



# Bergvesenet

Postboks 3021, N-7441 Trondheim

## Rapportarkivet

Bergvesenet rapport nr	Intern Journal nr	Internt arkiv nr	Rapport lokalisering	Gradering
6910				

Kommer fra ..arkiv	Ekstern rapport nr	Oversendt fra	Fortrolig pga	Fortrolig fra dato:
Grong Gruber AS		Grong Gruber a.s.		

Tittel  
Presentasjon for interesserte oljeselskap: Prospektering i Skorovasfeltet/Grongfeltet

Forfatter	Dato	År	Bedrift (Oppdragsgiver og/eller oppdragstaker)
Jensen, Roar	18.12	1981	Elkem AS, Grubedivisjonen

Kommune	Fylke	Bergdistrikt	1: 50 000 kartblad	1: 250 000 kartblad
Namsskogan Røyrvik	Nord-Trøndelag		1824 2	Grong

Fagområde	Dokument type	Forekomster (forekomst, gruvefelt, undersøkelsesfelt)
Geologi Geofysikk Økonomi		Skorovasfeltet Skorovas gruber Grongfeltet

Råstoffgruppe	Råstofftype
Malm/metall	Cu, Zn

Sammendrag, innholdsfortegnelse eller innholdsbeskrivelse  
Noe korrespondanse mellom Elkem AS og Grong Gruber A/S vedrørende:

En vurdering om en samlet innsats ovenfor interesserte oljeselskap mellom Elkem AS og Grong Gruber A/S.  
En presentasjon av Skorovasfeltet, varsler en tilsvarende for Grong gruber A/S noe senere.

Telefon fra Thor

29.03.87

Ref. møte m/BP hos Elken 26.03.

1. Hans uttalelse har ikke den samme oppfatning som jeg når det gjelder hvordan Elken uttrykker sitt engasjement. På meg virker det som de nå ønsker å delta i aktieprospekting.
2. Thor mener at et oljeselskap som vil bruke penger, må prospektere sammen med oss i et vist antall år (5 eller mer). Forutsetning må være et antall år i Gronsfjeld. Hvis det viser seg negativt, mulighet til sammen arbeide i andre områder.
3. Vi må ha styring.
4. Thor ikke på en enmodell 49-51 -størrelse til oss.  
Thor heller på en modell 15-85 for virksomhet.
5. Ikke den modell som skissert fra Elken.

H. Bechelmann BP Norge Friday 26.11.82

Tam Elden BPM Europa Elektronikk.

Mike Davis ansvar UK/Norge

R. Jensen

C. W. Carsthus

D. Guen

V. Wiik

A. Hauken

BP → NFF free to take 3. part  
but must take in NFF.

Hvilket vil vår reaksjon på et  
enske fra BP om hele Calidonidene  
som interesse-ansvar.

Gjort oppmerksom på at:

- reserverer et område rundt Joma

- den interessante forespørre.

Det er sagt at BP må gjerne komme til  
Joma for å se på mer stoff men etter at  
en reell interesse er uttrykt.

BP vil gjøre forsøk på å få klargjort hva som  
må gjøres og sin interesse manifest. Hils forpøstle

Postadr.: 7894 Limingen  
Telefon: Reyrvik (077) 35 200  
Bank: Forretningsbanken A/S  
Kamsos  
Bankkonto: 8671 08 04607  
Postgiro: 2 08 55 20  
Telex: 55001 joman

Elkem a/s  
Grubedivisjonen  
Postboks 5430 Majorstua  
OSLO 3

Deres ref.:

Vår ref.: IS/ah

7894 Limingen, 1. mars 1982

Att.: Direktør Leif Kopperstad

### PROSPEKTERING I GRONGFELTET.

Vi viser til Deres brev av 12. februar 1982 hvor De fremkaster visse synspunkter angående en prospekteringskampanje i samarbeid med et oljeselskap. Denne sak er behandlet i Grong Gruber's styre hvor man stilte seg positivt til et samarbeid med Elkem for å kunne kombinere alle tilgjengelige data i en felles presentasjon overfor interesserte oljeselskaper.

For å konkretisere en del punkter tillater vi oss å komme med følgende kommentarer og forslag:

#### 1. Presentasjon

Grong Gruber's presentasjon: "Prospecting and ore potentials in the Grong-field" vil være ferdig i uke 9. Etter opplysninger fra Elkem vil presentasjonen av Skorovassfeltet foreligge på samme tid. Vi vil foreslå at de to rapportene følger som bilag til et brev hvor rapportene oppsummeres og betingelsene overfor oljeselskapet fremsettes. Likeledes må det inneholde et forslag til fremdrift.

#### 2. Organisasjon

##### 2.1 Kontraktsforhandlinger

Til å føre kontraktsforhandlinger med potensielle samarbeidspartnere foreslås det nedsatt et utvalg på tre personer, en fra Elkem a/s, en fra Grong Gruber A/S og en av de andre eierne. Utvalget får i oppdrag innen opptrukne rammer, å forhandle seg frem til et avtaleverk som endelig må godkjennes av Elkem og Grong Gruber.

##### 2.2 Letefasen

Vi er litt usikre hva som menes med: "For gjennomføringen av programmet benyttes en operatør som bør knyttes sterkest mulig opp mot eierselskapene i Grong Gruber".

Organisasjonsmessig må man ha en klar forbindelse med oljeselskapet, og det ligger da naturlig å velge Grong Gruber. Vi foreslår at et utvalg av eierne danner en styringskomité som kontrollerer inngåtte avtale, omforenet frem-

driftsprogram og økonomi. Større endringer i program løpnes frem som store årsoppgifter. Oljeselskap og Grong Gruber rapporterer til styringskomiteen ved månedlige "progress-reports" inkludert økonomisk oversikt. Den bør detaljerte samarbeidsform mellom oljeselskapet og Grong Gruber må avtales spesielt.

### 3. Samarbeidsbetingelser

Vi er enige at kostnadsfordelingen bør være 20/80 i letefasen hvor oljeselskapet står for 80%. Dette er etter det vi forstår, normalt ved lignende avtaler. Belpens størrelse blir å fastsette i forhold til hittil pålepte kostnader omregnet til nåverdi som viser følgende tall:

	NOK mill.
Grong Gruber A/S	19,72
Elkem a/s	12,-
Total	31,72

Dersom man antar at undersøkelsesperioden strekker seg over 5 til 7 år med en årlig kostnad på kr 5 mill. vil man etter 20/80-fordelingen få:

	Fr. år	5 år	7 år
	mill. kr		
Grong Gruber A/S	0,8	4,0	5,6
Oljeselskap	4,0	20,0	28,0
	4,8	24,0	33,6

Oljeselskapet vil etter dette "dekke":

$$5 \text{ års-periode: } \frac{20 \times 100}{31,7 + 24} = 35,9\%$$

$$7 \text{ års-periode: } \frac{28 \times 100}{31,7 + 33,6} = 42,9\%$$

Etter det vi har fått opplyst skulle denne "andel" ligge innenfor rammen av lignende avtaler.

Letefasen's lengde kan være avhengig av nødvendige håndgivelsetid for noen av staten's bergrettigheter som ligger innenfor det aktuelle område.

### 4. Eventuelle dritverdige funn

En avtale med et oljeselskap må inneholde betingelser for et driftsselskap. Man er innforstått med at Grong Gruber alene, eller i samarbeid med et annet norsk selskap, må ha over 50% eierandel, og at Grong Gruber blir operatør. Denne del av avtalen må legges frem for Industridepartementet som vurderer om avtalen faller innenfor gjeldende lover og regelverk.

### 5. Avtale: Elkem a/s - Grong Gruber A/S - oljeselskap

De antyder et avtaleverk som skal regulere tre omtalte felter. Vi er av den mening at en prioritering av spesielle prosjekter i en avtale kan få uheldige utslag da resultater fra parallelle undersøkelser kan føre til nødvendige omprioriteringer. Angående verdisettingen av Elkem's godtgjørelse, ber vi Dem komme med et konkret forslag, da dette må være klarlagt for forhandlinger med et oljeselskap tar til.

6. Tilbud om ekspertise

Vi har notert oss tilbud med interesse. Bruk av denne ekspertise kan være avhengig av oljeselskapet's opplegg, men må selvsagt presenteres for oljeselskapet. Til orientering kan nevnes at A/S Sydvaranger har kommet med lignende tilbud. Vi er av den mening at man bør tilstrebe å bruke norsk ekspertise der denne er tilgjengelig.

7. Opsjonsrett - eiendomsområdet Skogsvatn

På det nåværende tidspunkt synes dette lite aktuelt, men en opsjon basert forkjøpsrett vil være aktuelt.

8. Samarbeidspartnere - oljeselskaper

Man er enig om å kontakte flere selskaper. De har allerede vært i forbindelse med BP Minerals, og som nevnt over telefon vil De underrette EP om at en formell henvendelse vil komme snart.

Vi vil kontrakte Shell og muligens et par andre. Norsk Hydro har vist interesse, men den er tydeligvis mest rettet mot Mo-mineraliseringen.

Avtalebetingelser mellom Norsk Hydro og EP må også avklares, noe De vil ta opp med EP.

9. Tidsplan

Det er av stor viktighet å få startet undersøkelsene allerede i år. Vi foreslår etter at interesserte selskaper er kontaktet, at det en mulig holdes innledende møter i Oslo 17. og 18. mars. Grong Gruber skal ha styremøte 19. mars.

10. Undersøkelsesområde

For Grong Grubers del må vi holde et nærmere spesifisert område rundt Jonaforekomsten utenfor avtalen. Dette skyldes avtalen med Staten angående drift av denne forekomst. Området's størrelse må nærmere fastsettes med Staten v/Industridepartementet. Vi har søkt Staten om håndgivelse av Skiftesnyr og 1 muting i Fremstfjell. Disse to vil i så fall inngå i undersøkelsesområdet.

Likelades må Deres håndgivelseavtale med Staten være klarlagt for en eventuell avtale.

Vi håper disse forslag og synspunkter har avklart en del punkter i et fremtidig avtaleforhold.

Med hilsen  
pr. Grong Gruber A/S

Ivar Dybdahl

Kopi: Direktør Fredrik Qvale, Elekro a/s, Oslo.



Elkem as  
Grubedivisjonen

53947

Deres ref

Vår ref

LBK/rk

Dato

12. februar 1982

Grong Gruber A/S

7894 LIMINGEN

K.

A. Haugum

Dybdal

Att.: Adm.direktør Ivar Dybdal

#### PROSPEKTERING I SKOROVASFELTET

Vi viser til tidligere kontakt om utnyttelse av den malmgeologiske viten om Skorovas-feltet som Elkem sitter inne med.

Denne viten omfatter delvis rapporter og annet materiale som selskapet disponerer, men er i avgjørende grad også knyttet til kunnskaper og erfaring hos de av våre ansatte som har vært tilknyttet virksomheter i forbindelse med drift og undersøkelser i feltet totalt.

Vi har hatt kontakt fra selskaper som har indikert interesse for å diskutere videre eventuell nyprospektering i Skorovas-feltet, men det er et tungtveiende ønske fra oss at man kan finne en ordning sammen med Grong Gruber som gjør at Grong-feltet som helhet kan dekkes av en ny prospekteringskampanje.

På møte i Skorovatn med representanter for Grong Gruber ble det 1.-2/2 i år redegjort for det materialet vi tenker oss kan ha interesse i denne sammenheng. Her ble det også gitt en liste over relevante rapporter, kart, borkjerner o.l. Samtidig ble det angitt en kostnad for å fremskaffe et tilsvarende materiale i 1982-kroner.

Ved diskusjonene i Skorovatn ble det konkludert med at Grongfeltet totalt, Skorovas-feltet og Molybden-feltene i Fremstfjell og Gaizer er tre konkrete prospekteringsobjekter å gå videre på.

Ved driftsstans 1/5-83 av Skorovas Gruber vil i henhold til avtalen med Staten bl.a. alle bergrettigheter og malmgeologisk materiale tilfalle Staten. I Industridepartementet er det redegjort for våre tanker, og det forhandles nå om en håndgivelsesavtale med Staten for bergrettighetene i Skorovas konsesjonsområde og det materiale som er knyttet til disse. Det forutsettes en 5 års avtaletid. Vi vil i tillegg til gjeldende bergrettigheter også munte objekter og anomalier som kan være av verdi ved en ny prospektering i feltet.



Vi tenker oss et avtaleverk mellom Grong Gruber, Elkem og et utenlandsk oljeselskap som skal regulere et f.eks. 5 års prospekteringsprogram for de 3 før omtalte feltene. Godtgjørelse til Elkem for å stille sitt materiale til disposisjon for gjennomføringen av programmet kan skje ved en engangsgodtgjørelse og eller ved årlig leie. Verdien av dette materialet kan sammen med verdien av Grong Grubers eget materiale utgjøre det beløp oljeselskapet skal dekke opp i prospekteringen. Skulle prospekteringen resultere i drivverdige funn må siktemålet være at Grong Gruber både blir operatør og få en eierandel over 50%.

I prospekteringsfasen kan kostnadene fordeles i forholdet f.eks. 20:80. Vi mener således at ved etableringen av avtalen kan vi i stor grad bygge på de samme forutsetninger og forhold som man har lagt til grunn for tilsvarende avtaler om prospekteringssamarbeid (f.eks. Union Minerals Norge i Fen-feltet). For gjennomføringen av programmet benyttes en operatør som bør knyttes sterkest mulig opp mot eierselskapene i Grong Gruber.

Dersom det ansees som ønskelig, kan man diskutere en opsjonsrett for Grong Gruber og et tredje selskap til innenfor avtale-perioden å overta det eiendomsområdet Elkem har i Skorovatn til en nærmere definert takstpris.

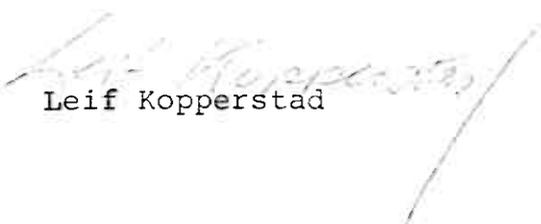
Ønskelig og tilgjengelig ekspertise innen prospektering og kjennskap til materialet og lokale forhold kan på nærmere avtalte betingelser stilles fra Elkem til operatøren for gjennomføringen av prospekteringsprogrammet.

Med disse tanker som utgangspunkt for videre forhandlinger, håper vi på snarlig svar slik at vi sammen kan starte arbeidet med å utforme avtaletekstene.

Det bør siktes på å få benytte feltsesongen 1982.

Dersom vi mot formodning ikke skulle lykkes i å oppnå enighet om disse forholdene, vil vi gå direkte mot oljeselskap med sikte på en undersøkelse begrenset til Skorovas eiendoms- og konsesjonsområde.

Med vennlig hilsen  
for Elkem a/s  
Grubedivisjonen

  
Leif Kopperstad



PROSPEKTERINGSMATERIALE FRA SKOROVAS

Møte i Skorovatn 1. - 2. februar 1982

Deltakere:           Fra Grong Gruber:   **A.Haugen**  
                                                                          **T.Sverdrup**  
                                                                          **V.Wiik**

**Fra Skorovas Gruber:   Ø.Johansen**  
                                                                          **C.W.Carstens**  
                                                                          **R.Jensen**

Hensikten med møtet er å få presentert det materialet som er lagret i Skorovatn og som kan ha betydning for fremtidige prospekteringsarbeider i Skorovas-området. En liste over slikt materiale og en prisantydning for kostnader ved å fremskaffe disse data pr. 1982 vil bli lagt frem.

Dersom tiden tillater dette, foreslås at vi diskuterer det faglige innholdet i et eventuelt prospekteringsprogram Grong Gruber eller Grong Gruber og Elkem i felleskap kan presentere overfor interesserte oljeselskap.

Program

- 1. februar kl. 07.00, avreise Fornebu
  - "       "    kl. 08.53, tog fra Stjørdal
  - "       "    kl. 12.07, ankomst Lassemoen
- Skorovas henter med bil.
- 1. Presentasjon av rapport og kart-arkiv.  
Gjennomgåelse av enkeltrapper etter gruppens ønske.
  - 2. Presentasjon av budsjettpriser for materialet.
  - 3. (Eventuelt) Diskusjon om fremtidige prospekteringsarbeider.
  - 4. Utarbeidelse av alternative program for slike arbeider.
- 2. februar kl. 16.27, avreise Lassemoen
  - "       "    kl. 19.45, ankomst Stjørdal
  - "       "    kl. 20.25, avreise Værnes
  - "       "    kl. 21.15, ankomst Fornebu

Forhandlinger om en avtale mellom Grong Gruber og Elkem vil kunne starte primo februar.

SAMLEPERM

Bilag 1	Oversikt over prospekteringsmateriale Verdisetting av prospekteringsmateriale	R.Jensen  R.Jensen
Bilag 2	Geological setting of the Skorovas orebody within the allochthonous volcanic stratigraphy of the Gjersvik Nappe, Central Norway	C.Halls, A.Reinsbakken I.Ferriday A.Haugen A.Rankin
Bilag 3	Geology of the Skorovas Mine: A volcanic Massive Sulphide Deposit in the Central Norwegian Caledonides	NGU-serien nr.360 A.Reinsbakken
Bilag 4	Malmletingstatus for Skorovas Gruber og mulighetene ved ytterligere prospektering	Notat fra C.W.Carstens 23.3.81
	Forslag til prospekteringsplan i Skorovasfeltet	
	Fig. 1: Forslag til prospekteringsområde	Notat fra C.W.Carstens 25.5.81
	Sammensetningskart over turamundersøkelser i grubefeltet	
	Sammenstillingskart av IP-undersøkelser i grubefeltet	
	Geologisk kart, Halls & Co. med omriss av foreslått prospekteringsområde	
Bilag 5	Situasjonskart over grenser/konsesjoner i Grongfeltet	
	Liste over geologiske og geofysiske rapporter i arkivhulle i Skorovas	



SKOROVAS GRUBER

Prospekteringsmateriale pr. Desember 1981

1. Topografiske kart  
 M = 1:10.000 (280 km<sup>2</sup>) (1955)  
 M = 1:2.000 (3 km<sup>2</sup>)  
 Eiendomsområde 155 km<sup>2</sup>  
 Eiendoms + konsesjonsområde 265 km<sup>2</sup>
  
2. Flyfotomosaikk  
 M = 1:10.000 (280 km<sup>2</sup>)  
 Flybilder dekker hele feltet.  
 M = 1:20.000 (Joma Bergverk 1966) (Hele Grongfeltet)
  
3. Geologiske kart  

Foslie	1930	1:100.000	
Gjelsvik	1970	M44	
Grønhaug	1970	1: 25.000	
Huseby	1971	1: 10.000	
Halls	1971-1977	1: 10.000	
Reinsbakken	1977	1: 2.000	
Grubekart og profiler		1:200	
Ferriday	1974-75		
  
4. Geokjemiske kart m/analyser Cu-Zn-Pb-Ni-Co  
 Terratest 1970 1:25.000 60 km<sup>2</sup> 235 pkt., 8 elementer  
 Skorovas/NGU 1972-75 1:50.000 320 pkt., 6 elementer + Skorovasklumpen.
  
5. Geofysiske målinger  
 Terratest flymålinger 1962 (280 km<sup>2</sup>) (250 m profilavst.)  
 Terratest helikopter 1972 ( 20 km<sup>2</sup>) (134 profil km)  
 NGU " 1974 (250 km<sup>2</sup>)



NGU	turam	1969	10 km <sup>2</sup>	
NGU	turam	1974	10 km <sup>2</sup>	
NGU	IP	1973	2 km <sup>2</sup>	← for smøret malområde
NGU	IP	1975	2 km <sup>2</sup>	
Cp, JP, PP og Turam i borkull				
Elkem AMT		1979	6 profilkm.	

6. Malmberegninger + driftskalkyle

Sydpstmalmen	450' t	1,69% Cu	(1,4% produksjon)
Sydmalmen	550' t	1,43% Cu	1,47% Zn <u>in situ</u>

7. Diamantboringer med kjærnebeskrivelser og malmanalyser.  
(Detaljboring for driftskontroll i gruva ikke tatt med).

	Totalt	Prospektering
a) DEH 1-100 fra 1913 og utover, 100 hull á ca. 150 m lengde =	15.000 m	1.500 m
b) Hull med bokstavnr. og dyphull fra gruva fra Foslie 1936 og utover	5.000 m	3.000 m
c) 10.000-serien 84 hull (200 m lengde)	18.000 m	15.500 m
	38.000 m	20.000 m

Kjærner fra prospekteringsboringer finnes lagret i Skorovatn.  
Resultatene (geol. beskrivelse og kjemiske analyser) er fremstilt  
på kart og profiler.

8. Opprettholdte bergrettigheter pr. 12. desember 1981.

- a) 3 lengdemål (1917)
- b) 2 flateutnål (1981)
- c) 14 mutinger,  
grubefeltet (1975)
- d) 1 muting, Nesåa (1975)
- e) 10 mutinger, Gaizer (1975)
- f) 5 mutinger, Gaizer (1977)

9. Materialet er samlet i gruvas brannsikre rom i arkiv med utarbeidede  
arkivmapper og kartoversikter.

Roar Jensen  
18.12.81

SKOROVAS GRUBER. PROSPECTERINGSMATERIALE. VERDISSETTING.

Oppgaven for utvalget var å gi en oversikt over kunnskaper og rettigheter som Elkem har om Skorovasfeltet (Grongfeltet). Dette er listet opp i mitt notat av 18. desember 1981.

Forhold omkring rettighetene blir behandlet av Myhrvold bl.a. etter spørsmålsliste i mitt notat til Myhrvold (21. desember 1981).

Forutsatt at materialet skulle utarbeides idag, har vi foretatt to alternativeveier for verdissetting.

- A) Markedspris for å få utført tilsvarende rapporter.
- B) Nåverdi av kostnadene Skorovas har hatt på prospektering.

A) Markedspris

Kostnadene er referert til tilsvarende punkter i notat av 18. desember 1981.

1 + 2	Topografiske kart + flybilder og mosaikk		kr. 350.000,-
3.	Geologiske kart.		
	a) Halls 1971-77, M= 1:10.000, 12 årsverk,	kr. 1.800'	
	b) Reinsbakken 1975-77, målestokk 1:2.000,	2 " " 300'	
	c) Grubekart og profiler,	4 " " 600'	
			" 2.700.000,-
4.	Geokjemiske kart m/analyser.		
	a) Terratest, 235 pkt. 8 elementer:		
	Prøvetaking	kr. 25'	
	Analyser	" 30'	
	Plotting	" 25'	
	b) Skorovas Gruber, ca. 600 pkt, 6 elementer:		
	Prøvetaking	" 45'	
	Analyser	" 50'	
	Plotting	" 40'	
			" 315.000,-



5. Geofysiske målinger.

Terratest flymålinger	kr.	280'	
" helikopter- målinger	"	245'	
NGU helikopter- målinger	"	525'	Nåverdi: 250 kr/profil/linje + 20.000 basekost
Turam 1938, -59 og -74,	"	220'	
IP, SP, VLF, AMT	"	150'	
			kr. 1.420.000,-

6. Malmberegninger, driftskalkyle.

Syd og Sydøstmalmen.

Skiftesmyr 1 årsverk, " 200.000,-

7. Diamantboringer med kjernebeskrivelser og malm-analyser.

Detaljeboring for driftskontroll i gruva ikke inklusive.

