaO / Na_2O + K_2O < 2$ for spilites.


F
A
M
3
9
15
12
14
10
16
11
18
4
13
7
1
5
6
21
22
8
19
20
2
17
* Daly's average
(basalts)


CaO
Na₂O
MgO
15
3
5
11
1
14
18
12
16
17
6
10
19
22
13
21
8
20
7
9
4
2


CaO
17
22
3
5
21
14-15-18-19
11
1
6
20
12
16
10
13
9
8
7
4
2
Na₂O
K₂O


CaO / Na2O+K2O
n° 17 = 51.4
n° 22 = 3.92
cf: Spilites and spilitic rocks p. 17 (Fiala)
spilites
SiO2
40
45
50
55
60


Na2O+K2O
Alkali-olivine basalt zone
High alumina basalt zone
Tholeiite zone
Kuno 1968
(Poldervaart treatise on rocks of basaltic composition pp 623-688)
SiO2
40
45
50
55
60

3.2.3.6. Diagram Alkali - Silica: $(Na_2O + K_2O) = f(SiO_2)$

This is the general diagram for basaltic rocks (Kuno 1968 in Poldervaart Treatise of Basalts pp. 623, 688 ...). The straight non continuous line is the limit, according to Fiala, Sukkeswala 1974 (Spilites and spilitic rocks) between alkali basalt (above) and tholeiite (under). But, as mentioned before (cf. 3.2.3.1 and 3.2.3.1.2) the interpretation of this diagram is not as good as the diagram of de la Roche, Rocci and Juteau.

3.2.4. Chemical conclusions

The conclusion of all these diagrams is:

- the rocks on the Kvaenangen side of the window are basaltic
- they have a clear tholeiitic character.

3.3. GEOCHRONOMETRY

We started within our personal researches a study of geochronometry (K/Ar method) with the Department of mineralogy, University of Geneva. The first series of samples was from the Alta side of the window. As we were working on the Kvaenangen side of the window for A/S Sulitjelma Gruber, we took the opportunity to sample rocks, in order to have a full geochronological cover of the window.

The chemical analyses (cf. par. 3.2.) have been done on the samples for geochronology.

Preliminary results (not published) show 3 ages-groups. They appear to be dependent on the "weathering grade" (saussuritisation, chloritisation, etc.) of the rock and on the grain size: coarse grained stones ar less affected by these transformations, so the loss of Argon during the metamorphism is smaller. The preliminary age is approx. $1,4 \cdot 10^9$ years. Due to the metamorphism, this age is certainly too young.

The following work will be done:

- isotopic dilution - analyse for some samples due to the very low content of K.
- some Rb/Sr age determination, this method being less sensitive to metamorphism.

The full results will be published later in Norway, after the agreement of A/S Sulitjelma Gruber.

IV Tectonic

IV. TECTONIC

4.1. Polarity

The polarity (or way up) criterons used to resolve the tectonic is:

- pillow lava (see 2.2.2.6.4.). The pillows as mentioned before, are the main tectonic element, as the lava-flows are rather regular and might be followed on long distance. These lavas are therefore the "marker layers" for the tectonic (not for the stratigraphy: the pillow layers occur at different stratigraphic levels);
- other features, confirming in every case the polarity observed on pillows, in tuffs, tuffites and tuffogenic beds, and also in some greywacke:
  - gradded bedding
  - cross bedding
  - angle between schistosity and layering.

4.2. Tectonic style

It is not possible to recognize and to use the usual tectonic elements (such as drag folds ...).

The tectonic style is rather hard, nearly not pliant. The dips are very often steep, the structure isoclinal, or as "schuppen" (monoclinal). It is rather seldom to find a real synclinal or anticlinal fold, except the syncline of St. Middavarri-Didnoidhar'ji (EC 530490 - EC 560520).

Often the tectonic units are separated by zones of "black schists" that seem to be crushed zones more than lithological facies. The observation of the cliff in the end of the Badderelva valley (EC 415485 to EC 440470) do confirm it.

4. 3. Tectonic map

Explanation to the tectonic map:

The circled numbers (1) , (2) are referring to the tectonic map.

(1) Monoclinal unit of mainly coarse grained metadiabase and black-greyish sediments (also some scapolite bearing dolomite to the W). Steep dip to the W, way up not known. Laying on unit number (3) with a thrust fault.

(2) Monoclinal unit of mainly lavas and volcano-sediments: pillow-lavas, tuffs, tuffites, fine grained lavas and some layers of coarse grained metadiabase. Steep dip to the SW. Way up: up-side down, shown by pillow-lava layers and sedimentary structures in tuffs/tuffites.
Between units (2) and (5) : zone of black schists, strongly tectonised.
Between units (2) and (3) : important fault;

(3) Monoclinal unit. Stratigraphy (rock types) similar to unit (2).
Steep to the W (SW dipping), less steep to the NE.
Close to the limit between units (3) and (4) , strongly tectonised zone, shown by deformed pillow-lavas (being elongated);

(4) Monoclinal unit of mainly coarse grained metadiabase, tuffs/tuffites and some dolomite. Low dipping to the NW, way up unknown;

(5) Monoclinal unit of coarse grained greenstone, dolomite layers and some tuffs/tuffites.
Many faults in this unit. Way up probably normal.
Between units (2) and (5) and (5) and (6), zone of black schists;

(6) Important monoclinal unit; upside down.
Volcano-sedimentary unit: important serie of pillow-lavas layers interbedded with usual lava streams and tuffs/tuffites. Way up shown by pillow-lavas and some good features of lava stream's bottom (gaz pipes ...), and also by sedimentary structures.
Dipping: low to the W, steep in the middle and to the E.
Between unit (6) and (7): zone of black schists and pelites.

(7) Monoclinal unit. Could be upper part of unit (6) , but this is not sure. Consisting mainly of lava streams inderbedded with tuffs/tuffites; the lowest lava-stream is showing a pillow-lava structure. Steep dipping to the W; upside down. Between unit (7) and (9) , (10): black schists .....

(8) Fold along an EW axis, dividing an anticlinal structure in two: (9) and (10) .

(9) Anticline, both limbs dipping to the W. The anticline axis is probably a fault, at least in the N. part of this anticline. Rock-types: meta-diabases, pillow-lavas streams, tuffs/tuffites and some important dolomite layers.

(10) Important volcanic sequence of pillow-lavas, columnar basalts, interbedded with tuffs/tuffites, pillow breccias. Dipping rather flat to the N, steep SE to the S.
This zone is forming an anticline, which was in fact the same as the Bergmark anticline (nb.(9)), but has been individualised by a folding along a EW synclinal axis;

(11) This zone is strongly covered by quaternary deposits. It consists of sedimentary layers (greywacke etc.) with septarian nodules, and black schists. Probably a tectonic discontinuity between unit (10) and (11) . Ultrabasic rocks (lherzolite, partly serpentinised, outcrops as hills);

(12) Lavas, pillow-lavas, tuffs/tuffites-
Very tectonized area, with many faults, thrust faults, etc.
General dipping to the W, very steep. Way upside down to vertical (way up to the E);

(13) Lavas (with columnar basalts), pillow-lavas, tuffs/tuffites.
Dipping ± vertical, way up to the E.
Between unit (11) and (13): black schists and tectonized zone; between unit (13) and (14) probably normal contact;

(14) Sandstone of the Upper Raipas sub-group.
Way up to the E. The upper part of this sub-group consists of interbedded sandstone and dolomite (see (15));

(15) Formation of interbedded dolomite and sandstone, with a quartzitic layer of about 10 m - 20 m at the bottom. The number and thickness of the dolomite layers decrease to the top of the formation and the greywacke is getting more wacke, and the colour changes from grey to greenish. The formation is forming a syncline, whose fold might be observed from coord. point EC 545513 to the NE on the side of Didnoidhar'ji. This formation is disappearing to the South because of an axial dip to the North on the Southern part of Middavarri-Nikkeluob'balat (EC 530470).
This unit is overlayed to the E, from the South to Didnoidhar'ji (EC 570515) by autochthonous and allochthonous units. On the North of Didnoidhar'ji, there is a fault between this formation and the next tectonic unit to the E;

(16) Unit of lavas, pillow-lavas, tuff/tuffites, dolomite & Lower Raipas), and the beginning of the Upper Raipas greywacke.
Dipping steep to the W; way up normal.
Very complex tectonic: this unit is laying over (?eo-cambrian ?) white quartzite (thrust fault);

(17) Mountain of lava (fine grained) on which no structure has been found in the Northern part. To the South, a pillow-lava stream and gradded bedding in tuffs/tuffites indicates that this zone is the front part of an anticline fold, the middle of the fault being faulted and the Eastern flank upside down;

(18) Serie of lavas, pillow-lavas, tuffs/tuffites, forming the limb of an anticline. The other limb is covered by the Bossekop quartzite in this area. This zone is the continuation of (17) , but is locally interrupted by faults;

(19) Dolomite and sandstone of the Upper Raipas sub-group;

(20) Same formation as (15), forming here a syncline too, but much more isoclinal in this case. To the N of Bavtavuolesjav'ri (EC 625520) the syncline axis disappears slowly in the air above Botnelvdalen, bending to the ENE. The Lovosvarre formation between Mattisdalen and Botnelvdalen is the continuation of this anticline-middle;

(21) This unit consists of the Lower Raipas sub-group. It is forming an anticline whose Eastern limb is upside down. The Northern part of the anticline has been strongly deformed during the folding, this showed by the folds in the dolomite to the North;

(22) "Island" of Lower Raipas meta-volcanites limited by a fault on the NW and unconformably covered by autochthonous tillites and quartzites to the E and S;

(23) Zone of Lower Raipas meta-volcanites, corresponding probably to unit (13), as other limb of the syncline whose syncline-axis is in the (15) unit. The structures (pillows, gradded beddings ...) are difficult to be found and are in a bad condition;

(24) Limited by faults, zone of autochthonous (tillites and quartzites) and allochthonous (nappes) covering the precambrian;

(25) Plateau with an important cover of boulders, showing some outcrops of Upper Raipas greywacke and some of a nappe made of quartzitic sandstone very similar and difficult to distinguish from Upper Raipas! (cf Ch. II nb. 2. 1. 1.);

(26) Very tectonized zone, with lots of tillite beds and tectonized greenstones. It is not certain that these greenstones are belonging to the window's structure, or if they are (precambrian) tectonic lenses within the autochthonous as it occurs in the autochthonous units North of Buv'ravžegiera river (EC 550540) - (personal communication from Mr. Inge Bakke, NGU).

