CAMBRIDGE UNIVERSITY GEOLOGICAL EXPEDITION

SPITSBERGEN '96

EXPEDITION AND SCIENTIFIC REPORTS

Approved by Cambridge Expedition Committee
Registered Charity Number : 311460

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SPITSBERGEN 96

INTRODUCTION

Spitsbergen is the largest island of the Svalbard archipelago which is located at 80°N. The island has an area of 390,000 km^2 and the landscape is dominated by fjords, mountains and glaciers. The periglacial environment and lack of vegetation make it a very suitable place for geology fieldwork.

The primary aim of Spitsbergen 96 was to undertake a 2 month geological mapping project of a transect across an orogenic belt in west Spitsbergen. Detailed work in this area is important to determine the relative movements of Europe and North America 60 Ma (million years) ago when the North Atlantic started to open. In addition, detailed knowledge of the geological structures and sediments in the area may help identify potential oil reservoirs in the Barents Sea, to the south of Spitsbergen.

From an early stage in the planning we discussed the aims of the project with relevant organisations (especially the Norsk Polarinstitutt and Cambridge Arctic Shelf Project) in order that the results would be of use to the scientific world. Although the work was based upon the requirements of Douglas's Part II Geological Mapping Project, we set out the project so that the work would be of use to contacts we had made.

This report is divided into three sections. The first section is a record of the planning, fundraising, and logistics involved, with appendices giving further details of contacts and full expedition accounts. The second is a narrative account of our time in the field. The last section is the detailed report from the scientific work that was undertaken.

EXPEDITION TEAM

It was decided early on to have a small expedition team and although this created more work for us during the planning stages, it dramatically reduced the amount of money that we had to raise.

Douglas Paton : (Leader) Queens' College, Cambridge. Third year geologist.
Laura Robinson : (Medical Officer) Pembroke College, Cambridge. Second year geologist.

LOCATION OF FIELD AREA

The area was a 15 km^2 area along Kongressdalen to the west of Grønfjorden, and is shown in 'Section C : Sedimentary Facies and Tectonics'. The nearest settlement was at the manned telecommunications radio station at Kappe Linne, 8 km to the north west. The nearest town was the Russian mining town of Barentsburg which was on the other side of Grønfjorden.

CAMBRIDGE UNIVERSITY
GEOLOGICAL EXPEDITION

SPITSBERGEN '96

SECTION A : PLANNING, FUNDRAISING AND LOGISTICS

By Douglas Paton

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SECTION A : PLANNING, FUNDRAISING AND LOGISTICS

1 : PLANNING

Our original idea was to carry out a geological expedition to Greenland. However we soon realised that this was going to be too expensive and logistically too difficult to arrange in 8 months, and the 'easy' option of Spitsbergen was chosen.

Contacts were quickly made with geologists who had carried out extensive work in Spitsbergen both in Britain and Norway. A list of contacts is in Appendix 1, but the principle ones were Cambridge Arctic Shelf Project (CASP), and Norsk Polarinstitutt (NPI). They were able to suggest an area which was both ideal for a mapping project, and useful to furthering the geological knowledge of Spitsbergen.

2 : PERMISSION

Under the Svalbard Treaty, any European or Russian national has the right to visit and carryout scientific work in Spitsbergen. However, Norway is tightening the rules, and although permission is not officially required, any expedition must inform the governor (Sysslemannen) of their plans, and we contacted him about 5 moths before going.

3 : SAFETY

As with field work anywhere in the world there are always potential dangers, and most of them are either solved, or even better prevented, by common sense. There were two specific problems we were aware of in Spitsbergen. The first was working in an isolated field area in a cold and inhospitable place, three hour's boat ride from Longyearbyen. This problem was reduced because we had a radio and knew that we were only a 15 minute helicopter trip form the nearest hospital. The second problem was polar bears. Although we never saw any, we still took all the correct precautions. In particular it is imperative to carry a rifle in the field at all times, to use bear trip wires connected to flares around the tents, to be very careful about storing and cooking food away from sleeping tents, and burn all food waste. We obtained safety details from the Sysslemannen.

We also had two first aid kits : A full expedition kit obtained from the Community Health Centre, University of Cambridge, and a small one which was always carried in the field.

4 : INSURANCE

We obtained a Sun Alliance travel policy with added cover for equipment.

5 : FUNDRAISING

During the time that we were making contacts and defining the aims of the expedition, we were also fund-raising, which was in done in two ways. The first was to produce a small prospectus (double sided A4) which was aimed at the general public and gave a brief overview of the expedition. We were able to get a local printer (Kall Kwik, Cambridge) to print these and headed paper for us. Approximately 200 were made and sent off to numerous charities, grant giving bodies and companies, and the response, although not wonderful, was reasonable and was generally small gifts of £50-100. Secondly we produced a full scientific proposal and 20 were sent to oil companies in the UK and Norway with an active interest in the geology of Spitsbergen. The response, however, was disappointing. Most companies replied saying that as our work was not directly related to their current projects they could not give us money. We did receive some money from oil companies but these were generally through specific mapping project sponsorships (e.g. Mobil and B.P.) In all cases, especially with oil companies, you need to 'sell' them something that they want. These scientific proposals were also sent off to specific charities for example the Gino Watkins Fund at the Scott Polar Institute, Gilchrest Educational Trust, Royal Geographical Society.

6 : EQUIPMENT

Early contact was made with the logistics managers at CASP and NPI, and over a few moths a list of exactly what was needed for every possible incident was made.
We already had a reasonable amount of equipment, and as the area we were going to was relatively tame in comparison to the rest of Spitsbergen, we did not too much extra. We hired equipment such as radios, bear flares, and Primus Stoves from NPI. Rifles were rented from Ing. Paulsen in Longyearbyen.

7 : FOOD

As Spitsbergen is Norwegian, it is very expensive and we therefore had to buy all our food in Britain and freight it up. We decided to save time and buy pre-boxed ex-army food rations rather than making up our own.

In total we took enough food for 110 man days and we spent 45 days in the field. This gave us enough spare if we had had problems such as bad weather delaying us or polar bears or foxes getting into the boxes. The mistake we did make was buying food for the first week from the supermarket in Longyearbyen which was expensive and we should have taken enough for then.

8 : TRANSPORT

Organising flights caused some problems. The first problem was getting the cheapest flight. We contacted about five travel agents and they all came up with different costings and flight arrangements. When we came to book the tickets we found that they had all made mistakes and the cheapest way to do it was an SAS flight from Heathrow to Oslo, followed by a Braathens SAFE flight from Oslo to Tromso to Longyearbyen. This was the cheapest deal we could get, although it still cost £650 each. The second problem was trying to get the correct dates. Spitsbergen is a popular place for tourist groups and the flights can be booked up very quickly and although we booked the flights in April and we were luck to get seats.

We tried to arrange transport to the field from Britain but we found the travel agents in Longyearbyen were unhelpful, so we had to wait until we got there. Our easiest way of getting into the field area was to get a tourist boat round to Barentsburg and then get a small dingy (Zodiack) across the fjord. Unfortunately we had to wait a week before we could get into the field. Part of the reason for this delay was that one of the travel agents was going to charge us £400 for the round trip whereas the other company (S.P.I.T.R.A.) was charging £200, so we had to wait for the cheaper boat.

For equipment and food there were two options, either to send it by air or sea. The air freight took four days to get there compared with at least four weeks for shipping, but is also considerably more expensive. However, we were able to get a company to sponsor us. They paid for the air-freighting and we had no problems at all.

9 : AERIAL PHOTOGRAPHS AND MAPS

As we were carrying out detailed mapping on a scale of 1:12,500, we needed good base maps. However, the best topographic maps were 1:100,000 and were suitable for general work but frequently made accurate work difficult. The maps were from the Norsk Polarinstitutt in Oslo. We enlarged the 1:100,000 to 1:12,500 and then traced the enlargement to reduce the line size. This was then photocopied onto card

and used as the base maps onto which the mapping was done. We also obtained 1:20,000 aerial photographs from NPI at a cost of £9. These were excellent quality and there is coverage of the whole of Spitsbergen in black and white. There is also now coverage in colour and infra-red. We did not order the photographs until mid-June, and we were very luck to get them two days before leaving Britain. Without them, the project could have fallen through.
The problem we had with the photographs was that we were unsure of the exact area so we got two photographs that just overlapped so that they would cover as wide an are as possible. However, because of distortion around the edges it was difficult to match them up which occasionally caused problems.

10 : ACKNOWLEDGEMENTS

Firstly, we would like to thank all organisations and companies that donated money (as listed in Accounts).
On the logistics aspect, Mr Russel Paterson (CASP), Mr Nick Cox (NERC), Mr Olsen and all at NPI, Longyearbyen, The Royal Geographic Society Advisor Centre, Scott Polar Institute, Joy Engineering for freighting our equipment, Kall Kwik, Cambridge for our printing.

The scientific side was viable because of the help from : Dr Peter Friend and Dr Brian Harland of the Department of Earth Sciences, Cambridge; Dr David MacDonald (CASP); Dr Dallmann Norsk Polarinstitutt Oslo, Dr Stuart Paton, Dr Judith Bunbury, Dr Braathens (University of Oslo), Dr L. Craig.

Thanks must also go to CUETC and many friends in Cambridge for giving us the much needed support, in particular Helen Bostock, Ian Burfield, Tom Edwards, Chloe Harford, Isabel Isherwood, Mr and Mrs Paton, Rob Pople, Mr and Mrs Robinson, Chin Whybrew, and Jake Willis.

Finally, special thanks to Gustav and everybody else at Isfjord Radio Station, without whom our stay in Kongressdalen would have been a cold, hungry and smelly one.

11 : CONTACT ADDRESS

Douglas Paton, Meikle Bein, Barrie Avenue, Larkhall, Lanarkshire ML9 1DB.
Tel. : 01698 881387

APPENEDIX 1 : LIST OF CONTACTS

Cambridge Arctic Shelf Project, Madingley Rise, Cambridge. Tel. 01223 337100
Russel Paterson (Logistics) is very good to discuss general logistics with, costs etc.
Dr. David MacDonald (Head Geologist) has extensive field work experience,

British Schools Expedition Society, based at the RGS. Have a trip upto Spitsbergen about 2-3 years contact them to find out if they are going.

Department of Earth Sciences. Cambridge University, Downing Street, Cambridge. Tel. 01223 333400. Dr Peter Friend has extensive fieldwork experience in Spitsbergen and Greenland.

John Hand Foods Tel. 01903 784414, Fax 01903 772707. Provided ex army rations for £1.75 per man day

Norsk Polarinstitutt. :
Oslo : (Fax: +47 22 95 95 01) Dr Dallmann, Chief Geologist; Bjorn Bastard, Aerial Photographs

Longyearbyen : Logistics unit (FAX: +47 79 02 15 61).

Royal Geographic Society, Kensington London.
Very good for reports of previous work in Spitsbergen and infact anywhere. Of special interest is Lorainne Craig (many years geology experience). Also funding and support.

Scott Polar Research Institute, Lensfield Road, Cambridge. Tel. 01223 336540.

Svalbard Safari, Longyearbyen (also known as Ing. Paulsen) fax +47 79 02 18 10 for rifle rental.

Sysslemannen (Governor of Spitsbergen), Longyearbyen (FAX: +47 79 02 11 66): Must be contacted for permission.

There is a University in Longyearbyen called UNIS which deals with Polar geology, geophysics, biology.

APPENDIX 2 : EXPEDITION ACCOUNTS

CREDIT	
Mobil North Sea Ltd	600
Amerada Hess	100
CoScan	100
HSG	50
Gino Watkins	400
Cambridge Expeditions Fund	400
Marr Memorial Fund	50
B.P.	250
Pembroke College	250
University of Cambridge Vacations Grant	450
Personal Contributions	700
Devon Charity	50
Equipment Sale	510
TOTAL	3910

DEBIT	
Pre Expedition	
International Flights	1300
Equipment	1000
Insurance	150
Medical	70
Administration	100
Food	300
Photographic	40
Aerial Photographs	40
Expedition	
Boat	200
Accommodation	40
Food	120
Equipment Rental	440
Post-expedition	
Photographic	50
Administration	60
TOTAL	3910

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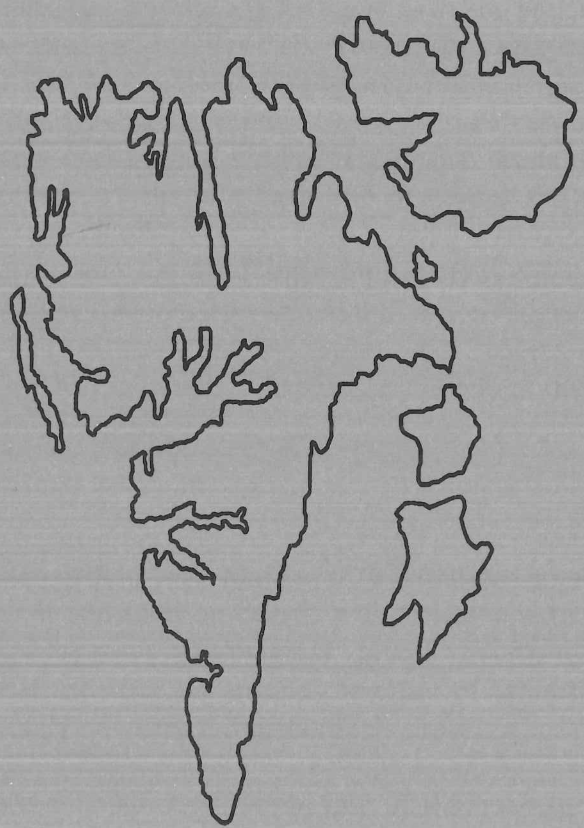

SPITSBERGEN '96

SECTION B : LIFE IN THE FIELD

By Laura Robinson

Approved by Cambridge Expedition Committee
Registered Charity Number : 311460

SECTION B : LIFE IN THE FIELD

Spitsbergen 1996 : 11th July - 31st August

11.7.96

Our route to Longyearbyen, the main Norwegian town in Spitsbergen, took place in three separate parts; Heathrow to Oslo, Oslo to Tromso, Tromso to Longyearbyen - the temperature at each stage rapidly decreasing and the people becoming more ruggedly dressed.

A first view of Longyearbyen was of a grey town - the road between the airport and centre of town is a trail of old and new coal-mining works, coal-heaps, seemingly derelict machinery and overhead cables. In stark contrast to this is a backdrop of Isfjord and the distant stunning snow-capped mountains.

Organisation of transport into the field enforced a week's wait on us; during this time we visited the museum, partook of seal-steaks and sorted out various logistical tasks. Our freight has safely arrived at the Norsk Polar Institutt. We hired rifles (762 Calibre) - this is a legal requirement for all expeditions enforced by the Governor. Despite precautions of this nature, several people are killed each year by polar bears.

18.7.96

A tourist boat - The Langøsund- was to take us to Grønfjord so at 9.15am we went down to the Quay to load our equipment and food on board. A little later the tourists arrived - mainly rich Norwegians who regard Spitsbergen as a "magical" place, which must be visited at least once during your lifetime. The boat trip took us around the coast of Isfjord in order to see the "bird-mountains", huge cliffs absolutely covered in Spitsbergen's breeding species.

Approaching Grønfjord, we had our first glimpse of Barentsberg, the Russian mining town, opposite which we would be camping, It is a town which by comparison makes Longyearbyen seem a colourful and lively place. The fjord had a huge gale blowing straight up it and the weather was dull, not what we had hoped for to camp in for six weeks. The tourists were dropped off at Barentsberg whilst the Langosund took us across the fjord. We were taken to the shore in a `Zodiac` rubber dinghy and watched as the Langosund took its passengers back to Longyearbyen.

Our first task was to find a suitable base camp. A decision had to be made as to which side of the river we should camp, and then a fairly sheltered spot of, hopefully, a smooth surface found. We chose well, our base camp was excellent. Our decision made, we turned to find the tide rapidly advancing on our equipment and hence the task of load carrying began.The tents were erected, the bear flares set up and the radio system put in place, all in time to make the first of our daily radio contacts with NPI. Most expeditions take advantage of this service, which enables you to report back on any problems and receive a weather report for the next day, as well as the important part of being able to speak to someone else each day....!

23.7.96

Several days into the field work we had a routine, which remained throughout the expedition

8am: Alarm - Doug makes breakfast of rolled oats and chocolate.

9am: Set off into the field carrying safety equipment including rifles, bear flares, and survival bags. We would work in approximately the same area for safety. Spending a day virtually isolated in such a wilderness is an amazing experience, it provides unique opportunities to think undisturbed, to observe the wildlife - abundant flowers which spring into life every summer as soon as the snow and ice melts; waders such as sandpipers and dunlins which follow you about singing, and the small herds of reindeer bearing beautiful velvety antlers.

1pm: Lunchtime - biscuits brown, pate, chocolate and biscuits fruit, standard army fare.

2pm: Work continues....

4-6pm: Return to base camp, washing in glacial melt river, tea, diary writing, project writing.

7pm: Laura cooks supper, usually something similar to reconstituted mashed potato, chicken supreme and peas, quite delicious!

9pm: Radio contact.

9.30pm: Rubbish burning, and other miscellaneous activities.

25.7.96

By this stage we decided we deserved a 'summer holiday'. Destination - Kapp Linne Radio Station. We had no idea what to expect and so set off on a six hour walk across the peninsula. We passed two lakes, Kongressvatnet and Linnevatnet, and some spectacular mountains. The hospitality we received was fantastic. We were invited in for dinner, absolutely delicious food, allowed to use the showers, and camped on the smooth ground out by the buildings. There are three people manning the station full time, Gustav, Jan and Gunner.

They receive all telecommunications for Spitsbergen and also run a tourist operation. People are helicoptered in either for an afternoon or to stay and see the beauty of the area.
We were sad to leave the next morning but were invited back, an offer which we took up twice more. On the second visit Gustav took us around to Barentsberg on his boat in order to look around the town. It was as grey and drab as it appeared from a distance, a truly depressing place. Most of the women and children were sent back to Russia two years ago as it was `uneconomical ` to keep them in the Arctic.

The men were left to work in the mine. They are not paid whilst on their contracts, but have their wages transferred to Moscow accounts. By the time they arrive home inflation has rendered it almost worthless. Nevertheless they are glad to have a house and food, a sobering thought to us when we got fed up with army rations.

31.7.96

We were told about three Russians stationed at "Van Posten" about three hours walk up the next valley from ours. We decided to pay them a visit to find out what they were doing. They live in a dingy hut all year round and seem to spend their time watching television and drinking vodka....We had become complacent about communication - all the Norwegian people spoke perfect English - however the Russians and us had only a smattering of German in common - conversation was thus a little limited! We discovered that they are supervising Barentsberg's supply of electricity which is generated by the lake and then sent via cables running beneath Grønfjord. Vascilli, the man in charge, had been there for seven years, and has not seen his wife or daughters for over two years.

15.8.96

Fieldwork suddenly became a little harder - blizzards during the night brought us drifts of over a metre high! The scenery was transformed - from dull greens, greys and browns, everything was fresh and white, contrasting with areas from which the snow had been blown. It was still possible to work as most of the gullies were still relatively well exposed. It did however make walking into the field area more tiring, particularly as boggy patches became indistinguishable. The snow melted withen a few days. However it gave us an indication of how it looks in the winter months when it is possible to ride from Longyearbyen to Kapp Linne by snow-mobile, over the frozen fjords and snow covered valleys.

28.8.96

By now all the fieldwork was completed - only packing up remained.....typically it rained heavily all day, making it a very difficult task. Rubbbish and ashes had to be boxed carefully - nothing can be left or buried as the permafrost brings everything to the surface within a few days - and the temperatures prevent biodegration.Our main tasks involved load carrying back down to the shore, moving stones from around the tents to the original positions and dismantling the radiomast. In the morning we completed our clearing up, leaving the site exactly as we found it. We then sat down to wait for the arrival of the Langøsund - full of fear that it may not arrive....at last it did - the Zodiac picked us up and we were on our way home!

The captain of the boat gave us the tragic news of a huge Aeroflot air-disaster - an aeroplane returning to Longyearbyen from Moscow crashed as it descended to land - killing everybody. The tourist boat had still come, but the visit was shortened, and we left with visions of the Russian people weeping by the Quayside.

29.8.96

Spitsbergen was a very sad place - we still had a week to go and did not wish to remain in Longyearbyen so we managed to bring our flights forward to Saturday 31st.

We spent our last two days returning equipment and....socialising....something we had almost forgotten about! We knew members of several other expeditions and were able to swap stories about our experiences - everyone having their own opinion about how they had found Spitsbergen.

Personally I found it a compelling place - one to which I will certainly return later in my life.

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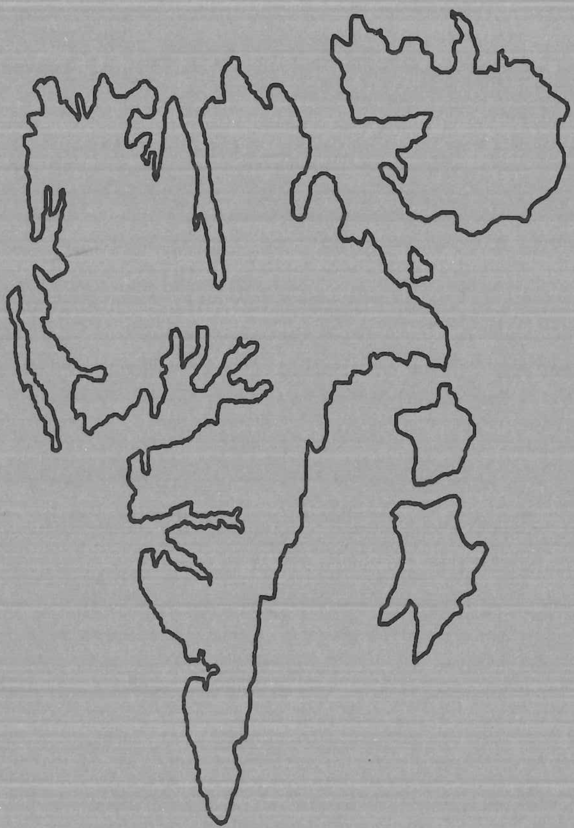


SPITSBERGEN '96

SECTION C : SCIENTIFIC REPORT

Sedimentary Facies and Tectonics of Kongressdalen,
West Spitsbergen.

By Douglas Paton

Approved by Cambridge Expedition Committee
Registered Charity Number : 311460

ABSTRACT

The study area is a 15 km^2 area to the west of Grønfjorden, West Spitsbergen and forms a transect across part of the Tertiary West Spitsbergen fold and thrust belt. .

There is an almost complete sedimentary record of marine and fluvial deposits from the middle Carboniferous to late Cretaceous, with limited Upper Jurassic - Lower Cretaceous doleritic intrusions.

The area has been extensively glaciated.

Thrusting and folding is common in the area with folds wavelengths ranging from centimetres to 400m.

I have shown that :

- Change in sedimentary facies in the area is driven by global sea level changes in a subsiding basin setting.
- There was north-east south-west shortening with limited north - south shortening.

CONTENTS

INTRODUCTION

Attention has recently been focused on Spitsbergen by Lyberis et al (e.g. 1993) who dispute the transpressive nature of the West Spitsbergen fold and thrust belt which is associated with the De Geer Fault Zone. The origin of the thrust belt as a transpressive orogeny during the opening of the North Atlantic and indeed the direction of compression have been called into question. This study examines the Kongressdalen, an area of 15 km^2 which forms a transect across most of the orogenic belt. There is excellent exposure, due to glaciation, of continuous marine and terrestrial sediments from Permian to Cretaceous, allowing detailed logging of sediments, interpretation of depositional environment; and analysis of structural features.

The study area (location shown in figure 1) was centred along the river Kongresselva and included the lake at the source of the river, Kongressvatnet, as well as the river's delta at the sea, on the west coast of Grønfjorden. The area was bounded by two mountains, Vøringen (560 m) to the north and Heftyefjellet (425 m) to the south. The field work was carried out over 33 days from a base camp on the Grønfjorden coast, and the mapping was based on 1:100,00 base topographic maps and 1:10,000 aerial photographs, both from Norsk Polarinstitutt.

Although the name Kongressdalen comes from a 1912 geology expedition along the main river in the valley, no detailed work has been carried out in this area. However, the orogenic belt as a whole has been intensively studied, in particular the Festningen section along the Isfjord coast 7 km to the north of Kongressdalen (e.g. Hoel and Orvin, 1937). Recent work has been carried out by Braathen et al (1995), and Ohta (1982), on the structural aspects, and Ohta et al (1992) on the most recent geological 1:100,000 map and overview of the west of Spitsbergen.

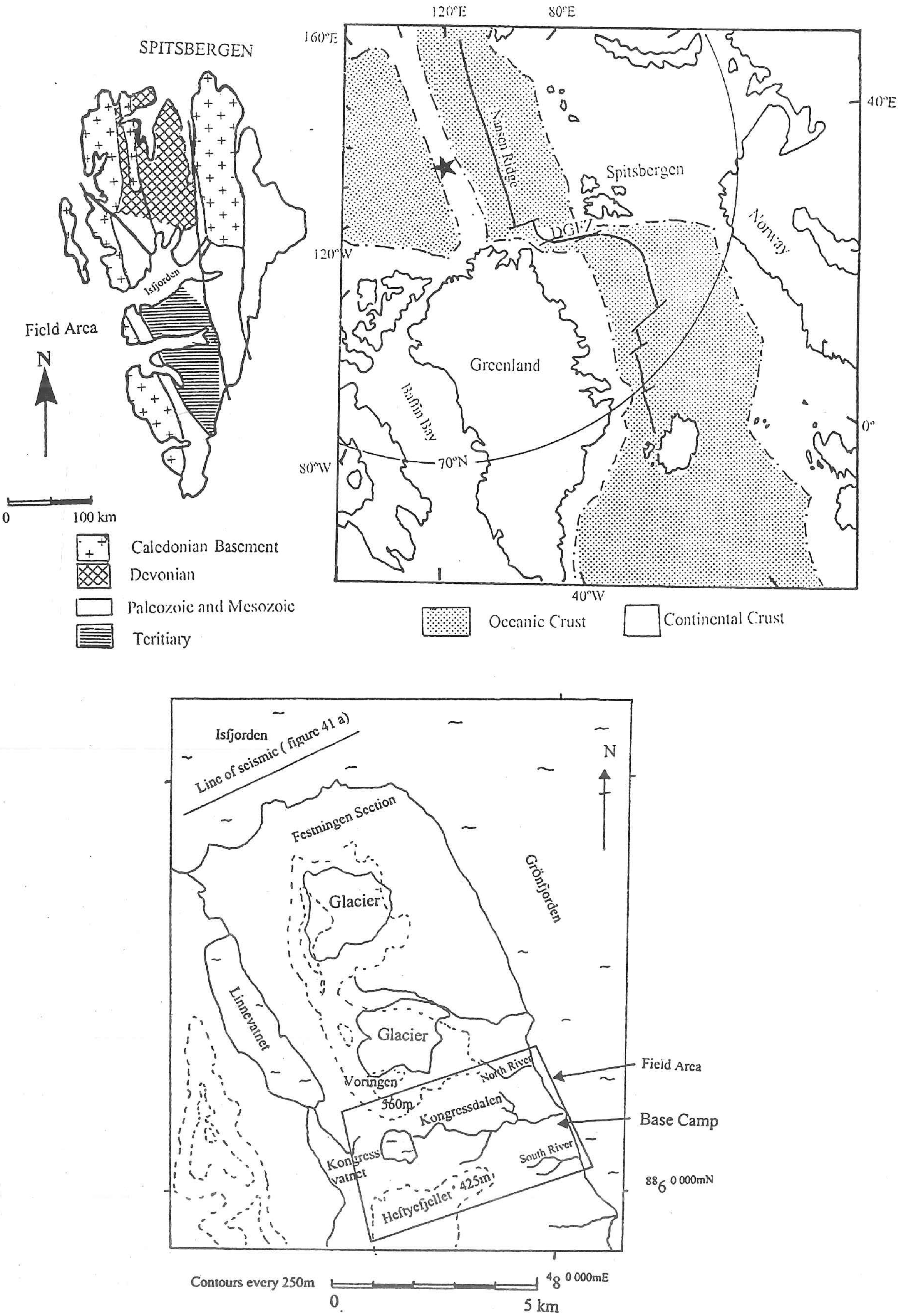


Figure 1a) : Location of Spitsbergen with respect to the North Pole (*), De Geer Fault Zone (DGFZ), North Atlantic Spreading Ridge and areas of continental and oceanic crust. b) Overview of the geology of Spitsbergen with field area marked. c) Peninsular west of Grönfjorden and south of Isfjorden. This shows the main topography, and rivers in the field area.