20.000 m x 300 kr/m: kr. 6.000'

20.000 m x 50 kr/m: " 1.000' *kyndig* " 7.000.000,-

8. Bergrettigheter (2 års avgift) " 20.000,-

9. Årslønn prosjektledere, grubegeolog, adm. av prospektering, 10 årsverk: " 1.500.000,-

kr. 13.405.000,-

B) Nåverdi av prospekteringsutgiftene

1954 - 1980 summert uten indeksjustering i henhold til liste 19.9.1978 med tillegg:

kr. 5.000.000,-

Justert til nåverdi: kr. 10.500.000,-

Årslønn for prosjektleder, geolog og administrasjon av prospekteringen (ikke bokført prospektering), 10 årsverk:

" 1.500.000,-

Sum prospektering

kr. 12.000.000,-

  
Roar Jensen



# Geological setting of the Skorovas orebody within the allochthonous volcanic stratigraphy of the Gjersvik Nappe, central Norway\*

C. Halls  
Division of Mining Geology, Royal School of Mines, London, England

A. Reinsbakken  
Geologisk Institutt, Norges Tekniske Høgskole, Trondheim, Norway

I. Ferriday  
Division of Mining Geology, Royal School of Mines, London, England

A. Haugen  
Grong Gruber A/S, Joma, Norway

A. Rankin  
Division of Mining Geology, Royal School of Mines, London, England

553.067: 553.277: 553.661.21(484.3)

## Synopsis

*The Skorovas orebody is one of the chief stratiform base-metal deposits within the allochthonous greenstone belt of the Central Norwegian Caledonides. It is contained in the volcanic level of a complex eruptive association of Lower to Middle Ordovician age defined as the Gjersvik Nappe. The rocks of this nappe are contained as a depressed segment of the larger Koli Nappe and defined to the north and south, respectively, by the Borgefjell and Grong-Olden basement culminations. The principal components of this nappe are a plutonic infrastructure of composite gabbroic intrusions within which has been emplaced a series of dioritic to granodioritic (trondhjemitic) bodies that form the roots of a consanguineous submarine polygenic volcanic sequence. The eruptive rocks are overlain unconformably by a sequence of polymict conglomerates and calcareous flysch sediments, the composition of which suggests immediate derivation by erosion from the underlying igneous complex.*

*Pre-tectonic segregations, veins and vesicle fillings of epidote, albite, chlorite, carbonate and quartz related to primary volcanic flow structures in the lava pile provide evidence of pervasive in-situ sea-floor metamorphism, and this interpretation is verified by the abundance of nearly monomineralic epidote clasts in the derived conglomerates.*

*The relationship of the eruptive and sedimentary suites is interpreted in terms of the evolution of an ensimatic island arc, of Lower to Middle Ordovician age, which underwent uplift and erosion prior to emplacement on the Fennoscandian basement during the climactic stages of collision tectonism of the Caledonian Orogeny in Silurian times.*

*The entire igneous and sedimentary assemblage has been affected by the tectonic stages of allochthonous emplacement, but the gross differences in competence between the component lithologies has resulted in a particularly hetero-*

*geneous style of deformation in which folding, componential sliding, fracturing and penetrative metamorphic refabrication have been governed largely by the geometry of the most competent lithologies, notably gabbro, diorite and granodiorite (trondhjemitic) intrusives and, within the extrusive sequence, compact dacitic flows and their spilitized aphanitic equivalents (keratophyres). The heterogeneous pattern of deformation is resolved in terms of two main stages of folding complicated by componential sliding movements.*

*Mineralization occurs at two levels in the eruptive sequence. The layered gabbros and lensoid metagabbros of the plutonic infrastructure contain small cumulus bodies of nickel-, copper- and platinum-bearing pyrrhotite-pyrite-magnetite ore of magmatic derivation. Mineralization of this type is at present only known in sub-economic quantities.*

*The Skorovas orebody, in common with other widely dispersed volcanic exhalites in the Gjersvik Nappe, occurs within the volcanic sequence at a level marked by episodes of explosive dacitic volcanism and associated fumarolic activity. The Skorovas orebody consists of approximately 10 000 000 tons of massive and disseminated predominantly pyritic ore with an approximate average grade of 1.3% Zn and 1.0% Cu, together with trace amounts of Pb, As and Ag. The complex lensoid geometry of the orebody is resolved in terms of the disjunction of a single stratiform unit by tight isoclinal folding and componential movements, probably involving both translation and rotation.*

*Enrichment of sphalerite, chalcopyrite and, locally, galena within the magnetite-pyrite ores at the stratigraphic top and margins of the ore lenses is interpreted as a primary feature. The banded magnetite-pyrite ores are commonly associated with magnetitic cherts or jaspers and are thus transitional in aspect to the thin, iron- and silica-rich, base-metal-depleted, exhalative sedimentary horizons that occur extensively within the extrusive sequence of the Gjersvik Nappe. These are interpreted as the products of settling of colloidal iron and silica hydrosols following explosive dispersal into an oxidizing submarine environment. They are valuable time-stratigraphic markers and indicators of way-up in complicated structures and are a potentially valuable tool in exploration for massive sulphide bodies formed in limited reducing environments.*

The belt of metamorphosed Lower Palaeozoic rocks, chiefly of Ordovician age, within which the important stratiform pyritic copper- and zinc-bearing orebodies of the Scandinavian Caledonides are located extends over 1500 km from Rogaland in southwestern Norway to Nord Troms. The divisions of this complex metallogenic belt have been described by Vokes<sup>73</sup> and Vokes and Gale,<sup>75</sup> and Fig. 1 shows the relationship of the principal districts to the thrust front of the Caledonian allochthon. The culminations of the underlying Precambrian basement, together with the effects of erosion, have produced the segmentation of the allochthon on which the division into separate districts is broadly based. Structural and stratigraphic correlations along the length of the belt are made difficult by the structural complexity of the allochthon, the sparsity of fossil remains and the penetrative effects of tectonic deformation and regional metamorphism. Sufficiently detailed studies have been made, however, in the regions of South Trøndelag (Trondheim district),<sup>49,50,52</sup> North Trøndelag (Grong-Gjersvik district)<sup>40</sup> and the geographically adjacent areas of Jämtland and Västerbotten in Sweden<sup>81,82,83</sup> to show that the stratiform ores of Skorovas, Joma, Stekanjökk, Lökken and Røros lie within the Koli Nappe, which is the upper

\*UNESCO-IUGS International Geological Correlation Programme, project no. 60: Correlation of Caledonian stratabound sulphides. Norwegian-British contribution no. 1.

structural unit of the Sveve-Köli Nappe complex first defined by Törnrohn.<sup>68</sup> The broad correlation within the Köli structural level can reasonably be carried into the Sulitjelma district of Nordland,<sup>39,80</sup> and in all probability this correlation can be extended into the ore district of Nord-Troms.

It is clear that the separate districts that comprise the Ordovician province of stratiform pyritic ores lie at a broadly comparable structural level in the Caledonian allochthon of the Scandinavian peninsula, but there are significant differences in the stratigraphy and metamorphic grade of the host

rocks from district to district. In general, the Ordovician host rocks comprise a varied assemblage of supracrustal volcanic and sedimentary rocks with closely associated plutonic masses of ultrabasic, basic and acid composition. The conspicuous quantity of basaltic to andesitic volcanics in the supracrustal sequences, taken together with their deformed and metamorphosed condition, ranging in grade from lower greenschist to almandine amphibolite facies, has led to the familiar use of the terms greenschist and greenstone in descriptions of the stratigraphy of various districts.<sup>61</sup> Goldschmidt<sup>22</sup> early lent authority to this usage by defining the 'Stamm der grünen Laven und Intrusivgesteine' as an important constituent rock kindred of the south and central parts of the Caledonian allochthon at the structural level now under discussion.

It is generally recognized that the stratiform pyritic orebodies have a close genetic relationship to the volcanic rocks with which they are associated<sup>73</sup> and that this relationship originated with the formation of tholeiitic and calc-alkaline eruptives at the margins of the Caledonian orogen in Ordovician times.<sup>15,16,47,75</sup> The genetic process that relates the ores and host rocks has been masked by the effects of metamorphic recrystallization and polyphase deformation, which affected both ores<sup>73,74</sup> and host rocks during the process of allochthonous tectonic emplacement consequent upon collision of the Scandinavian and Laurentian cratons during Middle Silurian times.<sup>10,24</sup> The palaeo-environmental interpretation of the rock assemblages contained in the structural elements of the Köli nappe is clearly of the greatest importance in interpreting the genesis of the associated ores; in a region of the tectonic complexity displayed by the Caledonian allochthon, however, it is clear that the primary geological framework must be established by a study of the field relationships at a level of regional detail such that the ore deposits can be considered at the scale of the geological phenomenon responsible for their formation. If a volcanogenic origin is postulated, an understanding of the volcano-stratigraphy and structure in an area that extends from 1 to 10 km outside the orebody itself must be sought. This has been the basis on which the present study of the environment of the Skorovas deposit was undertaken.

#### Regional structural and stratigraphic setting

Existing knowledge of the major structural and stratigraphic units of the Grongfelt originated with the regional geological mapping undertaken by Statsgeolog Steinar Foslie<sup>12,14</sup> during the period 1922–27, the details of which were amplified and interpreted by T. Strand<sup>14</sup> and C. Oftedahl. More recent regional studies by Zachrisson<sup>81</sup> in the adjacent Swedish area of Jämtland and Västerbotten have given an idea of the succession of structural units within the Köli Nappe sequence between the Grong and Stekenjokk areas. A compilation from these sources is made in Fig. 2, which shows the main second-order tectonic divisions that have been recognized within the Köli level of the Sveve-Köli nappe. Combining the terminologies of Foslie,<sup>12</sup> Oftedahl<sup>41</sup> and Zachrisson,<sup>81</sup> there are four divisions to be recognized. The first and uppermost of these is the Gjersvik Nappe, within which lie the Skorovas (Sk) and Gjersvik (Gj) orebodies. Below this lies the Leipik Nappe, within which, by extending the structural interpretation of Zachrisson, the Joma orebody (Jo) must lie. Below this lies the Gelvernokko Nappe and, finally, the Lower Köli Nappe unit, within which are situated the Stekenjokk orebodies (St) (the Stekenjokk malm and the Levimalm).<sup>82</sup>

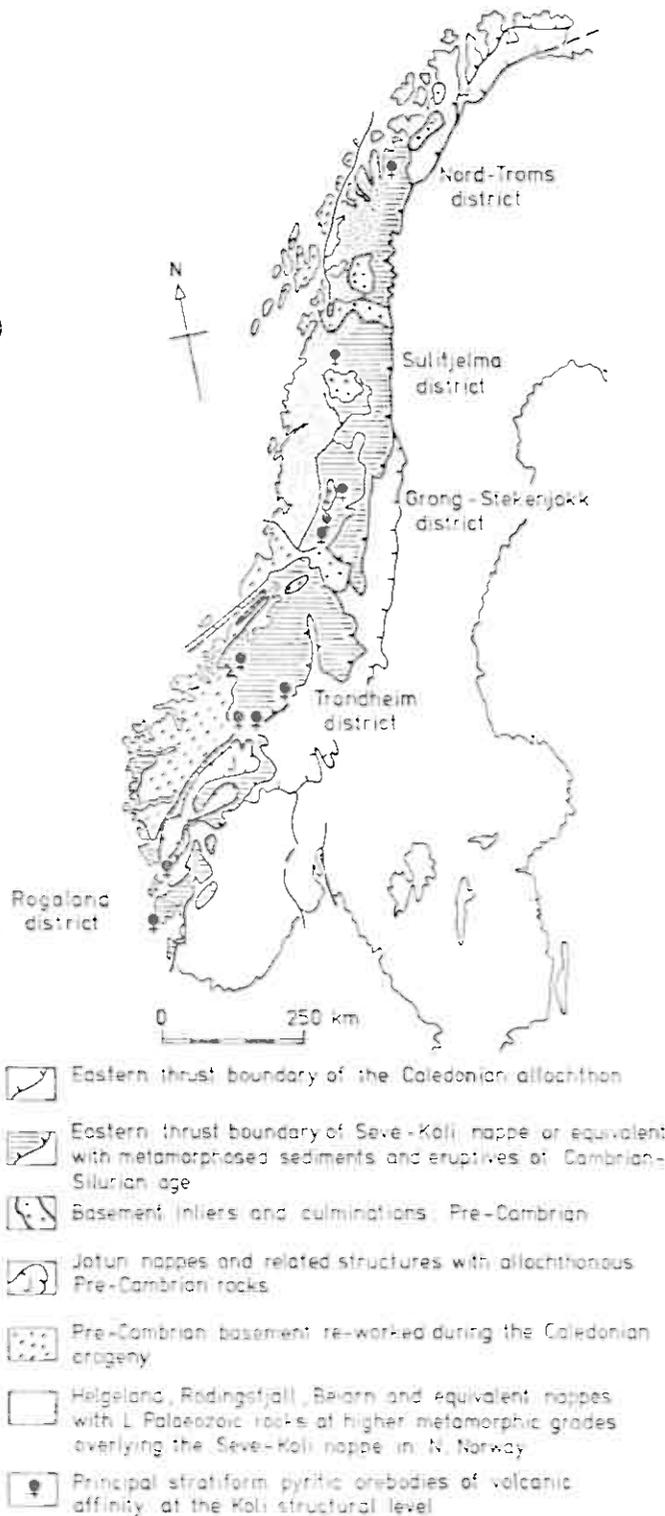
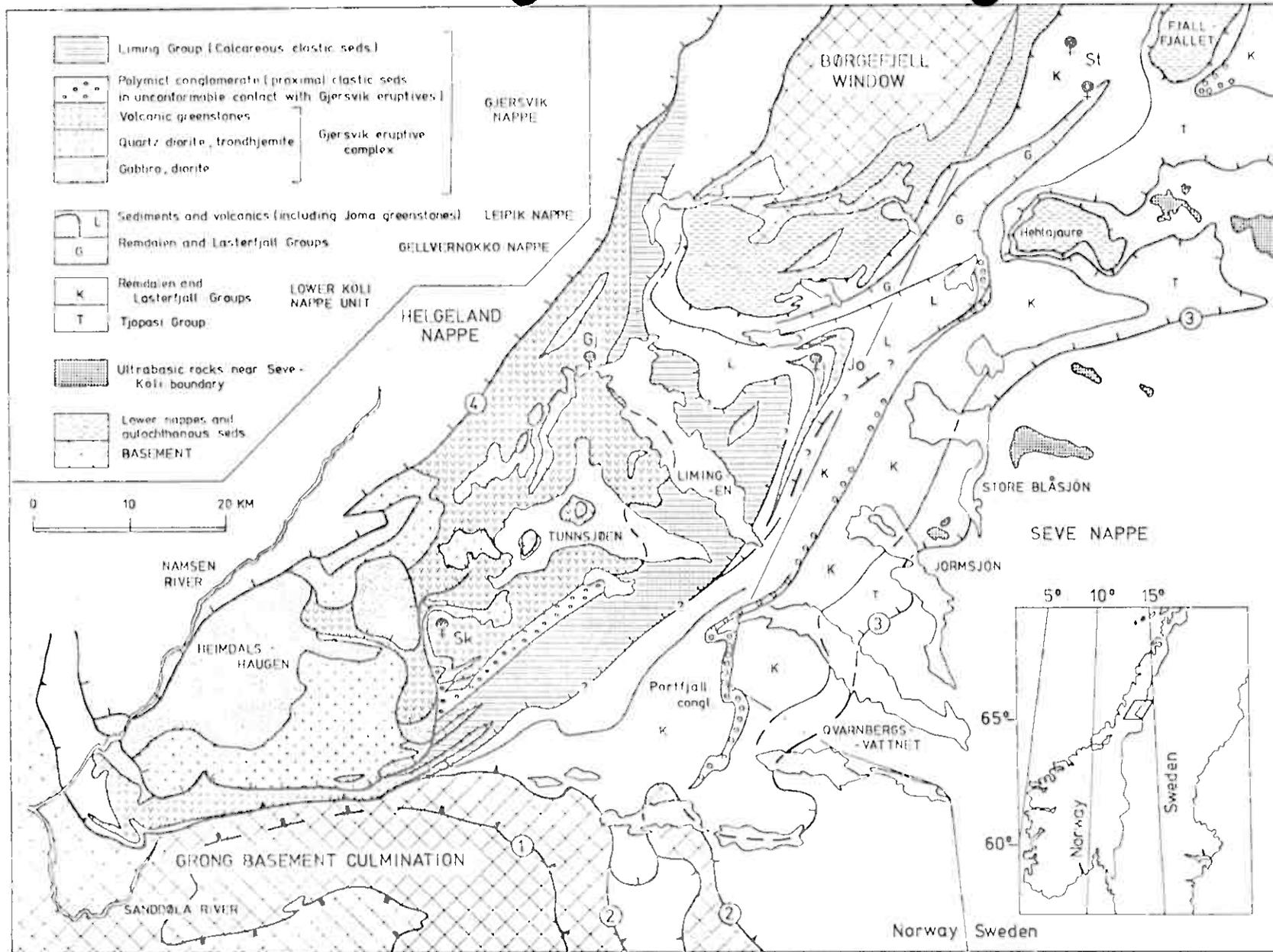


Fig. 1 Synoptic geological map of Scandinavian Caledonides showing main districts of stratiform volcano-genic ores at Köli structural level



**Fig. 2** Map showing location of main ore deposits in Grong—Stekenjokk district (Sk, Skorovas, Gj, Gjørvik, Jo, Joma and St, Stekenjokk) and main structural and stratigraphic units that can be distinguished within Köli Nappe. (1) Thrust at base of Olden basement nappe; (2) thrust at base of Seve—Köli Nappe; (3) thrust separating Seve and Köli sequences within Seve—Köli Nappe Complex; (4) thrust separating Gjørvik Nappe at top of Köli Nappe sequence from high-grade metamorphic rocks of Helgeland Nappe Complex. Boundaries based on geological information from Foslie, Oftedahl, Zachrisson, Gee and Gustavson



Lille Føndsild and Steinkjer conglomerates)<sup>50</sup> at the base of the Lower Hovin Group, overlying the Støren Group, led Holtedahl<sup>20</sup> to propose a tectonic event of regional significance that he termed the Trondheim Disturbance. Further comparative studies of stratigraphy in the Trondheim region led to the recognition of similar polymict conglomerates at higher stratigraphic levels. Vogt<sup>72</sup> identified an Ekne (Caradocian) Disturbance and also movements in the Lower Silurian which produced the basal quartzite conglomerate of the Horg Group (Lyngestein Conglomerate), which identified a Horg Disturbance. Further work by Roberts<sup>53</sup> has suggested additional refinements to the chronology of uplift and erosion in the Trondheim District during the mid-Ordovician, a separate event in Mid-Lower Hovin times being marked at the level of the Stokkvola conglomerate.<sup>53</sup> Tectonic evolution in the Trondheim region in Lower to Middle Ordovician time was evidently punctuated by episodes of vertical uplift and erosion, the Trondheim Disturbance being but the first of these. The polymict conglomerate, which overlies the Gjersvik eruptives at the base of the Limingen sedimentary series, evidently records a disturbance of the Trondheim type, which, to avoid confusion, will be named the Gjersvik Disturbance. This disturbance is probably most closely related in age to the Stokkvola event.<sup>53</sup>

Fig. 3 shows the inferred general stratigraphic correlation between the Lower Palaeozoic sequences in the Grong and Trondheim regions. Zachrisson<sup>82</sup> has cited the faunal evidence in support of a (Lower ?) Silurian age for the Stekenjokk orebodies, which lie within the lower part of the sequence of basic to acid volcanic rocks composing the upper part of the Lasterfjall Group (Fig. 2); this means that the rocks composing the Gjersvik, Leipik and Gelvernokko nappes and the upper parts of the Lower Kõli Nappe have a probable age range from Lower Ordovician to Lower Silurian, matching the age range of the Trondheim Supergroup as defined by Gale and Roberts.<sup>16</sup> The Skorovas and Gjersvik ore deposits lie within the Gjersvik Group of volcanic greenstones and must be approximately Lower to Middle Ordovician in age. It is, however, interesting that in the Stekenjokk area, accepting the fossil evidence of Zachrisson, conditions suitable for the formation of stratiform pyritic ores also existed in Lower-Middle Silurian times.

#### Tectonic style within Skorovas area of Gjersvik Nappe

The programme of field mapping in the Skorovas area, with which the present writers have been actively involved since 1971, was designed to re-examine the major structural and lithological boundaries within the plutonic to volcanic sequence of the Gjersvik Group and to extend, as far as possible, the geological interpretations of Foslie and Oftedahl as they affect the Skorovas area. Mapping in the scale range of 1:2000 to 1:10 000 has also enabled the first serious attempt to delineate the principal lithologies within the volcanic sequence, which were uniformly designated as greenstones by Foslie<sup>12</sup> on the 1:100 000 scale map of the Trones quadrangle. The Skorovas area, as shown in Fig. 4, lies close to the eastern boundary of one of the main plutonic massifs of the Gjersvik Nappe. From Fig. 2 it is clear that the massifs have distinctly tectonic boundaries of low to intermediate angle (Fig. 6). The plutonic rocks within these boundaries frequently preserve their original igneous fabrics, little modified by the penetrative effects of tectonic deformation. The volcanic rocks and minor intrusives outside them, in contrast, generally show intense penetrative tectonic fabrics. The plutonic massifs all have

tectonized envelopes and the intrusion of the complete range of basic to acid plutonic rocks evidently took place prior to the main tectonic event, which led to the emplacement of the Gjersvik Nappe within the allochthon and which was also responsible for the generation of major isoclinal folds and the early axial plane schistosity that is generally well developed within rocks of the volcanic sequence.

Because of gross differences in competence between the various rock types, notably between the plutonic masses and the supracrustal volcanic cover, this particularly heterogeneous style of deformation characterizes the intermediate level of the Gjersvik Nappe, the pattern being controlled, on the largest scale, by the form of the major gabbro, diorite and granodiorite bodies. Within the volcanic sequence itself, high-level doleritic dykes and sills, together with compact dacitic flows and their spilitized aphanitic equivalents, exert a more local influence.

In common with adjacent parts of the allochthon,<sup>81,82</sup> the history of regional deformation can be resolved in terms of two major stages, the first of which produced the principal Caledonian 'grain' of the terrain, creating isoclinal folds of the style illustrated in Fig. 5, and imposing the early schistosity mentioned above. It was during this stage that the main thrust and slide horizons that separate the plutonic and volcanic levels of the Gjersvik eruptive sequence were established. The plutonic bodies evidently behaved as massive tectonic wedges, piercing and, in part, overriding the superjacent volcanics to create the present pattern.

It should be emphasized that such planes of high tectonic strain also exist in several lesser orders within the volcanic sequence. These surfaces, as was noted above, are similarly formed at lithological boundaries, showing marked contrasts in competency, and can partly be explained in terms of componential movements along the thinned and extended limbs of isoclinal folds of the early basaltic lavas and pillow breccias. These rocks, under the influence of intense local strain, suffer a complete penetrative reorganization of their mineralogy to form chlorite-albite-epidote schists devoid of any earlier volcanic fabric. In the field the existence of these surfaces and the flattening produced in the adjacent units creates a peculiarly lenticulated style of deformation through which the early isoclinal fold pattern must be traced. The 'lenticulate style' appears to be a characteristic feature of highly deformed volcanostratigraphy and associated plutonics in other regions, notably in the Mauretaniides of West Africa (G. Pouit, personal communication). Minor fold structures of the early generation are not conspicuously evident within the volcanostratigraphy and are best observed in the finely stratified tuff bands and associated cherts and iron-rich chlorite schists of the exhalita facies (Fig. 7(a)). They can also be mapped over several tens of metres by following coherent chert horizons, acid tuff bands and dykes, and thence into the larger isoclines of the type illustrated in Fig. 5.

