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GEOLOGICAL STUDY ABOUT THE KNABEN-MOLYBDAEN DISTRICT

(VESTAGDER) NORWAY.

INTRODUCTION.

The present study is concerning two sectors of the mining distric of Knaben-gruvor (South Norway).
This district consists of, like the whole southern part of Norway, ancient precambrian grounds belonging to the old scandiniavian shield.
It consists essentially of gneiss and granites with their usual satellites:aplites,pegmatites,and quartz veins.
The outcrops are numerous and excellent,through the combined effect of the ancient quaternary glaciers with the present fluvial denudation.
There are numerous erratic stones with polished and striated wawing rocks on the surface of the battered table-plain,whose altitude decreases gradually towards the South from 700 to400m.
The fluvial denudation has cut inside right and deep valleys,whose dominating direction is North- South.
Many lakes and marshes are taking the hollows of this table-plain.
Generally the weathering of rocks is feeble,it is not going deeper as a few centimeters.
The small fissures are often filled by epidote.
The water of the lakes is strongly dyed in red brown with the small particules resulting from the decay of ferromagnesian minerals.
The way of the running water is often marked by ferrugineous coates

The surveyed areas are:

I°) An area directed North-South from Knaben-gruvor to Bjornvann at 7km Southwards.

2°). An area directed North-South alongside the Sirdalvatn,from Tonstadt to Oftedal at I5km Southwards and situated at I5km West from the first.

I) AREA KNABEN - BJORNVANN.

A geological map at I/IOOO scale of the roof of the actual working (Knaben-Homenvann) has been already done, just as a systematic prospection of molybdenite alongside a North-South direction the brook of Knaben and the Littleadalen.

My own work consisted in recognizing the mineralization Westwards and South-Eastwards of the already prospected region.

The gneiss, whose dip I5° or 20° Eastwards is easily visible on the right bank of Knabenbrook, has been changed into granite alongside a streak NE-SW from 3km. at least in width.

The eastern boundary line is marked about through the cliff which is bordering the right bank of Knabenbrook and after bends toward SW.

The eastern boundary line is located off the prospected area.

The gneiss has a varied appearance:

I) eye-gneiss with big numerous pink feldspars and a few biotite.

2) gray dark gneiss with tiny straight and parallel beds much more rich in mica than the precedent.

3) gneissose granite pink with little intricated beds, often very like granite.

The granites are of alcalin type, sodicopotassic with orthose and albite feldspars wether a porphyric type with big pink or white feldspars, or a tiny grained pink type.

Anyway the dark minerals are searce and the granites are often turning into aplites.

They are accompanied, as usual, with numerous white or pink pegmatitic veins with quartzose masses and big crystals of biotite, which are often turning into quartz veins. Many melky quartz veins compact or hollow can be followed freqently on 5 to IOm length. They cut the granite or the gneiss.

The aplitic formations are important: white or gray pink tiny grained aplite shaping into very irregularly ramified veins turning often into quartz veins. This formation follows the granitic formation underneath with about the same dip (20 or 30° Eastwards).

The underground works reaching to the mark 547m at the first level have proved that the aplitic formation is growing in thickness with the depth.

The aplite is often formed, on the surface, in the shape of small veins, with masses of big crystals of quartz and felspars in graphic association.

Locally, some dark green amphibolitic veins are found through granites or gneiss.

On the boundary line of granites and gneiss the transition is gradual but nearly fast. More often, the gneiss take a granitic appearance and lose their bedding. Sometimes the rock is crossed by dark straight or folded stripes very rich in ferromagnesian minerals. As we shall see later, this appearance is more frequently found in the area Tonstadt-Oftedal.

Mineralization.

It is connected with the granitization of the gneiss and with the usual satellites of granites :aplites pegmatites and quartz veins. It consists chiefly of sulphides :molybdenite,pyrite,chalcopyrite.These later minerals have no economic value,because they are too scattered and,during the treatment of molybden ore,these sulphides are striked out by solution in CyNa.

The average percentage of molybdenite in the worked parts of the rock is not very high ,from 0,I to 0,3 %.

I will now point out a few marks through which by overground investigations molybdenite can be more easily detected.

I) Great number of quartz veins crossing granite or aplite or rarely gneiss in the vicinity of granites,and usually connected with pegmatitic veins,is a very interesting indication.