1 : STRATIGRAPHY

The eight sedimentary formations which range from middle Carboniferous to late Cretaceous in age are shown in figure 2. These formations are the same as those recognised by the Norsk Polarinstitutt (Ohta et al 1992), and the lithology, sedimentary structures, fossils, and depositional environment of each will be discussed separately. All logged sections are along Kongresselva except where stated, and as most outcrops were along the river, there is no discussion regarding lateral continuity except in the Janusfjellet Formation.

EPOCH	AGE		Ma	GROUP	FORMATION
CRETACEOUS	Barremian		116	ADVENTDALEN	HELVETIAFJELLET
	Hautervian		121		JANUSFJELLET
	Valanginian		128		
	Berriasian		131		
JURASSIC	Portlandian		136		
	Kimmeridgian		145		
	Oxfordian		152		
	Callovian		157		
	Bathonina		165		
	Bajocian		171		
	Aalenian		179		
	Toarcian		186	TIME OF NO DEPOSIT	
	Pliensbachian		194		
	Sinemurian		201		
	Hettangian		210		
TRIASSIC	Rhaetian		216	KAPP TOSCANA	DE GEERDALEN
	Norian		223		
	Carnian		231		
				TIME OF NO DEPOSIT	
	Ladinian		236	SASSENDALEN	BRAVISBERGET
	Ansisian		240		TVILLINGODDEN
	Scythian	Spathian	243		VARDEBUKTA
		Smithian	245		
		Dienerian	246		
		Griesbachia	250		
PERMIAN	Tatarian			TEMPLEFJORDEN	KAPP STAROSTIN
	Kazanian				
	Kungurian				
	Artinskian			GIPSDALEN	GIPSHUKEN

Figure 2 : Stratigraphic Column (From Ohta et al., 1992).

1.1 : GIPSDALEN *GROUP*

1.1.2 : GIPSHUKEN *FORMATION*

Description

The Gipshuken Formation is frequently brecciated and frost shattered, and except on the west edge of the area does not outcrop significantly. The sedimentary log, with depositional interpretation is shown in Figure 3.

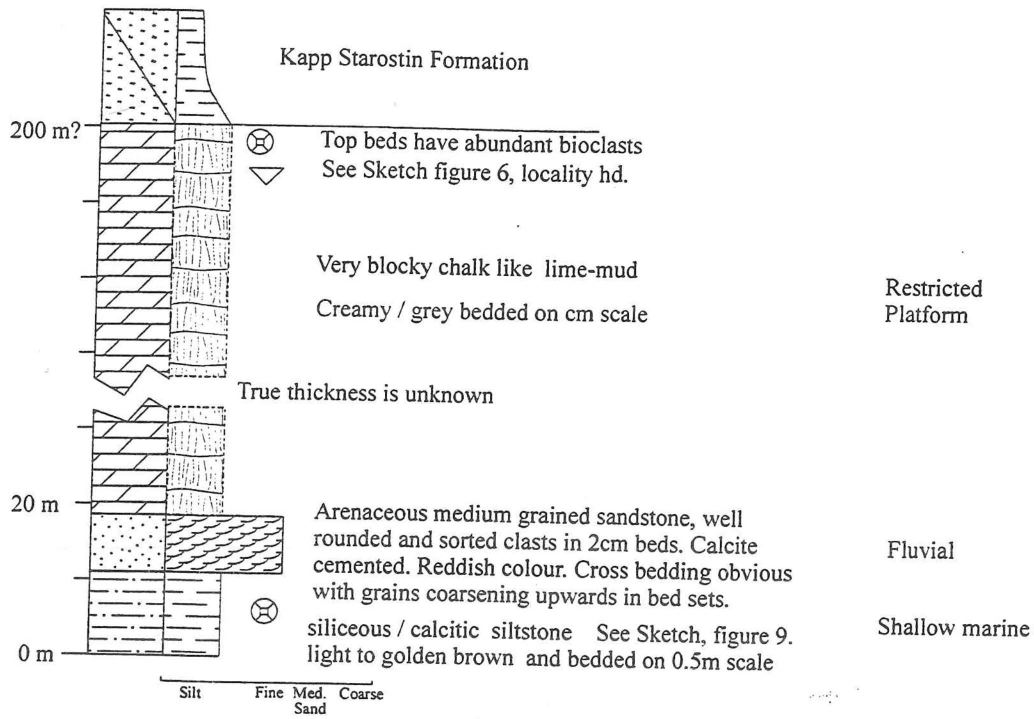


Figure 3 : Vertical Profile of the Gipshuken Formation, with depositional interpretation. Key to all logs is on pull out sheet at the back.

Its base is a fosiliferous siltstone that grades into an arenaceous, clast supported, cross bedded sandstone. The palaeocurrent vector, determined from the cross bedding, is shown in figure 4. The sandstone then grades into a grey dolomitic mud with abundant group corals (figure 5 for sketch). There is then approximately 180 m of highly brecciated white chalk like mud below a packed biomicrite bed that sits conformably below the siltstones of the Kapp Starostin Formation (figure 6 for sketch). The only sedimentary structures is soft sediment deformation in the sandstone.

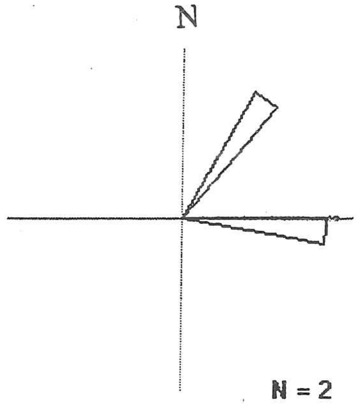
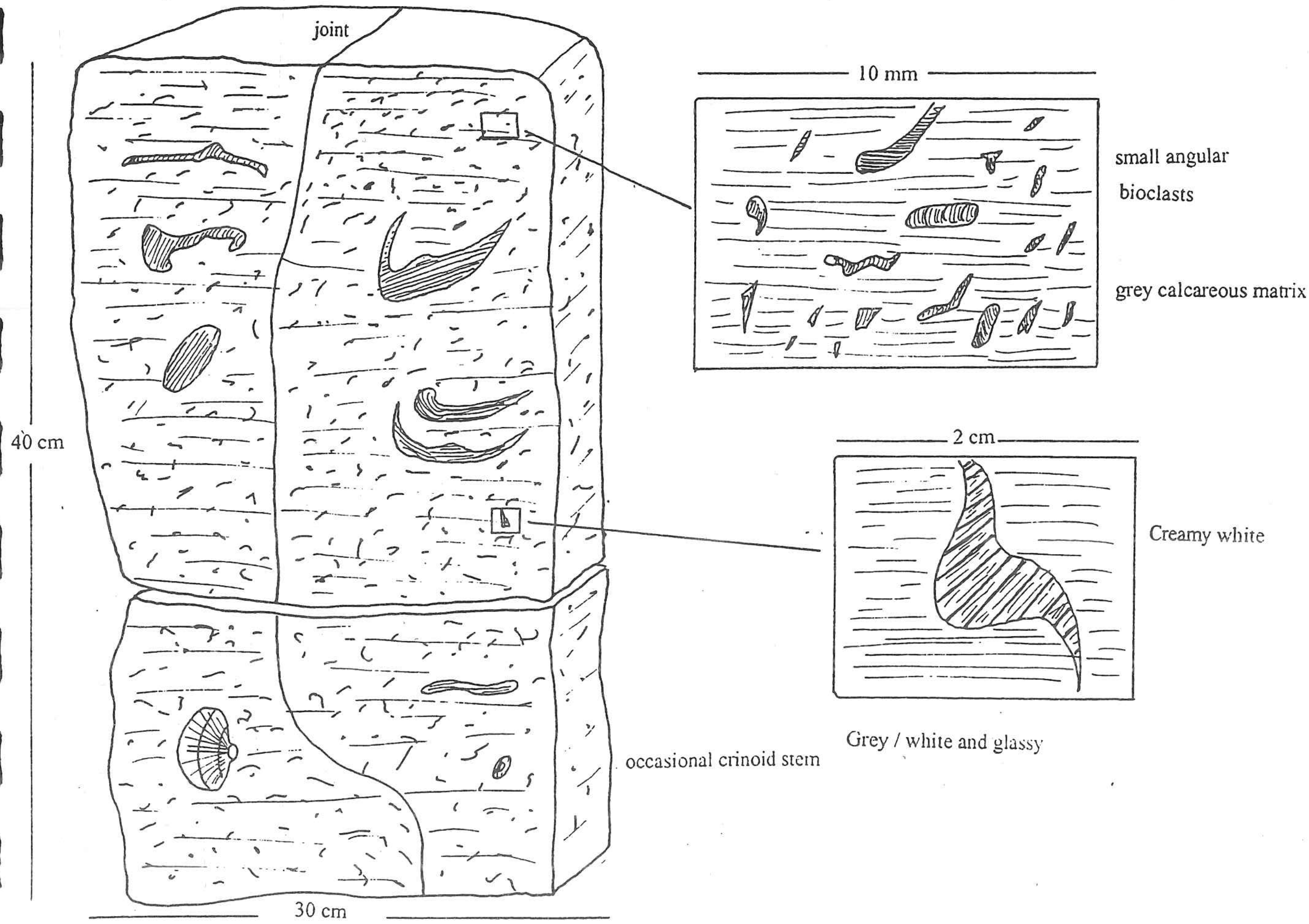


Figure 4 : Rose diagram of palaeocurrent vectors in the Gipshuken Formation which shows that current direction was towards the north east and east. The data has been adjusted to account for tectonic tilting. n=2 This is an average of the field data.

I ;ure 5 : Sketch of bioclastic lime mud in the Gipshuken Formation at locality hd. Position is also marked in the vertical profile, figure 3.



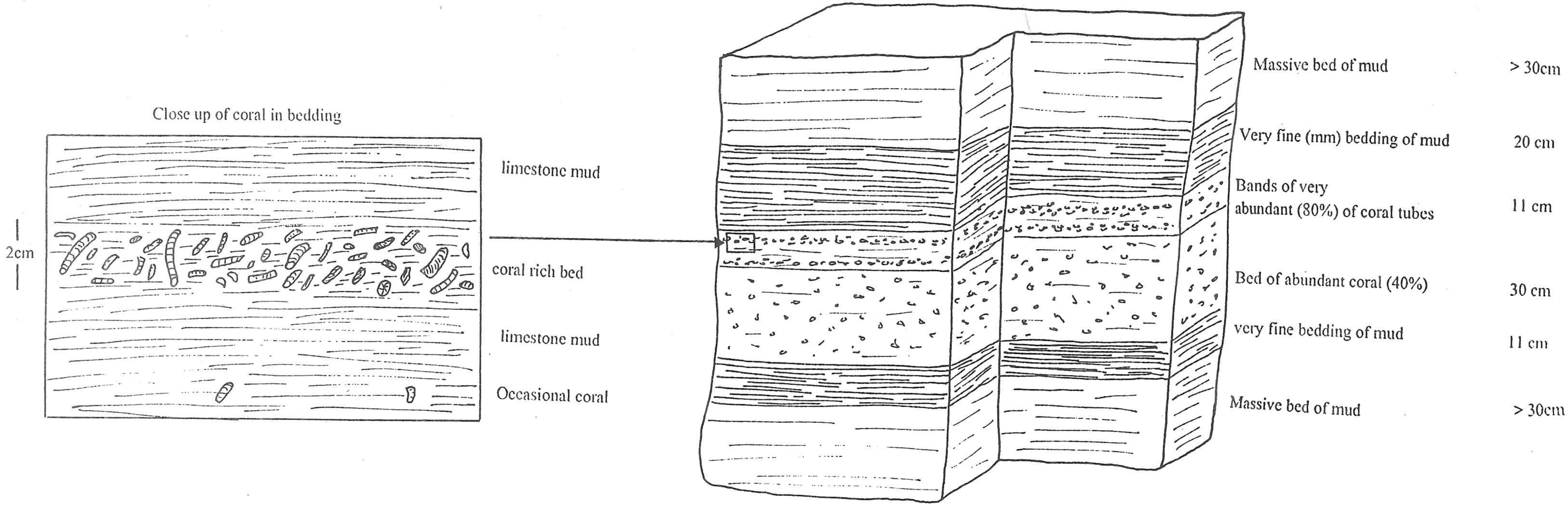


Figure 6 : Sketch of lime mud with beds of abundant coral at locality jo. Position is also marked in the vertical profile, figure 4.

Depositional Environment

The siltstones at the base are most likely to have been in a shallow marine environment because of the corals with a rapid transition to a fluvial environment because of a lack of marine fossils. It then became a restricted marine environment with the dolomitisation of limestones and anhydrite - gypsum deposits in other areas imply possibly a sabhka environment (Harland et al. 1988). At the top of the formation, there is a transition to a higher energy marine setting. Figure 7 shows a sketch of the depositional environment.

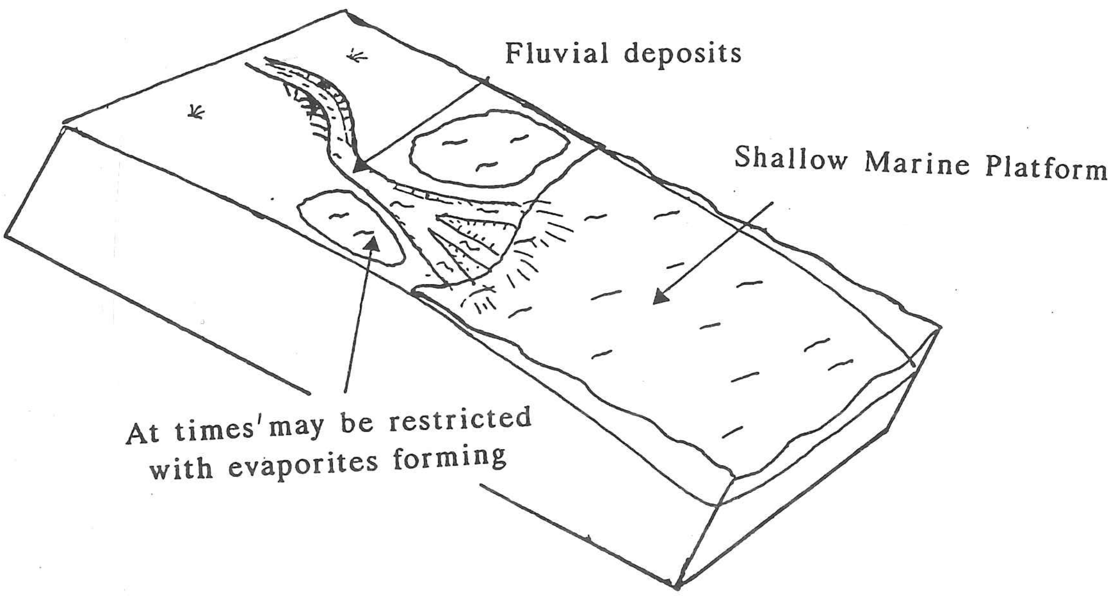


Figure 7 : Sketch of Depositional Environment of the Gipshuken Formation.

1.2 : TEMPLEFJORDEN GROUP

1.2.1 : KAPP STAROSTIN FORMATION

Throughout west Spitsbergen, the main mountain ranges are composed of the Kapp Starostin Formation, including Heftyefjellet and Vøringen in this area. Outcrop is common in the gullies and on the inaccessible north face of the ridge although it is frequently frost shattered.

Description

Figure 8 is a vertical profile of the three members of the Kapp Starostin Formation along Kongresselva, and shows the weathering nature of the rock. The Vøringen Member, which sits conformably on top of the Gipshuken Formation is a siliceous siltstone with productid (including *Horridonia spp* [1]) and occasional *Bactrynium spp* [2] brachiopod limestone beds (figure 9). The Vøringen member grades into a spiculitic chert which becomes increasingly interbedded with a limestone forming the second unit, the Svenskegga Member. This limestone is a highly abraded death assemblage of productid, spirifera and rhynchonellida brachiopods, *Fystelloporid, Fenestellid* (including *Rhomboporella spp* [3]) and *Trepostome* bryozoan and tabulate corals (Appendix 1 has a sketch of the thin section). This member grades over 5 m into the Hovtinden Member which is a spiculitic siltstone with a siliceous siltstone ontop. The siltstone has occasional limestone beds containing bryozoan (including *Cervella spp* [4])and productid and orthid (including *Pleurorthis spp* [5]) brachiopods.

Detailed lateral variation is difficult to determine because the mountain outcrops are highly frost shattered. On Heftyefjellet the three members could be determined to some extent. However, on Vøringen only a general member (Pk1) could be mapped.

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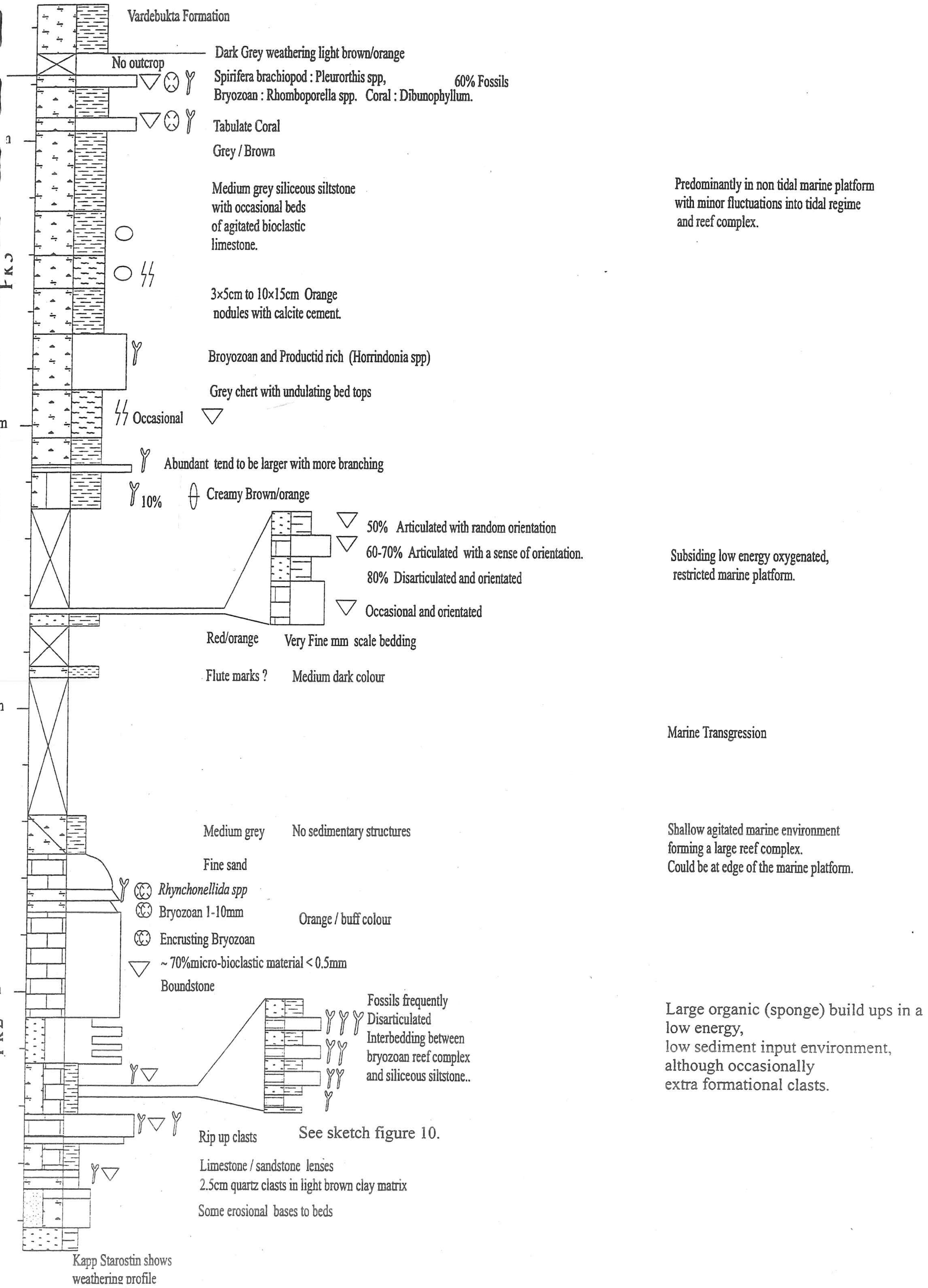
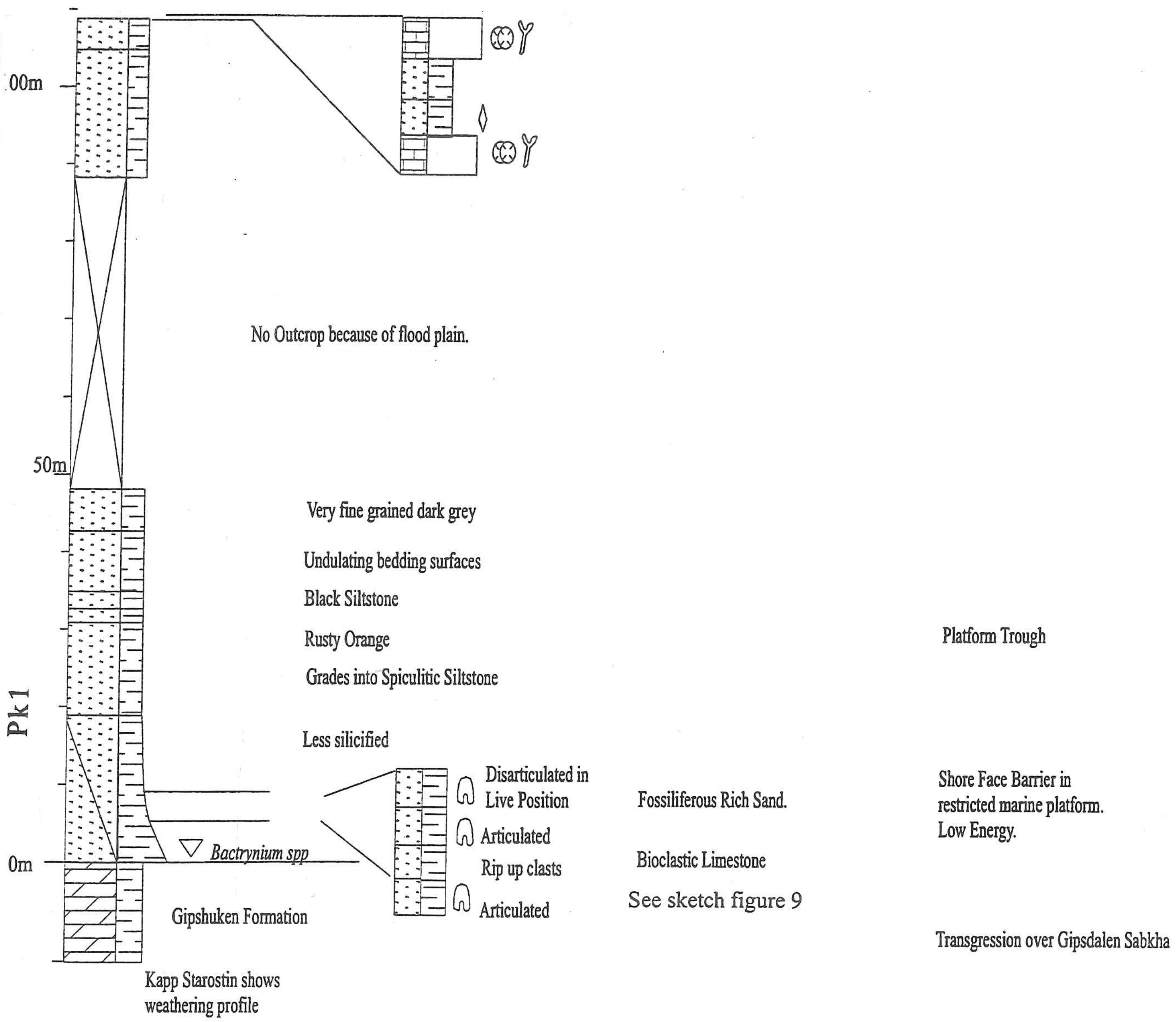
[1] Treatie on Invertebrate Paleontology H1 : Fig 371
[2] Treatie on Invertebrate Paleontology H1 : Fig 397.2
[3] Treatie on Invertebrate Paleontology G : Fig 96.3a, i-d.
[4] Treatie on Invertebrate Paleontology G : Fig 82.3a
[5] Treatie on Invertebrate Paleontology H1 : Fig 194.6a.

