Bergvesenet

Postboks 3021, 7002 Trondheim

Rapportarkivet

Bergvesenet rapport nr **BV 2035**	Intern Journal nr	Internt arkiv nr	Rapport lokalisering	Gradering ~~Fortrolig~~ åpen
Kommer fra ..arkiv Sulitjelma Bergverk A/S	Ekstern rapport nr "552132001"	Oversendt fra	Fortrolig pga	Fortrolig fra dato:

Tittel

Samleperm med materiale vedr. kartlegging av KongOscar

Forfatter	Dato 1984	Bedrift Sulitjelma Gruber A/S

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

Fagområde	Dokument type	Forekomster
Råstofftype	Emneord	

Sammendrag

Rapporter Kjell Nilsen, Aspro, og Hans Tore Mikkelsen. Geologiske kart, kjernebeskrivelser, analyser og annet mat. vedr. prosjekt 144; Kartlegging av KongOscar Geologi

Sammendrag kartleggingen av Kong-Oskar-sonen og sidebergarter sommeren 1986 Kjell S. Nilsen A/s Prospektering

Innledning

Kong-Oskar-sonens bergarter tilhører et bestemt nivå i undre del av Sjønstå-gruppas bergarter (beliggende stratigrafisk over Furulundgruppa med (Sulitjelmaamfibolitter

Nivået med tilgrensende bergarter er detaljkartlagt fra sydvestsiden av Laamivatn (ca 7 km SØ Sulitjelma) til østsiden av Balvatn (ca 22 km S Sulitjelma). Den nordlige delen er kartlagt på topografiske kart i målestokk 1:10 000 (eksisterer delvis forstørret til 1:2500) og sydlige delen syd for Calalvesjavre - Kjeldvand er kartlagt på flyfoto og rentegnet på flyfoto-mosaikk i målestokk ca 1:14 000.

Det meste av området er svært godt blottet, spesielt de høyest beliggende områdene mellom Laamivatn - Kong Oskar. Deler av sonen er mer eller mindre overdekket, bl.a. i området øst for Calalvesjavre, vest for Doarrevandene og et område 1-2 km på nordøstsiden av Balvatn.

Oversikt over bergartene

Furulundgruppa. Øvre del av Furulundgruppa er delvis kartlagt i avstand 100-200m og opptil 2 km bred sone fra Kong-Oskar-sonens bergarter

Furulundskiferen er oftest grå - grønnlig grå muskovittrik finkornet skifer med kalkholdige bånd, litt biotitt, av og til noe kloritt og kvarts-(feltspat) rikere bånd. Lys grå kalk-kvarts-rikere soner til mørkere grønnlig grå klorittrikere områder.

Det mest karakteristiske er de kalkholdige båndene som ofte gir en porøs, brunlig forvitret overflate.

Kjeldvann doleritt opptrer som amfibolittiske lagerganger til rundete massiver 20-300 m brede, vanligst i nordlige del av området. Massiv, homogen, delvis bevart gabbrotekstur i de største intrusivene, ellers mer eller mindre forskifret ((klorittholdig) spesielt langs kontaktene.

Sure intrusivganger er utbredt langs en spesiell sone 0,6-1 km nord for Kong-Oskar-sonen og er best kartlagt fra bredden av Laamivatn og 2 km mot vest, men ser ut til å fortsette videre til Kjelvand-Calalvesjaure og muligens enda lenger sydover. De er middelskornet-finkornet lys grå homogene med små mm feltspat og kvartsøyne, foruten feltspat og kvarts noe glimmer, litt amfibol (kloritt). De er vanligvis 10-50 m brede lagerganger, kan opptre som parallelle ganger og gangsvermer, noen forgreninger og tynnere apofyser er observert (tolkes som intrusive ganger)

Metabasalt. Grønn-grågrønn homogen finkornet og massiv, eventuelt vekslende med skifrige bånd (tuffer eller sterkt deformerte soner). Relativt godt bevarte og mer eller mindre deformerte putestrukturer og flyte-strømningsstrukturer er observert flere steder. Basaltene opptrer i flere forskjellige nivåer i syd og nord. I Skråningen syd for Calalvesjaure opptrer en tynnere (20 m bred) mer lokal sone med basalt på vestsiden i kontakt med Kong-Oskar-sonens bergarter. Basalt-(kloritt-)breksjer er også observert i et par borhull i Kong Oskar-feltet i det samme nivået. Basaltene opptrer også i høyere nivåer i Sjønstågruppa, i det sydlige området (Balvatn-Duolbavardo) forekommer en tynnere sone med basalt på østsiden av Kong-Oskar-sonen.

Metadacitt. Vest for Laamivatn er det registrert noen grå - mørk grå skifere og lys grå homogene massive bånd med kvarts-feltspat-amfibol-kloritt. Antatt intermediære vulkanitter. De lys grå båndene er fra dm til flere 10 m brede og veksler med mørkere mer klorittholdige basiske bånd, antatt lavaer. De intermediære skifrene består av fortrinnsvis kloritt med tynne kvarts-feltspatlag og slirer, antatt tuffer eller tuffitter.

Klorittskifer Øverst mot grensen til Kong-Oskarsonens bergarter er det skilt ut en sone med homogen grågrønn klorittskifer (fyllitt), nokså klorittrik, av og til med noe kalk eller feltspat. Antatt basisk tuffitt.

Kong-Oskar-sonens bergarter,

består av vekslende mengder grafittskifer, glimmerskifere, kalker og sur vulkanitt. Nivået er fulgt opp fra Laamivatn til Balvatn og er sammenhengende det meste av strekningen untatt området ved Risvandselven vest for Dorrovandene. Mektigheten varierer fra ca 1/2 m til over 100 m i Kong-Oskar-feltet hvor lagene kan være repetert opptil 5-10 ganger på grunn av langstrakte isoklinale F_1-folder. Vanlig mektighet i store deler av området er ellers fra ca 5 m til ca 20 m.

Stratigrafien er fra underst til øverst:

Grafittskifer, nokså ren med glimmerholdige (dels kloritt) og mer grafittrike bånd, ofte nokså kisrik og rusten (vesentlig fink. magnetkis, litt pyritt). Har nokså stor utbredelse langs sonen, lokalt opptil 5-6 m mektig, men er vanligvis relativt dårlig blottet.

Kalk (dolomitt) består av nokså rene karbonatbånd med kvarts- og glimmerholdige soner. En type gråblå middelskornet granulær kalk (mulig noe grafittholdig) er karakteristisk, ellers er en lys grålig kalk med brunlig-gulbrun forvitringsfarge den mest dominerende. I denne typen er det tidligere observert koraller. Det underste nivået med kalker har nokså stor utbredelse, opptil 10-20 m mektig, vanligvis 2-5 m, kan enkelte steder være den mest dominerende bergartstypen.

Sur vulkanitt, en lys grå, massiv, homogen bergart med små kvarts- og feltspatfenokrystaller, er mer mer eller mindre omvandlet langs grensene til blek keratofyr eller kvarts-cerisittskifer. Noen mørkere glimmer- (muskovitt) holdige bånd forekommer. Den friske typen av sur vulkanitt har sin utbredelse begrenset til Kong-Oskar-feltet, spesielt i sydlige del hvor den kan bli opptil 20-30 m mektig, og et lite område øst for Syrvann, 2 km syd for Calalvesjavre.

Kvarts-cerisittskifer og keratofyr. Blek grålig finkornet til nesten hvit, ofte helt rusten på grunn av magnetkisinnholdet. Tolkes som en hydrotermal omvandlingsbergart assosiert med den sure vulkanske aktiviteten. Kvarts-cerisittskiferen består av lyse glimmerholdige cerisittbånd og kvartsrike soner, noen steder silifiserte bånd. Keratofyriske bånd består av grålig finkornet-tett feltspat, ofte med bevarte relikter av andre mineraler (kvarts-glimmer-kloritt-amfibol) og eventuelle vulkanske teksturer (fenokrystaller). Grensene mot sidebergartene (grafittskifer, glimmerskifer, sur vulkanitt) er overgangsmessige og vanskelige å definere eksakt, består av stadig flere cerisittiske-, kvartsrikere eller felsiske bånd. Den rustne kvarts-cerisittskiferen er utbredt langs det meste av nivået, vanligvis meget tynn, mindre enn 1/2 meter, og mangelfullt utviklet, i Kong Oskar-feltet er den best utviklet og kan bli 10-20 m mektig.

Grafittskifer og kalk Tynne grafittholdige skifere forekommer enkelte steder over eller som tynne soner i kvarts-cerisitt-skifere eller tilgrensende kalk.

Kvarts-glimmerskifer består av homogene fin-middelskornete sedimenter (skifere-sandstener) med mulige innslag av surt tuffittisk materiale. Nederst er de vanligvis nokså mørke og glimmerrike (muskovitt, litt biotitt), kvartsinnholdet og kornstørrelsen øker noe oppover. Øverst kan den bestå av lys grå kvartsrik sandsten (uren kvartsitt) 1-5 m mektig. Enkelte steder (3 lokaliteter) er det observert konglomerater med uregelmessige skifrige boller i en tynn sone langs kontakten mot Muorki-skiferen. Kalkholdige bånd og urene glimmerholdige kalk-skifere er karakteristisk og kan opptre i 2-3 forskjellige nivåer, vanligvis ikke mer enn 1-5 m mektige, lokalt kan de utvikle seg til kalkrike bånd og renere kalker, bl. a. i Kong-Oskar-feltet sydlige del hvor kalklag nær bunnen av glimmerskiferne kan bli opptil 10-20 m mektige. Kvartsglimmerskiferne med kalkholdige bånd er den mest dominerende enheten og kan lokalt bli opptil 70-80 m mektig nord for Kong Oskar.

Muorki skifer i Sjønstågruppa består av grågrønne klorittholdige skifere med tynne kvartsbånd og slirer, brunlig karbonat, feltspat og noe magnetitt, enkelte pyrittkorn

Strukturer

Hele området domineres av en sterkt utviklet skifrighet S_1 oftest parallell primær lagning S_0. Skifrigheten bestemmer dominerende strøkretning og har vanligvis fall 20-40° mot vest (mot nordvest i det nordligste området).

Primære strukturer er mer eller mindre godt bevarte, f. eks. putelavaer i basaltene, gradert lagning i sedimentene og vulkanske breksjer (klonttbreksjer). Disse strukturene samt diskordans mellom Muorkiskifer og underliggende kvartsglimmerskifer viser rett vei opp mot øst, dvs. at lagene ligger invertert.

f_1-folder er vanligst i området fra Kong Oskar og 2-3km videre mot nordøst hvor de opptrer som ekstremt utdratte isoklinale folder med amplitude opptil 1 km ~~eller mer~~ og bølgelengde ca 20-50 m. Foldeknærne er spisse og kan være avslitte og opptrer i boudinerte linser videre langs akseplanet. Det kan være vanskelig å oppdage disse foldene dersom stratigrafien ikke er detaljert kjent. Akseretningen varierer en del, er stort sett relativt flattliggende med fall mot f. eks sydvest og sydsydvest eller nordøst i enkelte områder. Kong-Oskar-feltet kan oppfattes som et kompleks synklinorium på grunn av f_1-aksenes fallretning på nord- og sydsiden. Tilsvarende i området ved Andreas skjerp 1-3 km lenger nordøst.

f_1-folder er ellers observert som småfolder med 10-50 m amplitude på flere lokaliteter i hele området.

f_2-folder er vanlige i hele området, spesielt i sentrale og sydlige deler som småfolder, tette til åpne, med amplitude vanligvis 1-5 m og flattliggende akseplan.

Vanlig retning med slakt fall mot nord til nordnordvest eller noen ganger mot syd.

f_3 er mindre vanlige folder, åpne småfolder med liten amplitude i forhold til bølgelengde. Akseretning med moderat fall mot øst-sørøst med steiltstående Ø-V-gående akseplan med nordlig fall.

Mineraliseringstyper

De fleste bergartstyper har et svakt innhold av sulfider, vesentlig pyritt, litt magnetkis. I Kong-Oskar-sonens bergarter er grafittskiferne og spesielt kvarts-cerisittskiferne nokså kisrike, vesentlig magnetkis og/eller pyritt. I grafittskiferne, noen kalker og i undre del av kvarts-glimmerskiferne er det på noen lokaliteter observert små korn av kobberkis i ubetydelig mengde. Kvarts-cerisittskifere er relativt rike på magnetkis og pyritt (et område vestligst i Kong Oskar også en del magnetitt). I Kong Oskar-feltet og Andreas skjerp er kisene lokalt anriket i massive linser og bånd assosiert med de mest intensivt omvandlede skiferne og keratofyrene. De massive kislinsene har begrenset utbredelse, vanligvis ikke mer enn 1-2 m brede og 4-5 m lange og går over i tynnere bånd og svakere disseminasjon. Noe kobberkis og sinkblende opptrer vanlig sammen med magnetkis, lokalt meget rike klumper (også anriket på Ag og Au). Blyglans er også til stede, fortrinnsvis assosiert med kalkholdige soner. I silifiserte soner assosiert med tynne kvartsganger er det observert molybdenglans sammen med pyritt og kobberkis eller litt blyglans sammen med pyritt.

Langs kontakten av de sure intrusivgangene 700-1200 m nord-nordvest for Kong-Oskar-sonen er det nokså konsekvent observert rustsoner. De er noe avbleket (noe lys glimmer, cerisitt) og mineraliseringen består hovedsaklig av finkornet pyritt. De er oftest ½ - 2½ m brede og kan være nokså pyrittrike. Vest for Kong Oskar er det observert rustsoner på 5-7 m bredde, noe svakere mineralisert. Disse rustsonene tolkes som hydrotermalt omvandlete i forbindelse med intrusjonsaktiviteten. Det er samlet 4-5 prøver av disse sonene

Hydrotermale kvartsganger er observert mange steder i hele området, men har ofte ikke mineraliseringer (sulfider) av betydning. Fraområdet syd for Kong Oskar til området vest for Doarrevandene opptrer kvartsganger ca Ø-V-gående opptil ½-2m brede med mineraliseringer av pyritt, ilmenitt-hematitt, brunlig karbonat (ankeritt) og litt kobberkis. I et par kvartsganger er det observert blyglans

Konklusjon.

Det vesentligste av mineraliseringene i Kong-Oskar-sonens bergarter er tilknyttet rusten kisholdig kvarts-cerisittskifer eller keratofyr. Disse bergartene er tolket som syngenetiske hydrotermale omvandlingsprodukter av sure(-intermediære) vulkanitter og tilgrensende sedimenter fortrinnsvis i et grunt havbasseng. De massive kisstripene opptrer mest som ganger og kryssende over i de mest omvandlete bergartene, og kan tolkes som tilforselskanaler for de hydrotermale løsningene. De massive kis-klumpene i Kong-Oskar-feltet og Andreas skjerp med pyritt, magnetkis, kobberkis, sinkblende og blyglans er lokalt meget rike, men har meget begrenset utstrekning. Områdets bergarter er intens foldet, og disse rike kislinsene kan sannsynligvis oppfattes som tektoniske linser (boudiner) i forbindelse med de langstrakte isoklinale f_1-foldene. De foreløpige analysene av det første borhullet fra Kong Oskar viser at andre deler av kvarts-cerisitt-skiferne med tynne kisganger og kisrik impregnasjon har lave gehalter av Cu, Zn, Ag og Au. Dersom resten av de følgende analysene fra borhullene og prøvetatt materiale også blir negative, viser det at den vesentligste mineraliseringen først og fremst er tilknyttet de isolerte kisrike linsene. Eventuell malmtonnasje blir dermed meget liten.

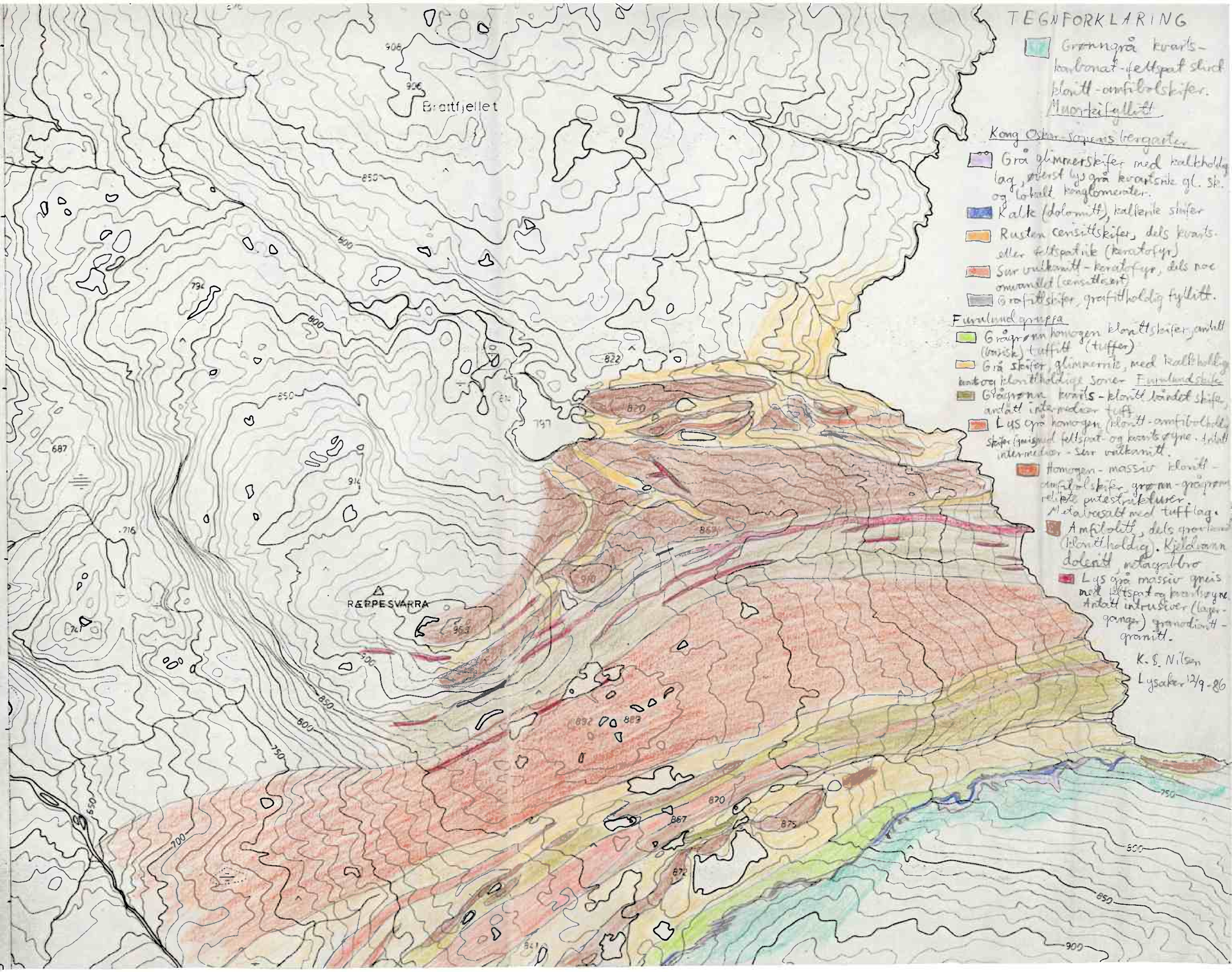
Resten av Kong-Oskar-sonens bergarter er prøvetatt med jevne mellomrom der hvor det er observert mineraliseringer, fortrinnsvis fra nivået med kvarts-cerisittskifere. De rustne skiferne er sjelden mer enn 1-2 m mektige utenfor Kong-Oskar-feltet. Tilsammen er det samlet ca 40 knakkprøver av kisholdige bergarter fra Kong-Oskar-sonens bergarter, noen kvartsganger, et par kisrike flyttblokker og rustsoner fra de ~~ka~~ sure intrusivgangene lenger nord.

De sure intrusivgangene kan antagelig tolkes som mulige tilførselskanaler for de overliggende sure vulkanittene i bl.a. Kong-Oskar-sonen. Nærmere petrologiske undersøkelser bør gjøres for å kunne bekrefte om dette eventuelt er riktig. Dersom de assosierte rustsonene med pyritt skulle vise seg å være edelmetallholdige, vil det også være tilsvarende interessante malmpotensialer langs utbredelsen av disse gangene i flere hundre meters bredde fra Laamivatn til Kjeldvand og muligens enda lenger syd.

Det geologiske miljøet for Kong-Oskar-sonens bergarter med sur vulkanisme og intensiv hydrotermal omvandling i et miljø som ellers domineres av basisk (-intermediær) vulkanisme og deriverte sedimenter, er et svært interessant miljø for potensielle edelmetall-(Au-) forekomster. I store trekk, bl.a. dersom Sulitjelma-områdets bergarter tolkes som deler av et eventuelt ophiolitt-kompleks med store mengder underliggende basiske-ultrabasiske vulkanitter, og de deriverte sure vulkanittene som en sen utvikling av den samme magmatiske suiten, vil (i teorien) de assosierte hydrotermale restløsningene inneholde interessante potensialer for dannelse av eventuelle edelmetall-(Au-) forekomster. Dersom de sure intrusivgangene viser seg å være tilførselen for de senere deriverte vulkanittene, vil det mest interessante malmpotensialet ligge langs disse. Analyseresultatene vil gi svar på om det kan være noen interessante edelmetallgehalter i Kong-Oskar-sonens bergarter, men disse undersøkelsene kan tyde på at det ikke er noe stort malmpotensiale i bergartene utenom de rikeste kis-linsene der.

Sulitjelma 9/10-86

Kjell S. Nilsen
geolog A/S Prospektering.


TEGNFORKLARING
▨ Grønngrå kvarts-karbonat-feltspat slirt kloritt-amfibolskifer. Muorkeifyllitt
Kong Oskar-sonens bergarter
▨ Grå glimmerskifer med kalkholdig lag, øverst lys grå kvartsrik gl. sk. og lokalt konglomerater.
▨ Kalk (dolomitt), kalkrik skifer
▨ Rusten sericittskifer, dels kvarts- eller feltspatrik (keratofyr)
▨ Sur vulkanitt - keratofyr, dels noe omvandlet (sericittisert)
▨ Grafittskifer, grafittholdig fyllitt.
Furulund gruppa
▨ Grågrønn homogen klorittskifer, antatt (basisk) tuffitt (tuffer)
▨ Grå skifer, glimmerrik, med kalkholdig karbonat og klorittholdige soner. Furulundskifer
▨ Grågrønn kvarts-kloritt båndet skifer, antatt intermediær tuff.
▨ Lys grå homogen (kloritt-amfibolholdig) skifer (gneis) med feltspat- og kvartsøyne. Antatt intermediær - sur vulkanitt.
▨ Homogen - massiv kloritt-amfibolskifer grønn-grågrønn relikte putestrukturer. Metabasalt med tufflag.
▨ Amfibolitt, dels granat (klorittholdig). Kjeldvann doleritt, metagabbro
▨ Lys grå massiv gneis med feltspat og kvartsøyne. Antatt intrusiver (lagerganger) granodioritt - granitt.
K. S. Nilsen
Lysaker 12/9-86
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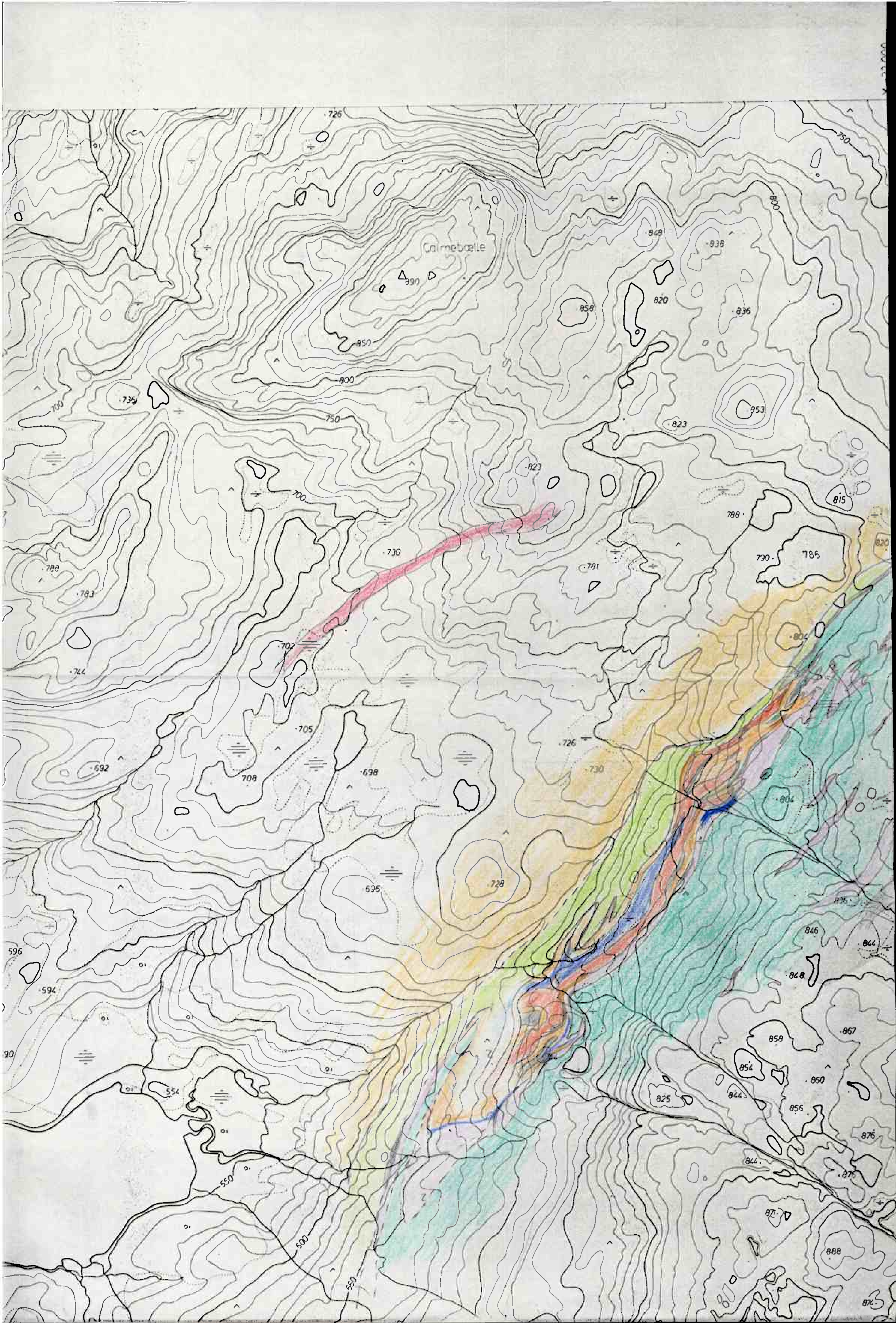
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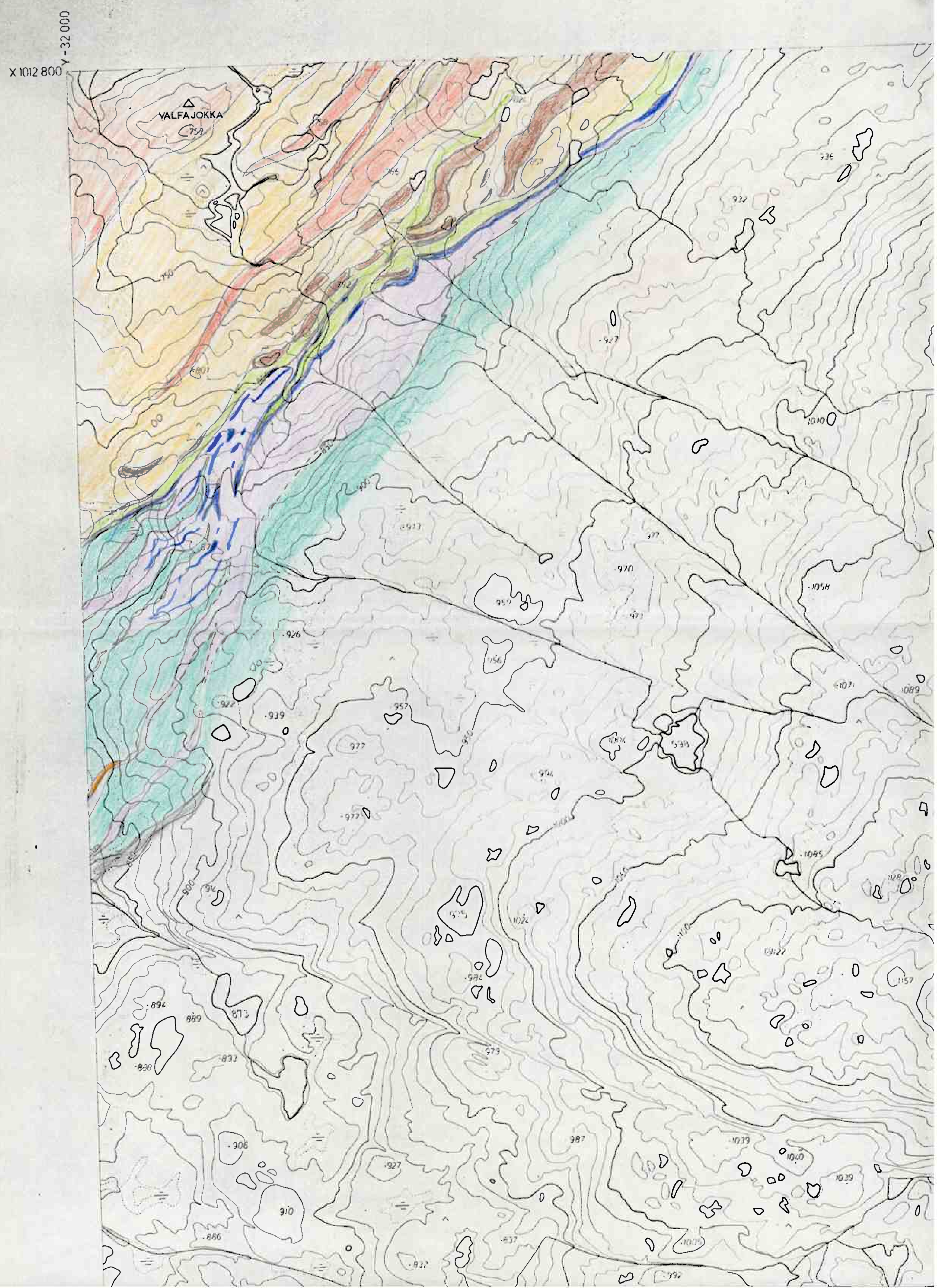
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Attn. Mr. Perry Kaspersen

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To repreparation and reanalysis for Au of the same samples @£7.45	111.75
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P. Kaspersen

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attn.: peter cazalet

i have sent 15 rock samples by air mail today for gold analysis as discussed over the phone with p. kaspersen.

with regards
sulitjelma bergverk as
nigel cook

ø
70128 MAL EI
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13TH AUGUST, 1985

TO: PERRY KASPERSSON

FROM:MERCURY ANALYTICAL, LIMERICK

SUB: AU RESULTS

SAMPLE NO.	AS RECEIVED		PULVERISED TO -75 MICRONS	
	AU	PPM	AU	PPM
42	-0.02	-0.02	-0.02	-0.02
43	-0.02	-0.02	-0.02	-0.02
44	-0.02	-0.02	-0.02	-0.02
45	-0.02	0.04	0.02	-0.02
46	-0.02	-0.02	0.02	0.04
47	-0.02	-0.02	-0.02	-0.02
48	-0.02	0.04	-0.02	0.04
49	0.12	0.11	0.10	0.12
50	0.02	-0.02	-0.02	0.04
54	-0.02	-0.02	-0.02	-0.02
55	0.02	-0.02	-0.02	-0.02
56	-0.02	-0.02	-0.02	-0.02
57	-0.02	-0.02	-0.02	-0.02
78	0.05	0.05	0.05	0.10
155	-0.02	-0.02	-0.02	-0.02

CONCLUSION: THERE IS NO SIGNIFICANT DIFFERENCE BETWEEN THE TWO PREPARATIONS. BUT REMEMBER THAT ALL THE POSITIVE VALUES HERE ARE CLOSE TO THE DETECTION LIMIT, AND THE DIFFERENCE IN PREPARATION COULD MATTER MORE IF HIGHER AU VALUES WERE ENCOUNTERED.

BEST REGARDS

PETER CAZALET

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TELEKS TELEKS TELEKS TELEKS TELEKS TELEKS

Kong Oscar 224 Samples for Au.

156	155-156m	3.3 ppm Ag	0.00% S	.05% Pb
55	54-55m.	4 ppm Ag	3.97% S	.04% Pb
42	41-42m.	4 ppm Ag	3.97% S	.03% Pb
43	42-43m.	5 ppm Ag	3.71% S	.02% Pb
78	77-78m.	3 ppm Ag	3.20% S	.05% Pb
54	53-54m.	1 ppm Ag	4.49% S	.02% Pb
56	55-56m.	3 ppm Ag	1.04% S	.01% Pb
57	56-57m.	3 ppm Ag	0.59% S	.00% Pb
44	43-44m.	2 ppm Ag	3.94% S	00% Pb
45	44-45m.	3 ppm Ag	4.22% S	.00% Pb
50	49-50m.	3 ppm Ag	1.82% S	.13% Pb
49	48-49m.	2 ppm Ag	3.90% S	.09% Pb
48	47-48m.	2 ppm Ag	4.42% S	04% Pb
46	45-46m.	2 ppm Ag	3.51% S	.04% Pb
47	46-47m	2 ppm Ag	3.97% S	.04% Pb

(15 samples)

10/7/85

MINERAL EXPLORATION SERVICES

Mercury Analytical Ltd. was formed in 1977 to provide a sampling and analytical service for the mineral exploration industry in Ireland. The company has recently moved into a new 4000 sq. foot laboratory on the outskirts of Limerick City, about 15 miles from Shannon International Airport. The company now provides both field and laboratory services for the mineral exploration industry in Ireland and Europe.

FIELD OPERATIONS

Field crews are available for stream sediment and soil sampling projects. Deep overburden sampling using Pionjar BR120 hand held percussion drills is also available on contract. Overburden of 20–25m. in thickness can be sampled using this technique. The company also has two tractor mounted diamond drill rigs both with full wireline equipment.

Charges for these services depend on the specific requirements of each project and are arranged on an individual project basis

LABORATORY

Our aim is to provide a fast, reliable analytical and assay service for exploration companies operating in Ireland and overseas. Normally the results for a batch of samples are returned within 10–15 working days from receipt at the laboratory. All overseas results are returned by telex. Facilities are available for a more rapid turnaround of samples on request.

A wide range of international ore and soil standards is held in the laboratory and all methods are regularly checked against them. Appropriate standards are analysed with each batch of samples and approximately 10% of the samples are reanalysed to check inter batch consistency.

Most of the analytical work is carried out on Perkin Elmer Atomic Absorption Spectrophotometers. Other methods include Ion Specific Electrodes, Fluorimetry and Colorimetry.

Routine detection limits and prices are set out on the following pages. Analysis of many other elements is available, prices on request.

All prices are in Irish pounds.

EOCHEMICAL ANALYSIS

Precision ± 15–20% at 95% confidence level.

~ kr. 9/IR£

	Detection limit (p.p.m.)	IR£
Group A		
Cadmium	1	
Chromium	1	
Cobalt	1	
Copper	1	
Iron	5	
Lead	1	
Manganese	5	
Nickel	1	
Silver	0.1	
Zinc	1	0.50 per element
Group B		
Barium	20	
Lithium	1	
Molybdenum	1	
Strontium	10	
Vanadium	2	2.35 per element
Group C		
Antimony	1	
Arsenic	1	
Bismuth	1	
Flourine	10	
Mercury	0.01	
Titanium	50	
Uranium	0.01	3.65 per element
Group D	25g. sample → 0.008	
Gold	10gm → 0.02	5.00
Tin	1	4.20
Tungsten	1	4.20

INTERMEDIATE ANALYSIS

We offer an intermediate level of precision (about 10%) using duplicate geochemical analysis. This is useful for minor elements in rock samples where precision better than 15–20% is desirable but full assay cost is not.

The cost of this service is 1.75X geochemical rate.

ASSAYS

Precision ± 2–5% (depending on element) at 95% confidence level.

			IR£
Cadmium	Iron	Silver	
Chromium	Lead	Zinc	
Cobalt	Manganese		
Copper	Nickel		3.85 per element
Barium	Molybdenum		5.30 per element
Antimony	Bismuth	Sulphur	
Arsenic	Mercury		7.65 per element
Flourine	Tungsten		
Tin	Uranium		9.20 per element
Gold			11.10 per sample

WHOLE ROCK ANALYSIS

Na,Ca,Mg,Si,Ti,Al,Fe,P,K,Mn,Cl,SO_4,LOI

4.40 per element

SAMPLE PREPARATION

Soil and sediment samples (drying and sieving to 80 mesh)	0.45 per sample
Rock chips (eg.RCD samples, grinding to 200 mesh)	2.45 per sample
Drill core, Large rock samples (crushing and grinding to 200 mesh)	4.60 per sample

MERCURY HYDROCARBONS LTD

Mercury Hydrocarbons Ltd., a subsidiary of Mercury Analytical, is developing a new mineral exploration technique using hydrocarbon gases in rocks as pathfinders. Hydrocarbons are released from rock samples by a heating technique and gases from methane to pentane are analysed by gas chromatography.

Orientation surveys around Pb–Zn deposits in the Lower Carboniferous of Ireland have shown distinct changes in the gas content of the rocks surrounding mineralization. Of particular interest is the large extent of the anomalies, which can be several kilometres across and may extend up to 1km above mineralization. This should allow the use of a lower density of samples than is necessary for conventional geochemical prospecting and also offers a potential for detecting deeply buried deposits.

The technique is still in the early stages of development but can already be offered as a rapid reconnaissance method for carbonate-hosted Pb–Zn deposits. With further research it is hoped that hydrocarbon gas geochemistry will also be useful for more detailed investigation of prospects and in exploration for other styles of mineralization.

A hydrocarbon gas survey requires fist-sized (200g–500g) samples of unweathered rock collected at a density of about 1 per km^2, from surface exposures or boreholes.

The analytical cost of this services is IR£ 15 - 18 per sample depending on the number of samples sent per batch and on the overall size of the programme.

An additional cost of 25% of the analytical charge is made for a written report on the results.

For further information on the technique please contact Dr. Jonathan Carter or Dr. Peter Cazalet.

SHIPPING INSTRUCTIONS

All samples should be described as 'GEOLOGICAL SAMPLES FOR LABORATORY ANALYSIS/NO COMMERCIAL VALUE" on customs documents and sample containers.

They should be addressed to

MERCURY ANALYTICAL LIMITED,
RAHEEN INDUSTRIAL ESTATE,
LIMERICK,
IRELAND.

All samples by airfreight should be sent to SHANNON AIRPORT

Please inform us, by telex if possible, of AWB number, despatch date and estimated arrival date.

Airport, customs clearance and handling charges will be paid by Mercury Analytical Ltd. for batches of samples exceeding IR£200 in value. For lower value batches these charges are passed on to the client at cost.

The minimum charge per batch is IR£100, but no charge is made for small batches of test samples.

DAVIS PRINTERS Ltd. Henry St., Limerick.

MERCURY ANALYTICAL Ltd.

MERCURY HYDROCARBONS Ltd.

LABORATORY PRICE LIST 1985

Raheen Industrial Estate
Limerick, Ireland.
Telephone; 061–29055
Telex; 70128 MAL EI

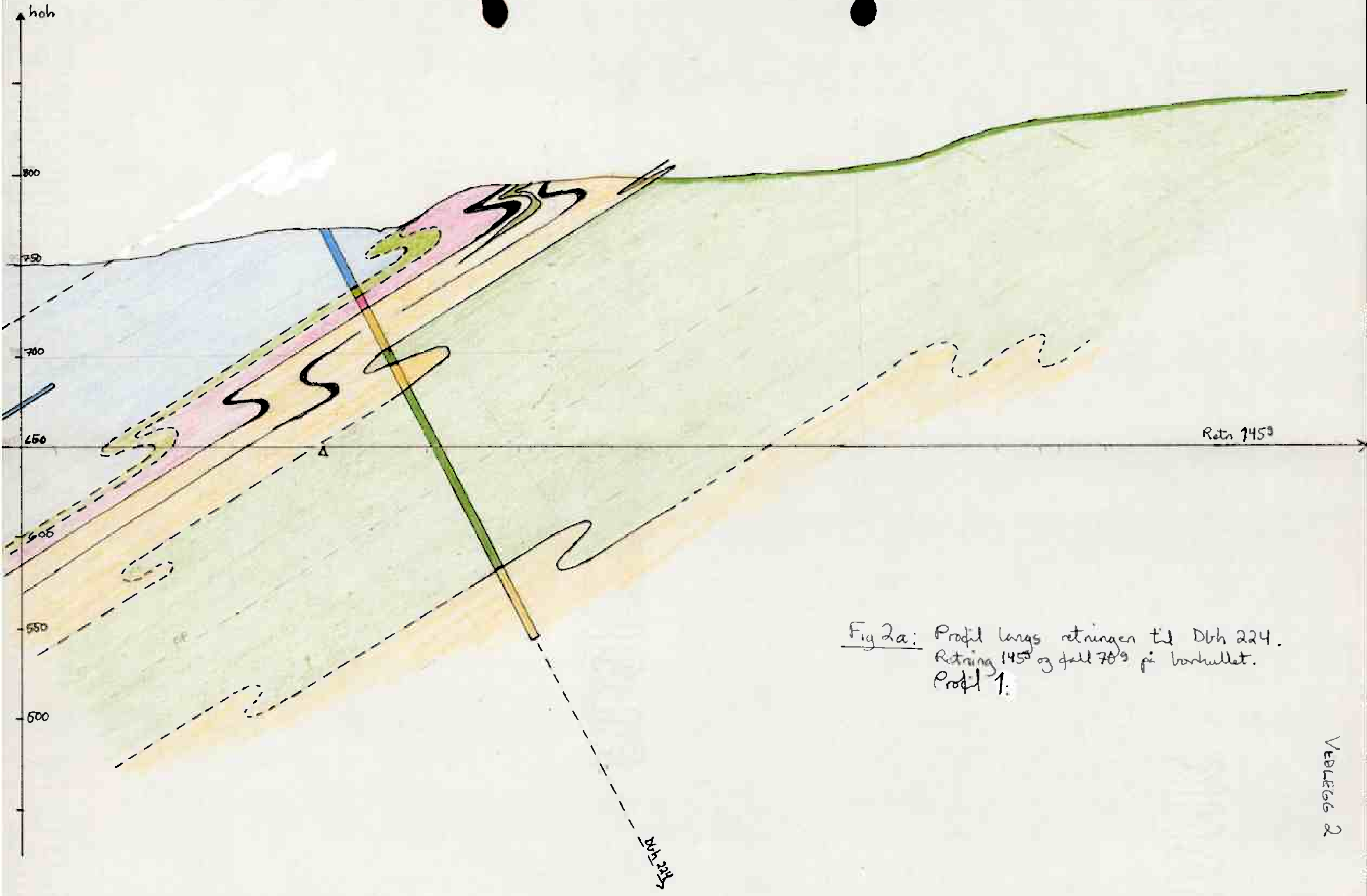

Fig 2a: Profil langs retningen til Dbh 224.
Retning 145g og fall 70g på borhullet.
Profil 1.

VEDLEGG 2

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: **Kong Oscar. D.b.h. 224.**

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr. Beliggenhet.	Tonn/Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H₂O	% Pb.
621	0,00 m - 1,00 m		0,01	0,01	0,00	0	3,1		0,02
22	1,00 " - 2,00 "		0,01	0,01	0,00	0	3,0		0,03
23	2,00 " - 3,00 "		0,01	0,01	0,00	0	3,5		0,03
24	3,00 " - 4,00 "		0,00	0,01	0,00	0	3,2		0,03
25	4,00 " - 5,00 "		0,00	0,01	0,00	0	2,9		0,04
26	5,00 " - 6,00 "		0,01	0,01	0,00	0	4,0		0,00
27	6,00 " - 7,00 "		0,01	0,01	0,00	0	3,8		0,01
28	7,00 " - 8,00 "		0,01	0,01	0,00	0	3,2		0,01
29	8,00 " - 9,00 "		0,01	0,01	0,00	0	3,1		0,00
30	9,00 " - 10,00 "		0,01	0,01	0,60	0	3,2		0,00

Rapp. til: **Vedi-Grin-Kaspersen-Sandwall.**

Sulitjelma den 15/3. 19 85. Sign._____

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr. Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H_2O	% Pb.
660	10,00 m - 11,00 m		0,01	0,01	0,20	3	3,2		0,01
61	11,00 " - 12,00 "		0,01	0,01	0,00	2	4,2		0,02
62	12,00 " - 13,00 "		0,01	0,01	0,00	2	4,0		0,02
63	13,00 " - 14,00 "		0,01	0,01	0,00	2	3,2		0,02
64	14,00 " - 15,00 "		0,01	0,01	0,98	2	4,7		0,02
65	15,00 " - 16,00 "		0,01	0,01	0,20	2	2,5		0,01
66	16,00 " - 17,00 "		0,01	0,01	0,13	2	1,9		0,00
67	17,00 " - 18,00 "		0,01	0,01	0,78	2	2,9		0,01
68	18,00 " - 19,00 "		0,01	0,01	0,13	2	2,9		0,01
69	19,00 " - 20,00 "		0,01	0,01	0,13	2	2,9		0,01

Rapp. til: Vedi-Grin-Kaspersen-Sandwall.

Sulitjelma den 22/ 3. 19 85. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: **Kong Oscar. D.b.h. 224.**

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H₂O	% Pb.
692	21.	20,00 m - 21,00 m		0,02	0,01	0,13	2	3,9		0,02
93	22.	21,00 " - 22,00 "		0,02	0,01	0,10	2	3,9		0,01
94	23.	22,00 " - 23,00 "		0,02	0,01	0,00	1	4,8		0,01
95	24.	23,00 " - 24,00 "		0,02	0,01	0,20	1	5,2		0,02
96	25.	24,00 " - 25,00 "		0,02	0,01	0,00	1	3,6		0,01
97	26.	25,00 " - 26,00 "		0,02	0,02	0,13	2	3,9		0,01
98	27.	26,00 " - 27,00 "		0,01	0,01	0,78	2	3,6		0,01
99	28.	27,00 " - 28,00 "		0,01	0,02	0,72	2	3,7		0,01
700	29.	28,00 " - 29,00 "		0,01	0,01	0,20	1	3,0		0,00
1	30.	29,00 " - 30,00 "		0,01	0,01	0,39	1	3,6		0,00

Rapp. til: **Vedi-Grin-Kaspersen-Sandwall.**

Sulitjelma den 26/3. 19 85. Sign._____

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn/Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H_2O	% Pb.
771	31.	30,00 m - 31,00 m		0,01	0,01	0,13	3	3,6		0,00
72	32.	31,00 " - 32,00 "		0,01	0,01	0,07	3	4,4		0,00
73	33.	32,00 " - 33,00 "		0,01	0,01	0,07	3	4,4		0,00
74	34.	33,00 " - 34,00 "		0,01	0,01	0,00	3	3,9		0,00
75	35.	34,00 " - 35,00 "		0,01	0,01	0,00	2	4,1		0,00
76	36.	35,00 " - 36,00 "		0,01	0,01	0,07	2	3,0		0,00
77	37.	36,00 " - 37,00 "		0,01	0,01	0,07	2,	1,8		0,00
78	38.	37,00 " - 38,00 "		0,01	0,01	0,07	2	2,2		0,00
79	39.	38,00 " - 39,00 "		0,01	0,01	0,00	2	2,1		0,00
80	40.	39,00 " - 40,00 "		0,01	0,02	0,33	2	1,7		0,00

Rapp. til: Vedi-Grin-Kaspersen-Sandwall.

Sulitjelma den 3/4. 1985. Sign._____

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

	Prövebeskrivelse.			%	%	%	ppm.	%	%	%
J.nr.	Nr.	Beliggenhet.	Tonn/Mekt.	Cu.	Zn.	S.	AG.	Fe.	H_20	Pb.
810	41.	40,00 m - 41,00 m		0,02	0,01	1,30	3	3,3		0,00
11	42.	41,00 " - 42,00 "		0,02	0,03	3,97	4	6,4		0,03
12	43.	42,00 " - 43,00 "		0,01	0,03	3,71	5	6,2		0,02
13	44.	43,00 " - 44,00 "		0,01	0,02	3,97	2	6,5		0,00
14	45.	44,00 " - 45,00 "		0,02	0,04	4,23	3	5,7		0,00
15	46.	45,00 " - 46,00 "		0,03	0,04	3,51	2	4,0		0,04
16	47.	46,00 " - 47,00 "		0,01	0,11	3,97	2	4,9		0,04
17	48.	47,00 " - 48,00 "		0,01	0,08	4,42	2	7,7		0,04
18	49.	48,00 " - 49,00 "		0,02	0,19	3,90	2	5,7		0,09
19	50.	49,00 " - 50,00 "		0,02	0,19	1,82	3	5,5		0,13

Rapp. til: Vedi-Grin-Kaspersen-Sandwall.

Sulitjelma den 12/4. 1985. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: **Kong Oscar. D.b.h. 224.**

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr. Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H$_2$0	% Pb.
848	51. 50,00 m - 51,00 m		0,01	0,01	1,69	1	2,5		0,01
49	52. 51,00 " - 52,00 "		0,01	0,02	2,28	0	3,1		0,02
50	53. 52,00 " - 53,00 "		0,02	0,02	1,37	2	1,9		0,07
51	54. 53,00 " - 54,00 "		0,05	0,01	4,49	1	7,2		0,02
52	55. 54,00 " - 55,00 "		0,03	0,00	3,97	4	5,7		0,04
892	56. 55,00 " - 56,00 "		0,01	0,01	1,04	3	1,8		0,01
93	57. 56,00 " - 57,00 "		0,01	0,00	0,59	3	0,5		0,00
94	58. 57,00 " - 58,00 "		0,01	0,01	0,59	1	0,7		0,01
95	59. 58,00 " - 59,00 "		0,01	0,00	0,20	2	0,7		0,00
96	60. 59,00 " - 60,00 "		0,01	0,01	0,65	2	2,1		0,01

Rapp. til: **Vedi-Grin-Kaspersen-Sandwall.**

Sulitjelma den 24/4. 19 85. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr. Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% Pb. ~~H_2O~~
905	61. 60,00 m - 61,00 m		0,01	0,01	0,39	0	0,3	0,03
6	62. 61,00 " - 62,00 "		0,01	0,01	0,98	0	0,2	0,01
7	63. 62,00 " - 63,00 "		0,01	0,01	0,85	0	0,3	0,01
8	64. 63,00 " - 64,00 "		0,00	0,01	0,10	0	0,0	0,00
9	65. 64,00 " - 65,00 "		0,01	0,00	0,52	0	0,3	0,01
10	66. 65,00 " - 66,00 "		0,00	0,01	0,29	2	2,4	0,00
11	67. 66,00 " - 67,00 "		0,00	0,00	0,20	3	1,8	0,00
12	68. 67,00 " - 68,00 "		0,00	0,00	0,10	1	1,7	0,00
13	69. 68,00 " - 69,00 "		0,00	0,00	0,00	1	1,5	0,00
14	70. 69,00 " - 70,00 "		0,01	0,01	0,10	1	1,1	0,00

Rapp. til: Vedi-Grin-Kaspersen-Sandwall.

Sulitjelma den 25/4. 19 85. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost __/__ . Den __/__ 19 __ Silo Nr. __

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H₂O	% Pb.
941	71.	70,00 m - 71,00 m		0,00	0,00	0,13	0	1,3		0,00
42	72.	71,00 " - 72,00 "		0,00	0,00	0,10	0	1,7		0,00
43	73.	72,00 " - 73,00 "		0,00	0,00	0,10	0	2,3		0,00
44	74.	73,00 " - 74,00 "		0,00	0,01	0,10	1	4,4		0,00
45	75.	74,00 " - 75,00 "		0,00	0,02	1,43	1	4,7		0,00
46	76.	75,00 " - 76,00 "		0,01	0,02	2,70	2	5,7		0,01
47	77.	76,00 " - 77,00 "		0,01	0,04	2,70	1	6,3		0,01
48	78.	77,00 " - 78,00 "		0,01	0,03	3,20	3	5,5		0,05
49	79.	78,00 " - 79,00 "		0,00	0,02	2,60	2	3,7		0,01
50	80.	79,00 " - 80,00 "		0,01	0,04	2,60	2	5,2		0,04

Rapp. til: Vedi-Grin-Kaspersen-Sandwall.

Sulitjelma den 26/4. 1985. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr. Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H_2O	% Pb.
965	81. 80,00 m - 81,00 m		0,02	0,14	1,52	0	2,3		0,08
66	82. 81,00 " - 82,00 "		0,00	0,02	0,33	0	3,4		0,01
67	83. 82,00 " - 83,00 "		0,00	0,00	0,10	0	0,9		0,00
68	84. 83,00 " - 84,00 "		0,00	0,01	0,53	0	0,2		0,00
69	85. 84,00 " - 85,00 "		0,00	0,00	0,10	0	1,1		0,00
70	86. 85,00 " - 86,00 "		0,00	0,00	0,13	0	0,9		0,02
71	87. 86,00 " - 87,00 "		0,00	0,00	0,20	0	1,3		0,02
72	88. 87,00 " - 88,00 "		0,01	0,00	0,20	0	1,1		0,04
73	89. 88,00 " - 89,00 "		0,00	0,00	0,00	0	1,3		0,02
74	90. 89,00 " - 90,00 "		0,01	0,00	0,13	0	1,7		0,02

Rapp. til: Vedi-Grin-Kaspersen-Sandwall.

Sulitjelma den 3/5. 19 85. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: **Kong Oscar. D.b.h. 224.**

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H_2O	% Pb.
1003	91.	90,00 m - 91,00 m		0,01	0,00	0,00	3	1,1		0,00
4	92.	91,00 " - 92,00 "		**forurenset.**						
5	93.	92,00 " - 93,00 "		0,01	0,00	0,13	2	0,8		0,00
6	94.	93,00 " - 94,00 "		0,01	0,00	0,13	1	0,6		0,00
7	95.	94,00 " - 95,00 "		0,01	0,00	0,07	1	0,5		0,00
8	96.	95,00 " - 96,00 "		0,00	0,00	0,00	2,5	1,6		0,00
9	97.	96,00 " - 97,00 "		0,00	0,00	0,00	1,7	2,0		0,00
10.	98.	97,00 " - 98,00 "		0,00	0,00	0,00	2,8	4,4		0,00
11.	99.	98,00 " - 99,00 "		0,00	0,01	0,00	2,6	4,6		0,00
12.	100.	99,00 " - 100,00 "		0,00	0,01	0,00	2,9	5,3		0,00

√Rapp. til: **Vedi-Grin-Kaspersen-Sandwall.**

Sulitjelma den 6 / 5. 1985. Sign. ____

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr. Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H₂O	% Pb.
1037	101. 100,00 m - 101,00 m		0,02	0,01	0,00	0,0	4,9		0,00
38	102. 101,00 " - 102,00 "		0,01	0,01	0,07	0,0	4,4		0,00
39	103. 102,00 " - 103,00 "		0,01	0,00	0,07	0,0	4,1		0,00
40	104. 103,00 " - 104,00 "		0,01	0,00	0,03	0,0	4,3		0,00
41	105. 104,00 " - 105,00 "		0,01	0,00	0,07	0,0	3,8		0,00
42	106. 105,00 " - 106,00 "		0,01	0,01	0,07	0,8	3,4		0,00
43	107. 106,00 " - 107,00 "		0,01	0,01	0,07	0,6	4,7		0,00
44	108. 107,00 " - 108,00 "		0,00	0,01	0,00	0,8	4,8		0,00
45	109. 108,00 " - 109,00 "		0,00	0,01	0,00	0,7	4,7		0,00
46	110, 109,00 " - 110,00 "		0,00	0,01	0,00	0,2	4,9		0,00

Rapp. til: Vedi-Grin-
Kaspersen-Sandwall.

Sulitjelma den 8 / 5. 19 85. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: **Kong Oscar. D.b.h. 224.**

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H₂O	% Pb.
1062	111.	110,00 m - 111,00 m		0,01	0,01	0,00	1,1	4,4		0,00
63	112.	111,00 " - 112,00 "		0,01	0,01	0,00	1,8	4,7		0,00
64	113.	112,00 " - 113,00 "		0,01	0,01	0,00	1,7	4,9		0,00
65	114.	113,00 " - 114,00 "		0,01	0,01	0,00	1,9	4,7		0,00
66	115.	114,00 " - 115,00 "		0,01	0,01	0,13	1,4	4,5		0,00
67	116.	115,00 " - 116,00 "		0,01	0,01	0,33	1,3	4,5		0,00
68	117.	116,00 " - 117,00 "		0,01	0,01	0,13	0,7	3,7		0,00
69	118.	117,00 " - 118,00 "		0,01	0,01	0,53	0,9	3,9		0,00
70	119.	118,00 " - 119,00 "		0,01	0,01	0,33	1,6	3,9		0,00
71	120.	119,00 " - 120,00 "		0,01	0,01	0,00	1,5	4,1		0,00

Rapp. til: **Vedi-Grin-Kaspersen-Sandwall.**

Sulitjelma den 9/5. 1985. Sign._____

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn/Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H_2O	% Pb.
1088	121.	120,00 m - 121,00 m		0,01	0,01	0,00	1,1	4,4		0,00
89	122.	121,00 " - 122,00 "		0,01	0,01	0,03	1,1	4,9		0,00
90	123.	122,00 " - 123,00 "		0,01	0,01	0,00	0,8	3,9		0,00
91	124.	123,00 " - 124,00 "		0,01	0,00	0,13	0,4	3,9		0,00
92	125.	124,00 " - 125,00 "		0,01	0,01	0,00	0,2	4,0		0,00
93	126.	125,00 " - 126,00 "		0,03	0,01	0,03	1,6	4,0		0,00
94	127.	126,00 " - 127,00 "		0,01	0,01	0,00	1,4	3,5		0,00
95	128.	127,00 " - 128,00 "		0,02	0,01	0,00	1,4	4,4		0,00
96	129.	128,00 " - 129,00 "		0,01	0,01	0,07	1,5	4,6		0,00
97	130.	129,00 " - 130,00 "		0,01	0,03	0,00	1,5	3,9		0,00

Rapp. til: Vedi-Grin-
Kaspersen-Sandwall.

Sulitjelma den 14/5. 1985. Sign.____

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H₂O	* Pb.
1127	131.	130,00 m - 131,00 m		0,01	0,01	0,07	2,6	3,6		0,00
28	132.	131,00 " - 132,00 "		0,01	0,01	0,26	2,6	3,4		0,00
29	133.	132,00 " - 133,00 "		0,01	0,01	0,07	2,6	3,8		0,00
30	134.	133,00 " - 134,00 "		0,00	0,01	0,03	2,2	3,2		0,00
31	135.	134,00 " - 135,00 "		0,00	0,01	0,13	2,5	2,8		0,00
32	136.	135,00 " - 136,00 "		0,01	0,01	0,03	0,5	5,1		0,01
33	137.	136,00 " - 137,00 "		0,01	0,01	0,00	0,7	4,7		0,01
34	138.	137,00 " - 138,00 "		0,01	0,01	0,26	0,5	4,2		0,00
35	139.	138,00 " - 139,00 "		0,01	0,01	0,46	0,1	4,2		0,01
36	140.	139,00 " - 140,00 "		0,01	0,01	0,13	0,1	4,3		0,00

Rapp. til: Vedi - Grin-
Kaspersen-Sandwall.

Sulitjelma den 21/5. 1985. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn/Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H$_2$O	% Pb.
1158	141.	140,00 m - 141,00 m		0,01	0,01	0,26	0,00	5,1		0,00
59	142.	141,00 " - 142,00 "		0,01	0,01	0,03	0,4	5,9		0,00
60	143.	142,00 " - 143,00 "		0,01	0,01	0,13	0,1	4,6		0,00
61	144.	143,00 " - 144,00 "		0,01	0,01	0,03	0,1	5,1		0,00
62	145.	144,00 " - 145,00 "		0,00	0,01	0,66	0,0	5,4		0,00
63	146.	145,00 " - 146,00 "		0,00	0,01	0,03	1,6	4,8		0,02
64	147.	146,00 " - 147,00 "		0,00	0,01	0,00	1,4	4,4		0,02
65	148.	147,00 " - 148,00 "		0,00	0,01	0,20	1,0	4,2		0,01
66	149.	148,00 " - 149,00 "		0,00	0,01	0,00	1,5	3,9		0,01
67	150.	149,00 " - 150,00 "		0,00	0,00	0,03	1,3	4,2		0,01

/Rapp. til: Vedi-Grin-Kaspersen-Sandwall.

Sulitjelma den 22/5. 19 85. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H₂O	% Pb.
1168	151.	150,00 m - 151,00 m		0,01	0,01	0,00	1,4	4,2		0,00
69	152.	151,00 " - 152,00 "		0,01	0,01	0,00	1,5	4,1		0,00
70	153.	152,00 " - 153,00 "		0,00	0,01	0,00	1,3	3,8		0,00
71	154.	153,00 " - 154,00 "		0,00	0,01	0,00	1,6	3,8		0,00
72	155.	154,00 " - 155,00 "		0,00	0,01	0,00	1,4	3,9		0,00
73	156.	155,00 " - 156,00 "		0,00	0,00	0,00	3,3	3,8		0,05
74	157.	156,00 " - 157,00 "		0,00	0,01	0,00	2,8	3,6		0,05
75	158.	157,00 " - 158,00 "		0,00	0,00	0,03	2,8	3,0		0,05
76	159.	158,00 " - 159,00 "		0,00	0,00	0,03	2,4	3,8		0,05
77	160.	159,00 " - 160,00 "		0,00	0,01	0,00	2,3	3,6		0,03

Rapp. til: Vedi-Grin-Kaspersen-Sandwall.

Sulitjelma den 24/5. 1985. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn/Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H_2O	% Pb.
1187	161.	160,00 m - 161,00 m		0,00	0,01	0,03	1,4	4,1		0,00
88	162.	161,00 " - 162,00 "		0,00	0,01	0,00	1,4	4,1		0,00
89	163.	162,00 " - 163,00 "		0,00	0,01	0,00	1,3	3,7		0,00
90	164.	163,00 " - 164,00 "		0,00	0,01	0,00	1,1	4,3		0,00
91	165.	164,00 " - 165,00 "		0,00	0,01	0,00	1,0	4,1		0,00
92	166.	165,00 " - 166,00 "		0,01	0,01	0,33	0,7	3,6		0,00
93.	167.	166,00 " - 167,00 "		0,01	0,01	0,00	0,3	3,5		0,00
94	168.	167,00 " - 168,00 "		0,01	0,01	0,00	0,4	3,5		0,00
95	169.	168,00 " - 169,00 "		0,01	0,01	0,00	0,3	3,3		0,00
96	170.	169,00 " - 170,00 "		0,00	0,01	0,00	0,2	3,2		0,00

√ Rapp. til: Vedi-Grin-
Kaspersen-Sandwall.

Sulitjelma den 29 /5. 19 85. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr. Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	%Pb ~~H_2O~~
1220	170,00 m - 171,00 m		0,01	0,02	0,26	0,7	4,7	0,00
21	171,00 " - 172,00 "		0,01	0,01	0,20	0,8	3,8	0,00
22	172,00 " - 173,00 "		0,01	0,01	0,13	0,4	3,8	0,00
23	173,00 " - 174,00 "		0,01	0,01	0,00	0,3	4,8	0,00
24	174,00 " - 175,00 "		0,00	0,01	0,00	0,7	3,9	0,00
25	175,00 " - 176,00 "		0,00	0,01	0,00	0,0	4,0	0,00
26	176,00 " - 177,00 "		0,00	0,01	0,00	0,0	3,5	0,00
27	177,00 " - 178,00 "		0,00	0,01	0,00	0,0	3,5	0,00
28	178,00 " - 179,00 "		0,00	0,01	0,00	0,0	3,6	0,00
29	179,00 " - 180,00 "		0,00	0,01	0,00	0,0	3,8	0,00

Rapp. til: Vedi-Grin-Kaspersen-Sandwall.

Sulitjelma den 6/6 1985. Sign._____

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr. Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H_2O	% Pb
1276	181. 180,00 m - 181,00 m		0,01	0,01	0,00	0,0	4,4		0,01
77	182. 181,00 " - 182,00 "		0,01	0,01	0,00	0,0	4,1		0,00
78	183. 182,00 " - 183,00 "		0,00	0,02	0,00	0,0	3,8		0,00
79	184. 183,00 " - 184,00 "		0,01	0,01	0,00	0,0	4,2		0,00
80	185. 184,00 " - 185,00 "		0,00	0,01	0,00	0,0	4,2		0,00
81	186. 185,00 " - 186,00 "		0,00	0,01	0,00	1,1	2,9		0,00
82	187. 186,00 " - 187,00 "		0,01	0,01	0,60	0,8	3,0		0,01
83	188. 187,00 " - 188,00 "		0,02	0,01	0,00	1,0	3,1		0,00
84	189. 188,00 " - 189,00 "		0,03	0,01	0,03	1,3	2,7		0,01
85	190. 189,00 " - 190,00 "		0,02	0,05	0,08	1,3	2,7		0,07

Rapp. til: Vedi-grin-Kaspersen.

Sulitjelma den 11/6. 1985. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn/Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% Pb.
1318	191.	190,00 m - 191,00 m		0,01	0,01	0,13	0,0	4,4	0,00
19	192.	191,00 " - 192,00 "		0,00	0,01	0,03	0,0	4,1	0,00
20	193.	192,00 " - 193,00 "		0,00	0,01	0,00	0,0	4,7	0,00
21	194.	193,00 " - 194,00 "		0,00	0,01	0,00	0,0	4,2	0,00
22	195.	194,00 " - 195,00 "		0,00	0,01	0,03	0,0	4,1	0,00
23	196.	195,00 " - 196,00 "		0,00	0,01	0,00	1,7	5,6	0,00
24	197.	196,00 " - 197,00 "		0,00	0,01	0,00	1,2	5,9	0,00
25	198.	197,00 " - 198,00 "		0,01	0,01	0,13	1,6	6,0	0,00
26	199.	198,00 " - 199,00 "		0,01	0,02	0,13	1,3	5,9	0,00
27	200.	199,00 " - 200,00 "		0,01	0,01	0,00	1,5	6,3	0,00

Rapp. til: Vedi-Grin-Kaspersen

Sulitjelma den 13/6. 1985. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . **Den** ___/___ **19** __ **Silo Nr.** ___

J.nr.	Prövebeskrivelse. Nr. Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% Pb ~~H2O~~
1346	201. 200,00 m - 201,00 m		0,02	0,01	0,31	2,2	4,9	0,00
47	202. 201,00 " - 202,00 "		0,01	0,01	0,18	1,8	4,3	0,00
48	203. 202,00 " - 203,00 "		0,01	0,01	0,00	1,6	4,8	0,00
49	204. 203,00 " - 204,00 "		0,01	0,01	0,12	1,4	4,0	0,00
50	205. 204,00 " - 205,00 "		0,01	0,01	0,12	1,4	4,4	0,00
51	206. 205,00 " - 206,00 "		0,01	0,01	0,12	1,9	4,9	0,00
52	207. 206,00 " - 207,00 "		0,04	0,02	0,50	1,8	5,2	0,01
53	208. 207,00 " - 208,00 "		0,01	0,03	0,12	1,7	5,7	0,00
54	209. 208,00 " - 209,00 "		0,01	0,01	0,12	1,6	4,9	0,00
55	210. 209,00 " - 210,00 "		0,02	0,01	0,06	1,4	4,8	0,00

Rapp. til: Vedi-Grin-Kaspersen. Sulitjelma den 14/6. 19 85. Sign.

Sulitjelma Bergverk AS.

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn/Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H_2O	% Pb.
1364	211.	210,00 m - 211,00 m		0,02	0,01	0,06	1,7	5,4		0,00
65	212.	211,00 " - 212,00 "		0,02	0,01	0,68	1,5	5,2		0,00
66	213.	212,00 " - 213,00 "		0,00	0,01	0,31	1,5	5,9		0,00
67	214.	213,00 " - 214,00 "		0,00	0,01	0,31	1,5	6,4		0,00
68	215.	214,00 " - 215,00 "		0,01	0,01	0,31	1,8	6,7		0,00
69	216.	215,00 " - 216,00 "		0,02	0,01	0,43	0,4	5,3		0,00
70	217,	216,00 " - 217,00 "		0,01	0,01	0,56	0,6	5,2		0,00
71	218.	217,00 " - 218,00 "		0,01	0,01	0,56	0,8	4,3		0,00
72	219.	218,00 " - 219,00 "		0,02	0,01	0,56	0,5	5,1		0,00
73	220.	219,00 " - 220,00 "		0,02	0,01	0,37	0,3	5,0		0,00

Rapp. til: Vedi-Kaspersen-Grin ✓ Sulitjelma den 18/6. 1985. Sign.