To the South, E of Baddervan, a zone of greywacke, probably Upper Raipas. But it cannot be completely excluded that there is here a ± quartzitic greywacke belonging to a nappe (cf. (25) and Ch. II nb. 2. 1. 1.) ;

(27) On the flank of Didnoidhar'ji white quartzite with a dip slope. To the E and SE of Storelvv^{nt} (Gåv'dajav'ri), folded rocks, quartzitic (- gneissic), belonging to the nappes.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
Definite Assumed
Thrust plane
Angular unconformity
Fault (thrust)
Fault or joint
Syncline
Anticline
Axial dip
Pillow showing: "way up„
Lineament
Dip: normal
Dip: up side down
Dip: no "way up„ indication
Zone of "black schists„
Upper Raipas subgroup
Lower Raipas subgroup
1, 2 etc... See description (report)
TECTONIC MAP OF THE
ALTA-KVAENANGEN WINDOW (Kvaenangen side)
N.-Troms, W.-Finnmark, Norway
Scale 1/50.000
Mapsheets: Kvaenangen 1734 I
Flintfjellet 1834 IV
Nov. 1975
A/S SULITJELMA GRUBER
André M. GAUTIER B.Sc
Dpt. de minéralogie
Université de Genève
13 r. des Maraîchers
CH-1211 GENEVE 4
Size: 790 × 560

V LOCAL DESCRIPTIONS

5.1. Middavarre (EC 460540)

Explanations to the geological sketch of Middavarre based on the air photos (E 7) E 8 (E 9), flight 2025 from Fjellanger-Widerøe A/S.

a - b way followed to establish the profile (next figure) from the cart track on the top of Middavarre to Gammeelva.

b the river has digged its bed in a flow of pillow-lavas; Further downstream from b the river has made a canon in the lava flow.

c good and didactic outcrop showing a pile of pillow-lavas with a characteristic "younging" or " sedimentary facing" ;

d cliff made of pillow-lavas. The cliff allows one to see the pillows in a three-dimensional view and to study the formation of a pillowed flow. The bleak plateau at the foot of the cliff (approx. between point b and d) is made entirely of pillow-lavas;

e on the track, cleaned from the lichens etc. by passing tractors, a typical outcrop of pillow breccia;

f glacier-polished surface cutting a pillow-lava flow in no particular direction, showing the internal structure of the pillow. About 10 m from there, a lava surface "covered" with the holes from the pipe vesicles;

g a pillow-lava breccia outcropping just on top of Middavarre;

h several good outcrops showing a polygonal pattern, which is a perpendicular section of columns of basalt (basalt with columnar jointing)

- at the end of the cart track to one of the old mines, outcrop free of lichens, "polished";
- on a small hillock, close to the lake;
- on some rock's surfaces outcropping close to the track;

j trenck of an old mine, with columnar jointing as a wall.

Quaternary cover

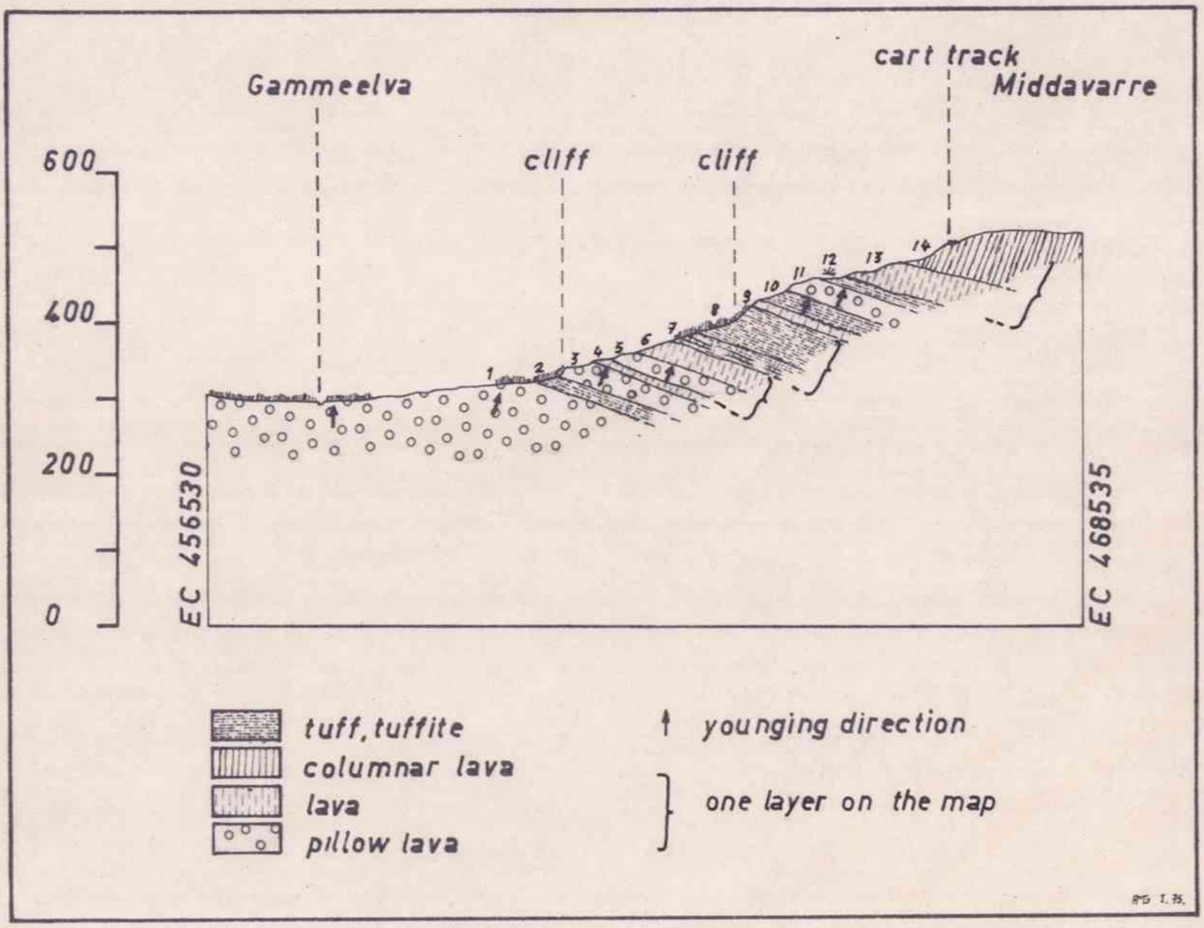
Eocambrian
Quartzite

Precambrian
Tuff, tuffite...
Pillow breccia
Pillow-lava
Lava

Cart track, track
Cliff
Mine
Angular unconformity
Rock boundary

Described profile
See explanation in the text below

PMG. I.75



1)pillow-lava 2)banded tuffite 3)pillow-lava 4)massive greenstone (lava) 5)small pillow-lava 6)massive greenstone (lava) 7)tuffite,with some carbonate beds 8)tuff/tuffite 9)massive greenstone (lava) 10)tuff/tuffite with cross bedding 11)pillow-lava,difficult to recognize on polished & weathered surfaces 12)banded tuffite (swamp) 13)massive greenstone (lava) 14)columnar lava

VI Economic geology

VI ECONOMIC GEOLOGY

As mentioned before (cf. "1.2.2. Previous work", "1.3. Old mining area" and " 1.4.1. Geological motives") the Alta-Kvaenangen window was an old district for economic geology. See Vokes (cf. references ch. X) for the description of mineralisations in Raipas /Alta.

Generally the greenstones are containing disseminated pyrite, as very small cristals.

The study of thin sections indicate the presence of leucoxene with traces of ilmenite (cf. " 3.2.2. geochemical datas"): the greenstones contain 1 - 1,5% TiO_2.

One can find "coating", "film" of malachite, disseminated in the field. These spots have often as origin a veinlet of calcite with one or two cristals of chalcopyrite, of some mm^3 only.
In the Bergmark anticline area, and also South of Djupvan, there are some dolomite layers containing quite a lot of idiomorph cristals of magnetite (octahedrons), often pseudomorphosed in limonite. They have a size of some 1/10 of mm.

Traces of malachite associated with oxydation products might be seen in the "black schists" in tectonized zones.

Malachite coating can seldom be found higher than the tree-line; this is probably due to the bleaching (snow and rain).

In sheared zones (faults), as between Lille and Stora Riiddevarre, there are some joints filled with asbestos (amphibol). No dolomite layer is pure and/or thick enough to allow any exploitation for this mineral.

We shall mention that all the visible traces of mineralisations have already been discovered during the active period of mining, end of XIX, beginning of XXth century. This is deduced from works met in the field, such as trenches, shafts etc.

The conclusion is that if there is an economic mineralisation in our research field, it is not visible just with "nacked eyes", but can be found only by geochemical or geophysical methods.

VII Discussion

VII. DISCUSSION

7.1. About the thickness of the series.

Due to the tectonic, it is very seldom to observe the stratigraphic pile continuously. The favorable zones for the evaluation of the thickness of the series are the Bergmark anticline on the Kvaenangen side of the window and the Kvaenvik area on the Alta side.

In the Bergmark anticline (Lower Raipas), the problem is the following: on the W, the series disappear under a zone of black schists (tectonic zone). Over this zone there are always rocks from the Lower Raipas. To the W, the anticline is followed by the highest part of the Lower Raipas, then by the beginning of the Upper Raipas. Now there is a tectonic "accident" further North, so that ultrabasic rocks are to be seen. This "accident" is going in direction of Flintvan, where it seems that is disappears. If this is the case and if it doesn't exist anymore at the level of Badderelva river, then it is possible to evaluate the thickness from the middle of the Bergmark anticline to the top of Lower Raipas. In this case (the most likely), the minimal thickness of the Bergmark anticline is approx. 1,5 km. (approximation due to the variation of dip along a profile).

If, on the contrary, this "accident" should go further than Flintvan, to the South parallel to the structures, up to a point where it would disappear under the overthrust, then we would not have a continuous series anymore and the evaluation of the minimal thickness would be indeterminated (due to the lack of marker layers).

The thickness evaluated in Alta by Holtedahl for the Lower Raipas was approx. 0,8 km. In Kvaenvik we estimated approx. 1 km. But it seems that the series is not completely present at its bottom. So the real thickness should be much more.

About Upper Raipas, between Blå fjellet and Middavarri (included the dolomite and greywacke/shale formation at the top of Upper Raipas), it is possible to evaluate, with the dip variations, a thickness of 1 - 1,5 km. This is of the same magnitude as the thickness mentioned by Holtedahl and Zenzen, Upper Raipas in Alta (~ 1 km).

7.2. About the sedimentation conditions and their relation with tuffs/tuffites/ tuffogenic sediments .

As mentioned in the chapter "Petrography", the term tuffs/tuffites/tuffogenic sediments includes rocks of different aspect (descriptive).

Now we should also consider the genesis of these deposits.

As a matter of fact, it is possible to have different formation mechanisms for the same final result.

We shall consider here two main possibilities:

Primary volcanic origin: hyaloclastites. Submarine volcanoes can produce, apart from lava streams, important amounts of hyaloclastites. They are formed by the fragmentation of the lava when it is in contact with cold water (Tazieff 1972). If the volcano is close to the surface, these vitreous fragments might be ejected in the air before felling down again in water.

This shows that purely volcanic rocks can be deposited in water as an usual sediment, this explaining sedimentation figures in tuffs/tuffites such as cross bedding, gradded bedding, Bouma sequence (turbidite).

Erosion "in situ" : we can also imagine the erosion and the deposition nearly "in situ" of local volcanic material, coming from a line of volcanic islands e.g. The result would be a kind of volcanic greywacke. In this case too the deposition happens in water producing the usual sedimentation figures.

The metamorphism, in the "greenschists facies" induced many transformations: the volcanic glass has been devitrificated, the rock has been homogeneisated, weathered; the structures, in a fine grained rock, disappeared. For these reasons it is not possible to distinguish from each other between these two possible origins of the rocks. (The chemical composition of these rocks is typically basaltic).

We personnally think that the first mode of formation was the most important: for the second one, a too big emerged area would be necessary. According to the numerous pillowed flows (= submarine) it is not the case.

We also did indicate on the map that some "tuffs/tuffites etc." are getting more "sedimentary" (pelite or carbonate). These rocks are named "tuffogenic", and are sometimes containing purely sedimentary rocks.

Our interpretation is the following:

The usual sedimentation of the sea bottom was mainly very fine material, showing a certain distance from the shore or a shallow: pelites, dolomites. The variable facies of some dolomites of the upper part of Lower Raipas might indicate a recifal type zone in places. The sedimentation ratio should be very low and regular. During the same period an important volcanic cycle did occur. Now it is evident that it is not possible to compare a lava stream of some meters (or more) thickness, or a hyaloclastite deposit up to some tens of meters, both formed in a few hours or less, with the depositions of sediments of some cm a year or a century .....