As often as I have found the molybdenite,it was in the shape of big crystals in the hollows of quartz veins,or as material filling small fissures into granites and rarely gneiss allways in proximity of quartz veins.

However,all the quartz veins are not mineralized ,but I think it is necessary to point out on the map all the outcrops where I have found a great quantity of quartz veins ,even though I did not find a visible mineralization into,because these outcrops deserve more investigations than I would do.

Often it is very interesting to inspect the quartzose alluvions which are accumulated by the running water in hollows of the ice-polished flags.Indeed I have found many crystals of molybdenite,chiefly on the points J24 ,J32,J33.Everytime the molybden ore was contained in proximity in little fissures of the rock.

2).The presence of other sulphides as pyrite or chalcopyrite is also a interesting indication.
Indeed I have often found these sulphides ,chiefly in quartz veins,beside the molybdenite,for instance on the points :J40,J46,J47,J50,J5I,J56 .In many cases pyrite and chalcopyrite lie without molybdenite ,for instance on the points :J16,J24,J43;However,in such cases,it proves that the mineralization exists in the vicinity and,if the investigations are pushed deeper,it is possible to find,the molybdenite.

3).The surficial ferrugineous coates on the rocks are sometimes interesting for the prospection,but very hazardous .
I note the outcrop J40,where little impregnations of molybdenite with pyrite are connected with some plentiful red-brown ferrugineous coates This fact is likely owned to the surficial oxidation of the pyrite in the rock.But very often this red brown colour is owned to running water without connexion with the mineralization.

I have seen neither molybdite,nor magnetite which is found in little masses about the Sirdalvatn.

The chalcopyrite is sometimes altered into green hydro-carbonate malachite.

The mineralized pegmatitic veins are rare. They contain only molybdenite without other sulphides, for instance the points J3, J5, J46.

As to conclusion, the outcrops which are interesting and deserve deeper investigations are those where the quartzose and pegmatitic formations are plentiful, where pyrite and chalcopyrite are found even alone, and accessorely where ferrugineous coates exists on the rock.

Surficial distribution of molybdenite.

The investigations which have operated this last war and my own work show that numerous mineralized points are scattered irregularly alongside the Knabenbrook and the Littleadalen from North to South. These points are very rich in molybdenite between the Knaben mine and the Homenvann on the roof of the present underground works.

The area situated between the Littleadalen and the Borknomknattan offers the same features.

On the contrary on the South of Kaldalen and chiefly on the gneiss, where the quartzose and pegmatitic formations are rather rare, the mineralized points are scattered and less rich.

An other direction from North to South, interesting about the mineralization, is situated between the Knabenvann and the Movastokn.

The richest areas are situated alongside the Atlakdalen and the Oyevann, then between the Movastokn and the Borknomknattan, where this second direction is meeting with the first.

Between these directions, I have found only few interesting indications, because this area is entirely covered by vegetation, and the rare outcrops I have met, are bearing no molybdenite.

The mineralization seems likely to proceed further Southwards why, as the topographical map points out, exist mining works named "Molybden-nedl", at 10km Southwards of Movastokn near Fjotland.

Study of underground mineralization.

The mining works are going deep into the montain from South of Knaben as far as the Homenvann at altitude 670m (first level), and the deepst level (10th: level) is at altitude 575m.

These works show:

At a given level: { a granitic formation bearing a rich mineralization parallel with NE-SW.
an aplitic formation;

In a vertical section:

the formation is going with a dip 30° Eastwards into the gneiss.
The thickness of the rich formation : (0,2 to 0,03%) is deacrising with the depth,

while,on the contrary,the thickness of aplitic formation increases.

The molybdenite appears in shape of little impregnations in the middle of ligth gray granite,containing plenty of white felspars,or associated with quartz or pegmatitic veins .Sometimes little masses of calc-spar are found.

An irregular mineralized zone exists parallel with the aplitic formation;its Northern part is rich,but in South the percentage of molybdenite decreases(0, 1%) with few localized enrichings,and belove the Homenvann this zone ends by mineralized quartz veins.

The granites which are situated between these two mineralized zones is often porphyric with big pink felspars.These granites and the aplitic formation are rarely mineralized.

Generally the molybdenite is localized ,where the granite is rich in quartz and felspars ,on the contrary,rare in the granites rich in dark minerals.

II).AREA TONSTADT -OFTEDAL.