Sulitjelma Bergverk AS ·

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn / Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H₂0	% Pb.
1374	221.	220,00 m - 221,00 m		0,02	0,01	0,37	0,2	5,6		0,00
75	222.	221,00 " - 222,00 "		0,01	0,01	0,37	0,4	6,0		0,00
76	223.	222,00 " - 223,00 "		0,00	0,01	0,06	0,5	5,0		0,00
77	224.	223,00 " - 224,00 "		0,01	0,01	0,31	0,1	5,2		0,00
78	225.	224,00 " - 225,00 "		0,01	0,01	0,12	0,1	5,0		0,00
79	226.	225,00 " - 226,00 "		0,01	0,01	0,03	0,3	4,4		0,00
80	227.	226,00 " - 227,00 "		0,01	0,02	0,12	0,5	4,1		0,00
81	228.	227,00 " - 228,00 "		0,01	0,01	0,50	0,4	5,0		0,00
82	229.	228,00 " - 229,00 "		0,01	0,01	0,19	0,4	4,1		0,00
83	230.	229,00 " - 230,00 "		0,01	0,01	0,50	0,3	3,9		0,00

Rapp. til: Vedi-Kaspersen-Grün. Sulitjelma den 19/6. 1985. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn/Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H_2O	% PB.
1411	231.	230,00 m - 231,00 m		0,00	0,01	0,12	0,5	4,1		0,01
12	232.	231,00 " - 232,00 "		0,00	0,01	0,03	0,3	4,6		0,01
13	233.	232,00 " - 233,00 "		0,01	0,01	0,31	0,6	5,6		0,02
14	234.	233,00 " - 234,00 "		0,00	0,01	0,03	0,2	5,0		0,02
15	235.	234,00 " - 235,00 "		0,01	0,01	0,25	0,1	4,7		0,02
16	236.	235,00 " - 236,00 "		0,00	0,01	0,00	0,4	4,1		0,00
17	237.	236,00 " - 237,00 "		0,01	0,01	0,31	0,5	3,5		0,00
18	238.	237,00 " - 238,00 "		0,01	0,01	0,12	0,8	3,9		0,00
19	239.	238,00 " - 239,00 "		0,01	0,01	0,12	0,8	5,1		0,00
20.	240.	239,00 " - 240,00 "		0,00	0,01	0,37	0,8	3,9		0,01

Rapp. til: Vedi-Grin-Kaspersen. Sulitjelma den 20/6. 1985. Sign.

Sulitjelma Bergverk AS

Laboratoriet

ANALYSERAPPORT

Pröve fra: Kong Oscar. D.b.h. 224.

Råmalmpost ___/___ . Den ___/___ 19 __ Silo Nr. ___

J.nr.	Prövebeskrivelse. Nr.	Beliggenhet.	Tonn/Mekt.	% Cu.	% Zn.	% S.	ppm. AG.	% Fe.	% H₂O	% PB.
1430	241.	240,00 m - 241,00 m		0,00	0,01	0,62	0,0	4,4		0,00
31	242.	241,00 " - 242,00 "		0,01	0,01	0,31	0,0	5,0		0,00
32	243.	242,00 " - 243,00 "		0,01	0,01	0,25	0,0	5,0		0,00
33	244.	243,00 " - 244,00 "		0,01	0,01	0,12	0,0	5,3		0,00
34	245.	244,00 " - 245,00 "		0,01	0,01	0,19	0,0	6,5		0,00
35	246.	245,00 " - 246,00 "		0,01	0,01	0,06	1,3	4,6		0,00
36	247.	246,00 " - 247,00 "		0,01	0,01	0,06	1,4	4,2		0,00
37	248.	247,00 " - 248,00 "		0,01	0,01	0,25	1,1	4,1		0,00
38	249.	248,00 " - 249,00 "		0,01	0,01	0,12	1,5	4,7		0,00
39	250.	249,00 " - 250,00 "		0,01	0,01	0,00	0,7	4,2		0,00
40	251.	250,00 " - 251,00 "		0,01	0,01	0,25	0,5	4,1		0,00
41	252.	251,00 " - 252,00 "		0,01	0,02	0,12	0,3	3,8		0,00
42	253.	252,00 " - 253,00 "		0,01	0,01	0,03	0,5	4,0		0,00

Rapp. til: Vedi-Grin-Kaspersen. Sulitjelma den 21/6. 1985. Sign. R.W.

POS[illegible]KVITTERING

Ta godt vare på kvitteringen. De må vise den fram ved eventuell reklamasjon.

☐ postanv. ☐ verdibrev 1) ☒ ~~reg. pakke~~

☐ innbet.kort ☐ rek.sending ☐ innsk.bok 2)

	Kroner	øre		Kroner	øre
Verdibeløp			Postoppkrav		

Til (navn)
Mercury Analytical LTD

Postnr. og postkontor
Limerick IRLAND

Nr.	Vekt (p. p.)	Porto/avgift
281	3,900 kg	121,- kr

☐ luftpost ☐ ekspress

1) ☐ forseglingsavg.

2) Nummeret på innskuddsboka

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2 DECEMBER 1983
FOR PERRY KASPERSEN
FROM MERCURY ANALYTICAL LIMERICK

YOUR TELEX 30/11-1983 JS/ELL

RESULTS FOR ROCK SAMPLES

SAMPLE	CU	PB	ZN	AG	FE	NI	CO	AU
A1	25	227	73	1.3	4.83	69	38	0.14
2	17	197	50	1.0	4.86	76	36	0.12
C	392	616	680	3.2	4.01	13	6	0.60
C4	26	92	10	17.9	17.90	5	3	0.24
5	157	452	384	5.8	21.70	52	28	0.27
7	6.18	5.44	11.35	357	15.20	30	9	3.19
→ 8	10.16	3.22	8.76	405	29.60	98	10	9.08
D1	772	301	535	4.6	1.96	10	7	0.02
F1	63	131	264	1+1	1.74	6	5	0.02
G	0.68	3.79	6.36	56	6.60	21	10	0.54
G3	450	7.05	22.65	186	11.20	24	5	0.12
5	0.34	2.01	1.87	30	4.53	21	10	0.52

— %

ALL VALUES IN PPM EXCEPT DECIMAL RESULTS FOR CU PB AND ZN IN C7,8 G,G3,G4, AND ALL FE RESULTS

CORECTION: AG IN SAMP F1 SHOULD BE 1.1 PPM

AU ON HM SAMPLES

THESE WERE UNFORTUNATELY OVERLOOKED. WE ARE VERY SORRY ABOUT THIS. YOU WILL HAVE THE RESULTS BY 7 DECEMBER.

FLUORINE METHOD

PREPARATION:	0.25 GM SAMPLES DIGESTED IN CONC HCL/ALCL3, THEN DILUTED TO 100ML WITH EDTA/SULFOSALICYLIC ACID BUFFER
ANALYSIS	ION-SPECIFIC ELECTRODE
DL:	10PPM
PRECISION:	+ OR - 20 PPM OR 15 PERCENT,WHICHEVER IS GREATER
REF STNDS:	CANMET SO1 AND SO3
COMMENT:	THIS METHOD DETERMINES FLUORITE AND OTHER RELATIVELY SIMPLE FORMS OF F ONLY. THE DIGESTION WOULD NOT ATTACK RESISTATE MINERALS CONTAINING F (EG TOURMALINE)

BEST REGARDS
PETER CAZALET+

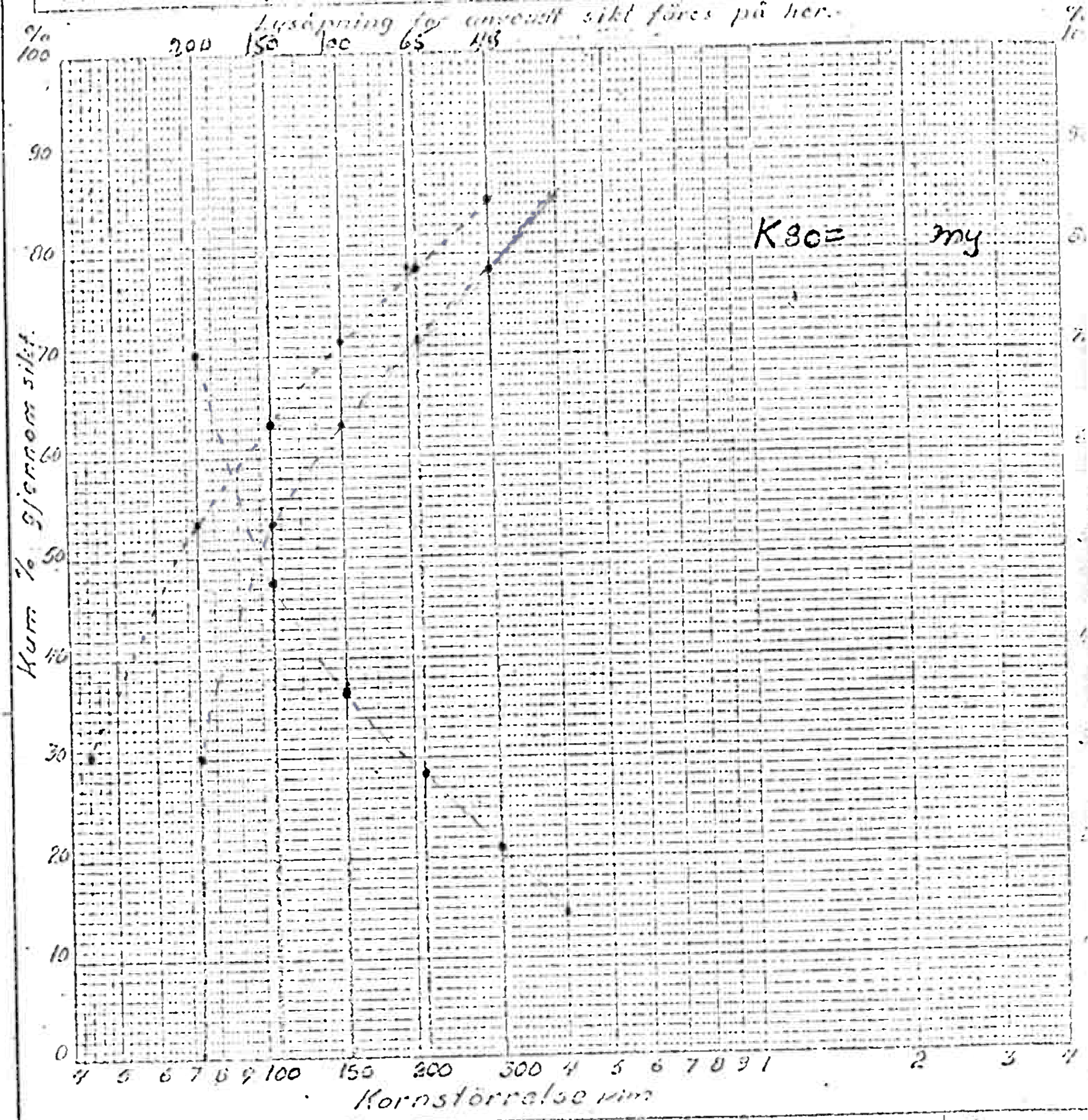
26808 MAL EI+

Kaspersen

1985.

Siktepröve av: Kong Oscar D.t.h. 224 (15m – 20m)

Utfört 28/3 – 1985. Signatur: F.L.



Fraksjon		%	Kum%	
÷	+			
mesh	mesh			
	48	14,06		
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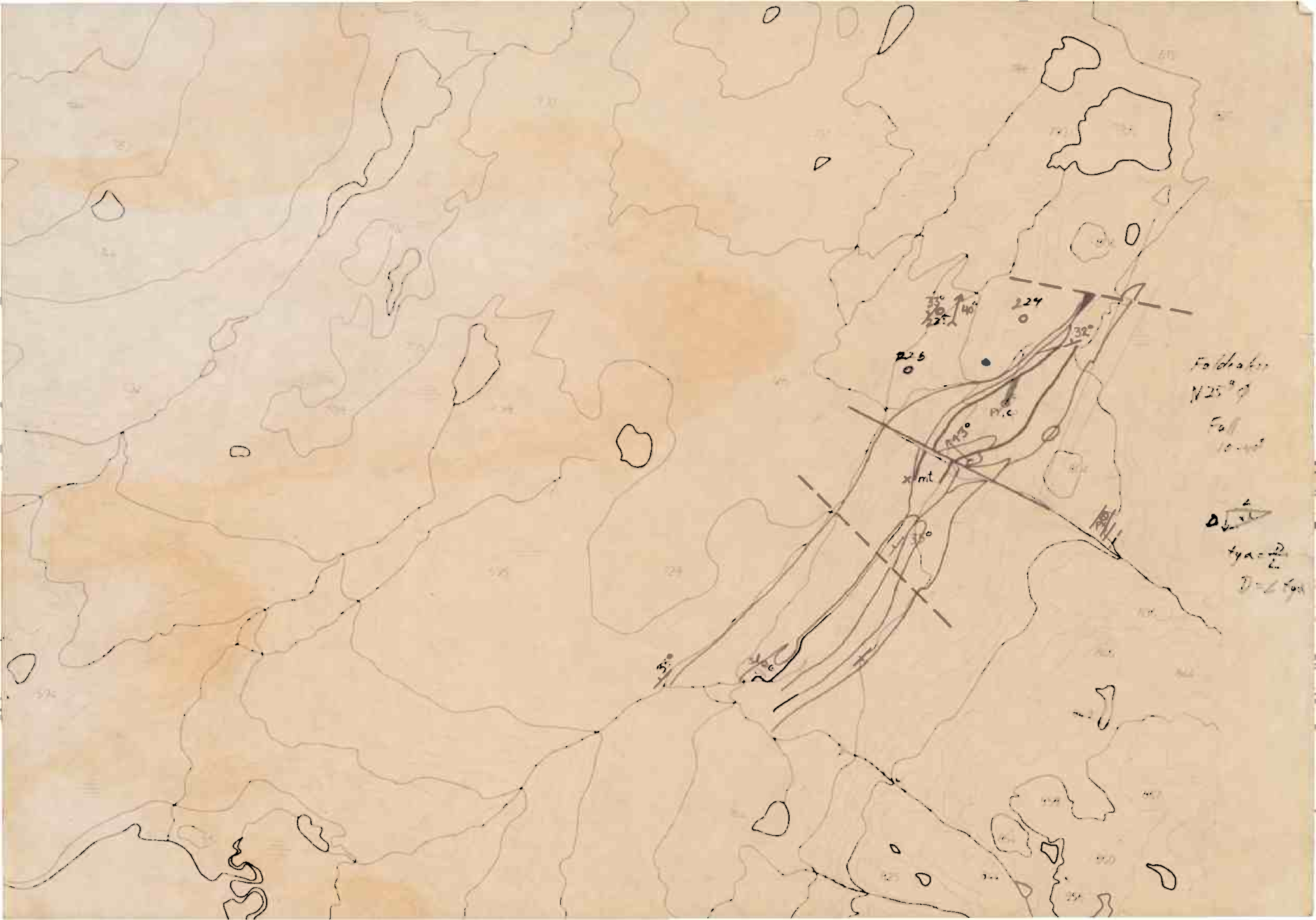
65	100	7.42		<1% >100 mesh
100	150	8.18		
150	200	9.82		
200	325	23,62		<10% >200 mesh
325		29.92		
Sum		99.74		
Differans:				



Foldeakse
N25°Ø
Fall
10-40°

$\tan\alpha = \frac{D}{L}$

$D = L \tan\alpha$

A/S SULITJELMA GRUBER

SULITJELMA M 1:10000 EKV. 10 M

EG 212	EH 212	EJ 212
EG 211	EH 211	EJ 211
EG 210		

Kong Oscar

Borsted: 228 Dagen/Gruva. Hull nr: 228 Nivå N.G.O: Nivå Sulis: Koord. N.G.O: X Y Koord. Sulis: X Y Ret./Fall 145/78

FRA Dato: 4/9 - 84 TIL Dato: /9 1984 Ref: P. Kaspersen

ull yp il	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S %
0 –		Kvartsitt skifer									
-13.3		(grå)									
-13.5		med biotitt mer									
		kvartsitt Silisit									
-11		Kvartsittisk m. sulf		Po i stokkverk							
-16,6		Kvartsitt med									
		stokkverk (breksjert)									
		av sulfidklaster		Spor-py							
-20		Skifer lys, enkelte									
		nivå med [illegible]									
-24.3		Kvartsittisk skifer									
-25,5		Skifer									
-26		Kvartsittisk sk.		Py 28,5							
				Py 31,5, 32,3, 34-35							
		Mer eller mindre									
		lik b.o.									
-39.5		Overgang b.o. med									
		noe mer skifer									

Nivå N.G.O:______ Koord. N.G.O: X__________ Y__________

Borsted:__________ Dagen/Gruva. Hull nr:_____ Nivå Sulis:______ Koord. Sulis: X__________ Y__________ Ret./Fall ____/____

FRA Dato:______/______ TIL Dato:______/______19___ Ref:__________

Hull dyp til	Tegn.	BERGARTDATA			Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S %
		Bergart	Str.	Mineralisering							

THE SAMPLING OF PARTICULATE MATERIALS—A GENERAL THEORY

By

PIERRE M. GY[1]

ABSTRACT

This paper is a summary of the general theory of sampling published by the author in 1975.

Sampling is a random process and its theory is a study of the numerous errors liable to take place in the course of its realization.

A complete sampling scheme is a sequence of sampling (proper) and preparation stages :

. At each stage, the total error ET is the sum of :

- Sampling errors EE arising from the selection process itself.
- Preparation errors EZ arising from the operations (crushing, transfer...) supported by the sampled material.

$$ET \equiv EE + EZ$$

. At each sampling stage, the (total) sampling error EE is the sum of seven independent errors :

- Weighting error ED resulting from the non-uniformity of the density or rate-of-flow of the sampled material.
- Integration error EI_1 resulting from the long-range distribution heterogeneity of the sampled material.
- Periodicity error EI_3 resulting eventually from periodic quality variations of the sampled material.
- Fundamental error EF resulting from the constitution heterogeneity of the sampled material.
- Segregation error ES resulting from the local distribution heterogeneity of the sampled material.
- Delimitation error EC resulting eventually from an incorrect shape of the volume delimiting the increments.
- Extraction error EP resulting from the actual extraction of the increments.

$$EE \equiv ED + EI_1 + EI_3 + EF + ES + EC + EP$$

. At each preparation stage, the (total) preparation error EZ is the sum of five independent errors.

- error EZ_1 : loss of particles belonging to the sample.
- error EZ_2 : contamination of the sample by foreign material.
- error EZ_3 : alteration of the critical characteristic to be measured on the final sample.
- Error EZ_4 : unintentional mistakes of the operator (e.g. mixing sub-samples belonging to different samples).
- Error EZ_5 : intentional alteration of the characteristic to be measured on the final sample.

$$EZ = EZ_1 + EZ_2 + EZ_3 + EZ_4 + EZ_5$$

Two complementary models of the sampling process are thoroughly developed to study these errors :

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Original manuscript received 7.7.76

The integration model dealing with the continuous, geometrical properties of the sampled material.

- The probabilist model dealing with the discontinuous, physical properties of the sampled material.

The errors ED, EI_1, EI_3, EF and ES can be quantitatively defined. Their mean (bias) and variance can be estimated from the result of a variographic experiment.

The errors EC, EP and EZ can only be qualitatively defined. They cannot be experimentally estimated but rules are given making it possible to suppress them and particularly to cancel out the always dangerous sampling biases.

1 - INTRODUCTION

I have been struck by a comment made recently by an Australian friend : "In this country most companies regard sampling as an unavoidable overhead and in many cases they spend as little money as possible on it".

Such a misunderstanding of the random nature of sampling, such a misappreciation of the risks attached to it show how necessary was a symposium on this subject.

The first thing that should be emphasized is that sampling is not a simple mechanical technique like crushing for instance : it is a random process liable to introduce errors such as chemical analysis. But whereas this latter is always carried out in laboratory conditions (I was tempted to say in "aseptic" conditions) by a well-trained specialized staff conscious of the necessity of accuracy and precision, sampling is usually carried out in field or plant conditions by unspecialized labour perfectly unaware of the importance of their work and unconscious of the mistakes to be avoided at any cost.

Sampling and analysis (chemical, size or moisture analysis) are the two complementary links of the quality estimation chain with the consequence that the total estimation error is the sum of the sampling error and of the analysis error.

The optimization of the "accuracy-cost" characteristics of an estimation demands that the same care be taken in sampling and in analysis.

Sampling should always be placed under the responsibility of the head of "quality control", not of the head of "production". It should be carried out by a specialized staff conscious of the numerous errors that may take place and knowing how to suppress or reduce these.

One may judge a crusher or a screen after its mechanical performance, not a sampler : the only touchstone of a sampler is its aptitude to avoid a certain number of errors and to maintain the others at an acceptable level. One may judge the products of a crusher or of a screen after the results of a simple test easy to carry out : the products contain the proofs of their qualities. This is not true of a sample : after it has been extracted from the lot, there is no way of recognizing a "good" sample from a "bad" one.

But what is a "good" sample and why is this other one "bad" ? It is the object of the sampling theory to answer this apparently simple but really subtle question. The sampling theory is nothing else than a thorough study of the sampling errors.

2 - QUALITIES OF A SELECTION PROCESS

Sampling is a complex selection process. A selection process may be qualified :

- Either in terms of "a priori qualities"
- or in terms of "a posteriori qualities".

. The "a priori qualities" are defined after the conditions of the selection :

- A selection process is said to be "probabilist" whenever each element of the lot is submitted to the selection with a given probability of being selected.

- It is said to be "non-probabilist" whenever it is not founded on the notion of probability. The "hammer and shovel" sampling method, based as it is on a purposive selection of the material destined to the sample, is a non-probabilist method. Such methods are inaccessible to a theoretical approach, they are therefore excluded from our study. They are usually heavily biased and should therefore be rejected.

- A selection process is said to be "correct" whenever all elements of the lot are submitted to the selection with a uniform probability (or density of probability) of being selected.

- It is said to be "incorrect" when, being probabilist, the above condition is not fulfilled.

.The "a posteriori" qualities are based on the results of the selection and more particularly on the statistical properties of the selection error e, relative difference between the critical content a_E of the sample E and the critical content a_L of the sampled lot L:

$$e = (a_E - a_L) / a_L$$

- A selection process is said to be "unbiased" when the mean of the selection error is nil :

$$m(e) = 0 \rightarrow m(a_E) = a_L$$

- It is said to be "biased" when the mean is not nil. The value of the mean is the "bias" B or relative systematical error:

$$B = m(e) \neq 0 \rightarrow m(a_E) \neq a_L$$

It is said to be "reproducible" when the variance of the selection error is not larger than a given "reproducibility standard" σ_0^2 :

$$\sigma^2(e) \leq \sigma_0^2$$

- It is said to be "exact" when the selection error is always nil :

$$m(e) = 0 \quad \text{and} \quad \sigma^2(e) = 0$$

- It is said to be "accurate" when it is at the same time unbiased and reproducible:

$$m(e) = 0 \quad \text{and} \quad \sigma^2(e) \leq \sigma_0^2$$

- It is said to be "representative" when the mean square of the error does not exceed a "representativity standard" R_0^2:

$$m(e^2) = m^2(e) + \sigma^2(e) \leq R_0^2$$

Practically speaking, the only non-utopic objective is representativity. Accuracy and exactitude are reached only at the limit.

The sampling theory may also be regarded as the search for relationships between the conditions and the results of a sampling, i. e. between its "a priori" and its "a posteriori" qualities.

3 - SAMPLING AND HETEROGENEITY

Any fraction of a batch of homogeneous material has the same composition as the batch itself. The sampling of a homogeneous material is therefore an exact selection process, whatever the conditions of sampling.

The fractions that can be extracted from a batch of heterogeneous material don't usually have the same composition as the batch itself. The sampling of a heterogeneous material is therefore a random selection process, generating sampling errors.

All sampling errors must be regarded as a consequence of one form or another of heterogeneity of the sampled material.

This notion of heterogeneity is multiform : we have been able to define and express mathematically :

- The constitution heterogeneity, an intrinsic property of the population of fragments. Blending or segregation has no effect on it.

- The distribution heterogeneity, a property of the fragments distribution throughout the domain occupied by the batch. Blending tends to decrease, segregation tends to increase the distribution heterogeneity.

The mathematical properties of these two forms of heterogeneity have been thoroughly studied and related to one another.

In our theory of sampling we shall have to describe and to characterize the distribution heterogeneity.

We shall use three descriptive functions:

. $a(X)$: an indicative function taking the value 1 when the point X falls within a domain occupied by the "critical component" (component taken more particularly into consideration, e.g. a valuable mineral) and the value 0 when the point X falls within a domain occupied by a non-critical component (including the voids between solid particles).

. $\mu(X)$: a weighting function taking the value of the specific gravity of the component present at point X (zero when X falls in the interstitial voids).

. $\omega(X) = a(X)\ \mu(X)$

The functions $a(X)$, $\mu(X)$ and $\omega(X)$ are punctual-functions. When the point X is replaced by a small domain D_c centered in X, we obtain the smoothed-functions" $a_c(X)$, $\mu_c(X)$ and $\omega_c(X)$:

. $a_c(X)$ is the "critical content" (proportion of critical component) of $D_c(X)$.

. $\mu_c(X)$ is the average specific gravity of the material contained in $D_c(X)$.

. $\omega_c(X) = a_c(X)\ \mu_c(X)$

But we never know the analytical expression of the functions $a(X)$ and $\mu(X)$. Experience shows that a given material, for instance the feed to a processing plant or to a smelter, possesses stable variability properties that may be characterized by means of the "variogram functions".

Let's denote by :

$y(X)$: any function of the point X and for instance $a(X)$, $\mu(X)$ or $\omega(X)$. In order to make the demonstration easier, we shall suppose that we are considering the sampling of a flowing stream of material at the discharge end of a conveyor belt, for instance and that X is a point on the time-axis.

θ : a time interval

$\Delta_y(X,\theta)$: the increase of the $y(X)$ function between the instants $X - \theta/2$ and $X + \theta/2$:

$$\Delta_y(X,\theta) = y(X+\theta/2) - y(X-\theta/2)$$

$v_y(\theta)$: the half mean square of $\Delta_y(X,\theta)$ calculated throughout the domain D_L occupied by the lot L (D_L represents here the duration of the flow).

$$v_y(\theta) = \frac{1}{2D_L}\int_{D_L} \Delta_y^2\ (X,\theta)dX$$

$v_y(\theta)$ is called the "variogram of (X)". It can often be represented by a linear function such as :

$$v_y(\theta) = v_{y1}\theta + v_{y2}$$

where v_{y1} and v_{y2} are the "variographic parameters". They can be experimentally determined (variographic experiment).

We shall see later on that the moments of several sampling errors can be expressed by means of the variographic parameters. The variographic experiment is therefore the key to the practical estimation of the sampling errors.

4 - ANALYSIS OF THE SAMPLING PROCESSES

Sampling (wide meaning) is usually an alternation of preparation stages (crushing, grinding, drying, blending, transfer...etc...) and of sampling stages proper (solid weight reduction), both susceptible of altering the critical content and therefore generating:

- preparation errors EZ (section 18)
- sampling errors EE (sections 6 to 17)

Then, the total error ET is :

$$ET = EE + EZ$$

Any probabilist sampling stage can be reduced to one of the two following processes :

- increment sampling process (weight reduction ratio usually between 10^{-4} and 10^{-2}).
  Prototype : cutting of a stream at the discharge end of a conveyor)
- Splitting process (weight reduction ratio between 10^{-2} and 0.5)
  Prototype : sampling by means of a riffles divider.

The former is usually applied to lots of material too heavy to be handled in totality and the latter to lots light enough to be handled.

The logical analysis of these probabilist sampling processes shows that they may be regarded as sequences of elementary operations.

4.1. Increment process :

a) Integration : selection of the "punctual-increments" throughout the domain occupied by the lot according to the "integration law".

b) Increments delimitation : definition of the boundaries of the "model-increments" around the punctual-increments.

c) Increments extraction : actual separation of the material contained in the model-increments, generating the "real-increments".

d) Reunion : The "real-sample" is obtained by reunion of the real-increments.

4.2. Splitting process.

a) Fractions delimitation : Geometrical division of the domain occupied by the lot, generating the "model-fractions".

b) Separation : materialization of the geometrical partition, generating the "real-fractions".

c) Selection : choice of the real-fractions that will be retained as "sub-samples"

d) Reunion : The "real-sample" is obtained by reunion of the sub-samples.

These elementary operations (except the reunion) considered either individually or grouped together, may be regarded as simple selection processes accessible to a theoretical approach. For instance :

- Integration is a selection process applied to the lot and generating points (the punctual-increments) which,once gathered, constitute the "punctual-sample".
- Integration + increments delimitation is a selection process applied also to the lot and generating volumes (the model-increments) which, once gathered, constitute the "model-sample".
- Increments extraction is a selection process applied to the model-increments and generating groups of fragments (the real-increments) which, gathered, constitute the " real-sample".

From the standpoint of the sampling errors we may consider that the total sampling error EE is the sum of :

- the (total) integration error EI_t
- the error of materialization of the punctual-increments EM

$$EE = EI_t + EM$$

The materialization itself can be broken up into a sequence of two operations :

the increments delimitation and the increments extraction. The materialization error is therefore the sum of two errors :

- the delimitation error EC
- the extraction error EP

$$EM = EC + EP$$

5 - INTRODUCTION TO THE SAMPLING MODELS

The theoretical study of these simple selection processes can be carried out by means of two models :

- the integration model
- the probabilist model

Any batch of material (solid or fluid, compact or particulate) may basically be looked at in two different ways :

- Either as a geometrically continuous medium. A lot of material L is then considered as the set of points belonging to a certain domain D_L of the geometrical space. Each point X is characterized by the values taken by the two functions $a(X)$ and $\mu(X)$.

The critical content a_L of L (proportion of critical component) is expressed by :

$$a_L = \int_{D_L} a(X)\ \mu(X)\ dX \ / \int_{D_L} \mu(X)\ dX$$

- Or as a physically discontinuous medium. The lot L is then regarded as a set of particles (atoms, molecules or fragments) surrounded by a passive medium (vacuum, air or water). If, for example, L is made of N_L fragments, each fragment F_i is characterized by the values taken by two parameters :

. a_i : the critical content of F_i
. M_i : the weight of F_i

The critical content a_L of L is then expressed by

$$a_L = \sum_i a_i M_i \ / \sum_i M_i$$

Both expressions of a_L are equally valid.

. The integration model is the model developed to represent a punctual selection process applied to a geometrically continuous medium. The selection process is characterized by an integration law (e.g. systematic, stratified random or random) and by a selection function $g(X)$ which is the density of selection probability at point X.

. The probabilist model is the model developed to represent a selection process applied to a physically discontinuous medium. The selection process is characterized by a set of selection parameters P_i, the probability of selection of the fragment F_i.

It should be well understood that both perspectives (continuous and discontinuous) and both models (integration and probabilist) are equally valid.

They are not competitive but complementary, exactly in the same way as the various projections of an object on different planes are complementary.

Generally speaking, it may be said that the integration model fits more closely the study of the long-range, large-scale properties of the sampled material. The lot is looked at as through a wide-angle lens in such a way that the discontinuities of the material appear as a fuzzy picture of a continuous matetial. The integration model is the model developed by MATHERON for the sampling of mineral deposits and we utilize in our theory results obtained by him.

On the other hand, the probabilist model fits more specifically the study of the short-range, small-scale properties of the sampled material. The lot is looked at as through a magnifying lens in such a way that the long-range structure of the distribution of the components are no more perceptible. The probabilist model is a generalization of the equiprobable model that we developed about 25 years ago.

These two models make it possible to study the sampling of any kind of material, solid or fluid, compact or particulate, of mineral.vegetable, animal or synthetic origin. This is why our study may by truly regarded as a general sampling theory fitting all sampling problems.

Now, when developing a model, we are aiming at establishing mathematical relationships between three groups of characteristics :

1 - The data of the problem : These data characterize the constitution and the distribution of the components of the sampled material.

2 - The free parameters : These are the factors on which we can play in order to solve the problem, e.g. type and mechanical characteristics of the sampling method or device.

3 - The appreciation factors : These are especially the mean and the variance of the sampling error or the mean and the variance of the sample critical content.

A sampling problem is said to be "soluble" when such relationships can be derived and when for instance a solution can be proposed meeting a given representativity standard.

It is said to be "insoluble" when such relationships cannot be derived and more generally when errors must be suspected that cannot be taken into account by a model.

A "solution" may be economical or non-economical. In this last case a compromise must be sought between cost and representativity.

For mechanical and economical reasons the sampling of three-dimension lots (extending equally in the three dimensions of space) of particulate materials is to be regarded as insoluble ; the sampling of two-dimension lots (flat heaps of small and nearly constant thickness) is soluble but usually uneconomical ; the sampling of one-dimension lots (especially lots transfered at nearly constant rate of flow on a conveyor belt) is easily soluble and cheap.

For this reason it is always advisable to sample a lot of ore when it is being transferred under the form of a one-dimension object. It is the only reliable kind of sampling. We have carried out and related in our books (see references in appendix) an exhaustive study of the errors liable to occur in this particular case.

6 - DEVELOPMENT OF THE INTEGRATION MODEL

MATHERON developed his model for the three-and two-dimension objects that represent mineral deposits. Our own study covers more especially one-dimension objects such as flowing streams of ore.

Integration laws : We have retained the three most usual integration laws :

- systematic (with random positioning)
- stratified random
- random

The development of the integration model leads for each integration law to the expression of :

- the mean $m(M_E)$, the variance $\sigma^2(M_E)$ and the relative variance $U^2(M_E)$ of the sample weight :

$$U^2(M_E) = \sigma^2(M_E) \ / \ m^2(M_E)$$

- The mean $m(A_E)$, the variance $\sigma^2(A_E)$ and the relative variance $U^2(A_E)$ of the weight of critical component in the sample :

$$U^2(A_E) = \sigma^2(A_E) \ / \ m^2(A_E)$$

- The mean $m(a_E)$ or the relative bias $B(a_E)$ of the critical content of the sample :

$$B(a_E) = \left[m(a_E) - a_L \right] / a_L$$

- The variance $\sigma^2(a_E)$ or the relative variance $U^2(a_E)$ of the critical content of the sample :

$$U^2(a_E) = \sigma^2(a_E) / a_L^2$$

as a function of :

- The characteristics (constitution and distribution) of the sampled material : variographic parameters v_{M1}, v_{M2}, v_{A1}, v_{A2}, v_{a1}, v_{a2}, $\rho(A,M)$ that can be experimentally determined; duration D_L of the flow of L ; weight M_L of L ; critical content a_L of the lot L.
- The characteristics of the integration law (type ; interval θ ; length of strata θ ; number Q of increments, according to the case).
- The characteristics of the increments cutter (width W ; velocity V ; duration of the cut $D_C = W / V$.

6.1. Systematic integration (index 1):

$$m_1(M_E) = M_L\, D_c / \theta \;;\; \sigma_1^2(M_E) = D_L \left[\frac{v_{M1}}{6} + \frac{v_{M2}}{\theta}\right]$$

$$m_1(A_E) = a_L M_L D_c / \theta \;;\; \sigma_1^2(A_E) = D_L \left[\frac{v_{A1}}{6} + \frac{v_{A2}}{\theta}\right]$$

$$B_1(a_E) = U_1^2(M_E) - \rho(A,M)\, U_1(A_E)\, U_1(M_E)$$

$$U_1^2(a_E) = U_1^2(A_E) + U_1^2(M_E) - 2\rho(A,M)U_1(A_E)U_1(M_E)$$

6.2. Stratified random integration (index 2) :

$$m_2(M_E) = M_L D_c/\theta \;;\; \sigma_2^2(M_E) = D_L \left[\frac{v_{M1}}{3} + \frac{v_{M2}}{\theta}\right]$$

$$m_2(A_E) = a_L M_L D_c /\theta \;;\; \sigma_2^2(A_E) = D_L\left[\frac{v_{A1}}{3} + \frac{v_{A2}}{\theta}\right]$$

$$B_2(a_E) = U_2^2(M_E) - \rho(A,M)\, U_2(A_E)\, U_2(M_E)$$

$$U_2^2(a_E) = U_2^2(A_E) + U_2^2(M_E) - 2\rho(A,M)\, U_2(A_E)U_2(M_E)$$

6.3. Random integration (index 3)

$$m_3(M_E) = QM_L D_C/D_L \;;\; \sigma_3^2(M_E) = Q\left[\frac{v_{M1}D_L}{3} + v_{M2}\right]$$

$$m_3(A_E) = Qa_L M_L D_c/D_L \;;\; \sigma_3^2(A_E) = Q\left[\frac{v_{A1}D_L}{3} + v_{A2}\right]$$

$$B_3(a_E) = U_3^2(M_E) - \rho(A,M)\, U_3(A_E)U_3(M_E)$$

$$U_3^2(a_E) = U_3^2(A_E) + U_3^2(M_E) - 2\rho(A,M)U_3(A_E)U_3(M_E)$$

In this latter case it is usually easier to use the results of the classical statistics (index 4).

$$U_4^2(M_E) = U^2(M_q) / Q \;;\; U_4^2(A_E) = U^2(A_q) / Q$$

with $U^2(M_q)$ and $U^2(A_q)$ relative variances of the weight M_q and the critical weight A_q of the increment G_q ($q = 1, 2, \ldots Q$).

$$U_4^2(a_E) = U_4^2(A_E) + U_4^2(M_E) - 2\rho(A,M)U_4(A_E)U_4(M_E)$$

6.4. Conclusions :

One of the most important results is that for theoretical reasons, the integration is usually biased :

$$m(a_E) \neq a_L$$

even when it is correct, i.e. defined by:

$$g(X) = g_o \text{ throughout } D_L$$
$$g(X) = 0 \text{ outside } D_L$$

This bias is however negligible (smaller than one tenth of the standard deviation) as long as the integration is correct and ceases to be presumably negligible as soon as the integration is incorrect. It cancels itself out, the integration assumed to be correct, when the correlation coefficient between a(X) and $\mu(X)$ is equal to zero.

This case includes particularly the following limit cases :

a) $\mu(X) = \mu_o$ = constant throughout D_L
b) $a(X) = a_L$ = constant throughout D_L

The bias cancels out, the integration being incorrect, when the correlation coefficient between a(X) and the product $\mu(X)\, g(X)$ is nil.

Practically speaking it is of the utmost importance to carry out a correct integration characterized by :

$$\begin{cases} g(X) = g_0 = \text{constant throughout } D_L \\ g(X) = 0 \quad \text{outside } D_L \end{cases}$$

It depends only on our good will that this condition be satisfied.

7-BREAKING UP OF THE TOTAL INTEGRATION ERROR.

Let's denote by EI_t the total integration error:

$$EI_t = (a_E - a_L) / a_L$$

$m(EI_t) = B(a_E)$ (relative bias committed on a_E)
$\sigma^2(EI_t) = U^2(a_E)$ (relative variance of a_E)

This error depends on the variability of the two functions a(X) and $\mu(X)$.

Let's suppose that $\mu(X)$ is maintained strictly constant throughout D_L or in other words that the function a(X) is isolated. The critical contents a_L and a_E then become $a_{L'}$, and $a_{E'}$. Let's denote by EI_a the integration error of a(X) :

$$EI_a = (a_{E'} - a_{L'}) / a_{L'}$$

We can define an independent weighting error ED in such a way that :

$$EI_t = ED + EI_a$$
$$m(EI_t) = m(ED) + m(EI_a)$$
$$\sigma^2(EI_t) = \sigma^2(ED) + \sigma^2(EI_a)$$

Now it has been shown that the function a(X) might be broken up into a sum of four terms :

$$a(X) = a_{L'} + a_1(X) + a_2(X) + a_3(X)$$

with

$a_{L'}$: unweighted mean of a(X) throughout D_L

$$a_{L'} = \int_{D_L} a(X)\, dX / D_L$$

$a_1(X)$: regional term carrying the long-range, large-scale non-periodic variations of a(X).
$a_2(X)$: local term carrying the short-range, small-scale variations of a(X) tied especially to the particulate nature of the sampled material and to the stochastic nature of the particles distribution.
$a_3(X)$: periodic term carrying the eventual periodic variations of a(X).

These terms may be regarded as representing phenomena independent of one another, with the consequence that the integration error EI_a may be considered as the sum of three independent integration errors EI_1, EI_2 and EI_3 corresponding respectively to the terms $a_1(X)$, $a_2(X)$ and $a_3(X)$.

We can therefore break up EI_t and its moments into sums of four independent terms.

$$EI_t = ED + EI_1 + EI_2 + EI_3$$
$$m(EI_t) = m(ED) + m(EI_1) + m(EI_2) + m(EI_3)$$
$$\sigma^2(EI_t) = \sigma^2(ED) + \sigma^2(EI_1) + \sigma^2(EI_2) + \sigma^2(EI_3)$$

8 - PROPERTIES OF THE WEIGHTING ERROR ED

a) The weighting bias $m(ED)$ is negligible whenever the integration is correct.

b) The weighting variance $\sigma^2(ED)$ is :

. negligible when the fluctuations of $\mu(X)$ do not exceed ± 10%.

. acceptable when the fluctuations of $\mu(X)$ do not exceed ± 20%

c) Practically speaking, it is always advisable to regulate the rate-of-flow of sampled material in order to reduce the weighting variance to an acceptable level. Regulation by weight is always more efficient than regulation by volume which is anyway better than no regulation at all.

9 - PROPERTIES OF THE INTEGRATION ERROR EI_1 OF THE REGIONAL TERM

a) The integration bias $m(EI_1)$ is nil when the integration is correct (first approx.)

b) The integration variance $\sigma^2(EI_1)$ can be expressed for the three usual integration laws :

$$\sigma_1^2(EI_1) = v_{a1}\theta^2/6D_L a_L^2 \ ; \ \sigma_2^2(EI_1) = v_{a1}\theta^2/3D_L a_L^2$$

$$\sigma_3^2(EI_1) = v_{a1}D_L/3Qa_L^2 = Q\sigma_2^2(EI_1) = 2Q\sigma_1^2(EI_1)$$

c) Practically speaking : When the variographic parameter v_{a1} is known from a reliable experiment, it is always possible to calculate values of θ or Q satisfying a given standard σ_o^2:

- For a systematic integration :
  $\theta \leq \theta_o = \sigma_o a_L \sqrt{6D_L} / v_{a1}$
- For a stratified random integration
  $\theta \leq \theta_o = \sigma_o a_L \sqrt{3D_L} / v_{a1}$
- For a random integration
  $Q \geq Q_o = v_{a1}D_L / 3\sigma_o^2 a_L^2$

When the variographic parameter v_{a1} is unknown, experience shows that with the usual distributions the integration variance $\sigma^2(EI_1)$ is always acceptable when $\theta \leq 10$ mn and when $Q \geq 50$ (systematic integration).

10 - PROPERTIES OF THE INTEGRATION ERROR EI_2 OF THE LOCAL TERM

a) The integration bias $m(EI_2)$ is nil when the integration is correct (first approx.)

b) The integration variance $\sigma^2(EI_2)$ can be expressed as a function of the variographic parameter v_{a2} :

$$\sigma_1^2(EI_2) = \sigma_2^2(EI_2) = \sigma_3^2(EI_2) = v_{a2}\theta / D_L a_L^2 = v_{a2} / Qa_L^2$$

c) The local term $a_2(X)$ reflects the discontinuous properties of the particulate material. The probabilist model has been developed in order to analyse the content of the variance $\sigma^2(EI_2)$. We shall see in section 13how this variance can be expressed as a function of the characteristics of the particulate material being sampled and how EI_2 can be split up into a sum of two errors :

$$EI_2 = EF + ES$$

11 - PROPERTIES OF THE INTEGRATION ERROR EI_3 OF THE PERIODIC TERM

Experience shows that periodic variations are more frequent than is usually thought. The term $a_3(t)$ may be regarded as the sum of a certain number of terms of the general form :

$$a_3(t) = a_3 \sin 2\pi t/T + a_3' \cos 2\pi t/T$$

with a_3, a_3' constants and T period of the phenomenon

a) The integration bias $m(EI_3)$ is nil when the integration is correct and when $D_L = kT$ (with k integer).

b) The integration variance $\sigma^2(EI_3)$ is very complex. Its maximum is reached with a systematic integration when the interval θ is a multiple of the period T. Then $\sigma_1^2(EI_3)_{max} = (a_3^2 + a_3'^2) / 2\,a_L^2$. For a stratified random integration, the maximum is : $\sigma_2^2(EI_3)_{max} = (a_3^2 + a_3'^2) / 2Qa_L^2$. The risk is Q times smaller with the stratified random integration which is in any case the safest solution.

12 - DEVELOPMENT OF THE PROBABILIST MODEL

The probabilist model is the theory of a selection process applied to fragments or small groups of fragments. In this model the lot L is considered as a set of N groups G_n of N_n fragments ($n = 1, 2, ..N$). N_n may eventually be uniformly equal to unity . Then,

$N = N_L$, number of fragments in L. These groups are regarded as indissociable batches taking part individually and independently in the selection process with a probability P_n of being selected.

If the group G_n is characterized by its weight M_n and its critical content a_n, the moments of the critical content a_E of the sample are (first approximation = index 1) :

$$m(a_E)_1 = \sum_n a_n M_n P_n / \sum_n M_n P_n = a_o \neq a_L$$

the selection process is biased :

$$\sigma^2(a_E)_1 = \sum_n (a_n - a_o)^2 M_n^2 P_n (1-P_n) / (\sum_n M_n P_n)^2$$

When the selection is correct, i.e. when the N values of P_n are uniformly equal to P :

$$m(a_E)_1 = \sum_n a_n M_n / \sum_n M_n = a_L \ ; \ B(a_E)_1 = 0$$

the selection is unbiased but only in first approximation. In second approximation (index 2):

$$B(a_E)_2 = -\frac{1-P}{P} \sum_n (a_n - a_L)\, M_n^2 / a_L M_L^2$$

this bias is not nil but usually negligible.

$$U^2(a_E)_1 = \frac{1-P}{P} \sum_n (a_n - a_L)^2 M_n^2 / a_L^2 M_L^2$$

The bias cancels itself out when there is no correlation between the distributions of a_n and M_n. This case covers particularly the two following cases :

- All M_n are equal
- All a_n are equal

In this last case, the selection process is exact.

Three problems can be solved by means of the probabilist model :

- analysis of the integration error EI_2,
- increments delimitation error EC,
- increments extraction error EP.

13 - ANALYSIS OF THE INTEGRATION ERROR EI_2 - FUNDAMENTAL ERROR EF AND SEGREGATION ERROR ES

We can express the moments of EI_2 according to both models. In both cases, we shall admit that the selection process consists in selecting at random Q groups G_q from a mother-population of N groups G_n which is the lot L. The selection probability P_n of the group G_n is therefore a constant P with :

$$P = Q / N$$

Integration model :

$$m(EI_2) = 0 \qquad \text{(first approximation)}$$
$$\sigma^2(EI_2) = v_{a_2} / Qa_L^2 = \sigma^2(a_q) / Qa_L^2$$

Probabilist model :

$$m(EI_2) = 0 \qquad \text{(first approximation)}$$

$$\sigma^2(EI_2) = \frac{1-P}{P} \sum_n (a_n - a_L)^2 M_n^2 / a_L^2 M_L^2$$

According to the theory of heterogeneity that constitutes the third part of our last book (ref. 3), this latter variance can be written :

$$\sigma^2(EI_2) = \frac{1-P}{P}(1+\xi\gamma)\sum_i (a_i - a_L)^2 M_i^2 / a_L^2 M_L^2 \quad \text{with:}$$

ξ : segregation factor : $0 \leq \xi \leq 1$
  $\xi = 0$ when the distribution is random(or uniform or homogeneous).
  $\xi = 1$ when the distribution is completely segregated (maximum heterogeneity)
γ : grouping factor : $\gamma = (N_L - N) / (N-1)$
  $\gamma = 0$ when $N = N_L$, i.e. when each group contains a single fragment.
  $\gamma > 0$ when $N < N_L$
a_i, M_i : critical content and weight of the fragment F_i.
a_L, M_L : critical content and weight of the lot L.
N_L : number of fragments in L

The product $\xi\gamma$ is always ≥ 0.

The variance $\sigma^2(EI_2)$ is therefore minimum when $\xi\gamma = 0$ which happens in two cases :

1) $\xi = 0$: the distribution is homogeneous,
2) $\gamma = 0$: the fragments are selected one by one.

13.1. Fundamental error EF :It is the minimum value of EI_2.

Its variance is :

$$\sigma^2(EF) = \frac{1-P}{P} \sum_i (a_i - a_L)^2 M_i^2 \;/\; a_L^2 M_L^2$$

This variance is identical to the relative variance of a_E when, according to the probabilist model, the N_L fragments F_i of L are submitted to the selection process with a uniform probability P of being selected.

The fundamental bias is (second approximation):

$$m(EF)_2 = -\frac{1-P}{P} \sum_i (a_i - a_L) M_L^2 \;/\; a_L M_L^2$$

This bias, though non-nil, is always practically negligible (exception : ores of precious minerals or metals).

The name of the fundamental error EF is justified by the fact that out of all the sampling errors, it is the only one that can never cancel out : it is the error that remains when the sampling is carried out under ideal conditions.

For this reason, the fundamental error plays an important part in the sampling strategy which consists in trying to cancel out all the other errors and to minimize the fundamental error. It can be shown that the variance $\sigma^2(EF)$ may be written more simply:

$$\sigma^2(EF) = c\,\ell\,f\,g\,d^3/M_E = Cd^3 / M_E$$

with :

c : "mineralogical factor". It is mathematically defined and can be calculated for each material.

ℓ : "liberation factor" : $0 \leq \ell \leq 1$.
It can be estimated either experimentally or by analogy.

f : "shape factor" : it is always near 0.5.

g : "size distribution factor" :
For non-calibrated materials g = 0.25
For calibrated materials g = 0.50

d : "diameter" of the largest fragments

M_E: sample weight

C : "sampling constant" of the material.

From this equality we may deduce that the fundamental variance is minimum:

- when the sample weight is maximum
- when the material is crushed or ground to the smallest possible size.

It can always be estimated. A slide rule has been devised in order to solve in a matter of a few seconds all problems related to the fundamental error and for instance how to calculate :

- The variance of the fundamental error actually committed :

$$\sigma^2(EF) = Cd^3 / M_E$$

- The sample weight ensuring a given reproducibility standard σ_E^2:

$$M_E \geq \sigma_E^2 / Cd^3$$

- The maximum fragment size ensuring a given reproducibility standard with a given sample weight :

$$d \leq \sqrt[3]{\sigma_E^2 M_E / C}$$

13.2. Segregation error ES.

This error ES is defined as the error whose moments are :

$$m(ES) = m(EI_2) - m(EF)$$

$$\sigma^2(ES) = \sigma^2(EI_2) - \sigma^2(EF) = \xi\,\gamma\,\sigma^2(EF)$$

The tactics are not to estimate ES but to carry out the sampling in such conditions that it is negligible i.e. to reduce the value of ξ, the segregation parameter, by blending the material whenever it is possible and economical to do so and that of γ, the grouping parameter, by taking increments as small as possible

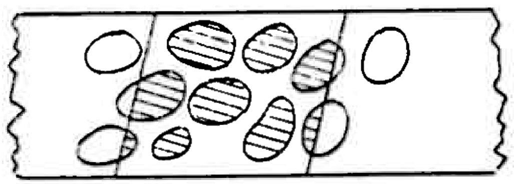
14 - FROM THE INTEGRATION MODEL TO REALITY

We have pointed out the fact that the integration model neglects the particulate nature of the sampled material. Fig.1/6 show how to pass from the "punctual-increment" of the integration model to the "real-increment" actually extracted from the lot :

1 - The integration model applied to the punctual functions generates "punctual-increments":

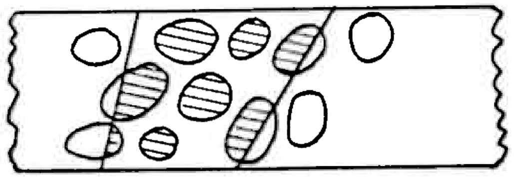
2 - The integration model applied to the smoothed functions generates segmentary increments. Practically equivalent to (1).

3 - The segmentary increments developed in a three-dimension space are transformed in three dimension increments with parallel faces. Strictly equivalent to (2)

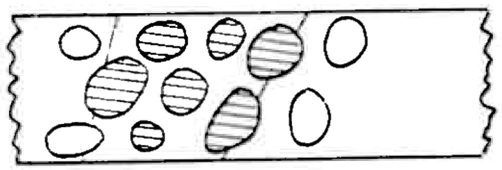


4 - The model-increment actually delimited may differ from the increment with parallel faces. (4) is not necessarily equivalent to (3) and then a delimitation error EC takes place.

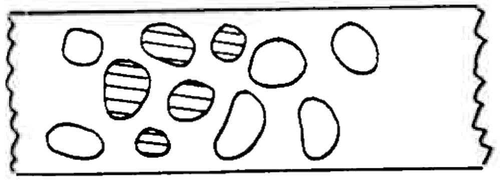
The model-increment does not respect the integrity of fragments, it is defined as the material contained between two surfaces.



5 - The discrete model-increment is derived from the latter according to the "rule of the centre of gravity". All fragments whose centre of gravity falls between the two surfaces delimiting the model-increment belong to the discrete model-increment. (5) is statistically equivalent to (4). The difference between (4) and (5) is taken into account by the fundamental error EF.



6 - The rule of the centre of gravity may be imperfectly followed. For this reason the real-increment may differ from the discrete model-increment, and the extraction error EP takes place.



The real-increment may therefore be affected by two (and only two) kinds of materialization errors not taken into account by the integration model.

- the delimitation error EC,
- the extraction error EP.

Let's denote by :

P_i : the selection probability of F_i. It is the probability of the random event : " F_i falls in the real-sample E_R".

P'_i : the inclusion probability of F_i : It is the probability of the random event : "F_i falls within the limits of the model-sample E_M".

P''_i : the extraction probability of F_i : It is the probability of the random event : "F_i that belongs to the model-sample E_M is actually extracted and falls in the real-sample E_R".

These two latter events being independent:

$$P_i = P'_i \, P''_i$$

The delimitation of the model-sample E_M is said to be correct when for all fragments F_i:

$$P'_i = P = \text{constant}$$

The extraction of the real-sample E_R is said to be correct when, for all fragments F_i :

$$P''_i = 1$$

The materialization is said to be correct when the delimitation and the extraction are both correct. Then, for all fragments F_i :

$$P_i = P = \text{constant}$$

When the delimitation and the extraction are correct, the delimitation and extraction errors EC and EP cancel themelves out, the statistical equivalence between steps (3) and (4) on the one hand and between (5) and (6) on the other hand are therefore taken into account by the fundamental error EF.

The tactics to resort to with the delimitation and extraction errors is therefore to design sampling methods and equipment in such a way that the delimitation and extraction processes be correctly carried out. This is the subject of the two following sections.

15 -CONDITIONS OF A CORRECT DELIMITATION

We shall restrict our demonstration to the flowing streams of materials sampled at the discharge of a conveyor by an intermittent cutter. The delimitation is correct when and only when every element of the cross-section of the stream is intercepted by the cutter with the same sampling ratio, or in other words during the same time. This is achieved when the following conditions are simultaneously fulfilled:

1 - Geometrical conditions :

a) Straight-path cutter : the edges should be parallel.

b) Arc-path cutter : the edges should be radial.

c) Manual cutters : as the path of manual cutters is neither straight nor circular, there is no correct shape of the cutter. Such cutters should be avoided as they are never correct.

d) These geometrical conditions should not be altered by accumulation of material on the cutter edges, by deformation of the cutter or by wear.

2 - Installation of the cutter :

The cutter should be installed in such a way that :

a) It cuts the totality of the stream cross-section.

b) It does not receive materials between cuts (dust for instance).

3 - Speed of the cutter :

The speed of the cutter should be uniform :

a) during each cut

b) from one cut to the next.

These conditions are best achieved with electric drive. The electric motors should be overdimensioned. Hydraulic and pneumatic drives should be avoided.

16 - CONDITIONS OF A CORRECT EXTRACTION

The extraction error takes place when the rule of the centre of gravity is not respected. It is practically respected when and only when the following conditions are simultaneously fulfilled :

1) The cutter edges should be horizontal.

2) The distance W between cutting edges should be larger than a minimum W_o with :

W_o = 3d when d > 3 mm
W_o = 10mm when d ≤ 3 mm

(d is the diameter of the largest fragments).

3) The cutter speed V should not exceed a maximum V'_o with :

$$V'_o = V_o \, W / W_o$$

and

$$V_o = 40 \text{ cm/s}$$

4) The depth of the scoop should be large enough to prevent material from bounding, splashing out or overflowing.

17 - SPLITTING PROCESSES

The theory of splitting processes is simple since usually the sampling error EE is reduced to

$$EE = EI_2 = EF + ES$$

The use of splitting processes is restricted to the sampling of lots small enough or valuable enough to support the cost of handling. With hand methods, the limit today is of a few tons but with mechanical shovels we have seen fractional shoveling applied to lots of 10.000 tons and over.

We shall make a quick review of the most usual splitting methods and devices.

Fractional shoveling : The lot is moved with one or several hand or mechanical shovels. Shovelfuls are extracted from the lot and successively discharged on the top of one of N heaps. At the end of the transfer, one of the N heaps is selected at random and retained as a sample. The sampling ratio is 1 / N. The lot should contain at least 50 N shovelfuls. For very large lots, it is advisable to choose N = 5 or 10. For small lots, with N = 2, fractional shoveling is known as "alternate shoveling". It is the simplest, the cheapest and also, when correctly carried out, the most reliable of all splitting methods. The degenerated method consisting of discharging one shovelful on the top of heap A and N - 1 shovelfuls (N > 2) on the top of heap B may be dangerous in commercial sampling (see below "the notion of equity") and should therefore be used only for technical sampling.

Coning and quartering : It is the ancestor of all sampling methods. Uselessly labour consuming, more costly than fractional shoveling and usually less reliable, this method should be avoided.

Riffle splitter : Everybody knows this device that belongs to the equipment of all sampling laboratories. It is cheap, convenient and reliable when correctly used.

Revolving splitters : Different types of revolving splitters can be used. They are also cheap, convenient and reliable.

The notion of equity : A commercial sampling is said to be "equitable" when the commercial value of the sampled lot, as calculated on the basis of the sample content a_E is a random variable with a mean equal to the value calculated on the basis of the lot content a_L.

The first quality of a commercial sampling is therefore to be equitable.

With the integration process, assuming the value of the lot to be a linear function of the content, the sampling is equitable when and only when it is technically unbiased.

But with the splitting processes we have shown that a sampling could be made equitable even when it is technically biased.

Any true splitting process generating N twin-fractions (N ≥ 2) may be considered as a sequence of two operations :

- a material separation operation generating N fractions. This operation may be and sometimes is biased.

- A selection of the fraction that will be retained as a sample.

If this selection is made at random, the splitting is equitable even when technically biased. If the selection is not random (for instance when retaining always the right bucket of a riffle splitter) the splitting is equitable only when it is technically unbiased.

The bias may have two different origins :

- technical defect of the splitter or unintentional mistake of the sampling operator,

- Intentional alteration of the sample content by the operator (for instance, when carrying out a hand splitting method, by helping the large fragments in or out of the sample).

When a random selection is carried out after the separation of the fractions, any intentional alteration of the splitting correctness will turn with equal probabilities to the advantage or to the disadvantage of the cheat.

18 - PREPARATION ERRORS EZ

Preparation errors are not sampling errors but they usually arise in sampling stations and are usually due to the sampling operator. They belong to five main types :

EZ_1 : loss of particles belonging to the sample (e.g. dust or material remaining in the sampling circuit after the operation).

EZ_2 : contamination of the sample by foreign material (e.g. external dust or material remaining in the sampling circuit before the operation ; rust or any material resulting from the corrosion or abrasion of the machinery in contact with the sampled material).

EZ_3 : alteration of the critical characteristic to be measured on the final sample : loss of critical constituent (e.g. when sampling for moisture, loss of moisture by exposure of the sample to a heat source; when sampling for the content in native sulphur, loss of sulphur by drying at a temperature higher than room temperature) ; external addition of critical constituent (e.g. when sampling for moisture, storage of the sample under the rain or in a damp atmosphere) ; destruction of a critical constituent (e.g. when sampling for the proportion of a coarse size class, breaking of coarse fragments during the handling operations) ; alteration of a non-critical constituent (e.g. loss of water belonging to the crystal lattice of a gangue) ..etc..

EZ_4 : Unintentional mistakes made by a sincere operator (e.g. mixing of sub-samples belonging to different samples ; labeling errors ; dropping of fractions ..etc...)

EZ_5 : Intentional alteration of the characteristic to be measured on the final sample by a dishonest operator. Such "errors" are to be expected only in commercial sampling operations.

In order to prevent errors EZ_1 to EZ_4, sampling should always be carried out by a specialized staff placed under the responsibility of the quality control service (sampling and analysis).

In order to prevent error EZ_5, all steps of a commercial sampling should be conducted in the presence of a qualified and competent representative of the vendor and of the buyer. Moreover, splitting processes should be resorted to as much as possible, without forgetting that equity is a property attached to the random selection of the sample, not to the splitting operation in itself.

19 - CONCLUSIONS

Sampling has always been and still is in many parts of the world the "poor relation" of the mining and metallurgical industries. Teaching courses are practically non-existent except in a handful of Universities. The advice given in the well-known handbooks to be found on the shelves of every mining engineer's or metallurgist's office seem to date back to Agricola's time or to be reproduced from a textbook of Alchemy.

It is not unusual to see in a mine, a processing plant and even a laboratory, sampling operations carried out by unspecialized labour completely unaware of the most elementary rules of sampling.

We recently saw in a North-American country famous for its scientific and technical development, a sampling operator throwing away the slimes of a flotation feed sample and another one, employed in the chemical laboratory, rejecting the oversize of the 100 mesh sieve used for the preparation of the final assay sample. Somewhere else on the same continent we saw a team of well trained specialists applying with wonderful discipline a completely obsolete sampling method that TAGGART considered already fifty years ago as heavily biased and most dangerous. We might multiply the examples.

This situation is worrying. It shows that, with a few exceptions, the people in charge of the mining and metallurgical industries from the general managers down to the young metallurgists are completely unaware and unconscious of the risks attached to sampling.

This is due to the fact that until recently, Universities and Research Centres showed a complete lack of interest in theory of sampling with the result that the teaching of it was practically non-existent.

A few timorous attempts had however been made but they emanated :

- Either from geologists, mining engineers or metallurgists lacking the mathematical background necessary to deal with a subject belonging to the calculus of probability.
- Or from statisticians lacking the indispensable knowledge of the physical properties of the sampled material.

These attempts resulted :

- Either in empirical formulas lacking any scientific basis and very often dangerous.
- Or in correct mathematical formulas involving parameters that could not be experimentally determined or at least estimated in a practical way.

In the various books and papers we published in the course of the last 25 years, we tried :

- To understand the mechanisms generating the sampling errors,
- to estimate the mean and variance of the most important sampling errors,
- to develop practical formulas that can be used by the average mining engineer, geologist or metallurgist,
- to formulate a general strategy which will eliminate a number of errors and maintain the others at an acceptable leval,
- to establish on a scientific basis the rules that should be respected when designing sampling devices and methods,
- to make a census of the insoluble and of the soluble sampling problems,
- in this latter case to indicate the solution that should be retained.

In the present paper we attempted to show the generality of our theoretical approach. We would like the reader, University Professor as well as sampling operator, to understand that sampling is not a simple handling technique where a solution can be improvised on the mere basis of good will and common sense.

Sampling is a science and must be treated as such.

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THE SAMPLING OF PARTICULATE MATERIALS—A GENERAL THEORY

By

PIERRE M. GY

ABSTRACT

This paper is a summary of the general theory of sampling published by the author in 1975.

Sampling is a random process and its theory is a study of the numerous errors liable to take place in the course of its realization.

A complete sampling scheme is a sequence of sampling (proper) and preparation stages :

. At each stage, the total error ET is the sum of :

- Sampling errors EE arising from the selection process itself.
- Preparation errors EZ arising from the operations (crushing, transfer...) supported by the sampled material.

$$ET = EE + EZ$$

. At each sampling stage, the (total) sampling error EE is the sum of seven independent errors :

- Weighting error ED resulting from the non-uniformity of the density or rate-of-flow of the sampled material.
- Integration error EI_1 resulting from the long-range distribution heterogeneity of the sampled material.
- Periodicity error EI_3 resulting eventually from periodic quality variations of the sampled material.
- Fundamental error EF resulting from the constitution heterogeneity of the sampled material.
- Segregation error ES resulting from the local distribution heterogeneity of the sampled material.
- Delimitation error EC resulting eventually from an incorrect shape of the volume delimiting the increments.
- Extraction error EP resulting from the actual extraction of the increments.

$$EE = ED + EI_1 + EI_3 + EF + ES + EC + EP$$

. At each preparation stage, the (total) preparation error EZ is the sum of five independent errors.

- error EZ_1 : loss of particles belonging to the sample.
- error EZ_2 : contamination of the sample by foreign material.
- error EZ_3 : alteration of the critical characteristic to be measured on the final sample.
- Error EZ_4 : unintentional mistakes of the operator (e.g. mixing sub-samples belonging to different samples).
- Error EZ_5 : intentional alteration of the characteristic to be measured on the final sample.

$$EZ = EZ_1 + EZ_2 + EZ_3 + EZ_4 + EZ_5$$

Two complementary models of the sampling process are thoroughly developed to study these errors :

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Original manuscript received 7.7.76

The integration model dealing with the continuous, geometrical properties of the sampled material.

- The probabilist model dealing with the discontinuous, physical properties of the sampled material.

The errors ED, EI$_1$, EI$_3$, EF and ES can be quantitatively defined. Their mean (bias) and variance can be estimated from the result of a variographic experiment.

The errors EC, EP and EZ can only be qualitatively defined. They cannot be experimentally estimated but rules are given making it possible to suppress them and particularly to cancel out the always dangerous sampling biases.

1 - INTRODUCTION

I have been struck by a comment made recently by an Australian friend : "In this country most companies regard sampling as an unavoidable overhead and in many cases they spend as little money as possible on it".

Such a misunderstanding of the random nature of sampling, such a misappreciation of the risks attached to it show how necessary was a symposium on this subject.

The first thing that should be emphasized is that sampling is not a simple mechanical technique like crushing for instance : it is a random process liable to introduce errors such as chemical analysis. But whereas this latter is always carried out in laboratory conditions (I was tempted to say in "aseptic" conditions) by a well-trained specialized staff conscious of the necessity of accuracy and precision, sampling is usually carried out in field or plant conditions by unspecialized labour perfectly unaware of the importance of their work and unconscious of the mistakes to be avoided at any cost.

Sampling and analysis (chemical, size or moisture analysis) are the two complementary links of the quality estimation chain with the consequence that the total estimation error is the sum of the sampling error and of the analysis error.

The optimization of the "accuracy-cost" characteristics of an estimation demands that the same care be taken in sampling and in analysis.

Sampling should always be placed under the responsibility of the head of "quality control", not of the head of "production". It should be carried out by a specialized staff conscious of the numerous errors that may take place and knowing how to suppress or reduce these.

One may judge a crusher or a screen after its mechanical performance, not a sampler : the only touchstone of a sampler is its aptitude to avoid a certain number of errors and to maintain the others at an acceptable level. One may judge the products of a crusher or of ascreen after the results of a simple test easy to carry out : the products contain the proofs of their qualities. This is not true of a sample : after it has been extracted from the lot, there is no way of recognizing a "good" sample from a "bad" one.

But what is a "good" sample and why is this other one "bad" ? It is the object of the sampling theory to answer this apparently simple but really subtle question. The sampling theory is nothing else than a thorough study of the sampling errors.

2 - QUALITIES OF A SELECTION PROCESS

Sampling is a complex selection process. A selection process may be qualified :

- Either in terms of "a priori qualities"
- or in terms of"a posteriori qualities".

. The "a priori qualities" are defined after the conditions of the selection :

- A selection process is said to be "probabilist" whenever each element of the lot is submitted to the selection with a given probability of being selected.

- It is said to be "non-probabilist" whenever it is not founded on the notion of probability. The "hammer and shovel" sampling method, based as it is on a purposive selection of the material destined to the sample, is a non-probabilist method. Such methods are inaccessible to a theoretical approach, they are therefore excluded from our study. They are usually heavily biased and should therefore be rejected.

- A selection process is said to be "correct" whenever all elements of the lot are submitted to the selection with a uniform probability (or density of probability) of being selected.

- It is said to be "incorrect" when, being probabilist, the above condition is not fulfilled.

.The "a posteriori" qualities are based on the results of the selection and more particularly on the statistical properties of the selection error e, relative difference between the critical content a_E of the sample E and the critical content a_L of the sampled lot L:

$$e = (a_E - a_L) / a_L$$

- A selection process is said to be "unbiased" when the mean of the selection error is nil :

$$m(e) = 0 \Leftrightarrow m(a_E) = a_L$$

- It is said to be "biased" when the mean is not nil. The value of the mean is the "bias" B or relative systematical error:

$$B = m(e) \neq 0 \Leftrightarrow m(a_E) \neq a_L$$

It is said to be "reproducible" when the variance of the selection error is not larger than a given"reproducibility standard" σ_0^2 :

$$\sigma^2(e) \leq \sigma_0^2$$

- It is said to be "exact" when the selection error is always nil :

$$m(e) = 0 \quad \text{and} \quad \sigma^2(e) = 0$$

- It is said to be "accurate" when it is at the same time unbiased and reproducible:

$$m(e) = 0 \quad \text{and} \quad \sigma^2(e) \leq \sigma_0^2$$

- It is said to be "representative" when the mean square of the error does not exceed a "representativity standard" R_0^2:

$$m(e^2) = m^2(e) + \sigma^2(e) \leq R_0^2$$

Practically speaking, the only non-utopic objective is representativity. Accuracy and exactitude are reached only at the limit.

The sampling theory may also be regarded as the search for relationships between the conditions and the results of a sampling, i. e. between its "a priori" and its "a posteriori" qualities.

3 - SAMPLING AND HETEROGENEITY

Any fraction of a batch of homogeneous material has the same composition as the batch itself. The sampling of a homogeneous material is therefore an exact selection process, whatever the conditions of sampling.

The fractions that can be extracted from a batch of heterogeneous material don't usually have the same composition as the batch itself. The sampling of a heterogeneous material is therefore a random selection process, generating sampling errors.