The configuration of these larger isoclines, taken together with the stratigraphic and structural evidence provided by the mapping of the surface of unconformity separating the eruptive sequence and the conglomerate series, demonstrates, at the present level of erosion, that the volcanic sequence in the Skorovas district lies inverted within the lower limb of a major southeast-facing fold, the identity of which can be broadly equated with the Gjersvik Nappe.

The second stage of deformation, superimposed on the grain of the early isoclines and schistosity, has created an open system of broad folds, which have resulted in an irregular pattern of dome and basin structures, the major

axes of which evidently bear a relationship to the contacts of the plutonic massifs lying to the west and north (Figs. 2 and 4(a)). The formation of the open dome and basin structures is accompanied by further movements along the low-angle planes generated during the first stage of deformation. These movements led to the creation of minor folds and a second-stage crenulation cleavage, which is typically local and specifically associated with these horizons of high strain. The scale of the phenomenon is variable and Fig. 7(b) shows part of the well-developed belt of second-stage folding in the volcanic sequence at the southwestern margin of the Grøndalsfjell massif. The vergence of the axial planes of these and other similar late folds implies that the principal tectonic stress responsible for this deformation was imposed from a west to northwest direction.

The deformation history can be interpreted in the following way. (1) Creation of the nappe, isoclinal folds and the

early schistose fabric, together with the several orders of internal thrust horizons, was a consequence of the stresses imposed during the main stage of emplacement of the allochthon during Mid-Silurian times. (2) The second generation of tectonic structures is considered to have been imposed upon the first as a consequence of equilibration between the depressed Scandinavian basement and the imposed load of the allochthon. The depression of the granitic basement into a field of higher temperature and pressure can have given rise to plasticity of the basement, enabling local isostatic adjustments to take place by the initiation of a system of domes and basins in the basement. The second-fold phase in the Skorovas region is interpreted as a consequence of forces imposed on the volcanic sequence by the massive plutonic bodies as they slid under the influence of gravity in an east to northeast direction from the flanks of a basement dome in the vicinity of the Grong culmination.

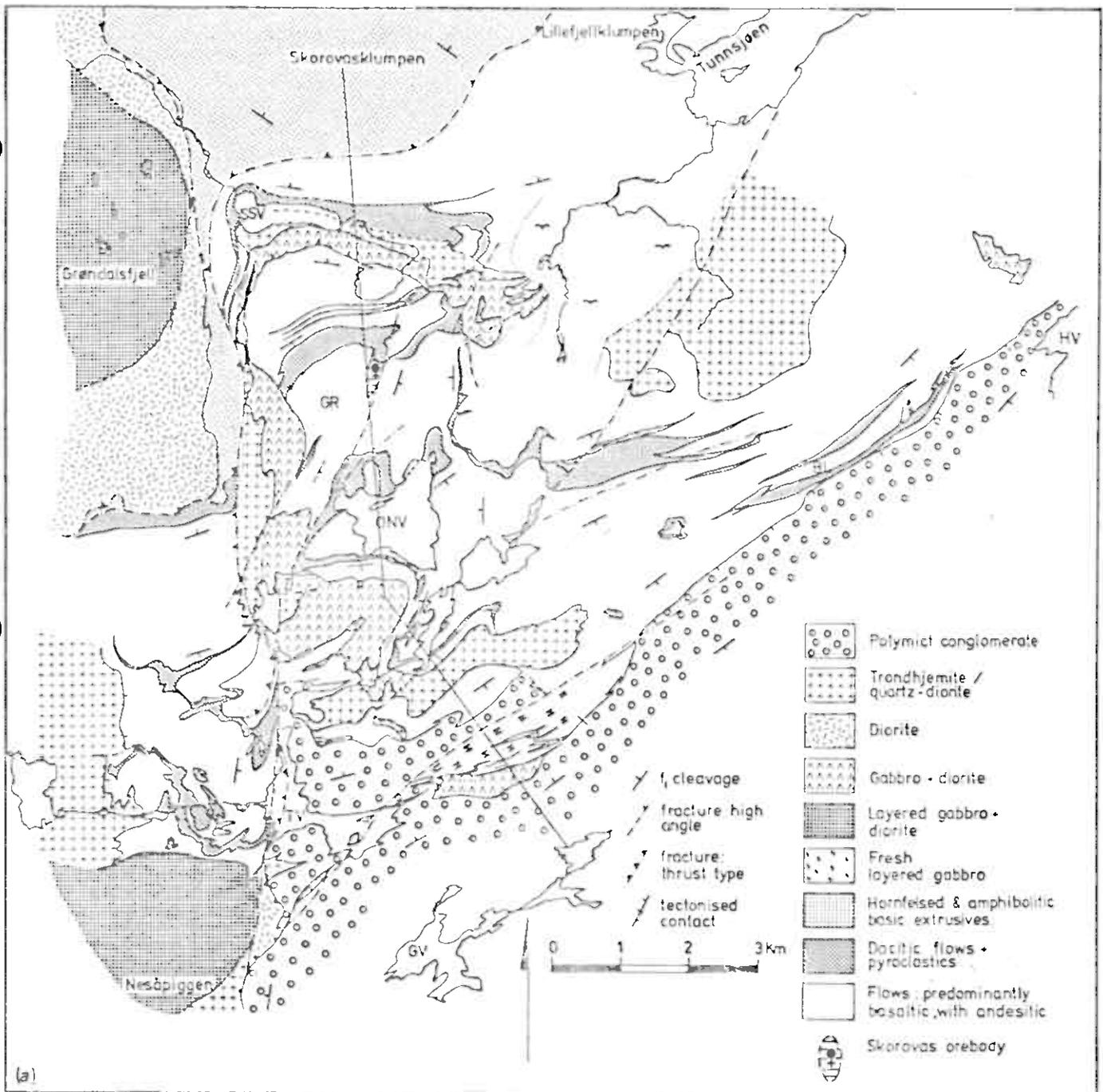


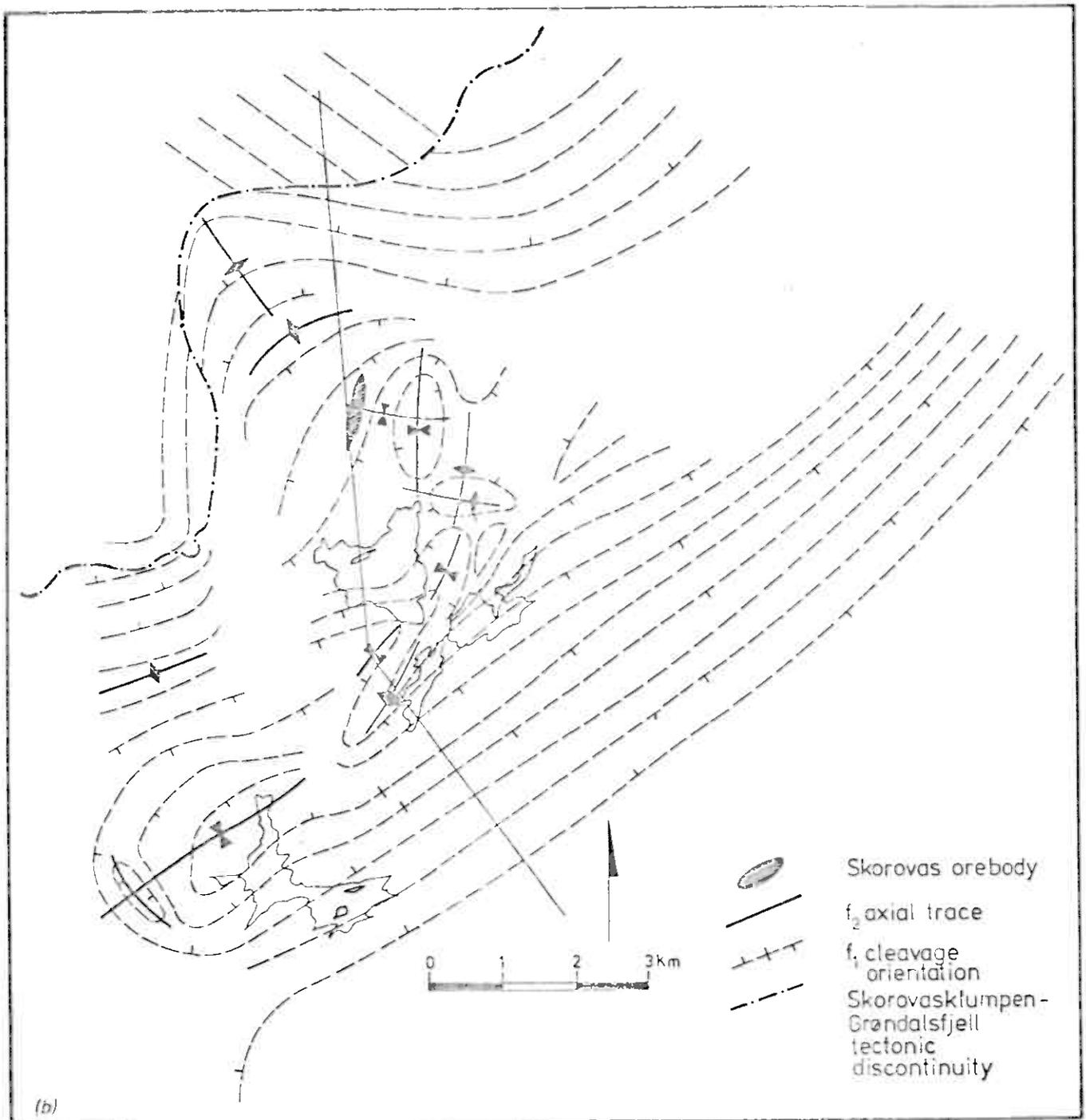
Fig. 4 Simplified geological map (a) of Skorovas area with line of section (Fig. 5) indicated (SSV, Store Skorovatt; GR, Grubefjellet; ONV, Øverste Nesåvatnet; TV, Tredjevattet; Bl, Blåhammeren; HV, Havdalsvatnet) and synoptic map (b) (see page 134) of principal structural trends

In addition to the mid- and low- to intermediate-angle thrust structures created during the first two periods of folding, the topography and geology of the Skorovas area has been strongly influenced by the formation of a complex system of high-angle faults and fractures. For the most part these have suffered small displacement of the order of metres, but along the southwest contact of the Gjersvik eruptive complex with the polymict conglomerate oblique slip normal faulting has resulted in a vertical displacement of the order of 500 m (Figs. 4(a) and 5). The trend of these fractures is predominantly in a NNE to northeast direction and their formation post-dates the main periods of folding in the area. The late fracture patterns in the Skorovas area remain a problem for future investigation. In all probability they can be attributed to the final stages of Caledonian tectonism, but the influence of later events, such as basement reactivation during Mesozoic rifting, cannot be discounted.

#### Plutonic members of Gjersvik eruptive sequence in Skorovas area

On the 1:100 000 scale map of the Trones quadrangle compiled from the work of Foslie<sup>12</sup> the plutonic rocks of the Skorovas area occur in two groups. The first group comprises the tectonically bounded massifs of Grøndalsfjell and Nesåpiggen, which, though they have strongly tectonized envelopes, preserve much of their original igneous fabric in the interior. The second group occurs as an arcuate belt lying within the volcanic succession to the north, west and south of the Skorovas ore deposit (Fig. 4(a)). The plutonic rocks of this belt have been subjected to the penetrative deformation that affected the enclosing volcanic rocks and have responded tectonically as part of the volcanic level during deformation.

The plutonic rocks of the Skorovas area were divided by Foslie into two principal compositional groupings, as shown in the map of the Trones quadrangle.<sup>12</sup> Gabbros



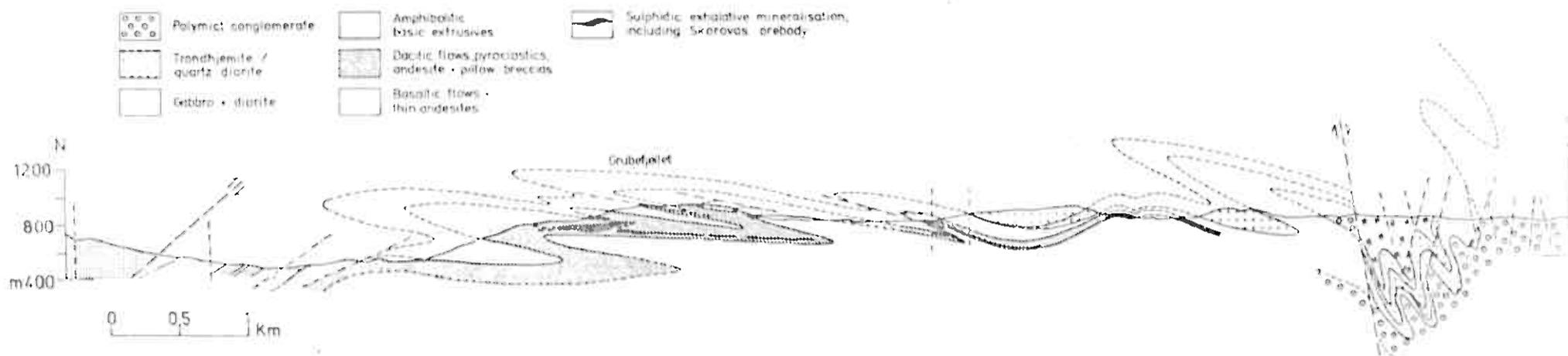


Fig. 5 Simplified geological section through Skorovas area

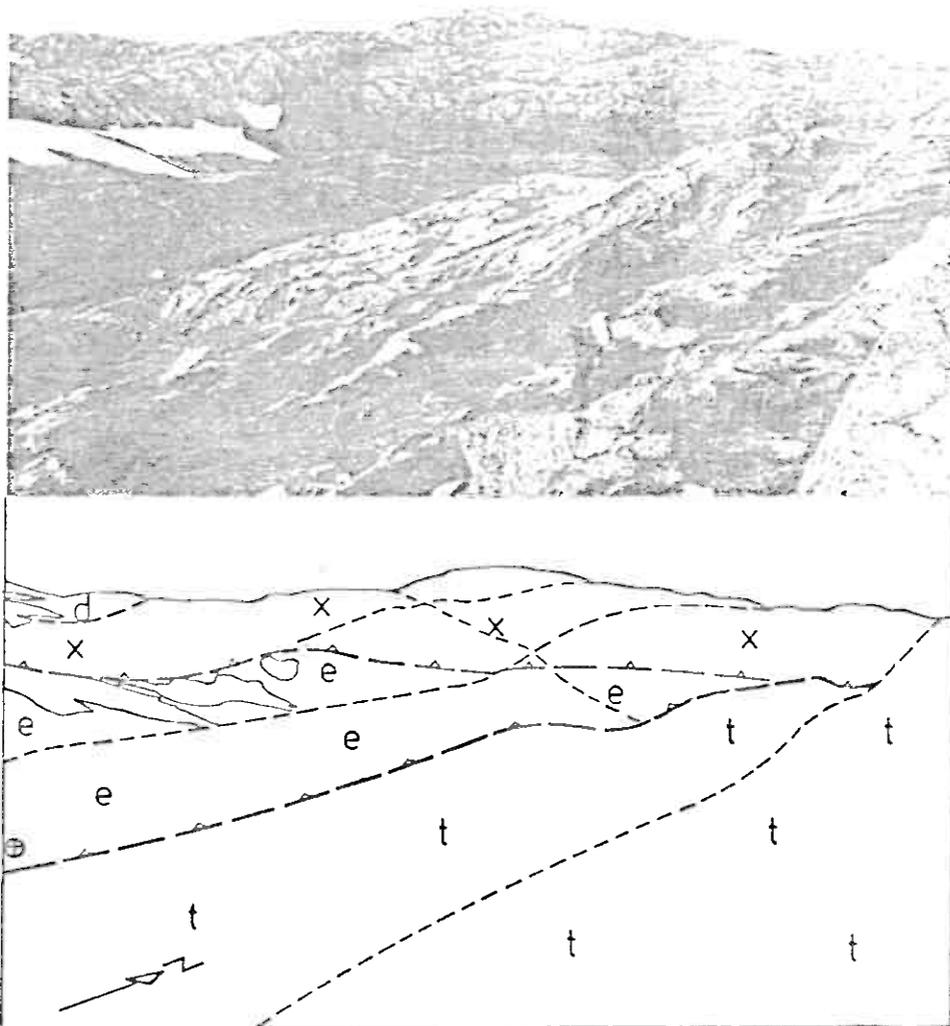


Fig. 6 Panoramic view of southeast margin of Grøndalsfjell massif seen from point of vantage on trondhjemite intrusive of Skorovas intrusive arc. Major thrust horizon separates diorite and gabbro (d) together with hornfelsed envelope (x) from structurally underlying schistose extrusives (e). A further thrust separates extrusives from trondhjemite (t) in foreground. Location of photograph (Fig. 7 (b)) shown by crossed circle at far left of vista

of various facies were distinguished and at the opposite end of the compositional scale trondhjemite, tectonized granite and granitic dykes and sills were also shown. There is no reference on the map to the occurrence of intermediate dioritic rocks in the immediate area of Skorovas, although Foslie was undoubtedly aware of their existence because diorites are mapped as a thin border zone to the north of the Grøndalsfjell massif and to the west of Heimdalshaugen. The detailed mapping carried out by the present writers has shown that dioritic rocks of intermediate composition form an important component in the plutonic sequence and that a definite relative chronology of intrusion can be recognized.

It has already been noted that the plutonic sequences in the Grøndalsfjell and Nesåpiggen massifs and the plutonic bodies that compose the arcuate intrusive belt (Fig. 4) are tectonically separated, and it is convenient to discuss their plutonic histories separately.

#### *Grøndalsfjell massif*

The starkly exposed rocks that compose the Grøndalsfjell

massif provide spectacular evidence of their relative ages. The earliest intrusives are fresh layered olivine gabbros, which occur as large xenolithic masses or rafts with maximum dimensions of the order of 70 m x 200 m, contained in a matrix of metamorphosed gabbro and hornblende diorite. The cumulus layering of the gabbro bodies is sub-vertical in attitude with a predominantly east-west trend. This must be accepted as evidence of significant post-cumulus displacement.

The composition of the layered gabbro varies from troctolite to hypersthene gabbro and in all facies hypersthene occurs, either as a reaction rim around olivine or as independent ophitic grains. The mineralogy of the gabbro is thus compatible with crystallization from a tholeiitic magma.<sup>25,67</sup>

The nature of the xenolithic relationship is shown in Fig. 8(a), and it is clear that the hornblende diorite is a major component of the Grøndalsfjell massif. The peripheral contacts of the fresh layered gabbro with the diorite display a distinctive pattern of retrograde alteration, which partly follows the primary igneous layering and partly exploits crosscutting joints to produce a distinctive weathered surface (Fig. 8(b)). The alteration leads to the

uralitization and chloritization of the augite and hypersthene, the serpentinization of the olivine and saussuritic degradation of the calcic plagioclase to produce albite, epidote, clinzoisite and calcite. In the troctolitic facies of the gabbro the growth of considerable quantities of chlorite within the plagioclase accompanies this breakdown. The alteration is ascribed to the contribution of water from the dioritic magma, which led to a retrograde subsolidus hydration in the pre-existing mass of layered gabbro.

The various facies of altered gabbro may extend for a considerable distance beyond the boundaries of the fresh layered rocks, and the distinction between altered gabbro and hornblende diorite is made in the field on the basis of the persistence of fluxion banding and layered structure within the surrounding aureole of hydration. The hornblende diorite is characteristically composed of subhedral dark green grains of hornblende together with saussuritized plagioclase of intermediate composition and accessory Fe-Ti oxides. The iron oxides are frequently altered to sphene and the hornblende is generally partly chloritized.

One of the most striking features of the hornblende diorite is the occurrence of coarse patches and pegmatoidal veins, 0.5–3 m wide, consisting of euhedral hornblendes, commonly up to 10 cm in length, set in a matrix of andesine feldspar together with accessory amounts of magnetite and pyrite. The pegmatoid veins show rhythmic banding parallel to their contacts. This can be interpreted



Fig. 7 Typical dislocated isoclinal style seen in minor folds of first generation in chert bands to south of Nesåklumpen (a) (top) and (b) localized post-schistosity folding and incipient crenulation cleavage of second generation formed in zone of high strain in schistose greenstones adjacent to tectonic boundary of Grøndalsfjell massif. Location of photograph is shown in caption to Fig. 6

as a result of episodic deuteric crystallization from hydrous fluids circulating within the largely consolidated dioritic body. These rocks can be justifiably described as appinites, and their presence implies that the level of exposure seen in the eastern margin of the Grøndalsfjell massif corresponds to the upper portion of a differentiated dioritic body.<sup>25,78</sup>

At the margins of the hornblende diorite, close to the contact of the plutonic mass with the enclosing greenstones, a quartz-diorite facies occurs locally.

At least two generations of impersistent basic dykes cut both the gabbro and the diorite with its appinitic facies. The dykes are thin, usually less than 20 cm in width, and have a northeasterly trend with steep dips to the northwest. They are composed of fine-grained hornblende and plagioclase, together with minor iron oxides, and are locally porphyritic with plagioclase crystals up to 7 mm long.

The final eruptive event within the Grøndalsfjell complex was the emplacement of a swarm of leucocratic porphyritic granodiorite dykes, which show a predominantly northeasterly trend and dip steeply to the northwest. The dykes are commonly 1–2 m thick and can be followed for distances of 1–2 km before they pinch out. Close to the margins of the plutonic mass, and also within it, these dykes show well-developed tectonic foliation and, locally, mylonitic facies, which demonstrates that the northeast-trending fracture system has been the focus of significant post-intrusion tectonic strain. The granodiorite dykes are composed dominantly of sodic plagioclase (roughly of

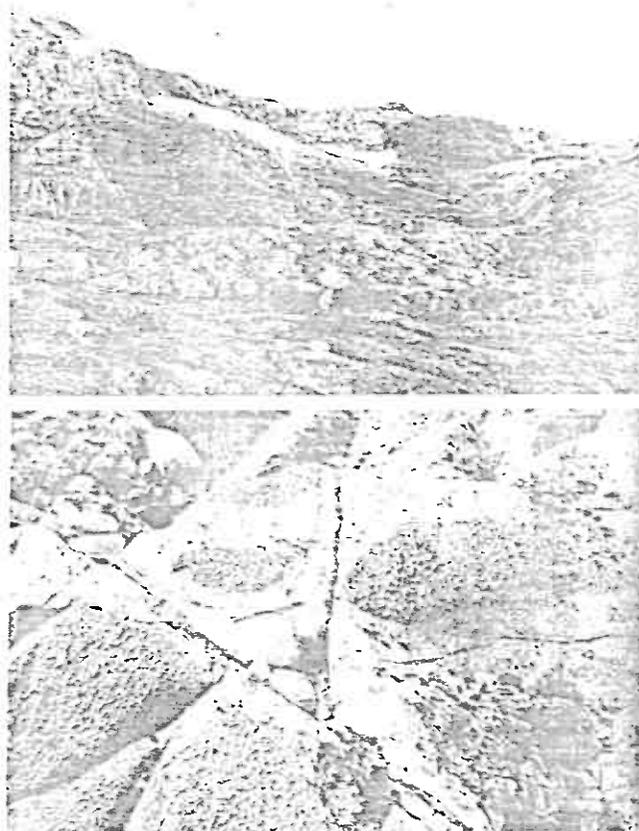


Fig. 8 Northeast face of Grøndalsfjell massif displaying occurrence of rafts of unaltered layered gabbro (dark) within dioritic matrix (a) (top) (rafts are of the order of 60–100 m x 200 m) and (b) field appearance of hydrated, uralitized envelope that borders large xenolithic masses of fresh layered gabbro on Grøndalsfjell (Fig. 8(a)). Troctolitic gabbro shows strong differential weathering of pyroxene, feldspar and olivine, producing pitted surface. Uralitized assemblage weathers uniformly by comparison

oligoclase composition), quartz and accessory microcline, biotite, hornblende and sphene. The ferromagnesian minerals are generally partly chloritized and the feldspars have been variably altered to fine micaceous aggregates (sericite or paragonite). Because of the modal composition of these dykes, which is dominantly oligoclase together with quartz and with only accessory amounts of potash feldspar, the rocks may properly be described as trondhjemite in the sense of the definition applied by Goldschmidt in 1916.<sup>22</sup>

This summary of the igneous relationships preserved within the plutonic massif of Grøndalsfjell shows clearly that a considerable volume of dioritic magma was emplaced, probably at an intermediate to high crustal level, evidently by invading a pre-existing mass of layered gabbro, which is the oldest and presumably the deepest representative of the plutonic assemblage in the Skorovas area. It may be added that magmatism must also have been bimodal — that is to say that the magmas were supplied from two genetically different sources, the first tholeiitic and the second calc-alkaline. A range of similar igneous relationships occurs in the Nesåpiggen massif to the south (Fig. 4).