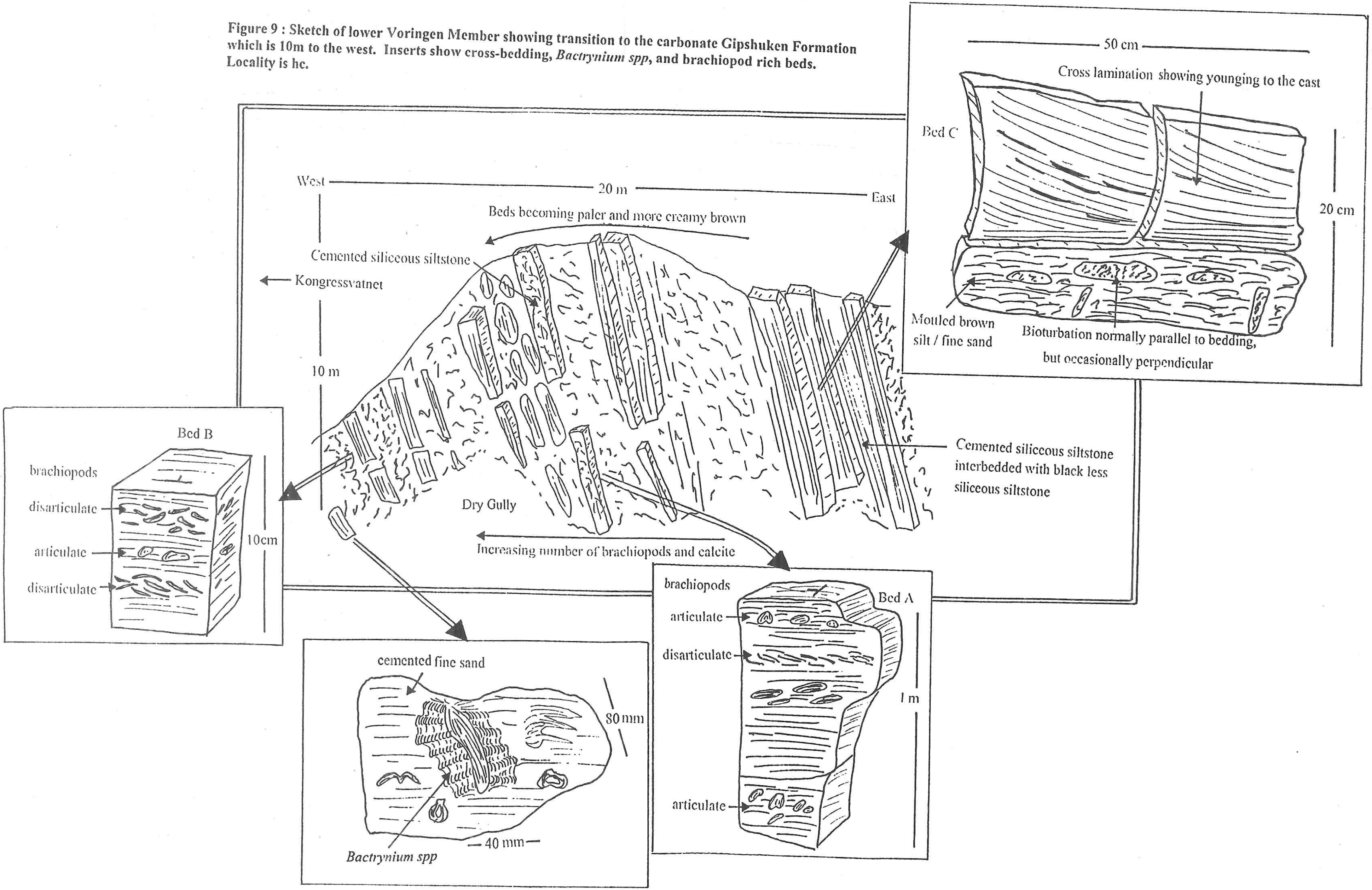
Figure 8 Vertical Profile of Kapp Starostin, with depositional interpretation





00m
50m
0m
Pk1
No Outcrop because of flood plain.
Very fine grained dark grey
Undulating bedding surfaces
Black Siltstone
Rusty Orange
Grades into Spiculitic Siltstone
Less silicified
Disarticulated in
Live Position
Articulated
Rip up clasts
Articulated
Bactrynium spp
Gipshuken Formation
Kapp Starostin shows
weathering profile
Fossiliferous Rich Sand.
Bioclastic Limestone
See sketch figure 9
Platform Trough
Shore Face Barrier in
restricted marine platform.
Low Energy.
Transgression over Gipsdalen Sabkha

Figure 9 : Sketch of lower Voringen Member showing transition to the carbonate Gipshuken Formation which is 10m to the west. Inserts show cross-bedding, *Bactrynium spp*, and brachiopod rich beds. Locality is hc.



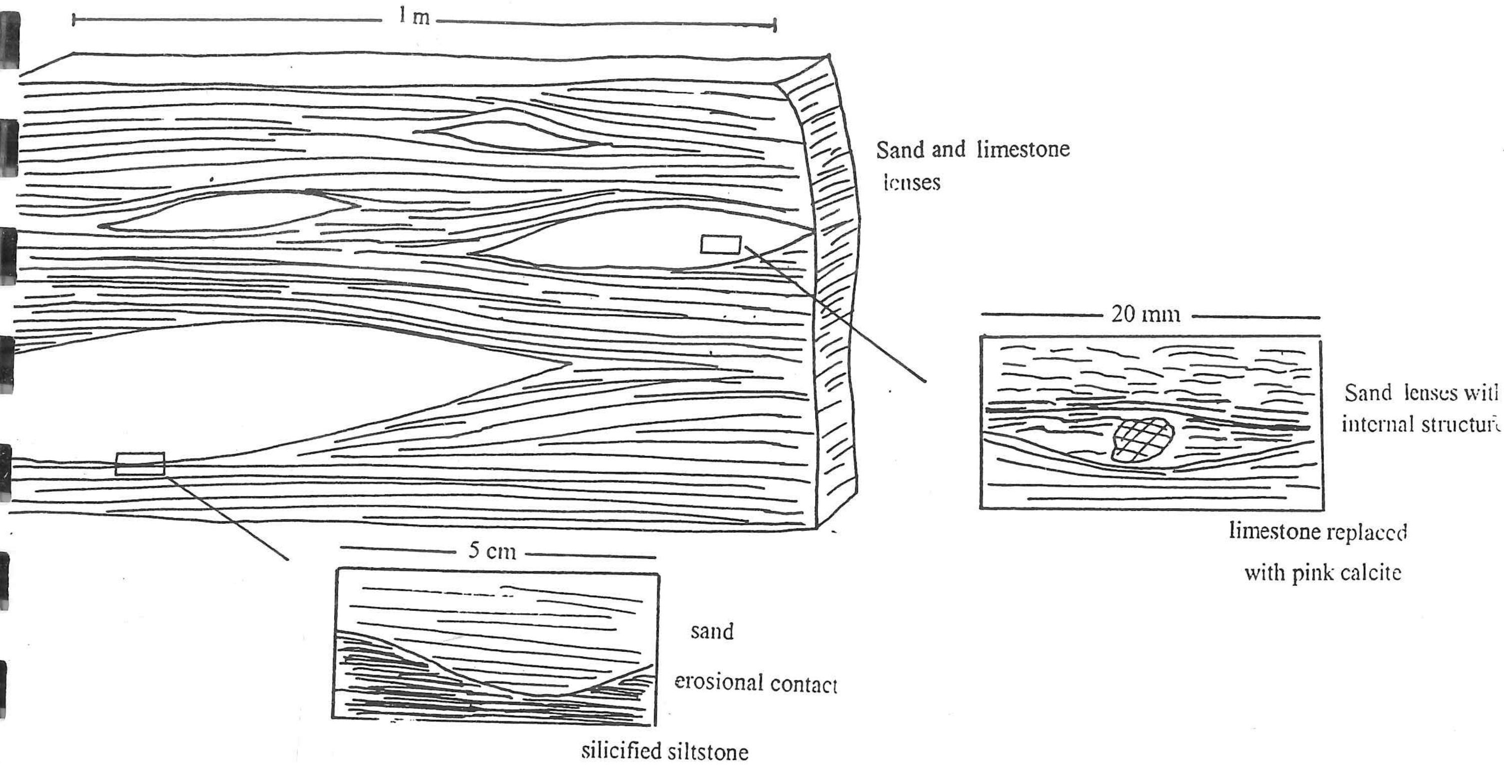


Figure 10 : Sand and Limestone lenses in siltstone in Kapp Starostin Formation. Locality fz.

Depositional Environment

The possible sabkha environment of the Gipshuken Formation changes to a shallow marine platform with the limestone forming a low energy reef which is shown by the live position of often articulated brachiopods, and productid brachiopods. The platform then becomes very suitable for sponge growth possibly in deep water (≈ 200m ?), with very low terrestrial, non-calcitic input, although occasional mud clasts are present. Fluctuations in coastal progradation are shown by interbedding of the reef complex and chert. The main bryozoan and coral framework reef complex of the Svenskegga and imprints of *Cervella spp* which imply a muddy soft substrate. A global sea level transgression and platform subsidence (Ohta et al., 1992) resulted in an oxygenated (known because of bioturbation), and low energy (known because of the abundance of articulated brachiopods) marine platform. The reef at the top of the formation consists of a harder substrate in a higher energy environment known from the orthids and spirifera respectively. Figure 11 shows sketches of the depositional environment.

1.3 SASSENDALEN GROUP

1.3.1 VARDEBUKTA FORMATION.

The Vardebukta Formation does not frequently outcrop although it is visible in Kongresselva and on top of the southern ridge.

Description

The formation consists of a general coarsening upward sequence and the vertical profile of the Vardebukta Formation is shown in figure 12. The lower unit, which sits ontop of the Kapp Starostin Formation is a non-fossiliferous, finely laminated siltstone of Griesbuchian age. This contact is gradational throughout the Isfjord area (Ohta, et al. 1992) although in this area it can only be positioned to within 10 m in the field. There is then no outcrop before thick interbedded mature quartz arenite sand and productid brachiopod rich limestone beds which show geopetal features, confirming a younging eastward of the sequence. The brachiopods in live position (figure 13 for photograph of thin section stained with Alizarin Red and potassium ferricyanide; Pink is Ferroan Calcite. Appendix 2 for sketch of thin section).

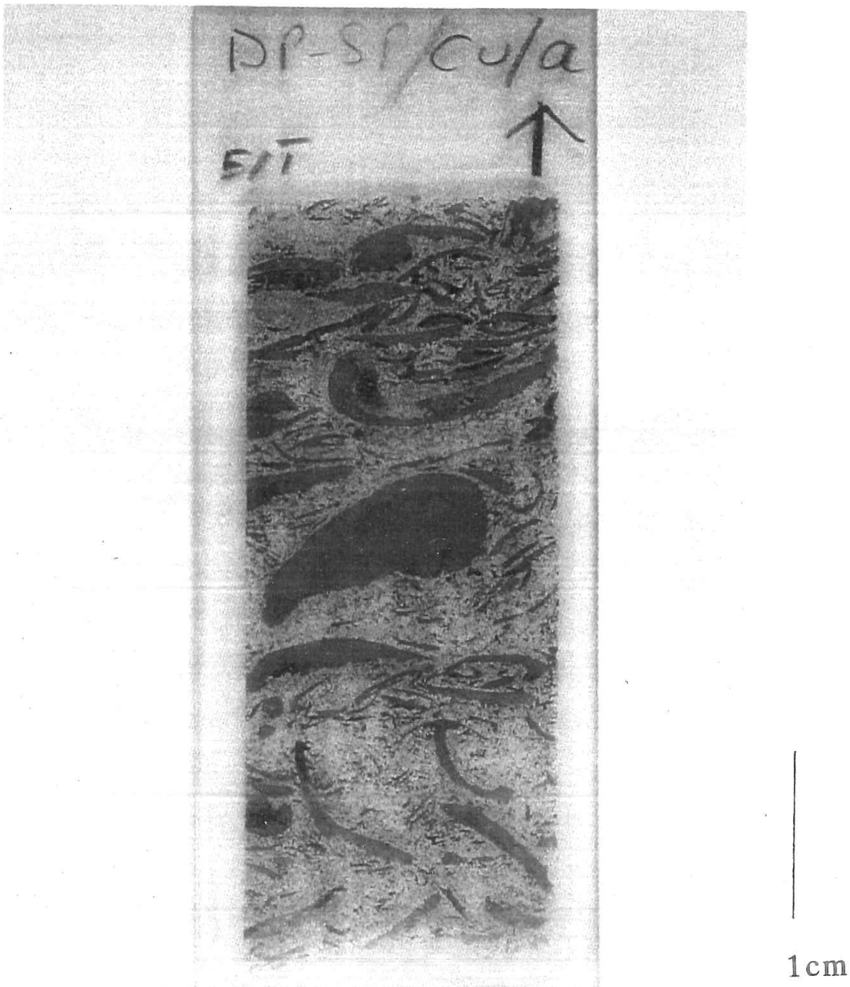


Figure 13 : Photograph of thin section of Productid rich limestone in the Vardebukta Formation

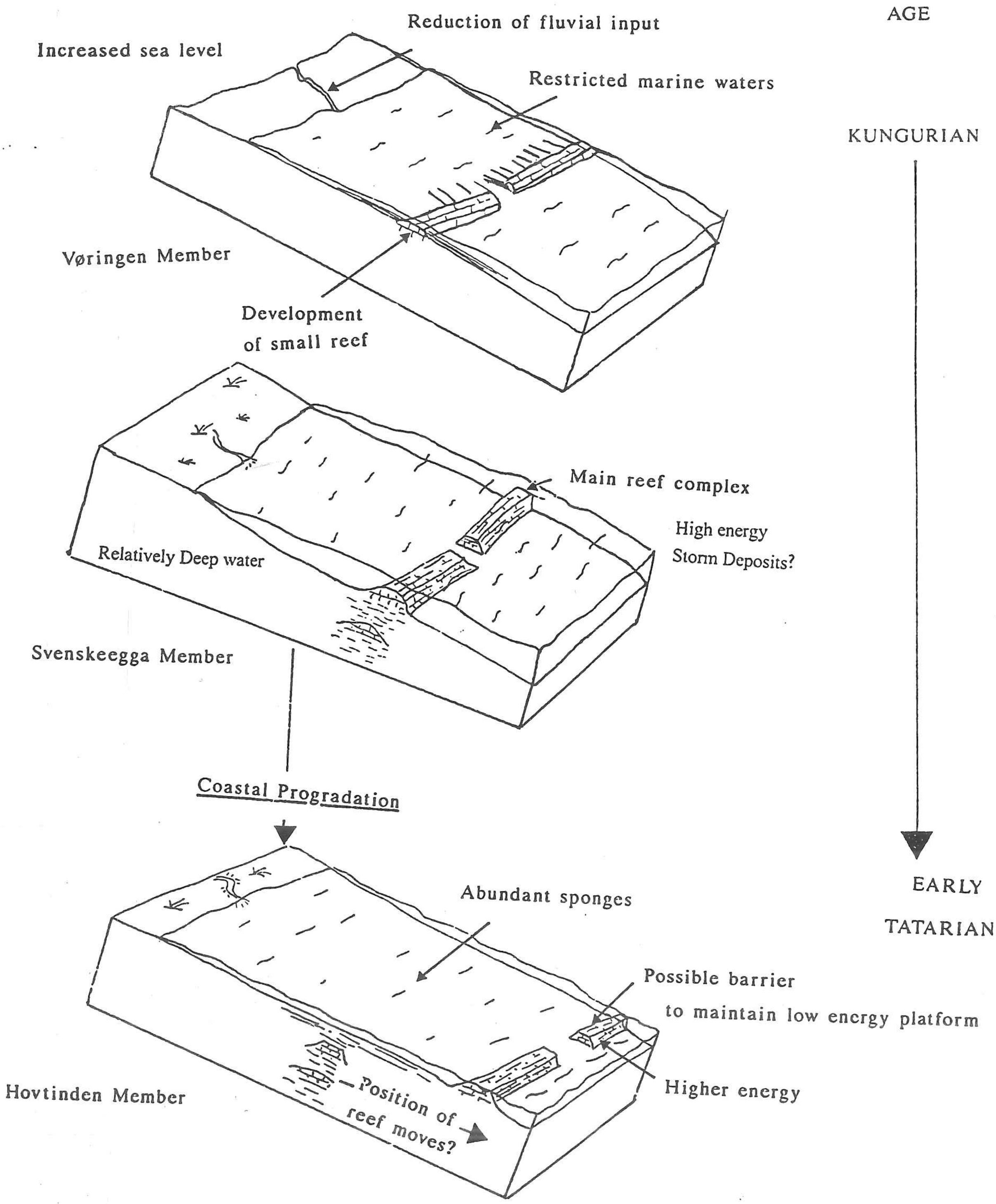
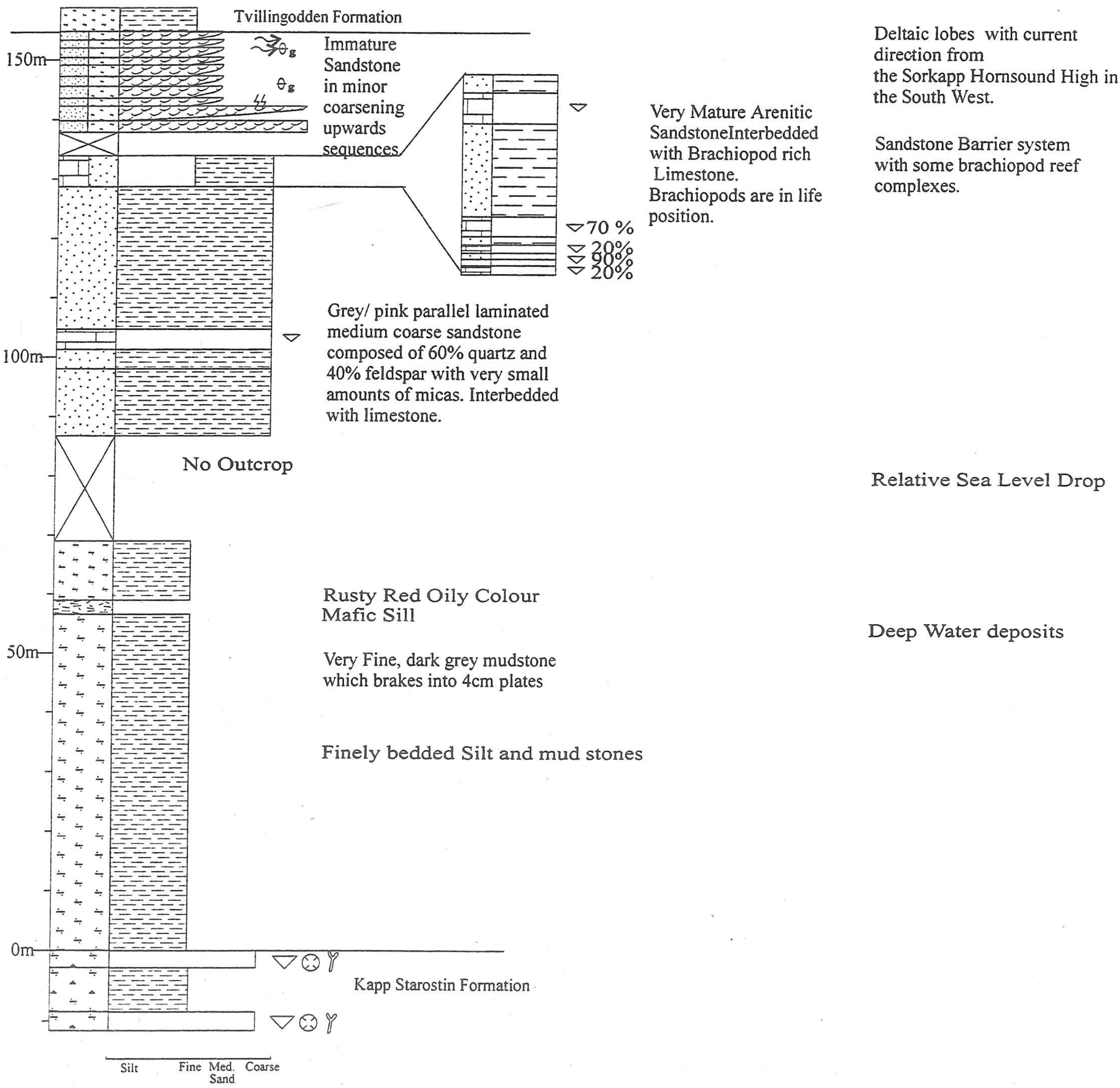


Figure 11 : Sketch of depositional environment of the Kapp Starostin Formation.

Figure 12 Vertical Profile of the Vardebukta Formation, with depositional interpretation



The top of the formation is characterised by minor 0.5 - 1m coarsening upward sequences from siltstone to a medium grained immature sand with abundant *Gyrochorte spp* trace fossils and 0.5 cm ripples (paleocurrent directions are shown in figure 14). This coarsening up is on a much finer scale compared with the general formation coarsening.

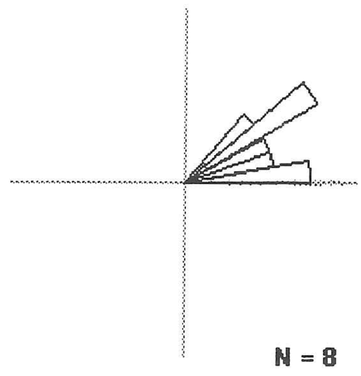


Figure 14 : Paleocurrent vectors of ripples at the top of the Vardebukta Formation showing current movement towards the north east. The data has been adjusted to account for tectonic tilting.

Depositional Environment

The non-bioturbated, parallel bedded siltstones suggest a relative sea level rise and an increase in clastic input at the Kapp Starostin and Vardebukta Formation transition. The upper Vardebukta Formation indicates thick mass sand deposits interbedded with in-situ low energy brachiopod bioherms. This unit is most likely to be a barrier system connected with a sea level drop.

The immature, small scale coarsening upward sequences of the top of the formation are most likely to be locally sourced deltaic lobes. Palaeocurrents indicate they are sourced from the south-west. Figure 12 shows sketches of depositional environment.

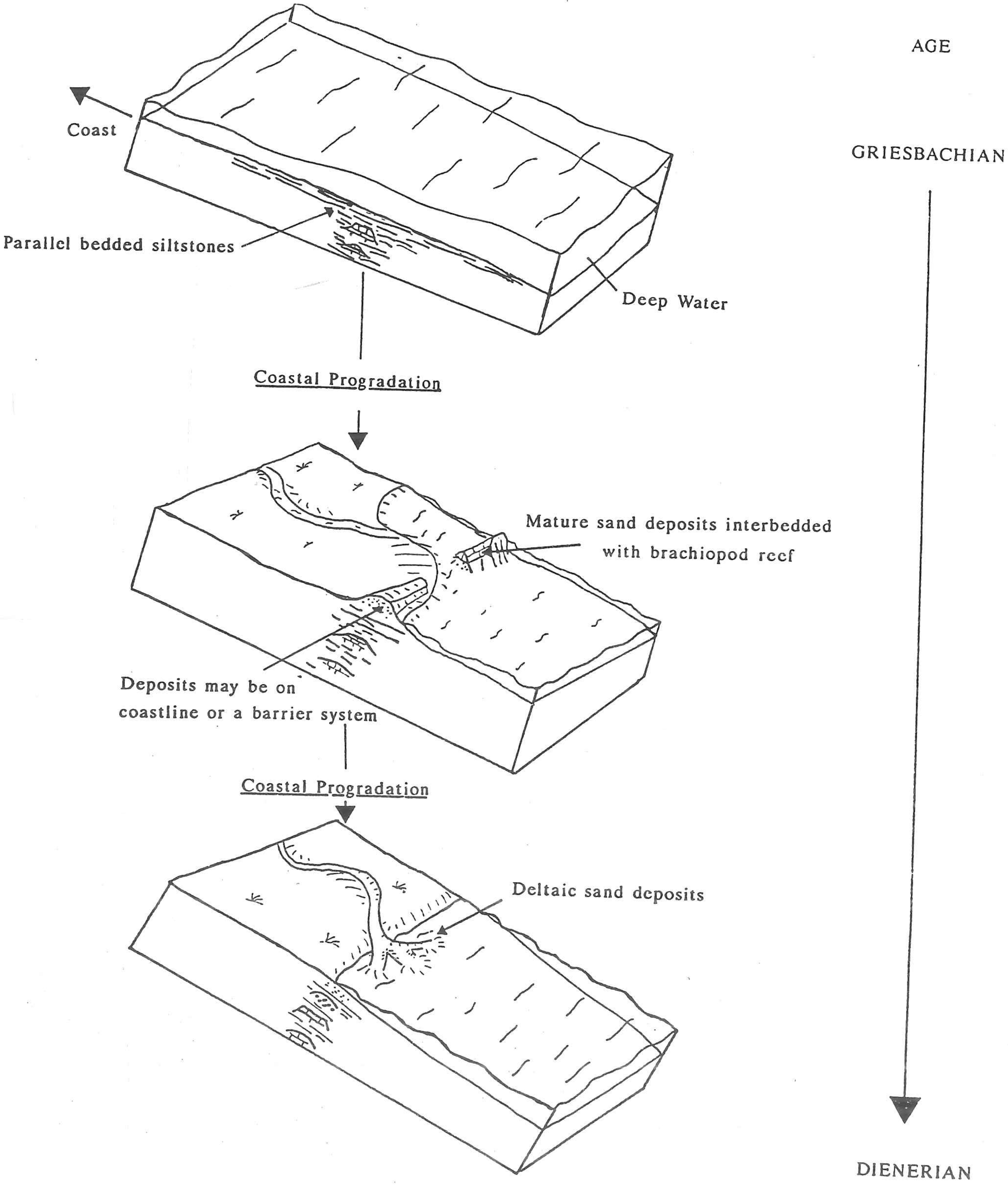


Figure 15 : Sketch of the Depositional Environment of the Vardebukta Formation

1.3.2 : TVILLINGODDEN FORMATION

As with the Vardebukta Formation, there is little outcrop except in Kongresselva and along the ridge, although the strike of beds is clearly visible in the tundra from high vantage points and especially aerial photographs. The formation also outcrops in the crags to the east of the Southern ridge.

Description

There is a 5 m transition from the conformable contact of the Vardebukta Formation to the laminated siltstones of the lower Tvillingodden Formation. (see Figure 16 for log). Overlying is a 50 m thick transition to cross bedded mature arkosic sandstones. Above sits a siltstone unit which is tectonically brecciated but appears to be coarsening upwards. After a section of no outcrop in Kongresselva, there is a 40 m thick cemented arenitic cross bedding sandstone, followed by three fining up sequences. The paleocurrent data for the cross bedding is shown in Figure 17. On top of the fining up sequences sits medium grained arkosic sandstones which contain abundant undifferentiated trace fossils.