All sampling errors must be regarded as a consequence of one form or another of heterogeneity of the sampled material.

This notion of heterogeneity is multiform : we have been able to define and express mathematically :

- The constitution heterogeneity, an intrinsic property of the population of fragments. Blending or segregation has no effect on it.

- The distribution heterogeneity, a property of the fragments distribution throughout the domain occupied by the batch. Blending tends to decrease, segregation tends to increase the distribution heterogeneity.

The mathematical properties of these two forms of heterogeneity have been thoroughly studied and related to one another.

In our theory of sampling we shall have to describe and to characterize the distribution heterogeneity.

We shall use three descriptive functions:

- $a(X)$: an indicative function taking the value 1 when the point X falls within a domain occupied by the "critical component" (component taken more particularly into consideration, e.g. a valuable mineral) and the value 0 when the point X falls within a domain occupied by a non-critical component (including the voids between solid particles).
- $\nu(X)$: a weighting function taking the value of the specific gravity of the component present at point X (zero when X falls in the interstitial voids).
- $\alpha(X) = a(X)\,\nu(X)$

The functions $a(X)$, $\nu(X)$ and $\alpha(X)$ are punctual-functions. When the point X is replaced by a small domain D_c centered in X, we obtain the smoothed-functions" $a_c(X)$, $\nu_c(X)$ and $\alpha_c(X)$:

- $a_c(X)$ is the "critical content" (proportion of critical component) of $D_c(X)$.
- $\nu_c(X)$ is the average specific gravity of the material contained in $D_c(X)$.
- $\alpha_c(X) = a_c(X)\,\nu_c(X)$

But we never know the analytical expression of the functions $a(X)$ and $\nu(X)$. Experience shows that a given material, for instance the feed to a processing plant or to a smelter, possesses stable variability properties that may be characterized by means of the "variogram functions".

Let's denote by :

$y(X)$: any function of the point X and for instance $a(X)$, $\nu(X)$ or $\alpha(X)$. In order to make the demonstration easier, we shall suppose that we are considering the sampling of a flowing stream of material at the discharge end of a conveyor belt, for instance and that X is a point on the time-axis.

θ : a time interval

$\Delta_y(X,\theta)$: the increase of the $y(X)$ function between the instants $X - \theta/2$ and $X + \theta/2$:

$\Delta_y(X,\theta) = y(X+\theta/2) - y(X-\theta/2)$

$v_y(\theta)$: the half mean square of $\Delta_y(X,\theta)$ calculated throughout the domain D_L occupied by the lot L (D_L represents here the duration of the flow).

$$v_y(\theta) = \frac{1}{2(D_L - \theta)} \int_{D_L} \Delta_y^2(X,\theta)\,dX$$

$v_y(\theta)$ is called the "variogram of (X)". It can often be represented by a linear function such as :

$$v_y(\theta) = v_{y1}\theta + v_{y2}$$

where v_{y1} and v_{y2} are the "variographic parameters". They can be experimentally determined (variographic experiment).

We shall see later on that the moments of several sampling errors can be expressed by means of the variographic parameters. The variographic experiment is therefore the key to the practical estimation of the sampling errors.

4 - ANALYSIS OF THE SAMPLING PROCESSES

Sampling (wide meaning) is usually an alternation of preparation stages (crushing, grinding, drying, blending, transfer...etc...) and of sampling stages proper (solid weight reduction), both susceptible of altering the critical content and therefore generating.

- preparation errors EZ (section 18)
- sampling errors EE (sections 5 to 17)

Then, the total error ET is :

$$ET = EE + EZ$$

Any probabilist sampling stage can be reduced to one of the two following processes :

- increment sampling process (weight reduction ratio usually between 10^{-4} and 10^{-2}).
  Prototype : cutting of a stream at the discharge end of a conveyor)
- Splitting process (weight reduction ratio between 10^{-2} and 0.5)
  Prototype : sampling by means of a riffles divider.

The former is usually applied to lots of material too heavy to be handled in totality and the latter to lots light enough to be handled.

The logical analysis of these probabilist sampling processes shows that they may be regarded as sequences of elementary operations.

4.1. Increment process :

a) Integration : selection of the "punctual-increments" throughout the domain occupied by the lot according to the "integration law".

b) Increments delimitation : definition of the boundaries of the "model-increments" around the punctual-increments.

c) Increments extraction : actual separation of the material contained in the model-increments, generating the "real-increments".

d) **Reunion** : The "real-sample" is obtained by reunion of the real-increments.

4.2. Splitting process.

a) Fractions delimitation : Geometrical division of the domain occupied by the lot, generating the "model-fractions".

b) Separation : materialization of the geometrical partition, generating the "real-fractions".

c) Selection : choice of the real-fractions that will be retained as "sub-samples"

d) Reunion : The "real-sample" is obtained by reunion of the sub-samples.

These elementary operations (except the reunion) considered either individually or grouped together, may be regarded as single selection processes accessible to a theoretical approach. For instance :

- Integration is a selection process applied to the lot and generating points (the punctual-increments) which, once gathered, constitute the "punctual-sample".
- Integration + increments delimitation is a selection process applied also to the lot and generating volumes (the model-increments) which, once gathered, constitute the "model-sample".
- Increments extraction is a selection process applied to the model-increments and generating groups of fragments (the real-increments) which, gathered, constitute the " real-sample".

From the standpoint of the sampling errors we may consider that the total sampling error EE is the sum of :

- the (total) integration error EI_t
- the error of materialization of the punctual-increments EM

$$EE = EI_t + EM$$

The materialization itself can be broken up into a sequence of two operations :

the increments delimitation and the increments extraction. The materialization error is therefore the sum of two errors :

- the delimitation error EC
- the extraction error EP

$$EM = EC + EP$$

5 - INTRODUCTION TO THE SAMPLING MODELS

The theoretical study of these simple selection processes can be carried out by means of two models :

- the integration model
- the probabilist model

Any batch of material (solid or fluid, compact or particulate) may basically be looked at in two different ways :

- Either as a geometrically continuous medium. A lot of material L is then considered as the set of points belonging to a certain domain D_L of the geometrical space. Each point X is characterized by the values taken by the two functions a(X) and u(X).

The critical content a_L of L (proportion of critical component) is expressed by :

$$a_L = \int_{D_L} a(X)\, u(X)\, dX \Big/ \int_{D_L} u(X)\, dX$$

- Or as a physically discontinuous medium. The lot L is then regarded as a set of particles (atoms, molecules or fragments) surrounded by a passive medium (vacuum, air or water). If, for example, L is made of N_L fragments, each fragment F_i is characterized by the values taken by two parameters :

. a_i : the critical content of F_i

. M_i : the weight of F_i

The critical content a_L of L is then expressed by

$$a_L = \sum_i a_i M_i \Big/ \sum_i M_i$$

Both expressions of a_L are equally valid.

. The integration model is the model developed to represent a punctual selection process applied to a geometrically continuous medium. The selection process is characterized by an integration law (e.g. systematic, stratified random or random) and by a selection function g(X) which is the density of selection probability at point X.

. The probabilist model is the model developed to represent a selection process applied to a physically discontinuous medium. The selection process is characterized by a set of selection parameters P_i, the probability of selection of the fragment F_i.

It should be well understood that both perspectives (continuous and discontinuous) and both models (integration and probabilist) are equally valid.

They are not competitive but complementary, exactly in the same way as the various projections of an object on different planes are complementary.

Generally speaking, it may be said that the integration model fits more closely the study of the long-range, large-scale properties of the sampled material. The lot is looked at as through a wide-angle lens in such a way that the discontinuities of the material appear as a fuzzy picture of a continuous material. The integration model is the model developed by MATHERON for the sampling of mineral deposits and we utilize in our theory results obtained by him.

On the other hand, the probabilist model fits more specifically the study of the short-range, small-scale properties of the sampled material. The lot is looked at as through a magnifying lens in such a way that the long-range structure of the distribution of the components are no more perceptible. The probabilist model is a generalization of the equiprobable model that we developed about 25 years ago.

These two models make it possible to study the sampling of any kind of material, solid or fluid, compact or particulate, of mineral, vegetable, animal or synthetic origin. This is why our study may by truly regarded as a general sampling theory fitting all sampling problems.

Now, when developing a model, we are aiming at establishing mathematical relationships between three groups of characteristics :

1 - The data of the problem : These data characterize the constitution and the distribution of the components of the sampled material.

2 - The free parameters : These are the factors on which we can play in order to solve the problem, e.g. type and mechanical characteristics of the sampling method or device.

3 - The appreciation factors : These are especially the mean and the variance of the sampling error or the mean and the variance of the sample critical content.

A sampling problem is said to be "soluble" when such relationships can be derived and when for instance a solution can be proposed meeting a given representativity standard.

It is said to be "insoluble" when such relationships cannot be derived and more generally when errors must be suspected that cannot be taken into account by a model.

A "solution" may be economical or non-economical. In this last case a compromise must be sought between cost and representativity.

For mechanical and economical reasons the sampling of three-dimension lots (extending equally in the three dimensions of space) of particulate materials is to be regarded as insoluble ; the sampling of two-dimension lots (flat heaps of small and nearly constant thickness) is soluble but usually uneconomical ; the sampling of one-dimension lots (especially lots transfered at nearly constant rate of flow on a conveyor belt) is easily soluble and cheap.

For this reason it is always advisable to sample a lot of ore when it is being transferred under the form of a one-dimension object. It is the only reliable kind of sampling. We have carried out and related in our books (see references in appendix) an exhaustive study of the errors liable to occur in this particular case.

6 - DEVELOPMENT OF THE INTEGRATION MODEL

MATHERON developed his model for the three-and two-dimension objects that represent mineral deposits. Our own study covers more especially one-dimension objects such as flowing streams of ore.

Integration laws : We have retained the three most usual integration laws :

- systematic (with random positioning)
- stratified random
- random

The development of the integration model leads for each integration law to the expression of :

- the mean $m(M_E)$, the variance $\sigma^2(M_E)$ and the relative variance $U^2(M_E)$ of the sample weight :

$$U^2(M_E) = \sigma^2(M_E) \,/\, m^2(M_E)$$

- The mean $m(A_E)$, the variance $\sigma^2(A_E)$ and the relative variance $U^2(A_E)$ of the weight of critical component in the sample :

$$U^2(A_E) = \sigma^2(A_E) \,/\, m^2(A_E)$$

- The mean $m(a_E)$ or the relative bias $B(a_E)$ of the critical content of the sample :

$$B(a_E) = [\, m(a_E) - a_L \,] / a_L$$

- The variance $\sigma^2(a_E)$ or the relative variance $U^2(a_E)$ of the critical content of the sample :

$$U^2(a_E) = \sigma^2(a_E) / a_L^2$$

as a function of :

- The characteristics (constitution and distribution) of the sampled material : variographic parameters v_{M1}, v_{M2}, v_{A1}, v_{A2}, v_{a1}, v_{a2}, $\rho(A,M)$ that can be experimentally determined; duration D_L of the flow of L ; weight M_L of L ; critical content a_L of the lot L.
- The characteristics of the integration law (type ; interval θ ; length of strata θ ; number Q of increments, according to the case).
- The characteristics of the increments cutter (width W ; velocity V ; duration of the cut $D_c = W / V$.

6.1. Systematic integration (index 1):

$$m_1(M_E) = M_L\, D_c / \theta \;;\; \sigma_1^2(M_E) = D_L \left[\frac{v_{M1}}{6} + \frac{v_{M2}}{\theta}\right]$$

$$m_1(A_E) = a_L M_L D_c / \theta \;;\; \sigma_1^2(A_E) = D_L \left[\frac{v_{A1}}{6} + \frac{v_{A2}}{\theta}\right]$$

$$B_1(a_E) = U_1^2(M_E) - \rho(A,M)\; U_1(A_E)\; U_1(M_E)$$

$$U_1^2(a_E) = U_1^2(A_E) + U_1^2(M_E) - 2\rho(A,M)U_1(A_E)U_1(M_E)$$

6.2. Stratified random integration (index 2) :

$$m_2(M_E) = M_L D_c/\theta \;;\; \sigma_2^2(M_E) = D_L \left[\frac{v_{M1}}{3} + \frac{v_{M2}}{\theta}\right]$$

$$m_2(A_E) = a_L M_L D_c /\theta \;;\; \sigma_2^2(A_E) = D_L\left[\frac{v_{A1}}{3} + \frac{v_{A2}}{\theta}\right]$$

$$B_2(a_E) = U_2^2(M_E) - \rho(A,M)\; U_2(A_E)\; U_2(M_E)$$

$$U_2^2(a_E) = U_2^2(A_E) + U_2^2(M_E) - 2\rho(A,M)\; U_2(A_E)U_2(M_E)$$

6.3. Random integration (index 3)

$$m_3(M_E) = QM_L D_C/D_L \;;\; \sigma_3^2(M_E) = Q\left[\frac{v_{M1} D_L}{3} + v_{M2}\right]$$

$$m_3(A_E) = Qa_L M_L D_c/D_L \;;\; \sigma_3^2(A_E) = Q\left[\frac{v_{A1} D_L}{3} + v_{A2}\right]$$

$$B_3(a_E) = U_3^2(M_E) - \rho(A,M)\; U_3(A_E)U_3(M_E)$$

$$U_3^2(a_E) = U_3^2(A_E) + U_3^2(M_E) - 2\rho(A,M)U_3(A_E)U_3(M_E)$$

In this latter case it is usually easier to use the results of the classical statistics (index 4).

$$U_4^2(M_E) = U^2(M_q) / Q \;;\; U_4^2(A_E) = U^2(A_q) / Q$$

with $U^2(M_q)$ and $U^2(A_q)$ relative variances of the weight M_q and the critical weight A_q of the increment G_q (q = 1,2, ... Q).

$$U_4^2(a_E) = U_4^2(A_E) + U_4^2(M_E) - 2\rho(A,M)U_4(A_E)U_4(M_E)$$

6.4. Conclusions :

One of the most important results is that for theoretical reasons, the integration is usually biased :

$$m(a_E) \neq a_L$$

even when it is correct, i.e. defined by:

$$g(X) = g_o \text{ throughout } D_L$$
$$g(X) = 0 \text{ outside } D_L$$

This bias is however negligible (smaller than one tenth of the standard deviation) as long as the integration is correct and ceases to be presumably negligible as soon as the integration is incorrect. It cancels itself out, the integration assumed to be correct, when the correlation coefficient between a(X) and ω(X) is equal to zero.

This case includes particularly the following limit cases :

a) $\omega(X) = \omega_o$ = constant throughout D_L
b) $a(X) = a_L$ = constant throughout D_L

The bias cancels out, the integration being incorrect, when the correlation coefficient between a(X) and the product ω(X) g(X) is nil.

Practically speaking it is of the utmost importance to carry out a correct integration characterized by :

$$g(X) = g_0 = \text{constant throughout } D_L$$
$$g(X) = 0 \quad \text{outside } D_L$$

It depends only on our good will that this condition be satisfied.

7-BREAKING UP OF THE TOTAL INTEGRATION ERROR.

Let's denote by EI_t the total integration error:

$$EI_t = (a_E - a_L) / a_L$$

$m(EI_t) = B(a_E)$ (relative bias committed on a_E)
$\sigma^2(EI_t) = U^2(a_E)$ (relative variance of a_E)

This error depends on the variability of the two functions a(X) and ω(X).

Let's suppose that ω(X) is maintained strictly constant throughout D_L or in other words that the function a(X) is isolated. The critical contents a_L and a_E then become $a_{L'}$ and $a_{E'}$. Let's denote by EI_a the integration error of a(X) :

$$EI_a = (a_{E'} - a_{L'}) / a_{L'}$$

We can define an independent weighting error ED in such a way that :

$$EI_t = ED + EI_a$$
$$m(EI_t) = m(ED) + m(EI_a)$$
$$\sigma^2(EI_t) = \sigma^2(ED) + \sigma^2(EI_a)$$

Now it has been shown that the function a(X) might be broken up into a sum of four terms :

$$a(X) = a_{L'} + a_1(X) + a_2(X) + a_3(X)$$

with

$a_{L'}$: unweighted mean of a(X) throughout D_L

$$a_{L'} = \int_{D_L} a(X)\, dX / D_L$$

$a_1(X)$: regional term carrying the long-range, large-scale non-periodic variations of a(X).

$a_2(X)$: local term carrying the short-range, small-scale variations of a(X) tied especially to the particulate nature of the sampled material and to the stochastic nature of the particles distribution.

$a_3(X)$: periodic term carrying the eventual periodic variations of a(X).

These terms may be regarded as representing phenomena independent of one another, with the consequence that the integration error EI_a may be considered as the sum of three independent integration errors EI_1, EI_2 and EI_3 corresponding respectively to the terms $a_1(X)$, $a_2(X)$ and $a_3(X)$.

We can therefore break up EI_t and its moments into sums of four independent terms.

$$EI_t = ED + EI_1 + EI_2 + EI_3$$
$$m(EI_t) = m(ED) + m(EI_1) + m(EI_2) + m(EI_3)$$
$$\sigma^2(EI_t) = \sigma^2(ED) + \sigma^2(EI_1) + \sigma^2(EI_2) + \sigma^2(EI_3)$$

8 - PROPERTIES OF THE WEIGHTING ERROR ED

a) The weighting bias m(ED) is negligible whenever the integration is correct.

b) The weighting variance σ^2(ED) is :

. negligible when the fluctuations of ω(X) do not exceed ± 10%.

. acceptable when the fluctuations of ω(X) do not exceed ± 20%

c) Practically speaking, it is always advisable to regulate the rate-of-flow of sampled material in order to reduce the weighting variance to an acceptable level. Regulation by weight is always more efficient than regulation by volume which is anyway better than no regulation at all.

9 - PROPERTIES OF THE INTEGRATION ERROR EI_1 OF THE REGIONAL TERM

a) The integration bias $m(EI_1)$ is nil when the integration is correct (first approx.)

b) The integration variance $\sigma^2(EI_1)$ can be expressed for the three usual integration laws :

$\sigma_1^2(EI_1) = v_{a1}\theta^2/6D_L a_L^2$; $\sigma_2^2(EI_1) = v_{a1}\theta^2/3D_L a_L^2$

$\sigma_3^2(EI_1) = v_{a1}D_L/3Qa_L^2 = Q\sigma_2^2(EI_1) = 2Q\sigma_1^2(EI_1)$

c) Practically speaking : When the variographic parameter v_{a1} is known from a reliable experiment, it is always possible to calculate values of θ or Q satisfying a given standard σ_E^2:

- For a systematic integration :
  $\theta \leq \theta_1 = \sigma_E a_L \sqrt{6D_L / v_{a1}}$
- For a stratified random integration
  $\theta \leq \theta_2 = \sigma_E a_L \sqrt{3D_L / v_{a1}}$
- For a random integration
  $Q \geq Q_0 = v_{a1}D_L / 3\sigma_E^2 a_L^2$

When the variographic parameter v_{a1} is unknown, experience shows that with the usual distributions the integration variance $\sigma^2(EI_1)$ is always acceptable when θ < 10 mn and when $Q \geq 50$ (systematic integration).

10 - PROPERTIES OF THE INTEGRATION ERROR EI_2 OF THE LOCAL TERM

a) The integration bias $m(EI_2)$ is nil when the integration is correct (first approx.)

b) The integration variance $\sigma^2(EI_2)$ can be expressed as a function of the variographic parameter v_{a2} :

$$\sigma_1^2(EI_2) = \sigma_2^2(EI_2) = \sigma_3^2(EI_2) = v_{a2}\theta / D_L a_L^2 = v_{a2} / Qa_L^2$$

c) The local term $a_2(X)$ reflects the discontinuous properties of the particulate material. The probabilist model has been developed in order to analyse the content of the variance $\sigma^2(EI_2)$. We shall see in section 13 how this variance can be expressed as a function of the characteristics of the particulate material being sampled and how EI_2 can be split up into a sum of two errors :

$$EI_2 = EF + ES$$

11 - PROPERTIES OF THE INTEGRATION ERROR EI_3 OF THE PERIODIC TERM

Experience shows that periodic variations are more frequent than is usually thought. The term $a_3(t)$ may be regarded as the sum of a certain number of terms of the general form :

$a_3(t) = a_3 \sin 2\pi t/T + a_3' \cos 2\pi t/T$

with a_3, a_3' constants and T period of the phenomenon

a) The integration bias $m(EI_3)$ is nil when the integration is correct and when $D_L = kT$ (with k integer).

b) The integration variance $\sigma^2(EI_3)$ is very complex. Its maximum is reached with a systematic integration when the interval θ is a multiple of the period T. Then $\sigma_1^2(EI_3)_{max} = (a_3^2 + a_3'^2) / 2a_L^2$. For a stratified random integration, the maximum is : $\sigma_2^2(EI_3)_{max} = (a_3^2 + a_3'^2) / 2Qa_L^2$. The risk is Q times smaller with the stratified random integration which is in any case the safest solution.

12 - DEVELOPMENT OF THE PROBABILIST MODEL

The probabilist model is the theory of a selection process applied to fragments or small groups of fragments. In this model the lot L is considered as a set of N groups G_n of N_n fragments (n = 1, 2, ..N). N_n may eventually be uniformly equal to unity . Then, $N = N_L$, number of fragments in L. These groups are regarded as indissociable batches taking part individually and independently in the selection process with a probability P_n of being selected.

If the group G_n is characterized by its weight M_n and its critical content a_n, the moments of the critical content a_E of the sample are (first approximation = index 1) :

$m(a_E)_1 = \sum_n a_n M_n P_n / \sum_n M_n P_n = a_0 \neq a_L$

the selection process is biased :

$\sigma^2(a_E)_1 = \sum_n (a_n - a_0)^2 M_n^2 P_n(1-P_n) / (\sum_n M_n P_n)^2$

When the selection is correct, i.e. when the N values of P_n are uniformly equal to P :

$m(a_E)_1 = \sum_n a_n M_n / \sum_n M_n = a_L$; $B(a_E)_1 = 0$

the selection is unbiased but only in first approximation. In second approximation (index 2):

$$B(a_E)_2 = -\frac{1-P}{P}\sum_n (a_n - a_L) M_n^2 / a_L M_L^2$$

this bias is not nil but usually negligible.

$$\sigma^2(a_E)_1 = \frac{1-P}{P}\sum_n (a_n - a_L)^2 M_n^2 / a_L^2 M_L^2$$

The bias cancels itself out when there is no correlation between the distributions of a_n and M_n. This case covers particularly the two following cases :

- All M_n are equal
- All a_n are equal

In this last case, the selection process is exact.

Three problems can be solved by means of the probabilist model :

- analysis of the integration error EI_2,
- increments delimitation error EC,
- increments extraction error EP.

13 - ANALYSIS OF THE INTEGRATION ERROR EI_2 - FUNDAMENTAL ERROR EF AND SEGREGATION ERROR ES

We can express the moments of EI_2 according to both models. In both cases, we shall admit that the selection process consists in selecting at random Q groups G_q from a mother-population of N groups G_n which is the lot L. The selection probability P_n of the group G_n is therefore a constant P with :

$$P = Q / N$$

Integration model :

$m(EI_2) = 0$ (first approximation)

$\sigma^2(EI_2) = v_{a2} / Qa_L^2 = \sigma^2(a_q) / Qa_L^2$

Probabilist model :

$m(EI_2) = 0$ (first approximation)

$$\sigma^2(EI_2) = \frac{1-P}{P}\sum_n (a_n - a_L)^2 M_n^2 / a_L^2 M_L^2$$

According to the theory of heterogeneity that constitutes the third part of our last book (ref. 3), this latter variance can be written :

$$\sigma^2(EI_2) = \frac{1-P}{P}(1+\xi\gamma)\sum_i (a_i - a_L)^2 M_i^2 / a_L^2 M_L^2$$ with:

ξ : segregation factor : $0 \leq \xi \leq 1$
  $\xi = 0$ when the distribution is random (or uniform or homogeneous).
  $\xi = 1$ when the distribution is completely segregated (maximum heterogeneity)

γ : grouping factor : $\gamma = (N_L - N) / (N-1)$
  $\gamma = 0$ when $N = N_L$, i.e. when each group contains a single fragment.
  $\gamma > 0$ when $N < N_L$

a_i, M_i : critical content and weight of the fragment F_i.

a_L, M_L : critical content and weight of the lot L.

N_L : number of fragments in L

The product $\xi\gamma$ is always ≥ 0.

The variance $\sigma^2(EI_2)$ is therefore minimum when $\xi\gamma = 0$ which happens in two cases :

1) $\xi = 0$: the distribution is homogeneous,
2) $\gamma = 0$: the fragments are selected one by one.

13.1. Fundamental error EF :It is the minimum

value of EI_2.
Its variance is :

$$\sigma^2(EF) = \frac{1-P}{P} \sum_i (a_i - a_L)^2 M_i^2 / a_L^2 M_L^2$$

This variance is identical to the relative variance of a_L when, according to the probabilist model, the N_L fragments F_i of L are submitted to the selection process with a uniform probability P of being selected.
The fundamental bias is (second approximation):

$$m(EF)_2 = -\frac{1-P}{P} \sum_i (a_i - a_L) M_i^2 / a_L M_L^2$$

This bias, though non-nil, is always practically negligible (exception : ores of precious minerals or metals).

The name of the fundamental error EF is justified by the fact that out of all the sampling errors, it is the only one that can never cancel out : it is the error that remains when the sampling is carried out under ideal conditions.

For this reason, the fundamental error plays an important part in the sampling strategy which consists in trying to cancel out all the other errors and to minimize the fundamental error. It can be shown that the variance $\sigma^2(EF)$ may be written more simply:

$$\sigma^2(EF) = c\,\ell\, f\, d^3/M_E = Cd^3 / M_E$$

with :
c : "mineralogical factor". It is mathematically defined and can be calculated for each material.
ℓ : "liberation factor" : $0 < \ell \leq 1$.
It can be estimated either experimentally or by analogy.
f : "shape factor" : it is always near 0.5.
g : "size distribution factor" :
For non-calibrated materials g = 0.25
For calibrated materials g = 0.50
d : "diameter" of the largest fragments
M_E: sample weight
C : "sampling constant" of the material.

From this equality we may deduce that the fundamental variance is minimum:

- when the sample weight is maximum
- when the material is crushed or ground to the smallest possible size.

It can always be estimated. A slide rule has been devised in order to solve in a matter of a few seconds all problems related to the fundamental error and for instance how to calculate :

- The variance of the fundamental error actually committed :

$$\sigma^2(EF) = Cd^3 / M_E$$

- The sample weight ensuring a given reproducibility standard σ_0^2:

$$M_E \geq \frac{1}{\sigma_0^2}\, Cd^3$$

- The maximum fragment size ensuring a given reproducibility standard with a given sample weight :

$$d \leq \sqrt[3]{\sigma_0^2 M_E / C}$$

13.2. Segregation error ES.

This error ES is defined as the error whose moments are :

$$m(ES) = m(EI_2) - m(EF)$$
$$\sigma^2(ES) = \sigma^2(EI_2) - \sigma^2(EF) = \xi\,\gamma\,\sigma^2(EF)$$

The tactics are not to estimate ES but to carry out the sampling in such conditions that it is negligible i.e. to reduce the value of ξ, the segregation parameter, by blending the material whenever it is possible and economical to do so and that of γ, the grouping parameter, by taking increments as small as possible

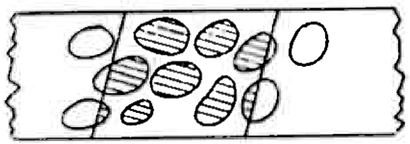
14 - FROM THE INTEGRATION MODEL TO REALITY

We have pointed out the fact that the integration model neglects the particulate nature of the sampled material. Fig.1/6 show how to pass from the "punctual-increment" of the integration model to the "real-increment" actually extracted from the lot :

1 - The integration model applied to the punctual functions generates "punctual-increments":

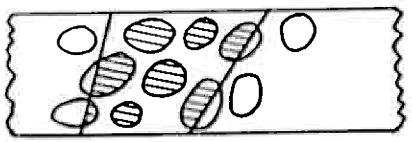
2 - The integration model applied to the smoothed functions generates segmentary increments. Practically equivalent to (1).

3 - The segmentary increments developed in a three-dimension space are transformed in three dimension increments with parallel faces. Strictly equivalent to (2)

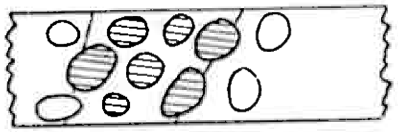


4 - The model-increment actually delimited may differ from the increment with parallel faces. (4) is not necessarily equivalent to (3) and then a delimitation error EC takes place.

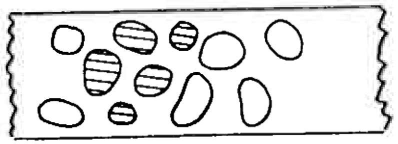
The model-increment does not respect the integrity of fragments, it is defined as the material contained between two surfaces.



5 - The discrete model-increment is derived from the latter according to the "rule of the centre of gravity". All fragments whose centre of gravity falls between the two surfaces delimiting the model-increment belong to the discrete model-increment. (5) is statistically equivalent to (4). The difference between (4) and (5) is taken into account by the fundamental error EF.



6 - The rule of the centre of gravity may be imperfectly followed. For this reason the real-increment may differ from the discrete model-increment, and the extraction error EP takes place.



The real-increment may therefore be affected by two (and only two) kinds of materialization errors not taken into account by the integration model.

- the delimitation error EC,
- the extraction error EP.

Let's denote by :

P_i : the selection probability of F_i. It is the probability of the random event :
" F_i falls in the real-sample E_R".

P'_i : the inclusion probability of F_i : It is the probability of the random event :
"F_i falls within the limits of the model-sample E_M".

P''_i : the extraction probability of F_i : It is the probability of the random event :
"F_i that belongs to the model-sample E_M is actually extracted and falls in the real-sample E_R".

These two latter events being independent:

$$P_i = P'_i\, P''_i$$

The delimitation of the model-sample E_M is said to be correct when for all fragments F_i :

$$P'_i = P = \text{constant}$$

The extraction of the real-sample E_R is said to be correct when, for all fragments F_i :

$$P''_i = 1$$

The materialization is said to be correct when the delimitation and the extraction are both correct. Then, for all fragments F_i :

$$P_i = P = \text{constant}$$

When the delimitation and the extraction are correct, the delimitation and extraction errors EC and EP cancel themelves out, the statistical equivalence between steps (3) and (4) on the one hand and between (5) and (6) on the other hand are therefore taken into account by the fundamental error EF.

The tactics to resort to with the delimitation and extraction errors is therefore to design sampling methods and equipment in such a way that the delimitation and extraction processes be correctly carried out. This is the subject of the two following sections.

15 -CONDITIONS OF A CORRECT DELIMITATION

We shall restrict our demonstration to the flowing streams of materials sampled at the discharge of a conveyor by an intermittent cutter. The delimitation is correct when and only when every element of the cross-section of the stream is intercepted by the cutter with the same sampling ratio, or in other words during the same time. This is achieved when the following conditions are simultaneously fulfilled:

1 - Geometrical conditions :

a) Straight-path cutter : the edges should be parallel.

b) Arc-path cutter : the edges should be radial.

c) Manual cutters : as the path of manual cutters is neither straight nor circular, there is no correct shape of the cutter. Such cutters should be avoided as they are never correct.

d) These geometrical conditions should not be altered by accumulation of material on the cutter edges, by deformation of the cutter or by wear.

2 - Installation of the cutter :

The cutter should be installed in such a way that :

a) It cuts the totality of the stream cross-section.

b) It does not receive materials between cuts (dust for instance).

3 - Speed of the cutter :

The speed of the cutter should be uniform :

a) during each cut

b) from one cut to the next.

These conditions are best achieved with electric drive. The electric motors should be overdimensioned. Hydraulic and pneumatic drives should be avoided.

16 - CONDITIONS OF A CORRECT EXTRACTION

The extraction error takes place when the rule of the centre of gravity is not respected. It is practically respected when and only when the following conditions are simultaneously fulfilled :

1) The cutter edges should be horizontal.

2) The distance W between cutting edges should be larger than a minimum W_o with :

$W_o = 3d$ when $d > 3$ mm

$W_o = 10$mm when $d \leq 3$ mm

(d is the diameter of the largest fragments).

3) The cutter speed V should not exceed a maximum V'_o with :

$$V'_o = V_o \, W / W_o$$

and

$$V_o = 40 \text{ cm/s}$$

4) The depth of the scoop should be large enough to prevent material from bounding, splashing out or overflowing.

17 - SPLITTING PROCESSES

The theory of splitting processes is simple since usually the sampling error EE is reduced to

$$EE = EI + EF + ES$$

The use of splitting processes is restricted to the sampling of lots small enough or valuable enough to support the cost of handling. With hand methods, the limit today is of a few tons but with mechanical shovels we have seen fractional shoveling applied to lots of 10.000 tons and over.

We shall make a quick review of the most usual splitting methods and devices.

Fractional shoveling : The lot is moved with one or several hand or mechanical shovels. Shovelfuls are extracted from the lot and successively discharged on the top of one of N heaps. At the end of the transfer, one of the N heaps is selected at random and retained as a sample. The sampling ratio is 1 / N. The lot should contain at least 50 N shovelfuls. For very large lots, it is advisable to choose N = 5 or 10. For small lots, with N = 2, fractional shoveling is known as "alternate shoveling". It is the simplest, the cheapest and also, when correctly carried out, the most reliable of all splitting methods. The degenerated method consisting of discharging one shovelful on the top of heap A and N - 1 shovelfuls (N > 2) on the top of heap B may be dangerous in commercial sampling (see below "the notion of equity") and should therefore be used only for technical sampling.

Coning and quartering : It is the ancestor of all sampling methods. Uselessly labour consuming, more costly than fractional shoveling and usually less reliable, this method should be avoided.

Riffle splitter : Everybody knows this device that belongs to the equipment of all sampling laboratories. It is cheap, convenient and reliable when correctly used.

Revolving splitters : Different types of revolving splitters can be used. They are also cheap, convenient and reliable.

The notion of equity : A commercial sampling is said to be "equitable" when the commercial value of the sampled lot, as calculated on the basis of the sample content a_E is a random variable with a mean equal to the value calculated on the basis of the lot content a_L.

The first quality of a commercial sampling is therefore to be equitable.

With the integration process, assuming the value of the lot to be a linear function of the content, the sampling is equitable when and only when it is technically unbiased.

But with the splitting processes we have shown that a sampling could be made equitable even when it is technically biased.

Any true splitting process generating N twin-fractions ($N \geq 2$) may be considered as a sequence of two operations :

- a material separation operation generating N fractions. This operation may be and sometimes is biased.
- A selection of the fraction that will be retained as a sample.

If this selection is made at random, the splitting is equitable even when technically biased. If the selection is not random (for instance when retaining always the right bucket of a riffle splitter) the splitting is equitable only when it is technically unbiased.

The bias may have two different origins :

- technical defect of the splitter or unintentional mistake of the sampling operator,

- Intentional alteration of the sample content by the operator (for instance, when carrying out a hand splitting method, by helping the large fragments in or out of the sample).

When a random selection is carried out after the separation of the fractions, any intentional alteration of the splitting correctness will turn with equal probabilities to the advantage or to the disadvantage of the cheat.

18 - PREPARATION ERRORS EZ

Preparation errors are not sampling errors but they usually arise in sampling stations and are usually due to the sampling operator. They belong to five main types :

EZ_1 : loss of particles belonging to the sample (e.g. dust or material remaining in the sampling circuit after the operation).

EZ_2 : contamination of the sample by foreign material (e.g. external dust or material remaining in the sampling circuit before the operation ; rust or any material resulting from the corrosion or abrasion of the machinery in contact with the sampled material).

EZ_3 : alteration of the critical characteristic to be measured on the final sample : loss of critical constituent (e.g. when sampling for moisture, loss of moisture by exposure of the sample to a heat source; when sampling for the content in native sulphur, loss of sulphur by drying at a temperature higher than room temperature) ; external addition of critical constituent (e.g. when sampling for moisture, storage of the sample under the rain or in a damp atmosphere) ; destruction of a critical constituent (e.g. when sampling for the proportion of a coarse size class, breaking of coarse fragments during the handling operations) ; alteration of a non-critical constituent (e.g. loss of water belonging to the crystal lattice of a gangue) ..etc..

EZ_4 : Unintentional mistakes made by a sincere operator (e.g. mixing of sub-samples belonging to different samples ; labeling errors ; dropping of fractions ..etc...)

EZ_5 : Intentional alteration of the characteristic to be measured on the final sample by a dishonest operator. Such "errors" are to be expected only in commercial sampling operations.

In order to prevent errors EZ_1 to EZ_4, sampling should always be carried out by a specialized staff placed under the responsibility of the quality control service (sampling and analysis).

In order to prevent error EZ_5, all steps of a commercial sampling should be conducted in the presence of a qualified and competent representative of the vendor and of the buyer. Moreover, splitting processes should be resorted to as much as possible, without forgetting that equity is a property attached to the random selection of the sample, not to the splitting operation in itself.

19 - CONCLUSIONS

Sampling has always been and still is in many parts of the world the "poor relation" of the mining and metallurgical industries. Teaching courses are practically non-existent except in a handful of Universities. The advice given in the well-known handbooks to be found on the shelves of every mining engineer's or metallurgist's office seem to date back to

Agricola's time or to be reproduced from a textbook of Alchemy.

It is not unusual to see in a mine, a processing plant and even a laboratory, sampling operations carried out by unspecialized labour completely unaware of the most elementary rules of sampling.

We recently saw in a North-American country famous for its scientific and technical development, a sampling operator throwing away the slimes of a flotation feed sample and another one, employed in the chemical laboratory, rejecting the oversize of the 100 mesh sieve used for the preparation of the final assay sample. Somewhere else on the same continent we saw a team of well trained specialists applying with wonderful discipline a completely obsolete sampling method that TAGGART considered already fifty years ago as heavily biased and most dangerous. We might multiply the examples.

This situation is worrying. It shows that, with a few exceptions, the people in charge of the mining and metallurgical industries from the general managers down to the young metallurgists are completely unaware and unconscious of the risks attached to sampling.

This is due to the fact that until recently, Universities and Research Centres showed a complete lack of interest in theory of sampling with the result that the teaching of it was practically non-existent.

A few timorous attempts had however been made but they emanated :

- Either from geologists, mining engineers or metallurgists lacking the mathematical background necessary to deal with a subject belonging to the calculus of probability.

- Or from statisticians lacking the indispensable knowledge of the physical properties of the sampled material.

These attempts resulted :

- Either in empirical formulas lacking any scientific basis and very often dangerous.

- Or in correct mathematical formulas involving parameters that could not be experimentally determined or at least estimated in a practical way.

In the various books and papers we published in the course of the last 25 years, we tried :

- To understand the mechanisms generating the sampling errors,

- to estimate the mean and variance of the most important sampling errors,

- to develop practical formulas that can be used by the average mining engineer, geologist or metallurgist,

- to formulate a general strategy which will eliminate number of errors and maintain the others at an acceptable leval,

- to establish on a scientific basis the rules that should be respected when designing sampling devices and methods,

- to make a census of the insoluble and of the soluble sampling problems,

- in this latter case to indicate the solution that should be retained.

In the present paper we attempted to show the generality of our theoretical approach. We would like the reader, University Professor as well as sampling operator, to understand that sampling is not a simple handling technique where a solution can be improvised on the mere basis of good will and common sense.

Sampling is a science and must be treated as such.

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ed. Hauser, D.M./Park, W.C.
in process mineralogy
Am. Inst. Min. Met. 1981

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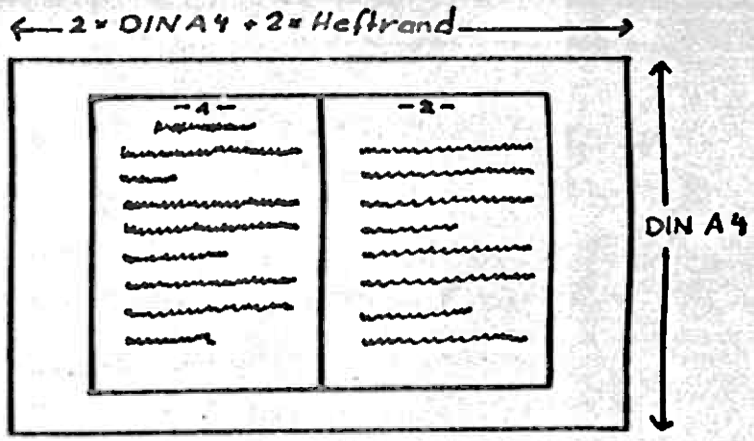

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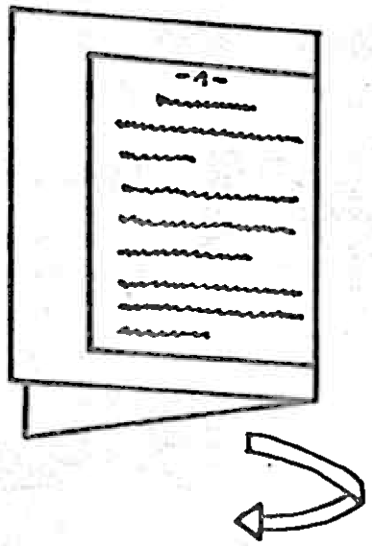

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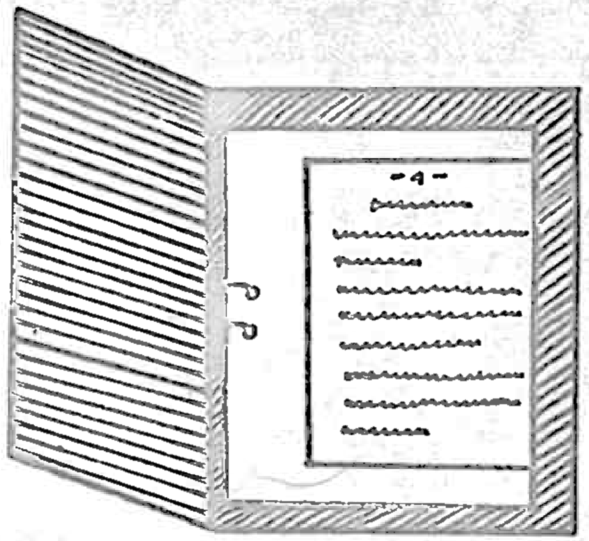

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SOME MINERALOGICAL APPLICATIONS FOR INVESTIGATIONS OF GOLD IN GEOLOGICAL AND METALLURGICAL SAMPLES

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In gold exploration and metallurgical testing, the role of the mineralogist is to assist in solving problems with regard to (a) sampling, (b) gold occurrences, and (c) petrologic classifications of host rocks.

The presence of "coarse" gold as a sampling problem can be overcome by various methods, including "screen fire assays," screened analyses and special gravity techniques which may be used to determine distributions of "coarse" versus fine gold.

Determinations of mineralogic associations of gold usually require special separation techniques, accompanied by fire-AA-mineralogic assays of the products. After accurate mineralogic analyses are obtained for various products, quantitative distributions of refractory gold associations can be calculated by the use of simultaneous equations.

Petrologic classifications are required by the geologist for mapping and interpretation of the various rocks. After the petrology and mineralogic differences of the rock units are determined, x-ray diffraction analyses of analytical pulps can be used for lithologic logging of drill cores. XRD logging is an efficient method for correlating lithologic units and alteration trends throughout a gold prospect.

Introduction

The role of the mineralogist in gold exploration is intertwined between the needs of the geologist and those of the metallurgist, beginning with the earliest days of exploration and testing and continuing into the actual operation of the mine and plant. The intention of this paper is to demonstrate the use of mineralogic techniques during the initial phases of surface sampling, preliminary metallurgical testing, and drilling of a gold prospect.

The mineralogist's responsibility is to characterize mineralized and barren samples in as quantitative a manner as possible. Typical questions asked of the mineralogist are: "What is the distribution of coarse versus fine gold?", "How is the gold associated with certain minerals (i.e., sulfides, ferruginous oxides, quartz, etc.)?", and "What are the petrologic characteristics of the rock types?".

Properties with gold assays of only several parts per million may become a commercial ore. To evaluate such low values can be difficult, since gold associations are often diverse in occurrence. Determinations may require assays of special separation products, followed by tedious calculations and interpretations of the results. The separation techniques discussed in this paper are applicable for highly complex ores, and the data obtained are only qualitative to semiquantitative at best. A more quantitative technique is the application of simultaneous equations (1) to products of known mineralogy.

A problem of special significance to the exploration geologist is the petrologic characteristics of rock types and their relationships to gold mineralization. Some of the conventional petrographic techniques are described. In addition, a brief description of lithologic classifications of ore types by x-ray diffraction is provided.

"Coarse Gold" Problem

Problems for sampling and assaying of gold are usually attributed to the following:

(a) The presence of "coarse gold",

(b) Low concentrations of only several parts per million may be ore,

(c) Sporatic or inhomogeneous occurrences.

"Coarse gold" is a loosely used term which is often applied to ore samples where precise assays cannot be obtained. The presence of nonhomogeneously "coarse gold" can result in erroneous results by conventional assaying techniques. By placer terminology (2), "coarse gold" is any gold particle that is retained on a ten mesh screen, for which the size openings are 1.65 mm. However, due to its high density of 12.5 to 19.3, serious segregation problems can occur when gold sizes are as fine as 0.10 to 0.15 mm, which approximate standard sieve sizes of 150 and 100 mesh, respectively.

In the field, "coarse gold" is suspected if a single particle is detected by the naked eye or by a low-power hand lens. During the initial phases of exploration, five to ten-pound samples are submitted to the laboratory for gold assays as random chips from outcrops. The mineralogist should solve the problem of identifying coarse gold in the samples submitted

from the field.

For assaying of suspected coarse gold, the "screen fire assay" technique is used. This technique was described by Fulton and Sharwood (3) as early as 1929 for the analysis of metallics. Applied to gold assaying, the total sample is crushed and pulverized, so that all but a maximum of sixty grams passes a 100 mesh sieve. All of the plus 100 mesh and one assay-ton samples of two splits from the minus 100 mesh fraction are fire assayed. The resulting gold assays are weighted for a calculated head assay and the amount of coarse gold retained on the 100 mesh screen. However, the amount of gold retained on 100 mesh can be exaggerated if the gold is locked with gangue.

If more than 25 percent of the gold is suggested to be "coarse" by "screen fire assay", more detailed studies are recommended. This is expecially true for samples assaying less than 0.1 oz/t gold. Two techniques are described below for a 200-pound sample which was collected from weathered outcrop. The whole sample was crushed to pass 10 mesh. Five pounds were split out for screen fire assay, which indicated the sample to contain 0.037 oz/ton gold, of which 25.9 percent was retained on the 100 mesh screen, suggesting a coarse gold problem.

At that time, 0.037 oz/ton gold was considered sub-economic for heap leaching. The following questions were asked:

1. Is the 0.037 oz/t gold assay valid?
2. How much of the total gold is truly coarse?
3. What will be the minimum size sample required for assay?

To resolve the above questions, additional five and ten-pound splits were removed for detailed screen analyses and for tabling tests, respectively.

Distributions of Gold by Screened Analyses

For samples of bedrock gold,* as opposed to placer gold, a considerable proportion of fine gold can be retained on the coarser fractions as lockings with other minerals.

The five pounds of minus 10 mesh material were screened on a 45 mesh sieve (0.350 mm). The oversize was reduced to pass 45 mesh. Screened fractions were classified into -45/+65, -65/+100, -100/+150, -150/+200, and -200/+325 and -325 mesh sizes. The minus 325 mesh fraction was further separated into sands and slimes by sedimentation and decantation. According to microscopic evaluation of sands and slimes, there was a distinct separation of grain sizes, so that the sands contained gangue particle sizes of 0.015 to 0.044 mm and the slimes consisted of sizes less than 0.015 mm. After drying, all fractions were weighed, then assayed for gold, resulting in data shown in Table I.

Data in Table I suggest falsely that most of the gold may be coarse. Calculated gold distributions show that 40.8 percent of the gold is in the plus 100 mesh fractions and 55.6 percent in the plus 150 mesh fractions.

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* Host rocks containing gold.

There is no doubt that a certain proportion of the gold is coarse, especially in the -45/+65 mesh fraction, which assayed 0.075 oz/t. However, fine gold lockings also occur in the coarse fractions. The weighted average for gold in the four finest fractions (-150/+200, -200/+325, -325 sands, -325 slimes) is 0.028 oz/ton. If this value is subtracted from gold assays for the three coarse fractions, then recalculated on a weighted basis, the results suggest that 21.8 percent is coarser than 0.105 mm and 78.4 percent is finer.

Epoxy mounts were prepared of the three coarse fractions to evaluate the gold microscopically. Coarse gold was not detected. However, gold concentrations were of such low values that insufficient gold particles were observed microscopically for absolute confirmation.

Table I. Gold Assays and Distributions for Screened Fractions

Sieve Ranges(mesh)	Size Ranges(mm)	Wt % of Fractions	Au oz/t	Au Dist(%)		
- 45/+ 65	0.350-0.208	6.2	0.075	12.9	40.8	55.6
- 65/+100	0.208-0.149	21.8	0.046	27.9		
-100/+150	0.149-0.105	15.7	0.034	14.8		
-150/+200	0.105-0.074	11.9	0.031	10.2		
-200/+325	0.074-0.044	11.9	0.024	8.0		
-325 Sands	0.044-0.015	11.0	0.033	10.1		
-325 Slimes	<0.015*	21.5	0.027	16.1		
Calculated Head		100.0	0.036	100.0		
Assayed Head		100.0	0.037	100.0		

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* Particle sizes estimated microscopically.

Gravity Separations of Screened Fractions

For confirmation of the distribution of coarse versus fine gold, screened fractions were passed over a Deister shaking table. Ten pounds of the minus 10 mesh materials were screened on 28 mesh. The oversize was ground to pass the 28 mesh sieve. The minus 28 mesh materials were classified into fractions of -28/+150, -150/+325 and minus 325 mesh. As before, the minus 325 mesh was separated into sands and slimes.

The -28/+150 and -150/+325 fractions were passed over the table. It was assumed that the coarse gold would be concentrated as tabled concentrates and the fine gold would occur in the tabled tailings. Even if gold is free from gangue lockings, fine gold of less than 0.02 mm will report to the tabled tails. All fractions, including the minus 325 mesh products, were weighed then submitted for gold assays, resulting in data shown in Table II.

A maximum of 24.3 percent of the gold is coarser than 0.105 mm in size. However, there is a suggestion that some of the gold approaches 0.105 mm in size, as indicated by an assay of 0.12 oz/t in the tabled concentrate for the -150/+325 mesh fraction; up to 28.0 percent of the gold may be near 0.105 mm or greater, according to these data.

Table II. Gold Assays and Distributions for Tabled Products

Products	Inferred Sizes of Gold (mm)	Wt % of Product	Au oz/ton	Au Dist(%)
-28/+150 Mesh				
Tabled Concentrate	0.589-0.105	2.5	0.35	24.3
Tabled Tailings	<0.105	30.3	0.024	20.2
-150/+325 Mesh				
Tabled Concentrate	0.105-0.044	1.1	0.12	3.7
Tabled Tailings	<0.044	29.1	0.033	26.7
-325 Mesh				
Sands	<0.044	25.5	0.020	14.2
Slimes	<0.044	11.5	0.034	10.9
Calculated Head		100.0	0.036	100.0
Assayed Head		100.0	0.037	100.0

The test was repeated to obtain products for microscopic evaluation of the gold. Retabled concentrates from the -28/+150 and -150/+325 mesh fractions were upgraded by separating in a liquid with a specific gravity of 2.8. The sink products were mounted in epoxy, then ground and polished for microscopic evaluation.

Mounts were completely traversed microscopically. When a gold particle was encountered, its measurements and associations with other minerals were noted. After traversing, the epoxy mount was reground to expose a new surface and polished, and the traverses were repeated.

A total of 29 gold particles were observed in the -28/+150 mesh concentrate. Two were coarse, measuring 0.18 and 0.19 mm across the maximum dimension. All remaining particles were considerably less than 0.10 mm, but were locked with coarser hematite and quartz.

In the -150/+325 mesh concentrate, 13 gold particles were detected. None exceeded 0.060 mm in size and all were included in coarse hematite and quartz.

A weighted average for fine gold in all fractions except the -28/+150 mesh tabled concentrate was calculated to be 0.028 oz/t. This was subtracted from the assayed value of 0.35 oz/t in the -28/+150 mesh fraction, after which the amount of coarse gold was calculated. According to these calculations, 22.4 percent of the gold is coarse, comparing with 21.8 percent coarse gold by simple screened analyses. This is slightly less than the 25.9 percent coarse gold indicated by the "screen fire assay" technique.

Minimum Sample Size Requirements

Calculations were made for the screened analyses in accordance with a method prescribed by Clifton, et al (4), who indicate that any sample which contains twenty particles of gold is sufficient for assay. The amount of sample which contains twenty particles is based on the particle diameter of the gold and the assay of a particular screened fraction. This, of course, does not take into account that a certain proportion of the gold is finer than the screen size, because it is locked with other minerals.

The effective diameter (De) was calculated from the screened analyses according to Gy's equation:

$$D_e = \left(\sum_j \frac{M_j}{M} d_j{}^3\right)^{1/3}$$

where:

M_j = mass of gold in sized fraction (in micrograms)

M = total mass of gold in sample

$d_j{}^3$ = midpoint of the sized fraction

Applying the effective diameter (0.17 mm) and the calculated head of 0.036 oz/t gold for the screened fractions to Clifton's method, a minimum sample size of 100 grams is required for assay of this particular sample.

Summary of Results

In answer to (1) the validity of the gold assay provided by the initial "screen fire assay", (2) the distributions of coarse gold, and (3) minimum sample size, the data from the various performed tests are summarized in Table III.

Table III. Summary of Data

	Screen Fire Assay	Screened Analyses	Tabled Screened Fractions
Head Assays (oz/t)	0.037	0.036	0.036
Coarse Gold Distributions (%)	25.9	21.8	22.4
Minimum Sample Size for Assay (gms)		100.0	

The amount of sample used for screen fire assay approaches or exceeds the calculated minimum sample size of 100 grams. From 30 to 60 grams of plus 100 mesh and 60 grams (two, one assay ton splits), or from 90 to 120 grams are assayed by the screen fire assay technique. The safeguard is that most of the coarse gold is concentrated on the plus 100 mesh sieve for fire assay.

Associations of Gold With Other Minerals

Due to low values, microscopic detection of gold occurrences and associations with other minerals is not always possible. Mineral separations are usually required to obtain various concentrates for gold assays and mineralogic studies. Some of the common techniques used for various mineral separation products include (a) flotation, (b) gravity, and (c) magnetic techniques. One or more of these techniques is utilized, depending on the nature of the problem and characteristics of the ore.

This section of the paper describes the use of these techniques and the interpretations of the gold associations, accompanied by calculations. In addition, the use of simultaneous equations (1) is demonstrated to evaluate associations of refractory gold with certain minerals.

Flotation

If gold is suspected to be free or locked with sulfides, flotation tests are conducted. Flotation produces a small fraction containing free particles of native gold, microscopically-visible gold lockings with sulfides and submicroscopic gold inclusions in the sulfides.

A simple example of the use of flotation is described here. A pyrite cleaner concentrate, a cleaner tailing and scavenger tailings were produced from a sample which assayed 0.042 oz/t gold. Small amounts of each flotation product were removed for microscopic examination and the remaining portions were submitted for gold assays which, together with calculated distributions, are shown in Table IV.

Table IV. Gold Assays and Distributions

Flotation Products	Wt % of Products	Au oz/ton	Au Dist(%)	Semiquant. Mineralogy(Wt %) Pyrite	Arseno-pyrite	Chalco-pyrite	Gangue
Cleaner Concentrate	0.18	21.03	86.8	85	1	1	13
Cleaner Tail	0.67	0.27	4.1	2	-	-	98
Scavenger Tail	99.15	0.004	9.1	Tr	-	-	100
Calculated Head	100.00	0.044	100.0				
Assayed Head	100.00	0.042	100.0				

Although the sample assayed only 0.042 oz/t gold, the cleaner concentrate assayed 21.03 oz/t, representing 86.8 percent of the total gold. Collectively, 90.9 percent of the gold was recovered in the cleaner concentrate and cleaner tailing, which together collectively comprise only 0.85 percent of the weight of the total sample. The scavenger tail assayed 0.004 oz/t gold, accounting for 9.1 percent of the gold, which probably occurs mostly as lockings with gangue silicates.

Microscopic examination of the cleaner concentrate and cleaner tailing revealed that most of the gold occurred as fine but microscopically-visible inclusions in pyrite. Particle sizes of the locked gold ranged from 0.005 to 0.025 mm, although several free gold particles measured approximately 0.05 mm. After regrinding of the cleaner concentrate and cleaner tailing, cyanidation removed 92 percent of the gold.

Two factors indicated that very little, if any, of the gold was submicroscopic, these being (a) the high 21.03:0.04 concentration ratio achieved, and (b) none of the microscopically visible gold was less than 0.005 mm in size.

Combination of Flotation - Heavy Liquid - Frantz Separations

A composite of three ore types (unoxidized, highly oxidized, and moderately oxidized ores), which contained an average of 0.278 oz/t gold, was separated into numerous products by flotation, heavy liquid separations and a Frantz Isodynamic separator. By microscopic counting techniques, the sample contained two percent pyrite and four percent hematite. Semiquantitative x-ray diffraction analysis indicated the gangue minerals to be quartz (44%), calcite (23%), dolomite (7%), illite (15%) and kaolin (5%).

The sample was floated to recover the pyrite in a cleaner concentrate and a cleaner tail. The rougher tail was deslimed, producing sands and slimes fractions. The sands were passed through a Frantz Isodynamic separator at a magnetic field strength of nearly 13,000 gauss to remove most of the hematite in a magnetics fraction. Frantz nonmagnetics were further separated by acetylene tetrabromide, which has a specific gravity of 2.96. Most of the remaining pyrite and hematite was recovered in the sink fraction, while quartz, calcite, dolomite, illite and kaolin were in part collected in the light mineral fraction. A partially successful attempt was made to separate quartz from the carbonates in this float product by diluting the acetylene tetrabromide to a specific gravity of 2.68 so that quartz would float and the carbonates would sink.

All separation products were weighed. Small amounts of each were removed for preparation into epoxy mounts to be examined microscopically for gold occurrences and for microscopic counting analyses to determine percentages of pyrite, hematite and gangue.

Remaining portions were pulverized for semiquantitative mineralogic analyses by x-ray diffraction and for gold assays. Gold assays and distributions and the mineralogic data are compared in Table V. In addition, qualitative microscopic observations for gold occurrences are shown.

Except for the flotation cleaner concentrate and Frantz magnetics, all other separation products are relatively impure. Nevertheless, the following semiquantitative to qualitative statements can be made about the gold occurrences:

1. Highest concentrations of gold occur in the flotation cleaner concentrate (3.23 oz/t), representing 29.1 percent of the gold and consisting largely of pyrite (80%). For a product of such high gold concentrations, only three gold particles were observed microscopically, suggesting that a certain proportion of the gold is submicroscopically associated with pyrite and would probably be refractory to cyanidation.

2. Relatively high gold concentrations also occur in the Frantz magnetics (1.85 oz/t), occurring largely as hematite (65%) and accounting for 44.1 percent of the gold. In this product nineteen fine gold particles were detected microscopically, suggesting that most of the gold associations with hematite are microscopically visible and probably amenable to cyanidation.

3. The flotation cleaner tail and heavy mineral fraction contain intermediate gold values of 0.28 oz/t and 0.42 oz/t, respectively. While relatively small pyrite

Table V. Gold Assays and Distributions, Semiquantitative Mineralogy and Gold Occurrences in Separation Products for a Composite Ore Sample

Products	Wt% of Products	Au oz/t	Au Dist(%)	Pyrite[1]	Hematite[1]	Quartz[2]	Calcite[2]	Dolomite[2]	Illite[2]	Kaolin[2]	Gold Occurrences[3]
Flotation Cleaner Conc.	2.5	3.23	29.1	80	1	8	3	2	5	1	3 Free Particles (0.01-0.025mm).
Flotation Cleaner Tail	4.6	0.28	4.6	6	Tr	51	18	5	15	5	None detected.
Flotation Scavenger Tail											
Slimes	28.2	0.041	4.2	Tr	Tr	30	18	3	35	14	None detected.
Sands											
Frantz Magnetics	5.6	1.85	44.1	Tr	65	15	10	5	5	Tr	1 Free (0.030mm), 18 with Hematite (0.003-0.015mm).
Frantz Nonmagnetics											
>2.96 Sp.G.	6.4	0.42	5.8	2	10	40	28	12	5	3	4 with Hematite (0.002-0.01mm).
2.68-2.96 Sp.G.	18.4	0.036	2.4	Tr	Tr	25	50	15	8	2	None detected.
<2.68 Sp.G.	34.3	0.082	9.8	Tr	Tr	72	15	6	5	2	None detected.
Calculated Head	100.0	0.27	100.0	2	4	44	23	7	15	5	
Assayed Head	100.0	0.28	100.0								

[1] - Determined by microscopic point-counting.
[2] - Semiquantitative XRD analysis.
[3] - Microscopic Evaluation.

(2-6%) and hematite (Tr-10%) values occur in these products, gold contents appear to be associated with these two minerals. Four gold particles were observed in the greater than 2.96 fraction as inclusions in hematite, further indicating the presence of microscopically visible gold with hematite.

4. All other products consist largely of gangue minerals, and gold values are relatively small, ranging from 0.036 oz/t in the "carbonate" concentrate to 0.082 oz/t in the "quartz" concentrate.

On a semiquantitative basis, 83.6 percent of the gold occurs in samples with significant pyrite and/or hematite. However, due to the relative impurity of the products, no concrete associations with the various minerals can be calculated.

Application of Simultaneous Equations

The ideal situation for the above separations would be to cyanide each product for the determination of soluble versus refractory gold. However, due to the treatment of the sample with flotation reagents and the organic heavy liquid (acetylene tetrabromide), the cyanidation of the gold would probably be inhibited. The deleterious effect of flotation collector to cyanidation was described by Finkelstein (5).

The application of simultaneous equations was used by Henley and Stevenson (1) for a variety of cyanided mill products to determine amounts of soluble and refractory gold associated with pyrite, galena and sphalerite.

This section of the paper applies their technique for the evaluation of gold associations in the three ore types which were used in the above study to demonstrate the combined flotation-heavy liquid-Frantz technique.

Three ore types, designated as A, B and C, were cyanided to remove the soluble gold. Epoxy mounts of the leached residues were prepared for microscopic point and gross-counting of pyrite, hematite and gangue. The assays, cyanide extraction data and microscopic counting analyses are shown in Table VI.

Gold extractions progressively increase with increasing oxidation from pyrite to hematite. In the unoxidized Sample A, only 1.8 percent of the gold is soluble, as compared to 95.1 percent in the highly oxidized Sample B and 82.7 percent in the moderately oxidized Sample C. As described previously, microscopically-visible gold is finely included in hematite but none was detected in the unoxidized Sample A. This indicated the following:

1. A certain proportion of gold is submicroscopically associated with pyrite and is refractory to cyanidation.
2. Most of the cyanide-soluble gold is associated with hematite.
3. A portion of the gold is associated with the gangue minerals.

Table VI. Assays, Extraction and Semiquantitative Mineralogy

	Sample A (Unoxidized)	Sample B (Highly) (Oxidized)	Sample C (Moderately) (Oxidized)
Assays and Extractions			
Au Before Cyanidation (oz/t)	0.165	0.41	0.26
Soluble Au After Cyanidation (oz/t)	0.003	0.39	0.215
Insoluble Au After Cyanida. (oz/t)	0.162	0.020	0.045
Cyanide Soluble Au (%)	1.8	95.1	82.7
Cyanide Insoluble Au (%)	98.2	4.9	17.3
Mineralogy (Wt %)*			
Pyrite	4.0	0.2	0.7
Hematite	0.2	8.3	2.2
Gangue	95.8	91.5	97.1

* Determined by microscopic point and gross-counting techniques.

To determine the amount of refractory gold within pyrite, hematite and gangue, simultaneous equations were arranged according to the following:

$$\text{Sample A:}\quad 4.0\,Py + 0.2\,H + 95.8\,G = 100 \times 0.162$$

$$\text{Sample B:}\quad 0.2\,Py + 8.3\,H + 91.5\,G = 100 \times 0.020$$

$$\text{Sample C:}\quad 0.7\,Py + 2.2\,H + 97.1\,G = 100 \times 0.045$$

where: Py, H, and G represent apparent gold contents in pyrite, hematite and gangue, respectively.

Calculation of the equations results in the following:

$$\text{Pyrite} = 3.48 \text{ oz/t gold}$$

$$\text{Hematite} \simeq 0.00 \text{ oz/t gold}$$

$$\text{Gangue} = 0.024 \text{ oz/t gold}$$

The data show that essentially all of the gold was removed from the hematite upon cyanidation. Most of the refractory gold (3.48 oz/t) was assumed to be submicroscopically contained in the pyrite. The gangue minerals contain 0.024 oz/t insoluble gold.

The contained gold within the minerals is used to calculate the gold distributions, as shown in Table VII.

Table VII. Distributions of Gold After Cyanidation

Insoluble Gold	Mineral %**	Contained Au (oz/t)	Calculated Au (oz/t)	Dist.(%)
Pyrite	1.6	3.48	0.056	19.8
Hematite	3.6	0.00	0.00	--
Gangue	94.8	0.024	0.023	8.1
Soluble Gold			0.20	72.1
Totals	100.0		0.279	100.0

** Average of microscopic counts for three samples.

Of the total gold, 72.1 percent was soluble, 19.8 percent occurs with pyrite and 8.1 percent is associated with gangue.

The unoxidized Sample A and moderately oxidized Sample C were oxidized by roasting at 550°C, then cyanided, which removed most of the gold. Since Sample B was already oxidized, it was not roasted. The data for the three samples are summarized in Table VIII.

Table VIII. Data for Oxidized Samples

	Sample A	Sample B[3]	Sample C
Pyrite (%)[1]	0.2	0.2	0.1
Hematite (%)	2.6[2]	8.3	2.6[2]
Gangue (%)	97.3	91.5	97.3
Au Before Roasting & Cyaniding (oz/t)	0.165	0.41	0.26
Insol. Au After Roasting & Cyaniding (oz/t)	0.025	(0.020)	0.045
Cyanide Soluble Au (%)	84.8	95.1	92.3

1 - Calculated from sulfur assays.
2 - Calculated on basis of the oxidation of pyrite to hematite then added to already existing hematite.
3 - Was not roasted because it was already oxidized.

As before, simultaneous equations were solved to determine gold distributions, as shown in Table IX.

Table IX. Distributions of Gold After Roasting and Cyanidation

Insoluble Gold	Mineral%	Contained Au (oz/t)	Calculated Au (oz/t)	Dist (%)
Pyrite	0.2	0.00	0.00	-
Hematite	4.5	0.063	0.003	1.1
Gangue	95.3	0.024	0.023	8.3
Soluble Gold			0.24	90.6
Totals	100.0		0.276	100.0

Oxidation roasting (@550°C) of Samples A and C resulted in 90.6 percent of the gold becoming soluble upon cyanidation. Calculations for unoxidized samples revealed that the gold occurrences with hematite were completely amenable to cyanidation. However, after roasting, 0.063 oz/t remained in the hematite, accounting for one percent of the total gold. The auriferous hematite appears to represent the auriferous pyrite before roasting, suggesting that a small amount of submicroscopic gold was retained in the relic pyrite after cyaniding.

After roasting, refractory gold in gangue remained insoluble to cyanidation. The same amounts of contained gold (0.024 oz/t) occur in the gangue for both the unroasted and roasted cyanide leach residues. Once the sample was roasted, nearly all of the refractory gold was associated with the gangue minerals.

Petrologic Evaluations of Rock Types from Gold Prospects

Rock type classifications and complete mineralogic analyses are important to the geologist for his evaluation of a gold prospect. Petrologic studies of potential gold ores are accomplished by conventional petrographic examination of polished thin sections, accompanied by semiquantitative x-ray diffraction analyses, which are described in this section of the paper. In addition, a technique for lithologic logging of drill cores by x-ray diffraction is described.

Conventional Petrologic Studies

Gold assays for the various petrographically-classified rocks are compared, which usually relays the most favorable rock types for gold mineralization. In addition to aiding the field geologist for mapping, features of alteration can be compared for the more mineralized rocks versus barren types.

A split of minus ten mesh material is mounted in epoxy, then systematically traversed microscopically to search for gold. Minus ten mesh is generally a suitable size for the evaluation of textural associations of gold-gangue lockings. Usually, only a few gold particles are detected, but preliminary information can be gained with regard to gold associations with certain minerals. To confirm the associations, mineral separations can be obtained as described in the previous section.

Lithologic Classifications of Ore Types by Computerized X-Ray Diffraction Techniques

Assay samples from gold prospects are often set aside and forgotten once the analytical results have been obtained. From a cost standpoint, drilling and preparation of assay samples represent a major portion of the exploration budget. For little additional expenditure, additional studies of assayed samples can provide needed information to the field geologist and metallurgist.

X-ray diffraction analyses of assay pulps can be used to characterize an orebody on the basis of mineralogic compositions. A computer technique was developed to convert x-ray diffraction mineralogic data into rock type classifications. This is a rapid, yet quantitative and inexpensive method for classifying large numbers of drill intervals into rock units that can be correlated from hole to hole in an unbiased manner.

The "XRD-computer logging" technique developed by D. M. Hausen and F. Kula of Newmont Exploration Limited (unpublished company report) is demonstrated here for one section along a prospect. Prior to x-ray diffraction analyses, petrographic studies were conducted to obtain an understanding of the major rock types, which included cherts, siltstones, shales, limestones and dolostones or dolomitic limestones. Megascopic field classifications of the drill cores were difficult because the features were often obscured by complex faulting and hydrothermal alteration of the limestones.