In addition to the main gabbro-diorite body of the Grøndalsfjell massif delineated by Foslie on the map of the Trones quadrangle, a significant mass of 'fine-grained gabbro' is also shown lying directly to the north of Skorovatn. This forms the imposing topographic feature of Skorovasklumpen in the basal slope of which lies the extension of the main thrust surface, which is interpreted as separating the tectonically 'massive' plutonic level from the highly deformed volcanic level. This feature is shown on the geological map of the Skorovas area and in the accompanying structural synthesis (Fig. 4). Investigation has shown that Skorovasklumpen and the narrow belt of similar character that can be followed along the eastern margin of the Grøndalsfjell massif are composed predominantly of metamorphosed basic volcanic rocks, together with interbands of acid (dacitic-keratophytic) composition and a proportion of high-level basic intrusive material. The basic rocks of the belt adjacent to the Grøndalsfjell massif are partly incorporated in a xenolithic screen of considerable complexity. The original igneous contact of the diorite with the volcanic country rocks is preserved intact within the main tectonic boundary (Fig. 4(a)) and can be mapped over a distance of 4 km. Original volcanic structures, notably pillow forms and vesicles, are preserved within xenolithic masses and testify to the volcanic origin of the country rocks. Similar textural evidence of volcanic origin has been found within the basic sequence that composes Skorovasklumpen.

The reason for the classification of the rocks of Skorovasklumpen as fine-grained gabbros by Foslie<sup>12</sup> and other workers lies in their amphibolitic metamorphic grade, which has produced a mineralogy dominated by hornblende and intermediate to calcic plagioclase. The presence of epidote as a constituent mineral throughout a significant part of the amphibolitic sequence implies that these higher-grade rocks span the epidote amphibolite facies to enter the field of amphibolite facies. Since there is no association with pelitic rocks, a precise description of the prograde regional metamorphism of the basic rocks of the Skorovas area depends chiefly upon a determination of the progressive changes in the composition of the hornblende and plagioclase, which must await further detailed work. Broadly, however, the mineral assemblages accord with the sequences regarded by Miyashiro<sup>31,32,36</sup> as typical for the regional metamorphism of mafic rocks at low to intermediate pressure.

One of the conspicuous features of the mineralogy of the amphibolite facies rocks of Skorovasklumpen is that pyrrhotite replaces pyrite as the accessory iron sulphide — an observation that is readily made in the field. The amphibolitic lavas locally display distinct penetrative tectonic lineation of the amphiboles, and this lineation can be observed in the amphibolitized volcanic xenoliths in the diorite. Amphibolite grade metamorphism evidently took place under the influence of early tectonic stresses with which the emplacement of the gabbro-diorite massif was partly synchronous. The establishment of a precise chronology for these events will depend upon the evidence provided by future detailed petrographic work. It is probable, however, that the contact aureole of the Grøndalsfjell massif and the amphibolitic rocks of Skorovasklumpen compose a continuum within the field of low to intermediate pressure in which regional and contact metamorphism converge.<sup>34</sup>

#### *Rocks of the arcuate intrusive belt*

The intrusive arc differs from the plutonic massif of Grøndalsfjell in three distinctive ways: (1) no unmetamorphosed gabbroic bodies have been found in which a plagioclase-pyroxene-olivine assemblage is preserved; (2) penetrative deformation has produced distinctly tectonic fabrics throughout most of the arc and mineral assemblages are reduced, for the most part, to those stable within the greenschist facies; and (3) quartz-rich dioritic to granodioritic rocks compose a large part of the complex and the eastern extremity of the arc joins a large granodiorite mass to the south of Tunnsjden (see Fig. 4(a)).

Apart from these significant differences, which can probably be explained in terms of the higher level of emplacement of the arc complex within the volcanic sequence, the relative chronology of intrusive episodes in the arc is the same as that observed in the Grøndalsfjell massif. The most basic rocks are the oldest and the successively younger intrusions become increasingly silicic.

The degree of deformation within the plutonic arc is often extreme; but, locally, the original geometry of intrusion is preserved as shown in Fig. 9. The range of compositions present in the rocks of the arc is very wide and includes hornblende gabbro, diorite and granodiorite (trondhjemite). The definition of the petrographic character of each generation is complicated by the incorporation of xenoliths of earlier basic volcanic and plutonic rocks as well as by extreme deformation, local silicification and reduction of the primary minerals to greenschist assemblages.



Fig. 9 Trondhjemitic net veining in mafic diorite and hornblende gabbro on southwest Grubefjell

It is sufficient for the purposes of the present discussion to confirm the presence of gabbro, diorite and trondhjemitic granodiorite as components of the arc and to suggest that these are, in part, equivalent to the plutonic complex observed in the Grøndalsfjell massif. Prior to the major stages of Caledonian deformation leading to the allochthonous emplacement of the Gjersvik Nappe, it is assumed that the rocks of the intrusive arc and those of Grøndalsfjell were part of the same complex plutonic continuum.

#### Volcanic rocks of Gjersvik eruptive sequence in Skorovas area and their metamorphic condition

The volcanic rocks of the Gjersvik eruptive complex are of geological and economic interest for they are the host rocks of the Skorovas deposit. The volcanic succession has suffered extremely from the effects of deformation and low-grade metamorphism under conditions of the greenschist facies. These modifications, together with the primary complexity of the volcanostratigraphy, have been obstacles to the systematic mapping of the greenstones.

It has long been recognized that the Gjersvik greenstones are composed of a sequence of basic to acid rocks, including basalts, andesites and keratophyres of distinctly spilitic affinity.<sup>21,41</sup> Because of the confinement of systematic geological studies to the immediate vicinity of the Skorovas mine itself, previous summaries of the volcanic stratigraphy have been limited. During the present study an attempt has been made to document the range of primary volcanic structures that can be observed at the macroscopic scale within the acid and basic members of the stratigraphy and to examine their geometry with respect to metamorphism and deformation.

It is difficult to assess the relative volumes of basic and acid rocks within the volcanic sequence, but it can be said with confidence on the basis of regional mapping that, in the general area of Skorovas, the dominant volcanic rock types are basalts and basaltic andesites with lesser amounts of andesitic and keratophyric rocks. This fact is apparent from the relative outcrop of acid and basic rocks shown in Fig. 4(a), although this can only be treated as an approximate guide. Because of the deformed and dislocated condition of the sequence and the present level of erosion, the maximum thickness of volcanics is difficult to assess. A reasonable estimate based on constructed geological sections, taking into account the effects of tectonic flattening and extension, can be given as 3–4 km.

The sedimentary component within the pile is limited to very thin, but stratigraphically persistent, iron- and silica-enriched beds produced as a result of chemical dispersion during volcanic activity. Banded calcareous greenschists, which have been considered by previous writers to be of sedimentary origin, can be explained as tectonic facies originating from metamorphosed and flattened basic flow units.

The primary mineralogy of all the rocks in the volcanic succession has been degraded to assemblages of the greenschist facies. Textural evidence shows that the creation of the greenschist facies assemblages took place during two episodes, the first of which was prior to the first stage of penetrative tectonic deformation. The evidence confirming this metamorphic chronology is best preserved within the basic members of the sequence.

#### Basaltic and andesitic lavas

The state of deformation of the basaltic rocks varies according to their position with relation to the early isoclinal folding, the numerous lower-order thrust horizons

and adjacent competent flow units (Fig. 10). It is possible, however, in the vicinity of Skorovas, to observe pillowed sequences in which the original geometries are nearly preserved, as shown in Fig. 10. The dimensions of pillows are variable, but diameters within the range 0.5–2 m are typical. In addition to pillowed basaltic flow units, there is a significant volume of deformed meta-hyaloclastite pillow breccia associated with the basaltic unit, which structurally overlies the orebody (see Fig. 17). The pillow breccia lithology is locally transitional to tuffaceous and agglomeratic basic pyroclastic facies and can be traced within a radius of 3 km around the orebody.

The abundance of amygdales, ranging in size from 2 to 10 mm and, exceptionally, reaching sizes of 5 cm, indicates that the lavas were erupted at relatively shallow depths, probably of the order of 100–500 m.<sup>29,37</sup> The primary mineralogy has been completely replaced or pseudomorphed by assemblages composed of chlorite, albite, epidote, actinolite, calcite and sphene. Stilpnomelane, regarded by Miyashiro<sup>36</sup> as atypical of low- to medium-pressure

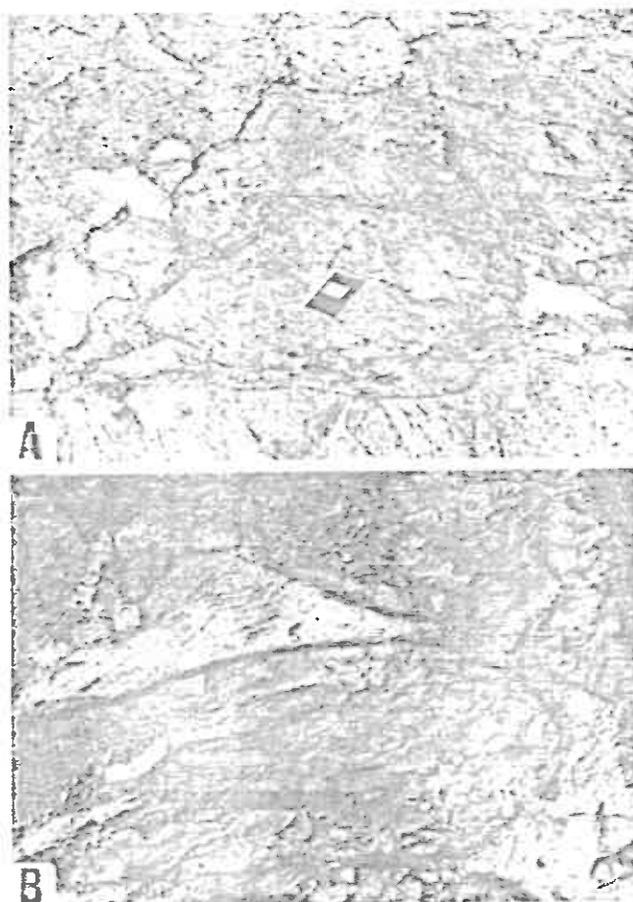


Fig. 10 *A*, Deformed basaltic pillow lavas observed on northern slopes of Grubefjell below orebody. Cuspate bodies of grey chert that occupy interstices between pillows are conspicuous. In cases of extreme deformation survival of these chert bodies within chloritic schist provides a useful guide to original volcanic structure of rocks. *B*, Basaltic pillows from flow exposed on southwest shore of Tredjevatnet. Eruption of pillowed basalts followed deposition of a dispersed exhalite horizon in vicinity of Tredjevatnet centre. Layer of ferruginous silica gel, disturbed during eruption of the basalts, formed a jasper matrix for the pillows. Chloritized chilled margin of pillows is conspicuous. Significant amounts of pyrite are also found in association with jasper pillow matrix, the pillow lavas lying stratigraphically but a few metres from horizon of massive pyrite

regional metamorphic assemblages, is a characteristic component of the basaltic andesites in the mine area. This can probably be explained in terms of the iron enrichment shown by these rocks (analysis 3, Table 1). Stilpnomelane, in common with the other greenschist minerals, occurs dispersed throughout the body of the rock and also as monomineralic fillings in amygdalae and in crosscutting veinlets. The dominant mineralogy of the amygdalae within the pillowed basalts varies widely. Combinations of two of the common greenschist mineral species are usual, involving quartz, epidote, calcite, chlorite, albite and pyrite. Actinolite is not usually found in amygdalae. Within certain parts of the Skorovas area the dimensions of the amygdalae and their mineralogy have been useful in discriminating between individual flow units, although amygdale mineralogy certainly cannot be applied as a universally reliable criterion of stratigraphy.

Within the more massive andesitic and basaltic rocks, original flow textures are preserved by the orientation of the altered plagioclase microlites. Augite phenocrysts are pseudomorphed by actinolite and chlorite and the accessory iron-titanium oxides are largely replaced by sphene. The basalts are not conspicuously porphyritic and igneous textures are frequently concealed in the meshwork of fine actinolite, chlorite, epidote-clinozoisite and albite into which the rocks have been transformed.

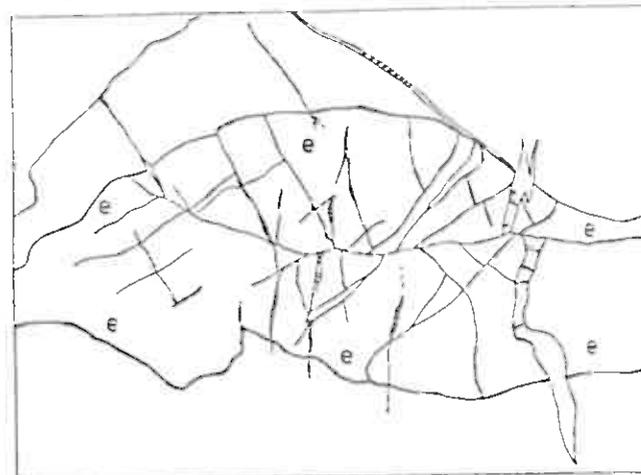
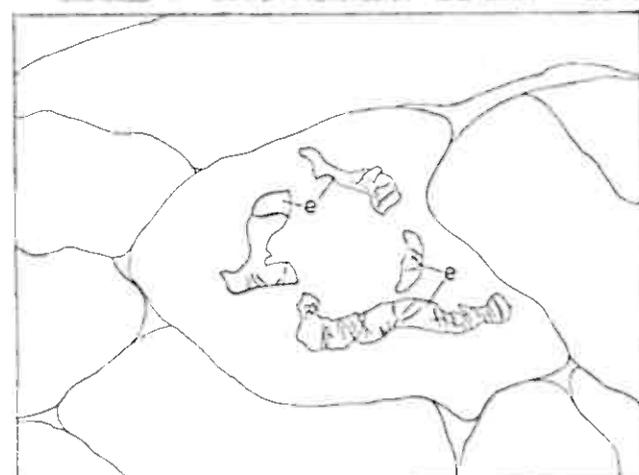
The effects of greenschist metamorphism are not only apparent at the micro scale but are also demonstrated by the gross redistribution of the rock components, which has produced massive bands and lenticular knots and spheroidal

bodies, the mineralogy of which is predominantly epidote with lesser amounts of albite, quartz, etc. These bodies with dimensions of the order of tens of centimetres are arranged parallel to the surfaces of the pillow structures or as discontinuous layers parallel to flow surfaces within massive basalts and basaltic andesites. The typical form of these bodies is shown in Fig. 11.

The epidote-rich segregations are evidently pre-tectonic. During the first period of penetrative deformation the chloritic mass of the pillowed basalts has tended to develop a good schistose fabric and the geometry of the pillows, as a whole, has become flattened to varying degrees. The epidote layers have behaved as competent bodies and have deformed by brittle fracturing; in extreme cases the epidote bodies are preserved as cataclastically reduced streaks and boudins within the highly flattened pillows. The textural evidence clearly demonstrates that an important episode of greenschist metamorphism was responsible for pervasive alteration and gross reorganization of the mineralogy of the basic rocks prior to the tectonic event responsible for the early penetrative schistosity in the Skorovas region.

Deformation of the volcanic pile also took place under conditions of the lower greenschist facies and the mineralogy established during the primary metamorphic episode was not changed, but tectonic facies were produced as a result of further redistribution and segregation of the various mineral species.

The metamorphic alteration that took place in the earliest event prior to the deformation of the rocks can be



**Fig. 11** A, Pillowed basaltic lavas from northwest of Haudalsvatn showing development of pre-deformational metamorphic segregations of epidote-rich materials (e) parallel to pillow margins. During tectonic flattening epidote layer has responded by developing a system of brittle fractures. B, Lenticular segregation of epidote (e) of pre-deformation age in massive andesitic lavas southeast of Store Skorovatn. Conjugate pattern of brittle fractures produced during deformation of competent lenses is explicitly developed, as in generation of dilatant fractures filled with quartz, chlorite and carbonate

Table 1 Whole-rock analyses of Skorovas volcanics. Analyses (1–9) with average values of ocean-floor basalt (10; Carr<sup>42</sup>) and island arc tholeiite (11; Pearce and Cann<sup>49</sup>) for comparison. 1, Porphyritic quartz keratophyre, Grubefjell; 2, quartz keratophyre, Grubefjell; 3, andesite with stilpnomelane, Grubefjell; 4, andesite, Grubefjell; 5, andesitic clasts in agglomerate, Grubefjell; 6, pillowed basalt, Grubefjell; 7, pillowed basalt, Grubefjell; 8, basalt, 6 km southwest of Grubefjell; 9, basalt, northeast Øverste Nesåvatn

%	1	2	3	4	5	6	7	8	9	10	11
SiO <sub>2</sub>	72.23	70.39	53.07	59.34	56.12	50.15	49.30	48.99	50.13	49.61	52.86
Al <sub>2</sub> O <sub>3</sub>	11.82	12.27	14.13	15.40	12.20	13.70	13.81	16.55	14.76	16.01	16.80
TiO <sub>2</sub>	0.80	0.27	0.77	1.06	0.96	1.54	1.89	1.30	1.24	1.43	0.83
Fe <sub>2</sub> O <sub>3</sub>	2.14	3.37	6.48	3.49	3.31	3.31	+	+	+	+	+
FeO	1.28	0.44	6.62	6.01	6.44	7.78	14.70*	13.97*	14.95*	+	+
MnO	0.03	0.01	0.19	0.23	0.11	0.16	0.21	0.17	0.15	0.18	+
MgO	0.36	0.45	4.40	2.68	4.70	4.70	5.49	5.74	6.00	7.84	6.06
CaO	1.27	0.24	4.66	2.38	4.44	4.89	4.92	5.33	3.50	11.32	10.52
Na <sub>2</sub> O	7.50	8.00	5.21	7.50	6.25	8.81	6.47	6.88	7.30	2.76	2.08
K <sub>2</sub> O	0.07	0.02	0.51	0.19	0.02	0.52	0.43	0.66	0.55	0.22	0.44
P <sub>2</sub> O <sub>5</sub>	0.24	0.03	0.10	0.18	0.12	0.17	0.11	0.06	0.03	0.14	+
Loss on ignition	1.06	2.24	1.90	2.24	3.57	2.81					
Total Fe as Fe <sub>2</sub> O <sub>3</sub>	3.56	3.86	13.63	10.17	10.46	11.95	+	+	+	12.63	11.45
Total	98.90	99.49	98.04	100.70	98.24	98.54	99.54	99.64	98.24		

\* Total Fe as FeO.

+ Value not obtained by analytical method used.

described to contemporaneous alteration of the volcanic rocks *in situ* as a result of the thermally driven circulation of sea water in the upper layers of the lava pile close to the site of eruption on the Ordovician sea-floor. Considerable evidence has accumulated in recent years to show that *in-situ* alteration of the mineralogy of submarine basalts to produce assemblages of greenschist and lower amphibolite facies is a phenomenon of wide occurrence within the upper layers of the sea-floor.<sup>33,35</sup> Humphris<sup>27</sup> recognized that the metamorphic assemblages in recent submarine basalts from the Mid-Atlantic Ridge can be divided into chlorite-dominated and epidote-dominated types. It is suspected that this division reflects a process of metamorphic segregation similar to that seen in the basalts of the Gjersvik sequence.

The *in-situ* hydrothermal alteration processes evidently involve the convective circulation of large volumes of sea water relative to the altered rock. Water:rock ratios of the order of > 10<sup>4</sup>:1 were calculated by Spooner and Fyfe<sup>59</sup> and the alteration process is believed to extend to a depth of at least 2 km within the lava pile.<sup>59,60</sup>

The *in-situ* sea-floor metamorphism of the Gjersvik volcanic sequence was evidently an important event and, as well as causing gross mineralogical changes by chemical redistribution within the scale of individual flow units, bulk changes in the chemical composition of the lavas also occurred, leading to the conspicuously spilitic chemistries shown by the analysis in Table 1.

The recognition of the pervasive pre-deformation *in-situ* sea-floor metamorphism of the Gjersvik basalts also helps to resolve the controversy that surrounds the tectonic status of disturbances of the Trondheim type.<sup>11,51,55</sup> The polymict conglomerate that unconformably overlies the volcanic sequence was formed prior to deformation and alloch-

thonous transport of the Gjersvik Nappe. This is easily demonstrated on a local scale by the pervasive schistose fabric of the matrix and the distinctive stretching of the competent clasts parallel to the axes of the early isoclinal folds (Fig. 12(A)). It can also be demonstrated on a regional scale by mapping the level of unconformity through the isoclinal folds of the first deformation (see Fig. 5).

The conglomerate is composed of boulders directly derived from the plutonic and volcanic sequence that underlies it. Locally, the composition is dominated by marble clasts with associated pebbles of jasper, and in other places the clast population is dominated by boulders of plianeritic granodiorite (trondhjemite), diorite, meta-gabbro and various of the resistant volcanic rocks. Pebbles of keratophyre are common, but of greatest interest are the pebbles of the metamorphic epidote assemblage (Fig. 12(B)), which have evidently been derived by erosion of the metamorphosed basalts.

Final and conclusive evidence is thus provided for a Lower–Middle Ordovician metamorphic event pre-dating the Gjersvik Disturbance. The metamorphism was produced by the thermal and hydrothermal effects associated with the contemporaneous eruptive activity embodied in the Gjersvik Nappe. The tectonic movements involved in the formation of the polymict conglomerate were predominantly vertical as opposed to lateral and must have been related to an early stage of tectonic evolution within the belt of Lower–Middle Ordovician eruptives of which the Gjersvik Complex was a part.