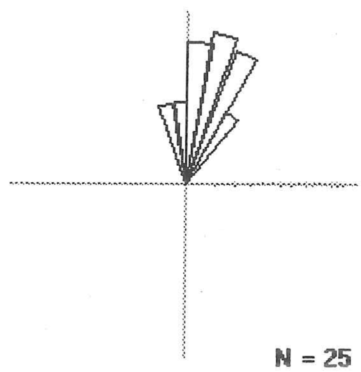
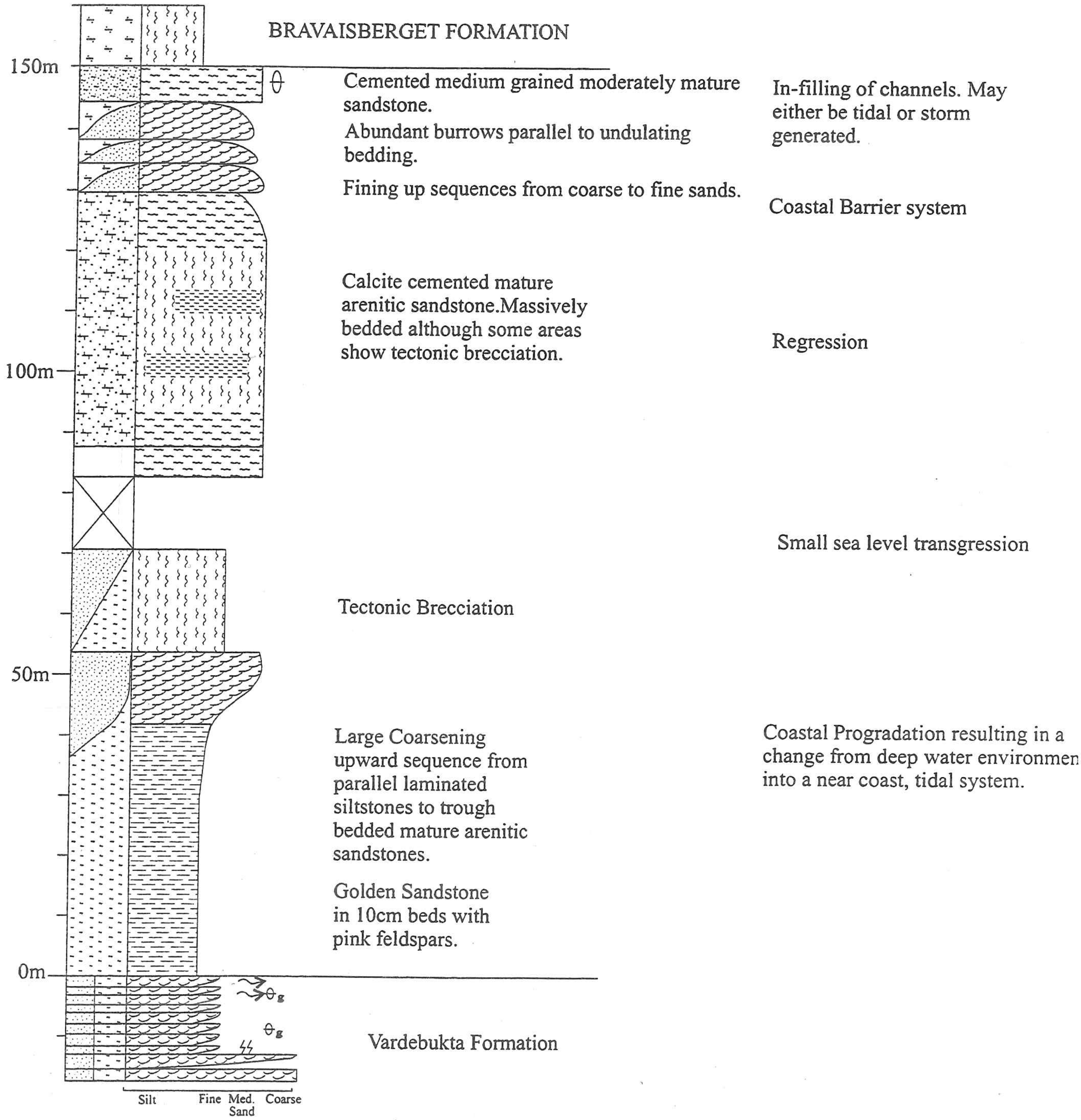


Figure 17 : Paleocurrent vectors at the top of the Tvillingodden Formation, showing current direction towards the north east. The data has been adjusted to account for tectonic tilting.

Figure 16 Vertical Profile of the Tvillingodden Formation, with depositional interpretation.



Depositional Environment

Despite the lack of outcrop in the middle of the sequence, it is possible to make out two major coarsening upward sequences which may be attributed to two sea level regressions with a rapid transgression in-between. The two deposition sequences do differ: the first regression ends in a inter-tidal environment with wave ripples, while the second is more like a barrier system and possibly storm related. The fining up section is most likely to be channel infills which are probably either tidal or storm generated. Figure 18 shows a sketch of the depositional environment.

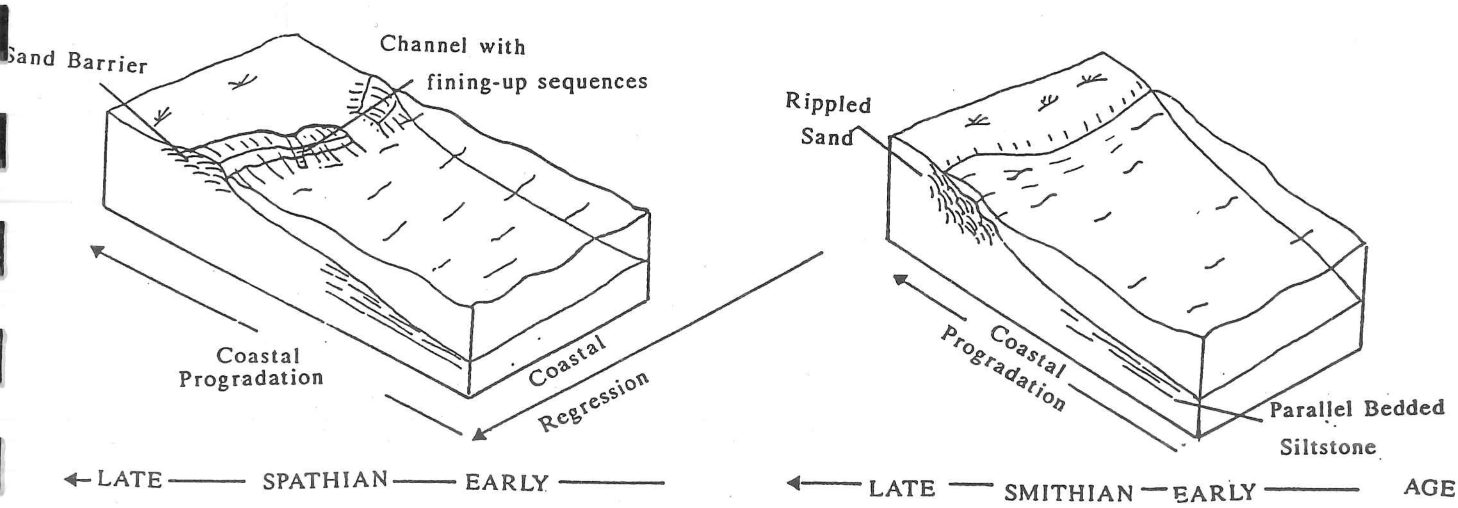


Figure 18 Sketch of the depositional environment of the Tvillingodden Formation.

1.3.3 : BRAVAISBERGET FORMATION

Although this formation is visible along the shoulder of the escarpment in the east of the area, it has almost continuous outcrops in the gullies, including Kongresselva, which cut through the shoulder.

Description

The logged section is in figure 19, although thicknesses are only approximate because certain sections were particularly brecciated and faulted

Above a tectonically brecciated mudstone section, there are dolomitised beds that contain brachiopods, elongated ceratites (see structures section) and abundant mud clasts that are generally composed of a finer, darker silt than the host sediment. The next siltstone unit contains *Planolites beverleyensis*[6] and *Paleophycus spp*[7] trace fossils. Above this there are occasional silicified siltstone beds.
The upper 10 m of the formation is a series of beds, coarsening upwards from mudstone to fine sandstone and at the top it grades into the medium sandstones of the De Geerdalen Formation.

Depositional Environment

The parallel bedded siltstones indicate a moderately deep marine platform and the *Planolites beverleyensis* and *Paleophycus spp* trace fossils show that it is oxygenated. This implies a rapid water deepening between the Tvillingodden Formation and the lower Bravaisberget Formation. At the top there is an increase in sand content that probably marks the beginning of coastal progradation.

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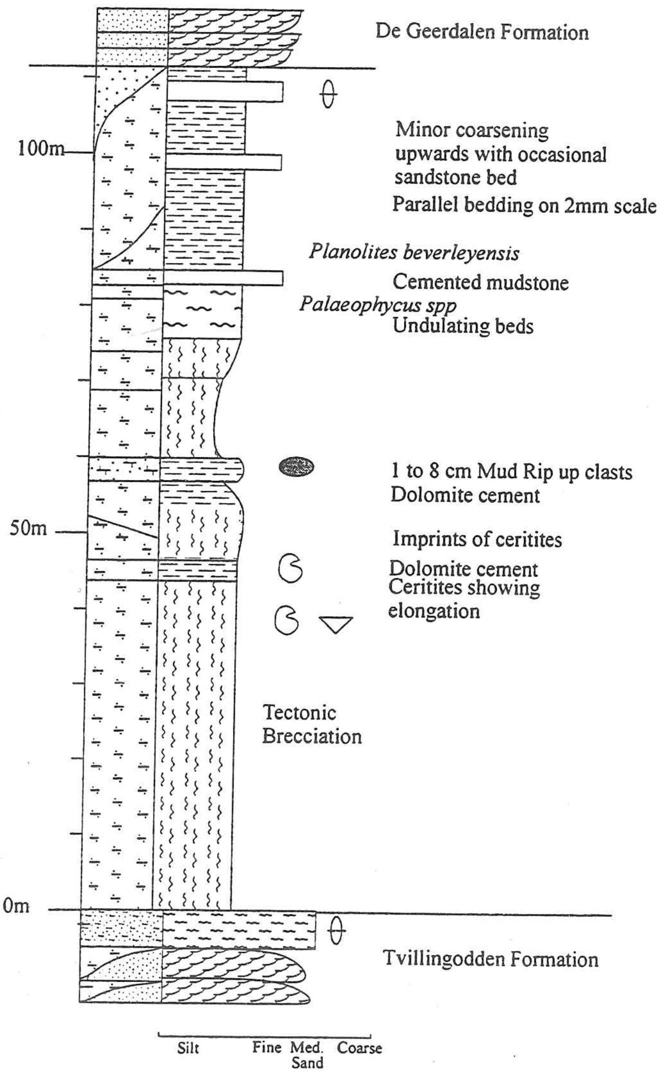
[6] Pemberton and Frey, 1982. Plates 2:5; 3:1; 5:12.
[7] Pemberton and Frey, 1982. Plate 2:5.

Figure 19 : Approximate vertical profile of the Bravaisberget Formation, with depositional interpretation.



Oxygenated water below wave base with occasional sand input

1.4 KAPP TOSCANA

1.4.1 DE GEERDALEN FORMATION

The De Geerdalen Formation outcrops either as a steep 30 m high escarpment in the east of the area or as 80m of boggy tundra to the east of the escarpment. Outcrop is common along the escarpment and along Kongresselva.

Description

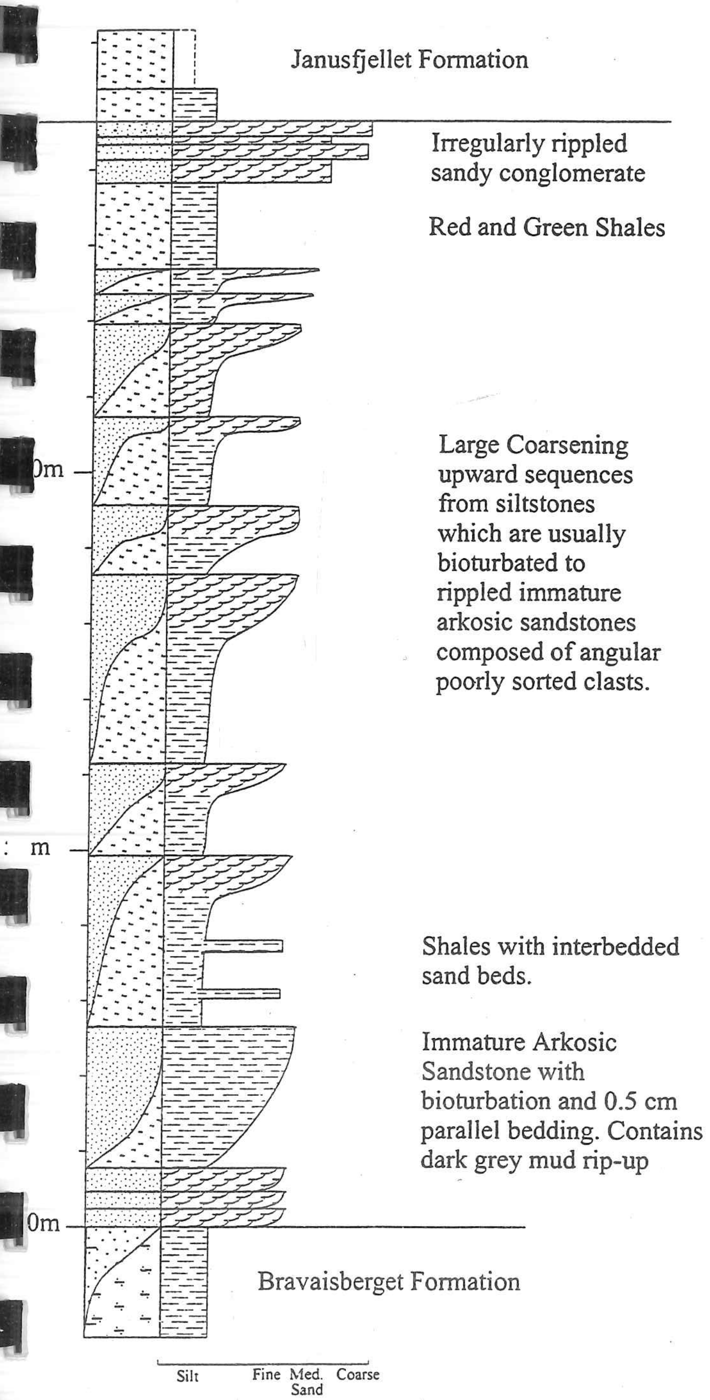
The formation consists of a series of units, coarsening upwards from parallel bedded siltstones to bioturbated cross bedded immature sandstones (see figure 20). The bioturbation made it impossible to determine palaeocurrent directions. At the top there is a unit composed of red and green shales which sits below a series of irregularly rippled sandy conglomerate beds.

The top of the De Geerdalen Formation is defined by a sharp change over 1 m from coarse conglomerate interbedded with shales, to the black shales of the Janusfjellet Formation.

Depositional Environment

Between the Bravaisberget Formation and the De Geerdalen Formation, the change from siltstones to sand beds indicates a transition from deeper water to shallower water. In the De Geerdalen Formation the coarsening upward series imply a cyclic change from deeper water siltstones to shallow water immature sandstone deposition in the wave zone, to relatively deep water and back. A possible explanation for this cyclicity is deltaic lobes prograding into a subsiding basin. Figure 21 is a sketch of the depositional environment.

Figure 20 : Vertical Profile of the De Geerdalen Formation



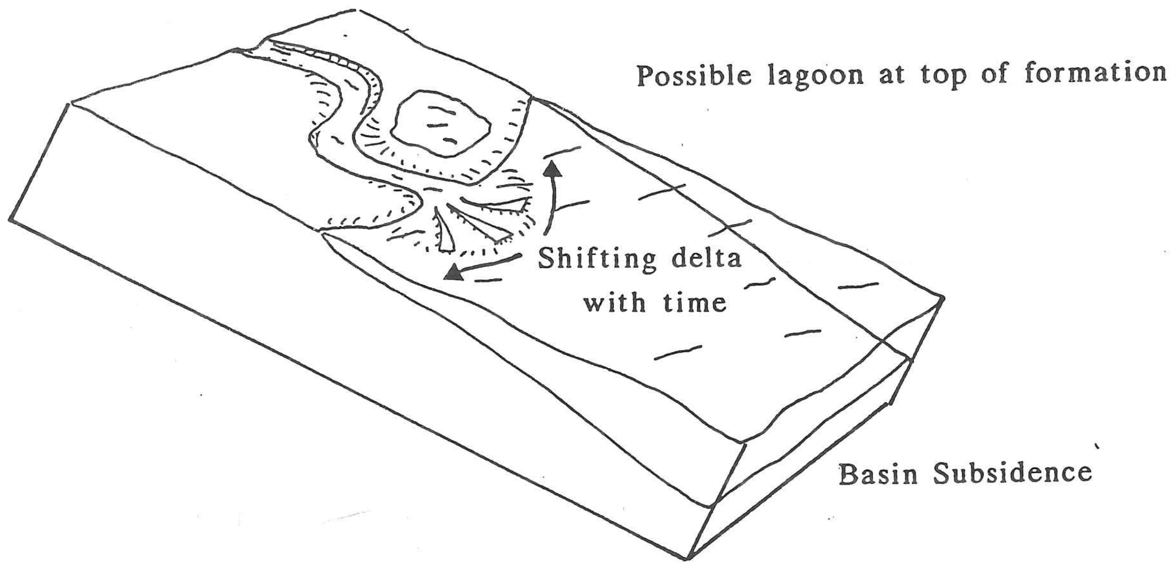


Figure 21 : Sketch of the Depositional Environment of the De Geerdalen Formation.

1.5 : ADVENTDALEN GROUP

1.5.1 : JANUSFJELLET FORMATION

The Janusfjellet Formation outcrops along all three river sections but did not outcrop in-between. Its presence was inferred from boggy tundra on the flat platform to the east of Grønfjorden and Figure 22 a-c shows vertical profiles of the formation along the three river sections. As with the Bravaisberget Formation, this formation is very faulted and micro folded, therefore the thicknesses are only approximate.

Description

The Janusfjellet Formation sits conformably on top of the conglomerates of the De Geerdalen Formation. The majority of this formation is a dark grey / black silty-mudstone, although some beds were rusty red or pistachio green / grey. It also contained some fine to medium sands which tended to be prominent because they were more weather resistant, and others were dolomitised. This dolomite cementation tended to be gradational. In the very finely laminated sandstone beds there were abundant *chondrites* that are possibly *Chondrites targonii* (Plate 1C, Fu, 1991).

The top of the Janusfjellet Formation is defined by a 4 m wide transition between a nodule rich siltstone and the cross-bedded sandstone of the Helvetiafjellet Formation shown in figure 23.

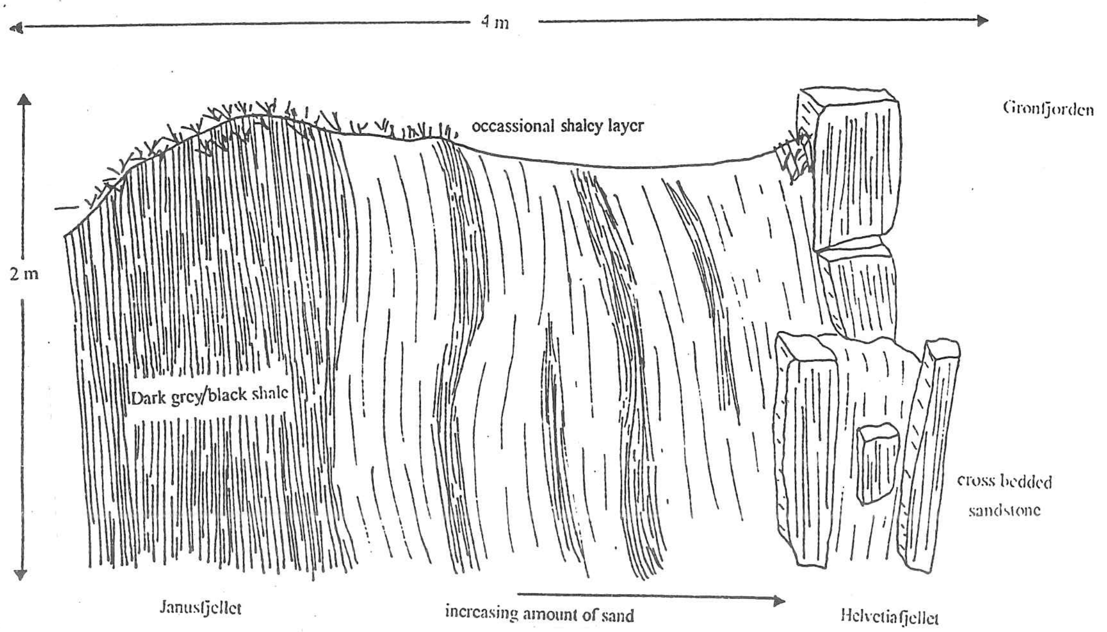
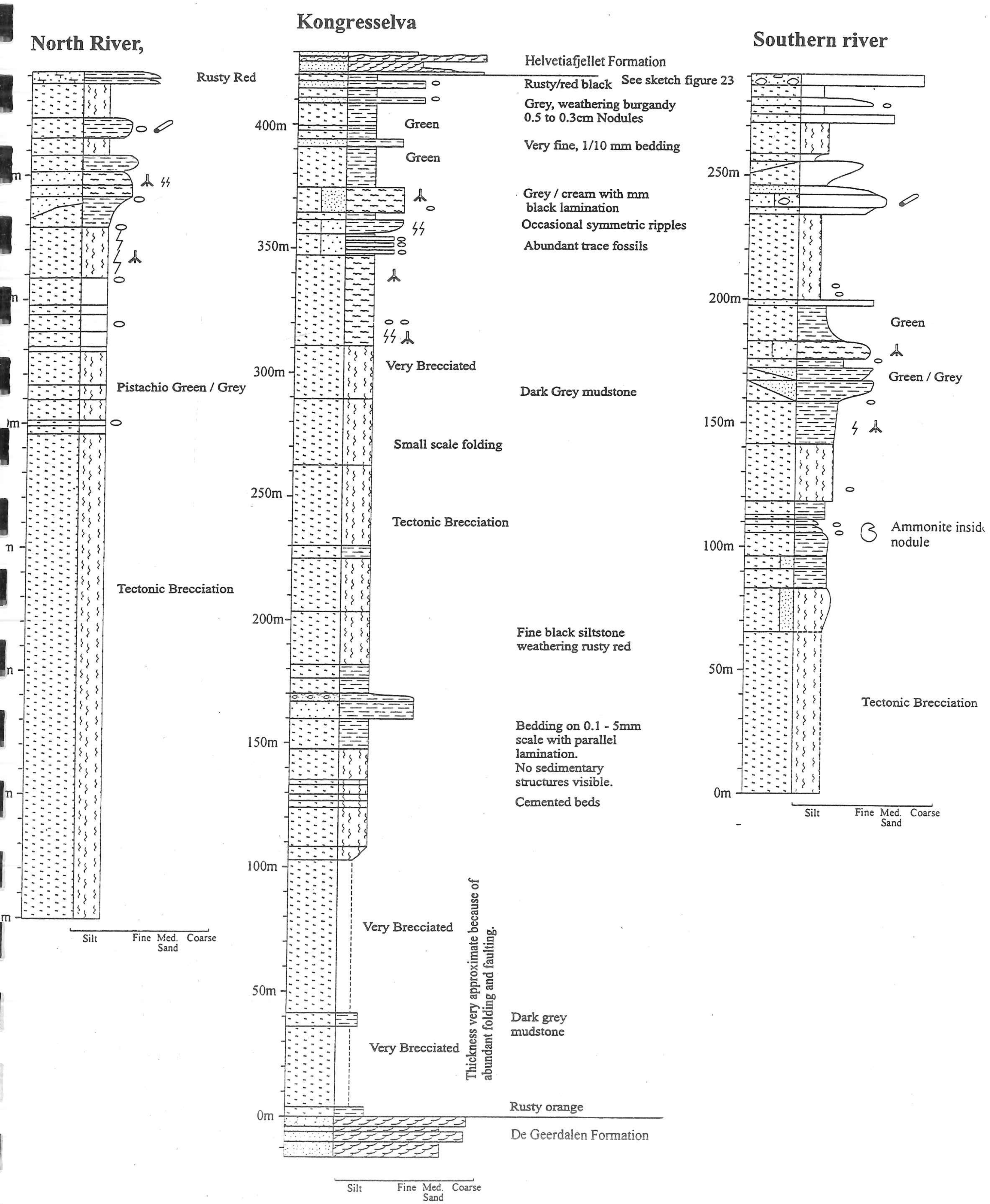


Figure 23 : Transition between the Janusfjellet and Helvetiafjellet Formations at locality VF.

Figure 22 : Vertical Sections of the Janusfjellet Formation from a) North River, b) Kongresselva and c) Southern river with insert of calcite cemented beds.



Although the three logs in figure 22 show the same general succession, they do differ considerably especially the abundance of sandier units and nodules lower in the Southern river log.

Nodules

The most striking feature of this formation is the abundance of bedded nodules, particularly in the upper part. These appeared from a few centimetres to one metre diameter and were generally sub-spherical although elongation of a largest / smallest circumference of 0.8 was common.

The nodules were frequently dark grey in colour although occasionally had an orange weathering on the surface. They were also dense. X-ray diffraction of the inside and outside of a nodule shows that it is uniformly composed of siderite, although there is some external alteration to chlorite

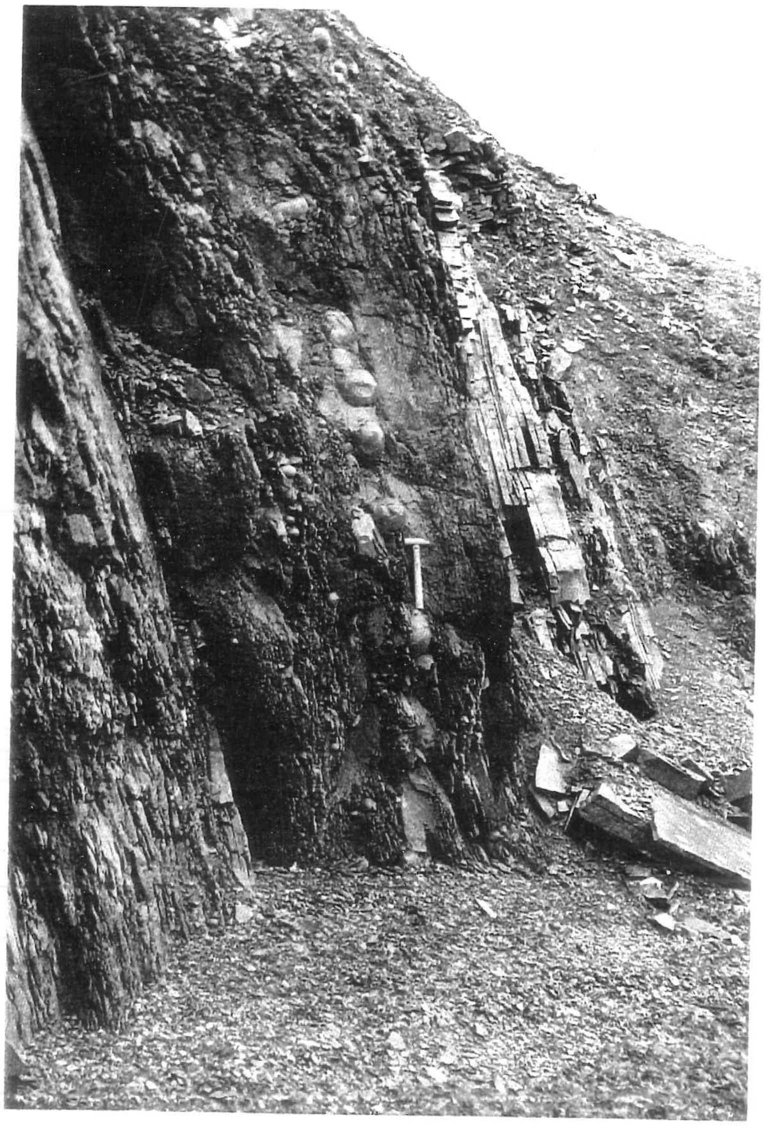
The grain size was silt to mud stone, very similar to the host rock, with non-compressed bedding structure internally and occasional biogenic nuclei.