The sedimentary material has been "dissolved" in the volcanic material.

But if the volcanic activity decreases or temporarily makes a break, then the deposition of "pure sediments would be visible again. This is the explanation of very fine, irregular beds of sediments.

Another point is to consider how far away the deposition place is from the volcanic vent or fissure:
For the hyaloclastites e.g. it is evident that as far it is from their origin, as important the deposit will be. And as much we will go away from this origin, as less volcanic material will be found. We can then consider that after a certain distance, the deposition of volcanic material will be of the same magnitude that sedimentary one, or even less. It is then possible to have all the intermediate steps between purely volcanic and purely sedimentary rocks, and it might be difficult to draw an accurate limit for the classification and field mapping of rock types such as tuffs, tuffites, tuffogenic rocks, argillites, etc.

7.3. About a particular pillow lava layer

We found several times a particular pillow lava layer whose structure is sometimes not very visible, and very difficult to detect, with pillows separated from each other by 1-2 cm of chert. The amygdules rim of approx. 1 cm inside from the outer border of the pillow, characteristic for all the pillows of the window, is absent. Instead, there is a zone of 2-3 cm with disseminated numerous, very little, black spots, nearly invisible. These pillow lavas are associated with lavas without any structure and very fine grained (like the pillows).

In some localities of the window, e.g. in Kvaenvik (Alta), at Luseskardet (EC 500525) - Blåfjellet, at Ruollačåk'ka (EC 630560), on a mountain without name (EC 605515), it is certain that this lava stream is the last pillowed stream of Lower Raipas. Maybe it is not the same, considering the distance, but anyway sister-lava-streams, belonging to the same volcanic event and in the same environment.

These lava streams are covered by the rather thick sequence of tuffs/tuffites etc. of the top of Lower Raipas.

Now we found a similar lava stream, with a N-S direction, running from Grönlifjellet (EC 425535) to Uldaidvarre (EC 435445), with an upside-down position, and being cut in its geological upper part (to the E in the field) by a shear-zone (w. black schists), so that it is not possible to see the upper part of Lower Raipas and Upper Raipas.

Our goal is to prove that if we accept the pillow lava morphology - described at the beginning of this paragraph - as characteristic of a particular horizon (= marker layer), then the ridge Grönlifjellet - Uldaidvarre will belong to the upper part of Lower Raipas.

7.4. About the extension and the volcanic vent of the lava streams.

It has been said before that the window is characterised by numerous and typical lava streams (in spite of the fact that in some cases there is still a doubt between lava stream and sill). Our field mapping revealed pillowed layers that could be followed continuously in the field on 13 km from one border of the window to the other one (Kvaenangen side). On the other hand it is possible to follow nearly continuously a pillowed stream that is recognised around the point EC 755650, going to the S, turning around Sukkertoppen (EC 630560), then SSW until it disappears under the autochthonous, approx. at the point EC 600500. The full distance is here of about 25 km !!! (NB: this layer is "crossing" our Ph. D. thesis field / mapping for Elkem Spigerverk and is then going through the area mapped for A/S Sulitjelma Gruber).

These 25 km are in fact a length measured along one extension direction only, subhorizontal originally. It is not possible to know the extension along the second dimension of the plane because of the tectonic structures (folds, faults etc.) with strong dips.

Nevertheless the study of some areas such as the Bergmark anticline, Middavarre, the zone (Elkem Spigerverk) between Uldašvag'gi (EC 670560) and Vasbotndalen (EC 650620), shows by drawing interpretation profiles with the synclines, anticlines etc. that this lateral extension of the lava flows should be at least of several kilometers (10 or more).

Now if we admit what has been discussed before (cf. 7. 3.), that there is a special pillowed layer that might be used as marker layer, this would mean that we have today an actual distance, projected on an axis perpendicular to the structures (= fold axis, faulted folds, "Schuppen" . . .) without defolding and " flattening" again these structures, of approx. 38 - 40 km. (from Grønlifjellet EC 425535 to Kvaenvik EC 814 595).

Although one can consider our way of calculation as not adequate, anyway it is showed that the two horizontal directions of extension are very big. For this reason we consider - according to the latest volcanic litterature - that these lavas cannot be emitted from a central volcanic mouth only, but from a volcanism of fissural type, such as the one observed and studied presently on the ocean floor (Atlantic, Pacific, Red Sea, Afar - today emerged - etc.)

In conclusion we consider that our field was an ocean floor. This hypothesis fits with the chemistry of the lava (tholeiitic, like the actual ocean floors). This would be an explanation to a certain copper anomaly in some sedimentary rocks of the window associated with lavas (cf. D. Rickard in Bartholomé 1974).

7.5. About the limit between Lower and Upper Raipas

The upper part of Lower Raipas is made of argillite with dolomite layers; the base of Upper Raipas is a sandstone. The transitional zone between these two sub-groups is always covered by quaternary deposits. The dip and strike are concordant. Reitan 1963 mentions an " assumed erosional unconformity" between these two sub-groups in the neighbouring Komagfjord window (NGU no. 221 p. 9). In the Alta-Kvaenangen window we found no element to confirm or contradict this unconformity.

Another way is to consider the paleographic relations between argillite and sandstone. But we don't know the source of the Upper Raipas sand... this happens beyond the limits of the window and we only can assume things and facts. So we can admit that an " assumed erosional unconformity" can occur.

7.6. Comparison of the type scheme for the "greenstone belt".

We tried here to compare the greenstones series of Lower Raipas with the type scheme for the "greenstones belt" established by G. Allard. This latter, who found important C_u ore bodies (sulfides) in Canada, e. g. Chibougano (Lac Doré, Quebec) developped a type scheme, after comparison with the big "greenstones belts" of the world; the observations concerning the mineralisation are confirmed.

From this model it can be stated that mineralised lenses of little economic interest can occur at every level, coming generally from the feeding dykes of acid intrusives. But economically important ore bodies are close to the acid intrusives, just above a chert layer whose thicknes s might vary (some cm. to some m !). On another hand it seems that the importance of the mineralisation is in relation with the thickness of the series.

In the Alta-Kvaenangen tectonic window, compared to Allard's model, we can state:

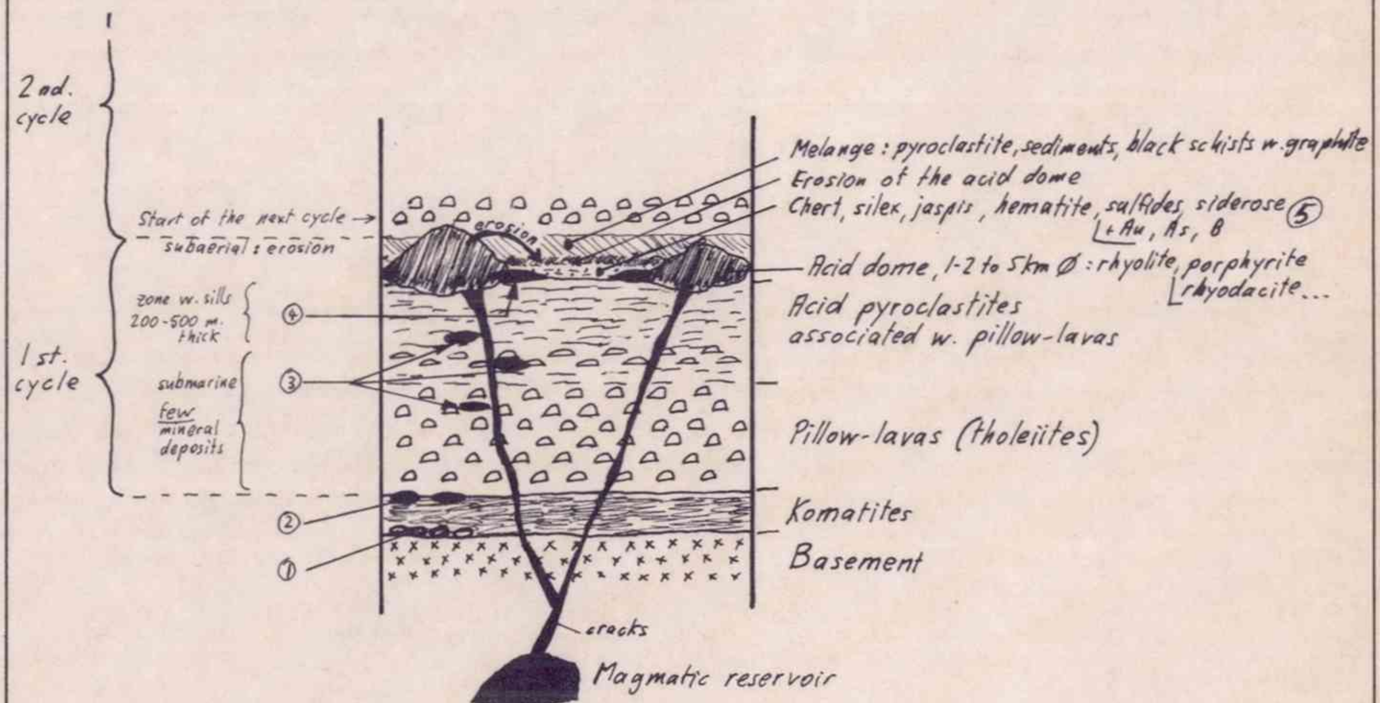
- the thickness of the serie is one magnitude smaller than greenstones belts (1 to 1, 5 km against 15 - 25 km)
- the tectonic divides the units in "small" fragments, so that it is not possible to "follow" a layer.
- there are no acid intrusives in the window.

From these points we can deduce either that we have here a greenstones series with a small thickness, or that we have only a part of a thicker series.

From the second criteron (tectonical) we think that the second hypothesis is more likely, as follows: during the folding phases the series has been cleaved along a plane more or less horizontal; the part above and under this plane have been tectonised apart. (cf. ch. IV, paragraphe 4. 2.). The upper part has been then divided into rather rigid blocks that have been nearly not deformed (this is proved by

Typical stratigraphy of the "greenstones belt" in the world, from the beginning of the Earth up to now...

Ideal model of a greenstones belt established by G. Allard (Georgia University USA and minerals research, Canadian government). Conference at the University of Geneva, spring 1975. This model, established in Chibougamo (Lac Doré Complex, Quebec, Canada) – locality of big sulfides lenses – has been compared with other greenstones belts in the world.



Comments:

Komatites: ultramafic lavas!!!, now serpentinised. Spinifex structure (: olivine in thin plates, up to 50 cm. long. Name from an herb: the olivine are looking like this latter. The olivine is now serpentinised. Very new discover: ultramafic lavas never described before in the litterature. Temperature of formation: 1600-1650°C.

① : Deposits of Zn (upper part), Cu Zn (middle ...), Cu (lower part) } + barite, + Pb during Proterozoic and Paleozoic, not in Archean.

② : Ni - Deposits. Example: Marbridge in Australia

③ : Small lenses of mineralisations due to the cracks/dykes.

④ : Important deposits, sedimentary exhalations: Cu + Zn. If the shield is uplifted, then eroded, it is then possible to find conglomerates, or interbedding of basement rocks and lavas, on the rim of the sedimentation bassins only.

⑤ : QFP (rhyolite porphyre): mineralisations: SiO_2, Carbonates, Sulfides

NB: – between the lava and the acid dome, no intermediate rocks such as andesite
– the thickness of the serie, comprising several (numerous!) cycles, is up to 20 – 25 km.
– the pillow-lavas are forming approx. 80% in every cycle.