Approximately 265 assay samples, each representing 20 feet of drilling composites from 14 drill holes, were analyzed by a Phillips x-ray diffraction unit. The pulps were mounted in standard sample holders, then stamped by the "Peters grid" technique to minimize preferred orientation effects.

Each sample was scanned from 2° to 40°, 2θ, utilizing a rotating sample holder. Measured peak heights for the individual minerals were fed to the computer which classified the rocks into the following lithologies:

Cherts - >70% quartz
Siltstone - 40-70% quartz
Shales - >30% total clays
Limestones - >40% calcite
Dolostones - >40% dolomite

Figure 1 shows lithologic distributions along a northwest-southeast section of the prospect. Anomalous gold values are outlined in two areas at the northwest and one to the southeast. The two anomalous areas at the northwest are generally stratiform, dipping approximately 30° to the southeast, extending in part into primary calcareous lithologies.

The anomalous area to the southeast is irregular in shape for which gold contours display an inverted U-shaped configuration, attributed to an intersection of a nearly vertical fault.

All three anomalous zones display siliceous siltstone and shale lithologies, but silicification is most prominent to the southeast where cherts and highly silicified siltstones occur.

Dolomitic limestones are irregular and discontinuous in distribution, occurring below or immediately adjacent to ore zones. They do not appear to form a continuous primary lithologic unit throughout the prospect.

The XRD mineralogic data for this section indicate the following:

1. Impure calcareous limestones comprise the major primary sequence in the deposit, hosting the gold mineralization adjacent to vertical fault structures.
2. Decarbonitization of limestones has occurred along vertical structures and along select bedding planes, resulting in the alteration of limestones to siltstones and shales in association with gold mineralization.
3. More advanced stages of decarbonitization are accompanied by silicification to form cherts and further silicify the siltstones.
4. Dolomitized zones are irregular, but appear to be in the proximity of gold mineralization.

Conclusions

This paper provides a few examples by which the process mineralogist serves as an intermediate source of information for the field geologist and extractive metallurgist in the exploration and testing of gold ores. Characterization of the ore is important to both, although for different purposes.

"Coarse" gold may pose one of the problems in the sampling of a gold prospect. Data on coarse versus fine gold distributions will aid the

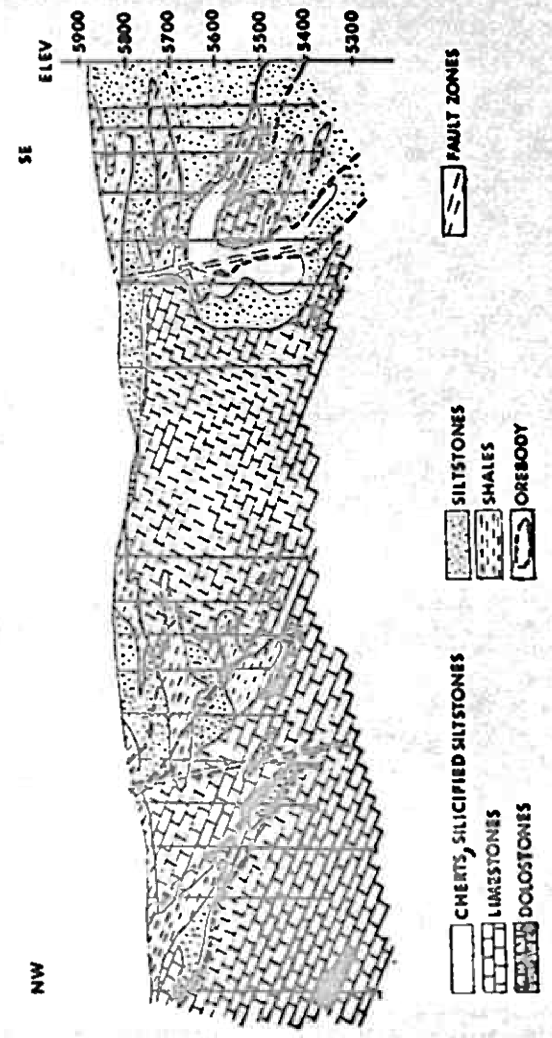

FIGURE 1 – DISTRIBUTION OF ROCK TYPES ALONG A SECTION OF A GOLD OREBODY NEAR CARLIN, NEVADA

geologist in planning his sampling program, revealing minimum sample requirements for accurate assays and can be utilized by the metallurgist to determine if the gold is extractable by cyanidation only, or if prior treatment by gravity techniques will be required. The presence of coarse gold can usually be established by the "screen-fire assay" technique.

On the basis of gold assays and mineralogic evaluation of separation products, gold associations may be defined. The application of simultaneous equations and microscopic counting data to cyanide residues is useful for determining the associations and distributions of refractory gold with certain sulfides or non-opaque minerals. From these data, the metallurgist can decide whether finer grinding or aqueous oxidation methods should be attempted to extract the gold in test work.

Conventional petrographic studies aid the geologist in mapping and understanding of the various rock types, often revealing most favorable host rock units. Once the compositions of the rock units are established, the "XRD-computer logging" technique may be used for numerous drill holes to characterize the orebody and to develop possible alteration trends for additional ore.

Semiquantitative mineralogic compositions developed by the above can be applied by the metallurgist for a better understanding of potentially deleterious components including cyanide consumers or clay minerals that could inhibit settling.

References

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2. J. E. Ranson, The Gold Hunters Field Book, Harper and Row, New York, 1975.
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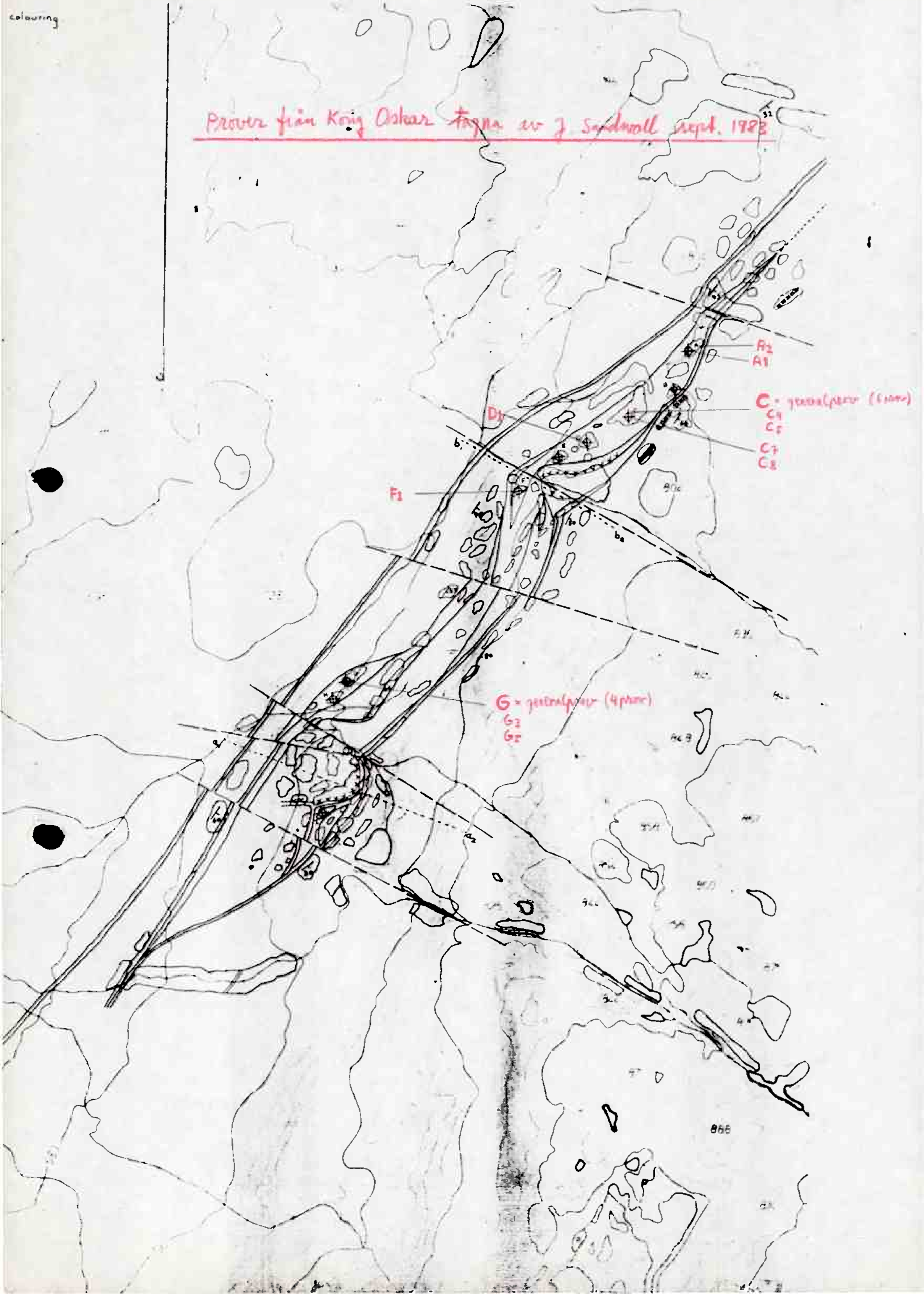
5. N. P. Finkelstein, "The Chemistry of the Extraction of Gold from Its Ores," pp. 284-351 in Gold Metallurgy in South Africa, R. J. Adamson, ed., Cape Town, Chamber of Mines in South Africa, Part II, Chapter 10, 1972.

THE ROLE OF THE PROCESS MINERALOGIST IN THE OPERATION OF MAGMA COPPER COMPANY'S MINE AND PLANT, SAN MANUEL, ARIZONA

W. Mueller
Newmont Exploration Limited
44 Briar Ridge Road
Danbury, Connecticut 06810

The function of a process mineralogist in the operation of a copper mine and plant is to assist in the identification and classification of the operation's main throughput. These include ore, concentrates, slag and matte, and to a lesser extent, refined products. In addition, a number of other products not normally thought of in association with mineralogy are examined. These include scales from submersible pumps, failed boiler tubes, acid plant, and shaft furnace; characterization of inclusions in failed compressor gear teeth as well as in copper rod; and flue dusts from a smelter, air transported particulates and coatings on passive copper anodes in the refinery. Techniques and equipment required for these studies include simple hand magnets to the high intensity Isodynamic separator, visual examination to electron microscopes, x-ray equipment, DTA, IR, heavy liquid separation, and contracted services of custom laboratories. Several examined products from Magma Copper Company have been selected to illustrate the range of techniques and equipment required by a process mineralogist.

colouring



Prover från Kong Oskar fagna av J. Sandvoll sept. 1983

Prover från Kong Oskar tagna av J. Sandwall sept 1983

C generalprov vid skärp C (6 prov tagna i 6 m lång profil)
C4 massiv malm från profil C
C5 —"—

G generalprov vid skärp G (4 prov tagna i 2,4 m lång profil)
G3 massiv malm från profil G
G5 —"—

F1 diss. malm (Py) från skärp F
D1 —"— skärp D
A1 massiv malm (Py) från skärp A
A2 dissmalm (Py) —"—

S.B. A/S

Materialrekvisisjon

AVGIFTSKODE
0 = Avg. fritt
4 = Innvest.avg.høy
5 = Mva. -avgift
7 = Invest.avg. Lav

Bilagsnr.

Priset dato 230784

Resk.nr.

KOSTNADS.... STED	AVD	ART	Avgift	VAREKODE	Enhets-kode	MENGDE BESTILT	MENGDE LEVERT	ENHETS PRIS	SUM	EVENT. LEV. VARENR. / TEKST
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—"—		—"—	4		1	1	1	49/71		Div oppvask midler.
—"—		—"—	4		1	1	1	515/56		Spisebestikk. m/m.
—"—		—"—	4		1	1	1	2894/51		Kjøleskap/kasseroller m/u.
—"—		—"—	4		1	1	1	13/00		Håndklær.

Sulitjelma Samv.lag.

Rekvirent: W. Haldorsen.

Rekv. dato

Sendes til avd.

tør:

Referanse/person:

1=Stk
2=Kilo
5=Par
6=Meter
7=Liter

10=Sett
12=Flasker
14=Tonn
16=Fat
20=Dusin
21=Hektoliter

OTA

Sulitjelma Samvirkelag

Hovedkontor : 8230 Sulitjelma
Telefon : (081) 40 100

vn Sulitjelma Bergverk
lresse Konto 14425
ststed

Debitor nr.	Levert fra avd.	Sign	Fakturanr.	Dato	TK
	6	R.A	11248	21/6.84	

VARESORT	KRONER	ØRE
3 håndklær	14.	40
Kv. 12,00		
REBELØP UTEN MOMS:		
MOMS:		
TOTALBELØP:	14,	40

ITTERING FOR VAREMOTTAK:

W. Haldorsen

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

nløsning:
AR LINDBAK & CO. A/S

IOTA

Sulitjelma Samvirkelag

Hovedkontor : 8230 Sulitjelma
Telefon : (081) 40 100

vn Sulitjelma Bergverk.
Iresse 14425
ststed

Debitor nr.	Levert fra avd.	Sign	Fakturanr.	Dato	TK
	3.	A.H.K.	11481	21/6-84	01

VARESORT	KRONER	ØRE
kasserolle	156	–
12 tallerkener	292	80
1 antenne	123	50
kabel.	71	25
1 kjøleskap	2830	–
Kv. 2894,51		
\REBELØP UTEN MOMS:		
MOMS:		
TOTALBELØP:	3473	55

'ITTERING FOR VAREMOTTAK:

O. Korsvik.

nløsning:
\R LINDBAK & CO. A/S

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

OTA

Sulitjelma Samvirkelag

avn Sulitjelma Bergverk.

dresse ~~14426~~ 14425

ststed

Hovedkontor : 8230 Sulitjelma
Telefon : (081) 40 100

Debitor nr.	Levert fra avd.	Sign	Fakturanr.	Dato	TK
	3	A.M.K.	11479	21/6-84.	01

VARESORT		KRONER	ØRE
2 kjelerist	18/95	37	90
1 fjøl		34	50
plastbolle		24	-
knivSkuff		17	95
Saks		72	-
visp		13	-
litermål		9	-
Stålbeger		31	90
bestikk		362	65
termometer		15	80
REBELØP UTEN MOMS:			
MOMS:	kw. 515,56		
TOTALBELØP:		618	70

ITTERING FOR VAREMOTTAK:

Tore-O. Korsvik

nløsning:
AR LINDBAK & CO. A/S

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

IOTA

Sulitjelma Samvirkelag

Hovedkontor : 8230 Sulitjelma
Telefon : (081) 40 100

avn Sulitjelma
dresse Bergverk
oststed konto 944 25

Debitor nr.	Levert fra avd.	Sign.	Fakturanr.	Dato	TK
	1	Chr	07555	21-6.84	01

VARESORT	KRONER	ØRE
1 fl. oppv. mid.	11.	50
1 skrubb	5.	95
1 oppv. [illegible]	12.	20
2 pk oppv. [illegible]	30.	–
	59.	65
REBELØP UTEN MOMS: W. 49/71		
MOMS:		
TOTALBELØP:	59.	65

ITTERING FOR VAREMOTTAK:

W. Haldorsen

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

nløsning:
AR LINDBAK & CO. A/S

IOTA

Sulitjelma Samvirkelag

vn Sulitjelma Bergverk

lresse 14425

ststed

Hovedkontor : 8230 Sulitjelma
Telefon : (081) 40 100

Debitor nr.	Levert fra avd.	Sign	Fakturanr.	Dato	TK
	3	AMK.	11480	21/6-84	01

VARESORT	KRONER	ØRE
kaffeboks	30	50
Salt og pepper bø-S	18	–
bestikkkasse	12	80
Stekepanne	115	–
egg-glass	30	50
kopper	50	40
glass	34	80
kaffe kjele	298	–
kasserolle	94	50
lokk	32	–
REBELØP UTEN MOMS: kasserolle	247	–
MOMS: kr. 802.89.		
TOTALBELØP:	963	50

ITTERING FOR VAREMOTTAK:

Arne-O. Korvik

mløsning:
AR LINDBAK & CO. A/S

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

IOT

avn

dresse

oststed

S.B. A/S

Materialrekvisisjon

AVGIFTS
0=Avg. fri
4=Innvest
5=Mva. -a
7=Invest.a

Bilagsnr.

Priset dato 230784

Resk.nr.

KOSTNADS... STED	AVD	ART	Avgift	VAREKODE	Enhets-kode	MENGDE BESTILT	MENGDE LEVERT	ENHETS PRIS	SUM	EVENT. LEV. VARENR. / TEKS
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—"—		—"—	4		1	2	2	97/75		Papp a/11m
14471		—"—	4		1	1	1	415/28		Div spise/kokkebestikk
—"—		—"—	4		1	1	1	94/96.		Div spisebestikk
—"—		—"—	4		1	1	1	60/42		—"—

[illegible]

Rekvirent: O. Valle

Rekv. dato

Sendes til avd.

Ekspeditør:

Referanse/person:

1=Stk	10=Sett
2=Kilo	12=Flas
5=Par	14=Ton
6=Meter	16=Fat
7=Liter	20=Dus
	21=Hek

AREBELØP UTEN MOMS: Kr. 2491,58

MOMS:

TOTALBELØP: 2990 —

ITTERING FOR VAREMOTTAK:

Olaug

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

nløsning:
AR LINDBAK & CO. A/S

OTA

Sulitjelma Samvirkelag

vn Sulitjelma Bergverk

Iresse Kontonummer: 14425

ststed 8230 Sulitjelma

Hovedkontor : 8230 Sulitjelma
Telefon : (081) 40 100

Debitor nr.	Levert fra avd.	Sign	Fakturanr.	Dato	TK
	Jern		08796		01

VARESORT	KRONER	ØRE
2 ruller papp (Icopal 1/2 rull)		
á 102,–	204	–
1 boks Icopallim	30	60
	234	60
REBELØP UTEN MOMS: 195,49		
MOMS:		
TOTALBELØP:	234	60

ITTERING FOR VAREMOTTAK:

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

nløsning:
AR LINDBAK & CO. A/S

OTA

Sulitjelma Samvirkelag

vn Sulitjelma Bergverk
resse Kontonummer 1447
ststed 8230 Sulitjelma

Hovedkontor : 8230 Sulitjelma
Telefon : (081) 40 100

Debitor nr.	Levert fra avd.	Sign	Fakturanr.	Dato	TK
	Jern.	A.M.O	07070	28/6-84	01

VARESORT	KRONER	ØRE
1 Kasserolle	82	50
1 Kasserolle	74	80
1 Lokk	24	65
1 Lokk	29	00
1 Kaffekjele	79	50
1 Steikepanne	115	00
1 Kjøkkenkniv	42	00
1 Ostehøvel	22	40
1 plastsleiv	8	40
1 Visp	20	10
REBELØP UTEN MOMS:		
MOMS: Uw 415,28		
TOTALBELØP:	498	35

ITTERING FOR VAREMOTTAK:

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

nlesning:
AR LINDBAK & CO. A/S

OTA

Sulitjelma Samvirkelag

vn Sulitjelma Bergverk
iresse Kontonummer 14471
ststed 8230 Sulitjelma

Hovedkontor : 8230 Sulitjelma
Telefon : (081) 40 100

Debitor nr.	Levert fra avd.	Sign	Fakturanr.	Dato	TK
	Jern	A.Mo	07071	28/6-84	

VARESORT	KRONER	ØRE
1 Boksåpner	6	65
2 Skjeer á 6.90	13	80
2 Kniver á 14.10	28	20
2 Gafler á 6.40	12	80
	61	45
Antenneplugg + Kabel +	52	50
	113	95
REBELØP UTEN MOMS: ✓		
MOMS: Kr 94,96		
TOTALBELØP:		

ITTERING FOR VAREMOTTAK:

A.Waen

nløsning:
AR LINDBAK & CO. A/S

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

OTA

Sulitjelma Samvirkelag

Hovedkontor : 8230 Sulitjelma
Telefon : (081) 40 100

vn Sulitjelma
resse Bergverk
ststed Kon. 144.71

Debitor nr.	Levert fra avd.	Sign	Fakturanr.	Dato	TK
	7	ZH	08751	28/6-81	

VARESORT	KRONER	ØRE
Flagg kritt	20	40
kost	12	20
Bestikk	39	90
REBELØP UTEN MOMS: kr 60.42		
MOMS:		
TOTALBELØP:	72	50

ITTERING FOR VAREMOTTAK:

....

BETALINGSVILKÅR:

Leveringsmåneden + 30 dager. Etter forfall regnes 2 % kontoutg. pr. påbegynt måned fra fakturadato. Selger beholder eiendomsretten til de leverte varer inntil hele kjøpesummen er betalt. Eventuelle reklamasjoner må skje omgående.

nløsning:
AR LINDBAK & CO. A/S

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DATE  9 17
SERIAL NO   4615
INSTR CORR   0.0
BASE INSTR CORR   0.0
BASE STATION FIELD DATUM   ,052.1
BASE STATION LABEL 145 W   00010 N
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PAGE   1

MOBILE

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 LINE  STATION               nT      CORR  FIELD nT      DIFF

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001 SW  00005 NW  15:28:20  52,223.6                    175.8
001 SW  00010 NW  15:28:35  52,155.4                    -68.2
001 SW  00015 NW  15:28:50  52,144.8                    -10.6
001 SW  00020 NW  15:29:00  52,184.3                     39.5
001 SW  00025 NW  15:29:15  52,231.0                     46.7
001 SW  00030 NW  15:29:25  52,356.4  246.1   ,110.3   -120.7
001 SW  00035 NW  15:29:40  52,327.0  245.6   ,081.4    -28.9
001 SW  00040 NW  15:29:50  52,288.5  246.2   ,042.3    -39.1
001 SW  00045 NW  15:30:00  52,287.3  246.3   ,041.0    - 1.3
001 SW  00050 NW  15:30:10  52,298.7  246.2   ,052.5     11.5
001 SW  00055 NW  15:31:35  52,318.9  246.1   ,072.8     20.3
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001 SW  00065 NW  15:32:00  52,258.1  245.9   ,012.2   -219.5
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001 SW  00075 NW  15:32:20  52,218.5                    -27.4
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001 SW  00165 NW  15:36:55  52,266.6  246.3   ,020.3   -211.0
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001 SW  00215 NW  15:39:05  52,230.6                     46.4
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PAGE   2

MOBILE

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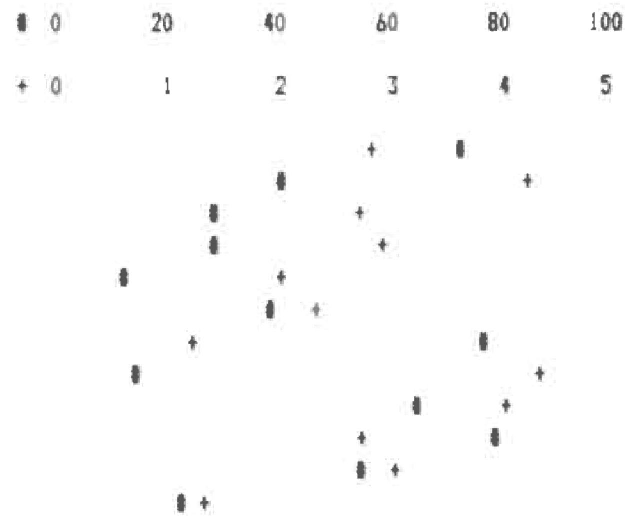
001 SW  00230 NW  15:39:50  52,139.3                    -62.6
002 SW  00300 NW  15:49:55  52,156.8                     17.5
002 SW  00295 NW  15:50:05  52,151.8                    - 5.0
002 SW  00290 NW  15:50:20  52,155.8                      4.0
002 SW  00285 NW  15:50:35  52,201.0                     45.2
002 SW  00280 NW  15:50:50  52,178.8                    -22.2
002 SW  00275 NW  15:51:40  52,163.6                    -15.2
002 SW  00270 NW  15:51:50  52,150.9                    -12.7
002 SW  00265 NW  15:52:00  52,149.8                    - 1.1
002 SW  00260 NW  15:52:10  52,137.3                    -12.5
002 SW  00255 NW  15:52:20  52,147.2                      9.9
002 SW  00250 NW  15:52:30  52,164.6                     17.4
002 SW  00245 NW  15:52:40  52,170.5                      5.9
002 SW  00240 NW  15:52:50  52,173.8                      3.3
002 SW  00235 NW  15:53:00  52,180.9                      7.1
002 SW  00230 NW  15:53:15  52,179.3                    - 1.6
002 SW  00225 NW  15:53:55  52,186.0                      6.7
002 SW  00220 NW  15:54:05  52,167.7                    -18.3
002 SW  00215 NW  15:54:15  52,181.5                     13.8
002 SW  00210 NW  15:54:25  52,215.5                     34.0
002 SW  00205 NW  15:54:40  52,190.3                    -25.2
002 SW  00200 NW  15:54:55  52,178.8                    -11.5
002 SW  00195 NW  15:56:05  52,168.0                    -10.8
002 SW  00190 NW  15:56:15  52,115.9                    -52.1
002 SW  00185 NW  15:56:45  52,164.6                     48.7
002 SW  00180 NW  15:56:55  52,162.2                    - 2.4
002 SW  00175 NW  15:57:05  52,160.0                    - 2.2
002 SW  00170 NW  15:57:15  52,187.4                     27.4
002 SW  00165 NW  15:57:25  52,169.0                    -18.4
002 SW  00160 NW  15:57:40  52,169.3                      0.3
002 SW  00155 NW  15:57:55  52,197.7                     28.4
002 SW  00150 NW  15:58:05  52,183.3                    -14.4
002 SW  00145 NW  15:58:40  52,175.5                    - 7.8
002 SW  00140 NW  15:58:50  52,169.9                    - 5.6
002 SW  00135 NW  15:59:00  52,130.5                    -39.4
002 SW  00130 NW  15:59:10  52,176.9                     46.4
002 SW  00125 NW  15:59:25  52,157.0                    -19.9
002 SW  00120 NW  15:59:35  52,172.4                     15.4
002 SW  00115 NW  15:59:45  52,183.6                     11.2
002 SW  00110 NW  15:59:55  52,146.4                    -37.2
002 SW  00105 NW  16:00:05  52,134.7                    -11.7
002 SW  00100 NW  16:00:15  52,227.5                     92.8
002 SW  00095 NW  16:01:00  52,191.3                    -36.2
002 SW  00090 NW  16:01:10  52,273.5  247.0   ,026.5   -164.8
002 SW  00085 NW  16:01:25  52,368.0  272.6   ,095.4     68.9
002 SW  00080 NW  16:01:35  52,384.0  272.3   ,111.7     16.3
002 SW  00075 NW  16:01:45  52,285.6  272.3   ,013.3    -98.4
002 SW  00070 NW  16:02:00  52,208.4                    195.1
002 SW  00065 NW  16:02:10  52,170.5                    -37.9
002 SW  00060 NW  16:02:20  52,203.5                     33.0
```

PAGE   3

MOBILE

```
   LABEL          TIME      FIELD    BASE  CORRECTED    FIRST     E
 LINE  STATION               nT      CORR  FIELD nT      DIFF