They were frequently bedded parallel to the host sediment which showed obvious signs of compression as shown in figure 24. However, because it was impossible to determine bedding inside the nodules, compression ratios could not be calculated.

Depositional Environment.

The conglomerates between the De Geerdalen formation and the Janusfjellet Formation are called the Brentskardhaugen Bed and are thought to have a storm related origin (Maher 1989), although insuffiecient evidence was found in the area. The very sharp transition into the non bioturbated parallel siltstones implies a change to deep anoxic conditions and this is supported by a sea level transgression between the De Geerdalen formation and the Janusfjellet Formation (Haq. et al. 1987). The appearance of *chondrites* and then other bioturbation at 300 m indicate a transition from anoxic to sub-oxic conditions in the water and high H_2S concentrations in the sediment (Bromley and Ekdale 1984). The increasing number of sand beds could be a result of distant prograding coastline as the Haq et al. curves show global sea level drop. See figure 25 for sketch of depositional environment.

The three logs show approximately the same trend of depositional environment although the thickness vary enormously despite the sections only being 1.5 km apart. This may reflect lateral differences in environment. For example the southern section may be closer to a river therefore has sand input earlier, or sedimentation rates may differ. However, as the formation is frequently highly brecciated, this discrepancy may be a result of alterations to true thickness.



Hammer is 30 cm long

Figure 24. Bedded nodules in the Janusfjellet Formation showing compression.

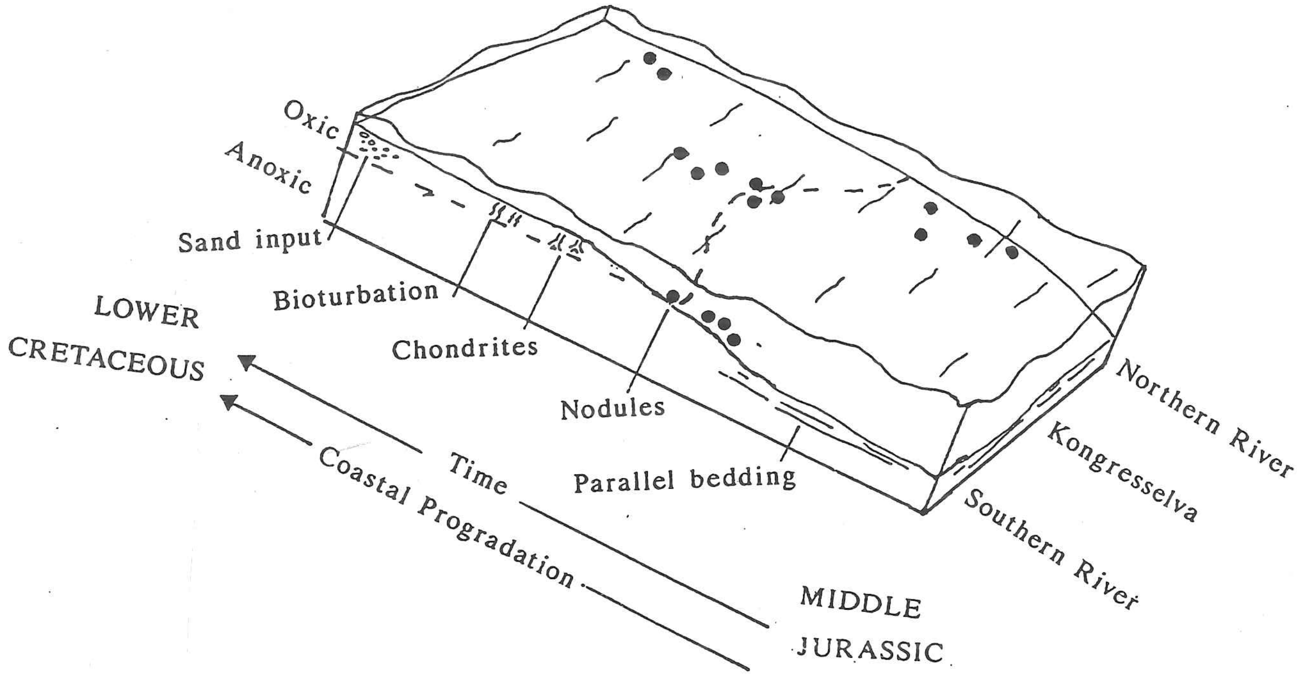


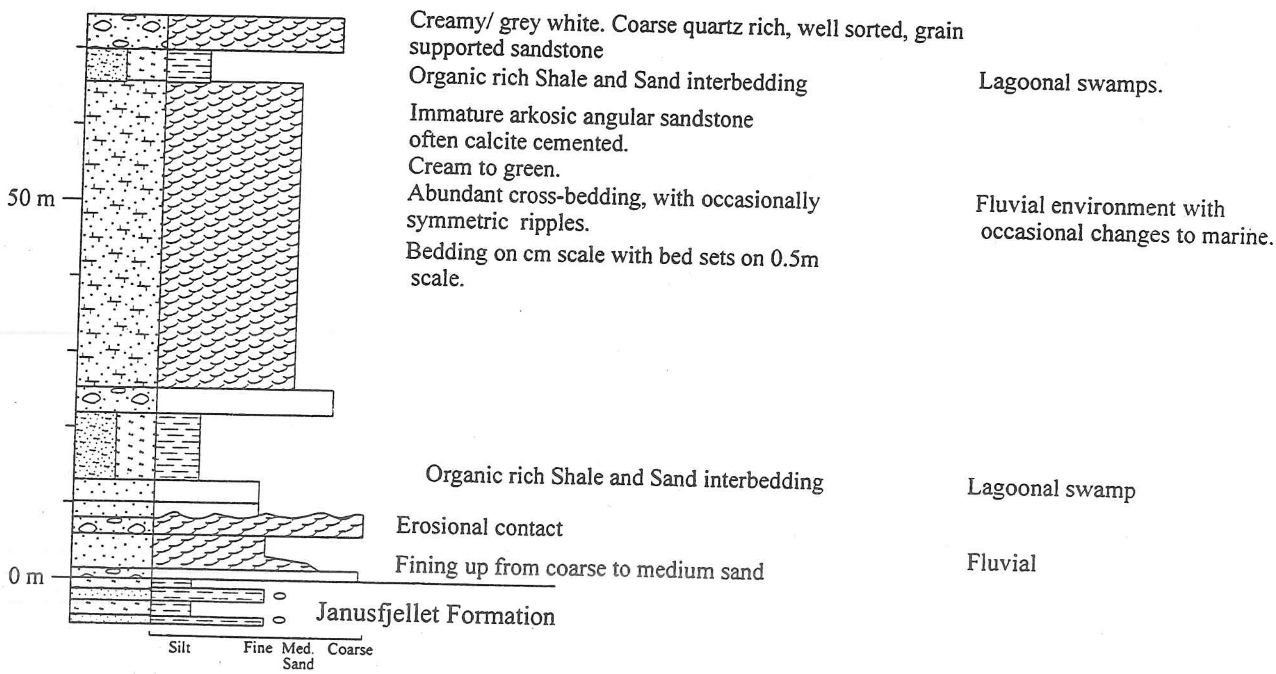
Figure 25 : Depositional Environment of the Janusfjellet Formation. This shows the variation with time as well as with along strike from the Northern River to the Southern River.

1.5.2 : HELVETIAFJELLET FORMATION

The Helvetiafjellet Formation is visible continuously as 10 m high cliffs along the West Coast of Grønfjorden although there is limited outcrop inland.

Description

The majority of the formation consists of fine to medium grained well sorted and (sub-) rounded quartz grains, and although occasionally golden brown coloured, it is generally a creamy grey-white (see figure 26 for the log). The matrix is grain supported although often a cement (sometimes dolomite) is present. Cross-bedding is common from which paleocurrent indicators were measured (figure 27) with some exceptionally well preserved ripples (figure 28).



Conglomerates : 80% Quartz, 10% rounded cherty clasts (Possibly from the Kapp Starostin Formation), size 0.5 cm

Most beds were devoid of fossils although some beds, especially the fine grades, had between 20 and 60% organic material probably wood. Some of the beds with organic matter were bioturbated.

Figure 26 Vertical Profile of the Helvetiafjellet Formation, with depositional interpretation.

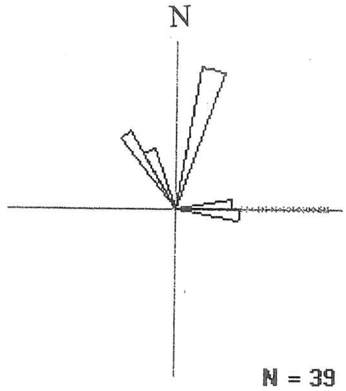


Figure 27 Palaeocurrent vectors of ripples in the Helvetiafjellet Formation, showing current direction towards the north east. The data has been adjusted to account for tectonic tilting.

Figure 28 : Photograph of ripples in the Helvetiafjellet Formation along the west coast of Grønfjorden at locality VF.

Depositional Environment

The shallow marine environment of the Janusfjellet Formation appears to change rapidly to the fluvial Helvetiafjellet Formation environment. It is most likely to be fluvial because of cross-bedding, interbedded conglomerates, abundant wood fragments, and lack of marine fossils. The organic rich shales imply that there were at times lagoonal swamps. Figure 29 is a sketch of the depositional environment.

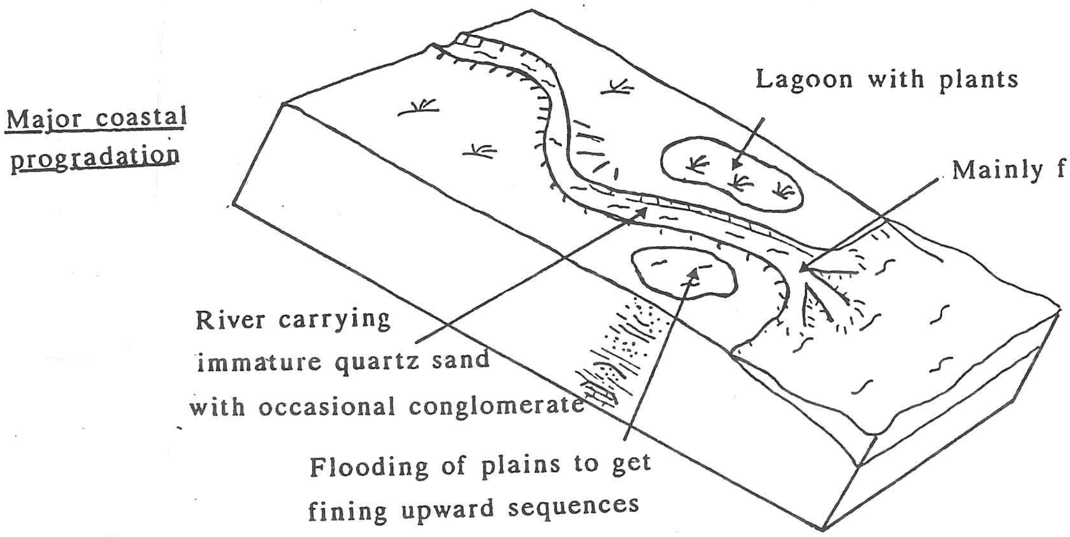


Figure 29: Sketch of the depositional environment of the Heftiafjellet Formation.

1.6 : MAFIC SILLS

DESCRIPTION

In the Carboniferous / Permian and Triassic formations there are three medium grained mafic sills which are emplaced parallel to the bedding of the host sediments. Precise thicknesses of the sills are unknown but are on the scale of 1 to 2 m. A sketch of the thin section is shown in Figure 30.

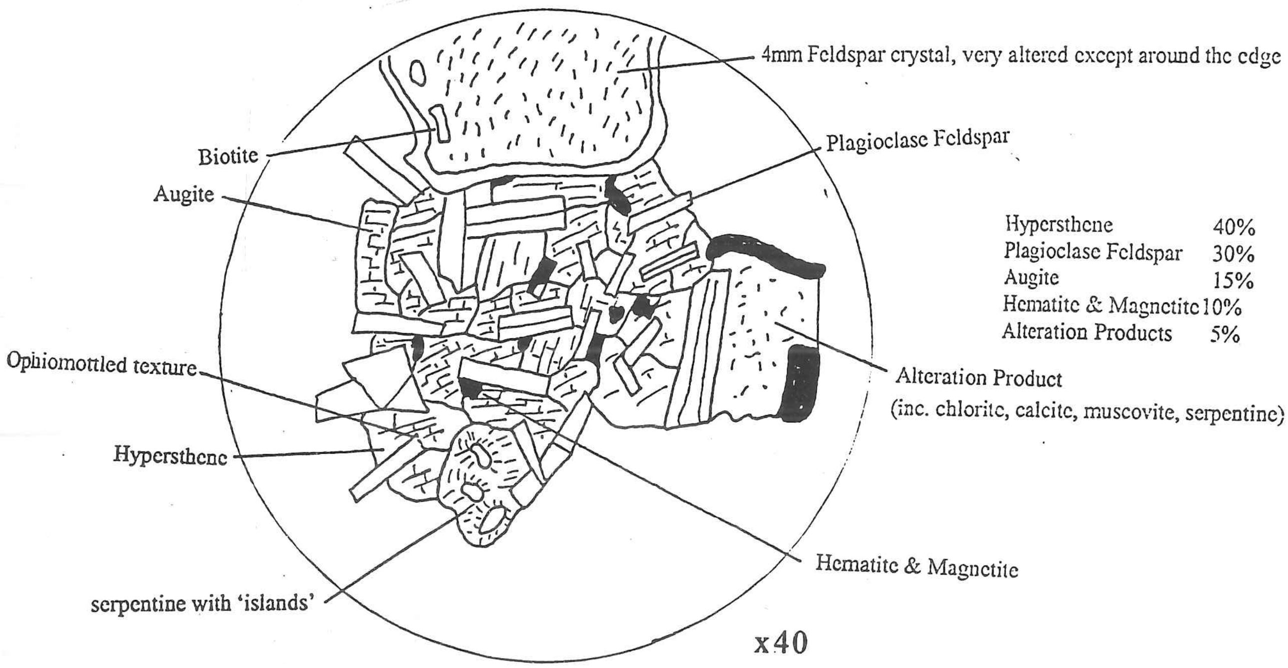


Figure 30 Sketch of thin section of dolerite sill. Rock sample is from locality OG.

INTERPRETATION

The sills are thin therefore they would have cooled in approximately 1 day (see time constant equation below).

$$\tau_a = \frac{a^2}{\pi \kappa} \qquad \Rightarrow \text{ 1 m sill cools} \approx \text{1day.}$$

However, as the rock contains coarse-grained aggregates of phenocrysts, these must have crystallised and aggregated more slowly, possibly in a magma chamber and prior to emplacement.

The sills are dolerite, with no olivine present now. However, the serpentine alteration with islands indicates olivine was present before alteration occurred.

The chlorite, serpentine and ceritie imply low temperature, hydrothermal alteration, and the calcite implies the fluids have passed through a calcite source, eg. limestone.

The origin of the sills is uncertain, but may be a result of regional extension and down-warping, see Section 3 : Regional Tectonics And Global Sea Level Changes :The Driving Force Behind Sedimentary Facies Changes ?

1.7 QUATERNARY / COVER LITHOLOGIES

The drift map shows the Quaternary and cover lithologies of the area.

There are two main Quaternary influences on this area. The first is that Spitsbergen lies within the area of continuous permafrost with the active layer between 0.3 m and 2.2 m (Ohta et al. 1992), often resulting in high degrees of frost shattering. As a result, the amount of in-situ outcrop is highly variable and the rocks are frequently brecciated and weathered. Occasionally the rocks fragments become vertically orientated and form 1 m to 2 m diameter stone polygons.(figure 31).

Figure 31 : Photograph of Stone Polygons taken from locality RH. Each is approximately 1 - 2 m in diameter.

The second effect was the last glacial maximum approximately 7,500 years before present. The dominant consequences have been the large U-shaped valley of Kongressdalen, possible raised beaches at 10 m, and glacial till in the east. In the last few thousands years although glaciers have been limited to the mountains, they have deposited terminal moraine on the south side of Kongreesvatnet, and are still depositing outwash into the plains of Kongresselva.

2 STRUCTURE

2.1 FOLDS

The dominant macroscopic structures, including bedding and fold axial traces, strike north-north-west.

Bedding, which dips east-north-east, is generally steep ranging from 30°E to 85°E, and consistently youngs towards the east without unit repetition or unconformity. However, there is a major anomaly in a 200 m to 1,000 m wide section encompassing the lower 50 m of the Bravaisberget Formation, the entire De Geerdalen Formation, and the upper 300 m of the Janusfjellet Formation (Cross section X-X' on the solid geology map) which is west-south-west dipping although east-north-east younging. Except in the south of this sequence, there is a 30 m sliver of the Tvillingodden Formation in the Bravaisberget Formation which is also west-south-west dipping. No large scale folding is evident in this sequence although bedding in the Janusfjellet Formation changes abruptly from west-south-west to vertical to east-north-east dipping towards the east.

In the north of the area bedding dips of the Gipshuken Group through to the Tvillingodden Formation are consistent with the macroscopic structure and are not folded.

In the south an antiformal and synformal pair with a wavelength of 400 m in the Kapp Starostin Formation is clearly visible on the north face of the southern mountain range, see sketch in Figure 32. This fold pair has a north-north-west trending axial trace, which is parallel to the macroscopic strike of bedding, and is plunging by 0.7° towards 334°. Data shown in stereonet figure 33. These folds are not present to the west and north of Kongressvatnet, and as the Gipshuken and Kapp Starostin Formation contact is undeformed, this implies these folds shallow out and disappear.

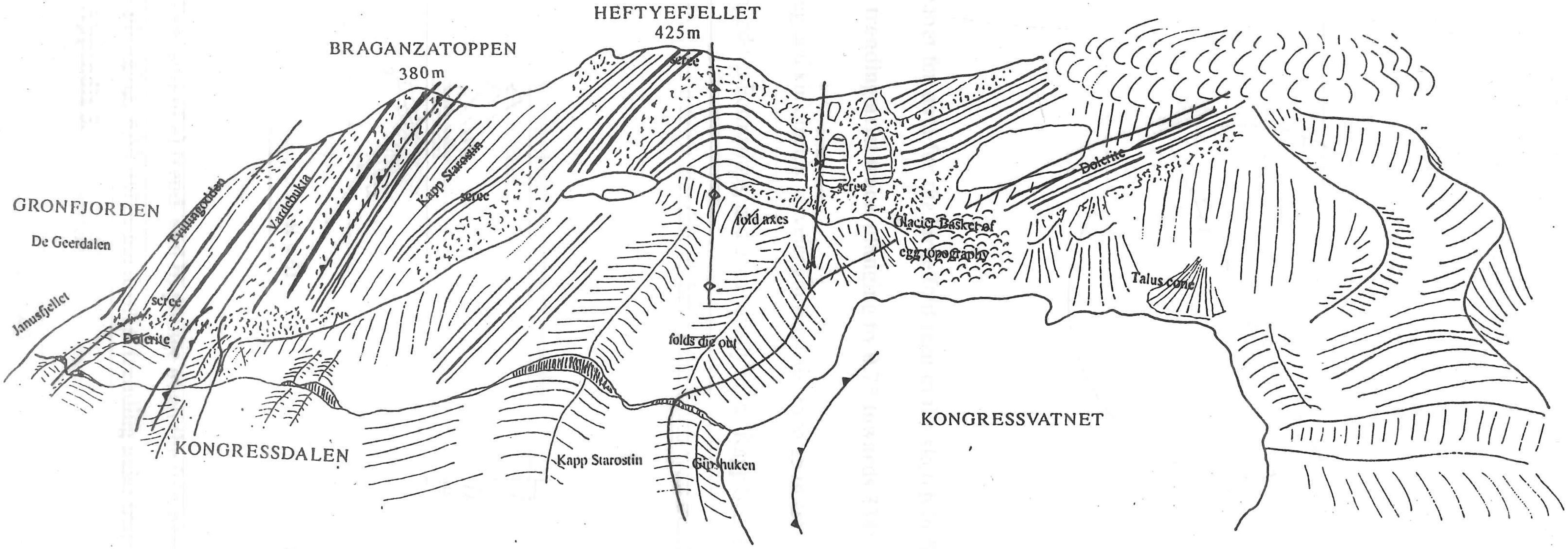


Figure 32 Sketch of fold in southern mountains with overlay showing the principle geological features. The stereonet for the fold data is in figure 33.

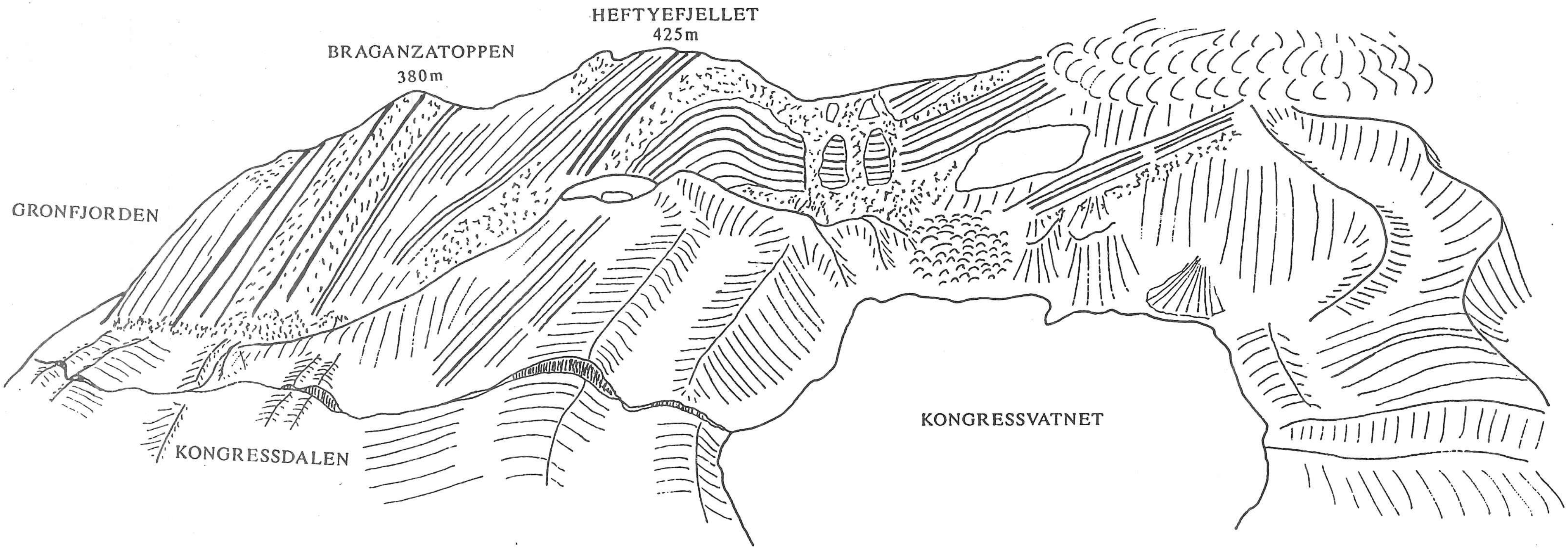


Figure 32 Sketch of fold in southern mountains with overlay showing the principle geological features. The stereonet for the fold data is in figure 33.

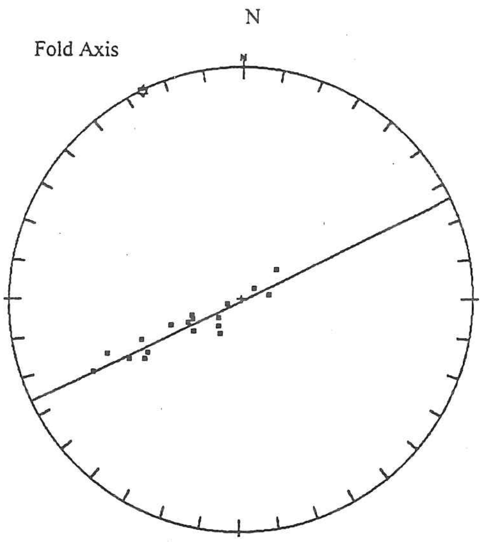


Figure 33 : Stereonet for data for the large fold seen in the sketch in figure 32 The fold pair has a north-north-west trending axial trace, plunging by 0.7° towards 334° N = 18

Smaller scale folding and kink bands, wavelength from 30 cm to 15 m are exposed in the Helvetiafjellet, Janusfjellet, Tvillingodden Formations, and occasionally in the Kapp Starostin Formation. The rose diagrams in figure 34 a and b show that they all have north-north-west trending axial traces and are gently plunging.

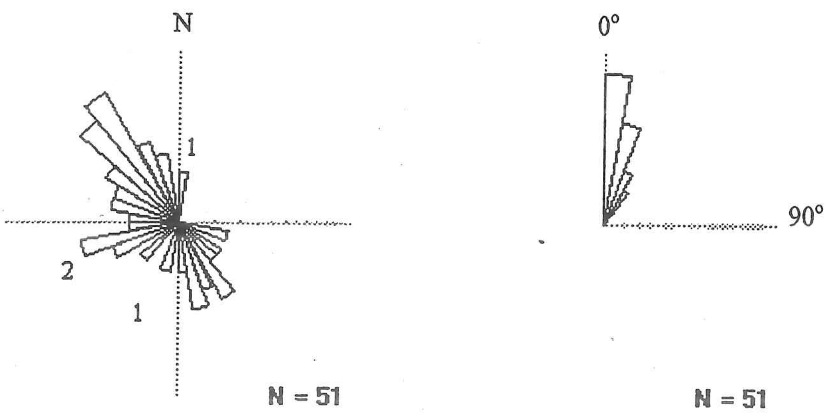


Figure 34 : Rose diagrams of a) trend and b) plunge of all the fold axial traces measured show the most are shallowly plunging, with north-north-west trending axial traces. Stereonets for individual folds are shown in Appendix 3.