PS: Consider this series folded, eroded, metamorphised, partly covered.....

AMG. X. 75.

the observation of non tectonised and deformed primary structures such as pillow-lavas and sedimentary structures), except some "hinge" zones, which are anyway often faulted. All these platy-blocks did slip over each other. In such a model we can even consider that the observed ultrabasic rocks, coming from much deeper, did not intrude as "warm bodies", but as diapyric intrusion, "cold" , as it is usual with serpentines.

These facts would prove that the ideal conditions to locate important ore bodies are far to be realised, or at least very much perturbated. For this reason we think that there is very little chance that the Alta-Kvaenangen window become a modern mining district.

VIII Further work

VIII. FURTHER WORK

We consider that we have described the structures and the stratigraphy of the window, mapped to the scale 1/50.000 (regional geology).

Academically speaking many researches might still be done in the area: detailed petrographical study, metamorphism, magnetical parameters of the different greenstones, study of the structure of the lava streams, geochemistry of trace elements, etc., etc...

Practically speaking (= mining industry): everything is depending from the results of the geochemistry. If they are negative, we think that this area should be considered as ininteresting (for mining purposes), according to the actual geochemistry and prospecting methods. If these geochemistry results are positive and a detailed geological map is needed later, to a scale such as 1/10.000, 1/5.000, 1/2000 etc., then we suggest: to divide more the terms of our legend, especially the "tuffs, tuffites and tuffogenic rocks", and also the "greenstones", that should be classified according to their detailed mineralogy. This would be a long-time and hard work, to be done with with the "help" of a great number of thin sections. The geologist in charge of such a work should first have to look at the typical rocktypes we described for the window,first along typical profil such as the one of Middavarre (cf. 5.1.). But such a detailed mapping can and shall be done only on small surfaces, directly on and around the target.

IX Conclusions

IX. CONCLUSIONS

Some 1500 to 2000 million years ago, the studied area was a sea bottom, probably a part of an ocean crust. The sedimentation was pelites and carbonates (limestone and dolomite), with an assumed small sedimentation speed. An important volcanic activity occurred on this sea bottom: volcanism (submarine) characterized by the formation of massive lava streams, lavas with the typical "pillow-lava" structures, pillow-breccias, interbedded with tuffs, tuffites and tuffogenic sediments. (cf. discussion). Some parts of the area were in shallow waters or as island; this is showed by columnar lava streams. All this volcanism, of fissural type, produces lava flows of big extent. The end of this volcanic period is marked by a more important deposition of tuffites, tuffogenic rocks and finally the sedimentation of an argillite bed.

This very fine pelitic material indicates a zone far from the shore or a shallow.

Associated with this argillite, there are beds of dolomite (dolomitised limestone ?) whose thickness and facies are variable (massive, brecciated .... etc.), and could be recifal-like.

All the rocks formed during the described period are forming an unit called Lower Raipas Subgroup, and are 1 to 2 km thick.

Later - and we cannot state if there is an "erosional unconformity" or not - the sedimentation is building a thick sandstone of about 1 km thick. This could be, as we think, a kind of "molassic bassin". A pure quartzite layer has been deposited on the top of this sandstone, containing some jaspis grains, on which lies a pile of alternating dolomite and sandstone/ argillite. These rocks are forming an unit called Upper Raipas Subgroup.

The Raipas group as a whole was folded a first time. The folding was of isoclinal type, with thrust faults, "Schuppen", monoclinals etc. so that in one locality it is possible to see ultrabasic rocks from the underlaying upper mantle (of the earth).

We think that the oceanic crust, laying on the mantle, after the beginning of the folding, has been separated from the upper mantle, then broken in rather rigid blocks that did slide over each other. Faults with big movements have been formed during this tectonic phase. (This is showed e.g. by the fact that the Altenes window has a structure completely different from the Alta-Kvaenangen window in spite of the close vicinity).

We presume that the mineralization phase (filling of cracks, fault breccia etc.) is from this period. The "greenschist facies" metamorphism is probably due to this first important and complex tectonic phase (orogen?).

An erosion phase followed this folding phase.

A sedimentation of quartzites with some shales layers occurs later on, during the eocambrian (approx. 600 - 700 Mo.y.): the Bossekop group, which is 160 m thick in Alta. Then we had a slight movement of the basement, producing a small tilt, followed by a transgression, with the Borras group: quartzites and tillites - showing an ancient glacial period. As consequence of this tilt, the Borras group is laying with an angular unconformity on the Bossekop group.

What happened directly after the deposition of the rocks of the Borras group is unknown, this group being covered by allochthonous units. Did we have Cambrian sediments and erosion, or sedimentation discontinuity (emersion ...) ?

Anyway, all the whole pile described up to now (Precambrian + Eocambrian) has been folded together, with big open folds: in spite of sometimes rather strong dips, the Bossekop and Borras groups are continuous enough to keep the name " autochthonous".

We assume that this folding phase is already due to the Caledonian orogen. This latter is marked in the studied area by the overthrusting of big nappes that covered basement and autochthonous (orogen: from 500 to 400 Mo.y.)

Important faults are running through both basement + autochthonous and allochthonous. They have probably been made at the end of the orogen (readjustings), maybe later.

An emersion phase, erosion and peneplanation succeeded to the building-up of the Caledonides, revealing some precambrian zones: the precambrian windows (we shall mention that in some cases where we observed a tectonic limit: fault).

In a much more recent time, at the end of the Tertiary (cainozoic), the Scandinavian area was uplifted, causing a reactivation of the relief, geomorphology (valleys ..), then covered by the quaternary glaciations (in the last 2 Mo. y.), with valleys getting deeper, sharper, complete change of the geomorphology, and, during the ice-melting, deposition of important moraines covering big surfaces, masking the bed-rock, and finally uplift of the Scandinavia (isostasic readjustment), with formation of glaci-fluvio terrasses etc. (sand and gravel deposits).

As last remark and conclusion, we shall mention that the Precambrian of the North of Scandinavia (Norway, Finland), is known very little. Very few geological, geochronological etc. works have been done in these wide areas. So we have not enough comparison elements to correlate our precambrian folding phases with recognized orogens.

X References
Maps, Air Photos
Equipment

10.1. REFERENCES (The most important ones are marked with a ● in the left column.)

American Geological Institute

Dictionary of geological terms, Ed. 1962
Dolphin Books, Doubleday & Company Inc., Garden City, NY

● Amstutz 1974

Spilites and spilitic rocks (Symposium)
Springer Verlag Berlin-Heidelberg-New York 1974

Bartholomé P. & al. 1974

Gisements stratiformes et provinces cuprifères.
Sté. Géologique de Belgique, Liège

● Blokhina L.I. & al. 1959

Principles of classification and nomenclature of the ancient volcanic clastic rocks.
International Geology Review Vol. 1 No. 12 Dec. 1959 pp. 56 - 61

Bonatti E. 1970

Deep sea volcanism.
Naturwissenschaften 57, 8 Berlin 1970 pp. 379-384

● Carlisle D. 1963

Pillow breccia and their aquagene tuffs, Quadra Island, British Columbia.
Journ. Geology 71 pp. 48 - 71

Fisher R.V. 1961

Proposed classification of volcaniclastic sediments and rocks.
The Geological Society of America Bulletin
Vol. 72 Sept. 61 No. 9 p. 1409-1414

● Furnes H. 1972

Meta hyaloclastite breccias associated with Ordovicinian pillow-lavas in the Solund area, West Norway.
Norsk Geologisk Tidsskrift, Vol. 52 pp. 385 - 407, Oslo 19'

Føyn S. 1964

The tillite bearing formations of the Alta district - a correlation with Eastern Finnmark and the interior of Finnmark.
NGU No. 228, 1964

Gautier A. 1971

Field report and geological map of the N and NE part of the Alta-Kvaenangen tectonic window.
Christiania Spigerverk (Elkem) cf Dr. H. P. Geis, chief geologist unpublished

——— 1973

Geological map 1/50.000 ALTA 1834 I, Precambrian
(Zwaan/Ryghaug, Føyn, Gautier, NGU 1973, Universitätsforlaget)

Geukens F. & Moreau J. 1960

Contribution à la géologie de la région de Talvik, Finnmark, Norvège
Intern. Geol. Congr.
Report of the 21st. session Norden 1960
Part IX Precambrian, Stratigraphy and correlation.

Holtedahl O. & al. 1960

Aspect of the geology of Northern Norway
Int. Geol. Congress XXI session Norden 1960
Guide to excursions No. A 3

Macdonals G. A. 1972

Volcanoes (510 p.)
Prentice Hall, Inc., Englewood Cliffs, N. J.

Marinelli G. 1973

Le tufiti.
Società Italiana Mineralogia e Petrologia, Milano 1973
Vol. XXIX (2) pp. 413 - 426

Milnes & Richties

Moore J. M. 1965

Petrology of deep-sea basalt near Hawaii
Am. Journal of Science Vol. 263 January 1965, pp. 40-52

Moore J.M., Cristofolini R. & Lo Giudice A. 1971
Development of pillows on the submarine extension of recent lava flows, Mt. Etna, Sicily

Geological Survey Research 1971 U.S. Geol. Survey Prof. Paper 750 - c pp. c 89 - c 97.

Mørk K.J. 1970

Hovedfagsopgave i geologi: En geologisk undersökelse av. omrädet omkring Kåfjord Kobbergruve, Kåfjord, Alta, Finnmark.

Universitet Oslo våren 1970 unpublished

Reitan P.H. 1960

Precambrian of Northern Norway, windows in the Caledonides in the Ofoten district, Troms and Finnmark, in "Geology of Norway"

NGU no. 208 pp. 67 - 72

________ 1963

The geology of the Komagfjord tectonic window of the Raipas suite, Finnmark, Norway.

NGU no. 221, 1963

Rittmann A. 1936

Vulkane und ihre Tätigkeit

Ferdinand Enke, Stuttgart

________ 1958

Volcanoes and their activity

Wiley Interscience Publisher N.Y. 305 p.

________ 1963

Les volcans et leur activité(éd. française par H. Tazieff)

Masson et Cie. Paris 1963

________ 1958

Il mecanismo di formazione delle lave a pillow e dei cosidetti tufi palagonitici.

Boll. Accad. Gioenia Sc. Nat., Catania (V)4, pp. 311-318

________ 1973

Lave a pillow ed ialoclastiti

Società Italiana Mineralogia e Petrologia, Milano 1973 Vol. XXLX (2) pp. 397 - 412

Shrock R.R. 1948

Sequence in layered rocks

Mc Graw Hill Book Co. Inc., N.Y. 1948

Stache 1970

Diplomarbeit : Die Geologie des Kupferbezirkes Kaafjord in den unteren Raipas Formationen von Nord Norwegen

Universität Clausthal-Zellerfeld, Febr. 1970 unpublished

Tazieff H. 1972

About deep sea volcanism

Geol. Rundschau 61.2 pp. 470-480 Stuttgart, Aug. 1972

________ 1972

Les volcans et la dérive des continents.

Collection S.V.P. Presses universitaires de France 1972

Tepley L. 1975 (?) (Movies Film 16 mm. 20 min. colour + optical sound)

"Fire under the sea", the origin of pillow lava. A dramatic documentary of man's first observations of red hot lava flowing underwater"

Filmed by Dr. Lee Tepley, scientific consultant Dr. James G. Moore (Kilavea, Hawaii)

Distributed by Moonlight Production, Dr. Lee Tepley 2650 California Street, Dept. GT, Mountain View, Calif. 94040

Vokes F.N. 1955

Observations at Raipas Mine, Alta, Finnmark

NGU no. 191, 1955

________ 1957

Some copper sulphides parageneses from the Raipas formation of Northern Norway

NGU no. 200 pp. 74-111 Oslo 1957

________ 1957

On the presence of minerals of the linnaeite series in some copper ores from the Raipas formation of Northern Norway

NGU no. 200 pp. 112 - 120 Oslo 1957

Vuagnat M. 1946

Sur quelques diabases suisses. Contribution à l'étude du problème des spilites et des pillow-lavas.