002 SW  00055 NW  16:02:35  52,172.8                    -30.7
002 SW  00050 NW  16:02:45  52,139.2                    -33.6
002 SW  00045 NW  16:04:30  52,127.7                    -11.5
002 SW  00040 NW  16:04:45  52,127.9                      0.2
002 SW  00035 NW  16:05:00  52,112.0                    -15.9
002 SW  00030 NW  16:05:15  52,137.3                     25.3
002 SW  00025 NW  16:05:30  52,076.2                    -61.1
002 SW  00020 NW  16:05:45  52,114.3                     38.1
002 SW  00015 NW  16:05:55  52,164.0                     49.7
002 SW  00010 NW  16:06:10  52,177.7                     13.7
002 SW  00005 NW  16:06:25  52,153.0                    -24.7
002 SW  00000 NW  16:06:40  52,121.3                    -31.7
```



TEGNFORKLARING TIL GEOLOGISK KART

VEDLEGG 1:

🟦	Grå kalkrik skifer (Furulund skifer).
🟩	Øvre Fyllitt.
🟥	Tuff.
⬛	Svartskifer.
🟧	Kvartsitt (omvandlet tuff).
🟦	Kalkrik kvartsitt og skifer.
🟩	Muorkifyllitt

TEGNFORKLARING:

⬭	Blottning.
──	Bergartsgrense.
- - - - -	Bergartsgrense usikker / overgangsmessig.
━━	Forkastning.
━ ━	Knusningssone / sprekkesone, mulig forkastning.
oooooo	Konglomerat.
⊥ 32° ✕ +	Strøk og fall på lagning. (32°, vertikal, horisontal)
⊥ 15	Strøk og fall falsk skifrighet. (15°)
↗ 84°	Strøk og fall for sprekkeflater (84°)
→ 25°	Foldeakse med angitt stupning (25°)
mt	Magnetitt.
py	Svovelkis.
cp	Kopperkis.
sl	Sinkblende.
⚒	Skjerp / Røsking.

"KONG OSKAR"
H.T. MIKKELSEN
1984

I.

S

Emo PROTOKOLLER

Emo oktav nr. 500 - 6 ark - 48 blad linjert

Levert av:

F83

Ved bestilling oppgi:

Emo oktav nr. 500 - 6 ark - 48 blad linjert

Levert av:

Revue Tommen:

🟦 101 Grå kalkrik skifer

🟩 229 ~~Grå skifer~~ m kvartsboudinage

🟨 31 Kvartsitt / tuff

⬛ 8749 Kvartsskifer av og til meget grafittrik

🟩 8733 Grå skifer (~~kvarts glimmerskifer~~

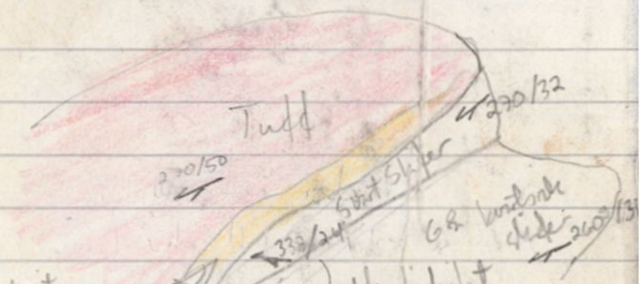
🟥 8729 Kvartsrike båndet b.a som lok ⑤-typen

🟩 8739 Grønnskifer. (fyllitt)
Kvartsbåndet b.a med kvarts-boudinage

↗ Foldeakse med stupning

✗ ⊥ ⊿ Strøk og fall hhv lagning, falde skifrighet og sprekkeflate.

Snitt Lok 4



hvit
lys kvartsitlag
stripig (feltspatisert).

Lok ①

28/6: Borplass (224). Grå, kalkrike skifer. (Velut utviklet) skifrighet. Rustfarge.
Strøk og fall $245^{g}/33^{\circ}$ S-folder

Lok ②. Overgangssone. silikat holdige linser av kvarts i skifer. – boudinage.
Kontakt grå skifer / kvartsgl. skifer. Rustfarge

Lok ③ Kvartsitt. Rustfarge. Bruser ikke for saltsyre. Grå. Rustfarge skyldes
Keratofyraktig – sur tuff. Mye feltspat?
Linser av mer motstandsdyktig materiale.
(kvartsittiske materiale).

tuff
Lok ④ Kontakt (kvartsitt) (tuffaktig) og grå skifer – Kan følges. Falske skifrighet – strøk og fall A ~~$146^{g}/26^{\circ}$~~ $332^{g}/24^{\circ}$
Skifer $270^{g}/32$. Kvartsitt strøk og fall $270^{g}/50$
Kvartsårer langs sprekkeretning ca vinkelrett på strøkretn $368^{g}/?$
Strøk og fall spr. retn: $350^{g}/76^{\circ}$

Lok ④ forts

Den grå til svarte skiferen er grafittrike øverst (svart) og nedover blir den mer grå. kvartsrike. Av og til blir den kvartsigl. skifer (går over i kvartsgl. skifer.

serisitt

og til slutt ~~serisitt~~ båndet kvartsholdig skifer.

⑤ Overgangssone b.a. Båndet m/ kvartsitiske soner. ~~?~~ Meget lett forvitr bar. Går over i serisittskifer

Prøve 1

Serisittskifer (tatt prøver), som sone.

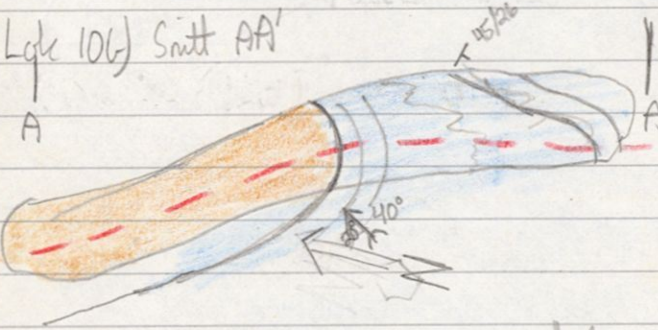
⑥ Tuff - feltspatiske - albittisert? Hvit forvitringshud.

⑦ Gjentett grå skifer grafittholdig
Strøk og fall ∠ 2729/40°

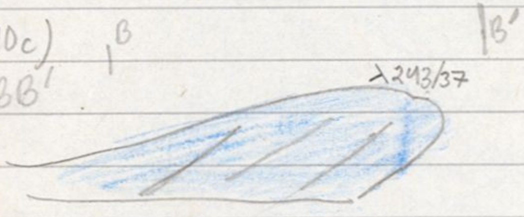
⑧ Myr - hva skjuler dette.
Grå skifer med falske skifrighet ~~?~~ mer erodert?
Kvarts linser i bergart. Bergarten inneslutter svovelkis. Kvarts-boudinage.

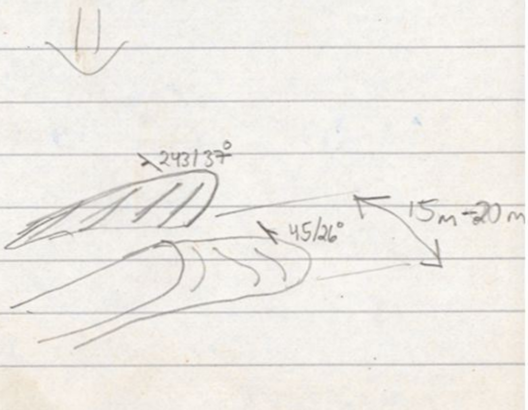
⑨ Kalkrike skifer. (Grønnskifer) båndet

Lok 10b) Snitt AA'



Lok 10c)
Snitt BB'





⑩ Stor-skala folding. Komplisert overfolding. Z- og S-folder i hver sin av to knauser.

⑪ Kvartsitt lys (tuff) ↗ 260°/52°

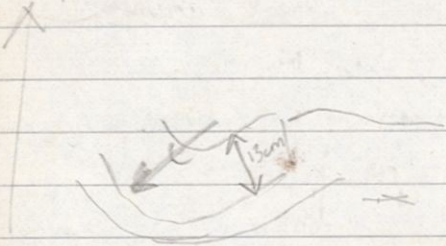
⑫ Stort skjerp. Massiv kis med noe Cu, Zn og svovelkis. 3-4 m mektighet

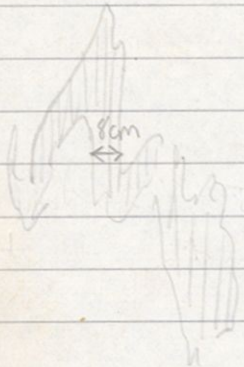
ok 10a) Kalkholdig kvartsittisk b.c. Meget opflet noe som tyder på at materiale er blitt lutet ut.

ok 10b) Stor-skala foldeombøyning (Hinge zone) Foldeaksen stuper 40° i retning 20°, dvs NNØ Se fig - motstående side. Z folder

ok 10c) Kalkholdig skifer. S-folder
∠ 243/37.

profilato





3/7-84 Tåke – dårlig sikt. Regn først på dagen
senere surt og kaldt.

⑬ Kontakt kvartsitt / mørk (gråsvart skifer)
Den mørke skiferen blir mer kvartsitt/
feltspatrik videre bortover langs profilaksen
Observasjon av foldeakse, se fig.
Stup 41° retn 195g (løsblokk?)

⑭ Kontakt grønnskifer / kvartsitt.
Kvartsitten er lys grå middelskornet.
Grønnskiferen er kalkholdig. Videre er
den båndet. ~~Pyrittkrystaller~~
Kvartsitt: ↗ 247g/48°. Kvartsitten er
gjennomsatt av sprekkeflater med retning
og fall ↗ 357g/78°. Kvartsutfellinger
se fig. Kan av og til se ut som folde-
strukturer (konvolute folder).

småbølget over ←
flate (småfoldet).

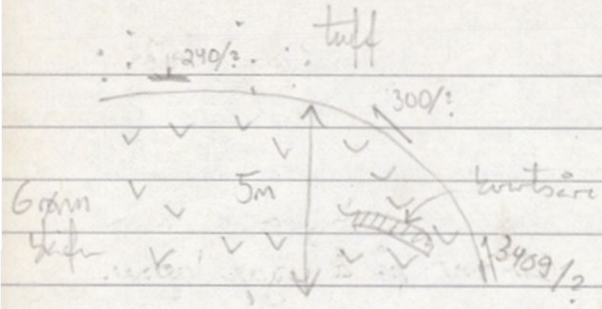
13/7-84

I dag skal grensen mellom vulkansk tilknyttede b.a og grønnskifer gås opp. Været er lettere i dag, dvs litt tåket, men noenlunde brukbar sikt og noe regn.

⑮ Kontakt kvartsitt (tuffaktig) og grønnskifer kan følges ned til myrkanten. Grønnskiferen er båndet med kvartslinser. Den er kalkholdig og inneholder fine pyritt krystaller. Av ytre tegn er den meget ruglet med mange små fordypninger. Kvartsitten er tuffaktig mellom-grå med bittesmå svarte flekker (biotitt?) jevnt dispergert innen bergarten. Kan videre bestå av små linser – nærmest i en tau-struktur

Strøk og fall på kontaktflaten ⊼ 242/42
Kvartsitten er gjennomsatt av kvartsåre ⊼ 345/55. Hovedspr. retn. ⊼ 358/76.

Hvorfor er konglomeratet på feil side på nordsida av myra? Fold!


tuff
240/?
300/?
5m
kvartsåre
Grön tuff
3409/?

⑯ Kontakten kvartsitt? / grønnskifer bøyer av mot myren, se fig.

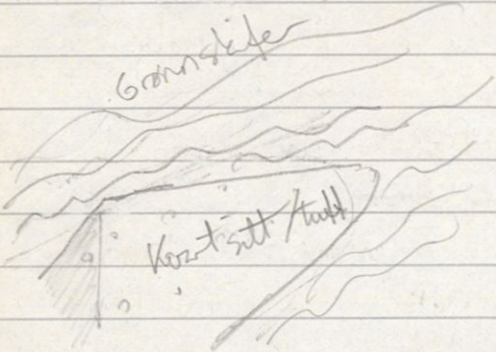
Meget tett tåke - umulig å orientere seg skikkelig. Går over på å logge kjerner.

4/7-84 Tett tåke og regn med dertil dårlig sikt. Valgte å bruke første del av dagen til å logge kjerner. Siste del av dagen vil jeg bruke til å gå opp grønnskifer / vulkanske b.a.-grensen.

ok 17. Kontakt kvartsitt (tuff?) / grønnskifer. Malakitt og kismineralisering. Tatt prøve.

Lok 18. Grense tuff / grønnskifer. Mener å kunne se avbøyning som fold? Retn og stup 397^g/17° stup mot nord

Snitt ØV

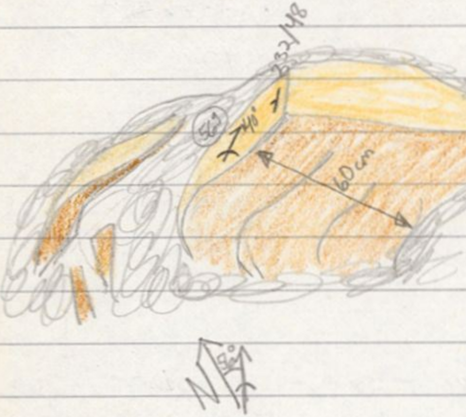


ok ⑲ Ved forkastning(!?) Kule av kvartsitt (tuff) i grønnskifer, se skisse motstående side (Huff nå snør/skypøser det)
Strøk og fall kontaktflate 248°/28°
5/7: Logging av kjerner.
0/7-84 En del av dagen vil bli brukt til å gå opp grensen mellom den grønne skiferen fyllitt) og de vulkanske derivate b.a mot SV, dernest gå opp profil langs borhull 224/225 og logge kjerner.
Været er godt med blå himmel og og sol.

Lok 20 Grense kvartsitt = ~~tuff~~ /, konglomerat / fyllitt (grønn skifer).

ok 21: Grense fyllitt (grønn) og kvartsitt-~~tuff~~ b.a. Observasjon av lukning av fold. → 36°/5° mot nord. Observasjon av S-folder i fyllitt. ∠ 34°/60°. Det er tatt prøve av kvartsitt/tuff begarten.

Lok. 22: Ombøyning fold: Strøkretning og fall: 56^g/26°(?) mot nø



Lok 22: Foldombøyning. Stupretning 56g og 40° (mot nordøst) (Losblokk ?). Ombøyning skjer i skifrig effusiv b.a. ∠ 232g/48°

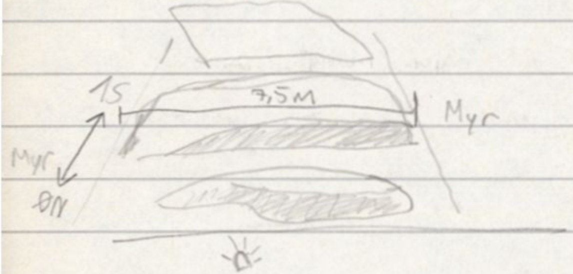
se fig. motst. side

Profil 225

Lok ㉓: Borplass-hull 225: Grå kalkholdig skifer

11/7: Pent vær - vind - grå skyer. Tur til Sulitjelma for å hente nytt sett kart og deler til oppvaskebenk.
Logging av kjerner på ~~etter middagen og~~ kvelden (hull 224)

12/7: Tett tåke og regn. preger været ute. Begynner dagen med å tegne av observasjoner fra tidligere på det nye kartet. Hvis tåka letter, begynner jeg med geologiske kartlegging, men først må loggingen av kjerner avsluttes.


1S
7,5M
Myr
Myr
8N

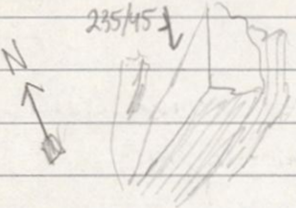

30cm

13/7-84 Meget godt vær med sol fra delvis skyfri himmel, og varmt.

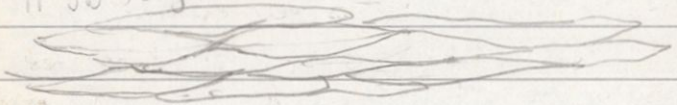
Lok 24: Ved å følge borretningen for hull 224 kommer man ut i et myr-terreng. Her ser man en rygg som stryker NØ-SV. Den består av den grå skiferen i lok 7 som her går over i en grå skifer som består av 1 mm tykke flak. Prøve er tatt, Denne blir gulbrun med røde flekker i forvitret tilstand. Sprekkeretning ∅ 350/84

Lok 25 Grå middelskornet (≈ 1mm). kvartsitt b.a. Ved forvitring blir den hvit i forvitringshuden. Bergarten er glimmerholdig den er massiv. Forvitring gir rustbrun farge. Den spalter opp etter hvilkårlige plan hvor glimmer gir svakhet og disse planene er gjerne rustbrune, til gulbrune. Kvartsitten ligger i kontakt med svart skifer. Prøve av bergarten er tatt. Følger man svartskiferen, ser det ut som om den er stukket inn i den skifrige kvartsitten, se fig

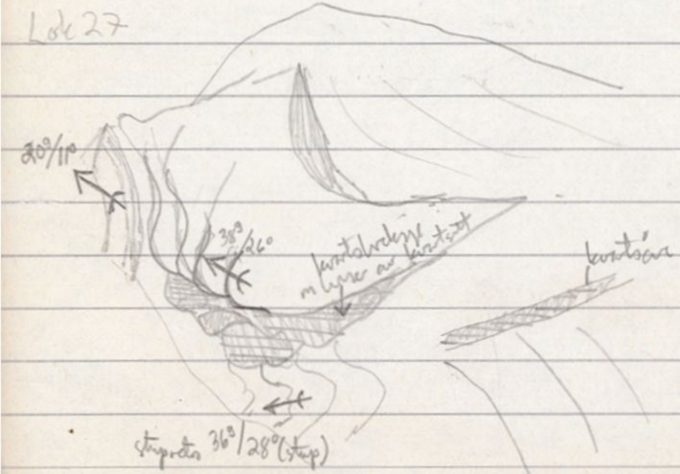
Lok 26



Tøffestruktur i bergart . Lok 27



Lok 27



Lok ㉖ Skifrig kvartsittisk bergart.
Strøk og fall: ⊥ 232/45 . Ser ut til å del
av foldeflanke, men det er vanskeligere å si noe
om stupningen av foldeaksen

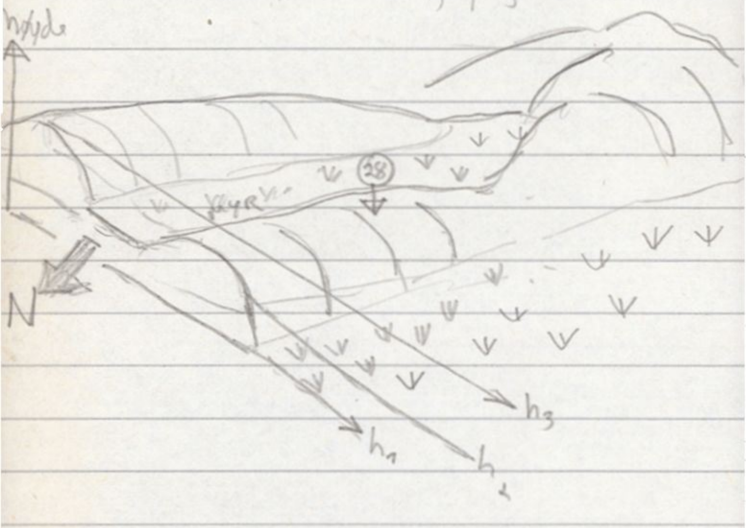
Strøk og fall i skifersone på 4 m mot nord:
⊥ 250/52 (?)

?
↓
Lok ㉗ Lys, nesten hvitgrå kvartsofyraktig b.a.
Den er bygget opp av opptil cm tykke linser med
lengde 3-5 cm. Linsene adskilles av plan med
sericitt som har en rustrød til brun farge.

Her sees også omboyningssone (Hinge)
av fold. Folden stuper 11^{g} . Stupretning = 20^{g}
Det kan også se ut som om det har skjedd en
overskyvning med folding og kvartsbrekkje mellom
de to skyveplanene? Se figuren på motstående
side.

Mot syd blir bergarten mer skifrig i belter
opptil 2 m. I disse skifrige sonene er bergarten
gråbrun. ⊥ 243/31 Sprekker ⊥ 369/61

Bergarten stikker opp som en knaus →
6-7 m bred med myr ved siden av og nedenfor
ved siden av, se kart og figur



Lok ㉘: Mellomgrå, fin til middels kornet tuff aktig bl.a. Bergarten er skifrig, men med noen variasjon i skifrighetsgrad. Den kan også i belter av 20-30 cm mektighet se lettforvitrbar ut. Disse beltene har en gråbrun forvitrings hud. Bergarten kan også ha et rosa fargeskjær. Bergarten er glimmer-holdig. Sprekkeretn: ↳ 350/79

Huff, nå kom den forbannede tåken sigende igjen for litt siden. Sikten begynner å bli dårlig! Kl. 15^{00} - Meget dårlig sikt - avslutter foreløpig. Går over til å tegne over på kart inne i leiren.

14/7-84:

Det er litt kaldt idag, men ingen regn, dessverre en del tåke i ny og ne. som kommer sigende. Det er litt kjølig i luften.

Hensikten med dagens økt blir en nøye gjennomgang langs bor profilene og senere oppgang av geologiske grenser mm.

Lok 29. Nær borplan hull 224. Mørke grå kvartsitt som er massiv. Av ytre er flatene ofte utlutet slik at fjellet er full av groper og fordypninger

Lok 30. Kontakt ~~grå kalkholdig~~ sort skifer og skifrig lys, hvit, feltspat/kvartsrik keratofyr. ∠240/35

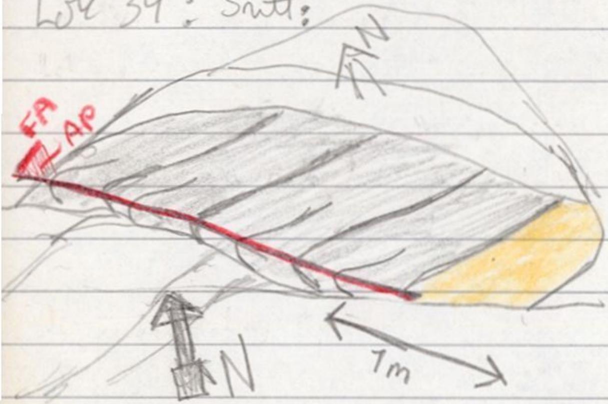
Lok 31 Kontakt mellom mørk grå, nesten svart skifer og kvartsporfyr. ∠ 272/35

Lok 32 Kontakt kvartsitt-tuff / grønn skifer (fyllitt) på den ene siden, og kvartsitt/tuff på den andre. ∠ 245/39. Rundt denne bergarten finner man grønn skifer. Kvartsitt-tuffen kiler ut og kan ikke følges videre i den umiddelbare nærhet i alle fall.

15/7-84 Været er godt. Hensikten med dagen blir å gå opp skifergrensene.

Lok 33. Mørk grå nesten svart skifer "kiler" ut, dvs det er ikke mulig å følge den pga overdekket. Overdekket markerer et lite søkk i terrenget som stryker tilnærmet nordover. Man kan tenke seg at denne skiferen munner ut i svart skifer horisonten lenger nord. ??

Lok 34: Snitt:



16/7-84 Været er ganske bra. Det er grått, men regner ikke. Tåka som lå tett på morgenen forsvant ut på formiddagen så satte jeg i gang med den geologiske kartleggingen.

Lok 34. Kontakt svart skifer / kvartsitt-tuff. Svartskiferen ser ut til å ha meget stor mektighet her. Den er meget svart, dvs grafittholdig. Ved denne lokaliteten kan man observere lukkingen av en fold, se forgyning motstående side. Måling av stupretning og stupning var litt vanskelig, men er (anslagsvis) 10° stupning og 35g stupretning mot nord. ∠241/38. (∠58g/7°)

Lok 35. Overgangsbergarter Lok 2 er litt mer båndet og likt den grønne skiferen med kvartsbåndinger. Denne er ~~litt~~ mer grå-svart

Lok 37

Lok 36 Den gåsvarte kvartsbandinage skiferen er underlagret av en gåsvart (grafitt-holdig) skifer som ikke reagerer på saltsyre. S-folder sees i snitt

Lok 37 Observasjon av avbøyende folde-flanke, se fig motstående side. Berg-arten er skifrige effusiver til skifrig kvartsittiske bergart. Stupning 10° i retning 40g NNØ. (Bergarten mot SSØ er mer massiv og kvartsofyraktig (lys nesten hvit)). ∠ 231/50

~~Lok 38. Svart skifer i kontakt med kvartsofyr ∠ 260/45~~

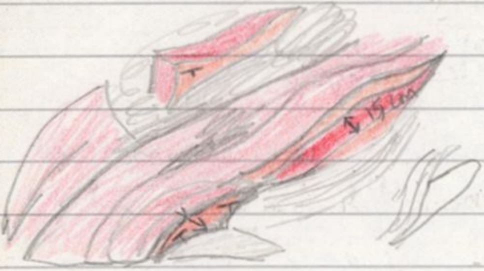
7/7: Det er oppholdsvær, men tåken er så tett som grøt. Vi får håpe den letter noe utpå formiddagen. Begynner dagen med å skissere borhullet grafisk.

Tåken lettet frem mot lunsj. Begynner kartleggingen etter lunsj.

<u>Lok 38.</u> Svart skifer som går over i mer gå kvartsittisk skifrig b.a (som i Lok 4.) Denne har strøk og fall ⅄ 250/60. Den svarte skiferen viser falske skifrighet med strøkretn. ca 320^{g} ("umulig" å måle pga liten blottlegging).

Lok 39 Svart skifer i kontakt med keratofyr. ⅄ 260/45. ∡ 344/26.

Lok 41:



og NØ

Lok 40: Svart skifer avgrenset mot SV av en lys kvartsporfyr. ⅄ 253/50

Nå kommer tåka sigende igjen !

(kalkspat)

Lok 41 Skifrig karbonat - b.a. Blekerosa av ytre farge. Kalkrik b.a. Grå med rosa slirer. "Ombøyning" av fold, se fig på motstående side.

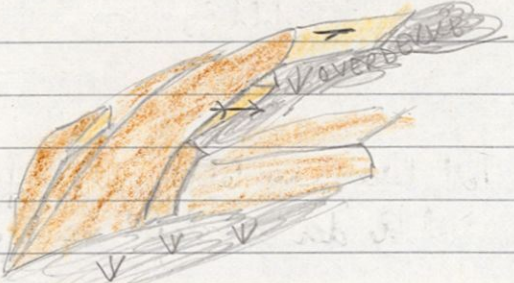
Stupning (?) 30° i retning 359 (NNØ).

kalkholdig

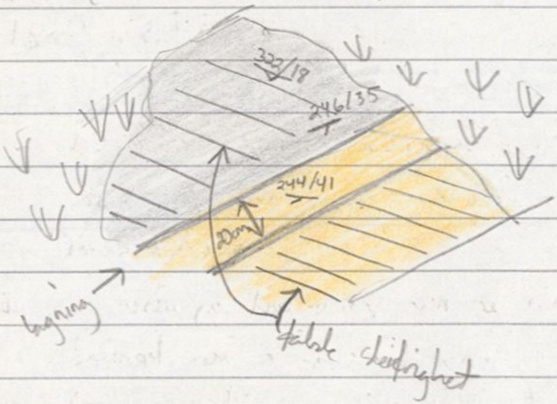
Lok 42: Kontakt grønn fyllitt og ~~tuff~~ ~~(kvartsitt-)~~ b.a. Observasjon av malakitt ⇒ utlutet kobber! S-folder i fyllitten

Lok 43: Grafittskifer. Kan av og til være grå ⅄ 260/41.

Lok 44



Lok 45 (snitt VNV-ØSØ)



([illegible])

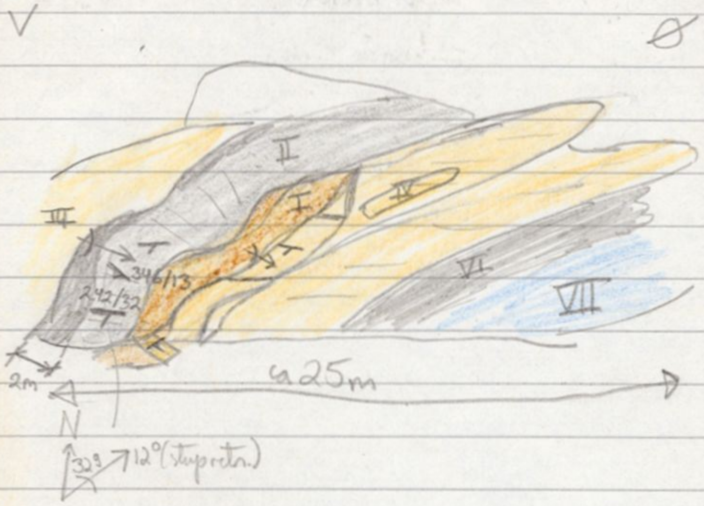
Lok 44. Skifrig keratofyr T. Observasjon av
lett ombøyning i fold, se fig motstående
side.

18/7-84 Tett tåke som letnet ut på formiddagen. Det ble da overskyet men godt væ

Lok 45. Ved sydlige "forkastning" i Vang
Oskar feltet – Skjær som går VNV-ØSØ
Kontakt mellom svartskifer (grafittskifer. og mørk grå karbonat b.a. Falsk skifrighet kan observeres i både grafittskiferen og
de mer skifrige karbonatene som ligger "under"
en dolomitt, 20cm tykkelse "
karbonat b.a., se fig. motstående side.
Kvartsitten er mer kompetent og viser ingen utpreget
skifrighet, mens den skifrige mer keratofyr (tuff) tilsvarende
b.a. under til alt overmål viser dette mye
bedre. ∠ 244/41 (i kvartsitt)
∠ 246/35 (skifer) ∆ 322/18

Kvartsitten inneholder spor av svovelkis

Lok 48:



I Keratofyr som ved forvitring går over i en serisittskifer som er mørke grå. Pyrittholdi

II Grafittskifer

III Serisittskifer (overgang fra mørke grå tuff) Serisittskiferen er lys. grå.

IV Skifrig mørkt materiale i serisittskifer Pyrittholdig (som terninger og masser)

VI Grafittskifer

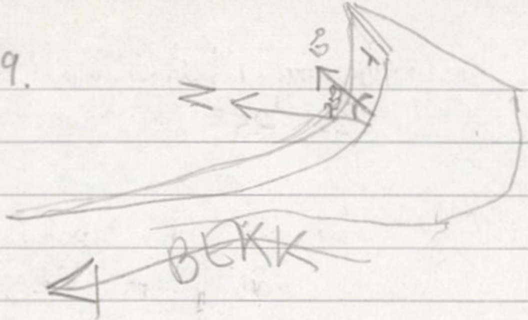
VII Kalkholdig skifer med soner av motstandsdyktig kalkholdig materiale. innimellom sterkt forvitret materiale. Falsk skifrighet, Rustbrun farge

Lok 46: Grense tuff (mørk grå) og grafitt-skifer. Den,, mørke grå tuffen går over i en ubestemmelig, skifrig serisittaktig(?) bergart ved forvitring. Grafittskiferen har et gulaktig grønt belegg på forvitringsflaten. Den har også et rødbrunt rust-belegg på sine steder i lokaliteten ∠ 247/49 (tuffen). Grafittskiferen ligger i kontakt med en grå kalkrike skifer

Lok 47: Grense mellom (hvit) lys kvartsofyr og grafittskifer. Kvartsofyren er bygd opp av linser og skifrig. ∠ 271/49. Z-folder

Lok 48 Hvit kvartsofyr "stuper" i bakken, se fig. på motstående side. Kvartsofyren er gått over i en mer serisittaktig ubestemmelig bergart. Denne er skifrig. Serisittskiferen grenser opp til en svart, hard grafittskifer. Man ser indre tydelig foldning.

Lok 49.



Lok 49. Foldombøyning i kalkrik b.a. (kalkstein
↗15° i retning 25g NNØ

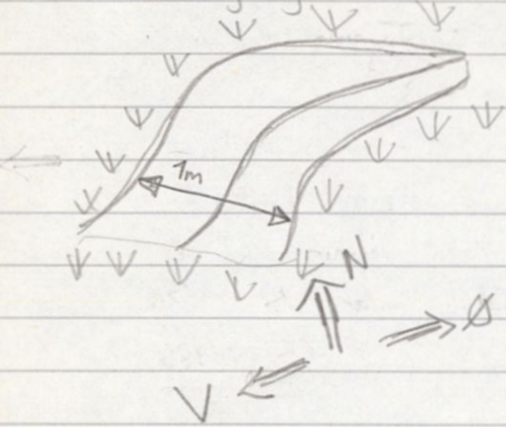
19/7 -84 Det er grått, men oppholdsvær og 9-10°C
Tåken lå tjukk som grøt på morgenen, men
letnet noe utover formiddagen.

Lok 50 Grå kalkholdig skifer med kvarts boudinage.

Lok 51: Grå tuffaktig b.a som inneholder svovelkis hovedsakelig. Syntes også jeg så spor av sinkblende. ⦣ 147/85 (?)

Lok 52: Lys hvit keratofyr b.a. Blokk av svart skifer som kan være løs blokk ?? Kompasset oppfører seg helt villt - nord er ikke lenger nord ⇒ magnetitt i bergarten omkring. Er ikke i stand til å observere magnetitt i b.a på overflata.

Lok 53: Plan Tegning (OBS Ikke snitt).

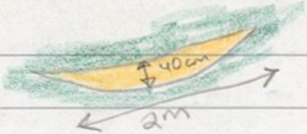


Lok 53. Foldekrølle i (keratofyr) tuff
Umulig å måle stupning. Se forøvrig fig. på motstående side.

Lok 54 Ved forkastning. Tuffen er sterkt oppsprukket. I soner finner man en sprekketetthet 4-6 spr. pr halvmeter ↘ 300/80
↘ 178/86

Fredag 20/7-84 Pga at aggregatet sviktet onsdagskveld dro jeg igår kveld til Jakobsbakken. Benyttet anledningen i dag til å dra ned til Sulitjelma og handle en del ferskvarer. Tåka har imidlertid ligget lavt. hele dag. Nå ut på ettermiddagen ser det ut til å lette litt. Benytter anledningen til å kartlegge litt. (kl 17^{00}).
Tåka legger seg igjen.

Lok. 55



Lok 55: Linse av kvartsitt i fyllitt. "Mektighet" ca 40cm og lengde ca 2m. Tatt prøve

Kl $19^{\underline{45}}$ Må bare slutte – klarer ikke å se mine egne fastpunkt.

23/7

Lok 56. Kontakt svartskifer / kvartsboudinageskifer

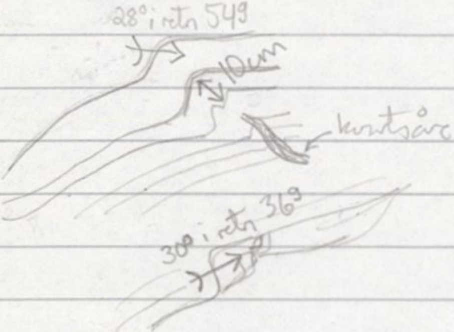
24/7-84:

Et forferdelig vær først på dagen med tåke og regn. Prøver å finne ut av grensen mellom grå kalkrik skifer og kvarts-boudinageskifer og dens relasjon til en observert svartskifer: Måtte gi opp arbeidet kl $10^{\underline{15}}$ pga regn og tåke.

Oppklaring under lunsjen. Gådd ut igjen kl. 11^{15}. Nye regnbyger og tåkebanker. Får prøve å holde ut lengst mulig.

~~Lok 57~~:

Lok 58:

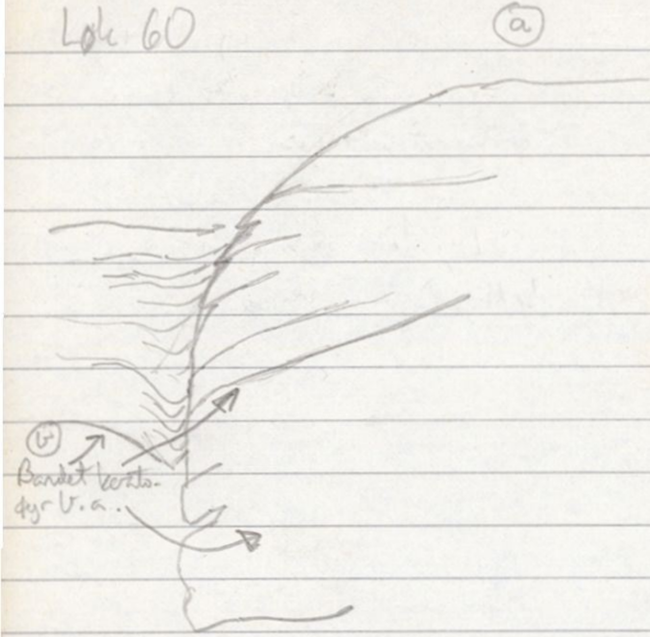


Lok 57: Skjerp / røsking : Svovelkisholdig (litt magnet kis) keratofyr. Begrenses av lys med rust på overflaten. Keratofyren går gradvis over til en serisitt b.a som etterhvert blir båndet og umulig å skille fra den grønne fyllitten av utseende. Den grønne fyllitten er imidlertid kalkholdig.

Lok 58: Ved bekk: Knekkfolder i sterkt omvandlet keratofyr. Foldene er S-folder. Foldene har stupning som vist i figuren på motstående side

24/7-84 Regn og tåkebanker på morgenen, men oppklarning fra ca 09^{00}. Senere godt vær med blå himmel og solskinn

Lok. 60

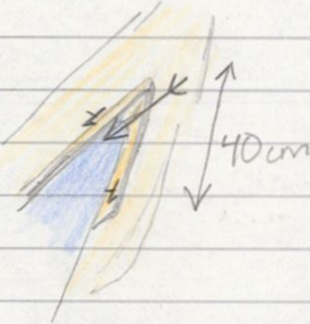


Lok 59: Grå, nesten svart kvartsrik fyllitt med kvartsboudinage. Lite kalk; b.a - såvidt den bruser for fortynnet saltsyre.

Lok 60: Mulig forkastningsplan? eller flexure. Tatt prøver av bergart på hver side.

Lok 61:

Lok 63



30/7-84 Været er bra, selv om det er overskyet. Enkelte innslag av blå himmel.

Lok 61: Folding av kvartsitt ved kontakten mot den grønne fyllitten, se fig. på motstående side. Prøve av kvartsitten er tatt. Den inneholder svovelkis

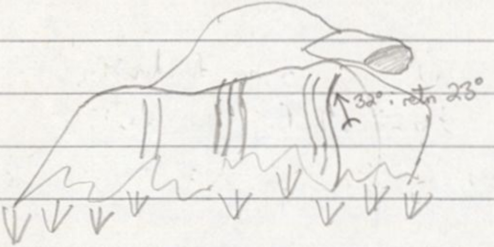
Lok 62 Porfyrisk tuff: Tatt prøve.

1/7-84 Pent vær. Blå himmel med solskinn. Sterk (relativt) vind.

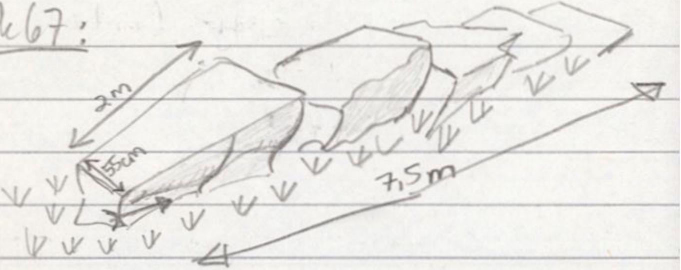
Lok 63: Linse av kalkholdig kvartsitt som muligens representerer et foldekne. Stupning 42° i retning 300^g

Lok 64 Tatt prøve av mørkt kvartsittisk? bergart, som er meget glimmerrik.

Lok 66.



Lok 67:



Lok 68:

Lok 65. Rav fyllittisk b.a. Tatt prøve.
Mourki-skifer?

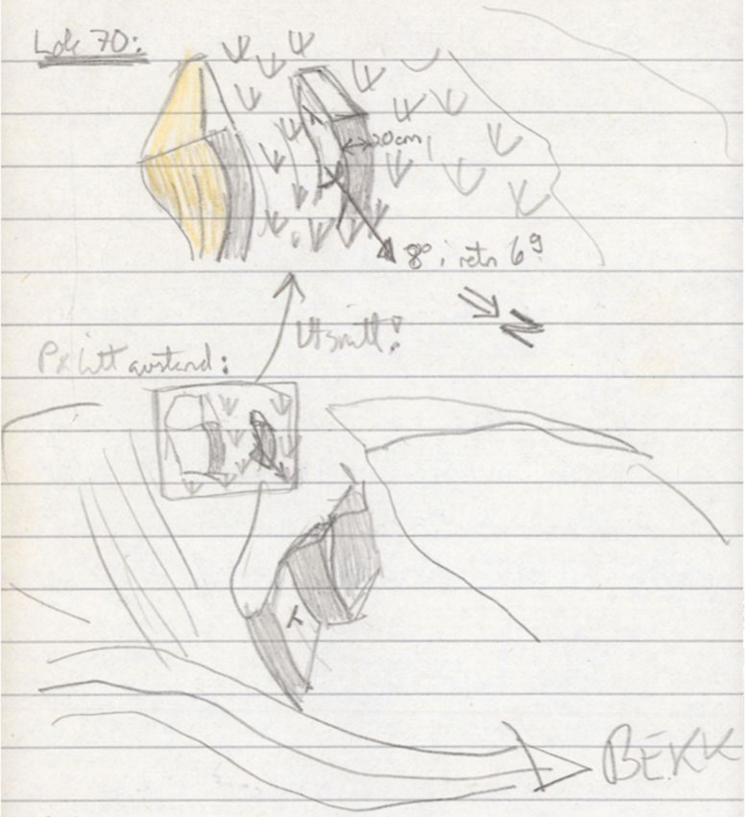
Lok 66: Observasjon av foldning i kvartsitt
(lys feltspatisk(?), linseoppbygget b.a).
Se forøvrig figur på motstående side.

Lok 67. Foldombøyning som viser stupning.
i lys, hvit, rusten "kvartsofyr" (kvartsitt).
(linseoppbygget b.a). Se fig
Stupning 15° i retn 47^g

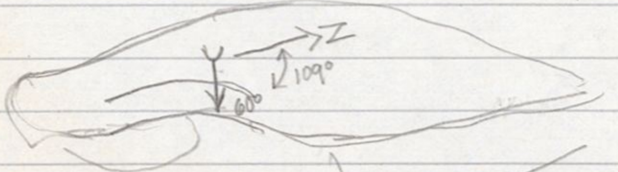
1/8-84. Det er halvskyet, sol og varmt. Det
blåser imidlertid kraftig vind.

Lok 68: Foldombøyning i kalkstein (kalkholdig
kvartsitt) Stupning 7° i retn 64^g, se
skisse.

Lok 70:



Lok 73:



Lok 69 Måling av stupning (+retn) for små parasittære folder i fyllitten (Mourki)
↗ Stupning 9° i retning 36^g

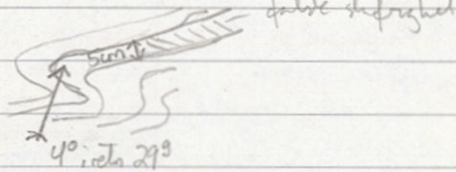
ok 70: Foldombøyning i svartskifer. Stupning 8° i retning 6^g se fig på motstående side

ok 71 Tatt prøve av b.a. Tuff (mørke kvartsitt ? i alle fall helt forskjellig fra den lyse bergarten bygget opp av linser). Magnetitt-holdig. En 20-25 cm tykk kvartsgang som stryker 365^g gjennomsetter b.a. Forvitringshuden er hvit

ok 72: Lysere kvartsittiske bergart (~~Tuff~~??) enn i lok 71. Albittisert tuff!

ok 73 Mulig foldombøyning i lys kvartsitt (linseoppbygget b.a), se fig motstående side.
Stupning 60° i retn 109^g

Lok 75



3/7-84 Pent vær. Noen solglytt innimellom
Det blåser en del.

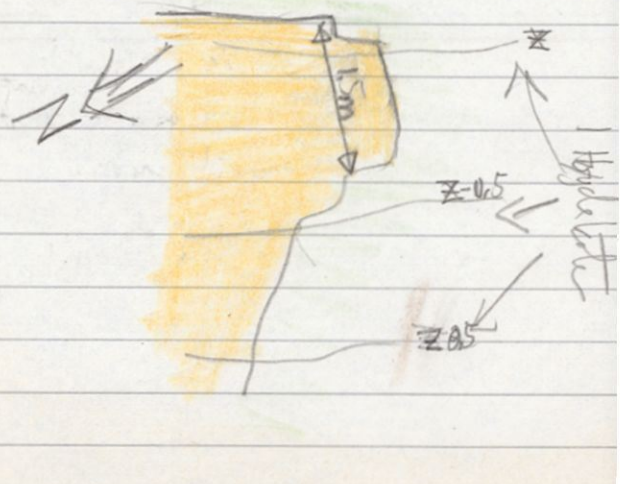
Lok 74: Mørke Grå kvartsitt i kontakten mot svartskifer. Dersom det har skjedd bevegelse langs skjæret, så er den ikke stor. (albittisert tuff)

Lok 75: Kontakt mellom grå fyllitt og serisittisert kvartsitt (mørke grå kvartsitt). Tatt prøve av fyllitten. Lenger mot øst finner man en kalkholdig skifer og kalkholdig kvartsitt. Småfolder har stupning 4° i retn 29g. S-folder
∠ 234/36 ∠ 406/22

ok 76: Bergart mer lik tuff ~~enn kvartsitt~~ ??

ok 77. Lys grå kvartsitt. Rust~~[illegible]~~ på bruddflatene ∠ 233/80. (Bergarten så ut til å stå steilt, men flaten det ble målt på var dårlig. (ruflet).

Lot 81



Tuff.
Lok 78 Lysgå ~~kvartsitt~~ i rosket område.
Den inneholder magnetitt

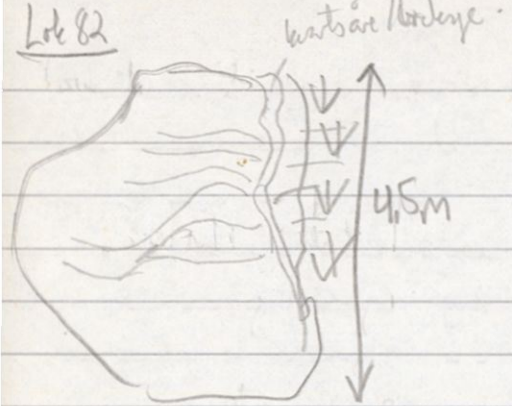
Lok 79: Type 6.a ? Tuff? (??) Tuff!

6/8 -84 Først på dagen lå tåka tett over Kong Oskar. I 10^{00}-11^{00}-tida begynte den å lette. Været var da meget bra, overskyet og varmt.

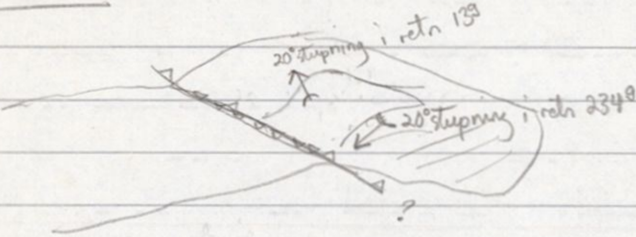
Lok 80; Ved fastmerke: Kontakt lys slirig kvartsitt (linseoppbygd, feltspatisert b.a). og grønn fyllitt. Kvartsitten inneholder litt svovelkis. Grensen mellom fyllitten og kvartsitten er diffus og vanskelig å se innen klotrengen.

Lok 81: Kule av kvartsitt (grå) i fyllitt,

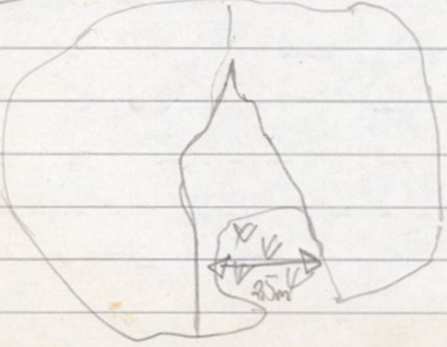
Lok 82



Lok 83:



Lok 84:



Lok 82 Grønn fyllitt med "drag"-folder mot kvarts gang (Bevegelse ?)

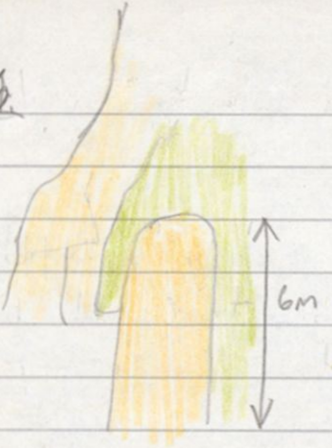
Lok 83 Grå glimmerrik kvartsitt. Man ser folding og en mulig liten skyvning, se fig.
⟋ 247/47

I nordvest ser man en sericittomr. kvartsitt. Den er egentlig gått over til sericittskifer. Ved siden av (mot V) ligger reste av en grafittskifer
Nå begynner det å regne!..

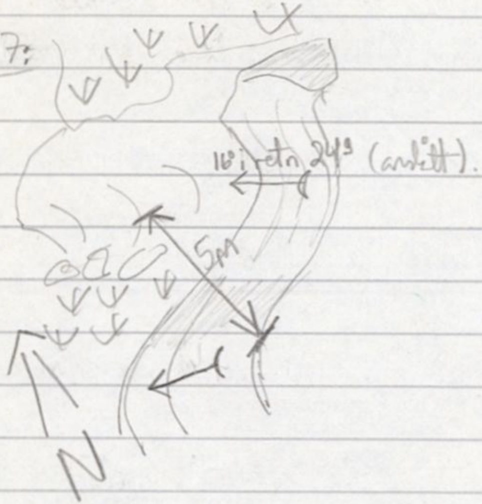
Lok 84: Foldombøyning i grønn (Muorta) fyllitt

Lok 85: Tuff (?) Oppsprukket med en serie sprekker som er parallelle. ⊿ 352/84
149/84

Lok 86.



Lok 87:



7/8-84 Godt vær, halvskyet og sol. Det blåser en del.

Lok 86: Kontaktet grønn/grå øvre fyllitt, og kvartsitt (sterkt serisittisert – nesten skifer) og kontakt kvartsitt/grå skifer (grafitt-skifer).

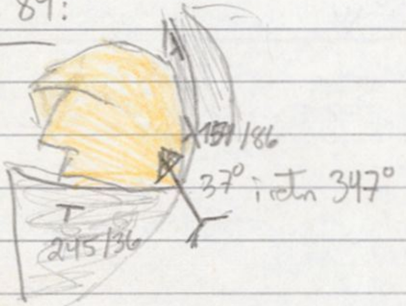
Lenger mot nord er en kile (inn-foldet) av kvartsitt i fyllitten, se fig.

Lok 87. Serisittomvandlet kvartsitt ~~(tuff?~~)
Krusklar utviklet. Inneholder svovelkis.
Småfolding ↗ 11° i retn 21°

b) ↗ 5° i retn 50°. Større fold, se skisse

Kl. 15^{00}; Nå begynner det å lyne og tordne. Regnet ser også ut til å følge.

Lok 89:



Lok 88: Steiltstående serisittomr. kvartsitt og fyllitt i kontakt.

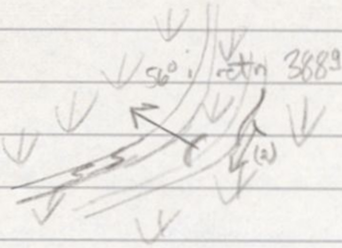
8/7-84: Grått vær, men heldigvis oppholdsvær. Det er litt kjølig i luften. I alle fall halve dagen skal benyttes til å oppklare visse uklarheter innen det kartlagte området:

Lok 89: Ombøyning fold. Lys kvartsfyr (kvartsitt?) omgitt av svartskifer. ↗37°; retn 347° ∠245/36° (Ved bekk, ved forkastning før tre-bekkemøte!

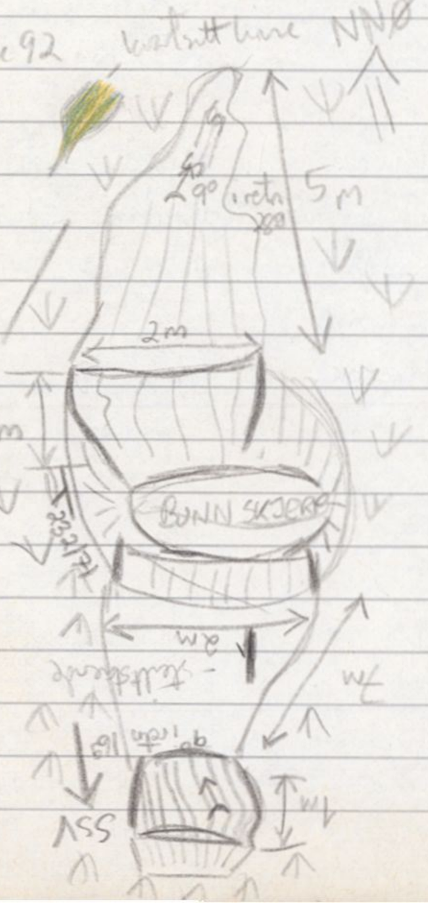
Det begynner å regne!

Nå legger tåka seg!

Lok 91:


56° i retn 388⁹
(2)

Lok 92


kvartsitt linse
NNØ
9
40
90° i retn 288
5 m
2m
1m
BUNN SKJERF
233/74
2m
- steiltstående
7m
9° i retn 169
1m
SSV

9/8-84 Tåka har lettet, løpet av natten
Det er oppholdsvær og bra temperatur.

<u>Lok 90:</u> Kontakt kalkstein og kvartsitt.
Kalksteinen viser små isoklinalfolder
Prøve av kalksteinen og kvartsitten er tatt.

<u>Lok 91:</u> Ombøyning av fold i kvarts-serisitt-skifer. ∠↗ Stupning 56°!, retn 388^g Kvarts-serisittskiferen inneholder svovelkis. S-folder i nedre flanken, se fig. En mindre fold har ∠ 8°, retn 51^g

<u>Lok 92:</u> Rustning/skjerp nær ~~Strømmen~~ Strømbu og linser av massiv kis (hovedsakelig svovelkis og noe sinkblende) i skifrig kvartsitt som kan være omvandlet til en kvartsserisittskifer.
Liten S-fold (mot nordøst) har stupning 9°; retn 28^g. ∠ noe varierende, men steiltstående. Et sted (nær hvor skjerp) ∠ 232^g/71°

Lok 93: Skjerp H; ([illegible]) Skifrig kvartsitt / ~~serisittskifer~~ kvarts-serisittskifer Inneholder ~~kis og~~ pyritt, sinkblende og syntes jeg å se kopperglans. ∠ 10° i retn 250g

Lok 94: Øvre fyllitt: Grønn m/ kvarts boudinage. Veldig lik Mosviks fylliter. Tatt prøve.

Lok 95: Tuffaktig l.a.? ~~Tatt prøve~~.

Lok 96 Mørke, grå skifer. Grafitt holdig? Tatt prøve

Lok 97: Serisittskifer (omv. kvartsitt) Pyritt-holdig.

VEDLEGG 3

Renskrevet 21/7-84.
H.T.Mildal

Nivå N.G.O: ______ Koord. N.G.O: X __________ Y __________

Borsted: KONG OSKAR Dagen/~~Gruva~~. Hull nr: 224 Nivå Sulis: ______ Koord. Sulis: X __________ Y __________ Ret./Fall 149°/40°

FRA Dato: ______/ ______ TIL Dato: ______/ ______19___ Ref: ______________

Hull dyp til	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%
207,5m –		Kvartsgl. skifer ? (fyllitt?)		Disseminasjoner og enkelte mm-tykke bånd av magnetkis,		Kvartsboudinage.	po, py, cp.			
221,2m				svovelkis og kopperkis		Bergarten inneholder				
						en del mørke mineraler				
						Bånding ca 85° –				
						96°				
221,2m –		Kvartsgl. skifer		Mindre mengder av de samme ertsmineralene som		Bånd av kvarts med	po, py, cp.			
243,3m		(grå fyllitt?).		ovenfor.		karbonat. Enkelte				
						2-4 cm tykke kvarts-				
						årer skjærer b.a.				
						Ved 234 m sees en				
						5 cm tykk svartskifer				
						sone. Varierende lag vinkel.				
243,3m		Vekslende kvartsglimmer-		Enkelte korn av magnetkis og svovelkis		Kvartsboudinage	po, py.			
– 252,7.		skifer og svarte skifer								

Nivå N.G.O:_______ Koord. N.G.O: X__________ Y__________

Borsted:___________ Dagen/Gruva. Hull nr:_____ Nivå Sulis:_______ Koord. Sulis: X__________ Y__________ Ret./Fall ____/ ___

FRA Dato:_______/ ______ TIL Dato:_______/ ______19___ Ref:____________________

Hull dyp til	Tegn.	BERGARTDATA			Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S%
		Bergart	Str.	Mineralisering							

VEDLEGG 3

21/7 H.T.M[illegible]
(Rambrudt logging.

Borsted: Kong Osvar Dagen/~~Gruva.~~ Hull nr: 224 Nivå N.G.O: ______ Nivå Sulis: ______ Koord. N.G.O: X ______ Y ______ Koord. Sulis: X ______ Y ______ Ret./Fall 149°/ 70°

FRA Dato: ______/ ______ TIL Dato: ______/ ______19___ Ref: ______

Hull dyp til	Tegn.	BERGARTDATA			Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S %
		Bergart	Str.	Mineralisering							
53,8 – 66m.		Lys tuff (kvartskeratofyr)		Disseminasjoner av svovelkis, magnetkis og kopperkis; bergarten frem til ca 55m. Minkende grad av malmmineraliseringer fra da av.		Bergarten viser folding. Lagningen har en vinkel på omkring 80° i forhold til kjerneaksen.	Po, py cp				
66m – 70,4m.		Porfyrisk tuff.		Enkelte korn av svovelkis og noe kopperkis.		Den porfyriske tuffen avsluttes med en 27 cm tykk kvartsåre.	py, (cp)				
70,4m – 72,7m		Kvartssericittskifer				Lagning ca 80°. i forhold til kjerneaksen.					
72,7m – 82m.		Fyllitt		Bergarten inneholder mye svovelkis, utviklet som fine krystaller (kuber).		Kvartsbåndet b.a. som er gjennom av [illegible]. Den viser folding.	py				
82m – 97m		Keratofyr.				Fin til middels kornet b.a., som blir båndet fra ca 94m. Båndene består av kvarts med litt karbonat.					

Renskrevet 21/2-84
Hans T Mikkelsen

Borsted: Kong Oskar Dagen/~~Gruva~~. Hull nr: 224 Nivå N.G.O: ______ Nivå Sulis: ______ Koord. N.G.O: X ______ Y ______ Koord. Sulis: X ______ Y ______ Ret./Fall 149°/ 70°

FRA Dato: ______/ ______ TIL Dato: ______/ ______ 19__ Ref: ______

ull yp il	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S%
97m – 139,8.		Fyllitt		Svovelkis forekommer som velutviklede krystaller		Bergarten er båndet med utvikling av kvartsbåndinger. Den er intenst foldet i cm-dm skala, noe som reflekteres av varierende vinkel på båndingen i forhold til kjerneaksen.	py				
139,8m – 200m		Fyllitt.		Bergarten inneholder svovelkis som før, men i tillegg magnetittrike soner, fra 139,8m til 141,8m, fra 148,3 til 148,4m, fra 153m til 153,2m, fra 171,4 til 171,8m, fra 172,6 til 173m, fra 196,6 til 197m og fra 191,5 til 192m.		Kvartsbåndinger er vanlig og likeså intens folding i mikro- og makro-skala. Ved 165,2m ser man en kvartsåre med et fiolett, nåleformet mineral (flusspat).	py, mt				
200m –207,5m		Fyllitt.		Bergarten inneholder flekker og disseminasjoner av magnetkis, kopperkis og noe svovelkis, dog en sone fra 201,1m til 206,6m inneholder praktisk talt ikke ertsmineraler.		Kvartsbåndinger	po, cp, py				

VEDLEGG 3

17/7-84

H.TM.

Borsted: Kong Oskar Dagen/Gruva. Hull nr: 224

Nivå N.G.O: ______ Koord. N.G.O: X ______ Y ______

Nivå Sulis: ______ Koord. Sulis: X ______ Y ______ Ret./Fall 149/ 70

FRA Dato: ____/____ TIL Dato: ____/____ 19__ Ref: ______

Hull dyp til	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S %
0-34,6m		Mørk grå skifer (kalkholdig)		Kvarts/karbonat årer. Kalkspatholdig.		Foldemønster. Lagning: se andre skjema.					
[illegible]		Mørk grå skifer									
34,6m-35m		Mørk grå kalkholdig skifer		Kvarts og kalkspatårer. Kalkspatholdig skifer		Knusningssone innledet med 2cm bred sleppesone (leir sleppe.					
35m-35,7m		Mørk grå kalkspat-holdig skifer		Kvarts og kalkspatårer							
35,7m-41,6m		Svart skifer		Litt magnetkis, svovelkis og kopperkis som impregnasjoner og tynne årer (mm tykkelse).		Av og til kvarts boudinage. Folding (mm~) av kvarts-årer.	Po, py, cp.				
41,6m-44,3m		Karbonatbreksje i veksling med svart skifer		Stor grad av "malmmineralisering". Magnetkis dominerer, men inneholder flekker av kopperkis. Pyritt forekommer også. Mineraliseringen forekommer som årer og fylling mellom breksjen sammen med svart skifermateriale. NB! Ikke massiv kis (dvs mer enn 50% malmmineraler). Mengde malmmineraler anslås til å ligge mellom 20-35% (?).			Po, cp og py.				

17/5-84 H.T.Mikkel

Borsted: Kong Oskar Dagen/Gruva. Hull nr: 224 Nivå N.G.O: ____ Nivå Sulis: ____ Koord. N.G.O: X ____ Y ____ Koord. Sulis: X ____ Y ____ Ret./Fall 149 / 70

FRA Dato: ____ / ____ TIL Dato: ____ / ____ 19__ Ref: ____

ull yp il	Tegn.	BERGARTDATA			Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S %
		Bergart	Str.	Mineralisering							
44,3m –45,8		Mørk skifer		Tynne striper og disseminasjoner av magnetkis og svovelkis, samt litt litt kopperkis. Kvartsårer			Po, py (cp).				
45,8– 47,7m		Kvartsitt		46–46,2: Opptil 5cm tykke bånd av pyritt, mellom 1cm tykke "kvartsittlinser". 10 siste cm er pyritten erstattet av magnetkis. 46,2–47,65: 1mm tykke bånd av pyritt og magnetkis. Lenger mellom båndene enn ovenfor.		Kvartsitten er skifrig nær til kont. kvartsittskifer. Kvartsårer av varierende tykkelse opp til 10cm.	Py, po, (cp).				
47,7– 48m		Svart skifer		Pyrittkrystaller			PY				
48 – 53,8m		Kvarts-sericitt skifer (tuffaktig)		Impregnasjoner og mm-tynne bånd av svovelkis, magnetkis og litt kopperkis. Man finner en opptil 10cm tykk sone som er mer kisrik fra 53,3m.			py, po, cp				
53,8m–		Lys skifrig effusiv b.a (bygget opp av linser), som går over i en mer tuff b.a		½mm-1cm tykke årer med hovedsakelig magnetkis og noe kopperkis.			po, cp				

VEDLEGG 3

12/7-84 Hans T [illegible]

Borsted: Kong Oscar Dagen/~~Gruva~~. Hull nr: 224 Nivå N.G.O: ______ Koord. N.G.O: X ______ Y ______
Nivå Sulis: ______ Koord. Sulis: X ______ Y ______ Ret./Fall 149°/ 70°

FRA Dato: ______/ ______ TIL Dato: ______/ ______19 84 Ref: ______

Hull dyp til	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S%
225,7m		Kvartsglimmer-skifer		Bergarten er grå med bånd av kvarts og karbonat		230m: 76°	Po, cp, py				
–				Enkelte 2-4 cm tykke kvartsårer skjærer bergarten.		Str: 140°					
				Enkelte små korn av magnetkis, kopperkis og		234,15: 88°					
243,3m				noe svovelkis sees		236m 77°					
				Ved 234 m sees en 5cm bred sone med svartskifer		240 m: 76°					
						241,2: 58°					
243,3m		Vekslende kvartsglimmerskifer		Kvartsholdige (kvartsbånd, kvartsboudinage)			po, py				
–252,7		og svarte skifer.		Enkelte korn av magnetkis og svovelkis "dis-		247,6 93°					
				pergert i bergarten.		251 m 90°					

Nivå N.G.O:______ Koord. N.G.O: X__________ Y__________

Borsted:__________ Dagen/Gruva. Hull nr:_____ Nivå Sulis:______ Koord. Sulis: X__________ Y__________ Ret./Fall ____/ ____

FRA Dato:______/ _____ TIL Dato:______/ ______19___ Ref:____________________

ull yp il	Tegn.	BERGARTDATA			Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Ni.%	Mek.	Cu%	S %
		Bergart	Str.	Mineralisering							

11/7-84 VEDLEGG 3

Hans T Mikkelsen

Borsted: Kong Oskar Dagen/~~Gruva~~. Hull nr: 224 Nivå N.G.O:______ Nivå Sulis:______ Koord. N.G.O: X______ Y______ Koord. Sulis: X______ Y______ Ret./Fall 149/70

FRA Dato:______/______ TIL Dato:______/______19 84 Ref:______

Hull dyp til	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%
141,8m -		Fyllitt		kvartsblandet / kvartsbåndinger / kvartsårer med		Boring:	mt,			
				(alle m/ kalkmin.). folder og foldeaksene delvis		151 m: 87^{g}				
				[illegible]. 15 cm bred sone med magnetitt ved 153 m		151,7 m: 0^{g} (parall.				
				30 cm tykk kvartsåre skjærer delvis gjennom bergarten		akser).				
				ved 157,7 m. Tilsvarende 5 cm tykk sone [illegible]		152 m: 98^{g}				
				under kvartsåre ved 159,6 m.		154 m: 87^{g}				
				S-folder (Z-folder) ved 164,85 m		159 m: 97^{g}				
				165,15 m: Kvartsgang med fiolett, nåleformet mineral		162 m: 100^{g}				
				(flusspat)		164 m: 91^{g}				
				167,7: 30 cm sone med s-folder.		stikk: 75^{g}				
				168,5 m: foldning		166,8 m: 87^{g}				
				170,5 m: 2 mm tykke bånd m/ svovelkis		stikk 136^{g}	py			
				171,45 m: 35 cm tykk mt-kis. sone.		168,5 m: ≈ 0^{g}				
				172,6 m 40 cm — "		stikk: 147^{g}				
				~~175 m~~		171 m: 90^{g}				
				~~180-185 småfolder~~		stikk: 129^{g}				
				196,6 m: 40 cm sone med magnetitt og svovelkis		173 m 94^{g}				
						175 m 89^{g}				
						177,5 m: 95^{g}				
						180 m 85				
						184,9 m 90^{g}				
						186,4 25^{g}				
						187 m: 14^{g}				
						189,5 m 98^{g}				
						190,95: 15^{g}				
						191 m 50^{g}				

12/7-84

Borsted: Kong Oskar Dagen/Gruva. Hull nr: 224 Nivå N.G.O: Nivå Sulis: Koord. N.G.O: X Y Koord. Sulis: X Y Ret./Fall 149°/ 70°

FRA Dato: / TIL Dato: / 1984 Ref:

Hull dyp til	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S %
-191-200m		Fyllitt		Grå til grønn med kraftig [illegible] båndning		Bånding					
				191,5m: 50 cm bred magnetittholdig sone		191,5m: 92° 192,8m: 43° Skif 44° 193,9 88° 193,5m: 40°	Mt mt				
200m-201,1m		Fyllitt		Linsdelt og kvartsbrudninger. Inneholder noen flekker av magnetkis, svovelkis og litt kopperkis			Po, (py), Cp				
201,1m -206,55		— " —		Som ovenfor men uten malmmineraler							
206,55m -207,5		Fyllitt		Kvartslinset og kvartsbrudninger. Dissemineringer av magnetkis og kopperkis og noe svovelkis		206,7m: 95°	Po, Cp, Py				
207,5m -221,2m		Kvartsgl. skifer (?)		Ikke ulik den ovenfor, men inneholder noe mindre mineraler. Kvartsbrudninger. Impregnert (disseminert) kis i bergarten. Enkelte cm-tykke bånd av kis		210m: 85° 215m 96°	Po, Py, Cp				
221,2m-225,7m		Kvartsgl. skifer		Kjernen er oppknust. Mindre grad av dissemineringer (lite malmmineraler som magnetkis, kopperkis og svovelkis		224,9m: 77°	Po, Cp, Py				

VEDLEGG 3

Borsted: Kong Oskar Dagen/Gruva. Hull nr: 224

Nivå N.G.O: ______

Nivå Sulis: ______

Koord. N.G.O: X ______ Y ______

Koord. Sulis: X ______ Y ______

Ret./Fall 149g/ 90g

FRA Dato: ______/ ______ TIL Dato: ______/ ______ 19___ Ref: ______

Hull dyp til	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Nu.%	Mck.	Cu%	S%
72,7m–82m		Kvartsbåndet b.a		Kvarts som årer, linser. Bergarten er grønnbl. fra til 73m, deretter blir den grå. Svovelkis finnes som små krystaller spredt i bergarten. Enkelte store krystaller (terninger) sees også. Enkelte mm-tykke bånd av kis finnes.		Kvartsbåndene er småfoldet Skifrighetsvinkelen ved ca 77,5m er 67g i forhold til kj. aksen	py, po				
82m–93,7m		Kvartsitt tuff		~~Bergarten er~~ består av små linser (cm-tykke) ~~[illegible]~~ i en [illegible]. Bergarten er mørk fra til 87m deretter et lyst parti fra til 88,3m, mørk fra til 91,25 og lys resten. Fin- til middelskornet b.a. Ved 87,9m er det et 5cm tykk bånd av kvartsbåndet b.a (som fra 72,7 til 82m). Det er også avgrenset med kvartsbåndinger. Kvartslinsene inneholder noe karbonat (bruser ikke for salt syre). Lite eller ingen malmmineralisering.							
93,7–97m		Kvartsittuff		Mer båndet men ellers samme type b.a. Kvarts årer og linser m/karbonat.		"Lagning" 76g					
97m–		Fyllitt		Hovedsakelig grønn, av og til grå. Kvartsbåndet. Man ser tydelig foldte strukturer på båndingen. Båndingen er fra ca 1mm opptil noen cm. Kvartsbånding.		Bånding 97,5m : 81g 98,45m : 99g 101,7 : 55g 102,3 : 91g 105 : 98g 106,1 : 87g					

10/7-84 H.T.Mikkelsen

Borsted: Kong Oskar Dagen/Gruva. Hull nr: 224 Nivå N.G.O: Nivå Sulis: Koord. N.G.O: X Y Koord. Sulis: X Y Ret./Fall 149°/40°

FRA Dato: / TIL Dato: / 1984 Ref:

ull yp il	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Nu.%	Mek.	Cu%	S %
-139,8m		Fyllitt		(m kvartsbåndinger og linser). Gjennomsatt av kvartsårer (enkelte), m/ kalk min. Pyritt, sone eller som store krystaller (kule terninger).		Banding: 109,1m: Parallelt (linser og bunket foldet). Foldet stupning 78° 115m: 97° 117m 96° 120m 90° foldet stupn. 140° 123m: 100° foldet stupn. 50° 126,2m: S-Z fold 128,2m banding 90° dito stup. 58° 134,7m: 100°					
139,8m -		Fyllitt		Kvartsbånding, kvartsbåndinger og årer med karbonat: Små svarte krystaller ......?			py				
139,6m -141,8		Fyllitt		Kvartsbånding, kvartsbåndinger og kvartsårer m/ karbonat. Bergarten inneholder linser små svarte krystaller dels oktaedriske (magnetitt). Tydelig magnetisk (relativt sterkt) ⇒ mt		Banding 140m: 87° Foldet stupning:	py + ?(mt)				
~~141,8~~ - 141,8m -				Bergart som ovenfor, men inneholder bare enkelte soner med spredte magnetitt korn og enkelte punktkorn. I soner dominerer kvarts ~~bakk~~ spredt kalk min som mer tydelige bånd. Disse er foldet — (konsekvente folder) Tynne lister av py - cm-tykke		10cm sone fra 148,3m Bånding: 142,3m: 97° 148,55m: 95° 147,3m: 66°	mt, py				

Borsted:__________ Dagen/Gruva. Hull nr:____ Nivå N.G.O:______ Nivå Sulis:______ Koord. N.G.O: X__________ Y__________ Koord. Sulis: X__________ Y__________ Ret./Fall ____/ _

FRA Dato:______/ _____ TIL Dato:______/ ______19__ Ref:__________

Hull dyp til	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po. Svovel Py. Magneti.Mt	Fu.	Mek.	Cu%
505m–58m		Tuff		Jevnt dispergert svovelkis, magnetkis i bergarten. Noe kopperkis forekommer også.		Lagning/Bånding 80g ?	py, po, cp			
58m–549m		Tuff		Foldet tuffbånd m/ kvartsårer. Malmmineraliseringen er meget jevnt dispergert ut i bergarten – Mer enn fra 505–58m.			po, py, cp			
54,9–57,95		Tuff		Liten grad av malmmineralisering. Små flekker av svovelkis, magnet og noe kopperkis, ~~små jevnt fordelte pyritt~~ ~~i hele bergarten, i sone~~		[illegible]	py, po, cp			
57,95 66 m		Lys Tuff		Meget ~~liten~~ grad av malmmineralisering. Enkelte 0,5cm store flekker m/ magnetkis og svovelkis. Lite kopperkis.		Lagning 80g				
66m–70,4		Porfyritt tuff t.a.		Enkelte korn av svovelkis og noe kopperkis. Den porfyriske tuffen avsluttes med en 27cm tykke kvartsåre		[illegible]	py (cp)			
70,4m–72,7m		Kvartsskiferlike (dekornert kvartsitt).				Lagning? 80g				
72,7m–75,55		Grønn-grå kvarts båndet t.a. (fyllitt ?)		Bergarten inneholder mye svovelkis		Bånding				

Borsted: Kong Oskar Dagen/Gruva. Hull nr: 224 Nivå N.G.O: ______ Nivå Sulis: ______ Koord. N.G.O: X ______ Y ______ Koord. Sulis: X ______ Y ______ Ret./Fall 149°/70°

FRA Dato: 5/7 TIL Dato: 6/7 1984 Ref: ______

Hull dyp til	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti.Mt	Vu.%	Mek.	Cu%	S %
46m – 46,2		Kvartsitt		Kvarts, feltspat bl.a. svovelkis og magnetkis i bånd på 3-5 mm vekslende med kv.bånd 3-10 mm		Båndning ca 55-60°; forhold til kjerneaksen.	Po, py				
46,2 – 47,7		Kvartsitt		Som ovenfor, men kis ligger mellom kisbånd og oftest tynnere bånd 0,5-1 mm. Kvartsårer 3-10 cm tykke.		Bånding 60°.	Po, py				
47,7 – 48,0		Mørk ~~kvartsitt~~ Kisføring b.a (kalk?)		Grovt dissiminert med svovelkis krystaller		Båndning 80°, forhold til aksen.	py.				
48,0 – 59,5m		Båndet kvartsitt (tykke og tynnere bånd)		Bånd, striper og flekker av svovel- og magnetkis. Disseminasjoner ~~[illegible]~~ ~~[illegible]~~ Foldestrukturer - 2-3 cm amplitude små			Py, Po, Cp				
– 66,5		Tuff		Liten grad av mineralisering, små flekker av py, po og noe cp. Svakt dissiminert pyritt			Py, po, cp				
65,5m –		Porfyrisk Tuff		Som ovenfor, men med utviklet porfyrtekstur			py, (cp)?				

4/7-84

VEDLEGG 3

Borsted: Kong Oskar Dagen/~~Gruva~~. Hull nr: 224

Nivå N.G.O:

Nivå Sulis:

Koord. N.G.O: X Y

Koord. Sulis: X Y

Ret./Fall 145°/[illegible]

FRA Dato: 3/6 TIL Dato: 4/6 1984 Ref:

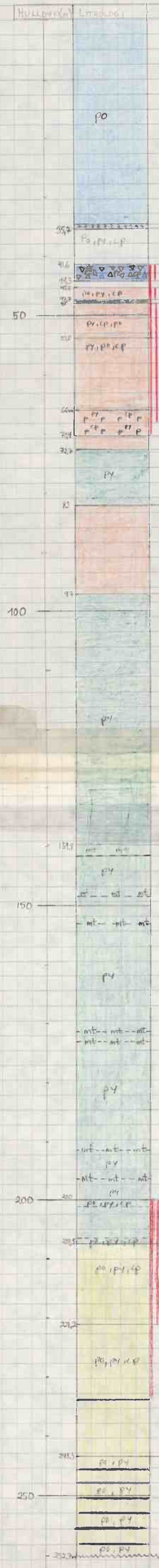
Hull dyp til	Tegn.	BERGARTDATA Bergart	Str.	Mineralisering	Lag	Diverse notater	Ertsdata Kopper Cp. Mag.kis Po Svovel Py. Magneti. Mt	Vu.%	Mek.	Cu%
0 – 15,08m		Mørk grå skifer		Skiferen er kalkholdig med bånd av kvarts. Båndene har varierende tykkelse, fra mm-tykke til bånd omkring 2 cm. Folde-strukturer sees! [illegible] Varierende skifrighetsvinkel (i forhold til kjerneaksen): fra 0 til 61°. Fra 0-1,16 m er skiferen spaltet opp i tynne skiver og korte stykker opptil 2-3 cm. Av og til sees magnetkis på kluftflater til kjernestykkene.		Skifrighet (1m) 61°	Po			
15,08m – 20m		Lys grå skifer		Kalkholdig skifer med tynne kvartsårer og linser. Vekslende lyse og mørke bånd. Folde-strukturer er svært vanlige – skiftende skifrighetsvinkel mot kjerneaksen. Kvartslinse fra ca 17,7m til 18,1m inneholder magnetkis.		16,10m: lagning 144°. 16,26m: lagning 107° (antyder foldning?)	Po (i kvartslinser og årer i skifer)			