This area whose approximate surface is 50km sq.,is elongated North-South in parallel direction with the Sirdalvatn .
Old investigations for molybdenite are to be seen above Avedal and on the South of Bergheie above Skibeli.
My own work has consisted in doing the geological survey (50000 scale and in the same time in the studying of the mineralization.

Geological feature of this area.

A line North-South passing slightly in the East of Oksendal parts two great systems:

West of this line:the granites which disappear in the Sirdalvatn

East of this line :the gneiss which I met as far as I could go Eastwards .i.e. spreading over 3km from the separative line.

THE GRANITES.

They lie generally like big rather irregular benches with a dip of 30 or 40° Eastwards .Like for all the rocks of this region ,the weathering is slight.The dark minerals and the felspars are partly chloritized and the secondary epidote fills the little fissures .
The granites are light gray or pink ;generally quartz and felspars are plentiful and the dark minerals are scattered on shape of little spots
Sometimes they are turning into aplite.In many places the granites are porphyric with big pink or white felspars .
Near Oftedal,the granite situated at the foot of the cliff contains many inclusions of magnetite visible with the naked eye.
The aplitic passages excepted,the pegmatitic veins are rather rare ; it is generally a pink pegmatite with biotite and quartz masses.
The quartz veins,so frequent in granites of Knaben,are very rare.
These granites crop out largely towards the South-East of Tonstadt , in the areas of Legeheie,Maridalen,Löyntj,and alongside the cliff rising above the road from Haughom to Oksendal.

Microscopical study.

It has been done with four samples: A ,B ,C ,170.
I took the samples A,B,C,on the North of Haughom along the road which follows the lake towards Tonstadt .
It is a light gray granite with dark minerals scattered in little grains and big felspars ordered in parallel lines.
It contains:

a great amount of quartz in large xenomorph crystals,

microcline (potassic felspar),a little oligoclase(calcoso-dic felspar)

often altered into a kind of white mica (damourite).
rather plentiful biotite ,very pleochroic (from yellow-green to dark brown).
a little muscovite.
big crystals of magnetite enclosing pyrite.
Sphene allways connected with magnetite;this association proves that this magnetite is really a titanomagnetite.

I have chosen the sample I70 in vicinity of the contact gneiss-granites
It contains:
a great amount of quartz.
prevailing microcline accompained by a little oligoclase.
frequent association of quartz and felspars :graphic micropegmatite and myrmekite.
rather rare biotie ,often chloritized.

Shortly,this granite is typically a calco-potassic granite with biotite.

However this granitic formation is not homogeneous.
Indeed the road cutting the rock alongside the Sirdalvatn shows some great continued outcrops with clear alterations of typic granitic appearance.I have chosen for type the outcrop situated between Haughom and the Rompen.
The succession ,from North to South,is as follows:

1°).Gray tiny grained granite ,often pophyric(A ,B,)

2°).Gray darker porphyric granite with ranks of big pink felspars (C)

3°).Gray granite crossed by little lenticular dark beds and wide aplitic stripes (D)

4°).Alternacy of dark beds enclosing many ranks of white felspars ,and pink aplitic stripes (E1 ,E2).

5°).The dark stripes are getting smaller ,then end into bevel a mid pink aplitic rock.

6°).The striped appearance comes back with many folded dark beds succeding to aplitic beds.(F).

7°).These allways many folded are getting wide,then disappear little by little.(G,H,I.).

8°).The rock turns into a homogeneous light granite with only few darksbeds.(J)

9°).The rock turns abruptly entirely dark with only few white folded aplitic beds.(K).

A little farther a very big quartz vein crosses these dark rocks perpendiculary to the foliation of rock.
The striped rocks with ranks of felspars in dark beds are largely developped near Haughom in each side of the road from Haughom to Oksendal and near the little lake of Oksendal,where they alternate with the

pink porphyric granites.A same succession is found before the first bridge of the road from Oksendal to Avedal,passing from a homogeneous gray granite to striped dark rock and again to the normal gray granite

Numerous reccurences of this appearance are visible alongside the road between Oftedal ,Haughom ,and Tonstadt.

The outcrop 27 shows a pink aplitic rock which is separated by a straight and clean line,from a dark rock containing little lenticular inclusions of aplite.

In these formations,the quartz veins are very rare ,on the contrary the pegmatitic veins ,more or less ramified,are very numerous and generally perpendicular to the bedding.

In all the outcrops already noted,the rocks have a clean dip Eastwards like the granites.