The status of a possible metamorphic event pre-dating the Trondheim Disturbance has been discussed elsewhere.<sup>11,65</sup> Further investigation will probably reveal the ubiquity of sea-floor-hydrothermal metamorphic assemblages as clastic constituents of the polymict conglomerates of the Venna

and equivalent horizons. It may be regarded as axiomatic that such assemblages should be incorporated into the conglomeratic rocks produced by episodic uplift of the Ordovician sea-floor and that the history of metamorphism would be as extended as the history of submarine volcanism.

Magmatic activity in the belt continued after the erosional event. The evidence for this is provided by quartz-feldspar porphyry dykes that cut both the eruptive complex, the unconformity and the overlying conglomerates prior to the first phase of deformation. These dykes are similar in composition to other granodioritic rocks within the eruptive complex and are regarded as the latest product of calc-alkaline magmatism within the Skorovas area.

#### *Acid to intermediate flows and pyroclastics*

There are, within the Skorovas region, a range of acid lavas, tuffs and agglomerates, which are locally abundant and form horizons that can be traced laterally over considerable distances (see Fig. 4(a)). These rocks are of critical interest because they are closely associated with both the Skorovas orebody itself and with a variety of iron- and silica-rich sediments, which, following the conceptual terminology of Carstens<sup>6,7,8</sup> and Oftedahl,<sup>42</sup> are appropriately described as 'exhalites'.

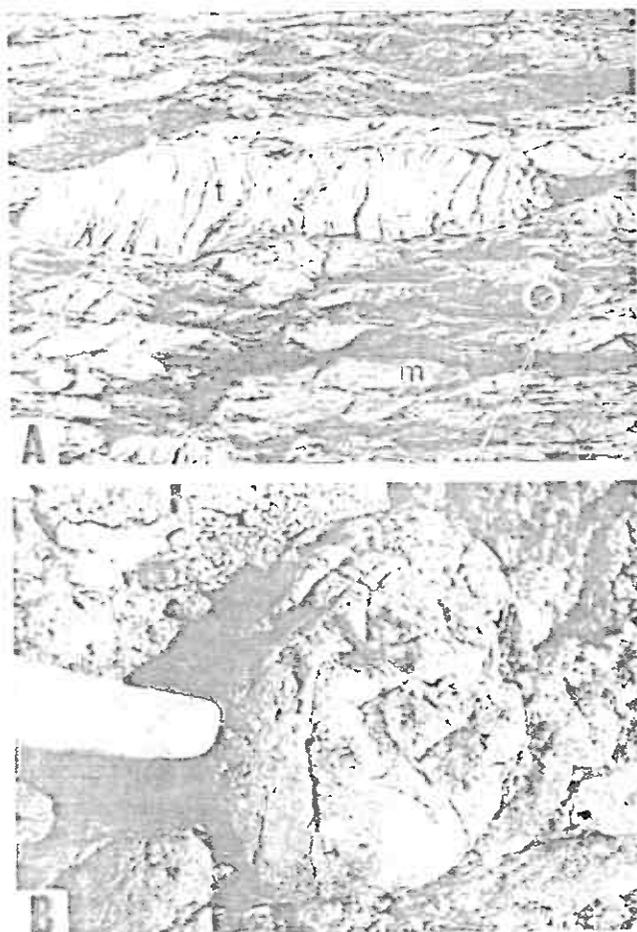


Fig. 12 A, Typical appearance of polymict conglomerates as seen to northwest of Havdalsvatnet. Flattened boulder of trondhjemite (t) displays tectonic fracture pattern characteristic of its brittle behaviour. Associated boulder of marble (m) has deformed in a ductile fashion. B, Large pebbles of pre-deformational epidote-rich metamorphic segregations derived by erosion from underlying lavas are a common constituent of greenstone-bearing facies of polymict conglomerate. Example photographed close to unconformity on southern shore of Tredjevatnet

Because of the deformation of the volcanic sequence and the inherent lateral variability of the volcanostratigraphy it is not possible to describe a unique and widely applicable type succession. The distribution of the various facies of acid rocks within specific parts of the Skorovas area suggests that a minimum of four centres of acid pyroclastic eruption were active. Their products are preserved, as far as it is possible to tell, at an approximately similar level in the volcanic sequence. In the vicinity of the Skorovas orebody there is stratigraphic evidence of at least two pyroclastic levels, the lowest of which is exposed in the basal slope of Skorovasklumpen to the north of Store Skorovatn (this is shown in Figs. 4(a) and 5).

The orebody itself evidently lies within the vicinity of one eruptive focus, which will be called the Grubefjell Centre. The other centres, tentatively distinguished, lie west and southwest of Tredjevatnet (the Tredjevatnet Centre), to the east of Overste Nesåvatn (the Nesåvatn Centre), and further east in the terrain near Blåhammeren (the Blåhammeren Centre). The main belts of acid rocks shown in Fig. 4(a) serve to identify these centres. It is difficult to judge whether the centres represent independent volcanic structures or lateral eruptions on the flanks of a single polygenetic edifice.

The acid volcanic horizons show a range of well-preserved pyroclastic fabrics to which Oftedahl<sup>41,42</sup> drew specific attention. Various agglomeratic facies are visible in the acid horizons in the immediate vicinity of the mine (see Fig. 14). Distal pyroclastic facies include fine tuff bands with associated exhalite sediments (Fig. 15(a)). Such horizons are spread over large areas and are thus valuable stratigraphic markers.

Pyroclastic facies can frequently be traced laterally into compact porphyritic and aphanitic bands of keratophyric aspect — presumably, flows or highly modified tuffs. In the vicinity of the Blåhammeren Centre porphyritic flows are physically continuous with porphyry dykes from which the eruptions appear to have originated. The dykes, in turn, can be traced towards the large mass of trondhjemite that occurs at the eastern end of the northern limb of the intrusive arc. The disjunction caused by deformation at the margins of the intrusive masses and within the volcanic sequence, however, denies a conclusive statement concerning the connections between the plutonic and volcanic levels during climatic episodes of acid eruptive activity.

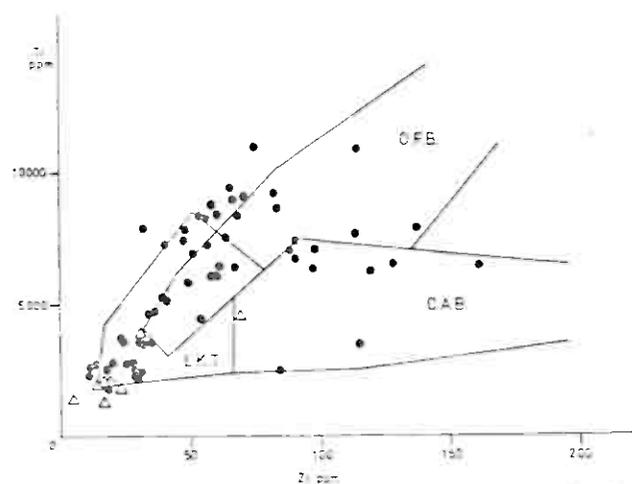


Fig. 13 Plot of Ti versus Zr contents for Skorovas basic extrusives (circles) and basic intrusives (triangles) showing abundance of low potash (island arc) tholeiites (LKT). Distinct trend towards field of calc-alkaline basalts (CAB) and grouping towards ocean-floor basalt (OFB) also shown

Chemistries of the acid extrusive rocks from the Skorovas ore level are distinctly soda-rich (see analyses 1 and 2 in Table 1). Petrographically, the rocks display a modal composition dominated by albite and quartz, occurring both as phenocrysts and as the constituents in the aphanitic groundmass, which is a mosaic of albitic plagioclase micro-lites and quartz. Whatever mafic silicates may have been present are now represented by dispersed chlorite. Pyrite is usually present as an accessory. The rocks are properly described as quartz keratophyres<sup>25,76</sup> and, taking into consideration the analyses from the basaltic and intermediate rocks shown in Table 1, it is clear that the Skorovas volcanic rocks are a spilitic suite.

The question is immediately raised as to the relationship that such a volcanic suite might have to the plutonic rocks at various structural levels in the immediate vicinity of Skorovas. The brief account of the plutonic rocks given above demonstrates the wide variation in the condition of metamorphism and deformation displayed by these rocks; there is no suggestion, however, that the compositions are abnormally sodic and the feldspars, though degraded by saussuritization, have original compositions in the range labradorite, in gabbro, to oligoclase, in trondhjemite.

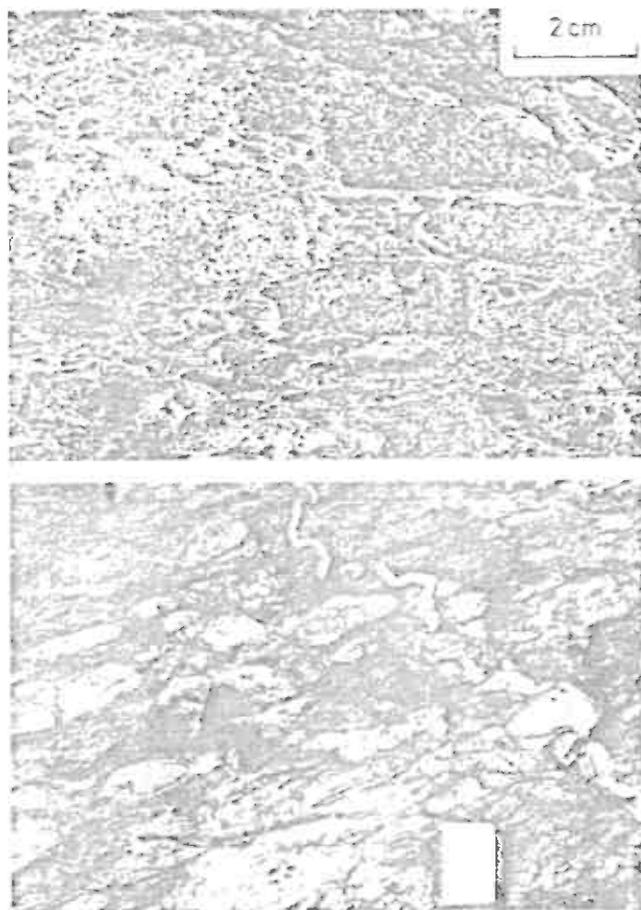


Fig. 14 Blocky pyroclastic texture (a) (top) seen in keratophyric flow unit on Grubefjell about 1200 m west of Skorovas orebody. Pyroclastic fragments are slightly flattened and siliceous matrix stands out as a reticular pattern. Flow is part of major acid horizon with which orebody is associated. (b) Agglomeratic facies of keratophyric horizon shown in (a). Locality is in immediate vicinity of ore horizon above mine entrance on northeast Grubefjell. Acid fragments are partly silicified and tectonically flattened. A competent quartz vein with orientation close to principal stress responsible for flattening during first stage of penetrative deformation has responded by buckle folding

Goldschmidt has given analyses of the type trondhjemite from the Trondhjem district and from localities in western Norway that show total  $\text{Na}_2\text{O}$  values in the range 4.3–6.0 wt % and  $\text{K}_2\text{O}$  values in the range 1–2.5 wt %. This gives a typical  $\text{Na}_2\text{O}:\text{K}_2\text{O}$  ratio for trondhjemite of the order of 3:1. Partial analyses of three trondhjemitic rocks from the Skorovas intrusive arc<sup>26</sup> show that the  $\text{Na}_2\text{O}$  contents fall in the range 2–4.5 wt % and  $\text{K}_2\text{O}$  values fall in the range 1–2.5 wt %.  $\text{Na}_2\text{O}:\text{K}_2\text{O}$  ratios are of the order 1:1.5–3:1. This range is clearly of the right order for trondhjemite to granodioritic rocks with  $\text{SiO}_2$  contents of about 70 wt %. The  $\text{Na}_2\text{O}:\text{K}_2\text{O}$  ratios of the spilitic rocks are one to two orders of magnitude greater than those seen in the regionally associated plutonics (see Table 1).

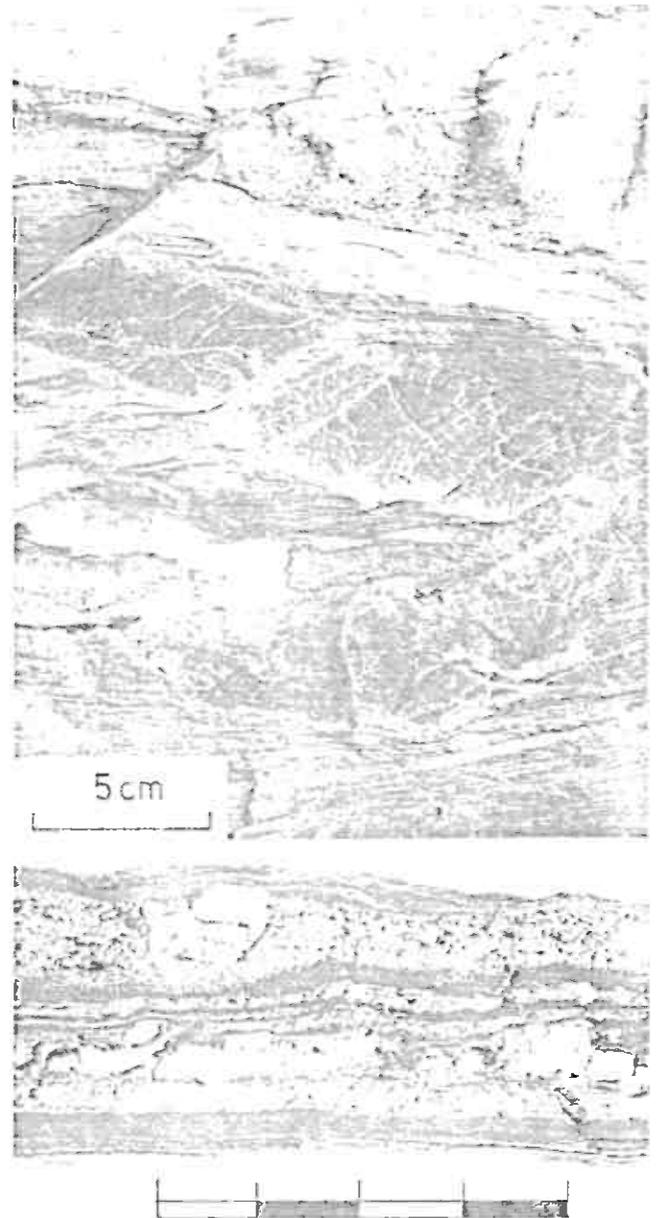


Fig. 15 Exhalite horizon (a) (top) 2 km east of Øverste Nesåvatn. Stratigraphic sequence is complex and made up of graded lapilli tuffs overlain by pink to brown coloured banded cherty sediments incorporating magnetite, hematite, stilpnomelane and iron-rich amphiboles. Purple chert band shows isoclinal fold style of earliest deformation with conspicuous refraction of early cleavage. (b) Banded pyrite-magnetite sediment typical of reduced facies of iron-rich exhalites (vasskis). Large pyrite porphyroblasts have suffered cataclasis and dislocation to varying degrees. Specimen from 1.5 km north of Blåhammeren. Scale in cm

A comprehensive programme of whole-rock analysis is being undertaken at the present time to establish the major differences in chemistry between the plutonic and the volcanic sequences, but it is clear that the most significant chemical difference does lie in the conspicuous enrichment in sodium, which has evidently occurred in the whole range of the volcanic suite.

The chemical discrepancy displayed by the volcanic and plutonic suites of the Skorovas area has been the root of a lengthy controversy concerning the affinities of spilitic rocks in general. The problem has been discussed by Wells,<sup>76,77</sup> Sundius<sup>66</sup> and Vallance,<sup>69,70</sup> among others, and it is clear, after the review of the problem by Vallance,<sup>69,70</sup> that the case for post-eruptive metasomatic alteration of alkali contents by circulating sea water is strong. Taken in conjunction with the textural evidence described above, there seems little reason to doubt that the spilitic character of the Skorovas volcanic sequence is the result of metasomatism, which accompanied the sea-floor metamorphism of the volcanic rocks during Lower Ordovician times. This metasomatic alteration by circulation of heated sea water changed the chemistry of the rocks, notably enhancing the Na<sub>2</sub>O content and concealing the natural magmatic consanguineity of the volcanic and plutonic rocks.

#### *Magmatic affinity of Skorovas eruptives and their tectonic significance*

The relative mobility of the major elements in basic and acid rocks during metamorphic alteration poses obvious problems with regard to the determination of the magmatic affinity of eruptive sequences and the confirmation of consanguineity within them. Cann,<sup>4</sup> in 1970, recognized the possibility of using certain elements, notably Y, Zr, Nb and Ti, which were unaffected by severe secondary alteration processes, as indicators of the magmatic affinity of ocean-floor basalts. Pearce and Cann<sup>46</sup> subsequently extended this concept for use in determining the tectonic setting of basic volcanic rocks by empirically defining the ranges of variation of the stable trace elements in suites of basaltic rocks collected from various defined oceanic and island arc environments.

Sixty-nine basaltic rocks from various parts of the Skorovas district have been analysed for stable trace elements. In Fig. 13 the values for Ti are plotted against those for Zr with reference to the fields of various basaltic magma types as defined by Pearce and Cann.<sup>46</sup> In addition, the Ti/Zr values for eight associated gabbroic to dioritic rocks from the intrusive arc are superimposed. These rocks were chosen for their even phaneritic texture and lack of conspicuous layering. The plot shows that the basaltic rocks of the Skorovas district concentrate in the field of island arc tholeiites with a notable trend towards the field of calc-alkali basalts. It is also possible to recognize a grouping of values towards the field of ocean-floor tholeiites. The coincidence of the analysed values in the plutonic rocks with the field of island arc tholeiites is regarded as a confirmation of consanguineity in the groups of basic plutonic and volcanic rocks falling in this field.

Study of the trace elements suggests that the eruptive sequence in the Skorovas area originated in a tectonic setting in which basaltic rocks typical of an immature island arc were being generated.<sup>19,28</sup> Moreover, a knowledge of the field relationships in terms of the chronology and relative volumes of the eruptive rocks at the plutonic and volcanic levels confirms this view. Little quantitative information is available concerning the relative volumes of

the various eruptive products in mature calc-alkaline arcs and in immature tholeiitic arcs. Baker<sup>2</sup> has given some comparative estimates based on observations of the South Sandwich Island volcanic sequence, and these are judged to be in the same order of proportion as those observed in the Skorovas area, notably basalt > andesite > dacite and rhyolite (or their spilitic equivalents). In the case of mature calc-alkaline arcs the relationship is of a distinctly different order — andesite > basalt. The field evidence, taken in conjunction with the supporting information from chemical analysis and petrographic examination, forces the conclusion that the eruptives of the Skorovas area are, in fact, the constituents of an immature island arc of Lower to Middle Ordovician age formed within an ensimatic setting peripheral to the Laurentian or the Scandinavian craton. The eruptive sequence, its magmatic evolution terminated, was emplaced as the structural and stratigraphic core of the Gjørsvik Nappe during the climactic stages of the Caledonian orogeny in mid-Silurian times. The tectonic decapitation of the island arc is believed to have originated with the collision between the Scandinavian craton—arc margin and a Laurentian counterpart,<sup>10,24</sup> the tectonic transport involved in the process of emplacement is estimated to have been at least 200–250 km.<sup>16,17,63,64</sup>

#### *Skorovas orebody and peripheral exhalative mineralization*

The description of the volcanic host rocks given above confirms the association between the Skorovas orebody and an eruptive sequence originating in an immature ensimatic island arc of Lower to Middle Ordovician age. It is appropriate to consider the morphology and mineralogy of the ore deposit and the peripheral exhalite mineralization of the Skorovas region in terms of the exhalative volcanic hydrothermal origin proposed for it by Oftedahl.<sup>41,42</sup>

The orebody is situated within a part of the volcanic sequence displaying distinctly calc-alkaline character. Apart from the keratophytic pyroclastic and flow units, at the level of which the orebody is located, the sequence includes a thickness of basaltic andesites and rocks in the range of silica contents appropriate to andesite and dacite, now represented by spilitic equivalents. The precise stratigraphic location of the orebody with respect to the acid horizons is difficult to establish owing to the disjunctive tectonic style, but there is no doubt that the association

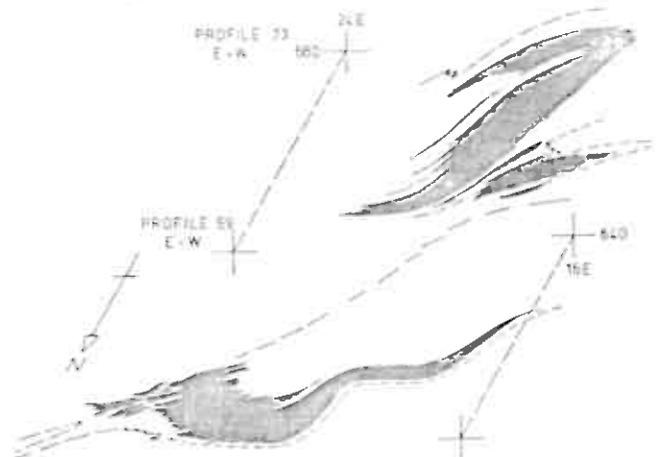


Fig. 16 Two sections of east orebody at profiles 59 and 73 east—west situated 140 m apart along morphological axis of orebody. Progressive development of a first-phase isoclinal fold is illustrated together with complex digitated style of isoclinal closures. Open style of second fold phase shown by undulation of lower contact of ore on profile 59 east—west

between ore and keratophytic extrusive rocks is intimate (see Figs. 4(a), 5 and 17).

The Skorovas orebody, at the present state of development, is estimated to comprise between 8 000 000 and 9 000 000 tons of massive sulphide ore, including 1 500 000 tons of essentially pyritic ore with minimal base-metal content. From the initiation of production in 1952 until 1975–76 approximately 4 700 000 tons of ore were milled to produce pyrite fines with an average grade of 1.2% Cu, 1.8% Zn and 45% S. This concentrate was marketed primarily for its high sulphur content. Following the decline in the market for sulphur-rich concentrates, a new beneficiation plant has been constructed for the production of Cu and Zn concentrates. Present ore reserves are calculated as approximately 2 000 000 tons with an average grade of 1.15% Cu and 2.29% Zn. It is a difficult problem to assess the average grade of the mineralized body as a whole since this clearly depends upon the geological-economic criteria chosen to define it. It is, nevertheless, possible to state that the mineralogy is dominantly pyritic and that the sulphur content of massive ore is of the average order of 35 wt % with  $Zn > Cu \gg Pb$ . Zinc content is of the order of 2 wt % and  $Cu \leq 1\%$ .

#### Structural style of orebody

The morphological complexity of the Skorovas orebody caused by tectonic disjunction of isoclinally folded lenses and the extreme tectonic deformation of the wallrock envelope has been a considerable obstacle to the clear formation of a genetic model.<sup>20</sup>

The orebody can be described as an *en-écheleon* array of closely spaced groups of massive sulphide lenses, the dis-

tribution of which has created an elongate ore zone with a length of approximately 600 m lying in a north to NNE orientation and with a width of the order of 200 m. A representative cross-section of the orebody is shown in Fig. 17.

The lenticular bodies have their principal planes orientated parallel to the axial planes of first-phase isoclinal folds and the individual lenses are apparently, to a significant degree, the products of partial disjunction of fold limbs within that fold system. In detail, as is shown by Fig. 17, the ore zone shows a longitudinal division into an eastern and a western orebody. This division may reflect the shape of the orebody at the site of accumulation prior to deformation. The lateral extremities of the ore lens systems characteristically show multiple digitation and bifurcation and there are frequently zones of sulphidic impregnation reaching ore grade that lie between the digitations of massive ore. As Gjelsvik<sup>20</sup> noted, discordance is locally observed between the contacts of some of the larger massive lenses and the schistosity of the wallrocks. This evidence, together with the irregular geometry of the orebody as a whole, was used in support of an epigenetic mode for the formation of the deposit, although Gjelsvik conceded that early folding had probably been an influence in creating its present morphology and that emplacement took place immediately following the eruption of the volcanic sequence in Lower Ordovician times.