The rose diagrams in figure 34 show some data that is not consistent with the macroscopic north-north-west trending folds. The points marked with (1) are poorly constrained because of lack of data. The points marked with (2) are significantly different and lie along a steeply dipping east-west trending fault.

Elongated Ceriatites.

In the Bravaisberget Formation there are elongated ceriatites which have elongation ratios of 0.7, with a mean compression direction along 020° after readjustment for tectonic tilt (see figure 35). Elongation ratios were calculated using logarithmic spirals (Ramsay and Huber, 1983).

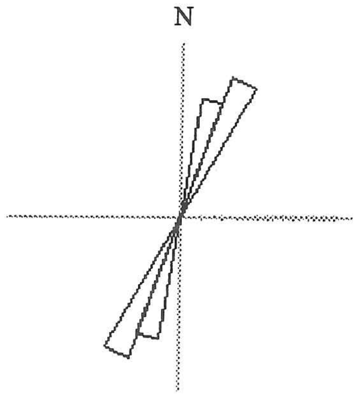


Figure 35 : Elongation direction of ceriatites in the Bravaisberget Formation. Adjusted for tectonic tilting. n = 10

2.2 : FAULTS

There are four thrust faults in the area and they all strike north-north-west and generally dip parallel to bedding.

The most westerly thrust is in the middle of the Gipshuken Formation and the evidence is a highly brecciated west side of Vøringen. The presence of the thrust is supported by the repetition of the upper part of the Gipshuken Formation north of the field area (Ohta et al., 1992). The exact position, however, is poorly constrained in the north and unknown in, and to the south of, Kongresselva.

An escarpment on the north face of the southern mountain and in southern Kongressdalen implies a major thrust at the top of the Vardebukta Formation. This escarpment, and evidence for the fault, disappears in the north of Kongressdalen. The fault, which dips at between 40° and 25°, is parallel to bedding therefore there is no obvious displacement.

The west-south-west dipping section with the repetition of the Tvillingodden Formation is bounded by a thrust dipping parallel to bedding on the west side. The thrust contact is not visible although its position is placed between the west-south-west and east-north-east dipping beds throughout and in a 10 m high north-north-west striking gully in the north. Evidence for a west dipping thrust is supported by a gully section at locality GO which shows abundant small scale shears 50 m to the east of the thrust (figure 36).

The fourth thrust is almost continuously visible along the west coast of Grønfjorden and is entirely within the Helvetiafjellet Formation.

There are also two east-west striking faults. The one in the west goes through the Gipshuken formation and appears to be vertical with 20 m of displacement. The second goes through part of Kapp Starostin

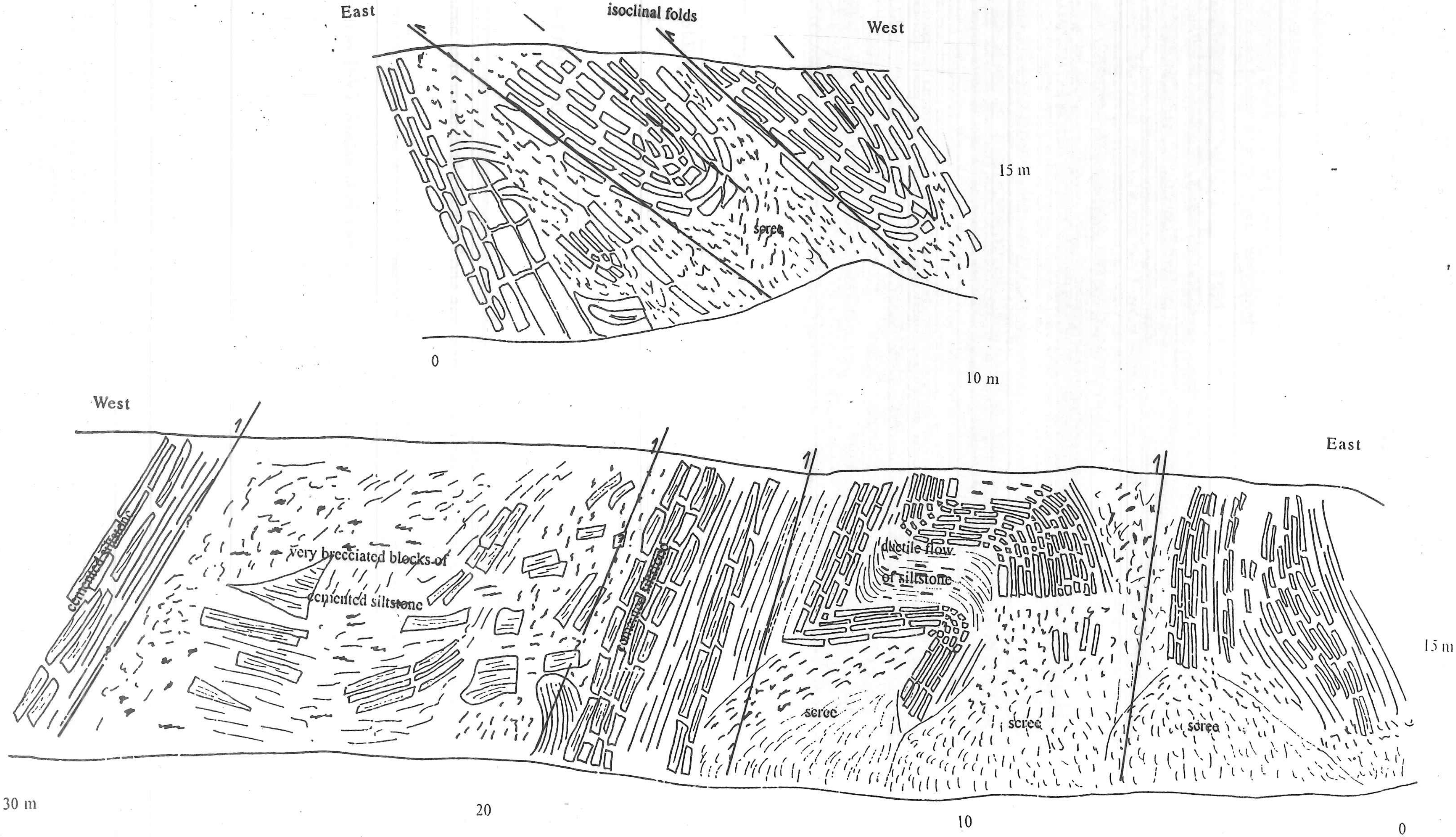


Figure 36 Sketch of gully in Tvillingodden Formation locality GO.

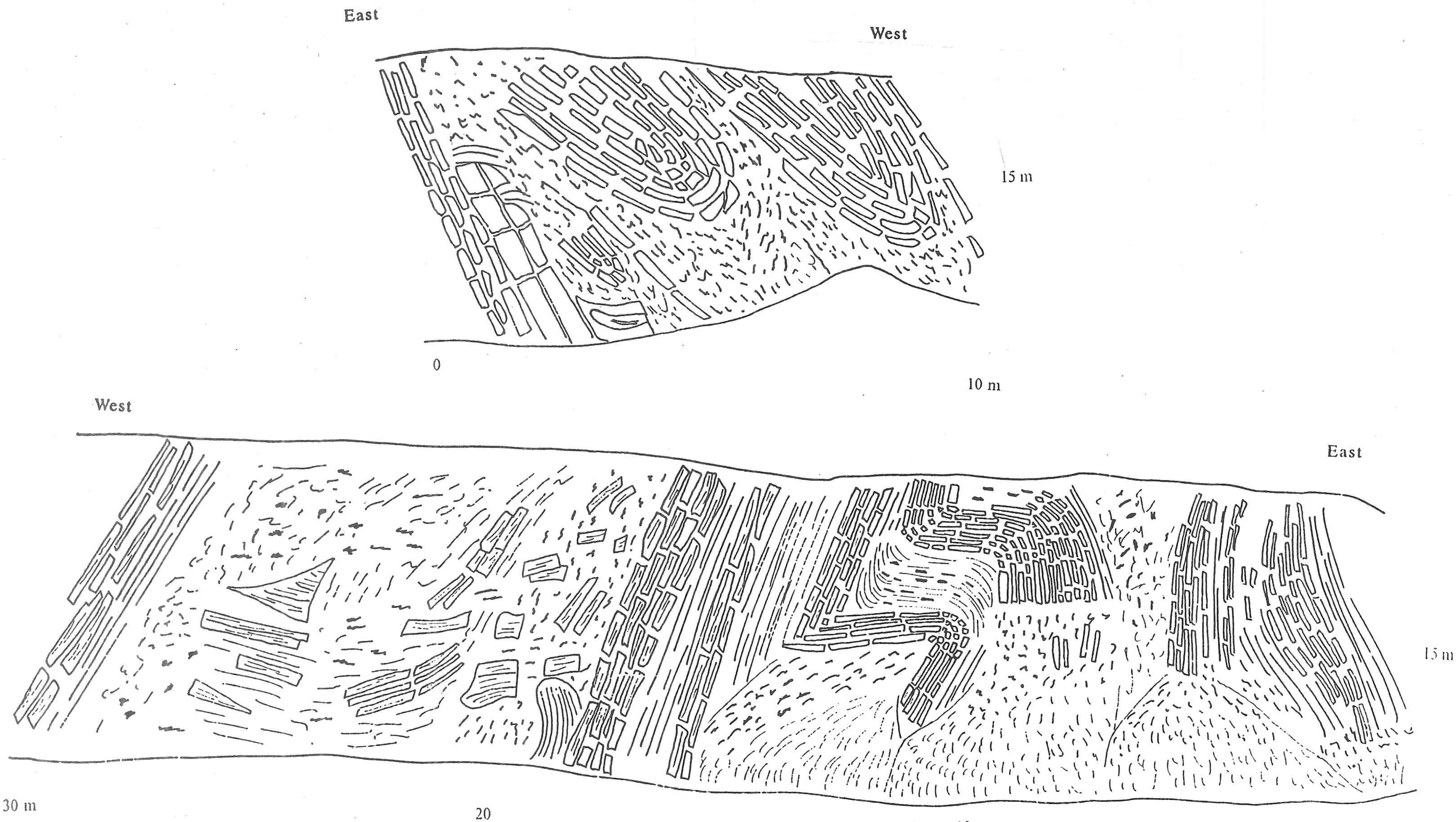


Figure 36 Sketch of gully in Tvillingodden Formation locality GO.

Formation (Cross section Y-Y', and figure 37), and dies out in the east close to the Vardebukta thrust fault. In the west it dies out before the Gipshuken and Kapp Starostin Formations' boundary.

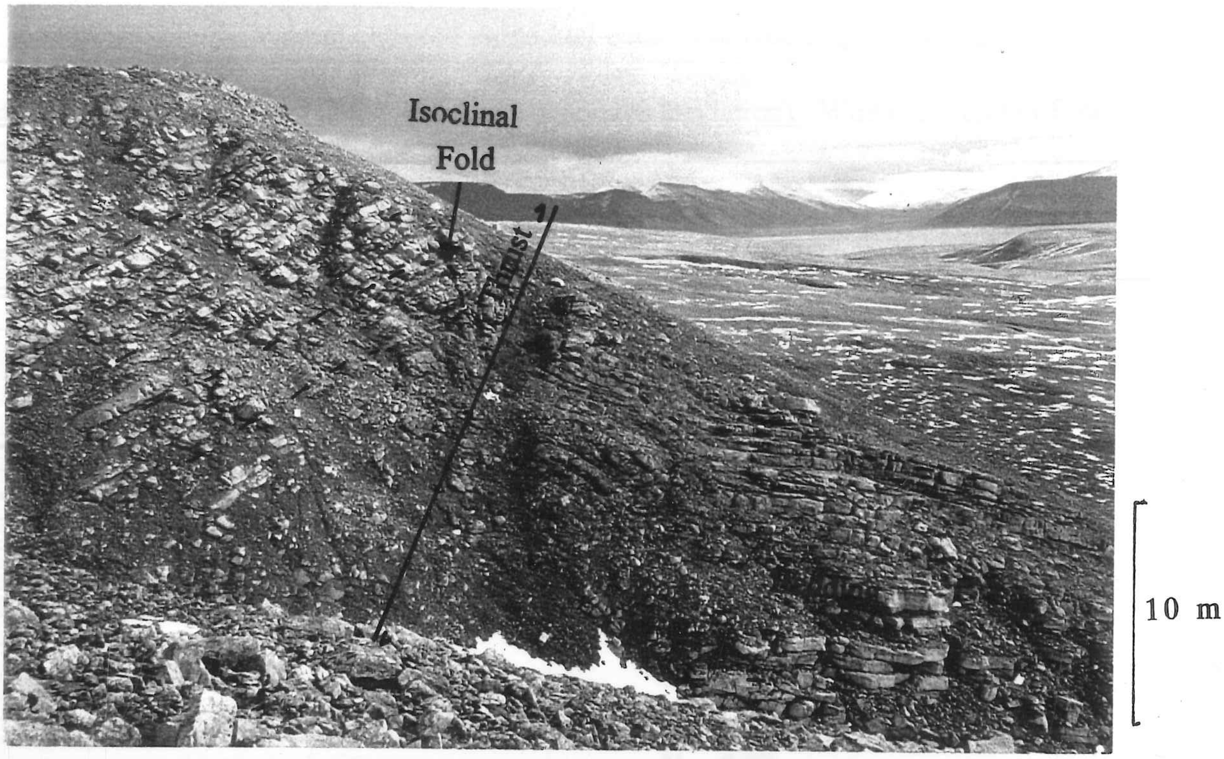


Figure 37 : Photograph of east-west striking thrust fault at cross-section Y-Y'. Overlay shows bedding, folding and direction of thrust.

TIMING OF FAULTING

In this area there is no direct evidence to suggest timing of the faults except that as the faulting is homogenous, it is most likely to be of one age, and it is younger than the youngest lithology i.e. mid Cretaceous. Work in other areas all suggest that they are Paleocene to Eocene (e.g. Harland 1969, Dallmann et al 1993, Maher et al 1995).

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2.3 : SLICKENSIDES

In addition to the four thrust faults, there is abundant evidence throughout the area from slickensides that there has been significant movement between individual beds. The rose diagram in Figure 38 shows the slickensides have a mean trend of 064.8 ±. 3.2° (1 Standard Deviation). Where direction of motion was obtained, they all indicated thrust movements.

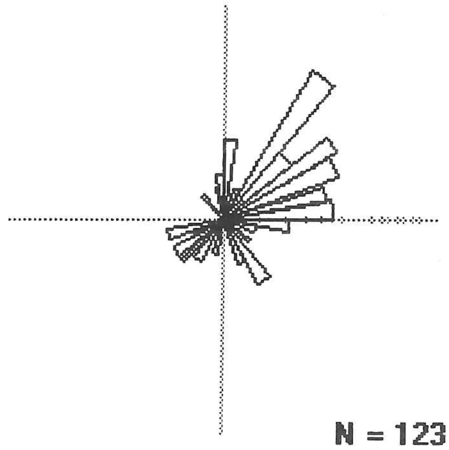


Figure 38: Slickenside data taken from throughout the area and showing a mean trend of 064.8 ±. 3.2° (1 Standard Deviation).

2.4 JOINTS

Jointing was present to some extent in most formations but was most obvious in the Gipshuken Formation. The rose diagram in figure 39a shows the Gipshuken Formation data, and figure 39b shows it for the whole area.

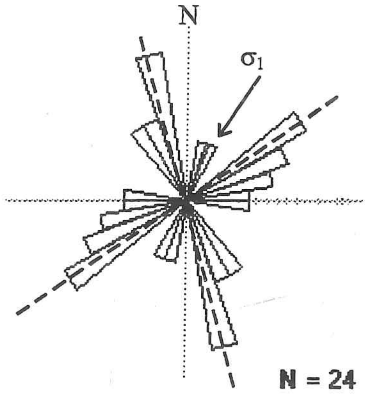


Figure 39 a

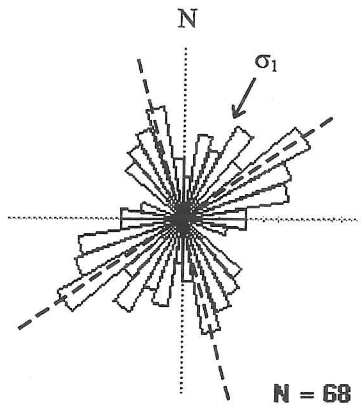


Figure 39b

Figure 39 : Strike of joint surfaces which are unaltered for tectonic tilt : a) data from Gipshuken Formation, b) data from the whole area. Both show principle stress direction along 020°

Despite a spread of data, one conjugate set of joints can be identified from the diagram with the principal stress axis (σ_1), which bisects the smaller angle between the joint set, direction of 020°.

2.5 : MISCELLANEOUS STRUCTURES

In some areas there are very different bedding dips adjuting each other with no clear indication of the general structures involved. Figure 40 shows such an area. It also shows discontinuity of bedding. The cause of both of these features, which are seen in other parts of the area, is most likely to be related to thrusting although there is no direct evidence for this.

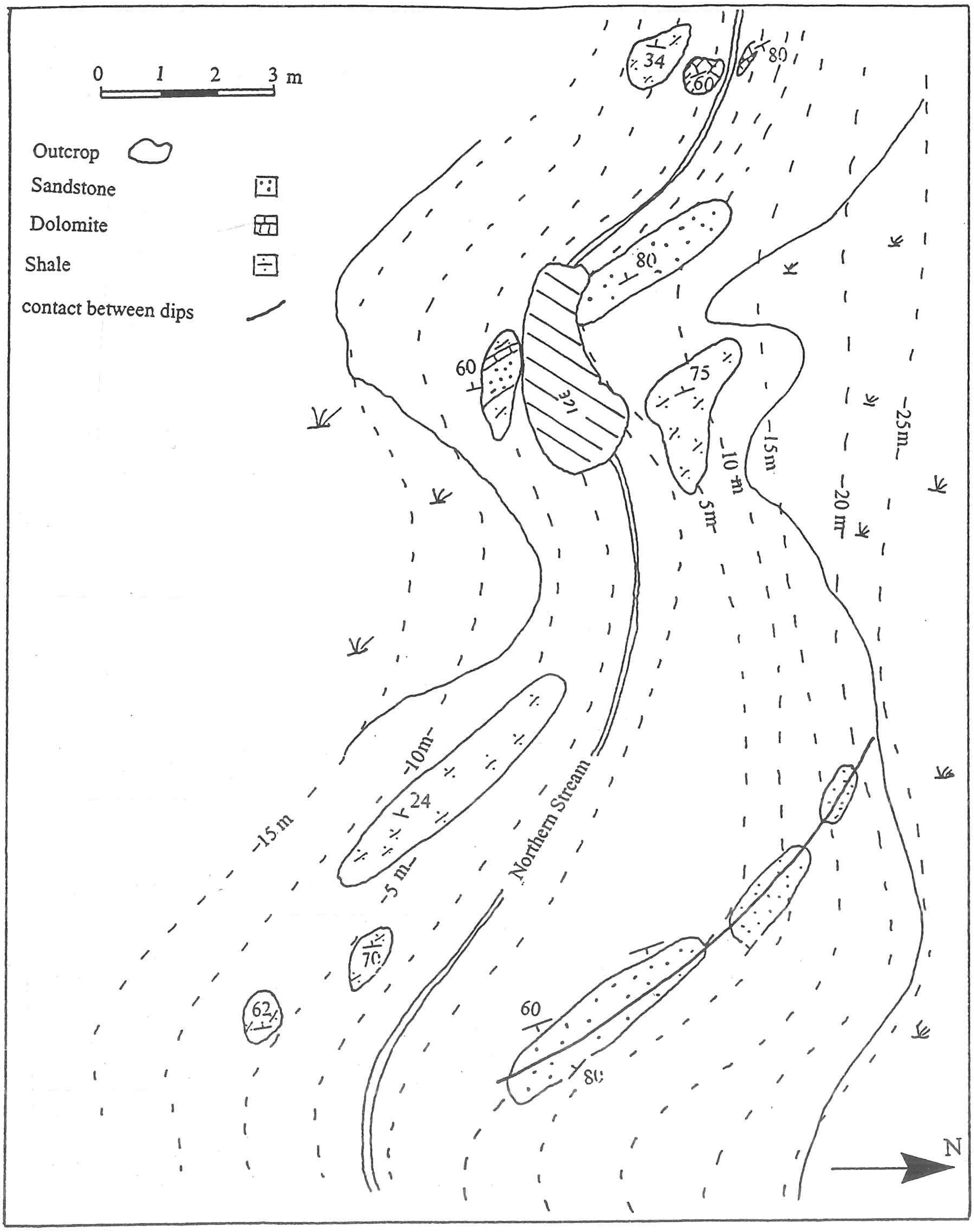
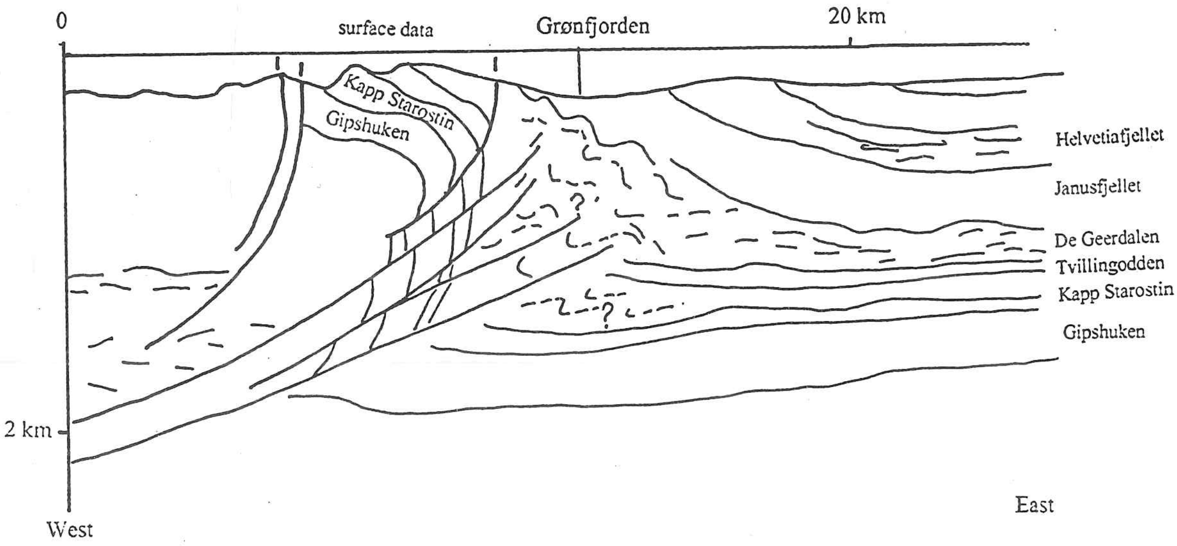


Figure 40 : Sketch Map of miscellaneous bedding features in the North River. See location on solid geology map. Note the abrupt change in bedding dip in the southern part.

2.6 INFERRED STRUCTURES AT DEPTH

The principle cross section (X-X') is simplified at depth and it is assumed that the beds tail into a detachment fault. This model fits in well with the evidence from the area. However Ohta (1982) published an interpreted seismic profile along a ENE-WSW strike a few kilometres off the Isfjord coast (figure 41a, and figure 1c for location). This is approximately 5km north of the mapping area and the geological map of the area in-between (Ohta et al. 1992) has the same general features as this area. A possible deep profile of this area is shown in figure 41b, based on Ohta's interpretation. This is speculative, and as I have not seen the original seismic, I have not used this as my primary profile.



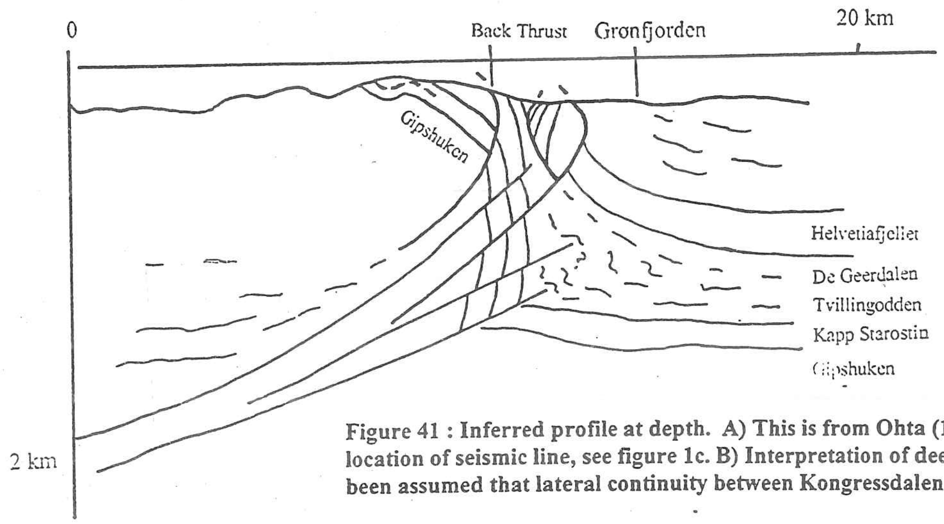


Figure 41 : Inferred profile at depth. A) This is from Ohta (1982) and includes his interpretation. For location of seismic line, see figure 1c. B) Interpretation of deep profile in the Kongressdalen area. It has been assumed that lateral continuity between Kongressdalen and seismic line.

3 : REGIONAL TECTONICS AND GLOBAL SEA LEVEL CHANGES :THE DRIVING FORCE BEHIND SEDIMENTARY FACIES CHANGES ?

The stratigraphic logs of this area show approximately 2 km of various marine facies from the Permian to mid Cretaceous which must have been deposited by subsidence. However, the subsidence can not be accounted for by the faults in the field area. The answer to the subsidence problem comes from an overview of tectonics on a regional scale (Steel et al., 1984).

Devonian deformation formed dominant north-west to south-east striking faults (seen in figure 1b) resulting in the Sørkapp-Hornsund and Nordfjorden Highs, with a graben in-between (figure 42). The graben underwent subsidence because of regional flexuring and down-warping during early Pemian to late Cretaceous. This therefore explains the subsiding basin sedimentation. Furthermore, as the Sørkapp-Hornsund High is to the west, it also explains the consistent paleocurrent directions from the west and south-west. The flexuring and down-warping may also produce extension and may explain the observed mafic sills.