Everytime the rock shows a streaked appearance,the dark or light straight or folded stripes are allways parallel.

Microscopical study.

The samples have been chosen in series, from the Rumpen to Haughom.They are going from normal homogeneous calco-alcalin granite (A,B,C to a very dark rock with few folded aplitic beds(K).

The D,EI,E2,F,correspond with the biginning of the striped rocks Their mineralogical composition is obviously changed:
green hornblend becomes prevailing,often connected with alittle biotite issued from its alteration.
Microcline disappears gradually and is replaced by oligoclase,proving the growing percentage of calcium,already indicated by the apparition of hornblend.
The associations of quartz and felspars (micropegmatite and myrmekite) are frequent,like the associations titanomagnetite,sphene,pyrite.

The sample EI taken in pink aplitic bed,contains a great amount of quartz and felspars often associated (myrmekite);biotite is rare. The chemical composition of felspars differs from that of the dark beds:indeed microcline(potassic) and oligoclase are in same proportion

From sample F,microcline disappears completely .The rock become clearly more calcic with green hornblend and biotite in variable relative proportion.A part of the biotite,often chloritized,issues probably from the alteration of the green hornblend.This alteration is accompained by a deposit of iron and titanium oxides.
Apatite and sometimes zircon are included in crystals of hornblend.
Epidote and sphene (calcic minerals) are issued directly from its alteration.
Biotite is often changed into felspar and magnetite,or chlorite.

The magnetite or titanomagnetite issued from the alteration of hornblend or biotite,have allways the shape of little torn crystals, whereas the original magnetite or titanomagnetite included in magma have allways the shape of big crystals enclosing pyrite.

The sample K corresponds with a very dark rock. As before (samples G H,I,J.),microcline is entirely lacking; there is only oligoclase.The dark minerals are plentiful ;but green hornblend is entirely lacking; biotite is accompained by big crystals of pyroxene:

orthorombic pyroxene (bronzite), and clinorhombic pyroxene(augite). This latter is rarely changed into a kind of serpentine and more often into biotite and chlorite.
The original magnetite is plentiful.

Shortly, these striped rocks are constitued by an alternacy of aplitic beds containing quartz ,oligoclase and microcline, and of dark beds containing quartz ,oligoclase, green hornblend, pyroxenes, and biotite.

THE GNEISS.

In the East of a line North-South passing near Oksendal, a great gneissose formation is found with dip from 30° to 40° Eastwards, which has a visible influence upon the topographical shape: on the eastern side of Avedal-valley the slope presents successive ledges, and on the opposite side the slope has the same declivity as the dip of the gneiss

Generally the gneiss is dark gray. It is compact and very hard; It is possible to distinguish two essential appearances in this formation:

1). A thin bedded gneiss : it consists of an alternacy of staight, dark and white beds. This appearance becomes prevailing Eastwards.

2). A folded gneiss: this appearance is very varied:

either: alternacy of white and dark beds parallel but undulated.

or: very intricate bedding with dark, folded and stretched beds on a white aplitic ground.

These foldings are sloping, stretched, drifted, on a small scale, exactly like the great foldings of sedimentary formations in the mountains. A very nice sample of these folded gneiss is visible on the large clift cutt by the brooks trough the rocks from Slettheie to Avedal-lake.

This appearance is chiefly distributed alongside the boundary-line granites-gneiss: Slettheie ,Stakkhomheie ,on the South of the Bergeheid alongside the Kleievann, and on the North of Avedal.

Locally the gneiss contains many little red garnets(pt.76.)
In all the gneissose formation, the aplitid, pegmatitic, quartz veins are very numerous, and sometimes these aplitic veins contain red garnets enclosing little quartz crystals.

Microscopical study.

(Samples 70, 76, 194.)

The gneiss 70, and 76, are of a thin bedded kind.
They contain:

puzzle of quartz crystals.

oligoclase alone.

very pleochroic brown-green biotite more or less chloritized
a little cordierite chiefly in the sample 70 .
a great number of big garnets(almandin) enclosing little
quartz crystals,in the sample 76.

I took the sample I94 near the the boundary-line granites-gneiss.
It shows:

a puzzle of quartz crystals.

prevailing oligoclase accompained by few microcline .

plentiful biotite.

no garnets nor cordierite.

Briefly,the gneiss is typically a calco-sodic gneiss with biotite, and silicates of metamorphism (garnet,cordierite).