It is possible to explain the local discordance between early schistosity and the contacts of the massive lenses in terms of the contrast in the mechanical behaviour of the base-metal-poor pyritic lenses and the volcanic wallrocks during the flattening and isoclinal folding of the first stage

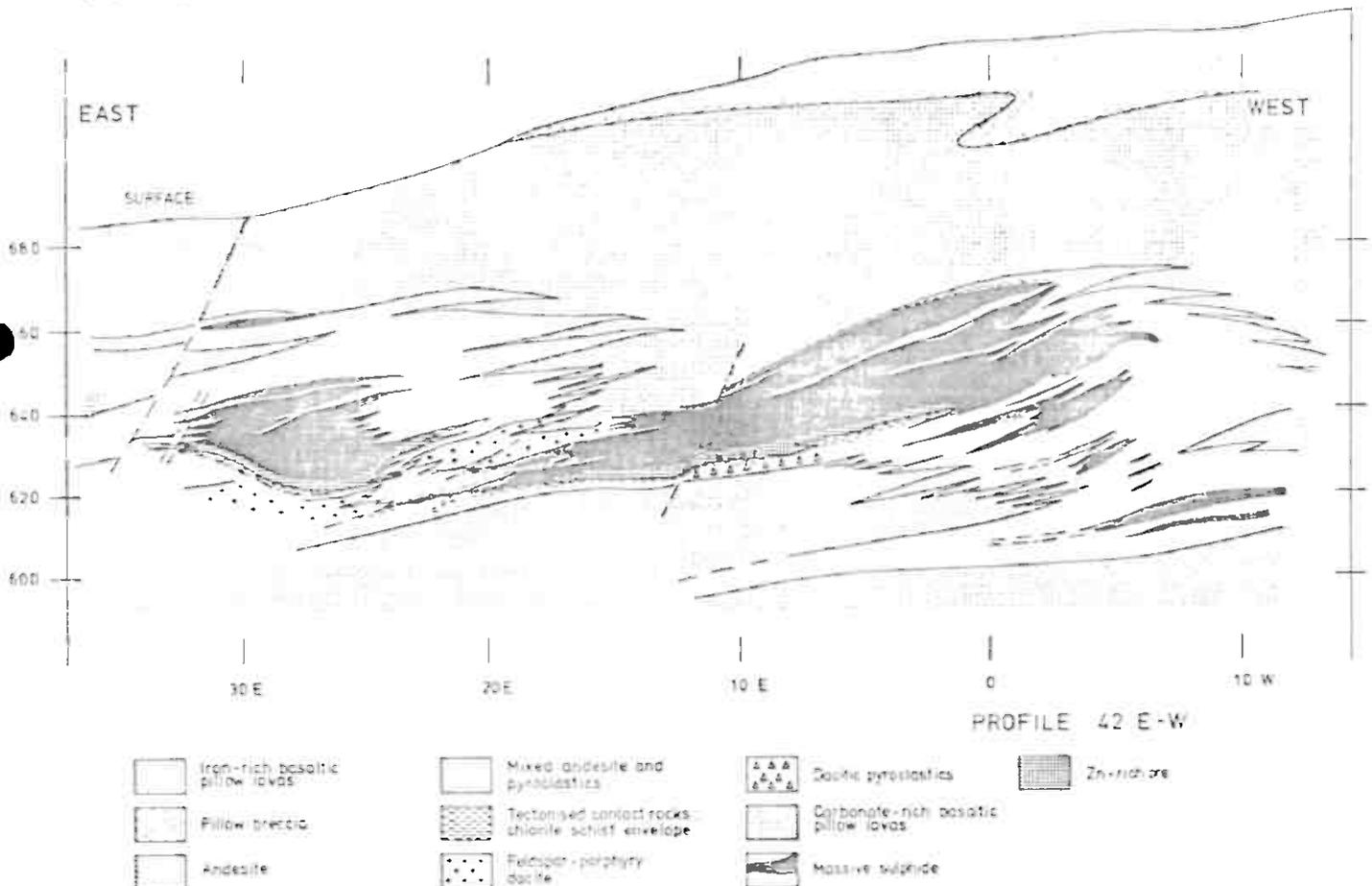


Fig. 17 Representative section through east and west orebodies at profile 42 east-west showing principal lithological divisions of host rocks and position of zinc-rich facies along footwall of principal eastern and western lenses. According to structural interpretation zinc-rich level is stratigraphic top of ore. Complex digitation of ore is well illustrated

of deformation. The disjunction created by componental movements at the ore contacts during this early phase must also have been magnified in response to the stresses imposed during the second period of folding.

The early deformation in the immediate contact zone of the orebody was sufficient, because of the contrast in competency, to create a schistose tectonic facies composed predominantly of chlorite, carbonate and, locally, talc. These components were derived by segregation from the altered basic host rocks — andesite, basaltic, andesite and basalt. The schistose tectonic envelope is shown locally in Fig. 17. The creation of this envelope facilitated the continuance of componental movements within the vicinity of the ore contacts during later deformation.

The history of structural deformation within the orebody can be summarized as follows:

- (1) Early isoclinal folding, accompanied by creation of a schistose envelope with componental movements in the vicinity of the orebody contacts, led to a tectonically disjunct style.
- (2) Periods of post-schistosity deformation produced folds of various scales. In the immediate contact zone small folds of up to several metres in wavelength occur sporadically in response to local variation in orebody geometry. The orebody as a whole, however, was folded on a broad open style, which is typical of later deformation in the Skorovas region. This is shown in the isometric projection (Fig. 16).
- (3) The final episode of deformation was marked by high-angle fractures of low displacement with a general northerly trend.

The early isoclinal structures display axial alignment in a north to NNE direction with axial planes dipping at approximately 25° towards the east. This is reflected in the axial elongation of the orebody. The later open folds, part of the regional dome and basin system shown in the structural analysis (Fig. 4(b)), have steeply dipping axial planes and an axial trend of approximately NNW orientation concordant with the pattern of the adjacent structural basis, on the flanks of which the orebody lies.

#### *Mineralogy and stratigraphy within orebody*

The bulk composition of the Skorovas orebody reflects a mineralogy of comparative simplicity. Pyrite, sphalerite, magnetite and chalcocopyrite are the dominant ore mineral species. Pyrrhotite is conspicuously absent. Galena occurs in much smaller amounts, and arsenopyrite and tennantite occur locally as accessory constituents. This mineralogy accounts for the average range of trace and minor metallic elements recorded in analyses of the orebody, the following values being considered as representative averages: Co, 100 ppm; Ni, 20 ppm; As, 300 ppm; Ag, 10 ppm; and Au, 0.1 ppm. Cadmium is notably enriched in sphalerite-rich facies of the ore, reaching values of several hundred ppm, and Mn reaches similar values in the pyritic facies. Most of the minor chemical variation can be accounted for by diadochic substitution within the common ore minerals. Arsenic and silver are notably contributed by arsenopyrite and tennantite, and grains of native gold have been observed as inclusions of 5 µm in size in arsenopyrite from peripheral parts of the ore. The principal gangue mineralogy of the ore consists of chlorite, quartz and calcite, together with lesser amounts of sericite and, locally, stilpnomelane.

The structural and stratigraphic evidence summarized here and by other authors<sup>20,21,41</sup> has confined the choice of genetic models for the orebody to the following

alternatives: (1) syngenetic deposition of the stratiform orebodies under submarine conditions as a result of emission of metal-rich fluids in the vicinity of an acid eruptive centre or (2) epigenetic emplacement of the orebody by replacement of part of the volcanic sequence in the vicinity of the eruptive centre, this taking place during post-eruptive hydrothermal activity in early Ordovician times.

If the first alternative is to be given favour, it would be desirable to be able to recognize some evidence of stratigraphy within the orebody. Gjelsvik<sup>20,21</sup> conducted a systematic analytical study of the major base-metal contents of ore from 43 drill-holes on selected profiles spanning the length and breadth of the orebody. The results of this study showed that the contents of zinc and copper varied antipathetically, zinc showing a tendency towards enrichment in the peripheral zones of the orebody and copper tending to concentrate in enriched core regions. It was also noted that the overall content of copper and zinc showed an increase towards south of the orebody. In the southern part Gjelsvik noted that zinc, in particular, is enriched towards the hanging-wall and in the eastern and western extremities of the ore lenses. In the central zone it is enriched in the vicinity of the footwall contact (Fig. 17). In the northern part of the orebody the composition is essentially pyritic, with minimal base-metal content. The analytical data prove a systematic variation in base-metal content both laterally and vertically within the orebody, and this is confirmed by petrographic studies and field observation.

In the course of the present study it has been possible to recognize facies of the ore that are probably of chemical-sedimentary origin and those which are essentially tectonic. The pattern described by Gjelsvik<sup>20,21</sup> probably reflects the influence of both processes. The primary textural evidence for the operation of sedimentary processes in ore deposition is given by the graded banding of the pyritic ores in which rapid changes of modal composition and grain size occur from band to band. This type of texture is shown in the banded pyrite, sphalerite magnetite ore of Fig. 18(C). It is highly unlikely that such banding is of tectonic origin. Moreover, where tectonism has had a pervasive effect on the ore, the textures are of distinctly tectonic style (see Figs. 18(B) and 18(D)). Figs. 18(A) and 18(B) show that the deformation of the pyritic lenses was marked by mutual impaction and cataclasis of the constituent grains. Any gross tectonic flattening or extension of the lenses must have been accomplished by relative movement between the individual grains accompanied by cataclastic degradation. This mechanism has been described as macroscopic ductility by Atkinson,<sup>1</sup> who has also shown that cataclasis is probably the only significant deformation mechanism available to pyrite, under dry conditions in the *P-T* range appropriate to the greenschist facies. It is unlikely that deformation took place under dry conditions,<sup>48</sup> but the range of textural evidence strongly suggests that, within the massive pyrite, cataclasis was the dominant deformation mechanism. Atkinson<sup>1</sup> also notes that the strength of polycrystalline pyrite is strongly and inversely dependent on porosity. Large volumes of the Skorovas orebody are composed by nearly monomineralic close-packed aggregates of pyrite with low porosity and, when lithified, these masses must have behaved in a highly competent manner relative to the adjacent chloritized lavas and pyroclastics. Under the influence of the tectonic stresses prevailing during the first period of deformation it seems reasonable to propose that the style of deformation within the orebody may have been controlled by the development of

narrow zones of cataclastic flow within which much of the tectonic strain would have been accommodated. In this way, the formation of a disjunct lenticular arrangement of ore lenses could be explained as well as the rarity of well-preserved isoclinal structures.

Tectonic mineralogical facies of the orebody are undoubtedly recognizable in the base-metal-enriched lenses and extremities on the lateral periphery of the ore. Zinc values are enhanced by an order of magnitude and lead values by two orders of magnitude. This is shown by analysis 5 in Table 2. The typical foliated texture of this ore is shown in Fig. 18(D), which also displays the incipient development of a crenulation cleavage related to the second phase of deformation.

Tectonic mechanisms are not, however, the sole explanation of the peripheral enrichment of base-metal values; nor do they completely explain the separation between maximum zinc and copper values in the pyritic ores. There appears to be a definite stratigraphy in which cupriferous pyritic ores (analyses 1 and 2 in Table 2) are overlain by zinc-rich ores with laterally developed facies rich in banded

magnetite and carbonate. Analyses for these ore types are shown as 3 and 4 in Table 2.

It appears also that a distinct primary lateral variation may also have been present to account for the generally depleted levels of copper and zinc in the northern part of the orebody. Final evidence of the operation of chemical-sedimentary processes in the formation of the orebody is provided by the occurrence of magnetitic and hematitic chert bands (jasper) in the foot- and hanging-walls of the orebody stratigraphically overlying the magnetite and zinc-rich facies.

Evidence of a primary stratigraphy within the orebody clearly exists despite considerable tectonic modification. It is also plain that the metal distribution can be interpreted in terms of a stratigraphic zonation, which resembles that found in orebodies of undisputed volcanic exhalative origin in such areas as the Miocene Green Tuff belt of Japan.<sup>30</sup>

The detailed palinspastic reconstruction of the lateral and vertical facies variation within the complex Skorovas orebody is the subject of a current study by Reinsbakken

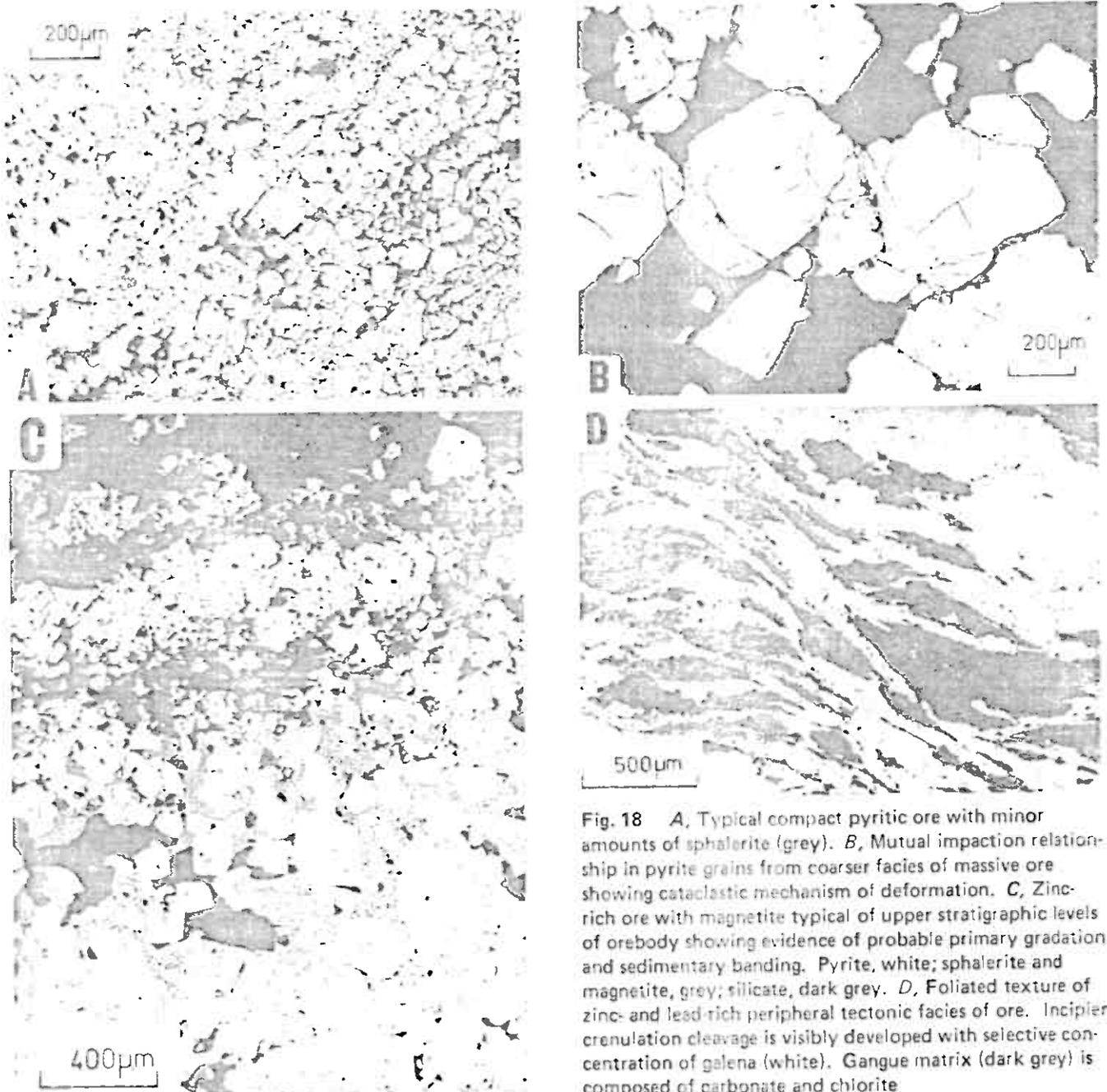


Fig. 18 A, Typical compact pyritic ore with minor amounts of sphalerite (grey). B, Mutual impaction relationship in pyrite grains from coarser facies of massive ore showing cataclastic mechanism of deformation. C, Zinc-rich ore with magnetite typical of upper stratigraphic levels of orebody showing evidence of probable primary gradation and sedimentary banding. Pyrite, white; sphalerite and magnetite, grey; silicate, dark grey. D, Foliated texture of zinc- and lead-rich peripheral tectonic facies of ore. Incipient crenulation cleavage is visibly developed with selective concentration of galena (white). Gangue matrix (dark grey) is composed of carbonate and chlorite.

and will not be discussed further here. It may be said, however, that the zonal distribution of copper and zinc within the pyritic mass suggests that precipitation of the ore minerals could be explained in terms of an evolving chloride-complex model such as that used by Sato to explain

**Table 2** Average metal values for Skorovas ore types and sulphide facies of an extensive exhalite

%	1	2	3	4	5	6	7
S	46.80	47.20	38.90	42.28	27.50		51.10
Cu	1.09	2.30	0.99	0.79	1.47	0.06	0.20
Zn	0.15	0.80	3.90	9.33	44.20	0.02	0.41
Pb	0.03	0.04	0.05	0.04	4.00	0.01	

1, Massive pyritic ore (27 samples); 2, copper-rich ore (14 samples); 3, banded magnetite-rich pyrite-sphalerite ore with carbonate (18 samples); 4, pyritic zinc-rich ore at stratigraphic top of orebody (13 samples); 5, Zn-Pb-Cu-rich peripheral ore — probably a tectonic facies (2 samples); 6 massive base-metal-depleted pyrite or 'vasskis', Haldalsvatn (1 sample); 7, relatively enriched pyritic ore, Skorovas (30 samples).

zonation within the Kuroko deposits.<sup>55</sup> The applicability of such a model depends on the existence of conditions such that the metal- and sulphur-enriched hydrothermal solutions are not rapidly and widely dispersed into the dominantly oxidizing conditions of the submarine environment. This requirement must be met by topographical barriers in the vicinity of the hydrothermal emanations or by density contrasts between the emanating brines and sea water.<sup>54</sup> It is upon the presence or absence of the conditions outlined that the distinction between the hydrothermally intensive and the hydrothermally extensive exhalite phenomena in the Skorovas area is based.

#### Peripheral exhalative mineralization

The magnetitic cherts and jasper found at the stratigraphic top of the Skorovas orebody signify the restoration of chemically normal oxidizing conditions in the vicinity of the orebody. These ferruginous siliceous horizons represent a continuum between the intensive and extensive facies of mineralization (see Fig. 19). The relative frequency of the association between acid pyroclastic horizons of various facies and banded magnetite-pyrite and chert in the Skorovas area, and within the Grongfelt as a whole, was one of the primary inspirations for the theory of exhalative-sedimentary ore genesis expounded by Oftedahl in 1958,<sup>41,42</sup> who carried forward the concepts formulated by C. W. Carstens<sup>78</sup> in his studies of the Leksdal type of sedimentary sulphide deposit in the Trondheim district. Oftedahl<sup>42</sup> emphasized the association between acid pyroclastic activity and the formation of the iron- and silica-enriched sediments. Understanding of the various exhalative facies has been carried forward in the course of the present study.

The main characteristics of the extensive peripheral exhalites are noted below.

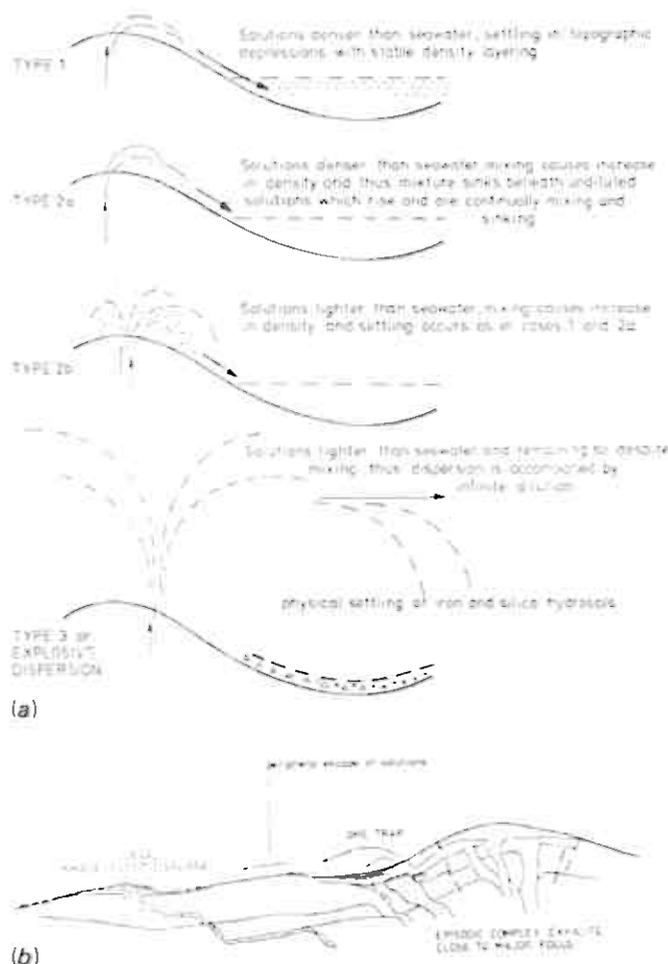
- (1) The exhalite horizons are relatively thin, 0.1–2 m in thickness, are laterally persistent within the volcano-stratigraphy and can be traced over distances of the order of several kilometres.
- (2) Internal variations of stratigraphy occur in detail. The sequence is always marked, however, by a change from a reducate sulphidic or magnetitic banded stratum to an oxidate ferruginous chert (jasper). These changes occur in a vertical sense (Fig. 20) and also, generally speaking, in a lateral sense.

- (3) The sulphide facies are characteristically impoverished in base metals other than iron and manganese (see analysis 6, Table 1).

These widespread bands can be explained by a mechanism of explosive volcanic dispersal during the climactic dacitic eruptions associated with the various volcanic centres. In the course of such a process rapid and complete mixing of the residual hydrous fraction of the dacitic magma with oxidizing sea water will have occurred. The base metals will have been subjected to infinite dilution in the course of such a process, leaving oxidized iron and silica hydrosols in suspension. The hydrosols will have suffered greater dispersion than the pyroclastic fragments and by subsequent settling will have produced a thin stratum of iron- and silica-rich sediment that extends well beyond the limits of the latter. It is for this reason that the extensive exhalite horizons are so named. They also constitute valuable time-stratigraphic markers within the intrinsically variable volcanostratigraphy.

The sulphide-magnetite mineralogy of the reducate facies is to be ascribed to post-depositional bacterial reduction of iron, deposited in the oxidized condition. A typical facies of this type is shown in Fig. 15(b).

The simple stratigraphy shown in the ideal section (Fig. 20) can be regarded as the product of a single dispersal event. Some exhalites, however, give evidence of episodic explosive and fumarolic activity that results in a complex cyclic stratigraphy in which tuff bands are intercalated



**Fig. 19** Scheme of interaction of hydrothermal brines with sea water (a) (top) (after Sato<sup>54</sup>) and schematic eruptive and hydrothermal events in Skorovas volcanic centre during climactic dacitic episode (b)

with iron-enriched chert bands that show a complex mineralogy, including stibnomelane, iron-rich amphiboles and chlorites, together with a spinel, commonly of magnetite composition (Fig. 15(a)).