20m – 34,6m		Mørk skifer		Kvarts- og kalkholdig skifer. Bånd ikke alltid [illegible]. Mørke bånd dominerer men de veksler med tynnere lyse (kvartsrike) bånd. Foldestrukturer sees ofte.			Po			
34,6m – 35m				To cm tykk kvartslinse. Oppknust kjerne videre (i større lengder og mer oppknust materiale).						

Borsted: Kong Oskar Dagen/Gruva. Hull nr: 224
Nivå N.G.O: ______ Koord. N.G.O: X ______ Y ______
Nivå Sulis: ______ Koord. Sulis: X ______ Y ______ Ret./Fall 149°/ 70°
FRA Dato: ______/ ______ TIL Dato: ______/ ______ 19 84 Ref: ______

Hull dyp til	Tegn.	BERGARTDATA: Bergart	Str.	Mineralisering (Kvartsbudiner)	Lag	Diverse notater	Ertsdata: Kopper Cp. Mag.kis Po Svovel Py. Magneti. Mt	Vu.	Mek.	Cu%	S%
30m – 40m		Mørk grå skifer		Inneholder litt kalkspat og små linser og kvartsårer [illegible]. Kvartsårene [illegible] opp, 2-3 cm tykke.							
40 40m – 41,60		Mørk skifer "		Kvartsbudiner, kvartsårer, konvolute folder (kvartz), tynne striper [illegible] med magnetkis, i skiferen. Magnetkis [illegible], svovelkis og kopperkis finnes i forbindelse med kvartsårene og linsene.			Po, py, cp.				
42 41,60 – 42	41,60										
43,10m 43,10		Karbonatbergart vekslinger med mørk skifer		Karbonatbergart. Magnetkis [illegible] i mellom karbonatbergart og skifer, også pyritt og kobberkis			Po, py, cp.				
43,10 – 43,57		Sericittskifer		Sericittskifer dissemineret med magnetkis			po				
43,57 – 46m		Mørk skifer		Disseminert av kis som striper og flekker hovedsakelig pyritt og magnetkis		Bånding 78° på kjerneaksen. Mørk og lys bånding. Min. senere [illegible].	po, py				

Kong Oskar : Hull nr 224. Retn./Fall : $149^g/70^g$

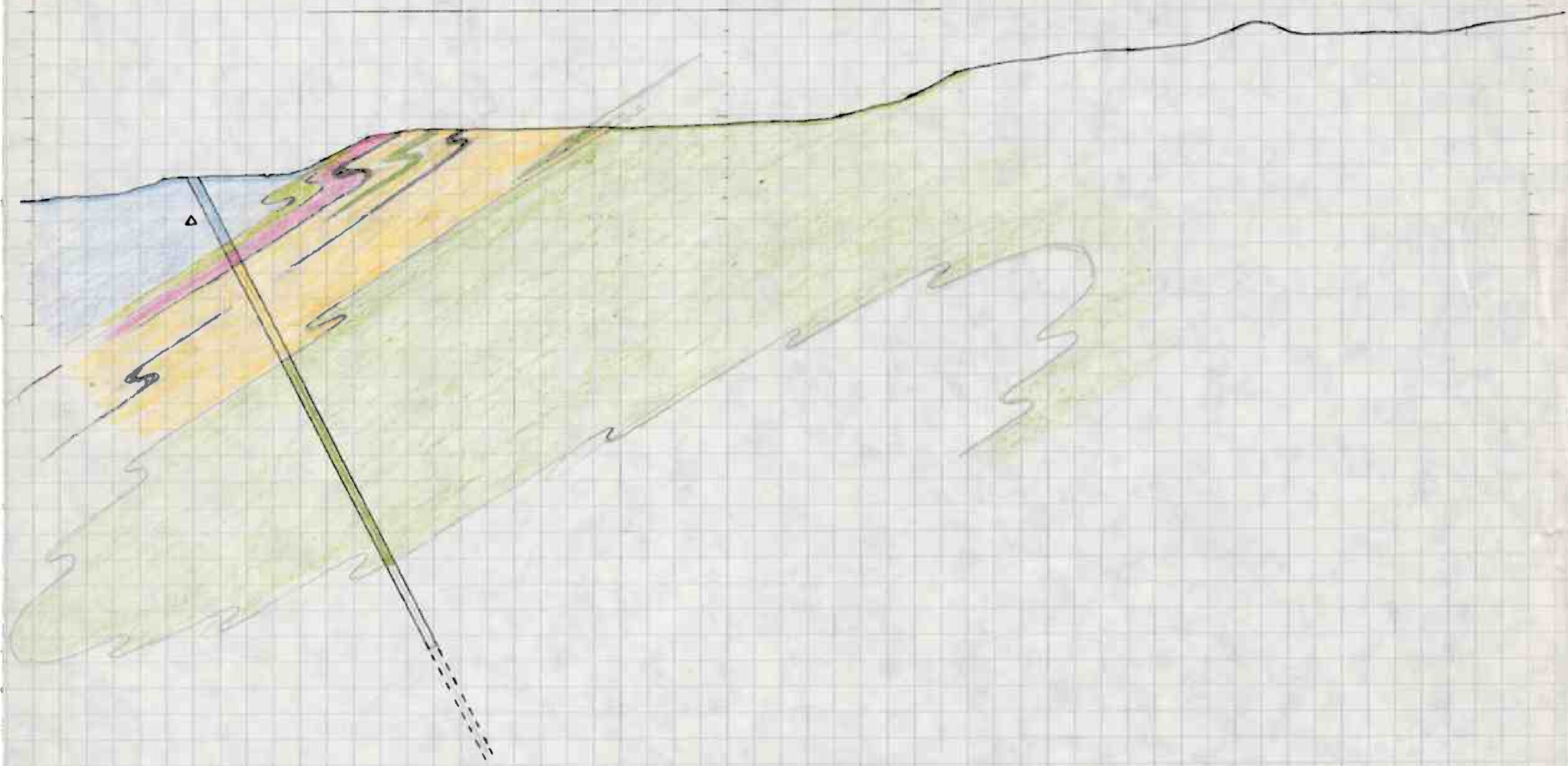
Vedlegg 3



Hulldyp(m)	Litologi	Bergartsbeskrivelse	Mineralisering
0–35,2	po	Mørk grå, kalkspatholdig, skifer: Man ser årer av karbonat og kvarts av varierende tykkelse opptil 2cm. Ofte vekslende mørke og lyse bånd. Foldemønstre i forskjellig skala, noe som fører til varierende lagning. Fra 34,6m ser man en 40cm tykk knusningssone som avsluttes med en 2cm tykk leirsleppe. Fra 35m - som de første 34,6m.	Av og til sees po i kvartsårer/linser og i skiferen.
35,2	po, py, cp	Svart (mykt?) skifer som av og til har kvarts-budinage. Småfolding av kvartsårer.	Po, py og cp som impregnasjoner og mm-tykke årer.
41,6		Karbonatbreksje i veksling med svart skifer.	Skifer: po, cp og py som impregnasjoner (20-40%)
44,3		Mørk skifer med kvartsårer	po, py og litt cp som disseminasjoner
44,6	po, py, cp	Kvarts-sericittskifer (omv. tuff)	Tette bånd av po, py m/noe cp.
47,7	py, cp, po	Kvarts-sericitt-skifer (omvandlet tuff):	Disseminasjoner og mm-tykke bånd av py, po med litt cp. 10cm tykk kis-sone fra 53,3m
55	py, po, cp	Kvartskeratofyr:	Disseminasjoner av py, po og cp fram til 55m. Minkende innhold av ertsmin. fra da av.
66m	p py p p cp p p cp p p py p	Porfyrisk tuff:	Enkelte korn av py og cp.
70,4		Kvarts-sericittskifer:	
72,7	py	Fyllitt: Kvartsbåndet /kvartsbudinage.	py-[illegible].
82		Kvartsfyr: Fin til middelskornet m/ bånd av kvarts som inneholder karbonat.	
97	py	Fyllitt: Båndet bra med utstrekning av kvartsbudinage som er foldet i makro-skala. Båndingens vinkel i forhold til kjerneaksen varierer som respons på foldingen av bergarten.	Velutviklede py-krystaller.
139,9	mt mt py mt mt mt mt mt mt py mt mt mt mt mt mt py mt mt mt py mt mt mt py	Fyllitt: Båndet, grønn b.a. med kvartsbudinage. Bergarten er foldet. Ved 165,2m ser man en kvartsåre m/flusspat.	Bergarten inneholder py og mt. Mt forekommer i soner.
200	po, py, cp	Fyllitt: Kvartsbudinage.	po, py, cp som flekker og disseminasjoner. Utenom sonen fra 201,7 til 206,6m
203,5	po, py, cp	Kvartsgl. skifer (fyllitt?): Kvartsbudinage. Bånding ca 95g - 96g.	po, py og cp som disseminasjoner og enkelte mm-tykke bånd
221,2	po, py, cp	Kvartsglimmerskifer (grå fyllitt?): Bånd av kvarts m. karbonat. 2-4cm tykke kvartsårer. 5cm tykk svartskifer ved 234m.	Som ovenfor men betydelig mindre mengder av ertsmineraler
243,3	po, py po, py po, py po, py	Vekslende kvartsgl. skifer og svarte skifer: Kvartsbudinage	Enkelte korn av po og py.
253,3			

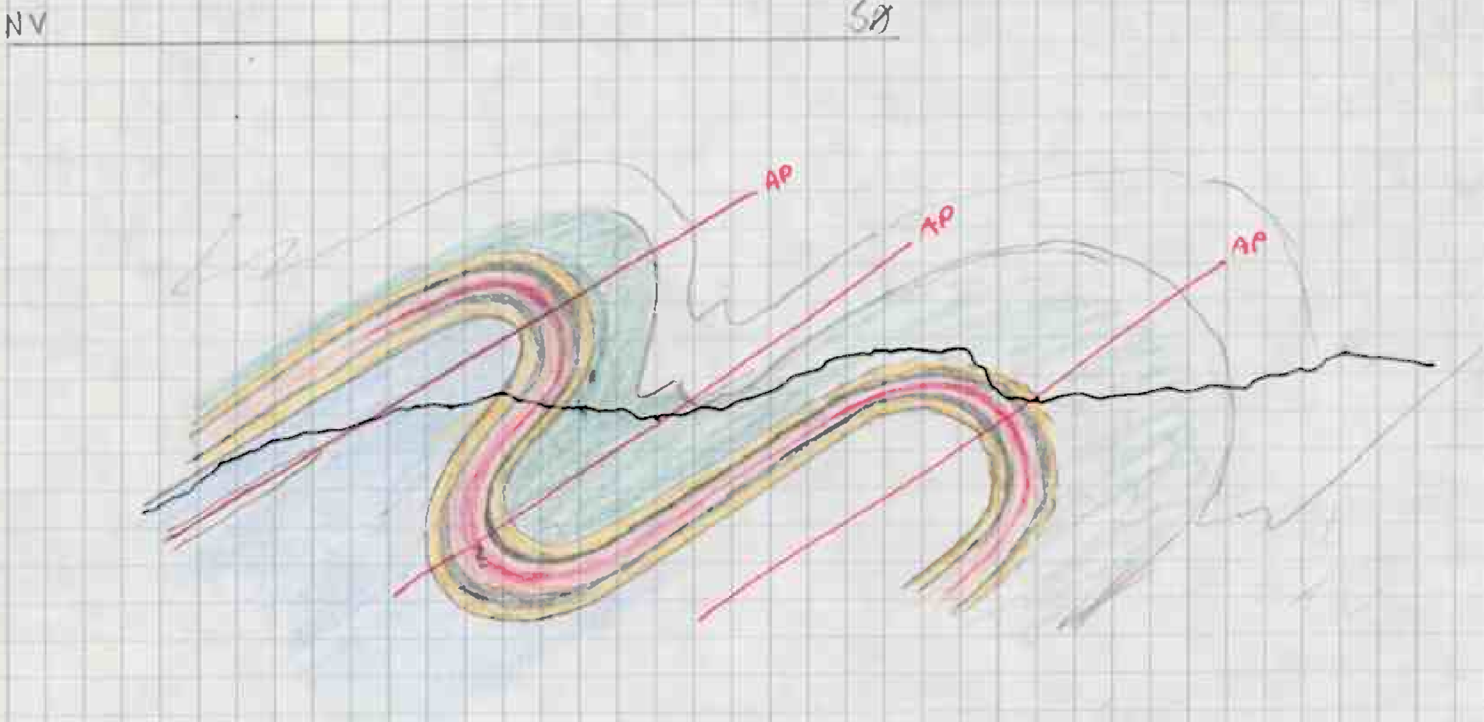
Dbh 224

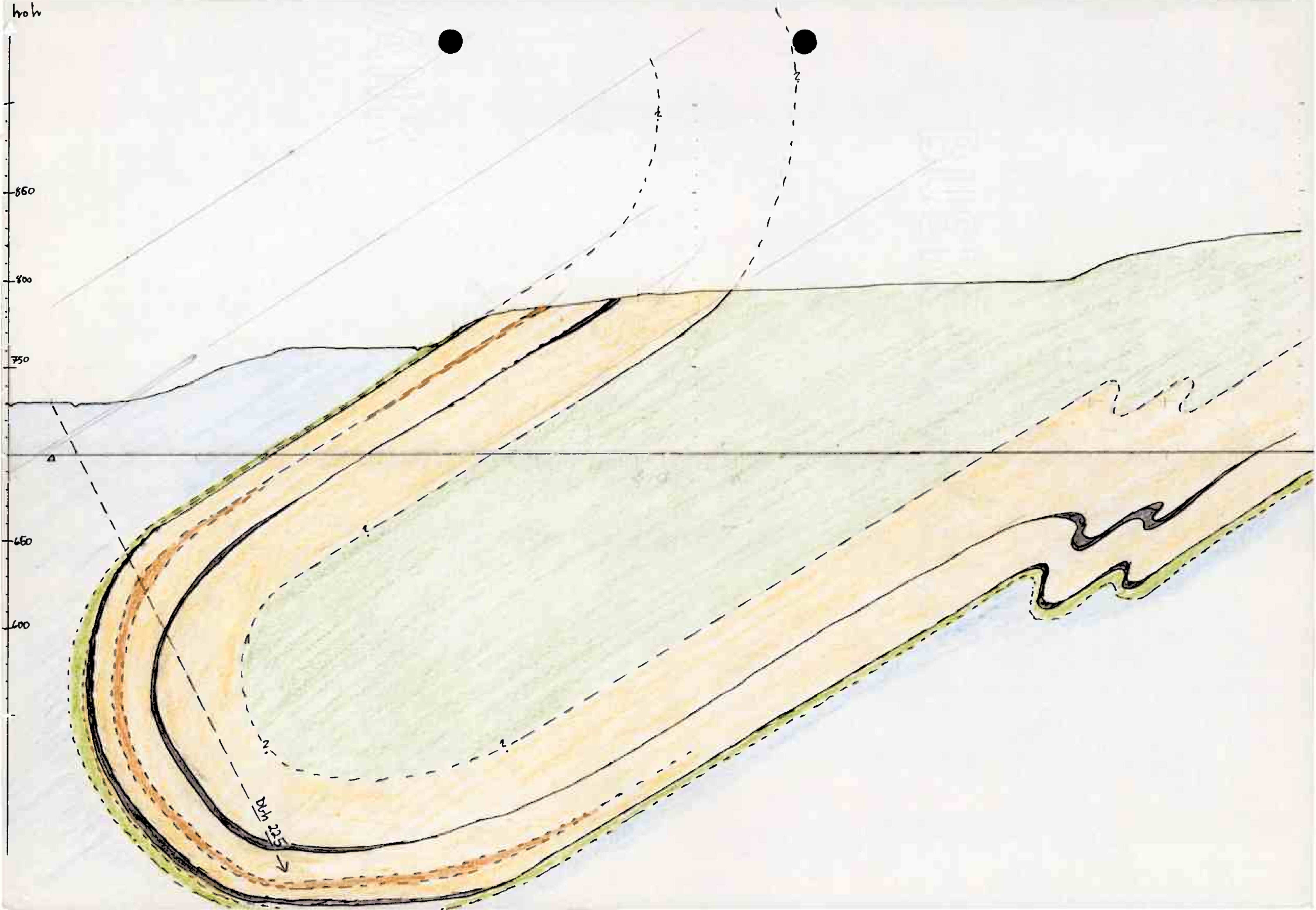
Skjematiske snitt langs borehull – 224



Dh 224

Snitt:




moh
850
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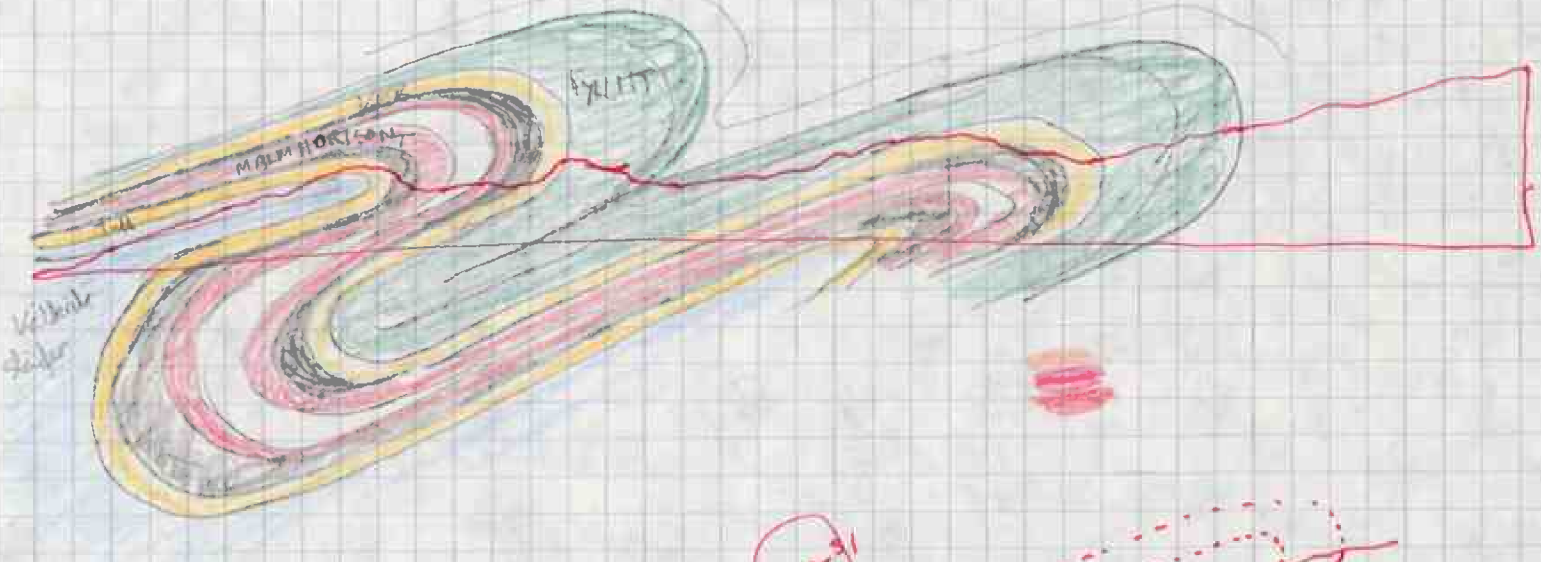
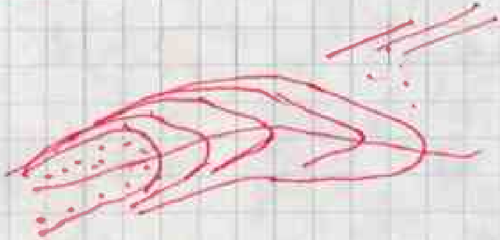
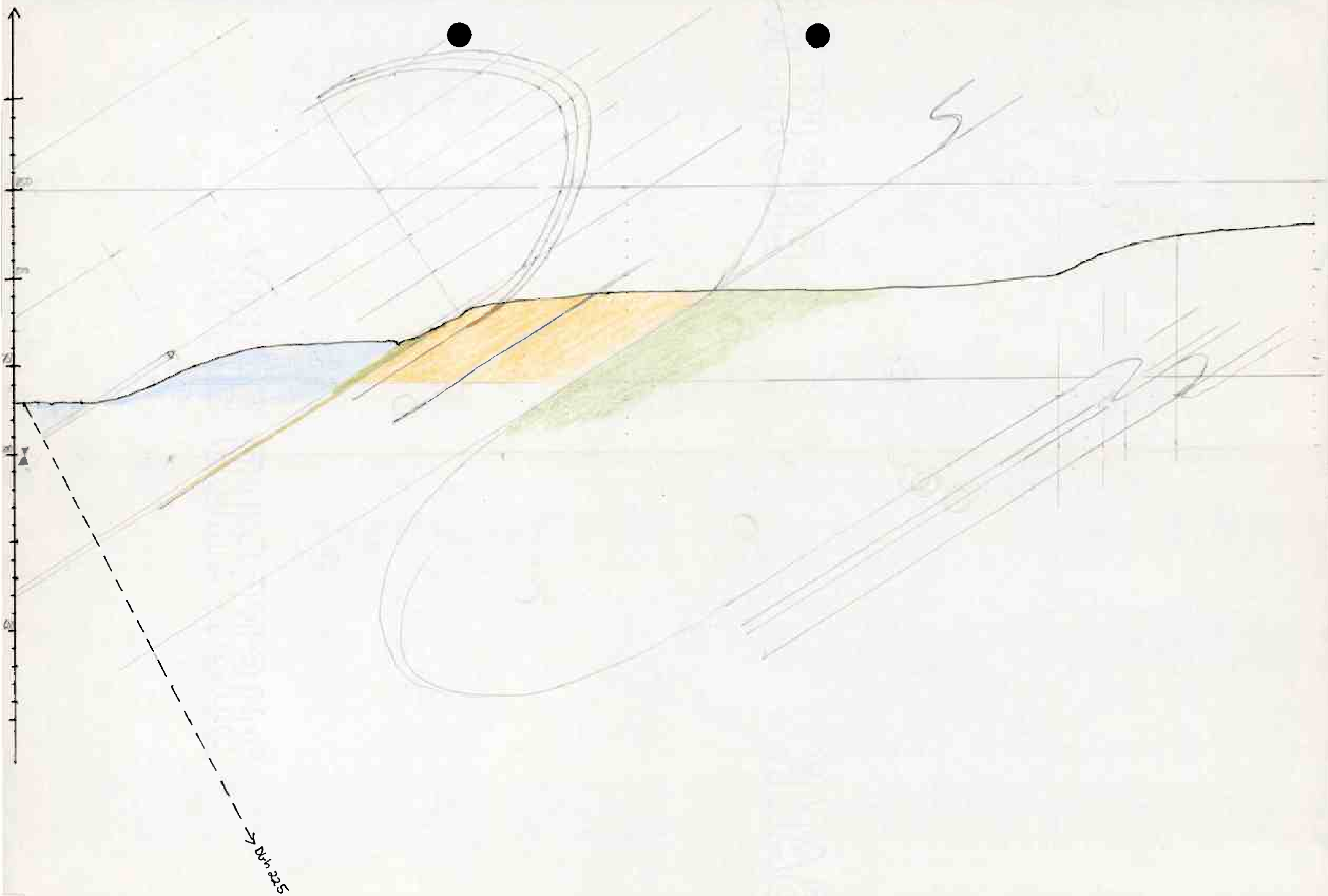
Bh 225


FYLLIT
MALM HORISONT
T-A


S1
S2




Bh 225

RAPPORT OVER GEOLOGISK KARTLEGGING I KONG OSKAR.

SOMMEREN 1984

Drangedal 23/8-84

Hans T Mikkelsen

INNHOLDSFORTEGNELSE

VEDLEGG 1: TEGNFORKLARING TIL GEOLOGISK KART I MÅLESTOKK 1:2500.

GEOLOGISK KART (1:2500).

" 2: PROFILER I MALESTOKK 1:2500.

" 3: BORRAPPORTSKJEMAER.

GRAFISK FREMSTILLING AV BORHULL 224.

" 4: TEGNFORKLARING TIL GEOLOGISK KART I MÅLESTOKK 1:10000.

GEOLOGISK KART I MÅLESTOKK 1:10000.

" 5: BERGARTSPRØVER SOM ER TATT.

Drangedal 23/8-84

Perry!

Jeg beklager at det har tatt såpass lang tid å bli ferdig med rapporten. Årsaken er at jeg ikke har vært helt i form uken etter at jeg avsluttet jobben i Sulitjelma og at den siste uken har vært litt hektisk.

Som du la merke til la jeg igjen kompasset jeg lånte. Resten av utstyret ligger igjen i leiren (saltsyre, målebånd, tusjer, magnet etc). Forøvrig har jeg lagt ved de fargeblyantene som jeg lånte i denne forsendelsen.

I forsendelsen ligger rapporten i plastlomme, de kartene jeg har tegnet på i felt, noen skisser av profiler o.l. og ikke minst dagboken.

Jeg håper rapporten kommer opp mot det forventede, men skulle det være noen spørsmål ennå, så har du jo adressen min. I tillegg kan jeg kontaktes på telefon (07) 52 3213 fra ca midten av september. Det området som er kartlagt, går frem av blottningskartet. Dessverre rakk jeg ikke å komme inn i den sydligste delen av feltet og lenger ut til sidene, dvs inn i Mourkifyllitten og Furuhundskiferen, og nord for den øverste mulige forkastningen på kartblad EH-211-8.

Hilsen

Hans I Mikkelsen

1.0 INNLEDNING:

Den geologiske kartleggingen i Kong Oskar er utført i tidsrommet 29/6 til 9/8 d.å. Kartleggingen har skjedd på kart i målestokk 1:2500 og på basis av dette er et geologisk kart i målestokk 1:10000 fremstilt. Videre var det planlagt fem borhull, hvorav ett (Dbh 224) var ferdig innen denne perioden. Feltloggen for dette borhullet er lagt ved. I tillegg er noen profiler utarbeidet. De viser antatt forløp av bergartene mot dypet. Vedleggene går forøvrig frem av innholdsfortegnelsen foran.

Været har delvis vært til hinder for arbeidet, særlig tåken som nesten daglig i perioder har ligget som et tett slør over det kartlagte området.

2.0. GEOGRAFISKE FORHOLD ETC:

Feltet Kong Oskar ligger ca 4 km øst for Kjelvannet på kartblad 2129 II Sulithjelma i målestokk 1:50000. Det kartlagte området ligger i 700-800 meters høyde over havet.

Vegetasjonen består hovedsakelig av lyng, mose, dvergbjørk osv. Terrenget reflekterer bergartenes hardhet eller motstandsdyktighet mot erosjon. I områder med relativt svake bergarter som feks kalkrike kvartsitter eller skifre, er det ofte utviklet myrer.

Blotningsgraden i området er jevnt over nokså stor, med noen unntak. Dette skulle forøvrig fremgå av vedlagte blotningskart.

3.0. BERGARTSBESKRIVELSER:

Dersom man går langs borretningen til diamantborhull 224, vil man gå gjennom en bergartsserie som stort sett inneholder den observerte lithologien i området. Først kommer en grå kalkrik skifer (Furulundskifer), en gråsvart til grønn fyllitt (Øvre fyllitt) og en sekvens med tuff, kvartsitt og til slutt en grønn fyllitt (Muorki fyllitt). Inni sekvensen av tuff og kvartsitt finner man flere svartskiferhorisonter.

1) **Grå kalkrik skifer (Furulundskifer):** Bergarten er grå med en skinnende glans. Man ser ofte rust utviklet på skifrighetsflatene. Bergarten er finkornet og den spalter opp etter velutviklede skifrighetsplan. Den inneholder kalkspat. Inni sekvensen av skifer finner man kalkrike kvartsitter som ikke er skilt ut som egne enheter under kartleggingen.

2. **Øvre fyllitt:** Bergarten er gråsvart i den nordlige delen av feltet, mens den blir grønn mot sør. Rust er vanligvis utviklet, særlig i forbindelse med kvartslinser (kvartsboudinage). Bergarten er finkornet.

Den er videre intenst foldet i mesoskopisk skala. Kruskløv finnes ofte utviklet. Bergarten er båndet med kvartsboudinage. Mineralogisk består den av kloritt, muskovitt, kvarts og noe kalkspat.

3. Tuff: Av farge er bergarten grå, men kan variere noe mht mørkhetsgrad. Den er finkornet med varierende grad av massivitet. Ofte er den skifrig, og da bygget opp av inntil cm-tykke langstrakte linser, som jeg tolker som en slags flytetekstur. Tuffen kan videre være porfyrisk eller inneholde mer grovklastisk materiale. Enkelte steder er den også magnetittholdig.

4. Svartskifer: Bergarten er oftest svart, men kan ved lavt grafittinnhold være grå. Ved forvitring blir den ofte rustrød langs skifrighetsflatene. Den er finkornet, ofte med velutviklet skifrighet langs lagningen og falsk skifrig skrått på lagningen.

5. Kvartsitt: Bergarten er neppe en kvartsitt, men navnet er brukt som feltbetegnelse. Den har mange teksturelle fellestrekk med tuffen i pkt 3, og tolkes som en feltspatisert variant av denne.

Bergarten er lys grå til hvit og finkornet. Den er oppbygget av langstrakte cm-tykke linser helt analog med tuffen. Av og til kan den være mer kvartsittlik og massiv. Den inneholder linser eller lag med kalkholdig kvartsitt. Mineralogien er relativt enkel med kvarts, feltspat, serisitt og ofte ertsmineraler, da hovedsaklig svovelkis. I tillegg finnes sinkblende og kopperkis.

Bergarten omvandles til kvartsserisittskifer eller serisittskifer og både i uomvandlet og omvandlet form inneholder den ertsmineraler, både som massiv kis, som feks skjerp C eller mer vanlig som disseminasjoner.

6. Serisittskifer: Bergarten er hvit til grå og finkornet. Ofte er det utviklet kruskløv. Ved forvitring blir bergarten rustrød/gulbrun til rødbrun. Serisittskifer ser ut til å være ett endeledd ved omvandling av tuff og kvartsitt.

7. Kvartsserisittskifer: Bergarten er bygget opp av kvartslinser med mellomliggende serisitt. Den er lys grå til grågrønn og inneholder ertsmineraler. I skjerp G og H finner man massiv kis i denne bergarten.

8. Muorki-fyllitt: Denne bergarten er helt lik øvre fyllitt, med det unntak av at klorittiseringen er fullstendig, dvs gir en grønn bergart over hele området. I tillegg inneholder Mourki-fyllitten av og til pene svovelkiskrystaller.

9. <u>Kalkrike kvartsitt og skifer:</u> Bergarten er som kvartsitt ellers, men inneholder en god del kalkspat. I tilknytning finner man ofte kalkrike skifre. Disse to enhetene er ikke skilt ut under kartleggingen. I tillegg finnes kalkrike kvartsitt som linser og lag i de øvrige kvartsittene (omvandlet tuff).

4.0. OMVANDLINGER OG METAMORFOSE:

Den vulkanske sekvensen ser ut til å representere en sekvens av tuff med mellomliggende svartskifre. Observasjoner av bergartene i felt, synes å tyde på at den sure tuffen er blitt albittisert. Denne omvandlingen har gitt en lys bergartsvariant som i felt er blitt kalt kvartsitt. Videre omvandles tuffen og kvartsitten til serisittskifer, særlig nær foldeomböyninger.

Metamorfosegraden er lav og ikke over grønnskiferfacies. Særlig Mourki fyllitten inneholder kloritt, men også kvartsitten kan være grønn, dvs inneholde kloritt eller epidot.

5.0. STRUKTURGEOLOGI:

Det viser seg at området er intenst foldet i alle skalaer. Dette reflekteres ved at mindre kompetente bergarter som feks skifre tynner ut og forsvinner. På den annen side har denne foldingen hatt betydning for malmdannelsen, med fortykninger i foldekreene.

Målinger av foldeaksenes stup og stupretning indikerer en nordøstlig til nord-nordøstlig foldefase, dvs en foldefase som stuper 5-40° i NØ-retning, vanligvis i 20-30°'s retning. I tillegg er det funnet folder med stupning 10-40° i retning V til VNV. Det er blitt gjort adskillig færre observasjoner av disse foldene.

Det synes derfor som om man i dette området har to foldefaser; en NØ-til NNØ-lig foldefase som gir opphav til tette isoklinalfolder, og en V- til VNV-lig foldefase som er påtrykt denne. Denne siste foldefasen er godt tilkjennegitt i blotning ved lokalitet 89 ved forkastning helt i sør på kartblad EH-211-8. Dette er skjematisk vist i fig. 7. Den V- til VNV-lige foldefasen gjør at vulkanittsekvensen stedvis kan forsvinne ved at den er erodert bort i antiformene. Man ser også at vulkanittsekvensen tynner ut mot nord, noe som sannsynligvis skyldes den NØ-lige stupningen av isoklinalfoldene, dvs man beveger seg oppover i sekvensen.

I tillegg til hovedfoldefasene ser man at det er utviklet parasittære folder i alle skalaer. I lok 16, kartblad EH 211-8 sees dette tydelig. Like så finner man parasittære folder i håndstykkeskala.

Det kartlagte området gjennomskjæres av ei sikker forkastning og to usikre forkastninger. Den nordligste er mest sannsynlig en knusningssone med minimal forskyvning. Svakhetssonen er uttrykt i terrenget ved et skar som stryker VNV-ØSØ på kartblad EH 211-8.

Den andre forkastningen ligger nesten helt i sør på kartblad EH 211-8 og stryker NV-SØ. En tilsynelatende lateral forskyvning på 20-25m kan måles. Tuffen nær dette skaret er tett gjennomsatt av parallelle sprekker. Pga bergartens kompetanse finner man at strøk og fall på sprekkeflatene varierer noe.

Den tredje forkastningen finner man på grensen mellom kartbladene EH 211-8 og EH-211-12. Terrenget er her karakterisert ved myrlendt terreng langs den mulige forkastningslinja. Hvis forskyvningen er reell, antas tilsynelatende horisontal forskyvning til å ligge omkring 5-10 m.

I tillegg finnes det en mindre forkastning i myr- nær-borhulls-retningen til DDH224, dvs ca 0,2 km øst for borplassen.

6.0. MALMGEOLOGI:

De effusive bergartene inneholder jevnt over ertsmineraler i små mengder, og hovedsakelig svovelkis. Isoklinal folding har ført til fortykning av malmen i foldombøyningen. I skjerp C (blotning 12) på kartblad E211-12 finnes malmen som et massivt legeme med 4-5 meters mektighet. Resultatene fra borhull 224 viser at dette massive kislegemet tynner ut mot nord, og i skjerpene sørøst for skjerp C er mektigheten liten.

Som nevnt tynner ut mot nord og borhull 224 skjærer gjennom en 20cm tykk strime som består av massiv kis, hovedsakelig svovelkis. I tillegg sees litt kopperkis og sporadisk sinkblende. Ellers finner man svovelkis og kopperkis som disseminasjoner i kvartsitten, se vedlegg 3.

På kartblad EH 211-12 ser man skjerpene Go og Ht, hhv. lok 92 og 93 hvor steiltstående kvartsitt og omvandlet kvartsitt (kvarts-serisitt skifer) inneholder massiv kis, hovedsakelig svovelkis og striper av sinkblende. Det ble observert lite kopperkis.

Lok 57 på kartblad EH 211-8 inneholder svovelkis i kvartsitt. Det ble ikke observert sinkblende eller kopperkis i fast fjell, men noe kopperkis fantes i løsblokk (stuff) nær skjerpet. Observasjon av omvandlet tuff styrker antakelsen om en isoklinalfoldet sekvens med NØ-stupende foldeakser.

Når det gjelder mulighetene for å finne fortsettelsen av det fortykkede malmlegemet i skjerp C burde sjansene være gode, se profil 2. Borhull 225 kan muligens skjære gjennom en foldombøyning som ligger under nåværende erosjonsflate, se profil 2, og eventuelt en ny malmfortykning.

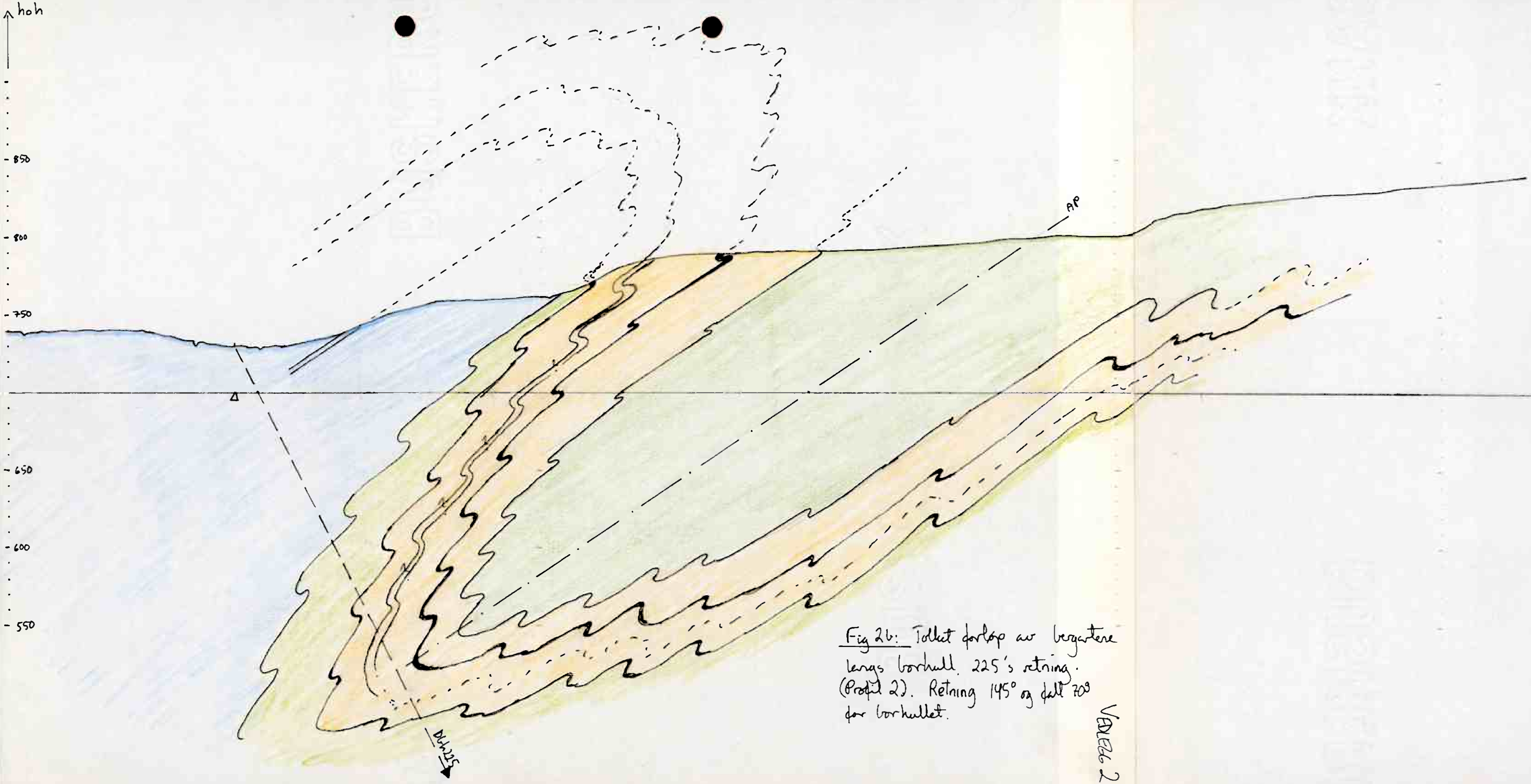


Fig 26: Tolket forløp av bergartene langs borhull 225's retning. (Profil 2). Retning 145° og fall 70° for borhullet.

VEDLEGG 2

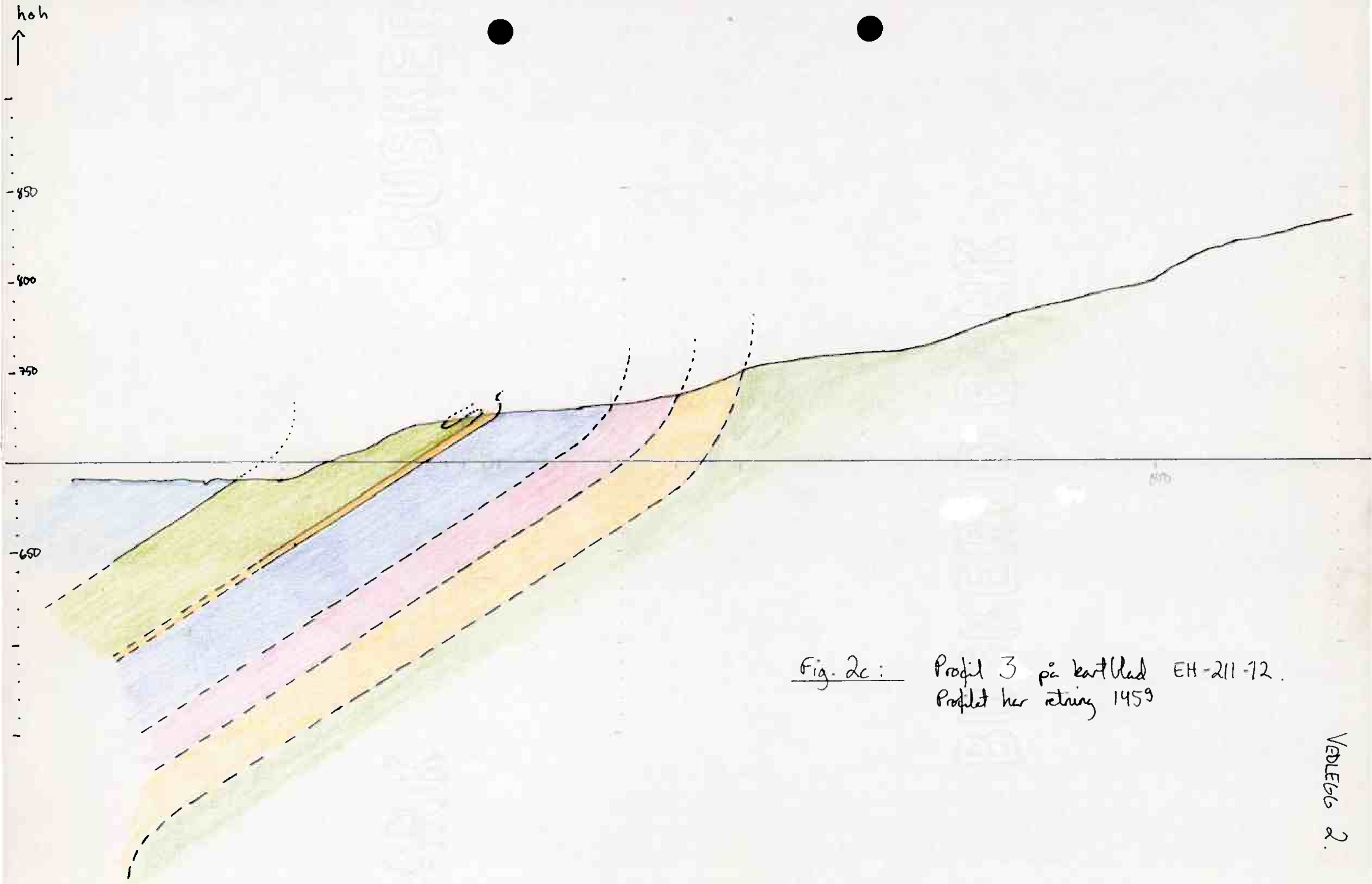
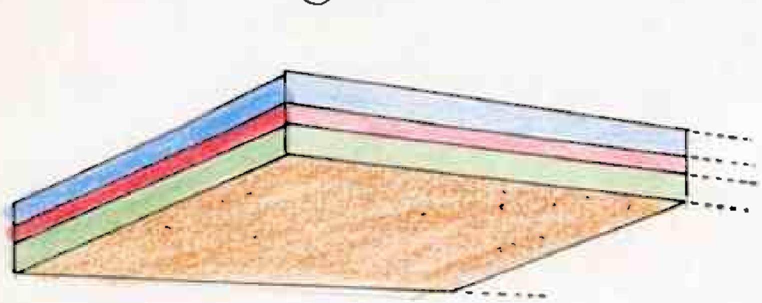


Fig. 2c: Profil 3 på kartblad EH-211-72.
Profilet har retning 145^g

VEDLEGG 2.

①



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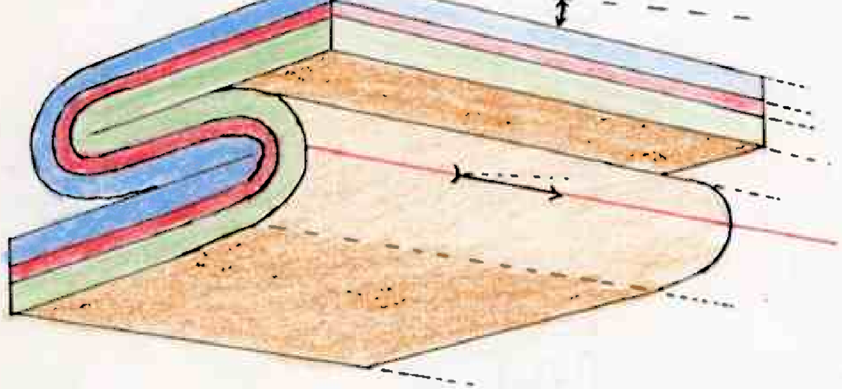

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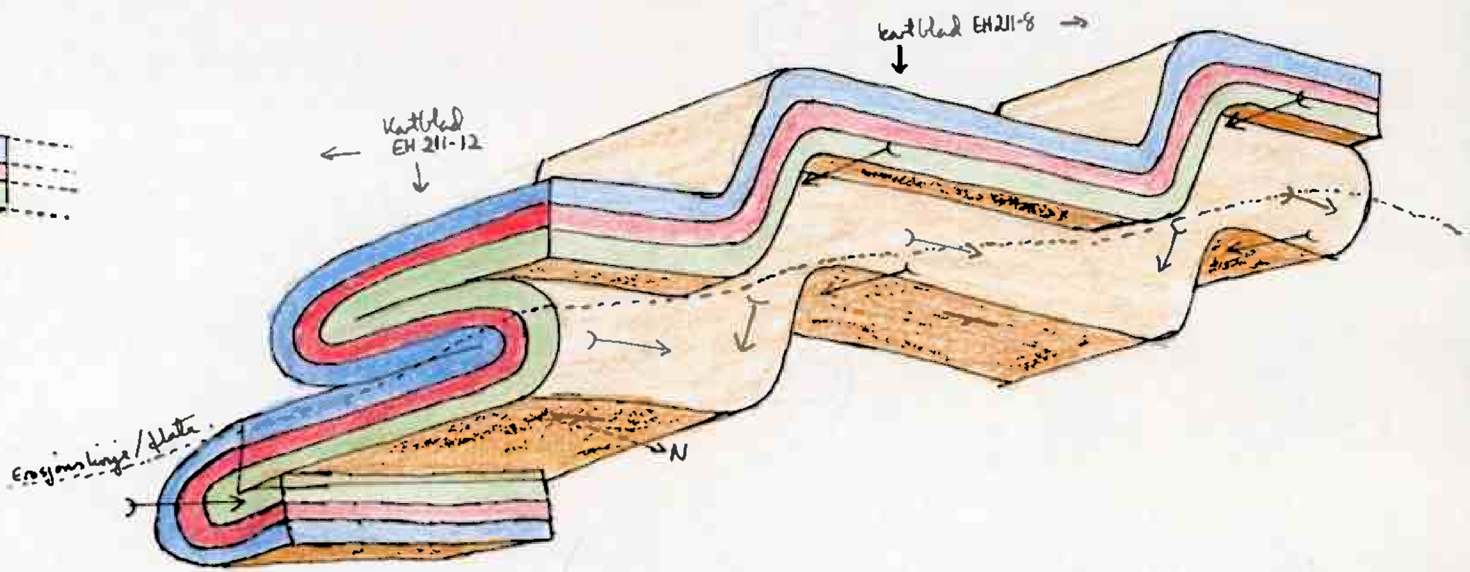


SKJEMATISK UTVIKLING AV GEOLOGIEN I KONG OSKAR:

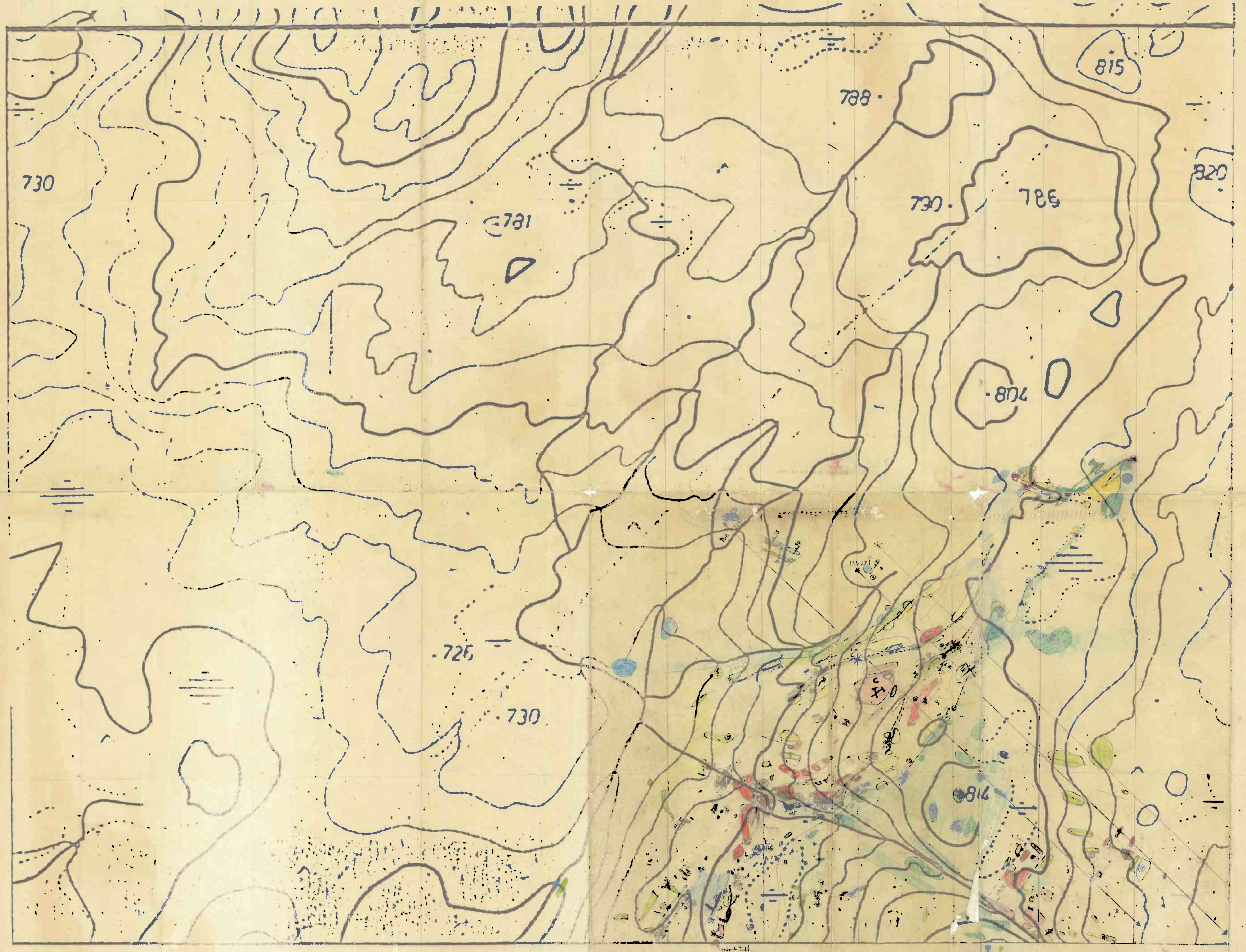
Fig. 1: Tenkt utvikling av bergartene i Kong Oskar.

1) Avsetning av de ulike enhetene, som nå kalles
2) En NØ–NNØ-lig foldefase folder bergartssekvensen i tette isoklinalfolder som stuper mot NØ og NNØ.
3) En ny vestlig foldefase folder bergartene som vist her. Stiplet linje viser tilstedeværelsen av nåværende overflate etter erosjon.

Prøver som er tatt:

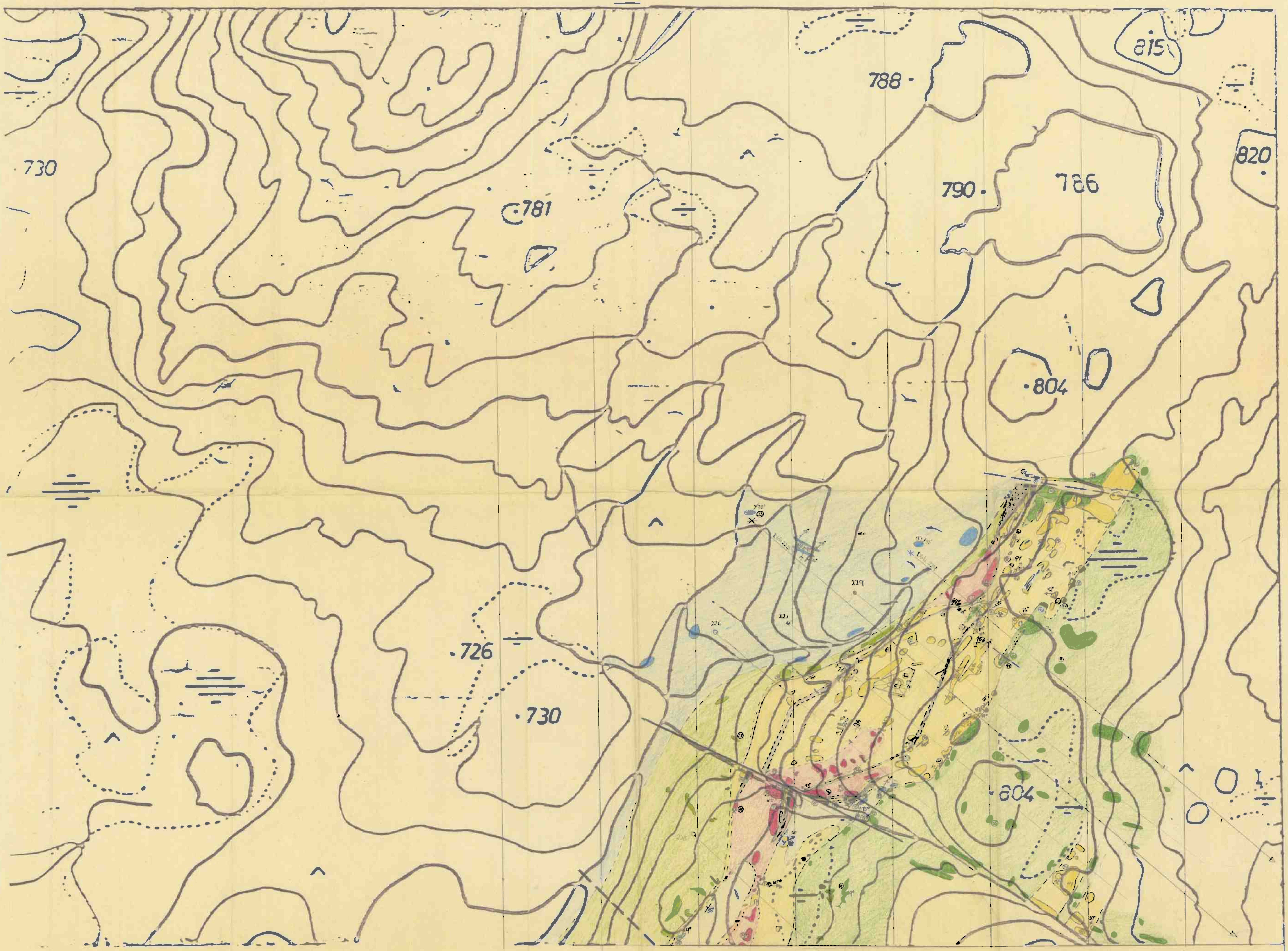
VEDLEGG 5.

Lok 1: Grå kalkrike skifer
Lok 2: Øvre fyllitt;
Lok 4: Tuff + svartskifer
Lok 5 Fyllitt (Mørkere fyllitt? eller øvre fyllitt?)
Lok 10: Kalkrik kvartsitt.
" 14: Kvartsitt + Mørke fyllitt.
" 17 —"— m/ kis + malakitt. (dim)
" 21 —— " ——
" 24 Sericittskifer (omv. tuff/kvartsitt)
" 25 Lys hvit kvartsitt (feltspatisert tuff). ~~kis~~ pyrittholdig
" 41 (44?) Lys kvartsitt.
" 61 — " —— -mineraler m/ svovelkis. (dim).
" 62 Porfyrisk tuff
" 64 Kvartsgl. skifer m/ svovelkis. dim
" 65 Mørke- eller øvre fyllitt? eller kvartsgl. skifer?
" 71 Tuff (kvartsitt?)
75 Øvre fyllitt: lys grønn til grå.
91. (Malmførende v.m.) Kvarts-sericittskifer. Har med disseminasjoner.
94 Øvre fyllitt. Kloritisert.
96 Gråsvart skifer - grafittholdig!
90 Kvartsitt og kalkstein. (kalkholdig kvartsitt).



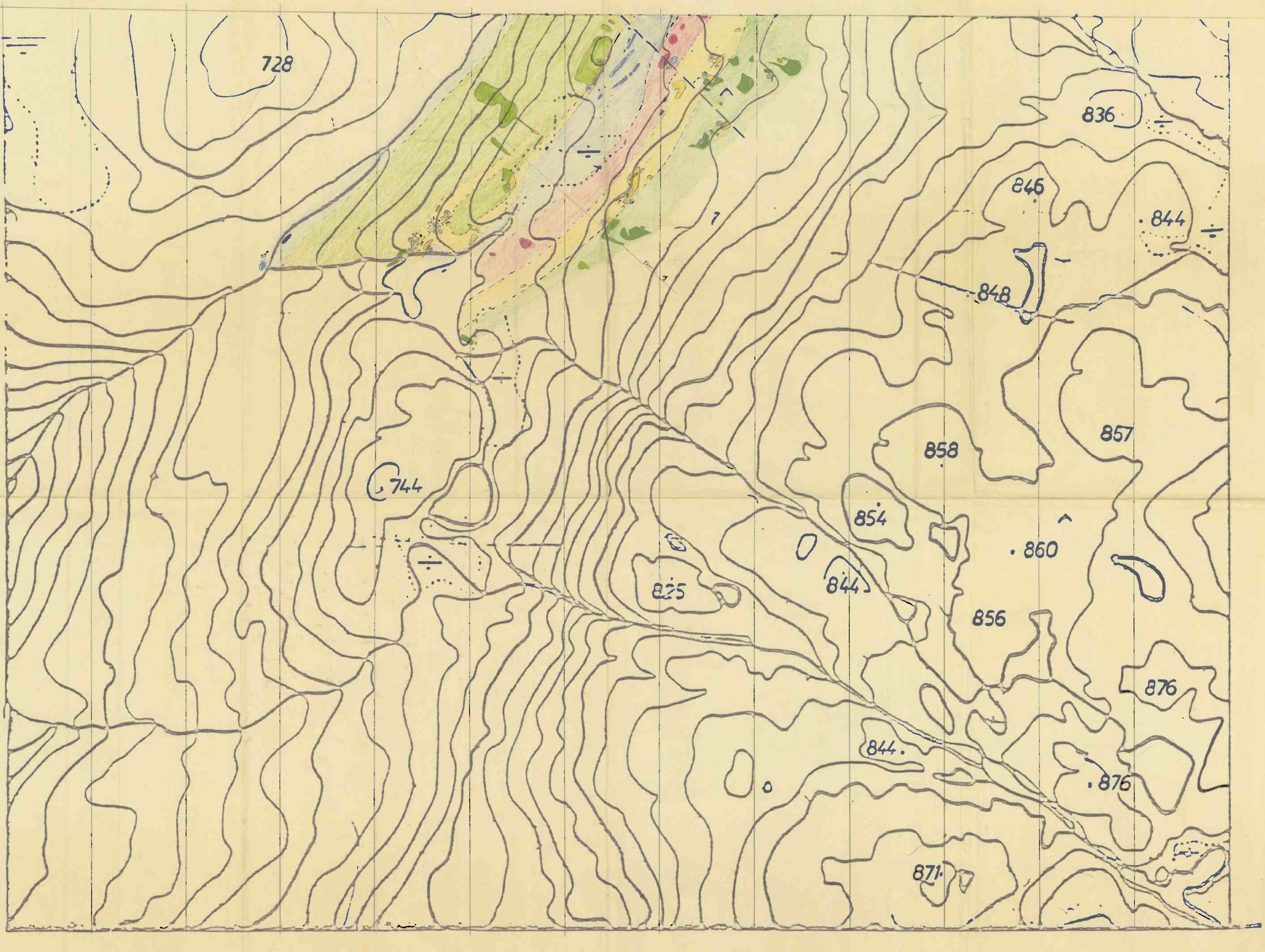
EH 211-8

VEDLEGG 1:



EH 211-8

VEDLEGG 1:



EH 211-12

⬭	Grå kalkrikskifer (Furulund skifer)
⬭	Øvre fyllitt
⬭	Tuff
⬭	Svartskifer
⬭	Kvartsitt (omvandlet tuff)
⬭	Kalkrik kvartsitt og skifer
⬭	Muorkifyllitt

⬭	Blottning
───	Bergartsgrense
- - - -	Bergartsgrense usikker/overgangsmessig
━━━	Forkastning
— —	Knusningssone/sprekkesone/mulig forkastning
ooooo	Konglomerat
32° ⟋ ⟋ +	Strøk og fall på lagning (32°, vertikal, horisontal)
15°	Strøk og fall falsk skifrighet (15°)
84°	Strok og fall for sprekkeflater (84°)
→ 25°	Foldeakse med angitt stupning (25°)
mt	Magnetitt
py	Svovelkis
cp	Kopperkis
sl	Sinkblende
⚒	Skjerp/røsking

TEGNFORKLARING TIL GEOLOGISK KART	Målestokk 1:2500	Tegn. Trac. Kfr.	H.T.M. t.w.
	Erstatning for		
PROSJEKT 144/1984 KONG OSCAR			
	Erstattet av		

▭	Furulundskifer
▭	Øvre fyllitt
▭	Tuff
▭	Svartskifer
▭	Feltspatisert tuff
▨	Kalkrik kvartsitt/kalkstein/kalkrik skifer
▭	Muorki fyllitt
—	Bergartsgrense
—	Forkastning
— — —	Mulig forkastning/knusningssone
30° + ×	Strøk og fall av bergarter (30°, vertikal, horisontal)
↗ 40°	Foldeakse med angitt stigning
mt	Magnetitt
py	Svovelkis
cp	Kopperkis
sl	Sinkblende
⊕	Skjerp/Røsking

TEGNFORKLARING TIL
GEOLOGISK KART

Målestokk 1:10000

Tegn H.T.M.
Trac. t.w.
Kfr.

Erstatning for

PROSJEKT 144/1984
KONG OSCAR

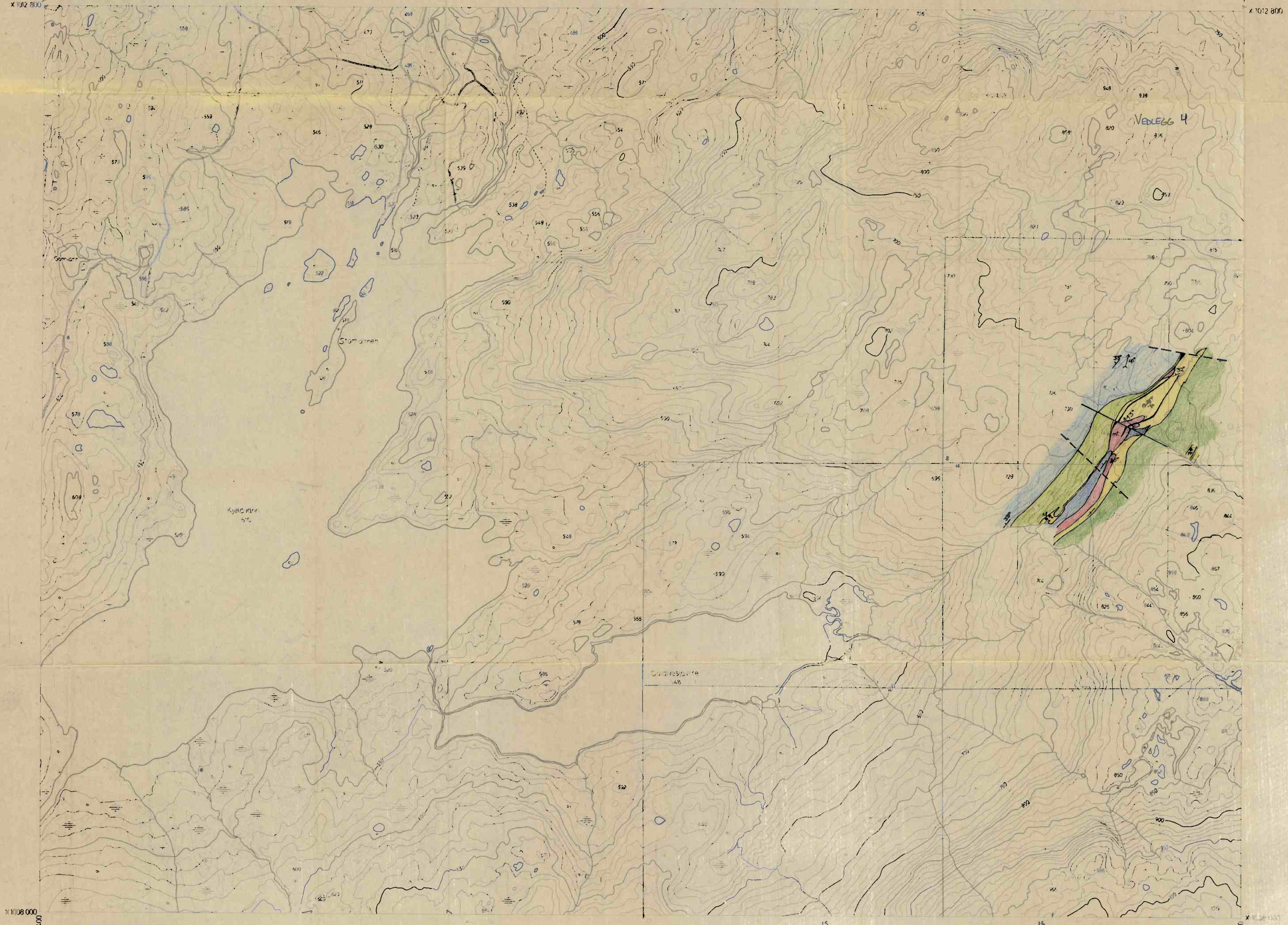
Erstattet av

VEDLEGG 4

TEGNFORKLARING GEOLOGISK KART 1 : 10 000

🟦	Furulund skifer
🟩	Øvre fyllitt
🟥	Tuff
⬛	Svartskifer
🟧	Feltspatisert tuff
🟦	Kalkrik kvartsitt / kalkstein / kalkrik skifer
🟩	Muorki fyllitt
—	Bergartsgrense.
━	Forkastning
— — —	Mulig forkastning / Knusningssone
⊥ 30° ┼ ✕	Strøk og fall av bergarter (30°, vertikal, horisontal)
↗ 40°	Foldeakse med angitt stupning.
mt	Magnetitt
py	Svovelkis
cp	Kopperkis
sl	Sinkblende
⊕	Skjerp / Røsking.

50963



FJELLANGER WIDERØE A-S
INGENIØR- OG ARKITEKTFIRMA

Fotogrammetrisk konstruksjon 1971

N G O s höyder og koordinatsystem

EG 212	EH 212	EJ 212
EG 211	EH 211	EJ 211
EG 210		

A/S SULITJELMA GRUBER

SULITJELMA M 1:10000 EKV. 10 M

GEOLOGICAL MAP OF THE KONG OSCAR OREFIELD

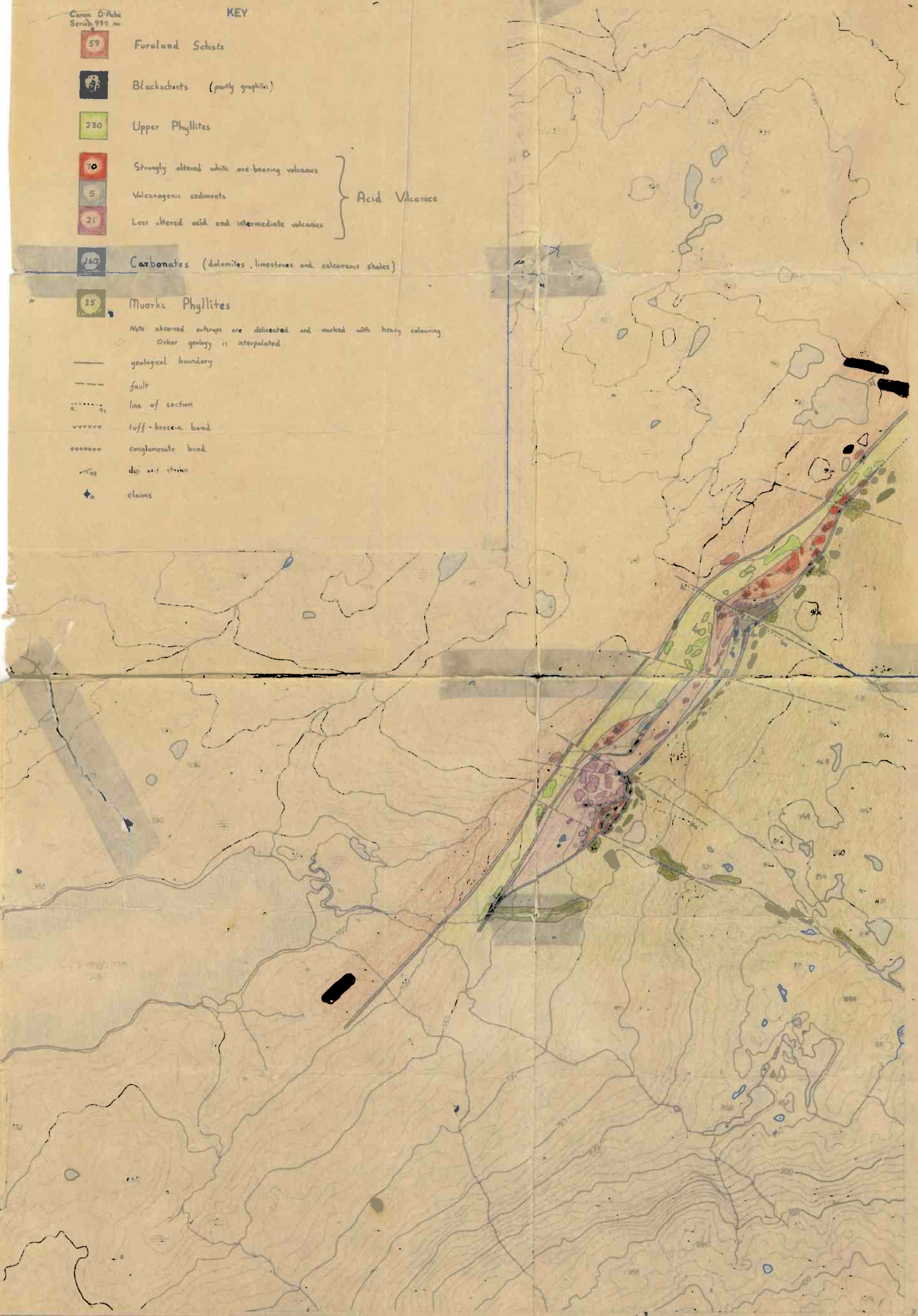
KEY

Caran D'Ache Series 999 No

59	Furuland Schists
9	Blackschists (partly graphitic)
230	Upper Phyllites
70	Strongly altered white ore-bearing volcanics } Acid Volcanics
5	Volcanogenic sediments } Acid Volcanics
21	Less altered acid and intermediate volcanics } Acid Volcanics
160	Carbonates (dolomites, limestones and calcareous shales)
25	Muorki Phyllites

Note: observed outcrops are delineated and marked with heavy colouring
Other geology is interpolated

——	geological boundary
– – –	fault
a ······ a₁	line of section
vvvvvv	tuff-breccia band
ooooooo	conglomerate band
⟋ 65	dip and strike
✦	claims



[redacted]

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KONG OSCAR MALMFELT
Detalj-geologisk blotningskartlegging

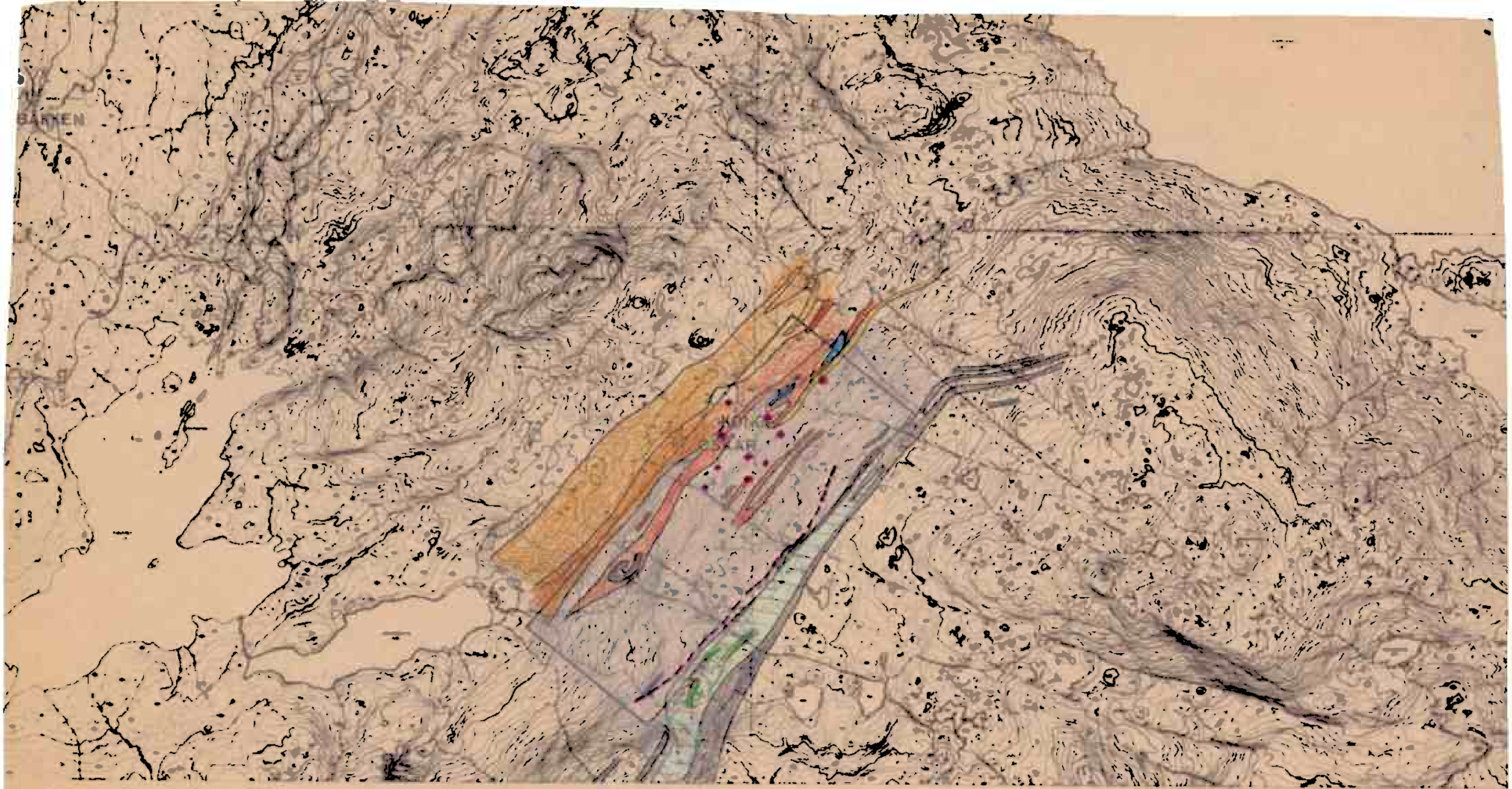
A/S SULITJELMA GRUBER
Prosjekt 7.502/A

Målestokk 1:10 000	Tegn. J.D.H.	30.9-75
	Trac. J.D.H.	30.9-75
	Kfr. T.S.H.	
Erstatning for.		
Erstattet av		

EG 212	EH 212	EJ 212
EG 211	EH 211	EJ 211
EG 210		

A/S SULITJELMA GRUBER

SULITJELMA M 1:10000 EKV. 10 M



59 ▨ kalkrik skifer
62 ▨ Undre skifer i grå fyllitt ofte i veksl. m/kalkrik skifer
64 ▨ Lyse, overveiende skifrige effusiver
70 ▨ Grønn til grå fyllitt
69 ● Grafittfyllitt (mørk fyllitt)
6 ● Kvartsitt
37 ● kalk
44 ▨ Grå effusiv. Magnetittrik
● Malmspunkter
--- Anmerkelser (Helling)

NORD- OG SYDGRUVEFELTET Prospektering i dagen 1975 Lokale og detaljerte prosjekter	Målestokk 1:50000	Tegn Trac RF 3/4-75 Kfr TSH 3/4-75
	Erstatning for	
A/S SULITJELMA GRUBER		
	Erstattet av	

Factors Affecting the Selection of Methods of Gold Analysis

By R. G. Burn*

There are a number of factors which need to be considered when deciding what method of analysis would be appropriate for a given gold-bearing material. These various factors, and the influence they exert on the choice of method, are discussed below.

ASSAYING is a means to an end and, strictly, can be viewed as the determination of the metal content of a relatively small sub-sample which may, or may not, be representative of the original bulk of material from which it was taken. In practice it should not be viewed in isolation because it is an integral part of much larger processes such as exploration reconnaissance, ore-body appraisal and evaluation, development and grade control, monitoring and control of mineral processing circuits, or smelting and refining.

Before selecting a method of gold analysis therefore, it is essential to consider the use to which it is intended to put the analytical results. If 'point' assay values are to be used to evaluate a larger bulk or a moving stream of gold-bearing material, then thought should be given to deciding exactly what is to be assessed, i.e. is the average value of the whole, the variability of its constituent parts or the total gold content, to be determined?

In the wider sense of 'gold analysis' it may be important to look at the other physical variables such as mineralogy and grain size, which from the standpoint of recoveries and costs, can be critical to the mineral processor.

In considering the factors which can influence the selection of appropriate methods of gold analysis, this article will examine the problems, pitfalls and shortcomings from the angle of the customer or end-user of the analytical results rather than from that of the analyst. Just what *should* a customer expect when submitting samples for gold analysis and what *can* he expect in practice? Consideration will be given also to determining what can be done to identify and correct any defects.

Gold's special properties

Gold is a metal which possesses certain unique properties that make it of special significance from an economic or utilitarian standpoint. However, many of these same properties combine to create particular problems when it comes to determining gold's concentration in natural materials.

Gold is a rare element which is not usually found in nature in large, mineable concentrations exceeding, say, about 30 g/t, although much higher concentrations may be encountered locally. Hard rock deposits containing as little as 1 g/t are currently being mined and alluvial concentration may be exploited at grades which are almost an order of magnitude lower.

The average concentration of gold in crustal rocks ranges between 0.002 and 0.005 g/t. Threshold values for geochemical exploration sample populations may commence as low as 0.02 g/t. At the other extreme, individual samples of high grade ore may range up to several hundreds of grammes per tonne with values in the low percent range being not unknown.

The gold content of metallurgical materials may range from concentrations as low as 1 μg/l for "barren" leach solutions up to 10-15 mg/l for pregnant solutions; from 0.1 g/t for "barren" tailings to hundreds of grammes per tonne for gold-rich base-metal concentrates or to values approaching 100% for some gravity concentrates, bullion and refined gold. The task which is set the analyst and customer alike is, therefore, a very daunting one.

Because of its high value, very low concentrations of gold may be economically exploitable. The problems which arise from this low gravimetric concentration are further compounded, especially in regard to obtaining representative samples, by gold's high density (19.33 when pure) which in turn is responsible for it occurring in even lower volumetric concentrations.

Further difficulties are often encountered when attempting to reduce samples of large bulk to assayable volumes. This is because, due to gold's extreme malleability, it is difficult to reduce its particle size without risking loss of gold on the moving parts of the sample reduction machinery.

Equally the mineralogy of gold ores can be very variable. Although native gold predominates, other gold minerals can also be of economic importance. Gold is also usually found in nature alloyed with silver in varying proportions; placer gold tending to be silver poor (usually <20%), whereas many Tertiary epithermal deposits contain silver-rich gold (>50%).

Gold tellurides, the other economically significant source of gold, include calaverite (Au Te$_2$), sylvanite ((Au Ag Te$_4$); krennerite ((Au Ag)Te$_2$) and petzite (Ag$_3$Au Te$_2$). Unlike native gold, the tellurides all possess a strong clevage and a brittle, uneven fracture. As a consequence, reduction of their particle size by crushing, grinding etc. usually presents no great difficulty.

Many of the problems in mineral processing which bedevil the liberation and recovery of gold from either free-milling or refractory ores also give rise to associated difficulties during assaying. If, for instance, gold particles are enclosed in gangue such as quartz, then their dissolution by an acid, to which the gangue is inert, will largely be a function of the extent to which grinding has liberated or exposed the gold to make it accessible to the acid attack. Similar problems are encountered in cyanidation or flotation processes and these can cause reduced recovery of the

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contained metal. We may be deluding ourselves, therefore, if we believe that analytical methods, which rely on dissolution of a sample, produce results which accurately indicate the total contained gold content. As is the case with metallurgical recovery, this bias will be largely a function of the degree of liberation of the gold particles, and will always be less than 100%

The nature of the associated minerals and gangue is one variable that may introduce a number of side effects which can influence the accuracy and/or precision of most analytical methods. Gold's natural associates are numerous and, while the geologist or engineer may view these from an economic aspect, the analyst may be more concerned with their relative gravimetric or volumetric abundance in the material to be tested. He might, therefore, be more interested in receiving advanced warning regarding the relative silica, iron or sulphide contents of a batch of samples rather than, say, their silver content.

On an established mine or smelter, an assayer is unlikely to be troubled with extreme variations in sample type. A custom laboratory, on the other hand, may be called upon to analyse material as varied as geochemical samples or ores, often from divers locations, through to high grade bullion or scrap. Logic suggests that there is a need for much greater synergy between the custom laboratory and its users than would be necessary in a more parochial situation and yet, in most instances, the reverse is probably nearer the truth.

Particle size

Possibly the most serious difficulties in achieving representative gold analyses arise from the particulate nature of gold and the low concentrations in which it is normally encountered. This, together with gold's extreme malleability, creates a major problem in the production of homogeneous sub-samples for assaying purposes.

To put the matter into perspective, a single spherical particle of gold about 210 µm in diameter (72 mesh) occurring in a 100 g sample would impart a value of just under 1 g Au/t. This is about the cut-off grade for low grade open pit/heap leach mining operations and high grade for placer mining or geochemical samples. Clearly a major problem arises if any attempt is made to take an aliquot, say 10 g, from this larger bulk. In such a case there would be only a 1 in 10 chance of any single 10 g aliquot containing the one gold particle and the gold content of this sub-sample would be either 0 g/t or about 10 g/t.

Either way there would be little purpose in assaying the 10 g aliquot because it would reveal nothing about the true nature of the original sample. Indeed, in this instance, unless all ten aliquots were assayed one would be little the wiser. Obviously, this would be rather an extreme solution to the problem and is unlikely to be practical as a routine application.

The above example is not as extreme as it may appear at first sight. Only when the size of the gold particles is consistently very fine and the gold grades are high relative to the sample and sub-sample volumes is there less reason for concern about representivity.

Having recognised that there could be a problem, it is important to determine whether or not one exists in reality. Two main investigative routes are available which can be applied at any stage in the life of a project, either as an initial orientation study or during the routine operational stages.

The first method is to undertake microscopic measurements of a large number of gold particles occurring within the bulk material, to determine the particle size distribution. In practice, this requires the examination of many polished sections, or in the case of placer deposits of panned concentrates, in order to find a sufficient number of gold particles to satisfy minimum statistical requirements. Substitution of this information, together with the other known parameters regarding grade, required sampling variance, etc., into Gy's equation[1,2] enables the weight of a representative sample to be calculated; or, for a given sample weight, the likely variance to be determined.

The second method is essentially empirical; it involves the comminution and sieve analysis of a number of representative samples and the assaying of their resultant products. Ahlrichs[3] gives an excellent account of this type of approach applied to the determination of gold particle sizes in a low grade (around 1 g/t) ore.

Additional useful information can be derived from this technique if the screen products are first subjected to gravity or heavy liquid separation in order to segregate the liberated gold for microscopic examination and measurement prior to assaying. This is a particularly realistic method because it examines the particle distribution of the gold after it has been exposed to the deforming effects of crushing and grinding. It is, after all, these modified particles which will determine the degree of homogeneity of the gold in the products which are ultimately submitted to the laboratory for routine assaying purposes.

Bearing in mind the aim, which is to present the analyst with a homogeneous, representative sample of material for gold assaying, it is preferable that sampling and sample preparation procedures should be designed around the samples rather than vice versa. If the characteristics of the bulk material can be established first, then the most appropriate sampling techniques and sample preparation equipment can be selected to minimise the effects of any natural and introduced sources of error.

A carefully thought out orientation study will serve to identify and quantify those factors which need to be taken into consideration when planning a sampling campaign and the design of subsequent, but all important, sample preparation and assaying stages.

Errors will inevitably be generated at each stage of the exercise right from the initial taking of the sample through to the ultimate step of the assaying procedure. The nature of these errors will differ depending upon their cause and can be categorised as follows:-

- Random errors, which arise from imprecise practice. By definition they are unlikely to be repeated and are statistically independent from observation to observation. They tend to be normally distributed about their mean value, which is zero.
- Systematic errors or bias. These are constant, unintentional errors of similar magnitude, having the same algebraic sign.
- Gross or illegitimate errors. These are generally of large magnitude and result from procedural mistakes.
- Deliberate errors which are caused by dishonest practice, e.g. salting.

Only random errors are acceptable and, while some degree of random error is inevitable, it should be kept within reasonable limits if satisfactory data are to be produced. The total random error component V_T is the sum of the variances generated at each stage of the sampling (V_S), sub-sampling (V_{SS}) and assaying (V_A) processes.

$$\text{i.e. } V_T=V_S+V_{SS}+V_A$$

The subject of sampling and sub-sampling errors has been discussed elsewhere[1,2,4].

It is sufficient, at this juncture, to recognise that the occurrence or persistence of any form of error can be minimised by the adoption of intelligently conceived sampling and assaying methods and by the institution of regular control procedures.

Finally, it should be noted in regard to random errors, that the sampling, preparation and assaying flow-sheet should be designed to ensure that the errors generated at each stage of the process are of a similar magnitude and that, in sum total, they are compatible with the purpose of the sampling exercise.

Sample types

A large custom laboratory can expect to receive samples for gold analysis in almost any form (solid or liquid), depending upon their source. Whatever form the samples take, it is stressed that it should be the responsibility of the client to ensure the integrity of those samples. The best that an analyst can do is to report the true gold content of the material submitted to him; he has no control over the relationship of this to the source from which it was derived, which it is supposed to represent.

If the analyst is to do his best in determining the gold content of the samples he receives it can often be of great assistance if he is given some information about their nature. Foreknowledge of the physical and chemical nature of the constituents, and indeed an order of magnitude indication of the anticipated gold content, can be generally valuable in selecting the most appropriate method of analysis. This is one positive contribution that the geologist/miner/metallurgist can make towards achieving more accurate assaying results. The other, even more important, contribution which he can make is to present the analyst with homogeneous sample material.

Imagine the thoughts which run through the mind of an analyst who receives a sample, weighing say 145 g, with an advice note saying "panned concentrate — please assay for gold". Is he to assume that the sample is homogeneous and that he can, therefore, split off an aliquot for assaying? May he assume alternatively, that it *can* be homogenised by further grinding or must he find some means of assaying the whole of the material in order to produce a "true" result? Could the sample actually contain a high concentration of gold or does the term relate only to the possibility of the sample containing a high proportion of refractory or "nasty" minerals?

Such a sample, and many other types besides, may well test the ingenuity of the most experienced, conscientious assayer, but what chance has the luckless prospector of making a strike if the assayer is as ignorant or thoughtless as himself? Certainly, if the geologist/engineer were better informed about the limitation of the techniques available to the analyst, he might be stimulated to improve the quality of both his samples and the accompanying information, thereby making a positive contribution towards improving the quality of the analysis.

Equally, there are times, possibly due to ignorance or expediency, when the analyst may be accused of blanket application of a method which may not be wholly appropriate. Any laboratory which is concerned about maintaining its integrity will doubtless make every effort to select the most appropriate analytical technique, but is heavily dependent upon the client for guidance in making this choice. A continuing dialogue and exchange of information are essential ingredients to establishing confidence and reliability.

It is, perhaps, pertinent at this point to consider the type of information which would benefit both parties and, in particular the quality of the analytical results.

Prior to agreeing routine procedures, the initial dialogue between the analyst and client should attempt to provide answers to the following:-

- The type of material being submitted
- Whether or not it requires any further treatment/preparation prior to assaying and, if so, what?
- Whether any special precautions are necessary during handling, treatment or assaying.
- Are analyses for other elements required which might affect the selection of an appropriate treatment/assaying procedure?
- Bearing in mind the purpose of the sampling exercise and the nature of the samples, consideration of what levels of precision and accuracy are (a) desirable and (b) practically achievable.
- Similarly, what lower limit of detection will be acceptable?
- Advice on whether there is anything special about the mineralogy of the samples (major, minor or trace minerals) which could influence the selection of an assaying method, e.g. refractories which might require a different flux in fire assaying or major elements which could cause interference in chemical or atomic absorption analysis.
- Advice on the possible form of the gold in the samples, the gold particle size and the range of values which might be expected, would be of the greatest use to the analyst in selecting the most appropriate method.

Characteristics of methods

While there is no analytical method for gold which might be considered to have universal application, many methods are sufficiently flexible to permit their adaptation to handle a wide variety of sample types.

When selecting a suitable laboratory a client would be well advised to consider the following points concerning the preferred characteristics of an analytical method and the type of service that he might hope to receive from a laboratory:-

- What types of samples does the laboratory routinely handle? If, for instance, these range between such extremes as geochemical samples and ores or bullion, does the laboratory minimise the risk of contamination by treating each sample type, from reception through preparation to assaying, in totally separate conditions? Although the control of laboratory performance is discussed later, it is relevant to stress at this stage that a laboratory with a high reputation for assaying ores and bullion may not necessarily be competent at say, geochemical analysis or vice versa. Quality of results is determined not only by selection of the appropriate method, it is equally dependent upon the analyst's skills.
- Does the laboratory offer one method, or a number of methods, having the ability to deal with various sample types and sizes, especially in relation to any inherent particulate sampling problems?
- Is the detection limit of the method satisfactory for the purpose to which the results will be applied? For example, a low detection limit is required for geochemical or tailings samples.
- What is the sensitivity of the method offered? If high precision is sought, is the sensitivity adequate over the particular range of values that is to be investigated? This may be particularly important, for instance, within the cut-off grade range for low-grade gold ores.
- Can the method adequately cope with variations in sample mineralogy on a routine basis or does it have to be adapted to meet the needs of individual samples? For example, where an acid attack is employed, the use of a constant volume of acid, irrespective of variations in mineralogy, could seriously affect the degree of dissolution of gold in the presence of varying amounts of, say, carbonates or sulphides. Elemental carbon can have a similar effect.
- Attention has already been drawn to the effects of variations in trace, minor and major element/mineral content on the reliability of assay results. The clients should ascertain whether the laboratory can demonstrate experience and competence in handling the type of sample which he intends to submit for analysis.
- Lastly, performance: while a laboratory's reputation may count a great deal, only the most trusting (and foolish) customer would submit samples for analysis without making some provision for monitoring the quality of the laboratory's performance. In addition to quality, other performance factors such as turn-

around time and cost must be taken into account. There can be instances when excessive precision or accuracy is unnecessary or could be sacrificed in order to achieve a more rapid or cheaper result. On-the-spot colorimetric analysis for geochemical base-metal prospecting is an example of such expediency. The lack of suitable, simple portable analytical methods for gold was one reason why pathfinder elements have often been used in the search for gold. In a similar vein, there must be many underground managers who would warmly welcome the advent of a method of rapidly determining whether development muck should be sent for ore or waste.

Cost of assaying may or may not be important. It is often a very small part of the total cost of acquiring sampling data and rarely justifies skimping on. Beware the cut-price offers. Cost-savings produced by increased efficiency are one thing, but reductions through the analyst cutting corners are not acceptable.

Quality control