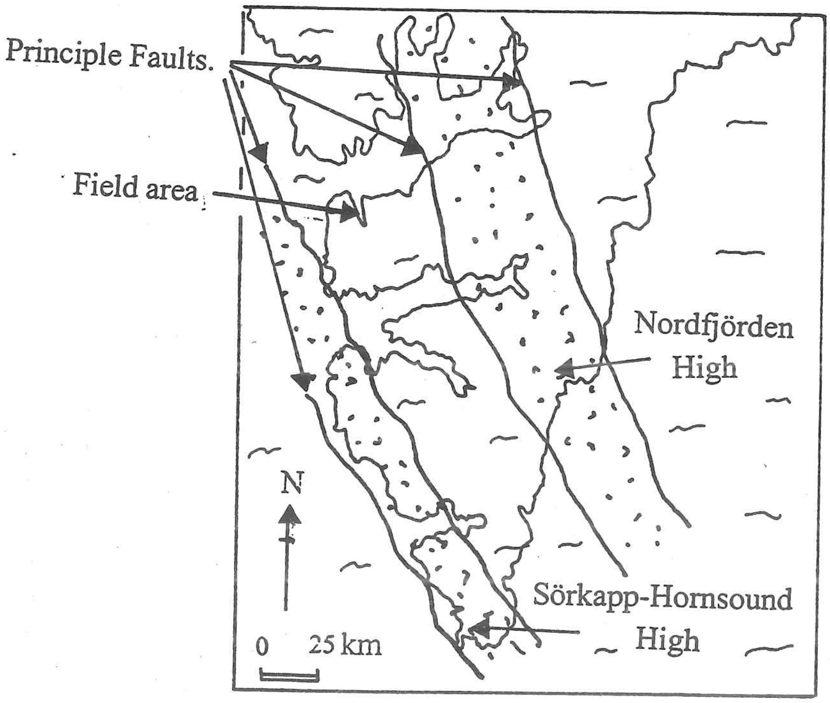


Figure 42 : The dominant structural framework of Spitsbergen during from the Permian to Early Cretaceous (Steel et al., 1984.).

The subsiding basin does not however explain the observed facies changes, in particular features such as the coarsening upward sequences in the Tvillingodden Formation.

Figure 43 shows global sea level changes from mid-Permian to mid-Cretaceous according to Haq et al. (1987). It also shows the inferred sea level changes from the facies changes in this area. The close correlation, especially in the Mesozoic, implies that although subsidence has produced a first order depositional environment, the global sea level changes have been the primary driving force behind facies change. This assumes that the rate of subsidence is proportional to sedimentation rate.

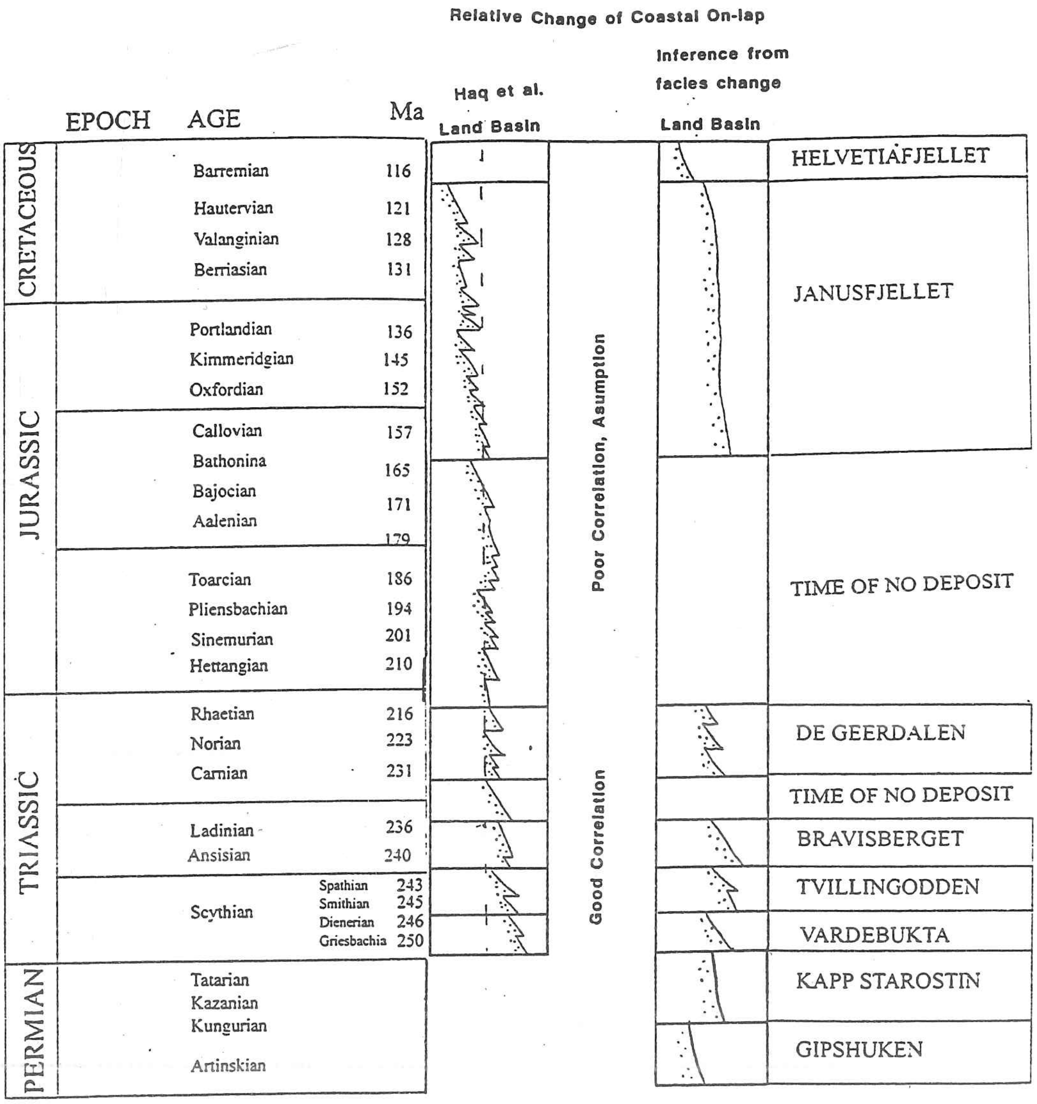


Figure 43 : The correlation between global sea level changes according to Haq et al (1987), and the inferred sea level changes from facies change in the field area.

Conclusions

Subsidence (Early Permian to Early Tertiary)

There is a total of ~2 km of deep platform to coastal silt and sandstones, including reef deposits exposed in the Kongressdalen area. The accommodation space has been produced by down-warping and flexuring of the graben between the Sørkapp-Hornsund and Nordfjorden Highs (Steel et al. 1984).

Detailed logging of the sediments and analysis of the depositional environment shows that the coastline frequently migrated and that the depth of water in which the sediments of the Kongressdalen area were deposited changed by as much as 200 m. The log is summarised in figure 44 although the periods of no deposits are from other work (Ohta et al. 1992). The timing of the coastal migrations correlate closely with those of the Haq et al. (1987) global sea level changes. This correlation implies rate of subsidence and sedimentation have been proportional over time, and sea level changes have driven facies change.

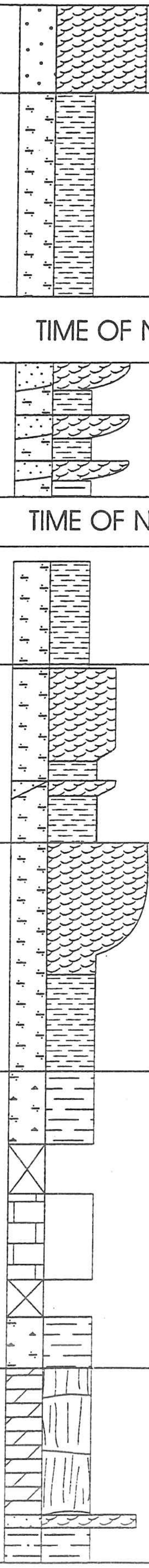
Volcanism (Upper Jurassic - Lower Cretaceous)

Doleritic sills were emplaced into the undeformed sediments and were of Jurassic/ Cretaceous age. These were emplaced during continued subsidence and are possibly a result of early extension during the down warping period.

Thrusting (Late Cretaceous)

Four major thrust faults are present in the study area and associated with them are numerous faults on the scale of centimetres to hundreds of metres. The main axis of compression is 045º ± 41 (1 Standard deviation), which was determined from fold axes, slickensides, joints and elongation of ceritites (see figure 45). As the main faults strike along 350º, the faulting is not perpendicular to the compression direction, hence thrusting in this area is transpression. This conclusion agrees with most other work on the West Spitsbergen fold and thrust belt including Harland (1969), Dallmann et al. (1993), and Maher et al (1995). It does, however disagree with Lyberis and Manby (e.g. 1993) who suggest that the general thrusting is purely compression.

Figure 44 : Summary section with depositional environment.



Period	Formation	Stratigraphic Summary	Depositional Environment
CRETACEOUS	Helvetiafjellet	Arkosic Sandstones with cross bedding.	Fluvial and occasional marine deposits
CRETACEOUS	Janusfjellet	Parallel bedded siltstones that are highly brecciated. Appearance of *chondrites* followed by other bioturbatio. Increasing amount of sand towards the	Quick transition from shallow water to deep anoxic water. Increasing oxygen levels and distant coastal
	TIME OF NO DEPOSITS		
TRIASSIC	De Geerdalen	Repeated coarsening upward sequences from parallel bedded siltstones to cross bedded sandstones.	Transition to shallow water, then prograding delta.
	TIME OF NO DEPOSITS		
TRIASSIC	Bravaisberget	Parralel bedded siltstones, but highly brecciated.	Deep water platform deposits.
TRIASSIC	Tvillingodden	Two coarsening upward sequences from siltstones to sandstones.	Two sea level regressions with barrier systems
TRIASSIC	Vardebukta	Siltstones at base with coarsening upward to massively bedded sandstones interbedded with brachiopod beds.	Deep water deposits then a coastal progradation to a sand barrier system and brachiopod bioherm
PERMIAN	Kapp Starostin	Silstones overlain by spiculitic siltstones then limestone and finally siltstones at the top.	Platform barrier with transition to restricted often deep platform with very little terestrial input..
PERMIAN	Gipshkuen	Siltstones with corals followed by sandstones and dolomitised limestone.	Shallow marine with some fluvial input

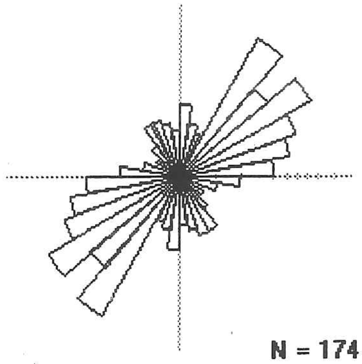


Figure 45 : This rose diagram has all compression data together and shows that the main axis of compression is 045º ± 41 (1 Standard deviation). The data is from fold axes, slickensides, joints and elongation of ceritites

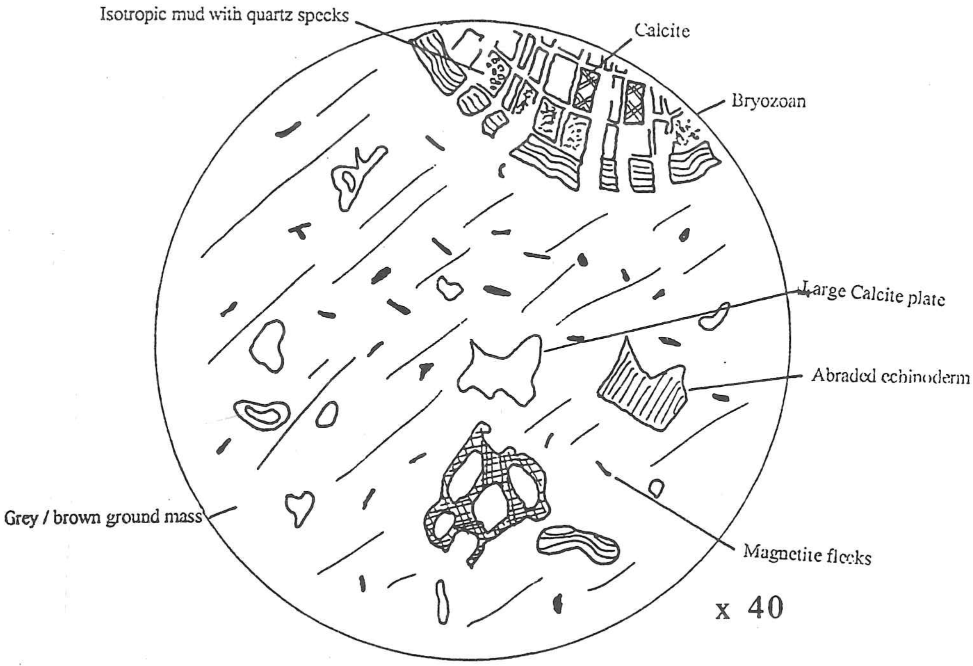
I have also shown that there has been some north - south shortening which has not been discussed in the literature.

I have interpreted the deeper profile of the area as a décollement fault with a ramp structure, but have also discussed an alternative involving back thrusting which was inferred from a seismic line 7 km to the north..

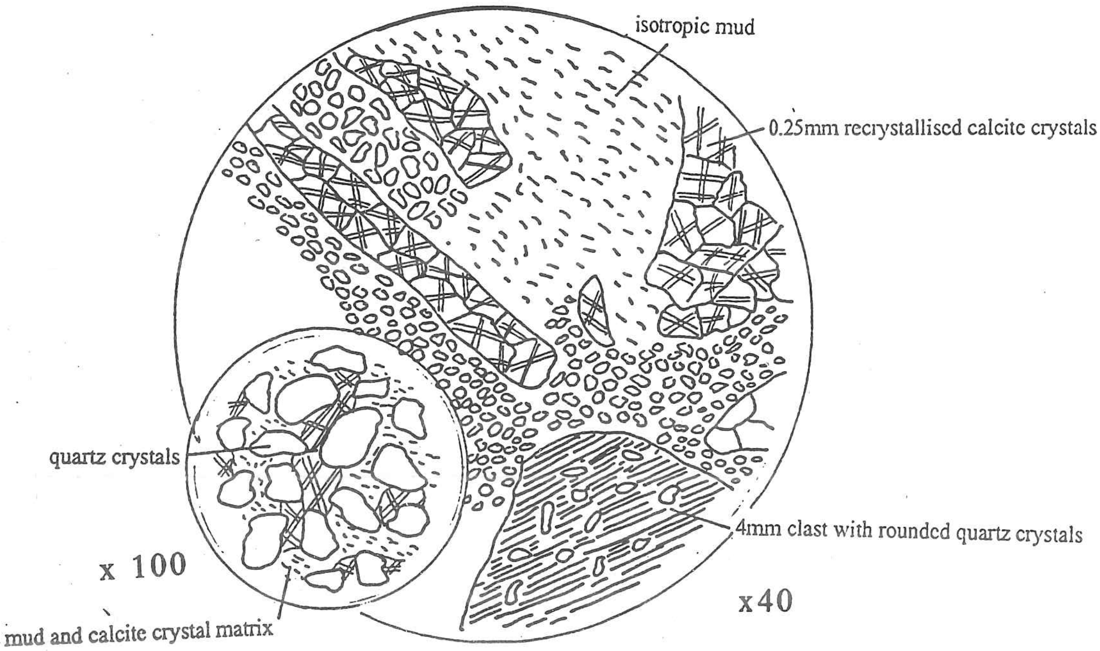
FURTHER WORK

Although there has been significant work done throughout the area, there is scope for more. The next main river to the north of Kongresselva shows equally good exposure and would be suitable for logging. This would show if there is local lateral continuity of formations, especially in the Janusfjellet Formation, and it would also be possible to compare it with the Festningen section. It would also provide further structural evidence especially in the units that are overturned.

APPENDIX 1 : Sketch of thin section of Kapp Starostin Formation.

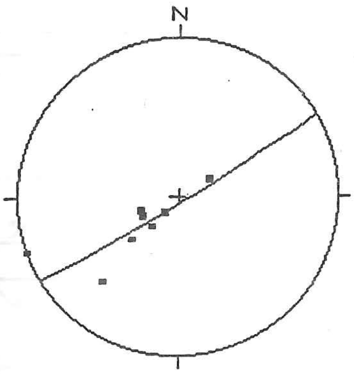


APPENDIX 2 : Sketch of Vardebukta limestone



APPENDIX 3 : Stereonets of fold data

Plunge and Trend of Fold Axes shown



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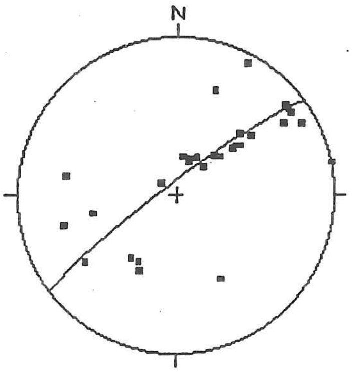
BD 3/329



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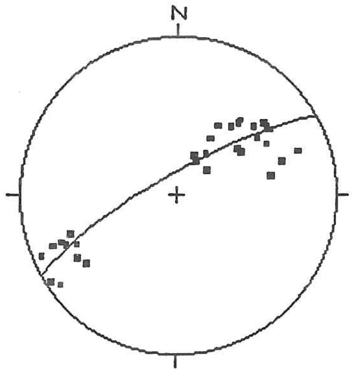
CN-1 6/142



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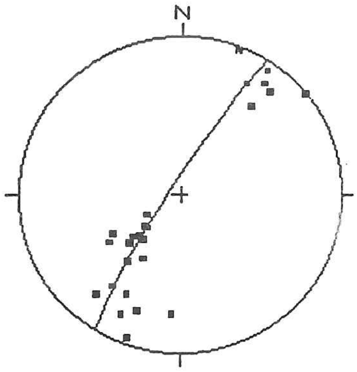
EB 10/149



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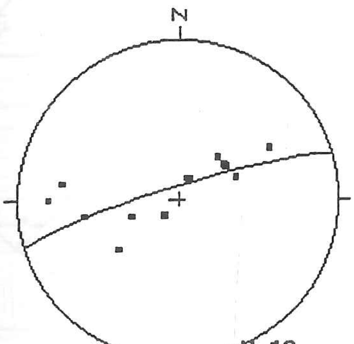
ED 7/162



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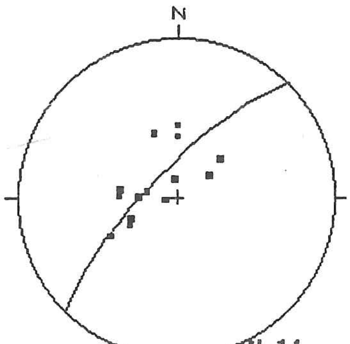

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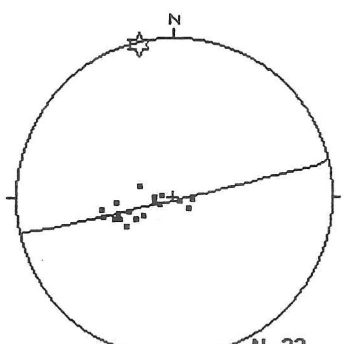

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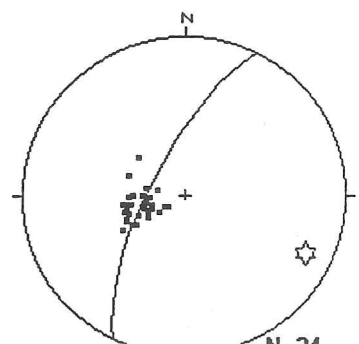

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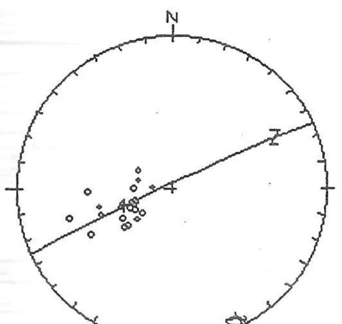
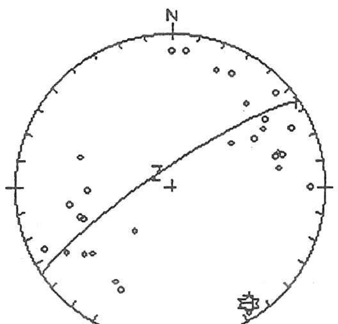
FT 18/115



N=21

FV 2/154



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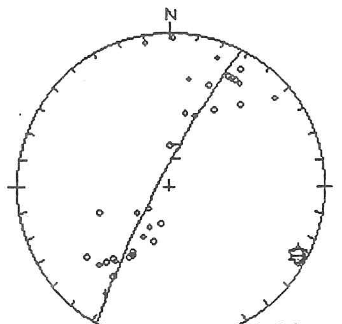
GJ-1 10/146



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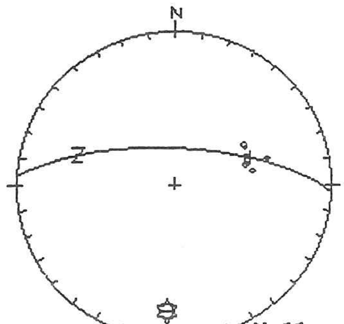
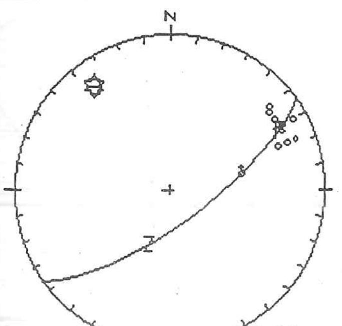
GJ-2 6/118



N=11

GJ-3 19/183



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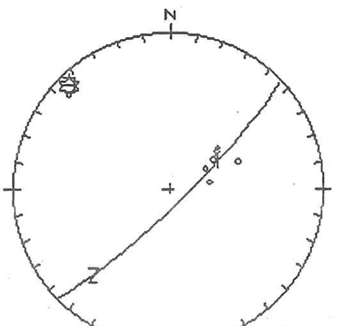
GJ-4. 17/243



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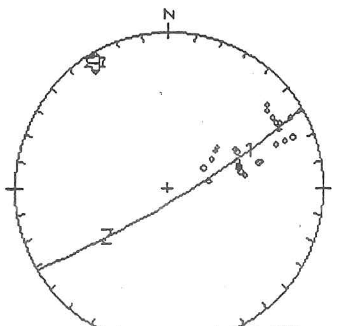
GJ-5 8/315



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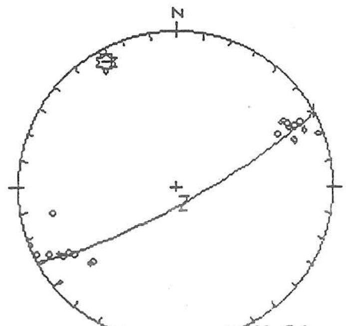
GJ 3,4+5 8/330



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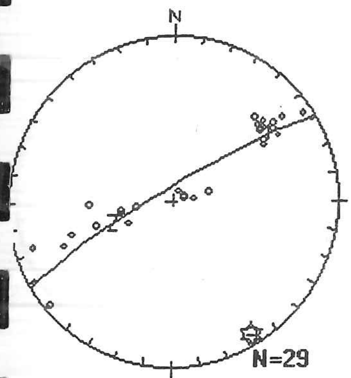
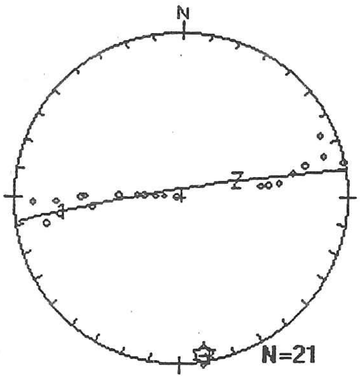
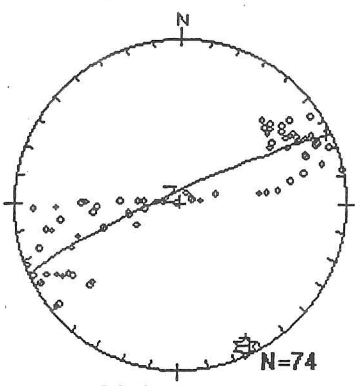
GO-1 9/330



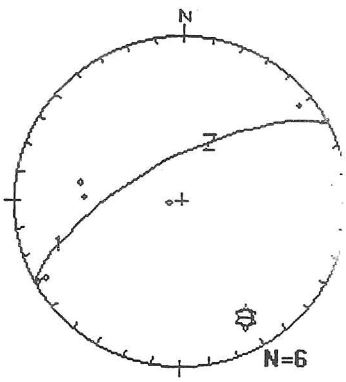
GO-2 5/150



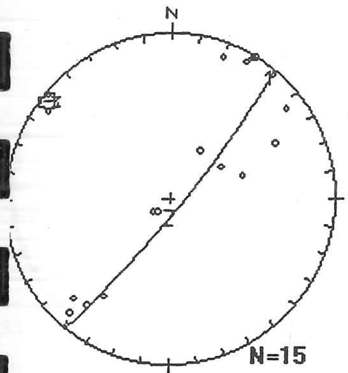
GO-3. 4/170



GO 1,2+2 5/162



IB. 15/151



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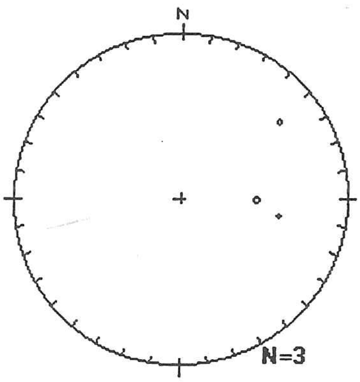

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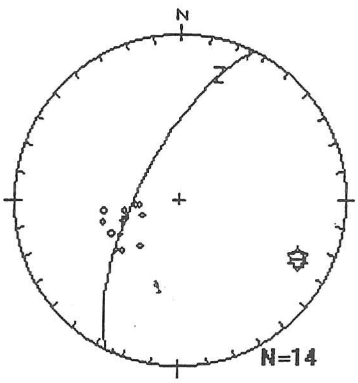

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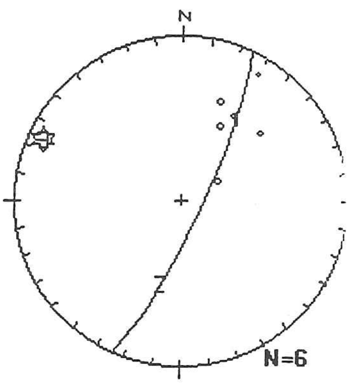

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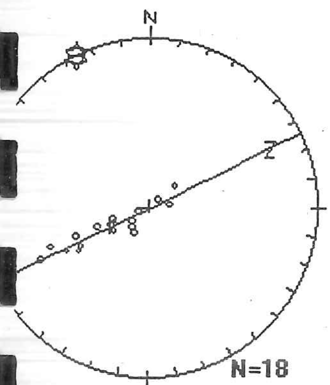

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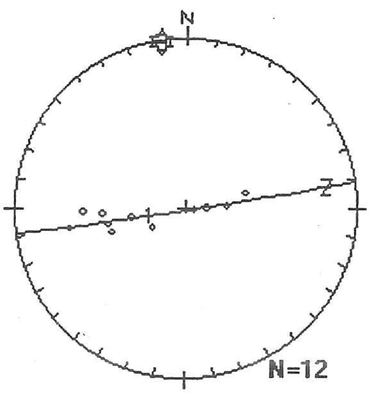