Bull. suisse mineral. petrogr., 26 pp. 116-228, 1946

Vuagnat M. & Pustaszeri L. 1965

Réflexions sur la structure et le mode de formation des coulées en coussins du Mont-Genièvre (Hautes-Alpes)

Arch. Sc. **Genève, 18, pp. 686-689 1965**

Zenzen N. **1915**

"Rapport öfver en geologisk undersökning at Alta Koppargrufvors umråde i Kvaenangen (Tromsöamt Norge)

+ Karter till rapport 1915, Sulitjelma Aktienbolag

NGU Bergarkivet, Rapport no. 105A and 105 B

X F

10.2. MAPS AND AIR PHOTOS

10.2.1. Maps NGO (Norges geografiske oppmåling)

Mapsheet 1/50.000 Series M 711

Edition 2 - NOR

Sheet	1734 I	Kvaenangen
Sheet	1834 IV	Flintfjellet
Sheet	1834 I	Alta

10.2.2. Air photos used : Fjellanger Widerøe A/S

Flight 490	J 24 - J 28
	K 46 - K 53
Flight 2025	C 1 - C 4
	D 1 - D 11
	E 1 - E 12
	F 1 - F 12
	G 1 - G 14
	H 1 - H 14
	J 1 - J 11
	K 2 - K 10
Flight 1800	J 1 - 8
	K 1 - 8
	L 1 - 9

10.3. EQUIPMENT

10.3.1. Office work and drawing

Mirror/ stereoscop (Topcon)

Iron plate + magnets for dito

Office lamp

Kodatrace (acetate sheets) for air photo

Rapidograph 0.2 0.4 0.6 0.8mm + ink and cleaning liquid

A pair of compasses

Graduated rule (30 - 40 cm)

Pencils

Colour pencils

Magic Markers (different colours) to colour the map

Soft rubber

Transparent tape

Masking tape (pressure sensitive tape)

Tracing paper ≥ 80 gr/m2

Paper A 4, white and squared

Cover C 5 and C 6

Fixed punch (DIN standard size)

Sorter A 4 with dividing sheets

Stapler and staples

10.3.2. Field work	geologist	assistant	team
Pocket stereoscop (Zeiss)	x		
Compass with clinometer (Silva)	x	x	
Altimeter (Thommen 5000 m)	x		
Hand-lens 8 to 10 x magnification	x		
Field magnet	x		
Penol marker (for samples)	x	x	
Hammer	x	x	
Chisel	x	x	
Binocular (field glasses) 7 x 35, 8 x 40 or 10 x 50	x		
Small polyethylen bottle for HCl 10%	x		
Berliner note book	x	x	
Bag for air picture	x		
Set of air pictures	x		
Set of topographical maps	x	x	
"Rucksack"	x	x	
Small portable stove (solid fuel or methylated spirit)			x
Safety			
Flares set	x	x	
Whistle	x	x	
nylon safety line ∅ 6 mm 20 m.			x
first aid outfit			x
safety blanket ("space blanket"), aluminised	x	x	

10.3.3. Camping and bivouac

2 person waterproof mountain tent (one for each)	x	x	
kitchen tent (one roof, without ground, as shelter, or upper roof of a "dobbelt")			x
Isolating matting("warme madrass")	x	x	
Sleeping bag + bag for it	x	x	
Butan stove (Primus) 2 burners			x

	geologist	assistant	team
Set of pans			x
Spoon, fork, knife, plate, cup	x	x	
Bucket 10 l with cover			x
Kitbags (seaman-bag) for all the camping equipment			x
Butan lamp (Primus) + reserve of burning elements			x
Rubber torch	x	x	
Repair kit for tents: roll of "Norges plaster" string etc.			x
Plastic sheet approx. 2 x 3 m			x
Mobiltelefon			x
Walkie-talkie when the assistant is a geologist too	x	x	

IX

529

NYTT I NORD Nordlys, torsdag 4. sept. 1975

Vulkansk i Kvænangen

— Av Bjørn Aage Krane —

Han sa lite om hva som kunne tenkes å finnes av mineralforekomster i fjellet, den sveitsiske geologen André Gautier som i sommer har foretatt geologisk kartlegging av fjellene ovenfor Burfjord på oppdrag av Sulitjelma Gruber. Med seg i sommer har han hatt geologistudent Arnfinn Johansen fra Øksfjordbotn.

Derimot er han mer enn villig til å fortelle at de har funnet ut at fjellet Middavarre for en stor del består av lava som er dannet under havoverflaten for minst 1,4 milliarder år siden. I Precambrium, om det har interesse, og lavaen kalles putelava på grunn av sin karakteristiske form.

— Men det som mer interesserer folk og myndigheter i Kvænangen, er om de finner mineraler det kan bli gruvedrift av.

— Det kan jeg ikke svare på, sier Gautier og ser opp over kaffekoppen på Kaasen Gård pensjonat i Burfjorddalen. Jeg har taushetsplikt — skrevet under erklæring, så min munn er lukket. Men jeg håper det ikke blir.

ØKOLOGISKE KONSEKVENSER

— Hvordan det?

— Jeg kommer fra et industrialisert land, og har sett de økologiske konsekvenser gruvedrift har. Ulempene er store, spesielt i arktisk klima, der gjenveksten er langsom. Men hvis jeg finner noe, må jeg selvsagt rapportere det til mine oppdragsgivere, — misforstå meg ikke.

Gautier har mange somre bak seg i Nord-Norge. Området han arbeider med kartlegging i, regner han som spesielt interessant. Det kalles Alta-Kvænangen-vinduet. Forsto vi ham rett, betyr det at man her finner atskillig eldre fjell enn i området omkring. Men geologi er ikke vår sterkeste side, selv om Gautier og Johansen gjorde en stor innsats for å opplyse oss.

Vi må forøvrig ta med at Gautier nettopp i sommer er i ferd med å ta sin doktorgrad i geologi på en avhandling nettopp om Alta-Kvænangen-vinduet.

INGEN FARE

— Når dere finer lava, betyr det altså at Kvænangen ligger på en vulkan. Når kan vi vente utbrudd?

— Ingen sjanser. Dette er av de roligste strøk i verden. Utbruddene her skjedde ved at lavaen strømmet ut gjennom store sprekker i fjellet, og det er ingen sjanse for gjentakelse.

Gautier sier at det er gode muligheter for å samle stein og mineraler i Kvænangen så lagt han kjenner forholdene. I samarbeid med skolen i Burfjord har han laget en samling med 405 mineraler og steintyper som han har funnet i Burfjord-området. De skal monteres slik at man kan se hvilken type de forskjellige er og hvor de er funnet.

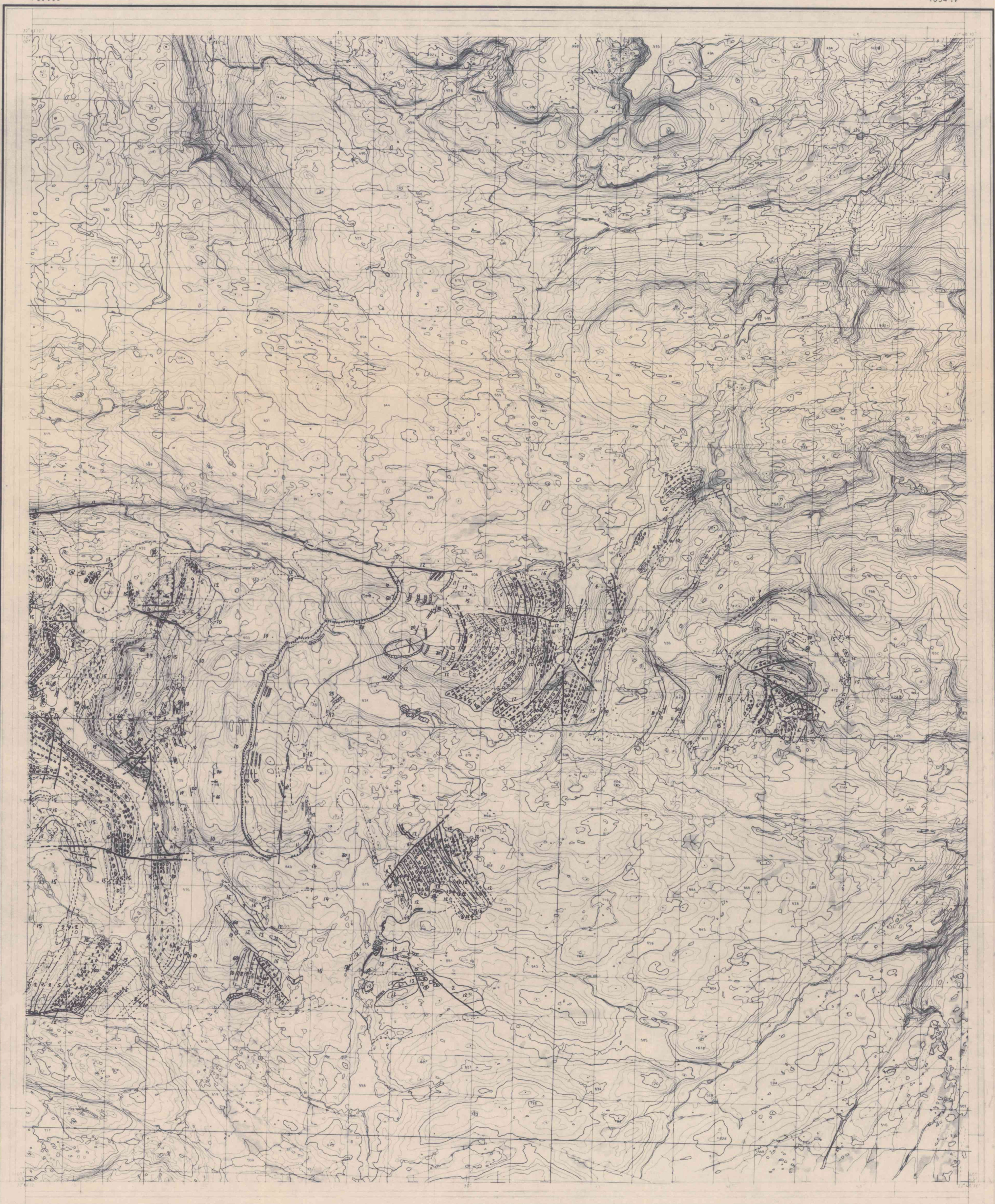
— Men her må det legges til slik at vi ikke får noe gullrush til Kvænangen, at det ikke dreier seg om edelstener. Ei anna sak er at det nok lar seg gjøre å finne stein som ved sliping kan brukes til smykker. Det er Arnfinn Johansen som legger til dette. Han begynte som student i geologi sist nyttår, og har derved et langt lerret igjen å bleike før han er ferdig. For ikke snakke om mange fjell å klatre...

Geolog André Gautier og student Arnfinn Johansen satte vår medarbeider på kondisjonsprøve ved å klatre opp til dette overhenget, for å vise fram et eksempel på typisk vulkansk aske. Putelavaen lå utenfor vår rekkevidde den dagen.