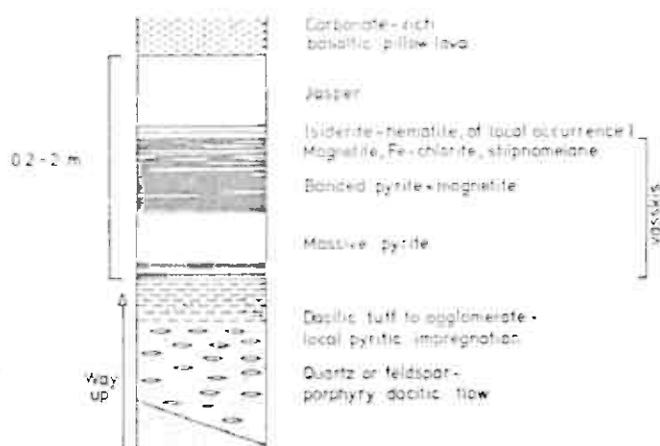


Fig. 20 Ideal section showing products of single event dispersal in extensive exhalite as observed in vicinity of Blåhammeren centre

As well as being valuable time-stratigraphic markers, the exhalites may be developed as a tool in identifying vent-proximal and vent-distal environments and have obvious value as a guide in exploration. An investigation of exhalites as an exploration tool is currently being carried out in the Skorovas area by Ferriday, Halls and Hembre.

### Conclusions

It was recognized in the early stages of the present study in 1972 that the Skorovas area provided a unique window on the eruptive and ore-forming processes that take place within a Palaeozoic island arc environment. An attempt has been made in this paper to describe the major eruptive, hydrothermal metamorphic and tectonic processes that have acted to produce the present geology of the Skorovas area in the context of its position in the Gjersvik Nappe.

Attention has been specifically directed to the hydrothermal processes that take place at the volcanic level, but it is important to record the occurrence of cumulus ores of magmatic origin within the plutonic complex. At Lillefjellklumpen, to the north of Skorovas (see Fig. 4(a)), a small platinum-bearing pyrrhotite-chalcocopyrite-pentlandite lens has been found in association with a minor body of metagabbro. This occurrence was described by Foslie and Johnson-Høst in 1932.<sup>13</sup> The present study has shown that small cumulus bodies of chalcocopyrite-pentlandite-bearing ore occur at a variety of sites in the layered gabbros of the deeper plutonic level. At the present time these bodies are of incidental economic interest only. The whole range of phenomena described can therefore be said to typify the ore-forming environment within an ensimatic pericratonic island arc, and only the porphyry style of sub-volcanic mineralization appears to be absent. This may, however, reflect the immature character of the arc.

The study has also placed the Gjersvik, Trondheim and related disturbances in their proper geological context as episodes of uplift associated with the stages of evolution of a pericratonic arc system in Lower to Middle Ordovician times. Vertical movements of this style can be said to be a characteristic feature of the evolution of arc systems,<sup>71</sup> and Murphy<sup>38</sup> has described fault-bounded back-arc basins of Tertiary age in Indonesia that contain up to 8 km thickness of clastic sediments,

which were deposited under subsurface to shallow marine conditions. It is, perhaps, a debatable exercise to attempt to correlate the timing of such movements, which may be intrinsically of intra-arc origin, with tectonic events of differing style taking place in other provinces of the Caledonides that could have been located, in Lower Ordovician times, on separate geographically and tectonically isolated margins of the orogenic system.<sup>3</sup>

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Tatt ut  
artikkel om Skovvass 1/1 A. Rensb.





N O T A T

FRA: C.W. Carstens

DATO: 23.3.81

MALMLETINGSSTATUS FOR SKOROVAS GRUBER OG MULIGHETENE VED  
YTTERLIGERE PROSPEKTERING

## INNHALDSFORTEGNELSE

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## 1. INNLEDNING (bakgrunn og sammendrag)

Undertegnede er blitt pålagt oppgaven å arkivere og sammenstille undersøkelsesdata fra tidligere malmundersøkelser, en oppgave som O.S.Hembre var kommet godt i gang med. Oppgaven er tenkt gjennomført innen en tidsramme på ca. 3 måneder.

Da det i utgangspunktet har hastverk med å komme igang med ytterligere malmeting, har man på grunnlag av en "røff" gjennomgåelse av geologiske "avhandlinger" og geofysiske rapporter forsøkt å gjøre seg opp en generell malmetingsstatus. Man håper notatet kan bidra til å motivere til planlegging av ytterligere undersøkelser. I det minste håper man at det kan frembringe en diskusjon om videre malmundersøkelser i Skorovasfeltet.

Som naturlig er, har tidligere malmundersøkelser stort sett vært konsentrert til Hovedmalmen og de marginale forekomstene Syd- og Sydøstmalmen. Et område av størrelsesorden 8-10 km<sup>2</sup> ansees for å være meget godt undersøkt ned til ca. 4-500 m under dagoverflaten.

Dels under nevnte nivå har imidlertid strukturgeologiske undersøkelser og boring ved Hovedmalmen indikert at grønnsteinssonen i hvilken malmen er tilknyttet, repeteres på dypet som et resultat av isoklinalfolding. Spredte A.M.T. undersøkelser indikerer at en "malmleder" også kan repeteres.

De foreliggende gode geologiske kart viser en utbredelse av betydelige grønnsteinsarealer som ikke er systematisk undersøkt geofysisk. Disse grønnsteinsarealer ligger relativt nær de eksisterende daganlegg, og de kan representere områder i hvilke det er muligheter for å finne mer dagnære malmkropper.

Spesielt turammålinger har vist seg å være en god geofysisk undersøkelsesmetode i Skorovasfeltet. "Sydmalmen" og "Sydøstmalmen" beliggende 200 - 250 m under dagen, fremtrer tydelig anomalt og man antar at turammetoden har en dybderekkevidde på 4-500 m under gunstige forhold. For videre malmleting vil man påpeke at det er viktig at strukturgeologiske undersøkelser bør danne en basis for et geofysisk undersøkelsesopplegg.

## 2. GEOLOGI

### 2.1. Innledning.

Geologisk kartlegging har vært utført siden 1930. 5 geologer har vært inne i bildet, og det har vært kartlagt både i regional og detalj målestokk (1:50000 - 1:2000). Geologisk arbeide pågår fremdeles gjennom A.Reinsbakkens Dr.ing.arbeider.

### 2.2. Grønnstein og malm.

Noe forenklet kan man si at 3 grønnsteinsserier finnes i feltet. Malmen opptrer på grensen mellom 2 serier hvor den ene serie er preget av mye eksplosiv vulkansk virksomhet. I de andre seriene finnes også skjerp og mineraliseringer. Det nevnes at Skiftesmyr, som forøvrig ikke ligger i Skorovasfeltet, synes å være knyttet til den nederste grønnsteinserie.

De 3 nevnte grønnsteinserier ansees i utgangspunktet å være potensielle moderbergarter for kismalm. Nevnte moderbergarter har et betydelig areal og finnes relativt nær eksisterende dag-anlegg. Det kan geologisk sett være nærliggende å trekke frem grensesonen i hvilket kjent malm finnes som en ledehorisont for videre malmleting.

### 2.3. Strukturgeologi.

Etter den primære dannelselse har bergartene blitt utsatt for nye bevegelser med overfoldninger.

2 foldefaser opptrer med akser henholdsvis mot SSV og SSØ, og begge er preget av isoklinalfoldning. Etter foldningene er feltet utsatt for relativt steile forkastninger. Forkastningen stryker mot NNO og NO.

Det er verdt å merke seg at ikke minst malmenes romgeometriske form er preget av nevnte foldninger. Malmen er meget oppstykket og har form av linser i et stjert om stjert mønster med akseretning mot syd. Det er eksempelvis sterke indiksjoner på at økonomiske mektigheter av malm har oppstått som et resultat av sterk isoklinalfoldning.

Et annet resultat av strukturkartlegging er indikasjoner på at grønnsteinssonen, som kjent malm er knyttet til, er repetert på dypt som et resultat av isoklinalfoldning. Dette er forøvrig delvis bekreftet ved resultatene fra 2 dype bornull.

En malm av form og størrelse lik hovedmalmen (ca. 10 mill. tonn) vil lett kunne mistes hvis man ukritisk setter igang med systematiske geofysiske bakkemålinger uten å ta hensyn til strukturgeologiske tolkninger. De geofysiske profiler kan da lett få en ugunstig retning og innbyrdes avstand i forhold til det søkte objekts størrelse og akseretning.

Strukturgeologisk kartlegging og en best mulig forståelse av malmenes stratigrafiske posisjon i vulkanittene har kort sagt stor betydning for å finne frem til områder i hvilket stratigrafiske og strukturelle betingelser kan finnes som kan kontrollere andre malmkroppers opptrøden.

Nevnte geologiske strukturstratigrafiske forhold som har betydning for prospektering ventes nærmere avklart gjennom A. Feinstakkers Dr. ing. arbeider.

### 3. GEOFYSIKK

#### 3.1. Innledning.

Geofysiske undersøkelser er utført i tidsrommet 1956 - 1979. De geofysiske hjelpemidler var lite tilgjengelige da malmen ble funnet og er derfor ikke utført i en ideell rekkefølge. I denne del blir elektriske og elektromagnetiske undersøkelser som spesielt har hatt betydning, viet oppmerksomhet. Det refereres forøvrig til den utmerkede BVL-rapport nr. 45 hvor noen sider blant annet omtandler nytteverdien av geofysikk i Skorvasfeltet.

#### 3.2. Geofysiske undersøkelser og resultater.

- a) Vanlige flymålinger i 150 m høyde har gitt svært usikre indikasjoner.
- b) Helikoptermålinger utført av Terratest og NGU gir skikkelige indikasjoner på utgående av hovedmalmen. Bortsett fra grønnsteinområdet nord og nordøst for Lille Skorvatn, er området målt. En del helikopteranomali er ikke oppklart.

c) Av utførte bakkeundersøkelser som I.P. Turam, VLF motstands-  
målinger og magnetiske undersøkelser, står turam og I.P. i en  
særklasse.

I.P. indikerer hovedmalmens fortsettelse mot syd, samt at den  
indikerer mineraliseringer vest for hovedmalmen og i underkant  
av denne. Undersøkelsene har derimot ikke gitt gode holde-  
punkter for boring vest for hovedmalmen. Man skal også merke  
seg at syd-øst-malmen fremkommer middels anomalt ved I.P.-  
undersøkelsene.

Turamundersøkelsene indikerer hovedmalmens utstrekning mot syd,  
samt at den indikerer klart både syd og syd-øst-malmen syd og  
syd-øst-malmen beliggende ca. 200 m under dagen er funnet som et  
resultat av prospektering hvor turamundersøkelser har spilt en  
sentral rolle. Det påpekes imidlertid/ <sup>at</sup> hele området mellom syd og  
syd-øst-malmen er turamanomalt. Ved konduktiv strømtilførsel har  
man ikke greid å skille marginalmalm fra fattige impregnasjoner.

d) A.M.T.undersøkelser er utført i et relativt beskjedent omfang.  
På grunnlag av et profil som passerer over Hovedmalmen, kan man  
si at denne fremkommer anomalt. Merkelig nok har man ikke fått  
skikkelige indikasjoner på Syd-syd-østmalmsonen. A.M.T.mål-  
ingene har gitt indikasjoner på en dyp leder ca. 800-900 m under  
dagen. Det er sannsynlig at nevnte indikasjoner kan gjenspeile  
en leder i grønnsteinsonen som synes å repeteres på dypet.

### 3.3. Konklusjon av tidligere undersøkelser.

Av tidligere utført geofysikk kan følgende konklusjoner trekkes:  
Dersom Hovedmalmen hadde vært ukjent idag, kunne den blitt funnet  
ved turam, I.P.motstand, VLF, A.M.T. og elektromagnetiske målinger  
fra helikopter. Syd- og syd-øst-malmsonen som ligger 200-250 m  
under bakken, ville kunne blitt funnet ved turammålinger.

På grunn av relativt stor elektrisk motstand i sidebergarten i  
Skorovasfeltet har nevnte geofysiske metoder god dybderekkevidde.  
Dersom ikke skjermende grunne ledere finnes, er dybderekkevidden  
omtrent som følger:

Helikoptermålinger	ca. 50 m
VLF-målinger	" 100 m
Turammålinger	" 500 m
A.M.T.-målinger	> 1000 m

#### 4. PROSPEKTERINGSSTATUS

Av konkrete objekter er "syd-øst-malmen" (600.000 t 1,41 Cu og 1,48 Zn) og "syd-malmen" (300.000 t 1,71 Cu og 0,31 Zn) funnet som et resultat av prospekteringen.

De nevnte marginalmalmer samt Hovedmalmen (10 mill.t) ligger innen for et turamundersøkt område på ca. 10 km<sup>2</sup>. Det påpekes at spesielt turammethoden synes å være velegnet i Skorovasfeltet. Nevnte områder anses for å være bra undersøkt ned til et dyp på ca. 2-300m under bakken.

Innenfor nevnte turammålt område er dog den nedfoldete grunnsteinen i hvilket malmen er tilknyttet, et prospekt for dypmalmleting. Strukturelt sett er det indikasjoner på at nevnte nedfoldete grunnsteinsone blir grunnere mot nord. A.M.T.-målinger tyder så langt på at en leder kan finnes ca.200-350 m i forlengelsen av dyphullene 10071 og 10035. Det påpekes at A.M.T.-resultatene er kun basert på resultatene fra to profiler hvis avstand innbyrdes er ca. 200 m.

Området bør undersøkes ytterligere med A.M.T.-målinger før man tar standpunkt til eventuelt å forlenge nevnte borchull eller bore andre hull. I utgangspunktet vil man prioritere slike dypundersøkelser omtrent likeverdig med mer grunnne undersøkelser utenfor nevnte område på 10 km<sup>2</sup>.

Majoriteten (over 90%) av berggrunnen utenfor utgjøres av grunnsteiner - grunnsteiner som også kan ligge strukturelt gjemt under andre bergarter. Undersøkelsene utenfor området har vært mer spredt.

Noen mineraliserte objekter er dog fremkommet av hvilke noen bør undersøkes videre. Nembre har laget en objektbeskrivelse.

I Guizernområdet finnes Mo-mineralisering og området henger strukturelt sett sammen med Fremstfjellområdet, hvor Grong-gruppen har interessante molybdenoppslag.

Man burde være motivert for å undersøke større områder systematisk ned til et dyp av 2-300m under dagoverflaten. I motsetning til de fleste andre bergverksområder har Skorovas-feltet svært stor blotningsgrad hvilket muliggjør at man kan komme langt med strukturgeologiske undersøkelser. Bergartene har dessuten relativt høy elektrisk motstand slik at man kan se relativt dypt med elektromagnetiske undersøkelsesmetoder.

Forslag til metodikkrekkefølge ved ytterligere malmundersøkelser er som følger:

- 1) Nærmere strukturgeologiske undersøkelser samt rekognoserende VLF-målinger.
- 2) Systematiske turamundersøkelser i området som prioriteres ut ifra VLF- og strukturundersøkelser.
- 3) Mer kostbare og tidkrevende A.M.T. undersøkelser bør utføres mer regionalt. Formålet er å detektere dypere objekter hvis turam skjermes av tynne ledere.  
A.M.T.metoden kan også bidra med å fremskaffe strukturelle opplysninger.

## 5. LITT OM PROSPEKTERING I MERÅKER-TYDALOMRÅDET

Skorovas Gruber har også drevet kismalmleting i Meråker-Tydalområdet. Dette område ansees neppe å få noen innvirkning på situasjonen i Skorovas, men da det har vært arbeidet i dette området i omlag 10 år fra 1965, synes man området bør nevnes i dette notat.

Skorovas Gruber har undersøkt en del gamle gruber og skjerp av hvilke kan nevnes: Kongens grube, Torsbjørk grube, Ramfjell grube, Fonnfjell grube, Lillefjell grube, Gilså, Klukan grube o.fl. Kongen grube, som ble drevet fra 1747 til 1793 var en av de mest kobberførende. Det har blitt produsert ca. 5000 tonn smelte-malm å 4,5% Cu. En del flyanomali er som ikke direkte har forbindelse med gamle gruber og skjerp er også undersøkt. Majoriteten av undersøkelsene har vært konsentrert til et område ved Storhusmannsberget i hvilket område det fra tidligere fantes endel skjerp. Foruten at det er boret 10 hull, er det gjort geokjemiske undersøkelser og IP og CP-målinger. "Malmberegninger" viser 7,5 mill.tonn med 0,3% Cu og 0,3% Zn.

Undersøkelsene har ikke ført frem til interessante kisobjekter. Det nevnes at endel geofysiske flyanomali er og bakkeanomali er ikke er oppklart.

Skorovas hadde tidligere endel mutinger i feltet, men de siste av disse gikk i det fri ved årsskiftet 80/81. I løpet av 1981 har Orkla delvis mutet våre tidligere rettigheter.

Man skal ikke se helt bort ifra at noen gruber og skjerp i Meråker-Tydalsfeltet kan inneholde edelmetaller. Den tid da Skoro-vas Gruber A/S utførte undersøkelser var ikke gull og sølvprisene interessante. Således er det tidligere bare utført ubetydelige edelmetallanalyser.

8 analyserte bly-magnetkisprøver fra Klukuken-området viser i snitt 238 ppm Ag. (normal sølvgehalt i Garpenberg er 110 ppm).

Prøvene er over-representative, men gir dog likevel en bra indikasjon.

Storhusmansberget i Meråker-feltet har som nevnt ca. 0,3%Cu og 0,3%Zn, og edelmetallanalyser er ikke gjort. (Aitik har gehalter på 0,35%Cu og 5 ppm Ag.)

## 6. ETTERORD

Bergverksindustrien er for tiden inne i en vanskelig periode. Grubeselskaper trues av nedleggelse, og både yngre og erfarne bergfolk går over i oljeindustrien. En basis for mineral og malmprospektering er gode geologiske regionalkart. Kartleggingen av Norge er en sørgelig historie. Med myndighetenes nåværende kapitalbevilgninger til NGU vil det ta omlag 130 år før landet vårt er geologisk kartlagt i målestokk 1:50.000.

For å prøve å sikre bergverksbransjens eksistensmuligheter, må vi være villige til å satse mer på prospektering. For at prospektering skal gi resultater må man ha gode ideer, god markeds-oversikt, god geologisk bakgrunn, god kjennskap til prospekterings-teknikker, og ikke minst være villige til å satse risiko-kapital. Enkeltvis mangler selskapene en del av overnevnte faktorer, og da kanskje spesielt vilje og kapital. En av de beste måter å unngå tap på, er å ha vilje til å satse relativt mye kapital på motiverte undersøkelsesobjekter.

Stagnasjon og nedbygging av bergverksindustrien bør kunne unngås gjennom et mer utstrakt prospekteringssamarbeide selskapene seg i mellom. Samarbeid med oljeselskaper er ikke minst interessant for å oppnå betydelig kapitalstøtte til prospektering.

Med utgangspunkt i produksjonsverdi av malmer og mineraler (ikke olje) pr. arealenhet ligger Norge på en klar jumboplass sammenlignet med f.eks. Sverige, Finland og Canada. Landet er underprospektert og burde som sådant være et godt objekt for investering i Malmleting.

Skorovasfeltet i hvilket en grube og flere skjerp finnes er i utgangspunktet et interessant objekt for malmleting. Resultatet av de gode geologiske arbeider som er utført i området er at en kjenner store grønnsteins arealer og strukturelt sett skulte grønnsteins områder i hvilket det burde være gode muligheter for å finne malm relativt nær de eksisterende daganlegg. På grunn av feltets relativt store elektriske motstand finnes det gode geofysiske elektromagnetiske teknikker som kan detektere mulige malmledere under overflaten.

Ved kapital- støtte fra f.eks. olje selskaper er man geologisk sett motivert til å satse på ytterligere prospektering i Skorovasfeltet. Fra et samfunnsmessig synspunkt har dette hastverk.



NOTAT

Fra: C.W.Carstens

Dato: 25.5.81

FORSLAG TIL PROSPEKTERINGSPLAN I SKOROVASFELTET

	Side
1. Innledning	1
2. Generell prospekteringsmetodikk	1
3. Generell beskrivelse av prospekteringsområdene	2
4. Gjennomføring, kostnader, tid.	3
Konklusjon	6

BILAG

1. Områdekart for prospektering
2. Geologisk kart av Halls & Co.



## FORSLAG TIL PROSPEKTERINGSPLAN I SKOROVASFELTET

### 1. Innledning.

Undertegnede er på bakgrunn av notatet "Malmløstingstatus for Skorovas Gruber og mulighetene ved ytterligere prospektering", blitt anmodet om å konkretisere et eventuelt opplegg for videre prospektering.

Et område av størrelsesorden  $60 \text{ km}^2$  som er ca. 6 ganger arealet av tidligere turammålt område innenfor hovedmalmen og syd- og sydøstmalmen, er i utgangspunktet medtatt. Området er geologisk interessant, men det er så stort at det må en meget hektisk og intensiv prospekteringskampanje til for å undersøke det relativt systematisk innen 1983. Hvis man ikke er villig til å trekke ut prospekteringen over en lengre periode, bør man overveie å konsentrere seg om et noe mindre område.

Området er delt inn i 4 deler i hvilke man etter nærmere diskusjoner og faglige studier kan prioritere en eventuell prospekteringskampanje.

### 2. Generell prospekteringsmetodikk.

I overensstemmelse med tidligere notat kan prospekteringen gjøres som følger:

1. Geologisk strukturkartlegging og VLF undersøkelser.
2. Turamundersøkelser
3. A.M.T.undersøkelser
4. Eventuelt tilleggsundersøkelser og boring.

Metode	Profilavstand	Målepunkt avstand
VLF	100 m	20 m
Turam	200 m	20 m
A.M.T.	200 m - 1 km	50-100 m

Spesielt strukturkartlegging forutsettes å være så krevende at en meget erfaren geolog må gjøre dette.

Hvis man sløyfet geologisk strukturkartlegging og VLF undersøkelser, måtte man måle turam med en profilavstand på mindre enn 100 m for å være sikker på ikke å miste en potensiell malm av størrelsesorden 10 mill.tonn. Slike undersøkelser ville bli mer kostbare og sannsynligvis ikke så gunstige som en forhåndsundersøkelse med strukturkartlegging og VLF. VLF-målinger vil ha betydning for å kunne optimalisere et turamkabelutlegg.

### 3. Generell beskrivelse av prospekteringsområdene.

Område 1. Områdets areal er ca. 26 km<sup>2</sup>. Majoriteten av området utgjøres av grønnstein, mens området mot Skorovasklumpen utgjøres av en mer amfibolittisk bergart som synes å ligge som et "lokk" over grønnsteinen. Man kan heller ikke utelukke at amfibolitten kan føre potensielle malmer.

Halls & Co's kart viser en sur tuff-agglomeratisk horisont nede i Skorovaslia. Denne ledehorisont og akseretningen på kjent malm danner en basis for utvelgelse av område 1. Området er dreiet noe mer mot NNØ i forhold til kjent malmdrag på grunn av kjente strukturer i området.