There are two separate responsibilities for quality control. The first lies with the laboratory which must exercise rigorous internal control in order to protect its own integrity, and the second resides with the client who, if he is to have faith in his interpretation of the results and at the same time protect his own professional credibility, must institute some means of checking the reliability of those results. Quality control may take the form of either spot checks or routine monitoring.

Attempts to control the reliability of analytical data must commence even before the first sample is taken. The complete process from the inception of a sampling campaign, through planning, orientation and routine control should include consideration of the following steps:-

(1) Definition of the objectives of the sampling exercise. What is to be assessed, what is the purpose of the estimations and what level of reliability can one reasonably expect to achieve? This might be termed the PLANNING PHASE.

(2) Determination of the nature of the material to be sampled. What constraints does this introduce upon sampling and sub-sampling representivity and upon analytical accuracy and precision? This represents the DETERMINISTIC STAGE OF THE ORIENTATION STUDY.

(3) The EXPERIMENTAL STAGE of the orientation study may involve:

- (a) Consideration of how the natural and other constraints can be overcome and the development of an optimum sampling campaign by selection, after experimentation, of the most effective sampling methods, sample sizes, sampling patterns and/or sampling frequency.
- (b) Selection and testing of the most appropriate methods of preparing and sub-sampling these materials to produce representative sub-samples for analysis.
- (c) Selection of, and testing, a suitable laboratory and/or method of gold assaying to ensure satisfactory precision, accuracy and consistency of results.

It is at this point that an acceptable procedure for the whole process can be established. Equally, it is only at this stage, with the knowledge derived from the orientation study, that it is possible to devise an appropriate method of quality control.

Ultimately it is the client, who has to use the analytical results in his interpretation or assessment, who must be responsible for ensuring the reliability of his data. To this end it usually is preferable for the sampling and sample preparation operations to be under the control of the client.

The purpose of quality control in this context is to minimise the various sources of error, both natural and introduced, to an acceptable level. Control, usual in the indirect sense, can only be exercised by the client who has established some procedure for monitoring laboratory performance. Without the information provided by some form of routine monitoring, no basis exists from which to judge the quality of results produced by an analyst or laboratory. This applies equally to the sampling and sample preparation processes.

Errors to monitor

Before discussing the various methods of monitoring or checking laboratory performance it is essential to reconsider the types of error which might be generated during routine analysis.

Accuracy

Perhaps the most difficult parameter to assess is accuracy, partly because it can be masked by the effects of the other forms of error and partly because of the difficulty in determining a basis for establishing exactly what is accurate. The problem of determining accuracy is probably nowhere better exemplified than by alluvial gold or tin or diamonds. For instance, assays of the total gold contents of a series of alluvial samples may be little help to a placer miner, although, of course, they might represent accurate analyses to someone else. The placer miner is only interested in an accurate assessment of, say, the plus 100 micron gold, i.e. that which he can readily recover in his plant. He still requires accuracy, but it is an accuracy which is relative to a different standard, i.e. total recoverable gold rather than total gold content.

This example epitomises the problem of accuracy for virtually all forms of assaying: accuracy can only be judged relative to some standard of performance for each technique. One may justifiably compare the accuracy of the results of atomic absorption analysis, neutron activation analysis and fire assaying but it may not be valid to equate them.

The majority of analytical methods probably have a slight tendency to under-estimate the absolute gold content because of their inability to extract 100% of the element for measurement purposes. However, bias can arise in any method for a variety of reasons, the most common possibly being incorrect instrument calibration, poor standardisation and interference of certain elements. Although cross-checking against other methods or laboratories should be a regular activity for both laboratory and client, it should be backed up by the insertion of samples of known control material into sample batches on a routine basis. Also, in the absence of knowledge about the presence of any elements likely to cause interference in a particular analytical technique, the conscientious analyst will undertake spot checks, usually using some form of rapid spectrographic scan, to check for such elements.

Ultimately, it is up to the user to decide what level of accuracy is necessary for the task in hand. The geochemist looking for subtle contrasts or anomalies is more likely to be concerned with precision than accuracy, whereas to the smelter and refiner a one-percent bias error in assaying might mean the difference between profit and loss.

One potentially dangerous source of bias is contamination. Although normally considered in the sense of the introduction of higher values, the term is equally pertinent to the effects of dilution. Because of the normally low concentrations in which gold occurs in natural materials, it takes the careless introduction of only very small quantities of a high grade substance to produce a significant positive bias. While this is more likely to occur during the preparation of a sample, it can be a hazard during analysis when, for instance, samples of varying types or those covering a large range of values are being assayed. It is essentially bad practice which gives rise to contamination. Washing out a pipette between taking aliquots from individual samples is obviously necessary, but if carelessly undertaken, it can easily lead to the addition of a few percent of barren diluent and the introduction, thereby of a negative bias. The analyst's life is not an easy one!

Precision

The causes of the degree of scatter of assays about their mean value may be legion. At ever stage of an assaying procedure where a measurement is made e.g. weighing, aliquoting etc., imprecision may arise. Of equal significance are the effects of inhomogeneity in the sampled material and other solids and solutions used in the assaying process, as well as variations between samples in their reaction time and the temperature aspects of leaching or melting.

As imprecision increases, estimation of the mean value of a group of samples becomes increasingly less certain. Whether one is applying classical statistics or geostatistics, excessive imprecision is undesirable. It either requires that a larger number of samples has to be taken, or more determinations made in order to reduce the standard error of the mean value to an acceptable level otherwise, in the case of the variogram, it can produce a pure nugget effect.

Where assaying is a small part of the cost of data acquisition, it does not pay to sacrifice precision to cost saving. If the imprecision arises because of subsampling difficulties, due to the presence of coarse particulate gold, and further homogenisation is impractical, then the only alternatives remaining are either to select a method which is capable of assaying larger samples or else to undertake replicate analysis. If costs are about equal, the latter approach is usually preferable as it provides additional information about within-sample variances.

Gross errors

Gross or illegitimate errors are usually, although not always, of sufficient magnitude as to be readily detectable by routine monitoring. They arise mostly from major misreadings in measurements, e.g. during weighing, pipetting or from procedural mistakes such as the omission of a particular step or incorrect preparation of a reagent.

It is one of the more embarrassing mistakes for a laboratory to make because it reflects so obviously upon their competence and because such errors should be readily detectable by in-house monitoring and calibration against standards.

Deliberate errors

Honesty is the ultimate test of the reputation of an assayer, laboratory, sampler etc. Dishonesty with the intent to defraud may be a criminal act but, in the past, it has not deterred the more unscrupulous operators. Salting of samples is probably the easiest to achieve and this is why it is imperative, when sampling for valuation purposes, that the person whose reputation is at stake (geologist or engineer) should ensure the integrity of his samples throughout the process, from collection to assaying if necessary. It is a sad reflection upon human frailty, but the maxim must be be 'if in doubt, trust no-one'.

Monitoring and control

Unlike quality control as applied to a manufacturing process, the assay results of 'unknown' samples cannot be recognised individually as being good or bad. Replicate assaying of individual samples may increase our confidence in their reliability and, perhaps, crosschecking by other laboratories will satisfy us, but we should not lose sight of the fact that each assay is only an estimate of an unknown value.

Although physical control may reside with the actual operator, it is possible to achieve overall control of a single multistage process by instituting an effective method for checking and monitoring results. To be effective the procedure should be capable of providing information on the magnitude of all forms of error and an indication of their sources.

Assessment of the quality of results should normally be the responsibility of both the client and the laboratory. While each has some part of the sampling, preparation or assaying process directly under his control, only the client has the opportunity to monitor or check every part of the process.

If there is any value to be derived from quality control it must be applied to all stages of the process. There are two general techniques available for collecting information about data quality (a) the random or spot check and (b) routine monitoring. Both can play a valuable part in quality control and in a large, on-going sampling programme each may be used as independent checks upon the efficacy of the other.

Control by the client

There are a number of methods available for testing data quality; the cost varies with the degree of control required and this latter should be determined by the use to which the data is to be put. There is certainly little point in wasting time and money on implementing detailed control procedures if the end use of the data does not justify it, but it would be even more irresponsible if inadequate quality control was to unnecessarily increase the risks associated with decision-making in any large project. Sadly those projects which are most in need of high quality data, such as those with marginal ore grades, are the least able to afford the greater cost of acquiring such data.

Methods vary in what they can check, i.e. accuracy, precision, salting, gross errors or contamination, and a combination of methods may be required if comprehensive control is required.

Sampling

Turning first to the control of sampling, virtually the only means of checking the reliability of sampling is by duplicate or replicate sampling. This may vary from the fairly simple repeated sampling of a relatively homogeneous liquid or pulp, through the more difficult sampling of broken ores for which some degree of homogeneity can be achieved, to the often extreme difficulties involved in trying to duplicate samples taken from solid ores.

When comparing the results of replicate sampling or the difference between duplicate pairs, the average variance or the average relative variance of the samples may contain variances from all or any of the sources mentioned earlier, including those arising from the sample preparation and assaying stages; these obviously have to be quantified in order to isolate those components which have originated at the sampling stage. This is most readily achieved by undertaking a series of hierarchical sampling experiments which involve progressive splitting of a sample and duplication or replication of the treatment process at each stage from sampling through sample preparation to assaying. The variances generated at each stage can then be separately identified and quantified[5].

The sampling variance, V_S, contains two components, V_E which represents the error generated by the inability of the sampler to exactly duplicate the original sample (e.g. equal volume, identical geometry) and V_I, the inherent, local, inhomogeneity of the solid or broken ore or pulp. These two variances are closely interrelated and their individual effects are usually difficult to identify separately.

V_I is a function of the sample size relative to the inherent inhomogeneity of the parent material. The representivity of a sample can be improved by an increase in volume, but sample geometry can also be a very significant factor for solid ores in which the valuable constituents are anisotropically distributed throughout the mass.

When recovery is 100%, diamond drill core is probably the most representative hard-rock sampling method, however, if the long axis of the hole is incorrectly orientated, it can introduce a considerable bias to the results if the ore values are anisotropically distributed. It is possible to obtain a good estimate of V_I by conducting a sufficient number of duplicate or replicate analyses of sliced diamond drill core. This assumes that V_I is by far the dominant contributor to the value of V_S in such circumstances. Also, in order to isolate V_S from the total variance V_T, the other components V_{SS} and V_A must be quantified. This is most readily achieved when duplicate core sampling is undertaken as an integrated part of a series of hierarchical sampling experiments.

Sample preparation

The process of preparing and transforming a raw sample into a small volume suitable for assaying can, if done in uncontrolled conditions, be a major source of variance. For instance, while only 10 g of sample may be used for assaying, this could represent an original pulp sample of say 100 g or a broken ore sample of perhaps 10 kg. The process of reducing both volume and particle size by many orders of magnitude must be based on a sound understanding of the characteristics of the ore. There is, therefore, very good reason for this part of the operation to be under the client's control. Laboratories offering a standard preparation procedure should be avoided and only those which demonstrate flexibility and an understanding of the seriousness of the likely problems warrant any consideration.

Even a properly designed and tested sample preparation process needs checking regularly to ensure that it continues to meet the product quality specifications. There are two aspects to the checking process: the first is intended to ensure that the purely mechanical requirements continue to be met, while the second is a check on variance.

The preparation process involves the progressive crushing or grinding of a sample (particle size reduction) and subsequent splitting into smaller amounts (volume reduction) prior to further grinding or assaying. The representivity of a sub-sample split is dependent, among other things, on the particle size of the fragments which constitute the sample. Consequently, it is important to ensure that the machinery is regularly adjusted to achieve the designed degree of comminution. Trial samples should be processed at regular intervals, each size product being sieved to ensure that the desired degree of crushing or grinding has been achieved.

On a routine basis, and at fairly frequent intervals, the other halves of the various sample splits should be onprocessed and assayed as a check on the level of variance being generated. If at any time this is found to depart significantly from the designed level, the cause should be sought.

The screen assay method described by Ahlrichs[3] can be employed as a way of assessing any coarse gold problem when, for instance, new ore types are to be treated or as a means of investigating possible sources of bias.

In sample preparation, as with sampling, cleanliness and good practice are essential if the products are to be a reliable quality. The tasks may be routine and uninspiring, but they are responsible ones requiring trustworthy employees and conscientious supervision. Control of the quality of sampling and preparation processes is very often a blind spot for many people, who may lavish excessive efforts on checking the assay laboratory but fail to recognise the shortcomings in the preceding stages. Control of assaying is the easier and more obvious procedure to implement. Even so, however well it is carried out, if it is not backed by control in the preceding stages, its results can lead to unjustified confidence in the reliability of the assaying data. In the worst cases very precise, accurate and trustworthy assays may be produced by the analyst, from the small sub-samples he has received, which bear little relevance to the values of the samples from which they were originally derived.

Assaying

The control of assaying should form an integral part of an overall scheme for a properly designed, well balanced, adequately controlled sampling system. Before discussing the various methods of checking the quality of assaying, it is stressed that, while it may be advantageous to the customer that the analyst is aware that his performance is being monitored, it is important that he should not be able to identify those samples which have been included for this specific purpose.

The means of checking may be either on a regular basis or it may take the form of non-routine spot checks. Checking can involve either the insertion of various types of control samples into batches despatched for analysis or the submission of duplicate sub-samples to other laboratories for independent assessment

Control samples

Control samples may be of the following types:-

Standard samples of internationally accepted reference material. These can be used as a check against accuracy, precision and deliberate gross errors, but only if the material is similar in appearance and character to the samples which it is meant to control. Such reference material is often expensive and it is usually impractical to use it for anything other than the occasional spot check on 'accuracy'.

Control samples may be prepared from similar, representative bulk samples of the type of material it is desired to control. Physically and mineralogically these control samples must resemble the sample batches into which they are inserted if they are to be non-identifiable and a fair check. The frequency of their insertion, which depends upon the level of reliability sought, may range from 1 in 2 to 1 in 20 or more if confidence in the laboratory is justifiably high. The inserted control samples should not be evenly spaced i.e. a 1 in 10 insertion rate does not mean that every tenth sample is a control but rather that in a batch of say 100 samples ten controls have been inserted at random. Also it goes almost without saying that sequential numbering of both samples and their included controls is a necessary part of the disguise.

If the presence of particulate gold is at all likely to give rise to sub-sampling errors in the control samples then the bulk material should be sieved at a sufficiently fine screen size to remove all but the finest particulate gold. Control samples are intended, after all, to quantify assaying errors and this task should not be hampered by the needless introduction of other sources of error. Properly homogenised control samples can be a valuable means of monitoring precision. If an accepted value has been determined for a batch of control material by at least two reliable laboratories it may be of use additionally for checking accuracy and for detecting gross errors and dishonest practice.

Controls can be either 'known' or 'unknown', the correct value for the former having been accurately predetermined prior to its adoption as a control. The value for the latter is determined progressively as a result of its use as a control and it is therefore limited in use to monitoring precision only.

Whether more than one control needs to be in use at any one time depends largely upon the range of values to be controlled. It may be that there are certain particular levels that are critical to decision-making which need to be specially controlled, such as cut-off grade, tailings grade, head grade etc. These requirements can obviously be catered for by the use of more than one control. Exploration and development samples often cover a very wide range of values and it may be necessary to em ploy a number of controls to cover this range, especially if the data is to be used for ore reserve purposes. Because populations of gold values of small samples from natural materials tend to display logonormal distributions there are relatively few very high values. However, in determining weighted averages these few high values have a disproportionate effect upon the mean value. It is not unusual for only 5% of the samples to contribute 50% of the value of the arithmetic mean of a group of samples. Control in these circumstances is difficult and it is usually cheaper and more reliable to submit duplicates for re-assaying, either to the same laboratory if precision is a problem or to another, 'referee' laboratory if the concern is over accuracy.

Blanks or barren control samples can be very helpful in checking for deliberate errors, gross errors or contamination.

Submission in Duplicate is an alternative to inserting controls, especially for small batches of samples when the cost of preparing bulk controls is not warranted. Depending upon the degree of checking required, duplicate pulps for all, or a percentage, of the samples are inserted at random in the batch and all samples renumbered. This can be a useful check on precision, but it supplies no information about accuracy or dishonesty.

Cross-Checking by submission of either all or selected samples to another laboratory can be an effective, if expensive, means of control. It can act as a check on all forms of error, except precision, and may be done either concurrently or, if time is not critical, retrospectively.

Control by the laboratory

Control within the laboratory cannot reside with the assayer; he is too directly involved to be sufficiently objective. The responsibility must lie with someone at supervisory level who is in a position to monitor independently the performance of his staff and to implement corrective measures speedily when unacceptable results are detected. In addition to being able to use control techniques similar to those available to the client, he can also check assayer against assayer and method against method. He can institute double-checking procedures such as stage repeats and, for wet methods, he can submit known or standard solutions as a check on accuracy.

Every laboratory which is concerned about producing reliable results must continually strive to minimise all significant sources of error. This can only be achieved by exercising continuous control over all stages of the assaying process. ■

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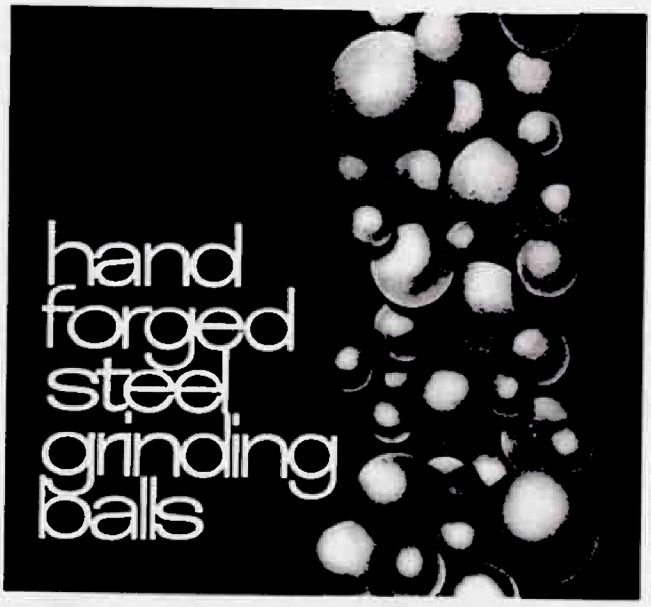

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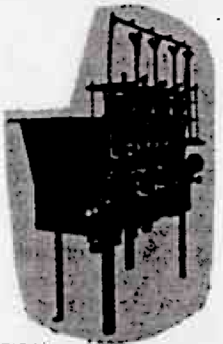

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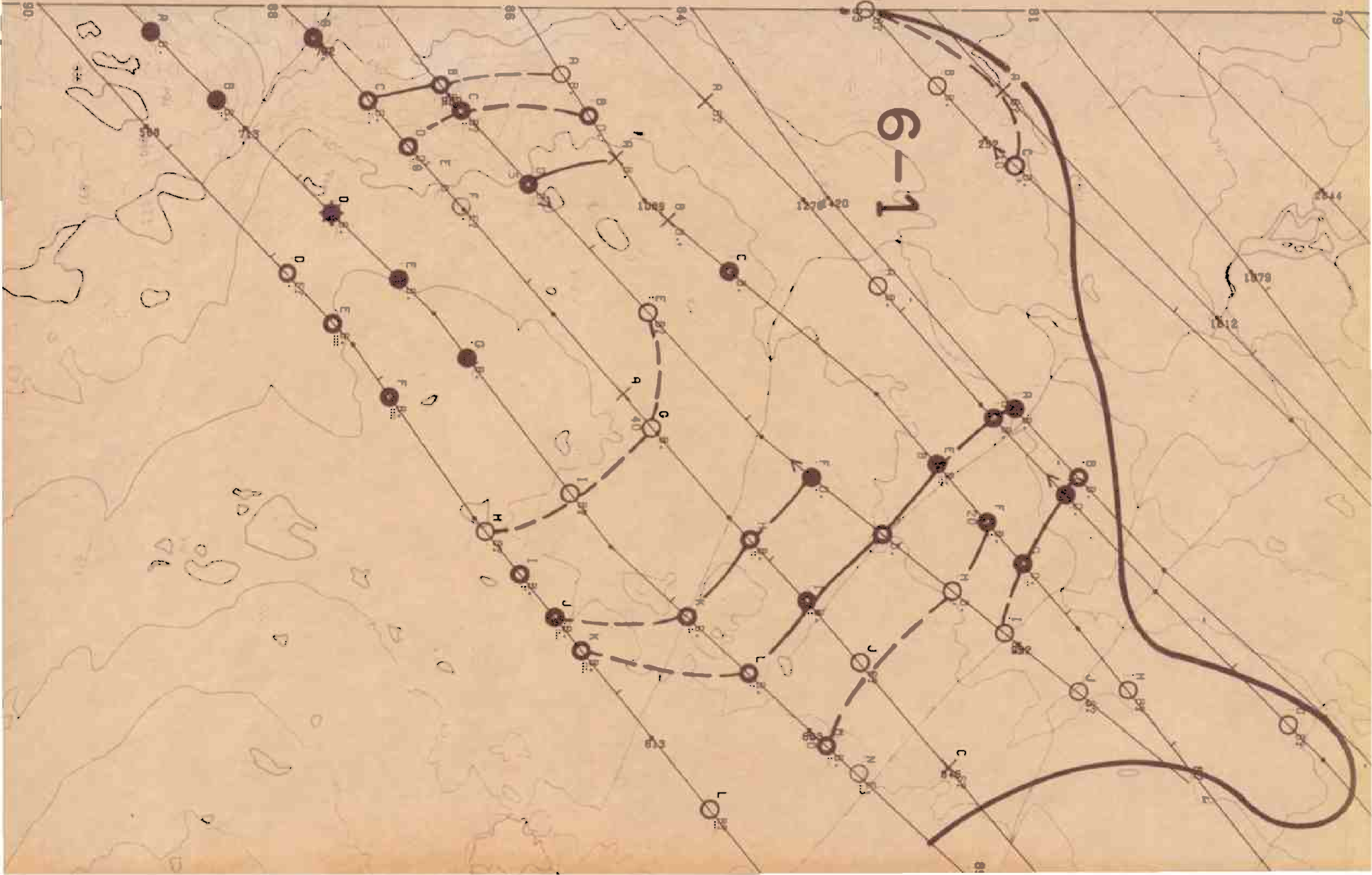

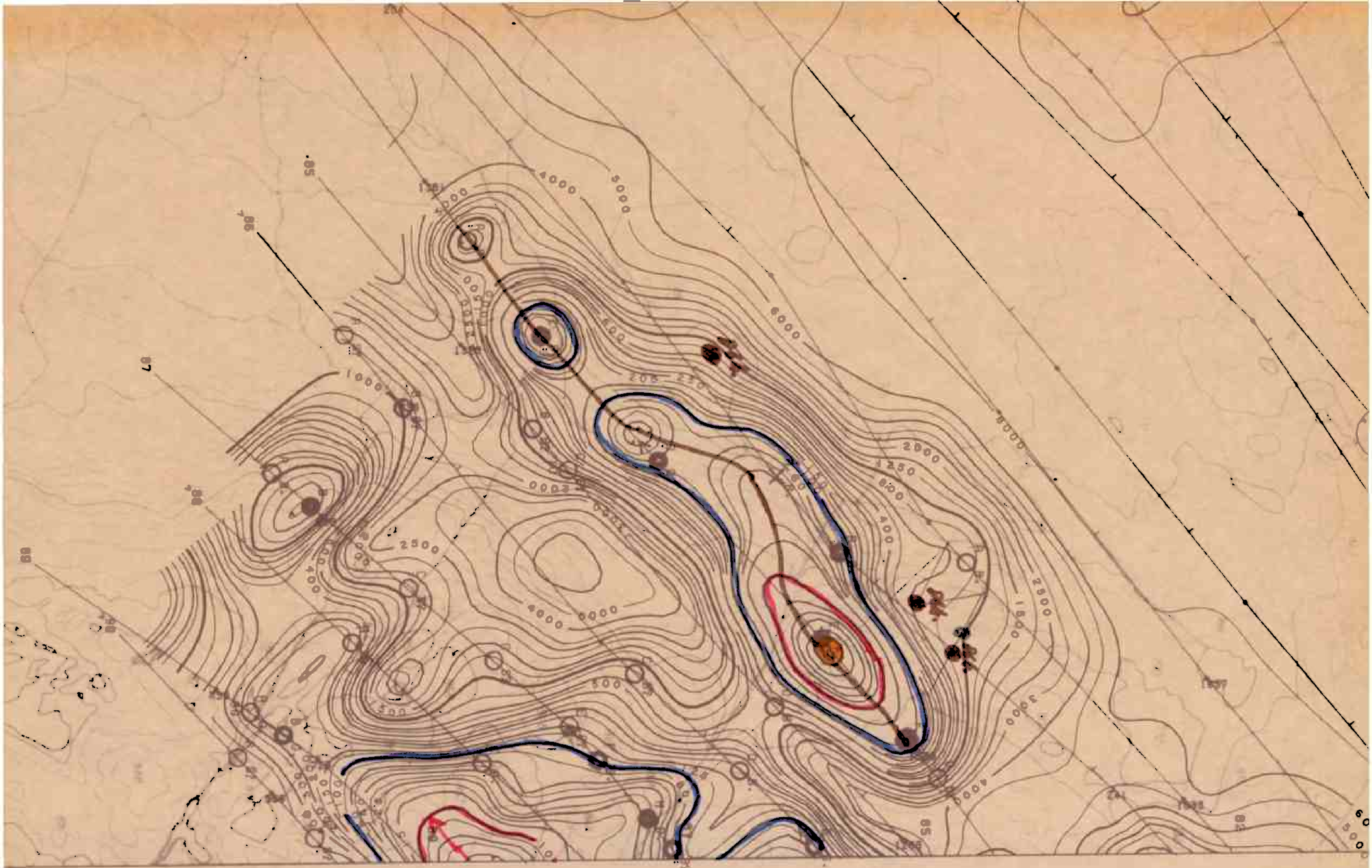

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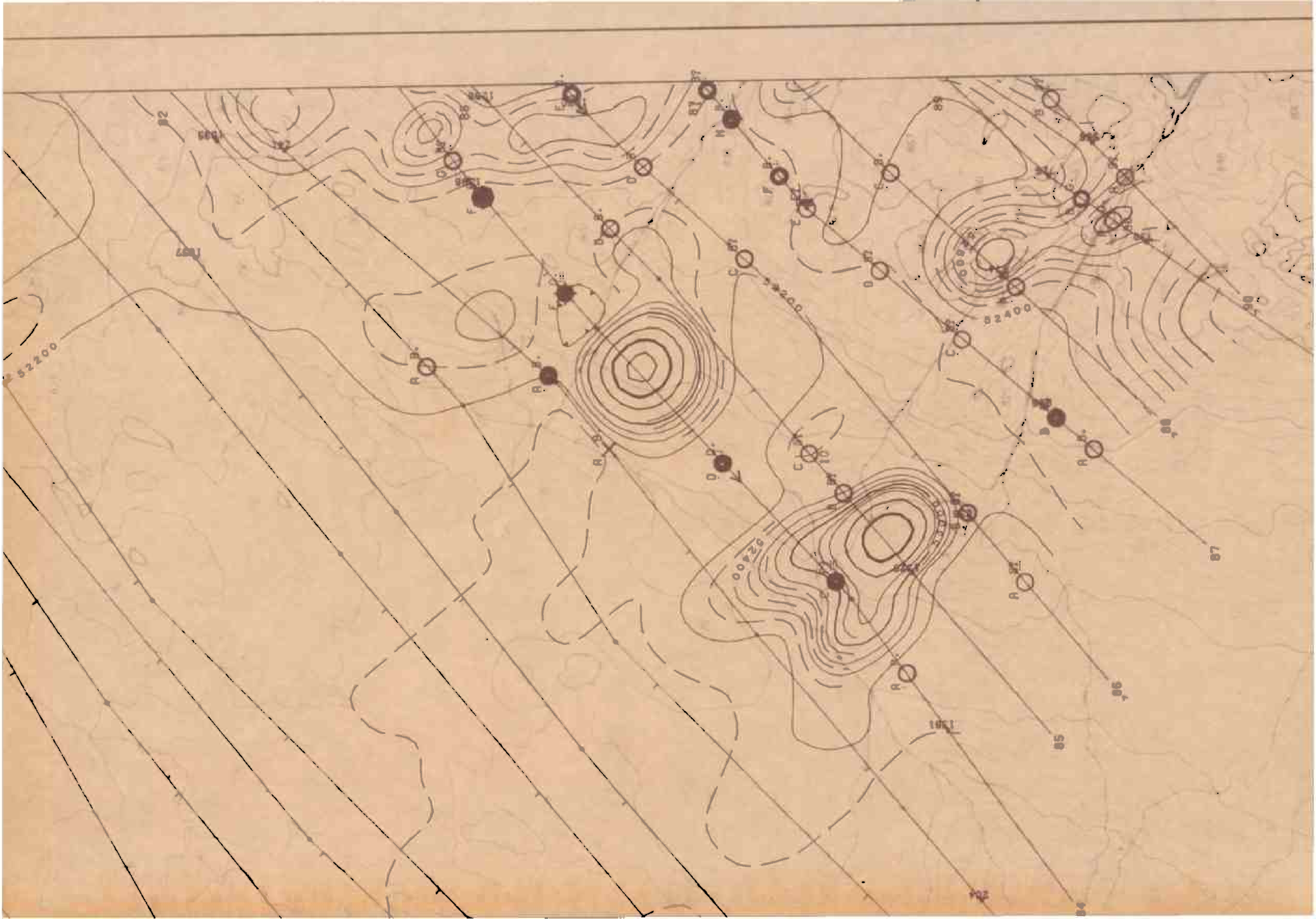
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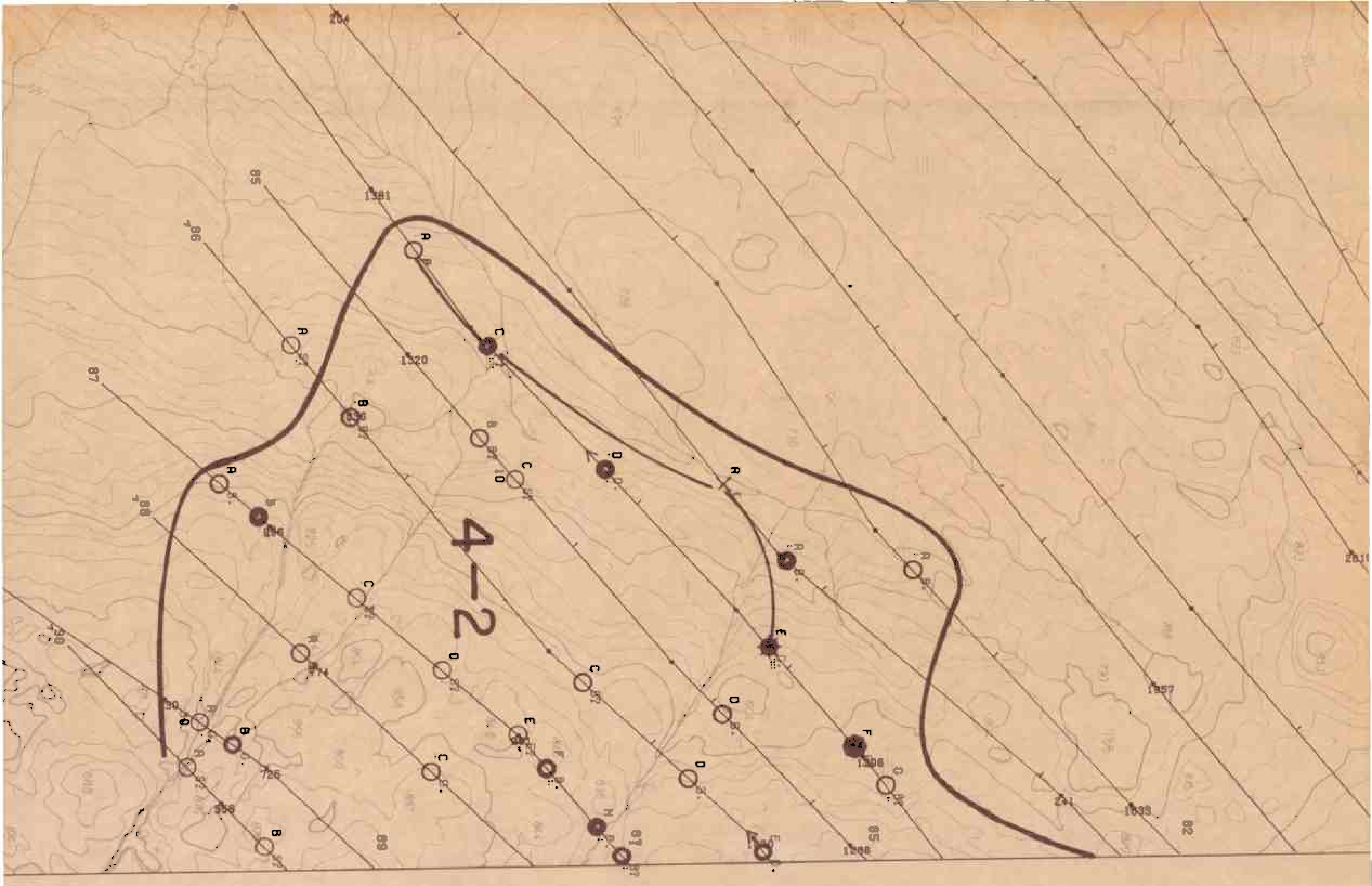

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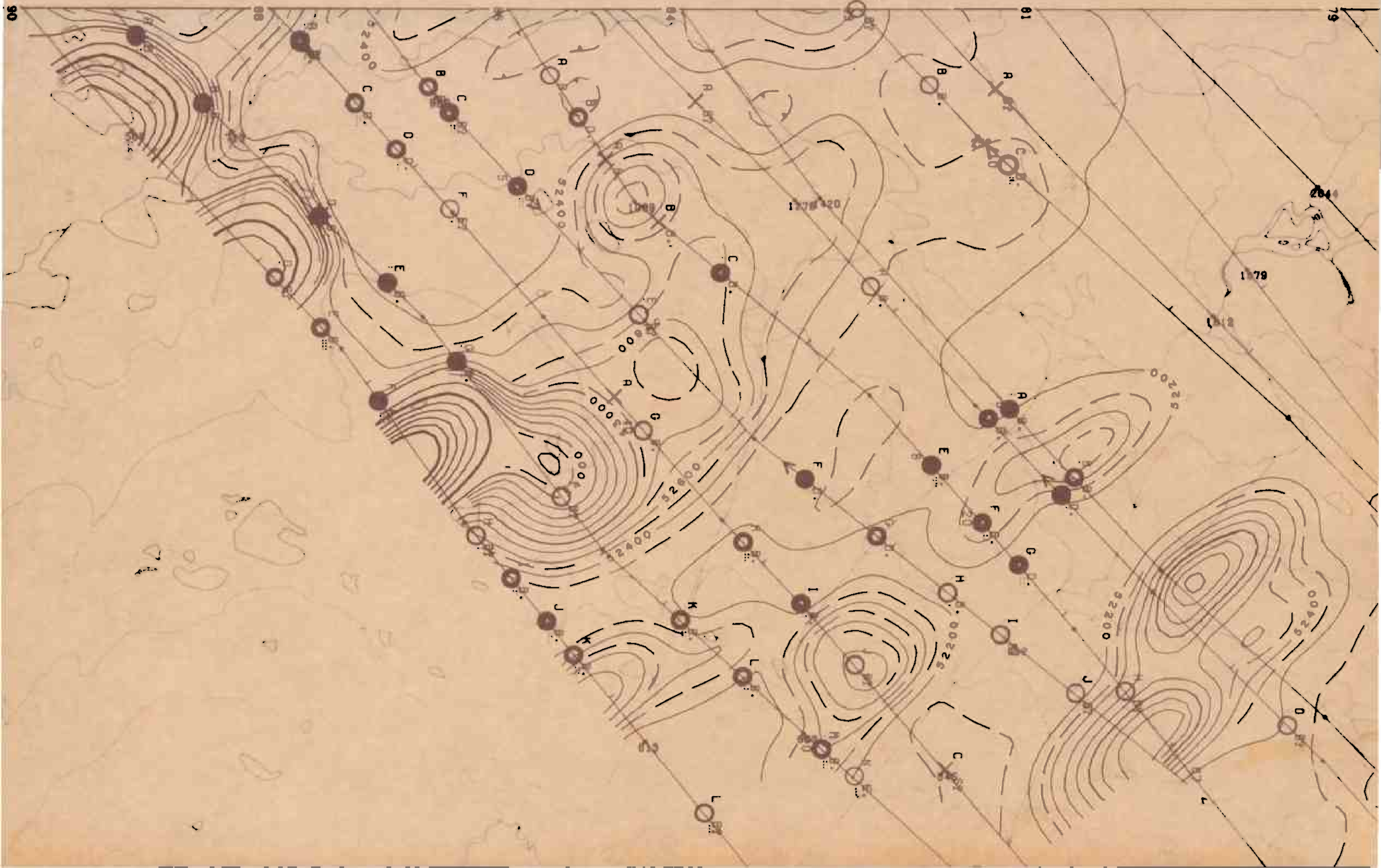

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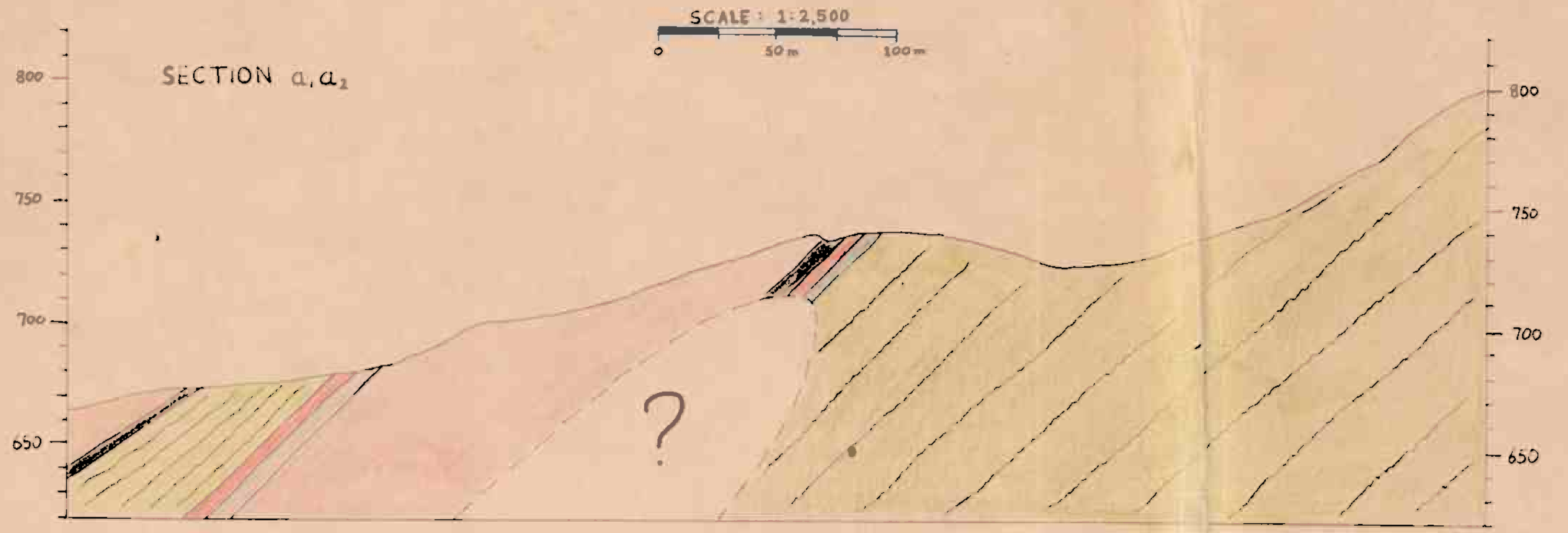

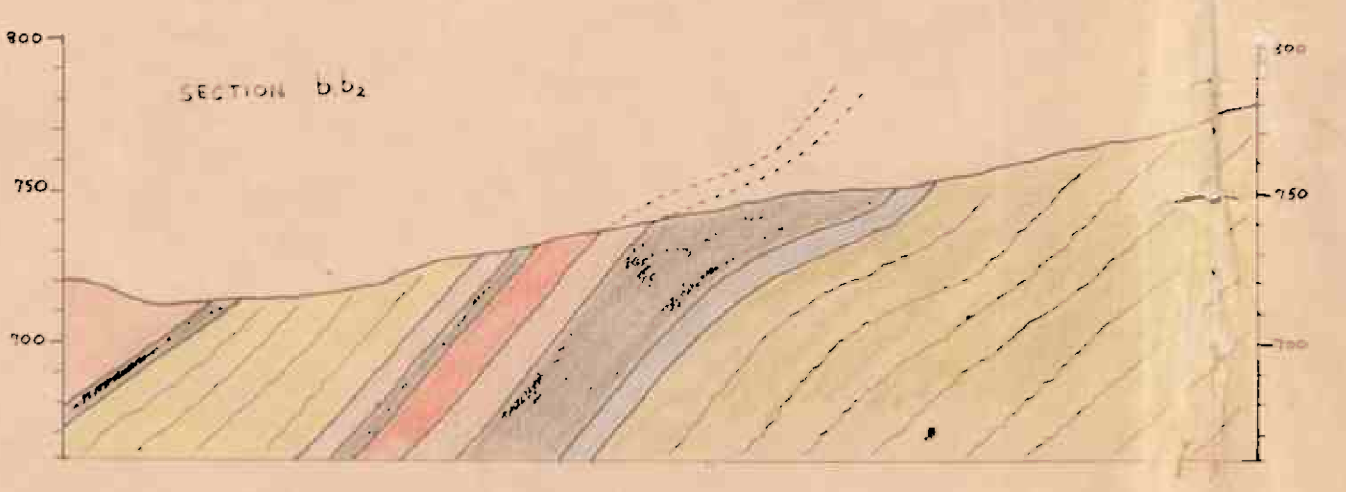

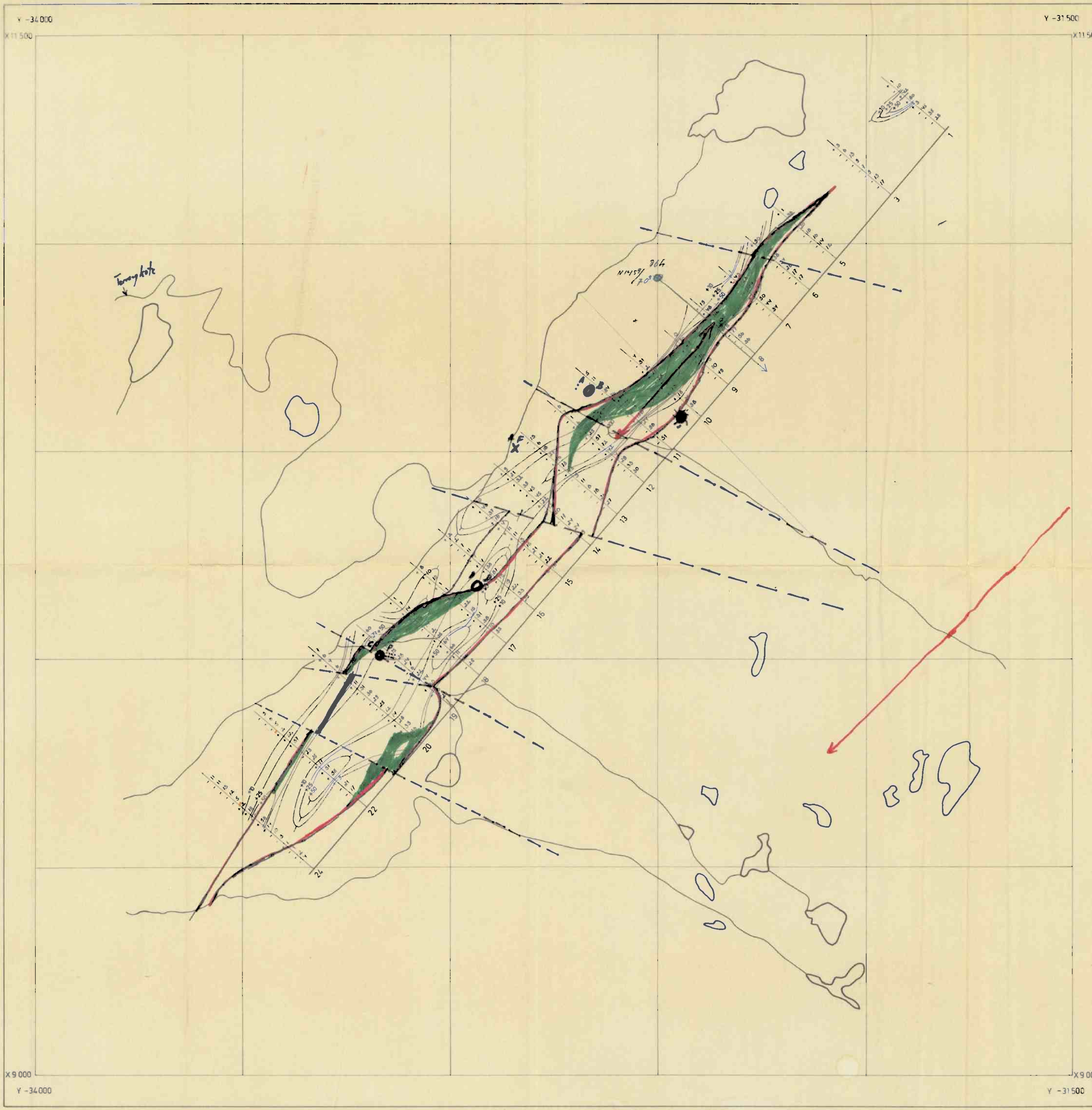

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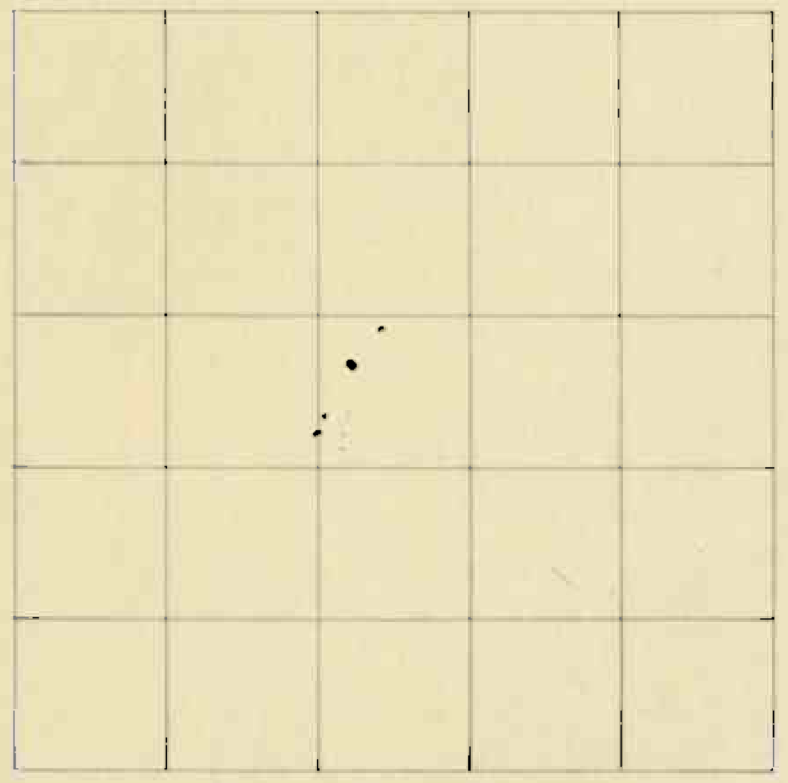

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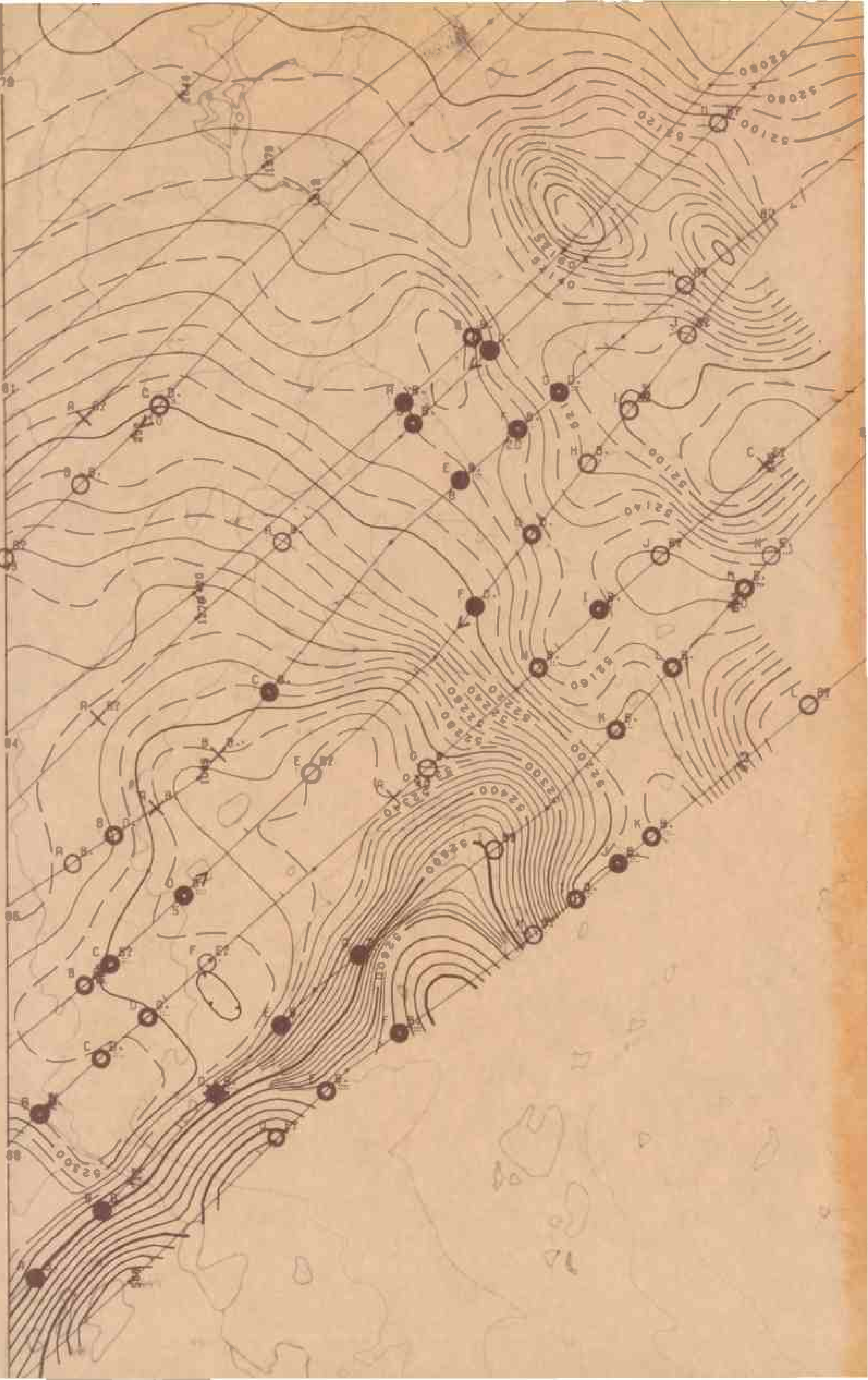
SULITJELMA
Kong Oscar Malmfelt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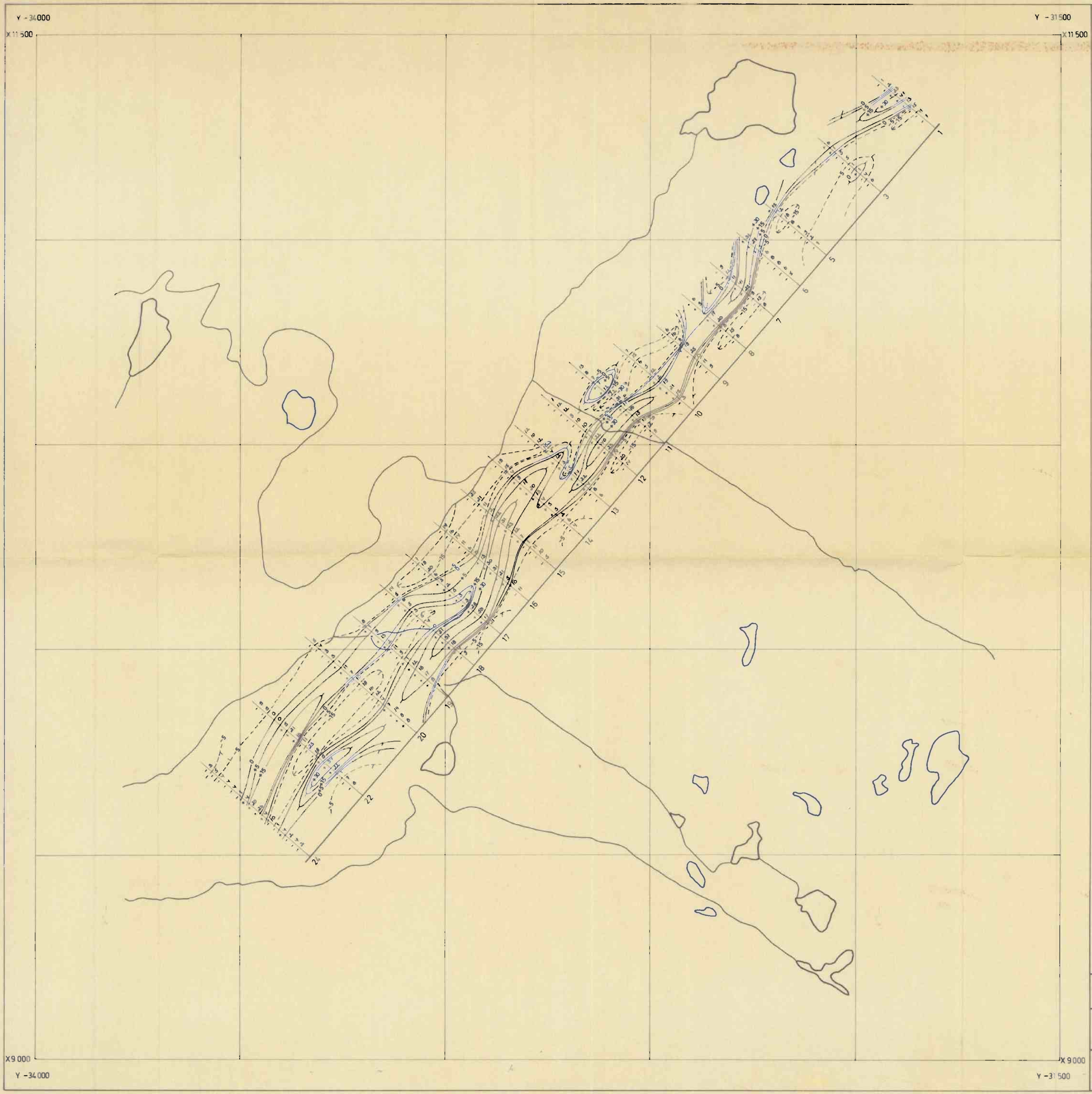

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Transmitter: FUO 15,1 kHz

Instrument: Geonics EM-16

Fraser - filtered

SUOMEN MALMI OY

1:5000

meas	RK	10.75
draw	AS	11.75
insp	PM	11.75

VLF - map
Imaginary component

SULITJELMA
Kong Oscar Malmfelt

MAG

University College London undergraduate mapping project

FIELD MAPPING PROJECT

SOUTHERN SULITJELMA NORWAY

Giles Kekwick 1982

Moorgate House,
Woodgate,
BROMSGROVE,
Worcs. B60 4HF,
England.

The Mine Geologist,
Sulitjelma Grüber,
Sulitjelma.

9-3-84

Dear Sir,

I hereby enclose a report and map for the field mapping I carried out in Sulitjelma, to the south-east of Fagerli, during July and August, 1982, as an undergraduate of University College, London. I apologize for sending it to you so late, but it seemed worthwhile waiting until now when the most important part of the work, a paper submitted for consideration with regard to publication in the Norges Geologisk Tidsskrift, had been completed. The paper outlines the latest evidence for inversion in Sulitjelma, which was discovered in the area mapped and suggests that the Kong Oscar ore forms a stratabound volcanogenic deposit and so other occurrences may exist in the same horizon, at the boundary of the Sjønstå and Furulund Groups.

I hope you find the enclosed information both interesting and useful.

Yours faithfully,

Giles Kekwick

GILES KEKWICK.

INTRODUCTION

Sulitjelma is situated in a copper-mining field amongst medium grade metamorphic rocks. The most interesting discovery in recent years has been part of an ophiolite (Boyle 1980) to the northwest of Sulitjelma. The igneous ocean floor basement together with the thick overlying submarine sediments is thought to have been thrust over the continental basement during the Caledonian orogeny. At some stage large-scale inversion resulted and this is discussed in Kekwick (in press).

While Nicholson (1966) studied rocks in a similar part of the succession to the east of Lomivann the area studied by the author, in the southeastern part of the region, has only received rather cursory attention from Sjögren (1900), Vogt (1927) and Henley (1968). Because metamorphic grade increases northwestwards the rocks are some of the lowest grade in the region. They are parts of what earlier workers have called the Furulund and Sjønstå Groups consisting of sediments deposited over oceanic crust. They are quartz-mica schists intruded by meta-igneous rocks which have been called the Kjeldvann Metadolerites.

Researches have determined at least five phases of deformation in Sulitjelma so there are many structural elements displayed by the study area. These include a maximum of two schistosities dipping at different angles to the west northwest, except where minor folding causes local disturbance.

The lithology and structure are reflected by the physiography. The west side of Balmidalen bears several knolls of resistant metadolerite. On the higher ground near the gentle slope of the Sjønstå Group the band of metavolcanic also forms a resistant feature. Glaciation has left the outcrops strewn with small erratics but there are no other glacial deposits, save ice. The floor of Balmidalen is well wooded, hampering the location of the infrequent exposures, but above the tree-line exposure is perhaps 30% on the Furulund Group and complete on the rocks of the Sjønstå Group. Thus great effort is well rewarded if one reaches the dizzy heights, high above the valley floor, where mosquito and horsefly infestation is tolerable enough to allow one to pause at the outcrops and make full use of the excellent exposure.

LITHOLOGIES

The stratigraphic nomenclature adopted in the exercise is outlined by Boyle et al. (in press) who summarise the lithologies from earlier work in Sulitjelma. Recent discoveries have shown that the sequence in the region is inverted (for a review see Kekwick, in press) so the stratigraphy is described in its order of deposition rather than the structural succession. Because of sedimentary facies variation, which has been shown to exist (Nicholson 1966), the boundaries interpreted by the author may not correlate with those in other areas.

FURULUND GROUP

The Furulund is a rather uniform series of schists with some phyllites and lavas. It has been divided into Upper, Middle and Lower parts, the Upper being absent rom the southern and eastern parts of Sulitjelma.

Middle Furulund

This is a unit of grey, plagioclase-rich quartz-mica schist containing some carbonate. It sometimes shows dark and light banding of variable thickness (<1m.) which is assumed to be bedding, this has been proved where graded bedding has been found parallel to the bands. There are few horizons of distinctive lithology in the area of schist studied One was found in a single exposure of a few black mudflakes or flattened mud clasts, about 10 x 1 cm., in a pale schistose matrix. The clasts are elongated in an approximately east-west direction. Henley (1968) mentions such a mudflake conglomerate containing fragments of graphitic schist and says that it forms a continuous bed southwest of Lomivann. Another type of lithology lies in an area near the top of the Middle Furulund. There is a broad but variable zone (up to 100 m. thick) of friable, easily weathered, brown biotite-rich phyllite with boundaries too indeterminate to be mapped.

Thin section of the schist show it to be composed mostly of quartz and plagioclase (approximately 50% on a visual estimate) occurring as interlocking grains 0.01 - 0.2 mm. in diameter. The principal mica is muscovite, except where biotite has been concentrated showing a preferred orientation. Carbonate (thin sections were not stained) is present as grains forming up to 10% of the rock. It is also present in veins and lenses often showing rusty staining. There is sometimes chlorite present. Some bands contain porphyroblasts including garnet, hornblende, pyrite, muscovite and biotite, which will be discussed later.

Lower Furulund

This unit is also mainly a plagioclase-rich quartz-mica schist with carbonate. It is generally pale and massive with occasional discontinuous horizons of dark grey schist, similar to the schist of the Middle Furulund, which are more frequent nearer the base of the unit. In thin section the massive, pale bands were indistinguishable from the Middle Furulund. Often the pale bands were dark when an unweathered surface was revealed.

At a particularly interesting exposure (GR 32281360) of a few square metres extent the bedding has weathered to reveal surfaces which have assumed the appearance of a series of very viscous flows with ropy crusts. The weathered surfaces have small holes which appear to be bubbles drawn out by flow. Fresh surfaces exhibit small (1 mm.) white crystals.

The Lower Furulund is composed of different rock types and the lithological differences are often indistinctive, local and difficult to map like the Lower Furulund east of Lomivann (Nicholson 1966). Some rocks are characterised by fracturing very easily into rubble of 0.3 - 0.5 mm. across, and sometimes look pillow-like. However there are two distinguishable members of the unit marked on the map. There is a small outcrop of rusty-weathering, light-coloured schist and a well exposed outcrop of pillowed lavas (Kekwick, in press).

SJØNSTÅ GROUP

The lower stratigraphic part of the Sjønstå Group was studied and it was found to be a fine, grey to grey-green schist with much quartz veining. In thin section the rock has up to 80% or 90% quartz and the rest is mica. Average grain size is about 0.2 mm. This rock type continues as a vary uniform lithology to the edge of the map, and the same characteristically vegetation-free, grey rock can be seen unchanging for some distance further.

The Furulund/Sjønstå contact is not clear. Dark schistose rocks alternate with the pale-weathering rocks of the Lower Furulund until gradually the schist becomes recognisable as Sjønstå. In the transition zone thereis a rock (GR 30881246) with light and dark bands 0.5 - 20 cm. thick (Plate 1). There is no grading between the bands and they are clearly delineated. An exposure well beyond the transition zone contained white, slightly elliptical clasts of quartz with diameters between 3 cm. and 10 cm. set in a matrix of grey schist (GR 31181108).

MARBLE

There are two bands of marble which are stained rusty on the weathered surface and are located in the Furulund/Sjønstå transition zone. They range in width from 0.5 m. to 10 m. Parts of the marble are massive but most of it is schistose. Some of it reacts with acid and some does not.

A small (about 1 cm. across) ring-shaped fossil (confirmed as such by Zachrisson, Gustavson and Søyland-Hansen pers. comm.) probably a crinoid ossicle, was found by the author in one of the bands about half a kilometre northeast of the study area. Approximately 1 km. to the southeast of the area a bryozoan was discovered by Søyland-Hansen.

KJELDVANN METADOLERITE

This has been called metadolerite because they have the appearance of sill intrusions of a medium-grained basic rock (Plate 2) which has undergone solid phase crystallisation. The black and white medium to coarse grains of amphibole, plagioclase and epidote make an extremely tough rock. Plagioclase is sometimes found in veins. According to Boyle (1979) the intrusions are tholeiitic basalts chemically.

Plate 2. Exposure of a characteristic sill intrusion of Kjeldvann Metadolerite.

STRUCTURE

The structural history of the region is still conjectural (Boyle et al. 1982; Kirk and Mason 1983). Despite this uncertainty the author has tried to adopt as far as possible the current nomenclature (see Appendix II) for ease of correlation.

Evidence of regional inversion is present in the area in the form of inverted grading(GR 34431306) and pillow structure, discussed by Kekwick (in press).

METASEDIMENTS

The dominant structural feature is a schistosity defined by the parallel to subparallel orientation of phyllosilicates, this is a result of what has been designated the D2 deformation (Boyle et al. 1982). It dips gently west northwest and is usually coplanar with bedding except in the hinge area of minor isoclinal folds which have axial planes coincident with schistosity. In these early folds sometimes there is evidence of pressure solution as folded beds are discontinuous (Fig. 1).

Frequently a second cleavage is present. It is sometimes observable as a crenulation cleavage, a lineation of hornblende or tails of garnet porphyroblasts, on the axial planar cleavage of minor folding (2 m. amplitude or wavelength) (Fig. 2). These tight, angular, usually similar folds tend to be overturned to the east. Psammitic and pelitic bands show refraction of the axial planar cleavage which varies from strain-slip to penetrative.

There is gentle folding, (up to 0.5 m. wavelength), but this is just gentle flexure of the D2 schistosity with axial planes perpendicular to this schistosity. No other schistosity has been observed associated with it.

Quartz veins are common in the Furulund Group and extremely frequent in the Sjønstå Group. There were several stages of vein intrusion. Some veins are pre-D2 because they show

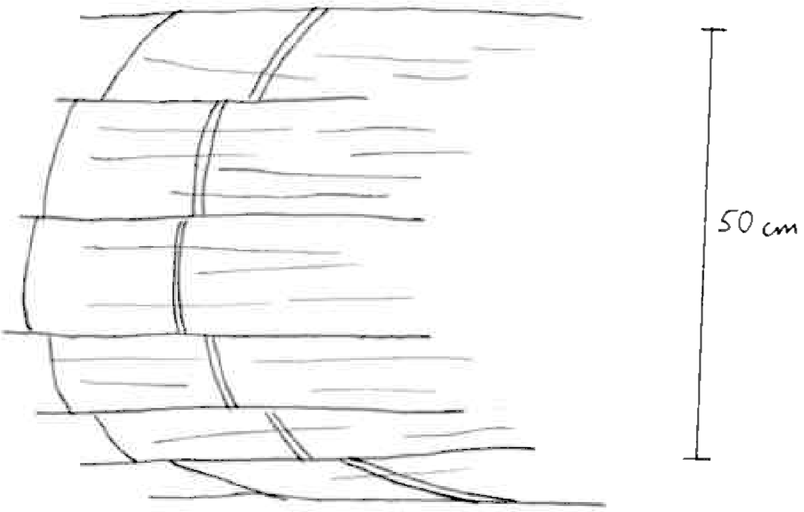

Fig. 1. Fold showing pressure solution.

rodding as a result of pressure solution during D2, others cut across one or both schistosities, and some are very late stage being restricted to joints.

Boudinage is present in the marble bands where they are thinner than 2 m. and show scar folding of the D2 schistosity in the surrounding schist. Boudinage is also present in quartz and calcite veins throughout the area particularly in the Sjønstå Group (Fig. 3).

A small exposure (2 m^2. approximately) of mullions up to 0.8 m. across was discovered at the Middle/Lower Furulund interface. The corrugations (Fig. 4) have parallel striations almost along their axes on the surface.

There is a conspicuous absence of faulting throughout the area. Only one fault with a throw of less than 2 metres was observed, near the structural base of the Middle Furulund.

KJELDVANN METADOLERITES

The metadolerites have been intruded parallel to bedding (Plate 2) and are of similar thickness (5 m.). Many of the intrusions are boudinaged and the D2 schistosity is infolded round the scar, and often those forming the tops of knolls are cambered. Occasionally a schistosity is manifested by the sub-parallel arrangement of black amphibole crystals, this is parallel to the D3 schistosity in the metasediments . Refraction of the D2 schistosity has been observed near the contact of the intrusions but D3 schistosity is unrefracted.

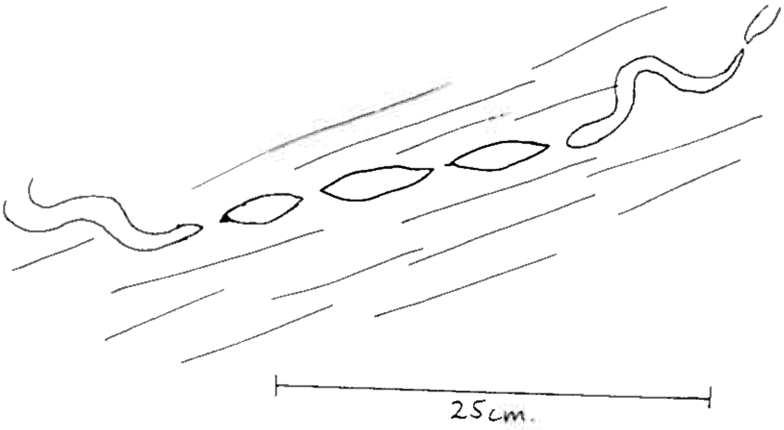

Fig. 3. Boudinage of quartz veins in the Sjønstå Group.

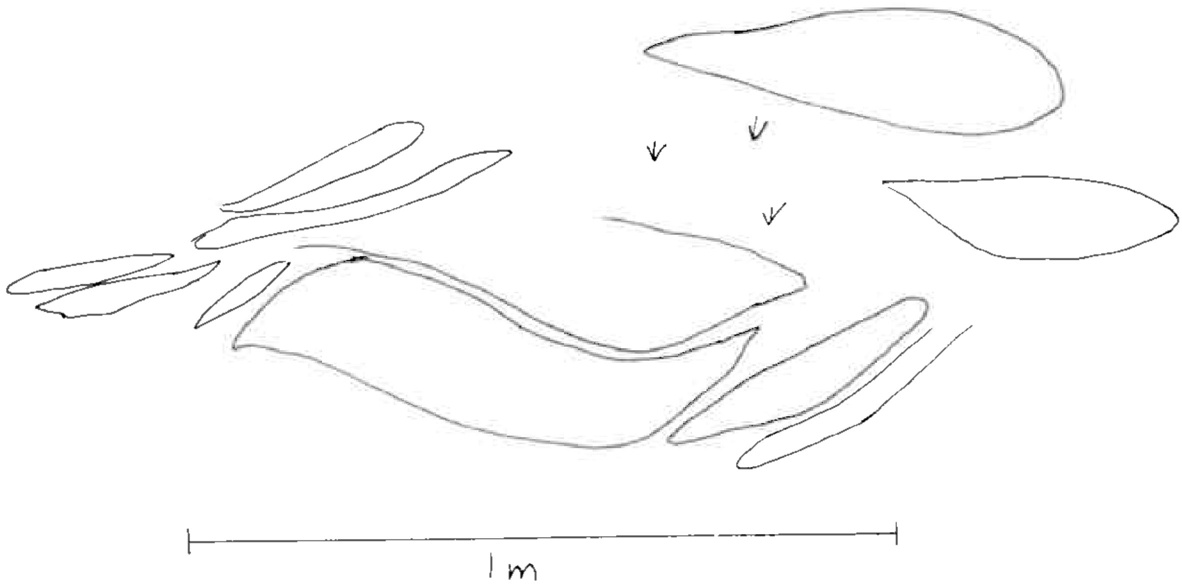

Fig. 4. Mullion showing difference in competence of Middle & Lower Furulund.

METAMORPHISM

The most recent interpretation of the metamorphic history is given in Boyle et al. (1982), much of this was based on extensive work carried out by Henley (1968, 1970).

REGIONAL METAMORPHISM

Both the metasediments and the Kjeldvann Metadolerites have undergone grain growth. The grains in the sediments are optically continuous up to their contacts with surrounding grains and there is no cement or matrix. Like the metasediments the grain-size in the Kjeldvann Metadolerites varies (1 mm. - 5 mm.), and the grain size can be too large to have formed in an intrusion only a few metres thick.

The presence of porphyroblasts in the metasediment has already been mentioned. Garnet and hornblende are restricted to rocks west of Henley's garnet/hornblende/oligoclase isograd. Biotite is present throughout most of the area. Muscovite and pyrite occur in many parts of the Furulund. Porphyroblast formation is controlled by original rock composition, especially garnet and hornblende which are restricted to particular bands. Porphyroblasts of biotite and muscovite are also restricted despite their ubiquitous occurrence as small grains. The porphyroblasts tend to be less than 3 mm. in size, apart from hornblende prisms which are usually longer. The latter occasionally exhibit garben texture. There are virtually no porphyroblasts in the Kjeldvann Metadolerite, although one large pyrite 1 cm. across was found. However the dolerite has undergone extensive recrystallisation forming an amphibolite (see Appensix I).

CONTACT METAMORPHISM

This occurs around the metadolerite in the metasediment. There is usually an obvious contact aureole up to 1 m. thick. It is greenish or a mixture of greenish and white when weathered.

There are two types of porphyroblast present in the contact zone: cordierite and andalusite. They have been observed within a few millimetres of each other. Within these there are a few inclusions of phyllosilicate which tend to be parallel to the D2 schistosity (Fig. 5) giving the crystals a sieve texture. The cordierite is sector twinned.

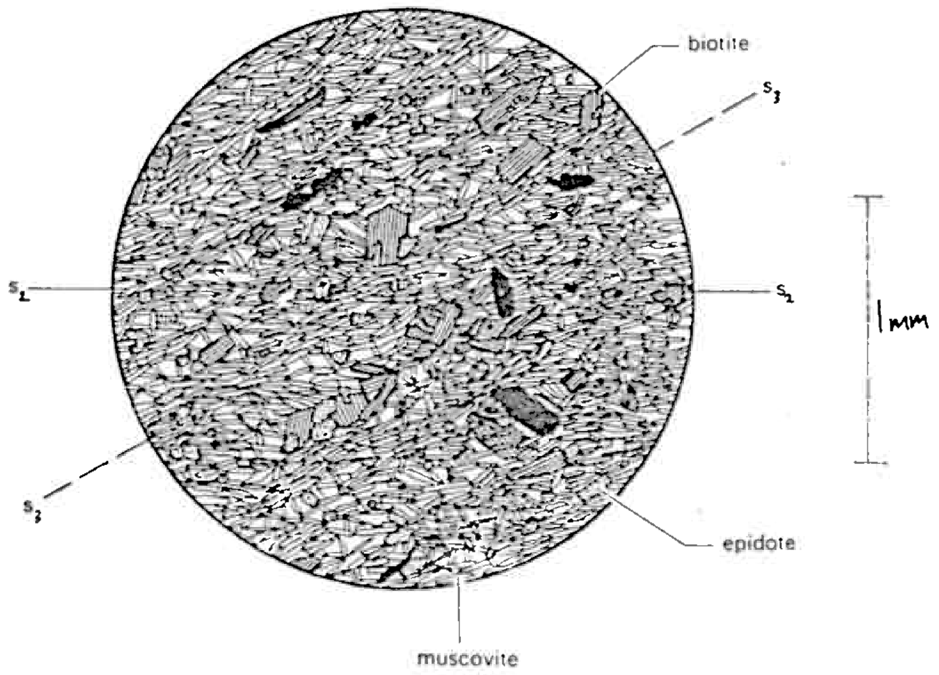

Fig. 5. D2 and D3 schistosity shown in thin section.

CONCLUSIONS

THE STRATIGRAPHIC RECORD

The sequence is continuous and inverted. According to Zachrisson (pers. comm.) the evidence of inversion furnished by the pillow lavas is a minor detail in an upright sequence. This seems unlikely because the only evidence of uprightness is a small exposure of upright graded bedding in an area greatly disturbed by minor folding near the Furulund/Sjønstå boundary.

The inverted sequence is one of rocks formed under oceanic conditions. The stratigraphic history of this sequence commenced with the formation of oceanic crust represented in part by the ophiolite complex. This was completed by an episode of submarine volcanics producing the massive and pillowed lavas north of Lomivann. The ocean floor was then overlain by clastic material derived from continental masses to form the Furulund and Sjønstå Groups, which have been studied in part for this exercise.

The inverted graded bedding and pillow lavas located in the study area indicate subaqueous deposition. The marble bands and their fossil contents indicate, according to Nicholson (1966) a shallow marine environment. It was pointed out by Stevens and Zachrisson (pers. comm.) how little interpillow sediment was present in the lava flow. While interpillow sediment is not a <u>sine</u> <u>qua</u> <u>non</u> for pillow lava, although it was suggested, it may indicate that the lava erupted under shallow water in which high current energy prevented sediment deposition. A shallow water environment is consistent with the evidence of the marble bands.

The pillow lavas clearly indicate another phase of submarine volcanism (after that N. of Lomivann). The round quartz clasts found in the Sjønstå Group are interpreted by the author as volcanic bombs and thus provide more evidence of volcanism. The discontinuous horizons of white-weathering slightly schistose rocks in the Lower Furulund, which Sjögren called 'greisen-altered' aplite, are further possible evidence of volcanism. Vogt considered it probable that these were volcanic but noted in addition that they resembled metasedimentary quartzites. In thin section the rocks do indeed resemble metasedimentary quartzites. On the other hand there is the exposure (GR 32281360) already described, which appears to be made up of very viscous flows with a ropy crust. These may be a type of pahoehoe lava flow, indicating subaerial extrusion, or sedimentary mudflows.