FLINTFJELLE

1:50 000

1834 IV



48

68

EKV.20m

COLOUR CODE

1 violet
2 light brown
3 light brown with blue symbols
4 rosa
5 rosa with red spots
6 rosa with blue spots
7 light blue
8 light green
9 light green with blue spots
10 dark yellow
11 dark blue
12 light yellow
13 lilac-colour
14 light & dark yellow bands
15 light grey

A/S SULITJELMA GRUBER

LEGEND

(COLOUR CODE)

15 Quaternary cover (sand,gravel,swamp...)

ALLOCHTHONOUS
not mapped except :
Dolomite
AUTOCHTHONOUS
12 Mainly white quartzite
12 Contorted quartzite
13 Tillite
— see report : tectonic map, (no 24,25,26,27)

14 Quartzite .... see report : tectonic map,(no 25) and Ch.II,2.1.2.

BASEMENT

Upper Raipas subgroup (stratigraphic order)

Luovusvarri formation
11 Individual dolomite layers showing structural trend
11 Dolomite interbedded with sandstones and shales
7 Basal quartzite (dots)and thick dolomite layer
Quartzite layer

Skoadduvarri formation
10 Greywacke with some argillaceous layers

Lower Raipas subgroup (not in stratigraphic order)
8 Black schists
8 Argillite with septarian nodules
8 Argillite
9 Argillite with dolomite lenses
7 Dolomite and dolomitic schists
5 Basaltic tuff and tuffite
5 Basaltic tuff and tuffite grading to tuffogenic sediments
6 Basaltic tuff and tuffite with small dolomite layers
4 Metabasalt and fine grained metadiabase
4 Metabasalt with pillow-lava structure (convex side showing up-side direction)
4 Metabasalt with pillow-lava structure (position unknown)
4 Metabasalt or fine grained metadiabase with tuff layers (showing structural trend)
2 Coarse grained metadiabase
2 Coarse grained metadiabase with tuff layers (showing struc- -tural trend)
3 Metadiabase "interbedded" with marble "layers" (tectonostratigraphic position uncertain -see report)
1 Ultrabasic

Strike & dip (in °/360)
Axial dip & syncline axis

DEFINITE	ASSUMED/PHOTOGEOLOGICAL	
——	- - - -	Rock boundary
▬▬	— — —	Fault or joint
▲▲▲▲	▲ ▲ ▲	Thrust fault/thrust

GEOLOGICAL MAP

Scale 1/50'000

Alta-Kvaenangen window
(Kvaenangen side)
N.-Troms,W.-Finnmark
Norway

Mapsheet :

Kvaenangen 1734 I
Flintfjellet 1834 IV

Field work :

Summer 1974 & 1975

Dr.André M. Gautier
Dept. of mineralogy
13 r. des Maraîchers
1211 GENEVA 4
Switzerland

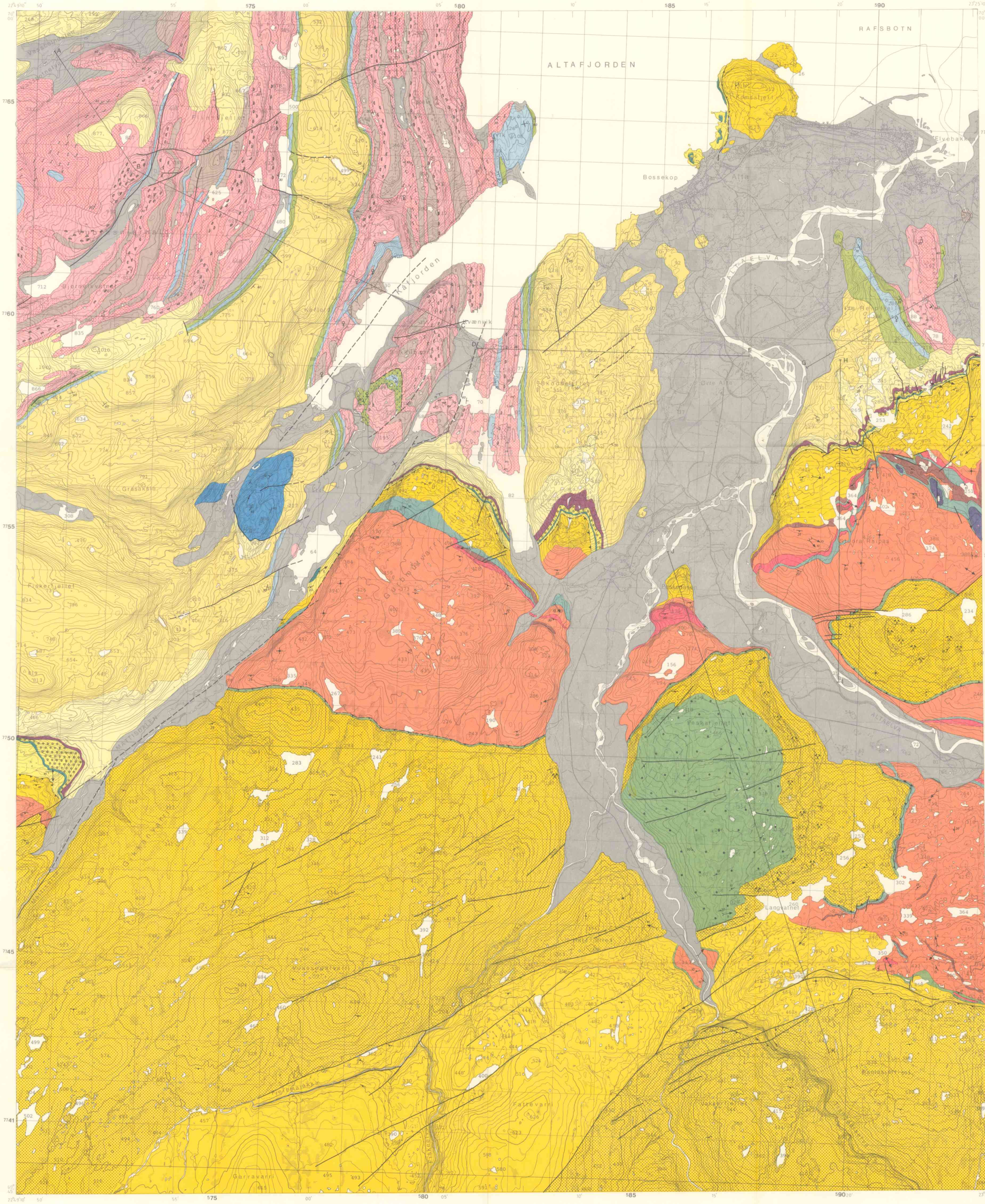
Geneva,1976

ALTA

1834 I

NORGES GEOLOGISKE UNDERSØKELSE

BERGGRUNNSKART 1:50 000



TEGNFORKLARING
Legend

OVERDEKKET (VESENTLIG SAND OG GRUS)
Covered (mainly sand and gravel)

ALLOKTONE ENHETER
Allochtonous units

NALGANAS-DEKKET (?EOKAMBRIUM)
Nalganas Nappe (?Eocambrian)

GRANATGLIMMERSKIFER
Garnet-mica schist

META-ARKOSE
Meta-arkose

GLIMMERSKIFER
Mica schist

GARGIA-DEKKET
Gargia-Nappe

NÅLFJELLGRUPPEN (UKJENT ALDER)
Nålfjell Group (unknown age)

GNEIS
Geiss

ULTRAMAFISKE BERGARTER
Ultramafic rocks

KALKGLIMMERSKIFER
Calc-mica schist

HORNBLENDESKIFER
Hornblende schist

KVARTSKERATOFYR
Quartz keratophyre

GNEIS
Gneiss

KOMSAGRUPPEN (?EOKAMBRIUM)
Komsa Group (?Eocambrian)

GLIMMERSKIFER
Mica schist

META-ARKOSE
Meta-arkose

AUTOKTONE ENHETER
Autochthonous units

BORRAS-GRUPPEN (?EOKAMBRIUM OG YNGRE)
Borras Group (?Eocambrian and younger)

KVARTSITT OG SKIFER
Quartzite and shale

BLÅ OG GRØNN SKIFER
Blue and green shale

KVARTSITT-KONGLOMERAT
Quartzitic conglomerate

TILLITT
Tillite

BOSSEKOP-GRUPPEN (SEN PREKAMBRIUM)
Bossekop Group (Late Precambrian)

KVARTSITT
Quartzite

RAIPAS-GRUPPEN (PREKAMBRIUM)
Raipas Group (Precambrian)

DOLOMITT I VEKSLING MED SANDSTEIN
Dolomite interbedded with sandstone

SANDSTEIN MED NOEN LEIRSKIFERLAG
Sandstone with some argillaceous layers

DOLOMITT OG KALKSTEIN
Dolomite and limestone

LEIRSKIFER
Argillite

LEIRSKIFER MED DOLOMITTLINSER
Argillite with dolomite lenses

BASALTISK TUFF OG TUFFITT
Basaltic tuff and tuffite

BASALTISK TUFF OG TUFFITT MED LEIRSKIFERLAG
Basaltic tuff and tuffite with argillaceous layers = (Tuffogenic sediments)

BASALTISK TUFF OG TUFFITT MED DOLOMITTLINSER
Basaltic tuff and tuffite with dolomite lenses

METABASALT
Metabasalt and metadiabase with fine to medium grains

METABASALT MED PUTESTRUKTUR
Metabasalt with pillow structure

METABASALT MED PUTESTRUKTUR UTEN OPP-NED KRITERIER
Metabasalt with pillow structure, younging unknown

METABASALT MED TUFFLAG
Metabasalt with tuff layers

METAGABBRO
Metagabbro (Metadiabase w coarse grains)

METAGABBRO MED BASALTISKE TUFFLAG
Metagabbro with basaltic tuff layers
Metadiabase w coarse grains

GEOLOGISKE SYMBOLER
Geological symbols

STRØK OG FALL, LAGDELING (VERTIKALT, HORISONTALT)
Strike and dip, layering (vertical, horizontal)

STRØK OG FALL, SKIFRIGHET (VERTIKALT, HORISONTALT)
Strike and dip, schistosity (vertical, horizontal)

FOLDINGSAKSER (HORISONTALT)
Fold axes (horizontal)

KONSTRUERTE SKIFRIGHETS-LINJER
Constructed schistosity lines

SIKRE DATA **Definite** — **USIKRE DATA/FOTOGEOLOGISKE DATA** **Assumed /photogeological**

BERGARTSGRENSE
Rock boundary

FORKASTNING ELLER SPREKK
Fault or joint

SKYVEPLAN
Thrust plane

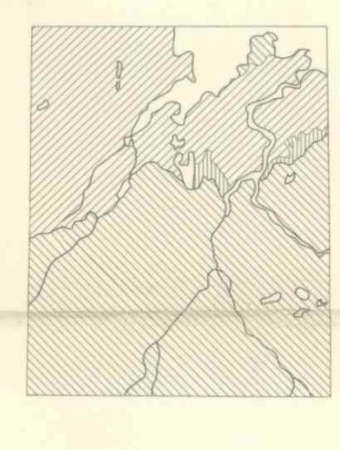
KOBBERKIS, SVOVELKIS
Chalcopyrite, pyrite

SKIFERBRUDD
Flagstone quarry

m MAGNETITTFØRENDE
Magnetite-bearing

Errata: Gult felt i profil J-K ved Peskenasen skal ikke ha sorte prikker
Yellow area in section J-K at Peskenasen should not have black dots

Geologisk kartlagt av S. Føyn (NGU pub.nr.228 1964), A. M. Gautier (Ecole des sciences de la terre, institut de minéralogie Geneve og Elkem-Spigerverket A/S 1971/72) og NGU (Nord-Norge prosjektet 1971/72). Redigert av K. B. Zwaan, NGU i 1972.