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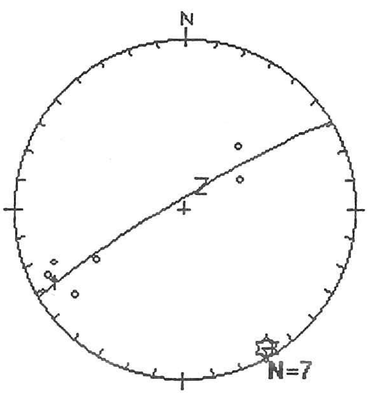

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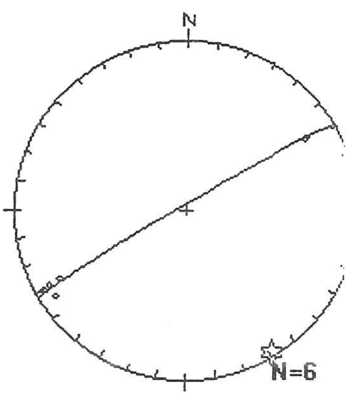

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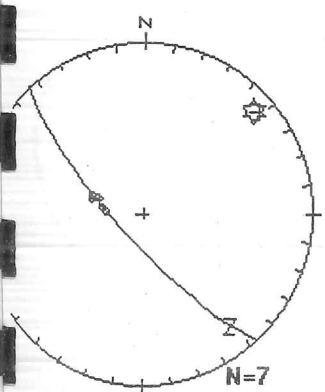

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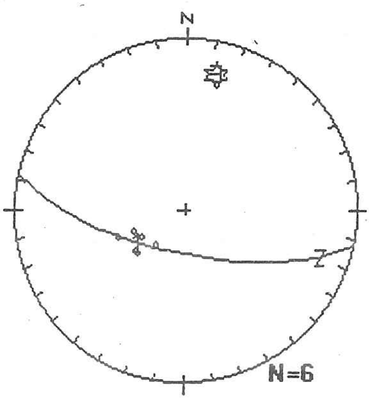

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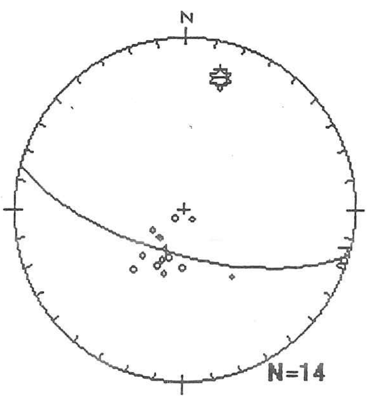

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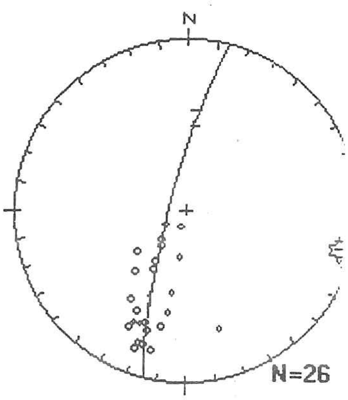
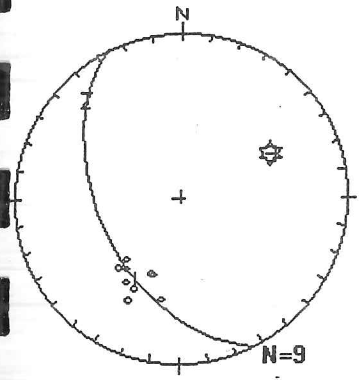


OP. 8/103



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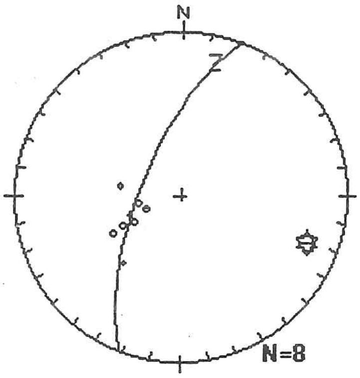

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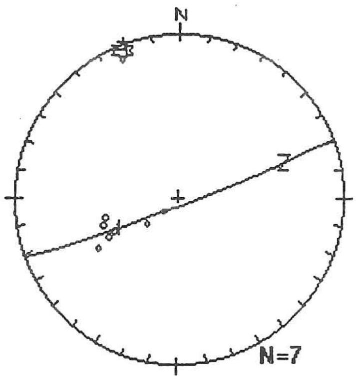
19/110



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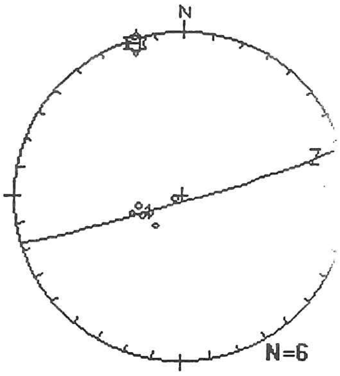
3/338



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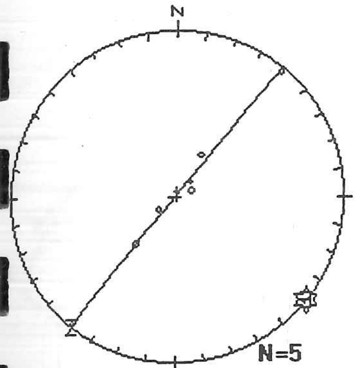
3/342



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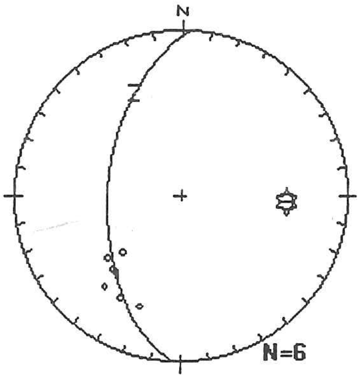

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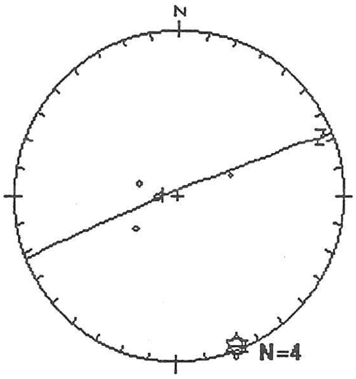
36/093



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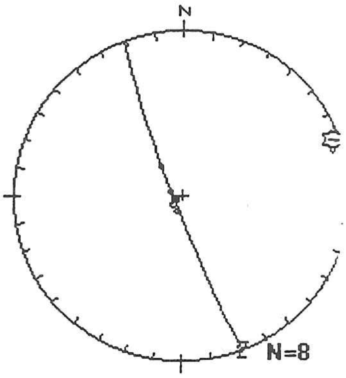
2/157



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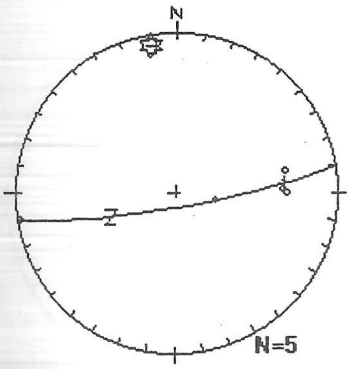
4/069



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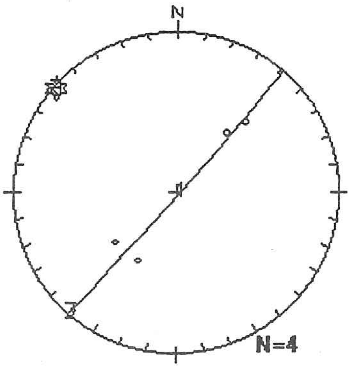
7/350



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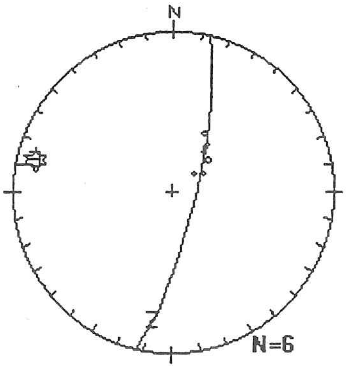
1/310



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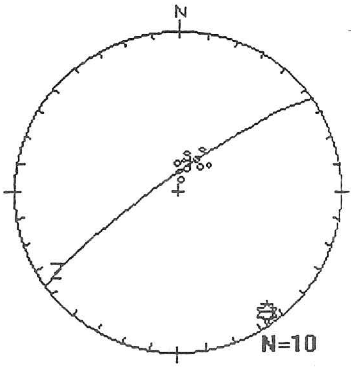
11/283



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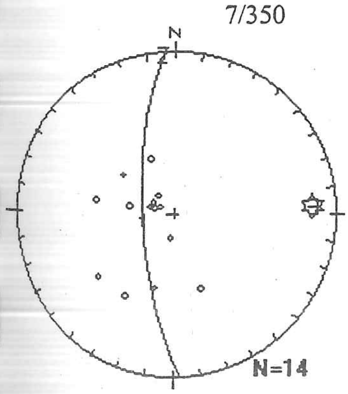
8/144



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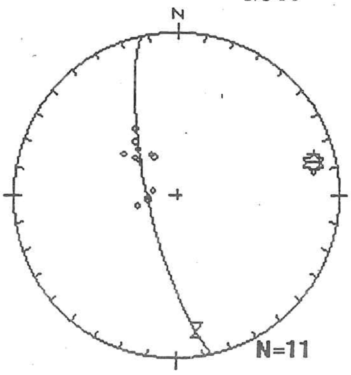
15/087



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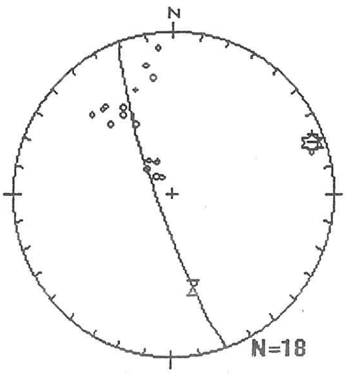
14/076



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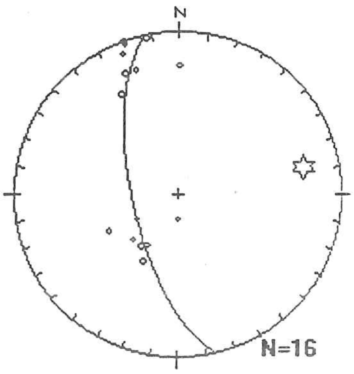
8/070



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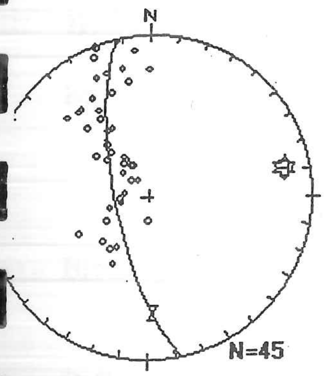

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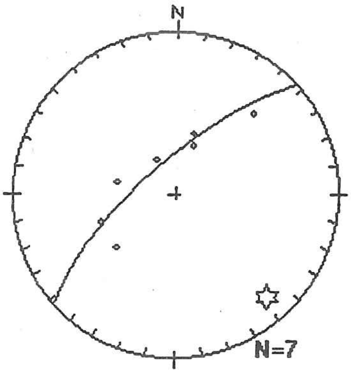

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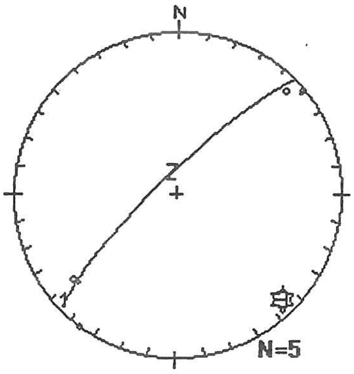

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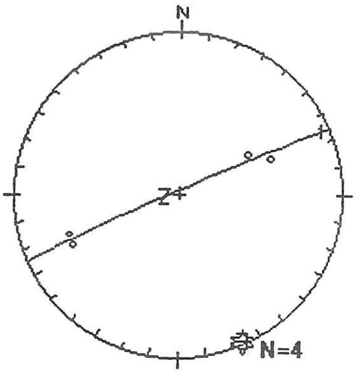

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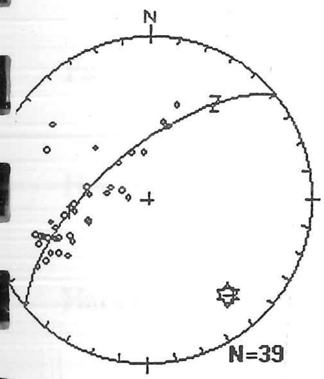

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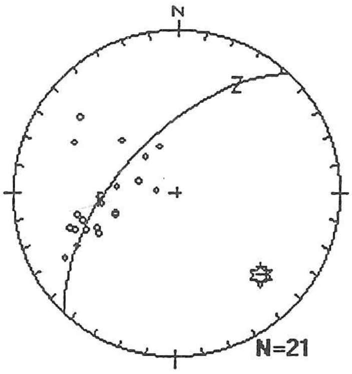

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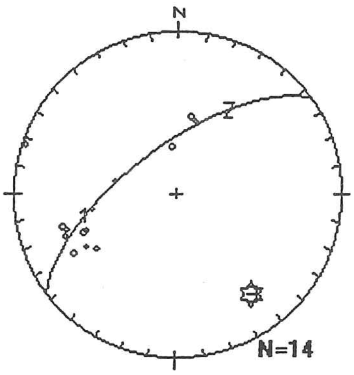

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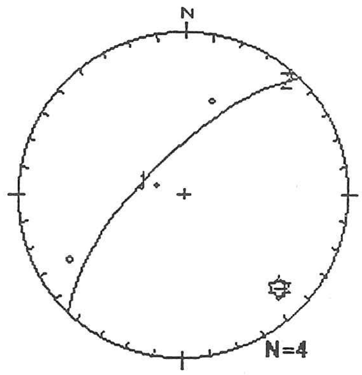

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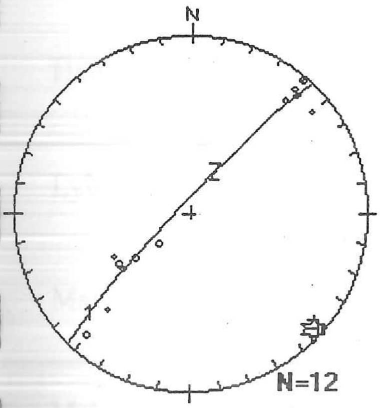

UG. 5/132

BIBLIOGRAPHY

Braathen, A., and Bergh,S.G., 1995. Structural outline of a Tertiary Basement-cored uplift / inversion structure in western Spitsbergen, Svalbard : Kinematics and controlling factors. *Tectonics,* **14 (1)**, 95-119.

Bromley, R.G., and Ekdale, A.A., 1984. *Chondrites* : A trace fossil indicator of anoxia in sediments. *Science*, **224**, 872-874.

Dallmann, W.K., Andresen, A., Bergh, S.G., Maher, H.D. and Ohta, Y. 1993. Tertiary fold and thrust belt of Spitsbergen, Svalbard. *Medd. Nor. Polarinstitutt*, **128**, 46pp.

Fu, 1991. Funktion, Verhalten und Einteilung fucoider und Iophocteniider Lebensspuren *Courier Forschunginstitut Senckenberg,* **135** 1-79.

Haq, B.U.and , Hardenbol, J., 1987. Chronology of Fluctuating Sea Levels since the Triassic. *Science*, **235**, 1156-1167.

Harland, W.B. 1969. Contribution of Svalbard to the evolution of the North Atlantic region. In : Kay. M. (ed.) North Atlantic Geology and Continental Drift. *American association of Petroleum Geologists Memoir*,**12,** 817-857.

Harland, W.B., Mann, A., and Townsend, C. 1988. Deformation of Anhydrite-gypsum rocks in central Spitsbergen. *Geological Magazine*, **125 (2)**, 103-116.

Hoel, A., and Orvin, A.K. 1937. Festnungsprofil auf Spitzbergen. Karbon-Kreide, I, Vermessungsresultate. *Norg. Svalbard Ishavs Unders. Skr.,* **18**, 1-59.

Lyberis, N., and Manby, G., 1993. The West Spitsbergen Fold Belt : the result of Late Cretaceous - Paleocene Greenland - Svalbard Convergence ?. *Geological Journal*, **28**, 125-136.

Maher, H.D. 1989. A storm related origin for the Jurassic Brentskardhaugen Bed of Spitsbergen, Norway. *Polar Research*, **7**, 67-77.

Maher,D.H., Braathen, A., Bergh, S.G., Dallmann, W.K. and Harland, W.B. 1995. Tertiary or Cretaceous age for Spitsbergen's fold -thrust belt on Barents Shelf. *Tectonics*, **14 (5)**, 1321-1326.

Ohta, Y. 1982. An additional presentation on the basement-platform boundary structures in N.W. Nordenskiöld Land Pp 32-33 in Dallmann, W.K., Ohta, Y.& Andresen, A. (eds.) : Tertiary structures of Svalbard. Extended abstracts from Symposium held in Oslo 26 and 27 April 1988. *Norsk Polarinstitutt Rapportserie 46.*

Ohta, Y., Hjelle, A., Andresen, A., Dallmann, W.K., and Salvigsen, O. 1992. Geological map of Svalbard, scale 1:100,000, sheet B9G Isfjorden, *Temakart* **16**. Oslo : Norsk Polarinstitutt.

Pemberton ,S.G., and Frey,R.W., 1982. Trace Fossil Nomenclature and the *Planolites - Palaeophcus* Dilemma. *Journal of Paleontology*, **56**, 843-881.

Ramsay, J.G., and Huber, M.I., 1983. *Techniques of Modern Structural Geology : Volume 1 : Strain Analysis,* 140-141. London : Academic Press, INC.

Steel, R.J., and Worsley, D., 1984. Svalbard's post - Caledonian strata - An atlas of sedimentation patterns and paleogeographic evolution. 109-135 in Spencer, A.M. et al (eds.). *Petroleum Geology of the North European Margin.* Norwegian Petroleum Society.

Treatie on Invertebrate Paleontology G : *Bryozoa* . 253pp. 1968. : The Geological Society of America inc. and University of Kansas Press.

Treatie on Invertebrate Paleontology H(1) : *Brachiopoda*. 521pp. 1965. Kansas : The Geological Society of America inc. and University of Kansas Press.

Topographic map used for base map : Map Sheet **B9 : Isfjorden** : 1: 100,000. Norsk Polarinstitutt, Oslo 1989.

Aerial Photographs : Flight LN-TVY HS/GJ ; Camera : RC8 15,2/23cm ; Date 19-8-1969 : Sheets **2492** & **2495**. Both 1:20,00 and enlarged to 1:10,000. Norsk Polarinstitutt.

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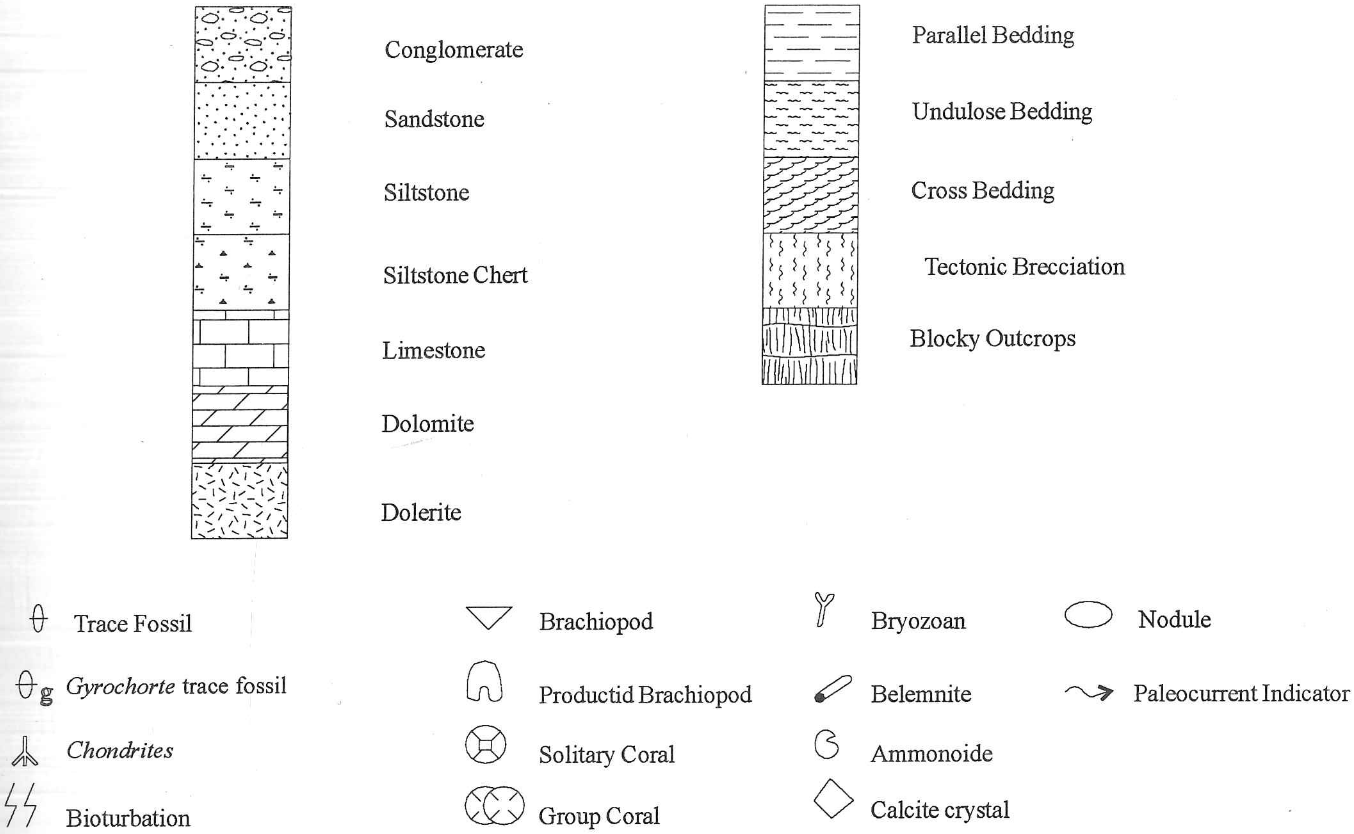
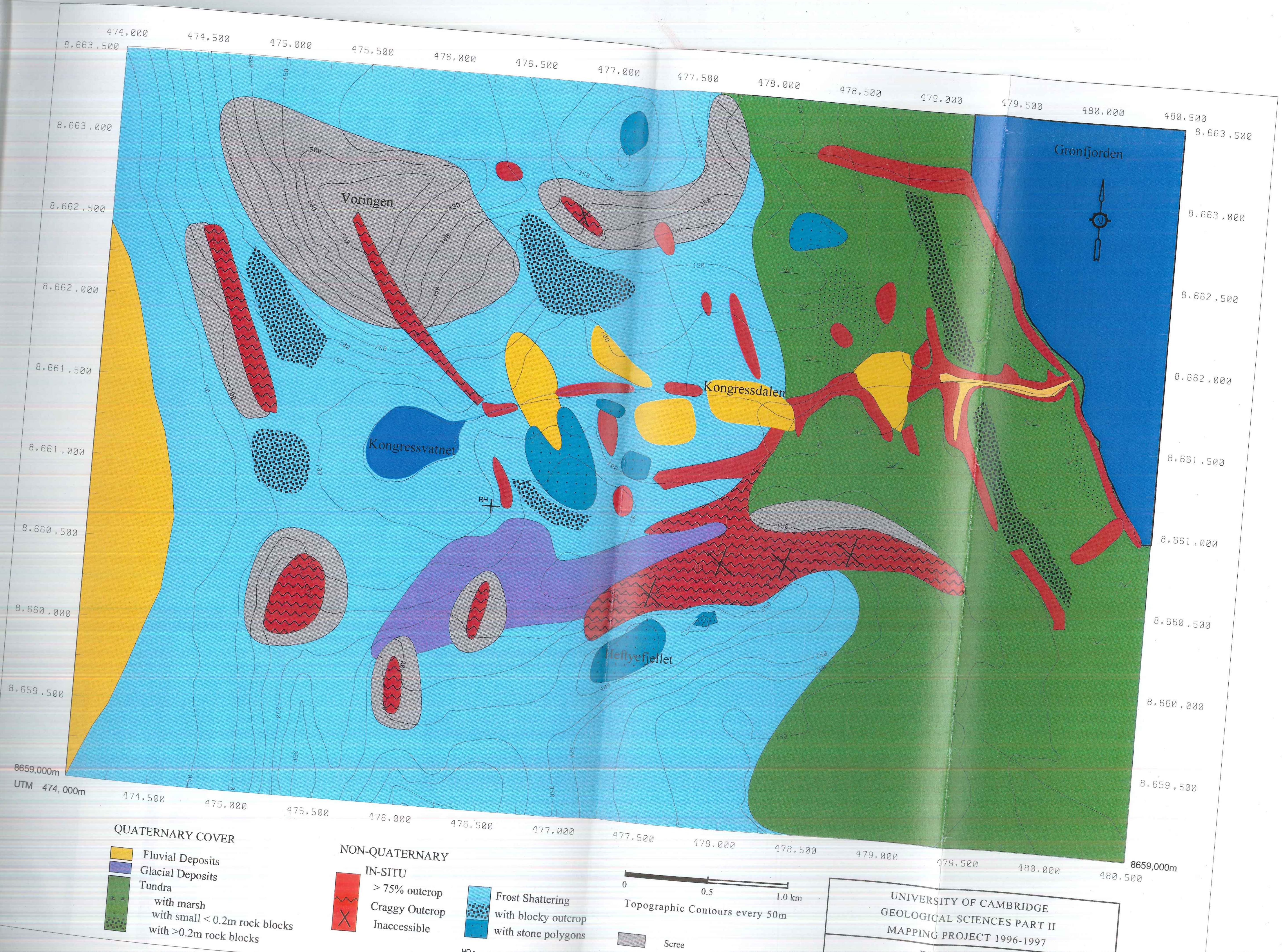
Key to Sedimentary Logs





Voringen
Kongressvatnet
Kongressdalen
Heftyefjellet
Grønfjorden
RH
8659,000m
UTM 474, 000m
QUATERNARY COVER
Fluvial Deposits
Glacial Deposits
Tundra
with marsh
with small < 0.2m rock blocks
with >0.2m rock blocks
NON-QUATERNARY
IN-SITU
> 75% outcrop
Craggy Outcrop
Inaccessible
Frost Shattering
with blocky outcrop
with stone polygons
0
0.5
1.0 km
Topographic Contours every 50m
Scree
UNIVERSITY OF CAMBRIDGE
GEOLOGICAL SCIENCES PART II
MAPPING PROJECT 1996-1997