Som en ser av vedlagte kart (fig.1), er deler av området tidligere turamundersøkt. Området fra Skorovaslia løpende mot Tunnsjøen viser svake anomalier som i følge A.Haugen ikke er fulgt opp.

Område 2. På grunnlag av A.M.T.målinger utført i 1979 har man fått indikasjoner på en dypleder som ligger i forlengelsen av dyphullene 10071 og 10035 - 7 - 900 m under dagen.

I overensstemmelse med tidligere strukturgeologiske undersøkelser har boringen dog indikert at grønnsteinsonen (som malmen er knyttet til) er nedfoldet. De geofysiske indikasjoner synes å kunne gjenspeile en elektrisk leder i denne. De strukturgeologiske resultater tyder videre på at denne nedfoldete grønnsteinsonsone kan bli grunnere mot nord, slik at en eventuell malm lettere kan angripes med en skråsynk fra Dausjøen.

Det foreslåtte området <sup>bør</sup> følges opp med systematiske A.M.T.målinger med 200 m profilavstand. Seismiske undersøkelser bør også overveies dersom nye A.M.T.målinger gir lovende resultater.



Område\_3. Områdets areal er ca. 15 km<sup>2</sup>. Lederhorisonten som hovedmalmen er knyttet til løper gjennom området, og ved Langtjønna er det påvist sulfidbånd hvis mineralisering finnes mer eller mindre sammenhengende innenfor en strøklengde på 4 km. Grong-gruppen har planlagt å undersøke S.Langtjønna-området nærmere denne sesong. Innenfor område 3 finnes også ikke undersøkte helikopteranomali-er.

Område\_4. Områdets areal er ca. 14 km<sup>2</sup>. Syd for Nesåvatnet finnes endel ikke undersøkte helikopteranomali-er som bør følges opp (se kart i tidligere notat). Man har dels trukket området ut i trondhemittene og de diorittiske gabbroer. Årsaken er at det ifølge Halls & Co's kart er indikasjoner på at hovedmalmens lederhorisont synes å strekke seg inn under nevnte bergarter.

#### 4. Gjennomføring, kostnader og tid.

Hvordan prospekteringen generelt er tenkt gjennomført med tilhørende overslagskostnader er satt opp i tabellform. Det vises til tabell 1.

En anstrengt og teoretisk tidsplan for en prospekteringskampanje er indikativt vist i tabell 2.

OVERSIKT OVER PROSPEKTERINGSMETODIK OG OVERSLAGSKOSTNADER

	Strukturkart- legging, noe kjernelogging og tolkning	V.L.F.	Turam	A.M.T.	Boring	Oppfølgings- geofysikk, turam, CP. etc.	Ledelse, sammenstil- ling, tolk- ning	Sum kostnader
	Spesialgeolog A.Reinsbakken	Studenter og assistenter	N.G.U.	EO-GE	Oppdrag	NGU-GE	Grong Gruber GE	
Område 1 ca. 25km <sup>2</sup>	6 mndr. 120.000 kr.	260km - 4,3mnd. 91.000 kr	130km 2,3mnd. 234.000 kr.	26km - 1,8mnd. 260.000kr.	5000 m 2 mill.kr.	300.000 kr.	7 mnd. 280.000kr.	3.3 mill
Område 2 4.4 km <sup>2</sup> (Dypprosp.)	1 mndr. 20.000 kr.			18 km - 1 mnd. 180.000 kr.	2000 m 800.000 kr.	100.000 kr.	1 mnd. 40.000kr.	1.1 mill
Område 4 14 km <sup>2</sup>	3 mndr. 60.000 kr.	140 km-2,3mndr. 49.000 kr.	70km - 1,3 mnd 126.000 kr.	14km - 1 mnd. 140.000 kr.	2500 m 1 mill.kr.	150.000 kr.	4 mndr. 160.000 kr.	1.7 mill
Område 3 15 km <sup>2</sup>	3 mndr. 60.000 kr.	150km - 2,5mndr. 53.000 kr.	75km.-1.3mnd. 135.000 kr.	15 km -1mnd. 150.000 kr.	2500 m 1 mill.	150.000 kr.	4 mndr. 160.000	1.7 mill
	260.000 kr.	193.000 kr.	495.000 kr.	730.000 kr.	4,8 mill.kr.	700.000 kr.	640.000 kr.	8 mill

# Tidsplan for prospektering.

ARBEIDSKATEGORI

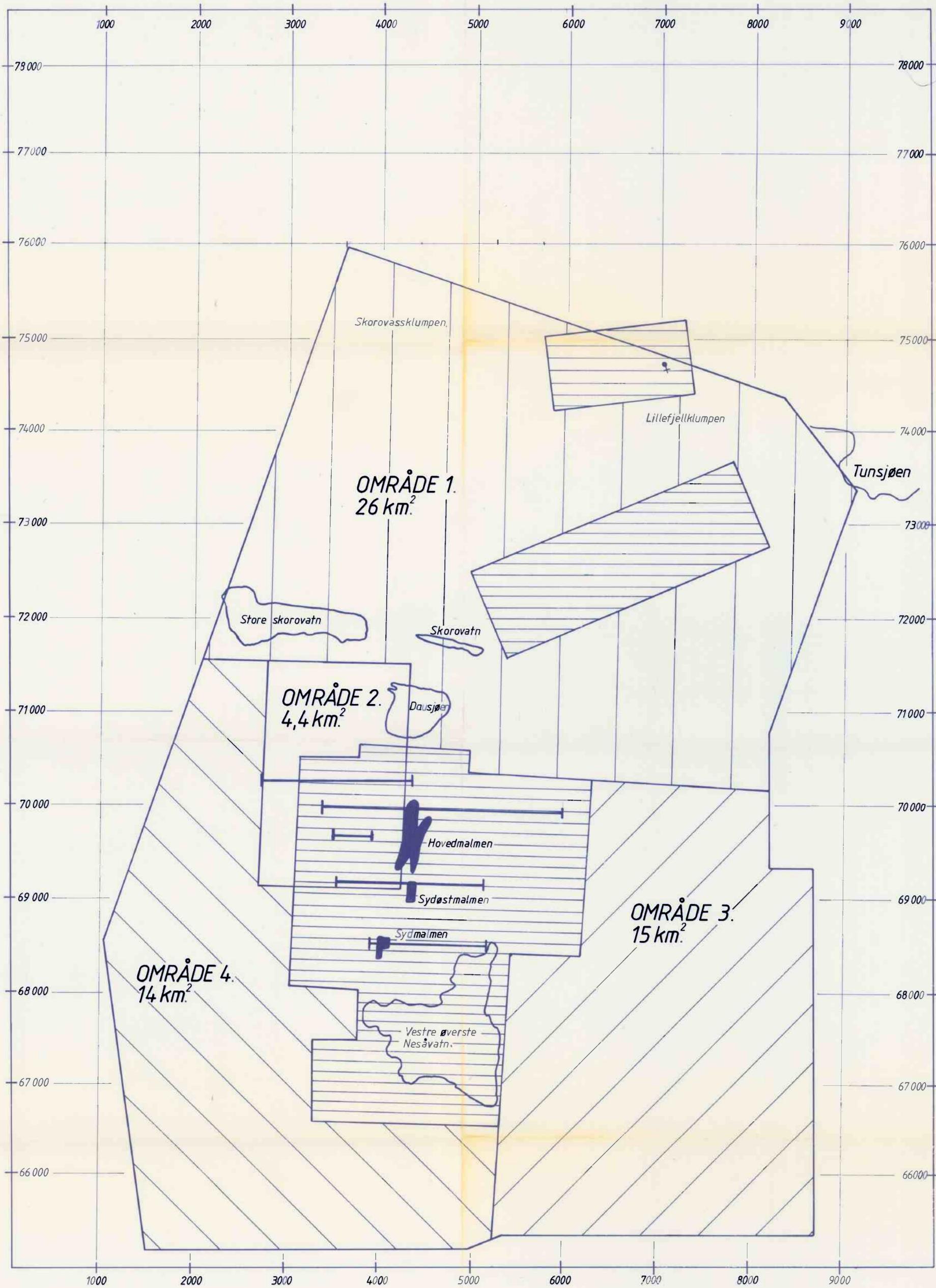
Indikativ tid  $\longrightarrow$

	Område nr.	82	83	84
Spesial Geologisk arbeide	1	-----	-----	-----
	2		-----	
	3	-----	-----	-----
	4	-----	-----	-----
V.L.F.	1	-----		
	2			
	3	-----		
	4		-----	
Turam	1		-----	
	2			
	3		-----	
	4		-----	
A.M.T.	1		-----	
	2	-----		
	3		-----	
	4		-----	
Boring	1		-----	-----
	2		-----	
	3		-----	-----
	4			-----



### Konklusjon.

Det er dårlig prospekteringsfilosofi å skjære ned på "kjøkkenhage"-prospektering fordi dagens metallpriser er lave. Basert på analyser fra hovedmalmen burde det være muligheter for å finne nye malmobjekter som består av kobberrike og spesielt sinkrike partier. Ved selektiv brytning er man da mindre avhengig av konturene. Man skal heller ikke se bort ifra at det om noen år kan bli lønnsomt å produsere svovelkis til energiutvinning.



A.M.T. profiler fra 1979.  
 Tidligere turammålte områder.  
 Nye undersøkelsesområder.

No. req'd	Description	Item	Drawing or Standard	Material	Unit	Total
Tolerances: except as stated		Weld according to		Projection		
This drawing is our property and must not without our permission be copied or made available to others. The receiver is responsible for every misuse.				File		
<b>OMRÅDEKART FOR PROSPEKTERING</b>			Scale	Drawn	81.	C.W.C.
<b>Figur 1. Skorovatn.</b>			1:25000	Traced	81.	M.D.
			Sheet	Checked		
			Next sheet	Approved		
 <b>Elkem as</b> Engineering Division Oslo, Norway				Revision		

2000Y 3000Y 4000Y 5000Y

72000X Store Skarvatn

71000X

Dalsjøen

70000X

69000X

68000X



IP undersøkt område



IP indikasjoner



AMT profiler

67000X

Vestre øverste  
Nesvatn

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File /

IP og AMT undersøkelser  
i Grubefeltet, Skarvatn

Scale  
1:25 000

Drawn CWC, 81  
Traced G.A.J., 82

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Date

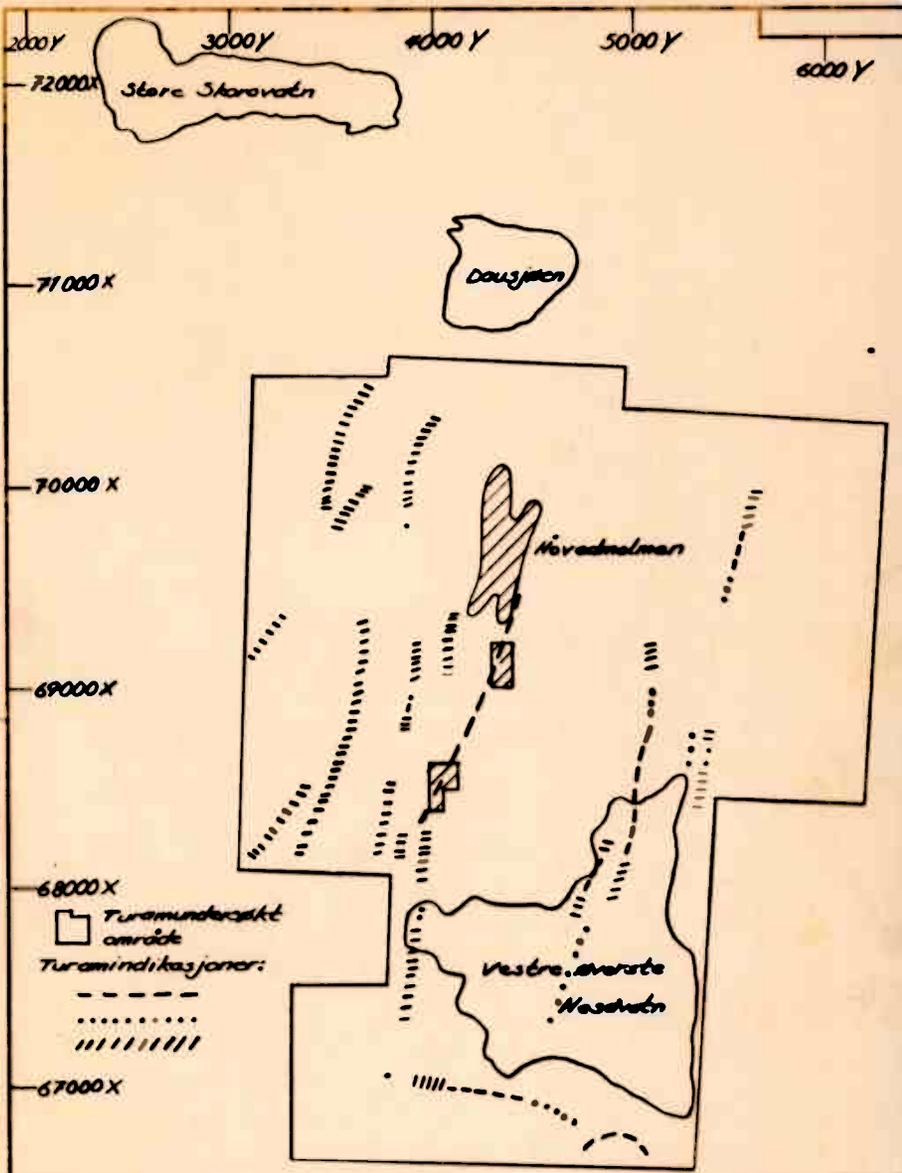
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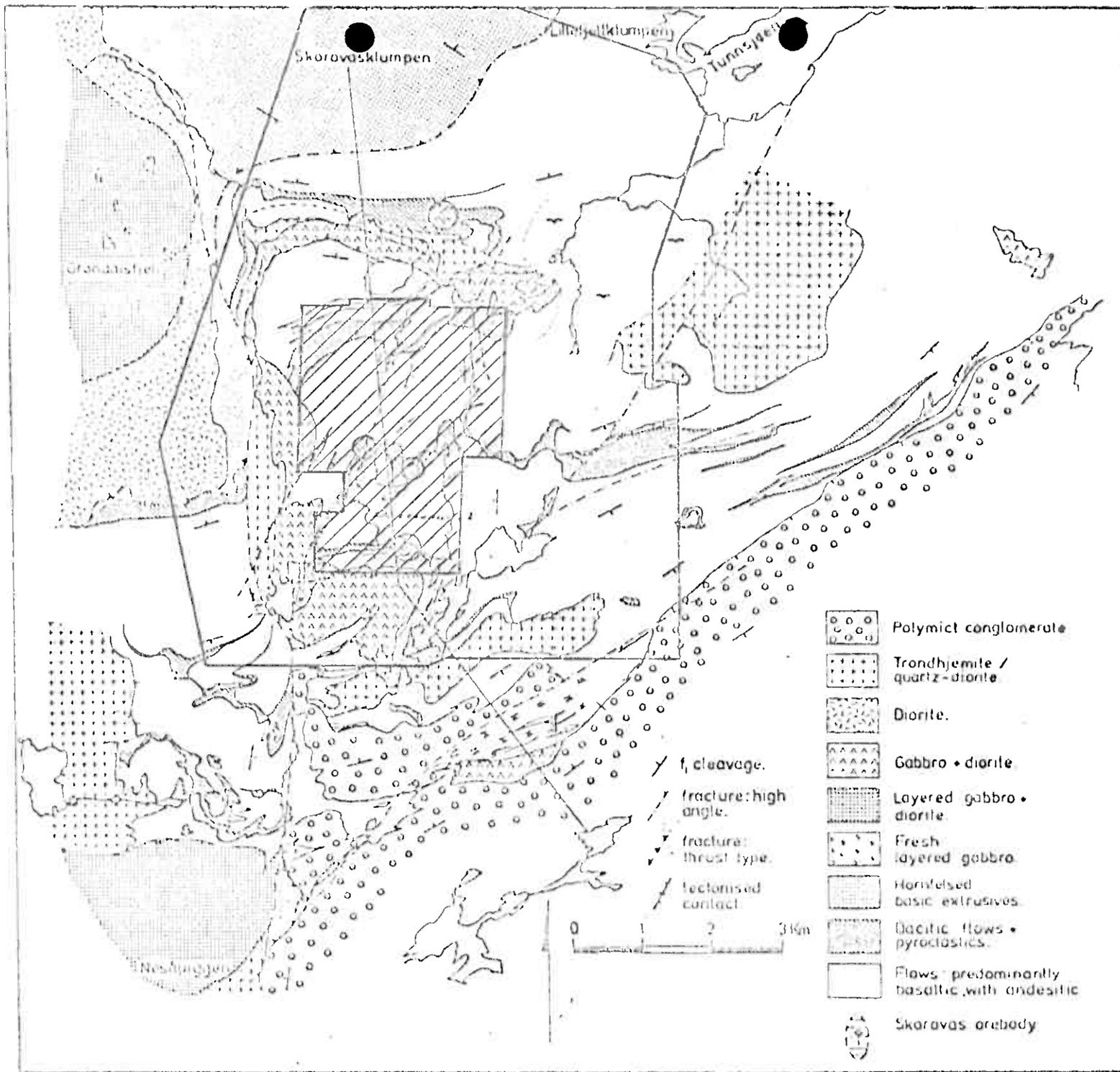
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## Sammenstilling av turamonomo- lier i Grubefeltet Skorovas

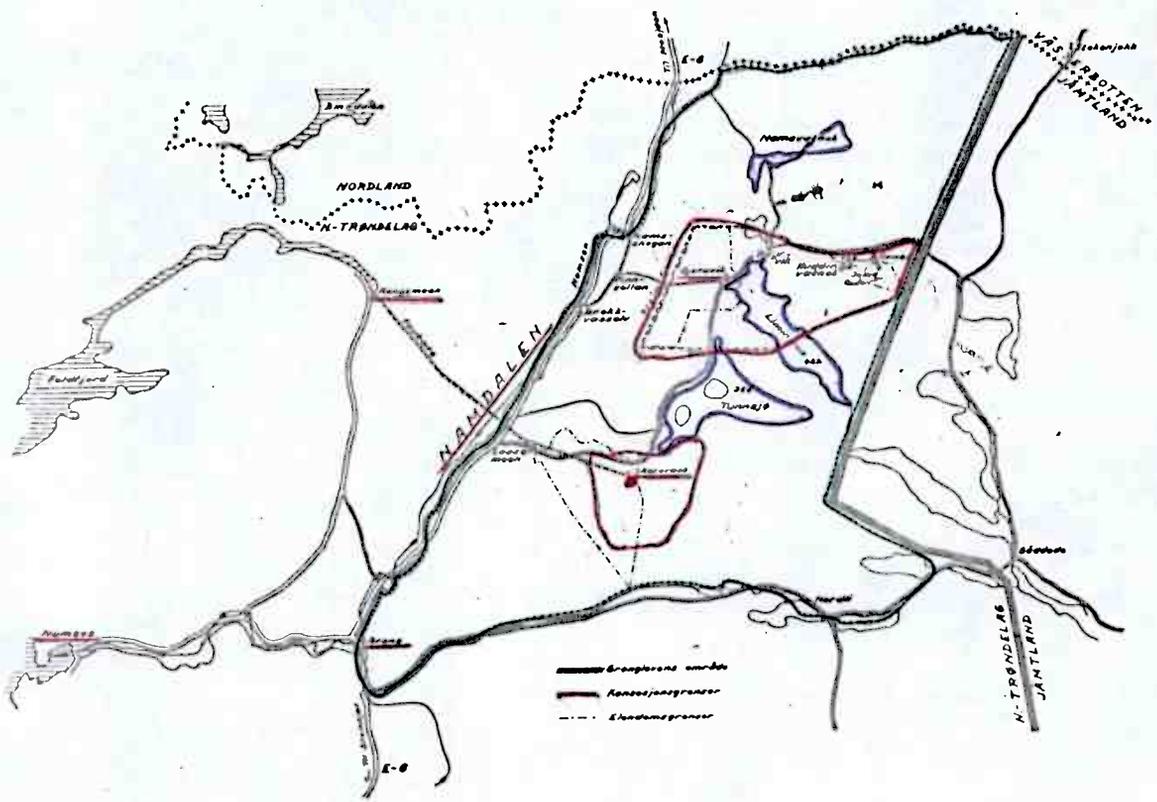
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Total sheet		Traced	G.A.J 82
		Checked	
		Approved	

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Foreløpig liste over geologiske rapporter i arkivhylla.

År	Forfatter	Institusjon	Tekst	Kommentarer
1971/1972	Volker Hirsinger	Imperial College	The Geology of Western Skorovasklumpen and vicinity.	Kart
1972	Stepen Flitton		The Geology of Eastern Skorovasklumpen.	8 ukers feltarbeid
1972	Quentin George Palmer	Royal School of Mines	The Geology of Eastern Skorovasklumpen and the Geology of the Lillefjellklumpen - Cu/Ni Assemblage	B.Sc Degree Kart
1972	Volker Hirsinger		Geological Report on Grubefjellet and the surrounding Area.	Sommerarbeid
1972	H.C. Gale		Geologi i Sandøla ømr.	NGU 1122
1973	— " —		Geologi i Sandøla ømr.	NGU 1189
1973	Peter Walker	Royal School of Mines	The Grønndalsfjell Gabbro.	
1973	Robert John Horsley		The Geology of the Skorovas Area.	Kart fra Douglasmin B.Sc Degree
1973	Roger D. Scott	Royal School of Mines	The Grubefjell Volcanics	
1973	Michael Horder		Blåhammeren-Havdalen region Geological Report.	Sommerarbeid
1973	Ivan Mayfield		Blåhammeren-Havdalen region Geological Report.	
1974	Roger S. White	Royal School of Mines	The Geology of the Haldalsvatn and Ingulsvatn Area. A geological study of igneous and sed. rocks, and a discussion on the paleotectonic setting of the Skorovas Region	Kart fjernet Omfattende verk
1977	A. Reisingbakken		The Geology of Skorovas Mine	NTNF Skisse

Foreløpig liste over geologiske rapporter i arkivhulle fra Skorvasfeltet.

År	Institusjon	Tekst	Kommentarer
1938	Geofysisk Malmleting	Turammålinger i Skorvas.	4 uker
1958	NGU 237	Turamundersøkelser.	
1959	Geofysisk Malmleting GM245	Turammålinger Nesåvatn.	ca. 14 dager
1963	ABEM	Flymålinger Del II.	
1970	Terratest	Magn. trekomponent målinger	et par dager
1971	NGU	Diverse undersøkelser (Grongprosjektet av Ø. Logn)	
1971	NGU 1084	CP Målinger Sydmalmen.	1 uke
1971	NGU 981	CP, IP, SP og PP Grubefjell.	1,5 uker
1971	Terratest	Helikopter målinger (Magn. + EM).	
1972	NGU 1121	CP, IP og ULF Målinger over Nordre Grubefjell.	ca. 14 dager
1973	NGU 1216	CP, IP ved Nordre Grubefjell.	14 dager
1974	NGU 1274	Helikopter målinger. Del II	
1975	NGU 1343	CP, IP og PP ved Grubefjell og Nesåvatn.	ca. 14 dager

År	Institusjon	Tekst	Kommentarer
1976	NGU 1536	CP og PP Målinger ved Nordre Grubefjell.	ca. 4 dager
1979	NGU 1645	EM Målinger i BH 10035 og 10071.	
1980	Elkem	A.M.T. Målinger.	9 dager
1980	NGU	Revudering av EM Målinger i BH 10071.	