A. M. Gautier

S. Føyn

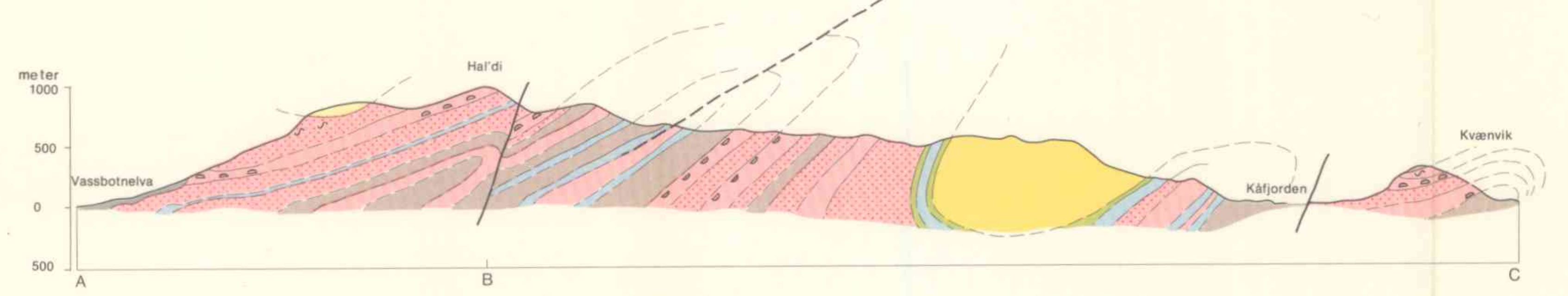
K. B. Zwaan
P. Ryghaug

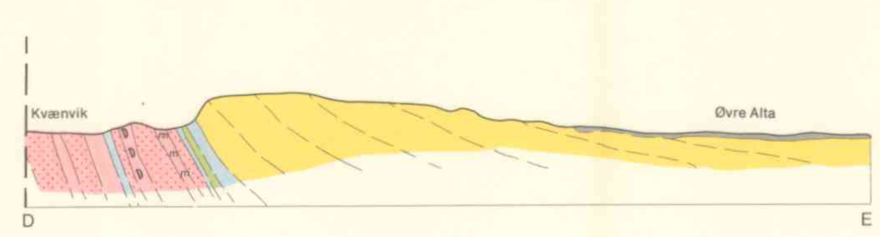
BRUK AV UTM RUTENETT FOR REFERANSEPUNKTER
Instruction in using UTM grid for reference points

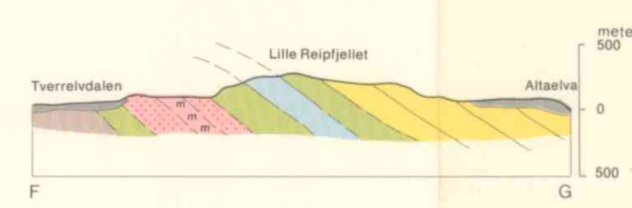
RUTETILVISING (KARTREFERENSE), NAERMESTE 100 m.		SONEOMRÅDE GRID ZONE DESIGNATION: 34W	TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METERS		
Eksempel: O ROSTEN		100 KM RUTE 100,000 M. SQUARE IDENTIFICATION	SAMPLE POINT: O ROSTEN		
km aust / km nord	83,2 / 54,5	EC	1. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin, or on the line itself: Estimate tenths from grid line to point:	83 / 2	
O ROSTEN	832545		2. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin, or on the line itself: Estimate tenths from grid line to point:		54 / 5
Merk at komma sløyfes og at 100 km tallene-de små tallene 5 aust og 77 nord-IKKE skal tas med. Ved meldinger utover 100 km eller hvis mere enn ett rutenett er merket på kartet, skal også 100 km ruten angis:			SAMPLE REFERENCE:	832545	
O ROSTEN	EC832545	IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figures of the grid number; example: 7740000	If reporting beyond 100,000 meters or if sheet bears an overlapping grid, prefix 100,000 Meter Square Identification, as:	EC832545	
Ved meldinger utover 9° nord, syd eller 18° aust, vest. skal også soneområde angis:					
O ROSTEN	34WEC832545		If reporting beyond 9°N-S or 18°E-W, prefix Grid Zone Designation, as:	34WEC832545	

Målestokk, Scale 1:50 000

1 1/2 0 1 2 3 4 5 Km

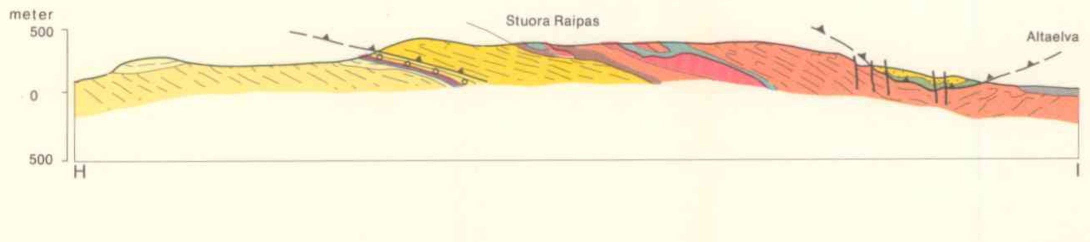


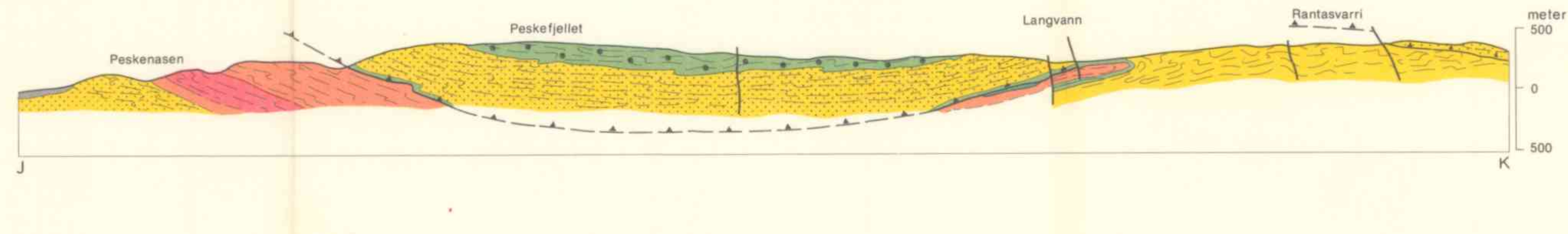




KARTBLADINNDELING
Location diagram

1835 III	1835 II	1935 III
1834 IV	1834 I	1934 IV
1834 III	1834 II	1934 III





Tor Søyland-Hansen
Avec les amitiés
d'un co-auteur
André M. Gautier

Kartgrunnlag : Norges geografiske oppmålings kart etter tillatelse
Reprografi : Norges geologiske undersøkelse - 1973
Trykk : Nordenfjelske Lito A/S - 1973
Forlag : Universitetsforlaget

Geochronology of the Alta - Kvaenangen Window rocks (northern Norway).

André GAUTIER, Fazil GULACAR and Michel DELALOYE,
Mineralogy Department, University of Geneva, Switzerland.

RESUME

Une approche géochronométrique par la méthode K-Ar a été tentée sur les roches vertes de la fenêtre tectonique d'Alta-Kvaenangen en Norvège septentrionale. Ces roches ont livré des âges minimum compris entre 1400 et 1500 m.a. confirmant l'âge Précambrien de ces séries ophiolitiques.

1. INTRODUCTION

Precambrian terranes of Northern Norway are not well known particularly from the geochronological point of view. Many factors contribute to this fact. Among them, the lack of fossiliferous formations and an uncomplete knowledge of the geological evolution can be pointed out.

The mapping of the area known as the Alta-Kvaenangen Window (Zwaan et al. 1973; Gautier 1977) has been carried out by one of us (A.G.) during four sommers from 1971 to 1975. In the same time, samples of pillow lavas and metadiabases have been collected to be dated by radiometric methods. We present here the results of this work.

2. GEOLOGICAL SETTING

The geological frame of the Alta-Kvaenangen Window is the following:

- a Precambrian basement, the Raipas Group, with an overlaying sedimentary Eo-Cambrian cover, the Bossekop and Borras Groups, occur in a window below the Caldeonide nappes.

- The Raipas Group is 2000 to 2500 meters thick and can be divided in two sub-groups: the Lower and Upper Raipas (Holtedahl et al., 1960). The Lower Raipas Group shows intrusive as well as ocean floor-type metavolcanic rocks of basaltic composition with a spilitic trend. They are interbedded with tuffs, clays and dolomites. Locally ultramafic bodies have been incorporated tectonically to this assemblage which is metamorphosed in the greenschist facies.

- The Upper Raipas Group consists of the Skoadduvarri sandstones and the Luovusvarri sandstones and dolomites (Gautier 1977 and unpublished data).

- As fossils are absent, the stratigraphic and tectonic relations between the different formations described above have been established in using the polarity criteria of pillow lavas and of sedimentary structures such as ripple-marks, gradded bedding, etc.

On a general point of view, the tectonic style of the area is characterized by large isoclinal foldings and of thrust sheets. Major vertical faults cut across the whole window.

The Bossekop and Borras Groups of the overlying cover (Føyn, 1964) are composed mainly of quartzites, schists and tillites.

The Caledonide nappes of Norway rest over this basement and its cover.

3. TYPES OF ROCKS USED FOR DATING

Radiometric dating by the Potassium-Argon method has been carried out on three different types of ignous rocks from the Lower Raipas Group: pillow lavas, fine grained metadiabases and coarse grained metadiabases. The chemical composition of these rocks is given in table 1.

3.1. Pillow lavas

Field evidence shows bona fide pillow lavas which are not or only slightly deformed. Their typical texture is well recognizable; a rim of chloritic material followed by a thin variolitic sheet and an important amygdulitic zone of intersertal structure are typical. Plagioclase has an acicular habit and the matrix is made mostly of actinolite and chlorite. Chlorite is less aboundant toward the center of the pillows where epidote and leucoxene are also present.

3.2. Metadiabases

The structure of these rocks is ophitic or intersertal but is usually erated by the secondary development of metamorphic minerals.

The major mineral assemblages observed are the following:
albite - augite - epidote - chlorite - leucoxene $\pm$ actinolite $\pm$ biotite.
albite - ouralite - leucoxene $\pm$ hornblende
albite - actinolite - epidote - leucoxene $\pm$ chlorite.
It is evident from petrographic studies that the fine grained diabases were more affected by the metamorphism than the coarse grained rocks. Primary minerals like augite are found only in coarse grained samples.

3.3. Tuffs

Tuffs having the same bulk composition than the diabases are common in the Window. These rocks have a relatively high specific gravity (2.86 to 2.94) but show clearly cross beddings and other sedimentary features.

4. EXPERIMENTAL PROCEDURES

4.1. Potassium-Argon method

Radiometric dating using the K-Ar method has been used extensively in this study.

Potassium has been determined by flame photometry or by X-Ray fluorescence spectrometry, while argon composition has been measured by isotopic dilution using an AEI MS10 mass spectrometer. The ^{38}Ar spike is from Schumacher, Bern (purity 99.99%). The decay constant used is $\lambda = 5.544 \cdot 10^{-10}\ y^{-1}$. Analytical procedure as well as statistical data on error calculations are described in Delaloye et al. 1974.

Potassium content of rocks with less than 0.1% K_2O has been measured by isotopic dilution on a mass spectrometer. This procedure increases the accuracy so that the ages obtained of these rocks have also a significance.