DEFORMATIONAL HISTORY

The D2 and D3 deformations which produced the schistosities already described were episodes of flattening. In both, the mica flakes aligned themselves perpendicular to the compression (at least to some degree in D3). In D2 there is also evidence of pressure solution e.g. quartz rods. At some stage there was a period of extension causing boudinage. Because the D2 schistosity is infolded round scars it seems likely that boudinage occurred after the D2 event.

All contacts between units were found to be stratigraphic, there was no evidence observed of the thrusting predicted by Kollung, Stevenson and Zachrisson (pers. comm.). The existence of only one fault which was more of a joint with a small displacement probably indicates that deformation was under sufficient depth for plastic deformation to occur. This was borne out by the tight plastic nature of the minor folding.

METAMORPHISM

Because the occurrence of porphyroblasts is restricted in the original rock it is not possible to define precisely on a scale of 1:10 000 the location of the garnet/hornblende/oligoclase isograd as the part of the area of study in which it lies is obscured by trees. Close to the isograd, near Kjeldvann, determination, using an electron microprobe, of the partition of Fe^{2+} and Mg between garnet and biotite has given a temperature of $409^{0}C$, and the pressure has been calculated to be 5.1 kb. from geobarometry of plagioclase, biotite, garnet and muscovite assemblages (Kirk, pers. comm.).

The age of the contact metamorphism around the metadolerite intrusions is later than the D2 event because the sieve textures of the andalusite and cordierite porphyroblasts have adopted a D2 fabric.

ACKNOWLEDGEMENTS

Gracious thanks are due to University College London for financing the author during the fieldwork, Ms. W. Kirk for extensive assistance at all times curing this work, Dr. R. Mason who inspired the project, Sulitjelma Gruber A/S for providing me with accommodation and cartographic facilities during the field season and Dr. R.G.O. Kekwick for providing a vehicle without which the fieldwork would have proved very difficult.

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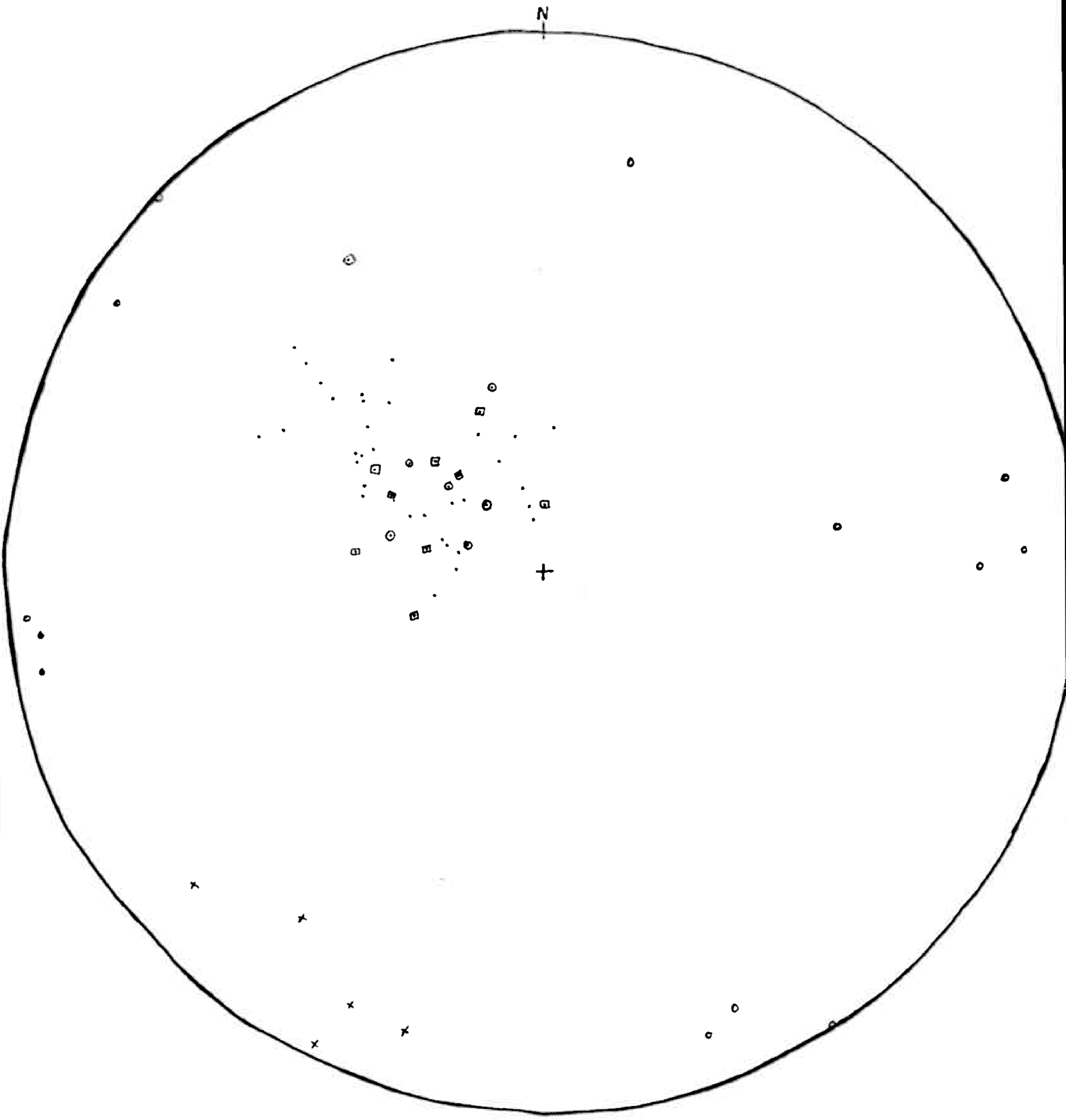
APPENDIX I

DESCRIPTION OF KJELDVANN METADOLERITE IN THIN SECTION

Amphibole occurs as ragged subhedral grains often strained and cracked. Its colour is pale green to almost colourless to medium to dark green. Plagioclase generally occurs as fine-grained aggregates of anhedral untwinned grains sieved with epidote, but occasional twinning may be present and also occasional larger crystals, again sieved with epidote. Epidote forms small sub- to euhedral crystals or fine-grained inclusions within plagioclase. Biotite is present in most of the metadolerites as randomly orientated medium to dark brown flakes, some of which may show alteration to chlorite. The latter also occurs as randomly orientated flakes.

APPENDIX II



Equal area, lower hemisphere projection of D_2 schistosity (•), D_3 schistosity (⊙), minor fold axes (+), poles to axial planes of minor folds (▫), and mineral lineations (∘). It can be seen that the minor folds were probably synchronous with either D_2 or D_3.

APPENDIX III

The Most Suitable Outcrops of Kjeldvann Metadolerite to be Extracted for Use in Building.

The most desirable property of an igneous rock for building is a large grain-size. A large grain-size gives permeability obviating condensation and gives a better appearance when polished. The grain sizes of the Kjeldvann Metadolerites show large variation between different outcrops and to a small extent in different parts of an intrusion.

The outcrops with the largest grain sizes occur in the northwest of the area, close to Fagerli, where metamorphic grade is higher. This area has the other advantages of closeness to Sulitjelma and several large outcrops occurring together. Like the other outcrops of metadolerite these are unjointed and generally have no schistosity. The average grain-size of these intrusions is about 5 mm.

Inverted Pillow Lava at the Base of the Furulund Group, Sulitjelma

G.R.P. Kekwick

Overturned pillow lavas have been discovered near the base of the Furulund Group and indicate regional inversion of the thick sequence of metasediments structurally below the Sulitjelma Ophiolite. These lavas and other volcanic rocks imply that the copper ore of the Kong Oscar Field at the base of the Furulund Group is a stratabound volcanogenic deposit, which suggests that other ore deposits may be present in the same horizon.

Introduction

The long established copper-mining district of Sulitjelma lies in the Norwegian part of the Caledonian orogenic belt, at 67° 10'N, 15° 20'E, close to the border with Sweden. The rocks in this area are regionally metamorphosed, and situated between post-metamorphic thrusts of low grade rocks in the Swedish Caledonides and the axial zone of the Caledonides in Norway, where high grade rocks show large scale folding. The continuation of mining in the district is dependent upon the discovery of new ore bodies by study of the structure and deformation history and by deep exploration.

Early workers assumed that the succession was continuous and upright because the Furulund Group was bounded above and below by different formations, the Sulitjelma Amphibolite and Sjønstå Groups respectively. Another observation, which has been adduced since as evidence of an upright succession, was an assemblage of fossils discovered at the base of the Furulund Group by von Schmalensee, working under Sjögren (1900). Vogt (1927) produced a detailed map of the locality and showed a photograph of a colony of bryozoa. Although Vogt did not refer to its orientation it has generally been assumed (e.g. Nicholson, 1966) that the fossil colony was in growth position and upright.

A different interpretation of the structure of Sulitjelma was proposed by Kautsky (1953), who had worked on the adjacent part of the Swedish Caledonides. He described the Sulitjelma sequence as being comprised of three post-metamorphic thrust nappes. Since then there has been considerable discussion of nappe interpretation in an upright succession (for a review see Wilson, 1973). In 1979 inverted pillow lavas were reported in the Sulitjelma amphibolites (Boyle, Griffiths and Mason, 1979). A new model to account for this inversion with a fold nappe structure has been put forward recently by Boyle, Hansen and Mason (1984). This has been supported by the downward facing of early folds, shown by graded bedding (Kirk and Mason, 1984) which indicates regional inversion at the top of the Furulund Group.

With evidence limited the way up of the succession has remained conjectural. New field evidence supporting regional inversion is described below. Its implications for the geology of the Kong Oscar ore deposit are discussed and its contribution to the clarification of the structure of Sulitjelma considered.

The Inverted Pillow Lavas

The Furulund Group is a thick sequence of metasediments with occasional volcanic horizons near the structural base. In this Group, within 600 m. of the boundary with the structurally lower Sjønstå Group, there is an extensive outcrop of pillow lavas with two smaller outcrops to the north-east (Fig. 1). Pyroclastic volcanic rocks, the nature of which is obscured by metamorphism, also occur adjacent to the contact with the Sjønstå Group.

Pillow lava is exposed on flat joint surfaces cutting nearly vertically through the flows. The evidence that the pillows are inverted are the rounded and convex surfaces, now on the bottom of the pillows, originally above, and the existence of concave surfaces and cusps (Fig. 2), now pointing skyward, where pillows filled the gaps between the underlying pillows when they formed. Interpillow sediment is very rare.

Vesicles frequently occur in the lava and are usually filled by quartz, biotite, calcite and plagioclase. Some exhibit a plano-convex lens shape confirming the way up determined from pillow shape. The mineral assemblages in the lava are mainly metamorphic, the principal minerals being quartz, biotite, albite (An_5) and calcite with some epidote, zoisite and chlorite. These occur as large crystals in a fine dusty matrix and some show a variolitic texture.

Discussion

The pillow lavas at the base of the Furulund Group result from a period of submarine volcanism which took place after the formation of the rocks of the Sulitjelma Ophiolite and the deposition of most of the Furulund Group.

The presence of biotite in the lava may indicate that it was originally high in potassium, suggesting a more continental source for the lava than that of the ophiolite. However, the surrounding meta-sediments are also rich in biotite, providing a possible source for metasomatic potassium. Vogt (1927) and Nicholson (1966) suggest that the volcanics near the base of the Furulund are spilitic, which is supported by the presence of sodium-rich plagioclase, although there is no analytical evidence that the rocks are enriched in sodium. The presence of coexisting calcite and sodium-rich plagioclase suggests that the rock is not necessarily sodium-enriched overall.

That the pillows formed in a shallow marine environment can be deduced from fossil fauna in the adjacent marble bands. The rarity and coarse grain-size of the interpillow sediment indicates that the environment had a high current energy.

The parts of the Furulund Group near the Sjønstå Group in the area east of Lomivann have been described by Nicholson (1966) and also contain volcanic rocks. These may be the approximate stratigraphic equivalent along strike of the pillows described here. They are highly variable, consisting of pyroclastics and structures which Nicholson described as being like pillows but lacking certain diagnostic features. Submarine lava usually expresses itself as pillow breccia, well-shaped pillows being unusual. Henley (1968) reproduces a photograph of some of these volcanics which look like pillows in a hyaloclastic matrix, i.e. pillow breccia. Vogt (1927) illustrated a thin section of this rock which has a texture similar to the lava of the present paper.

The presence of a horizon of volcanics at the structural base of the Furulund Group suggests that the copper ores of the Kong Oscar Field (lying within the volcanics) may be stratabound volcanogenic deposits, and therefore further ore bodies may exist in this horizon.

There are no minor folds in the vicinity of the pillows which could have caused their local inversion, nor larger scale disturbances. The pillows, therefore, indicate that a substantial body of rock is inverted. This agrees with recent predictions of widespread inversion (Boyle et. al., 1984; Kirk and Mason, 1984) but contradicts the supposed evidence of uprightness furnished by Vogt's illustration of a fossil bryozoan colony (1927) from the marble bands at the structural base of the Furulund Group. The photograph does not show that it was taken *in situ*; as it was not taken by Vogt (who did all the field photography) but by B. Larssen (who took all the laboratory photographs) it can be assumed to have been photographed in the laboratory. Nowhere in the text did Vogt state that the fossils were found right way up. Thus in the sequence structurally below the amphibolites all evidence of way up so far discovered shows that it is inverted.

More recently, on the evidence of graded bedding in the upper part of the Furulund Group it has been suggested that the whole Group is inverted (Kirk and Mason, 1984). However, graded bedding may not be a reliable indicator of way up. The present evidence from pillow lavas is unequivocal. Since it lies at the structural base of the Furulund Group, close to the interbedded stratigraphic contact of the Sjønstå Group, it seems likely that not only is the Furulund Group inverted but perhaps part of the Sjønstå Group as well. Such a conclusion supports the hypothesis of Boyle *et al*. (1984) that much of the Sulitjelma area forms the inverted limb of a recumbent regional fold.

ACKNOWLEDGEMENTS

The author is grateful to University College London for financial assistance, Sulitjelma Gruber A/S for accommodation and maps, and the Technical Laboratory of University College London Geology Department. I also wish to thank Ms. W.L. Kirk for fieldwork supervision and Dr. R. Mason for reading the manuscript.

FIGURE CAPTIONS

FIG. 1 Geological sketch-map of Sulitjelma.

FIG. 2 Inverted pillow lavas in the Furulund Group showing the incurved upper surfaces and convex lower surfaces, which signify inversion.

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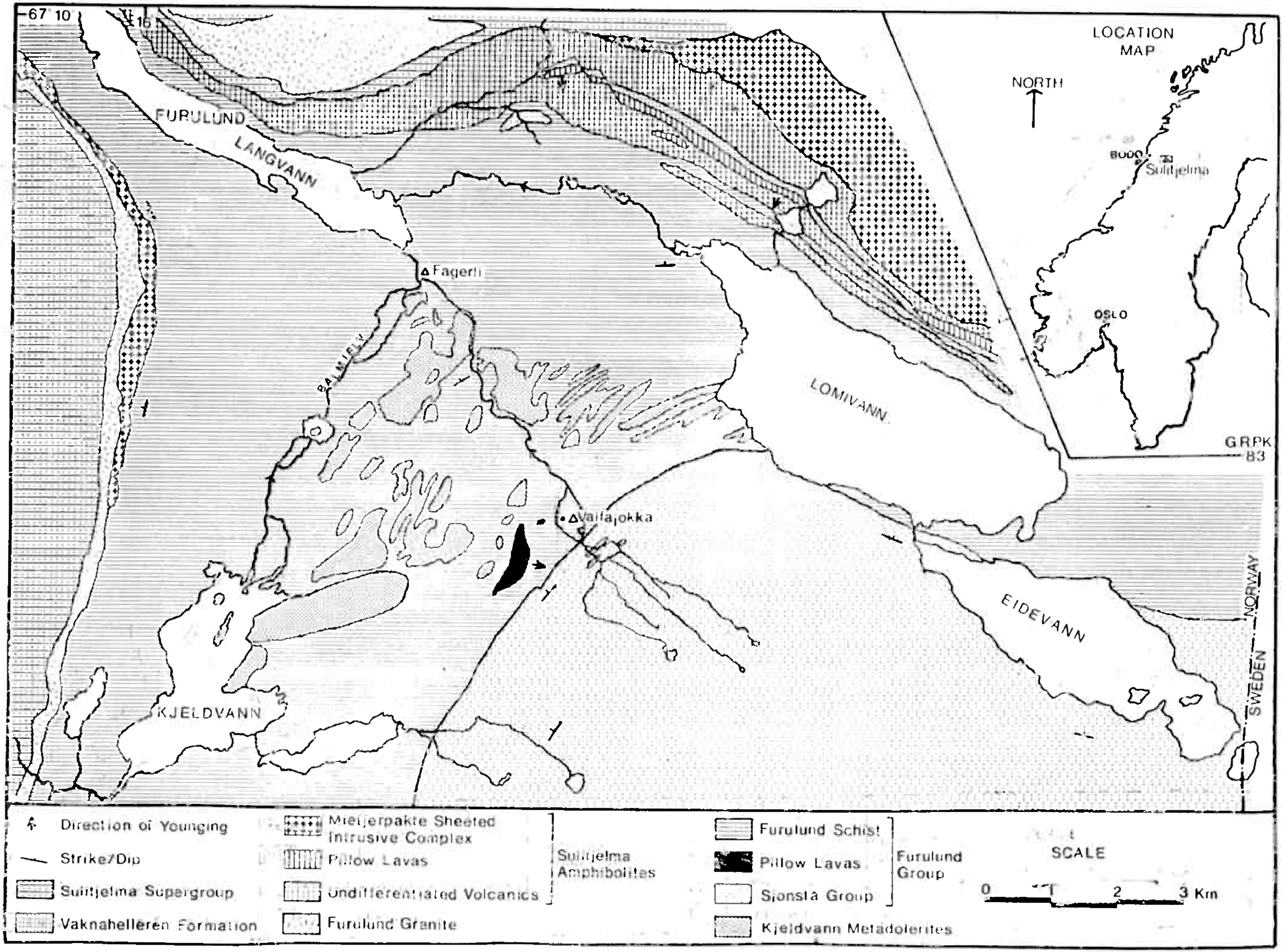
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16
FURULUND
LANGVANN
Fagerli
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Valfajokka
LOMIVANN
EIDEVANN
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SWEDEN
LOCATION MAP
NORTH
BODO
Sulitjelma
OSLO
GRPK 83
Direction of Younging
Strike/Dip
Sulitjelma Supergroup
Vaknahelleren Formation
Mietjerpakte Sheeted Intrusive Complex
Pillow Lavas
Undifferentiated Volcanics
Furulund Granite
Sulitjelma Amphibolites
Furulund Schist
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Kjeldvann Metadolerites
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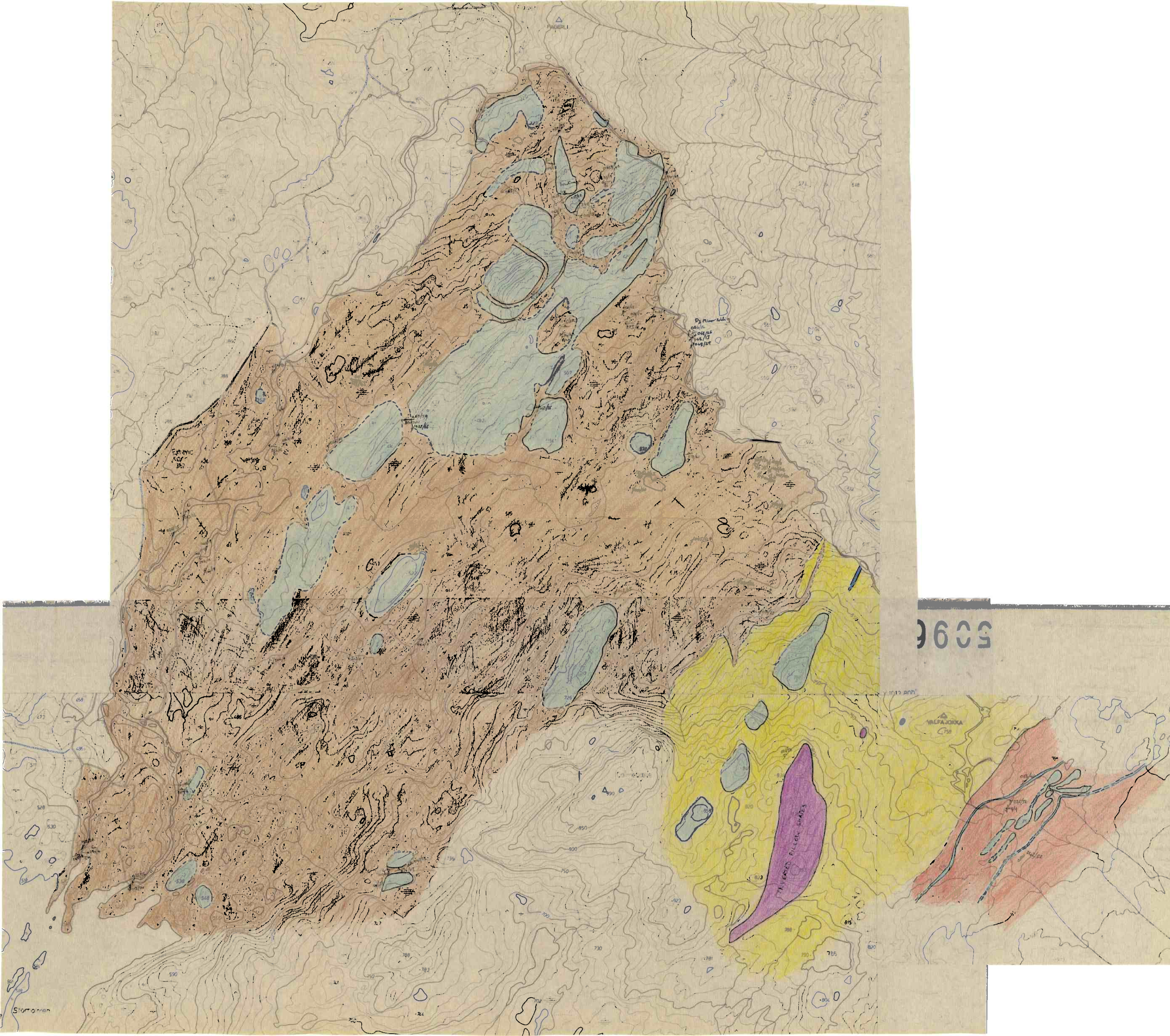
Fig. 1


FAGERLI
D2 Minor folding
026/12
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INTERBEDDED PILLOW SHALES
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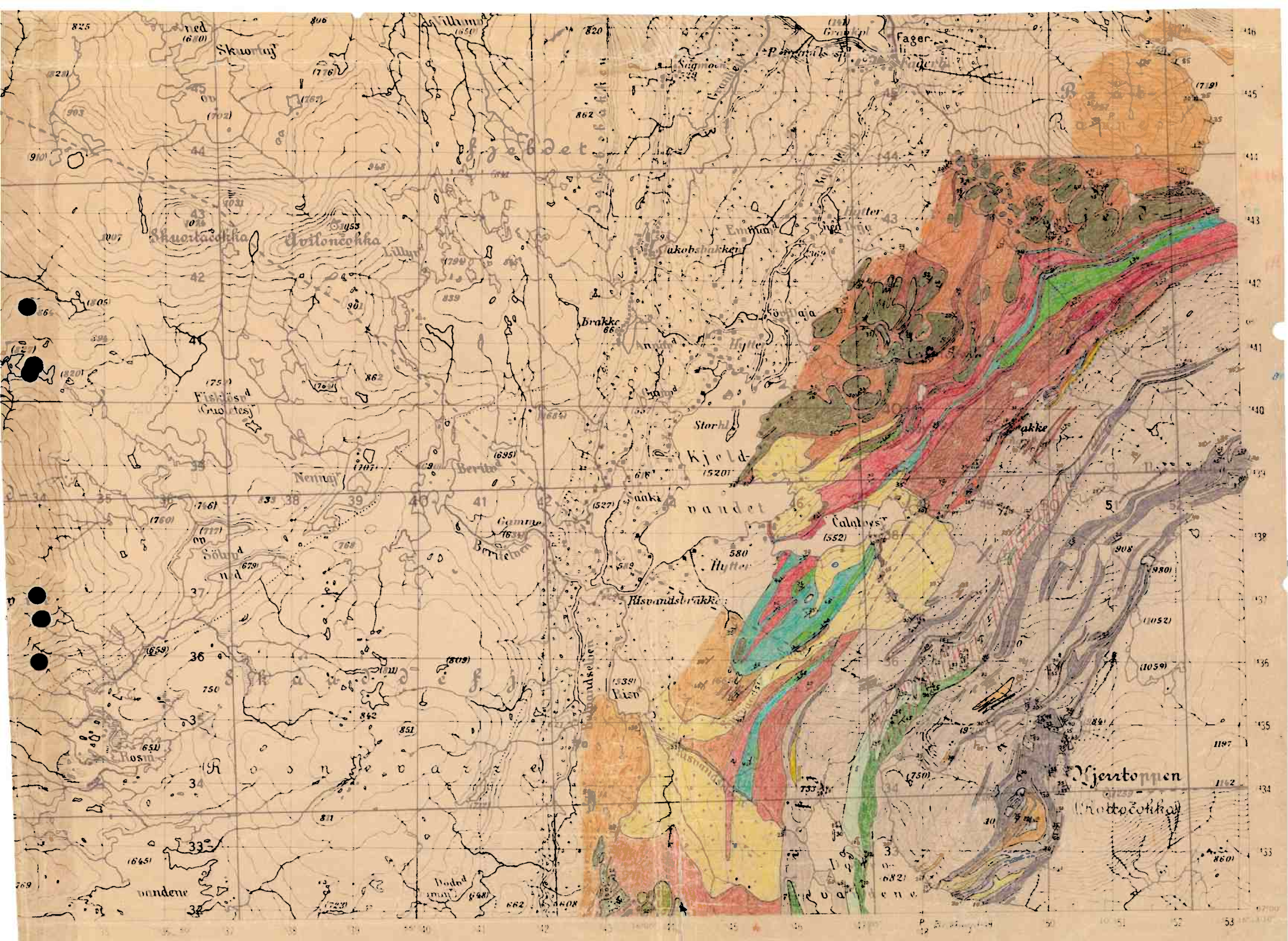
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Fiskløsv
Nennaj
Beritv
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Roonevarre
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Kjerrtoppen
(Kottočokka)

Geologisk kart
Låmivann - Dorrovann.

KONG OSCAR - BALVANN

Magnetisk totalfelt
vertikal gradient
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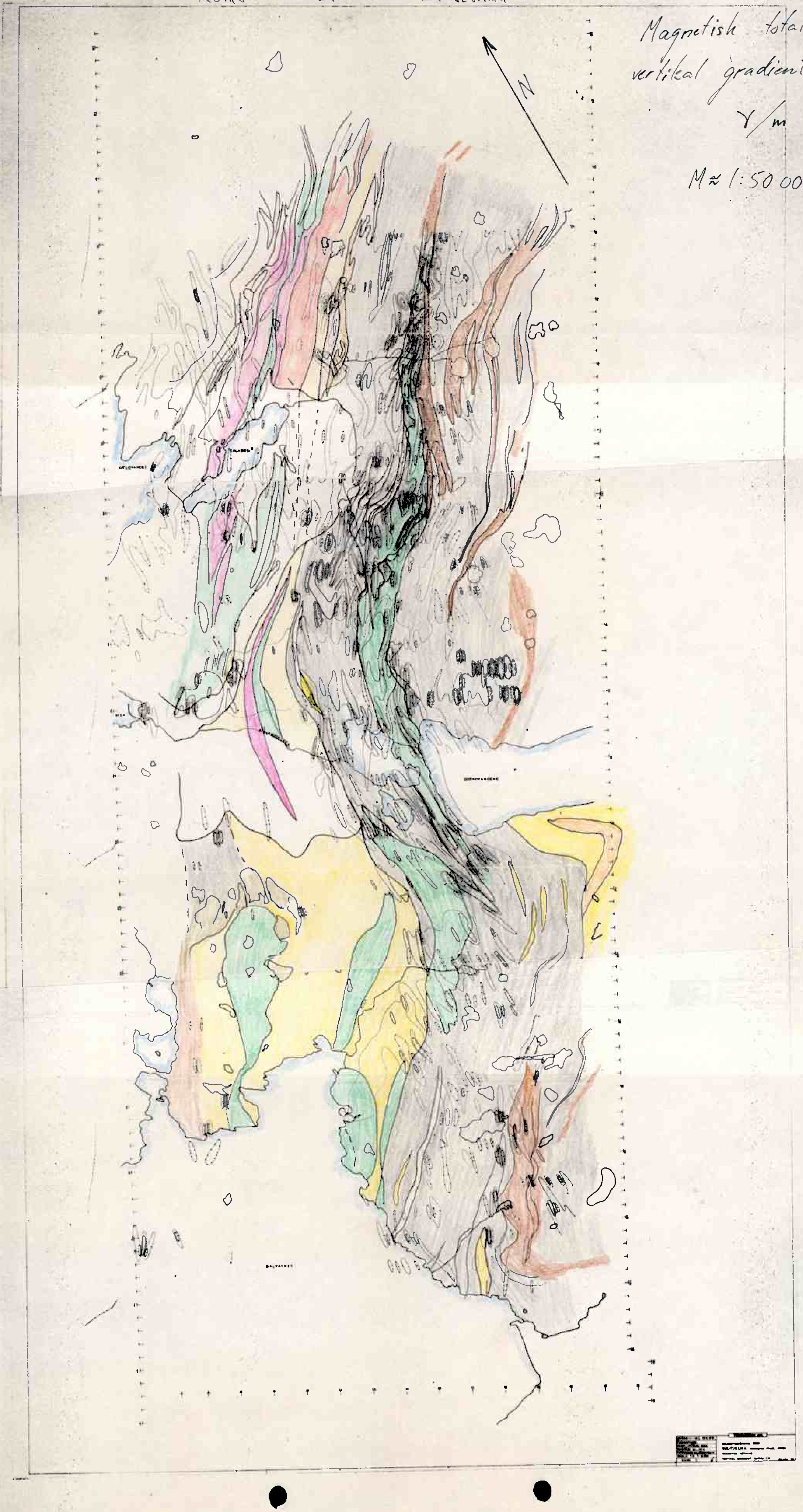

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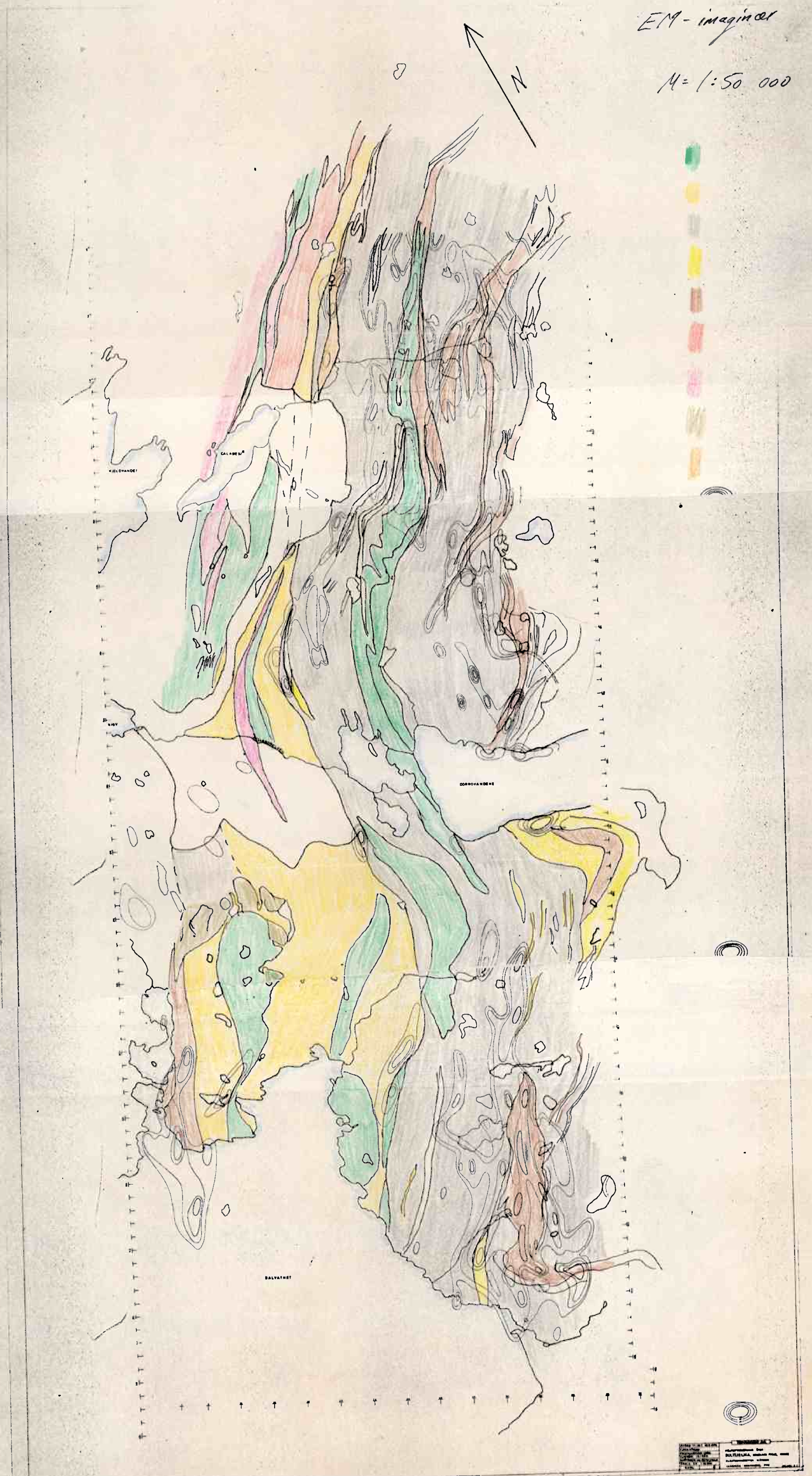
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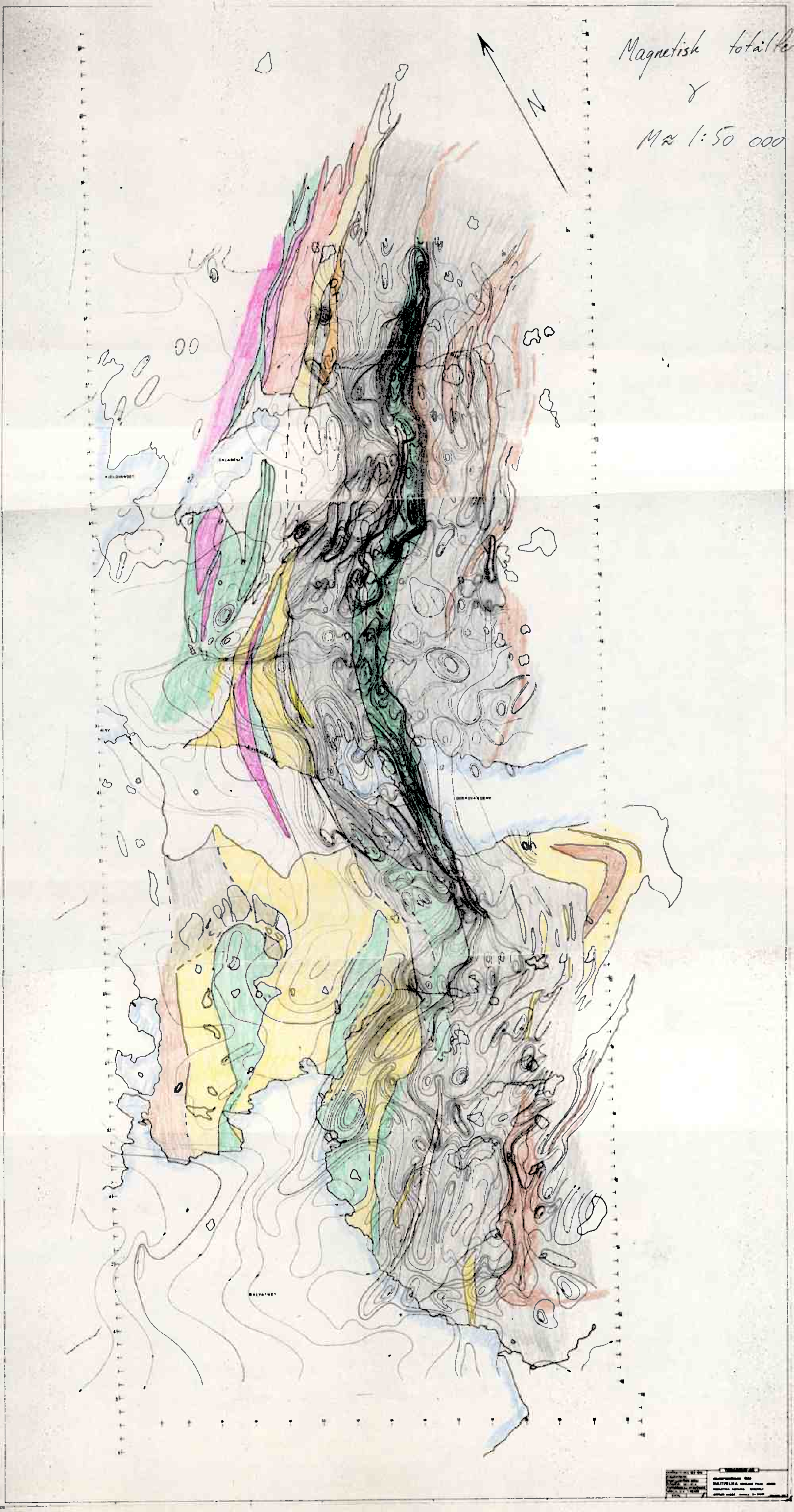

Magnetisk totalfelt

γ

M≈ 1:50 000

P. Kaspersen

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Effective — April 1, 1984

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Professional and Technical Staff, Vancouver, Canada, 1983.

SAMPLE PACKAGING AND SHIPPING INSTRUCTIONS

Effective geochemical exploration programs require rapid and accurate analytical work. To expedite sample processing and delivery of results, we suggest the following sample packaging and shipping procedures.

(1) Unprepared samples (soils and stream sediments) should be placed in waterproof paper bags without a polyethylene liner.

(2) Sample bags containing soil or rock should be clearly marked with waterproof ink.

(3) Samples should be packed in sequence in durable cardboard boxes. A few sheets of absorbent paper separating each layer of samples will help prevent loss of the sample numbers in transit.

(4) Fill out and enclose white and yellow copies of Chemex Labs sample submittal and analytical requisition form with each sample shipment. Retain the pink copy as a field record.

(5) Include with each shipment your return address, billing instructions and instructions describing the type of analyses required on the enclosed samples.

(6) All international sample shipments should be clearly marked as follows: "GEOLOGICAL MATERIALS — NO COMMERCIAL VALUE". Appropriately addressed shipping labels are available at no cost, on request.

SAMPLE HANDLING AND STORAGE

(1) Sample pickup service —
    (a) Vancouver, B.C. — telephone: (604) 984-0221
    (b) Sparks, Nevada — telephone: (702) 356-5395
    (c) Mississauga, Ontario — telephone: (416) 890-0310

(2) Sample storage service —
    (a) Geochemical Samples — The sieved portion of all stream sediment and soil samples and rock geochem pulps are stored free of charge for a period of two years. The samples can be retrieved for further geochemical analyses at your request.
    (b) Assay Pulps and Reject — All assay pulps are retained free of charge for a period of two years. Coarse reject of rock or drill core samples is stored free for one year.

TECHNICAL INFORMATION SERVICES

(1) Instruction in accepted soil, sediment and water sampling techniques, in sample handling, in use of field kits and in instrumental analysis is provided by Chemex Labs personnel free of charge. Technical sessions are scheduled throughout the year as required.

(2) Consulting services and applied research in analytical chemistry.

FIELD KITS, CHEMICALS AND SUPPLIES

		Price
(1)	CX Copper — 500 determinations	$240.00
(2)	CX Heavy Metals — 500 determinations	240.00
(3)	Replacement chemicals for CX Copper or CX Heavy Metals Kit — 400 determinations	125.00
(4)	Acetate — Tartrate Buffer, pH 6.5 — 2 litres	85.00
(5)	Zinc Spot-Spray Test Reagents	50.00
(6)	K-Feldspar Staining Kit	120.00

Sample Bags — Geochemical
Waterproof, kraft wet-strength bags are available at cost and are recommended for soil, stream sediment and biological materials.

Sample Bags — Assay
A variety of plastic bags, ties and waterproof assay tags are available at cost. Shipping tags and sample submittal and analytical requisition forms are provided to clients on request, at no cost.

Prices in Canadian dollars or U.S. equivalent.

LAB PREPARATION OF GEOLOGICAL, GEOCHEMICAL AND BIOLOGICAL MATERIALS

Sample handling and preparation procedures are as important as field sampling techniques. A poorly prepared sample is neither representative of the material obtained in the field nor can it be analysed with any degree of confidence. For this reason we spend considerable time studying handling and preparation procedures for each project.

Prep. Code*	Sample Type	Preparation Procedure	Price/Sample
GEOCHEMICAL			
201	Soil or Sediment	Dry, sieve through -80 mesh screen	$ 0.70
202	Soil or Sediment	Dry, sieve through -80 mesh screen and save +80 mesh fraction	1.00
203	Soil or Sediment	Dry, sieve through -35 mesh screen and ring pulverize to approx. -100 mesh	2.00
205	Rock or Core	Crush, subsample and ring pulverize to approx. -100 mesh. Over 2 lbs. see code 251	2.50
217	Soil or Sediment	Ring pulverize to approx. -100 mesh	2.00
235	Pan Concentrate	Ring pulverize to approx. -100 mesh	2.00
210	Vegetation	Milled to -20 mesh	4.00
213	Stream Sediments Pan Concentrates	Separation of heavy minerals having a specific gravity greater than 2.96. Ring pulverize to -100 mesh	14.00
214	Pulp	No additional preparation required	N/C
ASSAY			
207	Rock or Core (Precious metals)	Primary and secondary jaw crushing, tertiary cone crushing, rotary pulverize and screen to -100 mesh. Screen is examined for "metallics".	$ 3.75
208	Rock or Core	Primary and secondary jaw crushing, tertiary cone crushing. Ring pulverize to approx. -100 mesh.	3.25
209	Concentrate	Ring pulverize and screen to -100 mesh	3.75
225	Metal or Pulp	No additional preparation required	N/C
MISCELLANEOUS			
221	Water	No additional preparation required	N/C
227	Pulp	Rolling charge (Homogenizing pulp)	$ 1.00
261	Pulp	Compositing charge (Combining pulps)	1.00 per included sample
231		1 - Assay ton fire assay — surcharge	1.00
216		Screen to -140 mesh — surcharge	1.00
230		Screen to -200 mesh — surcharge	2.00
219		Samples requiring additional drying	2.00
251		Overweight charge on assay samples > 15 lbs. (7 Kg) and geochem samples > 2 lbs. (1 Kg)	0.25/lb.

* *Occurs in the first column of each certificate of analysis.*

GEOCHEMICAL ANALYSES

Soil, sediment, rock and biogeochemical materials.

INSTRUMENTAL AND CHEMICAL ANALYSES
Group A — Gold & Platinum Group Elements *

Element		Detection Limit	Price/Sample
Gold (Aqua regia digestion — MIBK ext.)		10 ppb	$ 5.00
Gold (F.A. & A.A.)		5 ppb	6.25
Gold (F.A. & N.A.A.)		1 ppb	6.25
Gold (Direct N.A.A.)		50 ppb	8.50
Gold, Platinum (F.A. & N.A.A.)		1, 20 ppb	12.50
Gold, Platinum, Palladium (F.A. & A.A.)		5, 100, 20 ppb	14.25
Rhodium (F.A. & A.A.)		2 ppb	6.25
Gold)		5 ppb	6 elements—
Iridium)	Nickel Sulfide — fire assay	5 ppb	$75.00
Osmium)	collection with neutron	5 ppb	
Palladium)	activation finish	5 ppb	
Platinum)		5 ppb	
Ruthenium)		5 ppb	

F.A. & A.A. — Fire Assay preconcentration with Atomic Absorption Analysis
F.A. & N.A.A. — Fire Assay preconcentration with Neutron Activation Analysis
Direct N.A.A. — Activation analysis of -100 mesh sample pulp

** Minimum of 60 grams required for platinum and palladium, and 10 grams for gold analysis.*

Group B — Perchloric-nitric acid digestion **

Element	Detection Limit	Price/Sample
* Cadmium	0.1 ppm	1st element — $2.00
* Cobalt	1 ppm	Each additional element —
Copper	2 ppm	$0.90
Iron	2 ppm	
* Lead	1 ppm	
Manganese	5 ppm	
Molybdenum	1 ppm	
* Nickel	1 ppm	
* Silver	0.1 ppm	
Zinc	1 ppm	

Typical concentration values range from our published detection limit up to 0.1% (1000 ppm).

** Background correction applied to atomic absorption analysis at no additional cost.*

*** Other digestion techniques available on request.*

Group C — Elements requiring specific digestion, extraction and analytical techniques.

Element	Detection Limit	Price/Sample
* Antimony	0.2 ppm	$3.75
* Antimony & Bismuth (on same sample)	0.2 ppm	5.75
Arsenic	1 ppm	3.25
Beryllium	0.1 ppm	4.00
* Bismuth	0.2 ppm	3.75
Carbon (Total)	20 ppm	6.00
Fluorine	20 ppm	4.00
Gallium	1 ppm	5.00
Mercury	5 ppb	4.00

Prices in Canadian dollars or U.S. equivalent.

GEOCHEMICAL ANALYSES (continued)

Soil, sediment, rock and biogeochemical materials.

Group C — Elements requiring specific digestion, extraction and analytical techniques. (continued)

Element	Detection Limit	Price/Sample
Niobium	5 ppm	$7.00
Phosphorus	5 ppm	4.00
Selenium	1 ppm	5.00
* Silver (Aqua regia digestion)	0.1 ppm	2.00
Sulfur (Total)	20 ppm	6.00
Tellurium	0.05 ppm	5.50
Thallium	0.1 ppm	5.00
Tin	2 ppm	4.00
Tungsten	2 ppm	4.00
Uranium (Fluorometric Analysis)	0.5 ppm	3.75
Uranium (Neutron Activation Analysis)	0.5 ppm	3.75

* *Background correction applied to atomic absorption analysis at no additional cost.*

Group D — Perchloric-nitric-hydrofluoric acid digestion.

Element	Detection Limit	Price/Sample
Aluminum	10 ppm	1st element — $4.00 Each additional element — $2.00
Barium	10 ppm	
Calcium	10 ppm	
Chromium	5 ppm	
Lithium	1 ppm	
Magnesium	2 ppm	
Rubidium	1 ppm	
Strontium	1 ppm	
Titanium	5 ppm	
Vanadium	5 ppm	

Typical concentration values range from our published detection limit up to 10,000 ppm.

NEUTRON ACTIVATION ANALYSIS

Soil, sediment and geological materials.

Element	Detection Limit	Price/Sample
Antimony	1 ppm	1st element — $7.50 Each additional element — $2.00
Arsenic	1 ppm	
Bromine	2 ppm	
Cesium	1 ppm	
Hafnium	2 ppm	
Tantalum	2 ppm	
Thorium	1 ppm	
Tungsten	1 ppm	

Quantitative Rare Earth Scan.

Element	Detection Limit	Price/Sample
Cerium	2 ppm	1st element — $10.00 Each additional element — $5.00
Europium	1 ppm	
Lanthanum	1 ppm	
Lutetium	1 ppm	
Neodymium	5 ppm	
Samarium	0.1 ppm	
Terbium	1 ppm	
Ytterbium	1 ppm	

Prices in Canadian dollars or U.S. equivalent

MULTI-ELEMENT ICP ANALYSES

Soil, sediment and rock materials.

INDUCTIVELY COUPLED PLASMA — ATOMIC EMISSION SPECTROMETRY (ICP-AES)
Chemex Labs chose a Jobin-Yvon 48P for simultaneous multi-element analysis by ICP-AES. The Jobin-Yvon was selected for its analytical sensitivity, spectral resolution, low stray light, computer controlled background correction, and instrumental stability. These features are prerequisites for the successful analysis of diverse geological materials. The instrument is automated from sample introduction to tabulation of results.

Element	Detection Limit	Digestion $HClO_4$ HNO_3	Digestion $HClO_4$ HNO_3 HF
Aluminum	0.01%		x
Arsenic	10 ppm	x	
Barium	1 ppm		x
Beryllium	0.5 ppm		x
Bismuth	2 ppm	x	x
Cadmium	0.5 ppm	x	x
Calcium	0.01%		x
Chromium	1 ppm		x
Cobalt	1 ppm	x	x
Copper	1 ppm	x	x
Iron	0.01%	x	x
Lead	2 ppm	x	x
Magnesium	0.01%		x

Element	Detection Limit	Digestion $HClO_4$ HNO_3	Digestion $HClO_4$ HNO_3 HF
Manganese	1 ppm	x	x
Molybdenum	1 ppm	x	x
Nickel	1 ppm	x	x
Phosphorus	10 ppm	x	x
Potassium	0.01%		x
Silver	0.2 ppm	x	x
Sodium	0.01%		x
Strontium	1 ppm		x
Titanium	0.001%		x
Tungsten	10 ppm		x
Vanadium	1 ppm		x
Zinc	1 ppm	x	x

Digestion	Price/Sample
Perchloric-nitric acid ($HClO_4$ - HNO_3)	13 elements — $8.00
Perchloric-nitric-hydrofluoric acid ($HClO_4$ - HNO_3 - HF)	13 elements — $10.50 24 elements — $13.00

WHOLE ROCK ANALYSIS

(Constituents in Percent) —	Price/Sample
SiO_2, Al_2O_3, Total Fe (as Fe_2O_3), TiO_2 MgO, CaO, Na_2O, K_2O, P_2O_5, MnO & LOI	$25.00
Additional constituents FeO, S, Ba, CO_2 H_2O+, H_2O-, each —	$ 6.00

EMISSION SPECTROGRAPHIC ANALYSIS

Soil, sediment, rock and biogeochemical materials.	Price/Sample
20 element semiquantitative spectrograph analysis — Sb, As, Ba, Be, Bi, B, Cd, Cr, Co, Cu, Pb, Mn, Mo, Ni, Ag, Sn, Ti, V, Zn & Zr	$24.00
30 element semiquantitative spectrograph analysis — Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Cr, Co, Cu, Ge, Fe, Pb, Mg, Mn, Mo, Ni, Nb, K, Si, Ag, Na, Th, Sn, Ti, V, Zn & Zr	$30.00
Individual or additional elements —	$ 8.00

Prices in Canadian dollars or U.S. equivalent.

ASSAY FEES

Geological, Mineralogical and Metallurgical Materials.

Element	Price/Sample
Gold (Fire Assay & Gravimetric Finish)	$ 7.50
Gold (F.A. & A.A. Finish)	7.50
Gold (Fineness)	30.00
Gold (Bullion)	50.00
Gold & Silver (F.A.)	10.50
Palladium (F.A. & A.A. Finish)	24.00
Platinum (F.A. & A.A. Finish)	24.00
Platinum & Palladium (F.A.)	30.00
Silver (A.A.)	7.50
Silver (F.A.)	7.50
Silver (Fineness)	30.00
Aluminum	10.00
Antimony	8.00
Arsenic (N.A.A.)	8.00
Barium (Gravimetric)	10.00
Barium (N.A.A.)	8.00
Beryllium	11.00
Bismuth	9.00
Bromine (N.A.A.)	8.00
Bulk Density	6.00
Cadmium	7.00
Calcium (A.A.)	7.00
Calcium (Volumetric)	11.00
Carbon	6.00
Carbon Dioxide	10.00
Cerium (N.A.A.)	8.00
Cesium (N.A.A.)	8.00
Chlorine	8.00
Chromium (A.A.)	10.00
Chromium (N.A.A.)	8.00
Cobalt	6.00
Copper (Total)	5.50
Copper (Non Sulphide)	7.00
Fluorine	10.00
Gallium (N.A.A.)	8.00
Germanium	20.00
Hafnium (N.A.A.)	8.00
Iron (Total)	10.00
Iron (Acid Soluble)	8.00
Iron (Ferrous)	10.00

Element	Price/Sample
Lanthanum (N.A.A.)	$ 8.00
Lead	5.50
Lead (Non Sulphide)	7.00
Lithium	10.00
Loss on Ignition	5.00
Magnesium	9.00
Manganese	8.00
Mercury	10.00
Moisture	5.00
Molybdenum (Total)	6.00
MoS_2 or MoO_3	7.50
Neodymium (N.A.A.)	8.00
Nickel	6.00
Niobium	12.00
Phosphorus	10.00
Potassium	10.00
Rhenium (N.A.A.)	24.00
Rubidium (N.A.A.)	8.00
Scandium (N.A.A.)	8.00
Selenium (N.A.A.)	8.00
Silica (Insoluble)	6.00
Silica (Fusion)	10.00
Sodium	10.00
Specific Gravity	6.00
Strontium	10.00
Sulfur (Gravimetric)	9.00
Sulfur (Induction)	6.00
Tantalum (N.A.A.)	8.00
Tellurium	20.00
Thorium (N.A.A.)	8.00
Tin	8.00
Titanium	10.00
Tungsten (Colorimetric)	10.00
Tungsten (N.A.A.)	8.00
Uranium (Fluorometric)	10.00
Uranium (N.A.A.)	8.00
Vanadium	10.00
Zinc	5.50
Zinc (Non Sulphide)	7.00

CONCENTRATES — Replicate assays of concentrate materials at three times list price.

CONTROL AND UMPIRE ASSAYING — By Quotation.

PRIORITY FIRE ASSAYING FOR SILVER AND GOLD: 48 to 72 hour rush service up to 20 samples per client, per day or as volume permits. The cost will be 50% above regular schedule.

Prices in Canadian dollars or U.S. equivalent.

RADIOISOTOPE ANALYSES

Chemex radioisotope laboratory includes instrumentation for low level monitoring and tracer studies. The establishment of this laboratory enables us to measure radionuclides in the environment and reaffirms our commitment to offer the necessary monitoring services required by our clients. Trace analyses are carried out using a low level proportional counter in addition to Alpha spectroscopy and Gamma spectroscopy [Ge (Li)] systems.

RADIOCHEMICAL ANALYSIS

Water.

Analysis	**Absolute Detection Limit**	**Price/Sample**
Gross Alpha	0.05 Bq*	$ 25.00
Gross Beta	0.15 Bq*	25.00
Gross Alpha & Beta	0.05, 0.15 Bq*	40.00
Lead^{210} (Total or dissolved)	0.05 Bq	60.00
Polonium^{210} (Total or dissolved)	0.01 Bq	50.00
Potassium^{40}	0.005 Bq	30.00
Radium^{226} (Total or dissolved)	0.01 Bq	60.00
Radium^{226} (Total and dissolved)	0.01 Bq	100.00
Thorium Isotopes (Total or dissolved)		
Thorium^{228}, Thorium^{230}, Thorium^{232}	0.05 Bq	75.00
Thorium^{232} (Neutron Activation)	0.2 ug	20.00
Cesium^{137}	0.1 Bq	40.00

** Detection limits may be slightly higher for waters high in total solids.*
All detection limits reported at the 95% confidence level.

GAMMA SPECTROSCOPY

Ore, soil, sediment, dust, vegetation and rock materials.

Isotope	**Detection Limit**	**Isotope**	**Detection Limit**	**Price/Sample**
Ra^{226}	0.005 Bq/g	Pb^{212}	0.005 Bq/g	22 isotope gamma scan — $100.00
U^{238}	0.05 Bq/g	Bi^{212}	0.005 Bq/g	
Th^{234}	0.05 Bq/g	Po^{212}	0.005 Bq/g	
Po^{214}	0.005 Bq/g	Tl^{208}	0.005 Bq/g	
Pb^{210}	0.05 Bq/g	U^{235}	0.01 Bq/g	
Ra^{228}	0.005 Bq/g	K^{40}	0.01 Bq/g	
Ac^{228}	0.005 Bq/g	Cs^{137}	0.002 Bq/g	
Th^{228}	0.005 Bq/g	Rn^{222}	0.005 Bq/g	
Ra^{224}	0.005 Bq/g	Po^{218}	0.005 Bq/g	
Rn^{220}	0.005 Bq/g	Pb^{214}	0.005 Bq/g	
Po^{216}	0.005 Bq/g	Bi^{214}	0.005 Bq/g	

Note: Requires a minimum of 100g of sample material.
All detection limits reported at the 95% confidence level.

Prices in Canadian dollars or U.S. equivalent.

WATER QUALITY ANALYSES

	Price/Sample
Alkalinity & Acidity	$10.50
B.O.D. (5-day Biochemical Oxygen Demand)	26.00
Boron	20.00
Carbon	
— Total Organic Carbon	21.00
— Total Inorganic Carbon	10.00
C.O.D. (Chemical Oxygen Demand)	28.00
Chloride	10.50
Chlorophyll	27.00
Colour	6.50
Conductivity	6.50
Cyanide	30.00
Dustfall	32.00
Fluoride	8.75
Hardness — Total	10.50
Nitrate-Nitrites — NOX	14.00
— NO_3	14.00
— NO_2	10.50
Nitrogen-Kjeldahl	17.00
Ammonia	12.50
Oil & Grease	20.00
Oxygen — Dissolved	6.00
pH	4.00
Phenols	26.00
Phosphates — Total	13.00
— Ortho	8.50
— 3 ppb det.	16.00
Silica	11.00
Solids — Total, Dissolved, Suspended — each	10.50
+ Volatiles on above — each	3.00
Sulphate	10.00
Sulfide	17.00
Surfactants (MBAS)	26.00
Tannin & Lignin	13.00
Turbidity	6.00
Thiocyanate	11.00

	Price/Sample
Metals — Cd, Cr, Co, Cu Pb, Mn, Mo, Ni, Ag, Zn — total/dissolved, by pre-concentration or solvent extraction — to 1 ppb	1st element — $11.00 Each additional element — $5.00
Metals — Cd, Cr, Co, Cu Fe, Pb, Mn, Mo, Ni, Ag, Zn — by direct AA analysis — to 20 ppb	1st element — $6.00 Each additional element — $4.00
Metals — by specific analytical techniques	
— Aluminum	10.00
— Antimony	16.00
— Arsenic	18.00
— Barium	10.00
— Calcium	10.00
— Lithium	10.00
— Magnesium	10.00
— Mercury	21.00
— Potassium	10.00
— Selenium	18.00
— Sodium	10.00
— Strontium	10.00
— Tin	16.00
— Uranium	16.00
— Vanadium	10.00
Biological Parameters	
Bioassay — 24-hour Static	By Quotation
— 96-hour Static	
— 96-hour Multi Dilution	
— 96-hour Trout Check	
Total Coliform	22.00
Fecal Coliform	22.00
Total and Fecal Coliform	27.00

Price discounts for more than 5 samples or prices for non-routine work will be quoted prior to undertaking work. We urge you to discuss your requirements with us before beginning field work or submitting samples for analysis.

Suitable sample bottles and instructions for the collection, treatment and shipping of water samples are available on request.

DATA TRANSFER AND PROCESSING SERVICES

Mineral exploration programs by their very nature often require timely evaluation of geochemical data. As a result, much effort and expense is devoted to minimizing sample transit time to the laboratory and to expediting the chemical analysis once the samples are in the laboratory. In addition to these time saving measures our experience has shown that transmitting data electronically to client field offices can further reduce the turnaround time.

COMPUTER DATA BASE

To streamline exploration, all analytical data generated at Chemex Labs, since 1980, are stored in our VAX 11/750 computer. These data are part of our internal record management and accounting system and thus are stored at no cost to our clients.

24-HOUR, DIAL-UP ACCESS

At client request, certified assay and geochemical data can also be stored in a password-protected, client-dedicated, account. These dedicated timesharing accounts can be accessed, 24 hours a day, by authorized client geologists located anywhere in the world, using a suitable computer terminal. In most areas, access is available by dialing into the local telephone system or into the public, packet switching network which eliminates long distance telephone charges.

ELECTRONIC DATA TRANSMISSION

The terminal receiving the encoded data can be as simple as a portable printer or as complex as a mainframe computer system. Any personal computer with communications software and a modem can be used to retrieve data from a Chemex Labs timesharing account. Geochemical data are available in formats which are directly compatible with commercially available software packages such as LOTUS 1, 2, 3.

Electronic transmission of data is advantageous because the geologist can retrieve analytical results more quickly than by conventional means. This can be particularly helpful on drilling projects where drill placement can be optimized by rapid turnaround of assay data.

GEOLOGICAL DATA BASE MANAGEMENT

In addition to data transmission, dial-up data base management services are also available. Using interactive software, geologists can rapidly evaluate, sort, merge and printout masses of geochemical data in a variety of formats suitable for inclusion in exploration reports.

For further information on these exclusive services ask for our data distribution and management system brochure or contact our Data Processing Services Manager.

OTHER SERVICES

MINERAL SEPARATIONS Concentration of overburden or stream sediment, exploration samples by panning, table, heavy liquid separation, magnetic separation or by hand picking, as required, per hour	$25.00
ROCK AND MINERAL IDENTIFICATION Preparation of thin and polished sections. Photography and identification of rock and mineral specimens, per hour	$35.00
CORE SPLITTING, per hour	$25.00
COAL TESTING AND ANALYSES	Price list on request
HYDROCARBON ANALYSES	Price list on request
BULK CARGO SAMPLING AND ANALYSES	By quotation

Chemex Labs Ltd.

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for time and cost-efficient results

Bulk Cargo Commodity Testing

Chemex provides efficient, independent sample analyses vital to prompt certification of import and export cargo materials.

Quality assurance analyses by ASTM and AOAC Standard Procedures are conducted on a growing range of materials including:

☐ coal
☐ mineral concentrates
☐ petrochemical products
☐ propane
☐ wood chips
☐ fertilizer
☐ potash
☐ sulphur
☐ agricultural products
☐ a wide variety of chemicals.

Computer Data Processing

Chemex professionals are constantly developing and streamlining computer systems and procedures to deliver the rapid reliable data exploration programs require.

Our VAX 11/750 computer has enabled us to expand our data base and overall data management services providing greater flexibility in formatting analytical data and interpreting statistical information through our Q'Gas Data Analysis System.

Our service provides high speed data transmission to our clients' remote terminals and indefinite storage of client data.

Chemex Labs Ltd.

Our *Chemex* team of analytical chemists, assayers, technologists and technicians work round the clock to deliver effective economic solutions to clients round the world.

We at *Chemex* are proud of our reputation for innovative . . . efficient . . . prompt . . . reliable service.

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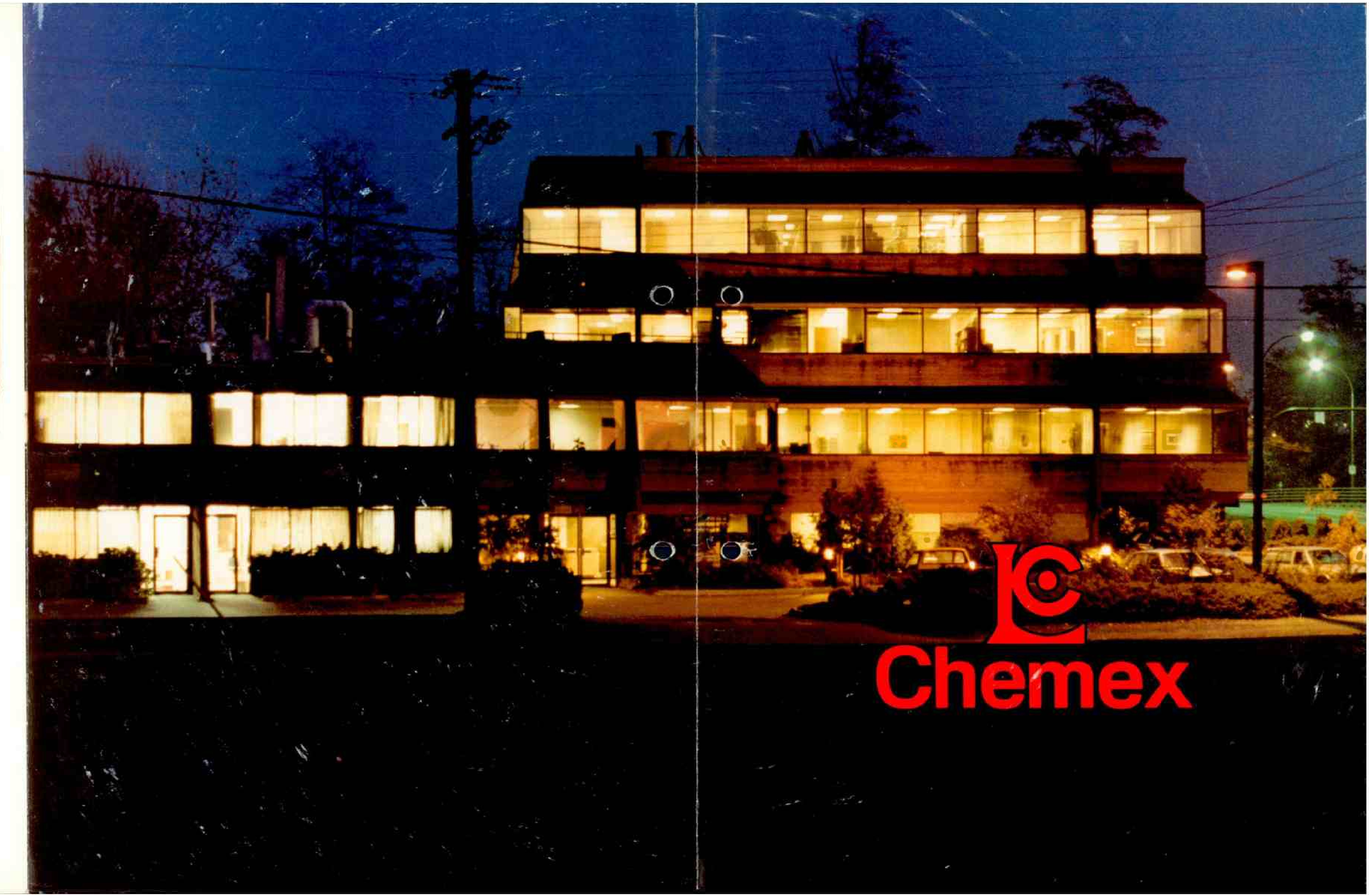


pioneers from the start

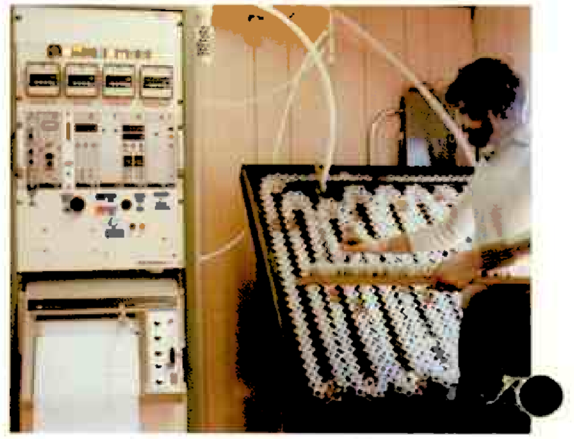
Chemex — one of the largest commercial laboratories in the Pacific Rim — provides analytical, technical and consulting services for clients in industry and government the world over.

While trace metal analysis and assaying remain the primary focus of our activities, technological advances have enabled us to substantially expand and diversify our operations.

Today our comprehensive services include:
- ☐ chemical and geochemical analysis
- ☐ assaying
- ☐ neutron activation analysis
- ☐ plasma (ICP), spectrographic and chromatographic techniques
- ☐ environmental sampling, monitoring and analysis
- ☐ coal and coal ash analysis
- ☐ bulk cargo commodity testing
- ☐ data management and project coordination

Centralization of operations in Vancouver affords *Chemex* professionals great flexibility in the application of classical, instrumental and physical techniques . . . either separately or simultaneously . . . across our entire range of services.

Innovation . . . the bedrock on which our Canadian owned company was founded in 1966, remains a constant in our strategy for growth.



Chemex was one of the first laboratories to —
- ☐ develop commercially viable applications of neutron activation analyses
- ☐ build separate and extensive laboratory facilities designed on a modular concept, ensuring peak efficiency in the handling, preparation and processing of all materials in a controlled environment
- ☐ design equipment and systems to our own specifications, improving efficiency in operations and increasing the quality of results. (Items range from constant-temperature water baths and perchloric acid fumehoods to pneumatic controllers for our pulverizers . . . and a continuous, chain auto-loading device for neutron activation samples.)
- ☐ transmit electronic data direct to client field operations, saving up to two weeks in turnaround time for as little as 1% of the analytical costs

Efficiency and Economy . . . through our multi-disciplinary approach, combines staff expertise and experience with state of the art technology, ensuring timely project completion.

Our separate laboratories for analyzing elements, such as — tin, tungsten, uranium, arsenic and mercury — guarantee contamination-free testing and maximize throughput efficiency. In addition, our in-house workshop services the entire analytical facility. *Chemex* ensures the consistent, rapid turnaround time so critical to exploration personnel.

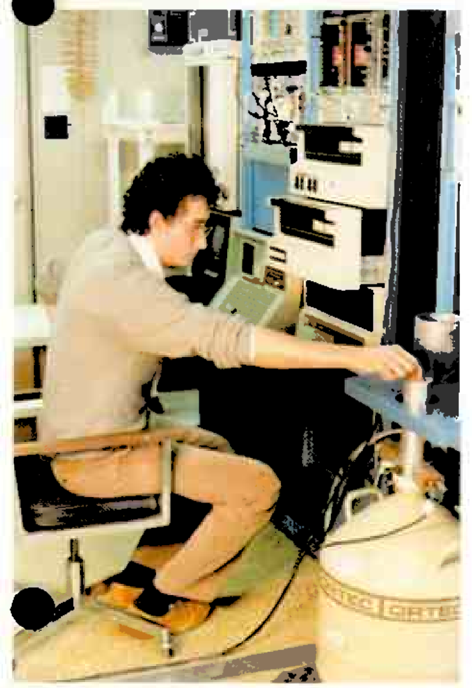
Computer data processing and transmission systems round out our total service package. *Chemex* can deliver analytical and statistical data the same day results are completed.

Reliability . . . is a tradition at *Chemex*.

Our technical staff actively participate in ongoing research and development of new and improved preparation and analytical procedures and data processing services.

Chemex problem-solvers deliver the efficient and economic solutions our clients need.

Chemex offers a growing range of services



Neutron Activation

Chemex, one of Canada's pioneers in the field, offers neutron activation analyses to complement atomic absorption and plasma techniques, and round out our total analytical package.

Neutron activation is the most reliable method for determining gold and platinum group elements, and the only procedure for effectively measuring rare earth elements at trace levels.

We apply this multi-element technique in assaying and trace metal analysis of a diversity of matrices — geological materials (exploration and environmental), metallurgical products, biological tissues, bulk commodities and foodstuffs.

Plasma (ICP) & Spectrographic

Chemex provides simultaneous analysis of up to 35 elements in geochemical materials, water samples, mineral ores and concentrates.

Fully automated to analyze batch streams and tabulate results, our Jobin-Yvon JY-48 plasma spectrometer offers —
- ☐ superior analytical sensitivity
- ☐ spectral selectivity
- ☐ computerized background correction.

DC arc emission spectrography is also available as a semi-quantitative technique for multi-element scan of geological samples.

Sample Handling & Preparation

Chemex professionals carefully study each project to design appropriate handling and preparation procedures vital to quality analysis.

To ensure the most accurate results, we provide —
- ☐ separate handling and processing facilities
- ☐ storage and retention services

for all geochemical samples and geological materials. The care we take with our clients' sample materials is a key factor in the quality of our analytical services. Discard of retained materials is always subject to client approval.

We also offer clients instruction in soil, sediment and water sampling techniques; sample handling and the use of field kits and instrumentation.

Geochemical

Chemex geochemical analytical services provide —
- ☐ a detection limit for each element, below background levels encountered in most geological environments
- ☐ the most effective analytical range of elements for the exploration industry . . . including pathfinders for gold, such as — arsenic, antimony, tellurium, bismuth and mercury
- ☐ maximum throughput efficiency in our isolated, contamination-free laboratory complex.

Instrumental and chemical methods are used to determine trace elements in soil, silt, rock, water, lake and marine sediments, tissue and vegetation.

Assaying

Chemex is a founding participant in the Canadian Certified Reference Materials Project (CCRMP). Accuracy and precision are critical in certifying economic concentrations of constituents in —
- ☐ rock chips
- ☐ drill core
- ☐ percussion material
- ☐ mineral concentrates
- ☐ bullion.

Assay procedures range from classical volumetric, gravimetric and fire assay techniques to instrumental and physical methods involving neutron activation and atomic absorption.

Environmental

Chemex offers environmental baseline studies, field sampling and monitoring services to clients on a turnkey basis.

Standardized analytical procedures, such as —
- ☐ Standard Methods APHA – AWWA – WPCF
- ☐ ASTM Standard Procedures
- ☐ Analytical Methods WQB – Environment Canada

are routinely applied in a variety of studies, including water and waste water, ambient air, biological tissue and geological matter.

We combine state of the art nuclear counting equipment with our expertise in analytical and environmental chemistry to produce highly successful radionuclide tracer studies for industry and government.