The spike used in this technique is prepared with enriched KCl (^{39}K = 61.10%, ^{40}K = 35.71%, ^{41}K = 3.18%) from Oak Ridge Laboratories. 100 to 300 mg of rock is digested by 1 ml $HClO_4$ conc. and 3 ml HF 40% in a Teflon bomb during 24 hours at 110°C. A known weight of spike is added before the acid attack. The ratio weight of sample versus weight of spike is calculated in order to have on the mass spectrometer a ratio $^{40}K/^{41}K$ close to one.

The isotopic analysis is carried out on an Atlas-Bremen CH4 mass spectrometer. A tantalum thermoionisation filament is used. The isotopic ratios of K are measured for 6 different temperatures of the filament. At each temperature 10 swipes are registred. The accuracy on the K content varies between 0.3 and 0.6%. The blank of the overall procedure gives a K content of 0.288 μ g.

4.2. Rubidium - Strontium Method

An assay has been made with this method on the same samples used for the K-Ar age determinations. The rubidium concentration was very low (< 2 ppm) on all measured samples from this area and while on the contrary the strontium content was relatively high (> 100 ppm). This unfavourable ratio introduces an analytical error which is very large, so we cannot attribute much significance ot the Rb-Sr calculated ages.

5. DISCUSSION OF THE RESULTS

The rocks of the Alta-Kvaenangen Window have low potassium concentrations which strongly limit the choice of the samples for K-Ar dating purposes. It was also impossible to carry out mineral separations because of the ophitic texture: metamorphic minerals are inclosed within primary minerals. Consequently only whole rocks have been analysed.

5.1. Pillow Lavas

Radiometric ages obtained for the lavas (Table 2) are spread over a very large period of time. The explanation has to be found in the various stages of alteration which must have caused possible loss of argon in variable amounts. The alteration is visible under the microscope. Some kind of a plateau at 1200 m.y. as it is shown in Fig. 1. points probably toward a maximum apparent age for the pillow lavas as the samples no KA-820 to KA-823 are less altered than the others.

5.2. Fine grained metadiabases

Except for the samples no KA-579 (2509 m.y.) and no KA-748 (1947 m.y.), the ages of the fine grained metadiabases are grouped between 640 and 840 m.y.. It is possible that these diabases were rejuvenated under the green-schist facies metamorphic conditions. It seems that the loss of radiogenic argon has been more or less homogeneous for most of the different outcrops of fine-grained diabases. Sample no KA-579 seems to us to be without any statistical significance. Sample no KA-748 comes from a typical columnar basalt flow from Middavarre. Its granulometry is intermediate between coarse and fine-grained diabase. In the coarse-grained group, the 1900 m.y. age obtained on this flow would fit better with other samples, particularly no KA-749.

5.3. Coarse-grained metadiabases

It seems clear, as shown by the petrographic observations that the coarse grained diabases are less altered than the other rock-types. They show a cluster of ages between 1300 and 1500 m.y. in spite of the fact that they have also undergone a certain metamorphism. As pointed out above, the age of about 1990 m.y. appears twice. This suggest that 2000 m.y. is the true age of these formations but we have no other evidence to verify this hypothesis.

6. CONCLUSIONS

Field evidence shows that coarse grained diabases are interbedded with pillow lavas, tuffs and also fine grained metadiabases. Consequently these rocks must have approximately the same age. From the table 2, we see that the coarse grained diabases yields the oldest ages. A possible explanation of our results is that the pillow lavas and the fine grained metadiabases were strongly rejuvenated by the greenschist facies metamorphism. The coarse grained diabases in contrast, resisted better to the same metamorphism lossing much less radiogenic argon.

As a general conclusion, it is possible to say that the ignous rocks of the Alta-Kvaenangen Window have a minimum age of 1400 to 1500 m.y. so that they are probably of Middle Proterozoic age. A formation age of 1800 to 2000 m.y. according to some of our data is also probable.

Acknowledgments

We thank A/S Sulitjelma Gruber and Elkem Spigerverket A/S for permission to publish these results and the Swiss National Foundation for financial assistance.

Critical reading of the text and helpfull suggestions have been made by Professor Roger Laurent, Laval University, Quebec.

Delaloye, M. and Wagner, J.J. 1974: Potassium-Argon Dating: an automatic equipment with digital output for computer processing.
C.R. Soc. Phys. Hist. nat. Genève, 9, 66-74.

Føyn, S. 1964: Den tillittførende formasjonsgruppe i Alta-en jevnføring med Øst-Finnmark og med indre Finnmark.
Nor. Geol. Unders. 288, 139-150.

Gautier, A. 1977: Géologie de la fenêtre précambrienne d'Alta-Kvaenangen (partie NE), W-Finnmark, Laponie norvégienne.
Thèse no 1740, Université de Genève.

Holtedahl, O. et al. 1960: Geology of Norway.
Nor. Geol. Unders., 208.

Zwaan, K.B., Gautier, A.M., Føyn, S. and Ryghaug, P. 1973: Berggrunnskart Alta 1834 I (M:1/50.000).
Nor. Geol. Unders.

Table 1. Chemical analyses of dated samples

KA	573	576	583	820	821	822	823	560	572	575	579	580
	PILLOW LAVA							FINE GRAINED METADIABASES				
SiO_2	52.33	42.37		48.92	49.48	45.93	46.79	50.45	50.31	49.81	47.97	
TiO_2	1.13	2.14		0.96	0.95	1.03	0.97	1.24	1.28	1.34	1.54	
Al_2O_3	12.45	14.18		11.96	11.94	14.19	12.51	11.30	13.18	13.01	13.84	
Fe_2O_3	4.30	6.20		2.55	2.40	2.92	3.08	3.05	4.21	3.70	6.09	
FeO	9.48	14.03		9.97	9.81	10.64	11.00	7.25	8.22	9.41	8.33	
MnO	0.23	0.50		0.19	0.19	0.26	0.28	0.14	0.19	0.20	0.23	
MgO	6.64	7.05		9.82	9.61	9.81	10.63	5.89	6.38	8.05	6.72	
CaO	6.87	5.36		9.32	8.50	8.89	9.23	10.30	11.16	9.30	8.23	
Na_2O	4.32	3.25		2.23	2.72	1.60	0.90	1.86	2.18	2.01	3.31	
K_2O	0.03	0.01	0.15	0.01	0.01	0.06	0.03	0.17	0.17	0.76	0.02	1.38
P_2O_5	0.09	0.18		0.14	0.15	0.17	0.17	0.10	0.13	0.13	0.13	
H_2O^+	3.10	6.12		3.25	3.25	3.83	3.57	3.71	2.96	3.57	3.96	
CO_2	0.05	0.32		0.39	0.51	0.21	0.21	3.50	0.21	0.00	0.08	
SOMME	101.02	101.71		99.71	99.52	99.54	99.37	99.05	100.58	101.29	100.45	

KA	581	744	748	559	574	578	582	743	745	747	749	746
	FINE	GRAINED	M.		COARSE	GRAINED		METADIABASES				TUFF
SiO_2		46.60	47.33	48.83	48.52	49.70		49.11	47.11	49.06	49.14	45.69
TiO_2		1.47	1.05	1.31	2.09	1.81		0.95	1.40	1.33	1.08	1.15
Al_2O_3		14.18	12.43	13.74	11.52	11.83		13.39	13.66	12.39	14.04	13.75
Fe_2O_3		3.42	2.50	3.56	5.09	11.18		3.13	3.79	3.51	3.30	4.54
FeO		11.51	7.95	8.99	11.20	6.86		11.39	11.66	11.36	9.77	9.22
MnO		0.22	0.22	0.20	0.22	0.11		0.29	0.28	0.20	0.22	0.18
MgO		6.84	13.19	6.97	5.28	6.18		6.02	6.43	6.42	6.82	5.03
CaO		8.24	13.37	10.89	10.59	4.49		8.92	10.35	8.90	10.11	11.34
Na_2O		3.80	0.16	2.11	1.57	4.94		2.77	2.26	2.76	2.13	2.52
K_2O	0.70	0.37	0.10	0.61	0.06	1.15	0.32	0.40	0.10	0.64	0.11	0.13
P_2O_5		0.19	0.16	0.12	0.19	0.17		0.18	0.16	0.19	0.13	0.15
H_2O^+		3.63	1.62	3.27	3.68	2.08		2.43	2.15	2.64	2.60	3.54
CO_2		0.19	0.46	0.00	0.17	0.16		0.23	0.29	0.16	0.10	2.97
SOMME		100.66	100.54	100.60	100.18	100.66		99.21	99.64	99.56	99.55	100.21

Table 2. Potassium-Argon Data and Age Results

No	Rock type/location	% K[1]	% Ar^{40}_{rad}	Ar^{40}_{rad} moles/g	Age (m.y.)
Pillow lava					
KA-573	EC 661595	0.0399	64.1	$0.501\cdot10^{-10}$	600 ± 80
576	EC 796581	0.0578	81.3	$0.186\cdot10^{-10}$	172 ± 12
583	EC 797622	0.1308	87.9	$0.259\cdot10^{-9}$	872 ± 61
820	rim } EC 462531	0.0580	77.8	$0.183\cdot10^{-9}$	1257 ± 58
821	core } EC 462531	0.0874	85.0	$0.214\cdot10^{-9}$	1043 ± 81
822	rim } EC 342541	0.2000	90.6	$0.470\cdot10^{-9}$	1011 ± 38
823	core } EC 342541	0.1270	89.8	$0.268\cdot10^{-9}$	930 ± 38
Fine grained metadiabases					
KA-560	EC 813598	0.14	89.9	$0.196\cdot10^{-9}$	641 ± 22
572	EC 708616	0.18	92.8	$0.320\cdot10^{-9}$	801 ± 55
575	EC 778581	0.69	95.2	$0.115\cdot10^{-8}$	761 ± 78
579	EC 712622	0.0690	92.8	$0.645\cdot10^{-9}$	2509 ± 128
580	EC 736690	1.15	96.3	$0.181\cdot10^{-8}$	737 ± 33
581	EC 791705	0.5853	95.6	$0.110\cdot10^{-8}$	840 ± 38
744	EC 435550	0.3452	94.9	$0.481\cdot10^{-9}$	664 ± 23
748	[2] EC 461540	0.0860	94.6	$0.522\cdot10^{-9}$	1947 ± 71
Coarse grained metadiabases					
KA-559	EC 792600	0.56	97.0	$0.917\cdot10^{-9}$	746 ± 77
574	EC 797647	0.1059	78.3	$0.427\cdot10^{-9}$	1488 ± 170
578	EC 776602	0.96	99.9	$0.376\cdot10^{-8}$	1457 ± 70
582	EC 776605	0.2748	88.2	$0.106\cdot10^{-8}$	1444 ± 103
743	EC 401542	0.3351	84.0	$0.114\cdot10^{-8}$	1324 ± 141
745	EC 342552	0.1091	96.5	$0.457\cdot10^{-9}$	1533 ± 52
747	EC 409581	0.5405	92.5	$0.178\cdot10^{-8}$	1297 ± 44
749	EC 334602	0.1149	96.0	$0.724\cdot10^{-9}$	1990 ± 71
Tuff					
KA-746	EC 464533	0.1629	93.6	$0.444\cdot10^{-9}$	1130 ± 40

[1] K values with 4 digits were determined by isotopic dilution and values with 2 digits by flame photometry.

[2] Columnar basalt of Middavarre.

ALTA-KVÆNANGEN PRECAMBRIAN WINDOW

GEOLOGICAL MAP, SIMPLIFIED AFTER GAUTIER A.M. (1973 AND UNPUBLISHED DATA).