The gneissose formation is not everywhere homogeneous.
On the border of the boundary-line granites-gneiss ,it contains a large quantity of granitic inclusions getting more rare towards the East. They are often too little to be marked on the map at I/50000 scale , for instance,around the Slettheie ,Stakkhomheie, Bergeheie,where the granitization is diffuse through the folded gray gneiss.

On the contrary these granitic inclusions are more considerable on the South-West of the Stakkhomfjeld in Avedal-valley,around the Vardefj and alongside the Kleievann.

Along the path which goes up from the bottom of the Avedal-valley to Stakkhomfjeld,I saw at first a dark folded gneiss,and after a interruption owing to marshes and vegetation ,a light gray granite.This granite turns gradually into white aplite with in various places,dark diffuse beds like clouds.This cloudylike aplite turns gradually into a typic dark thin bedded gneiss.

Tis progressive transformation from granite to gneiss takes place within a length of 200m.

The Vardefj area shows also a excellent sample of gradually transformation of granite into gneiss along the path from Listol-farm towards the Vardefj.

These granitic inclusions have various appearances:sometimes gray or pink tiny grained ,sometimes porphyric with big felspars.

They are often crossed by many quartz or pegmatitic veins,and contain few little red garnets.

Further ,the granites are often crossed by dark folded stripes like they are along the road from Haughom to Tonstadt.

Over Avedal (Slettheie)the old investigations for molybdenite show a complex succession of appearances in the folded gray gneiss.

The outcrop II3presents a succession as follows:

I).tiny grained gray granite crossed by dark folded stripes.(sample I).

2).thin bedded gray gneiss crossed by big quartz veins containing a little pyrite (sample 2)

3).white aplite followed by dark striped rock (sample 3)

4). thin bedded gray gneiss crossed by quartz veins containing big crystals of pyrite.

The series of samples (a,b,c,d,e,f,g.) proceeded from a old surficial investigation for molybdenite. It shows also a succession of granites, gneiss, aplites and dark striped rocks, crossed by many quartz veins.
These successions are visible on the South of Bergeheie and in Avedal-valley. The outcrop 2IO shows a gray gneiss with few pink aplitic beds parallel with the foliation cutt by a big vertical quartz vein; it proves right that the quartz vein is later than the aplitic beds consecutive to the granitization of gneiss.

Microscopical study.

I). Vardefj area. (samples 24I, 235.)

Sample 24I.: light gray granite containing: quartz ,prevailing microcline, a little oligoclase, much biotite partly altered into chlorite or felspar with magnetite.

Sample 235.: dark gray granite, containing: quartz, microcline and a little oligoclase; biotite accompained by green hornblend partly altered into chlorite, biotite and epidote.

II). Slettheie area. (samples II3, I76, series a,b,c,d,e,f,g.)

Sample I76; dark porphyric granite with big white felspars. It contains: quartz, prevailing microcline, oligoclase, frequent micropegmatitic association, many biotite often altered into chlorite and magnetite.

Series II3; the first sample contains: quartz, many oligoclase, with micropegmatitic association, rare biotite, a great amount of magnetite and titanomagnetite often altered into sphene.

thesecond, similar to the typic gray gneiss, contains: quartz, many oligoclase, a little microcline, green brown biotite, many magnetite crystals.

the third ,dark granite crossed by dark stripes, contains: quartz ,oligoclase, and many pyroxenes: bronzite and chiefly augite partly altered into biotite, chlorite, epidote, sphene, magnetite.

Series a,b,c,d,e,f,g.

The samples (a,b,c.) correspond with a light gray granite turning into aplite. They contain: a puzzle of quartz crysta ,oligoclase and microcline ,with micropegmatitic association rather rare green brown biotite, a little cordierite, pyrite, and magnetite.

The following samples (d,e,f,g.) have been taken in gray granite crossed by dark folded streaks.

The prevailing felspar is allways the oligoclase.Biotite is accompained by many crystals of green hornblend,which is often altered into biotite ,chlorite,epidote, sphene, and magnetite.
In the sample d,biotite and green hornblend are accompained by augite altered into a kind of green hornblend(ouralite.) Magnetite is accompained by titanomagnetite altered into sphene and contain little inclusions of pyrite.

III.) Avedal-valley area.

(Samples 204, 209, 210 .)

Sample 204. Tiny grained pink granite containing:a great amount of quartz, microcline and oligoclase,with micropegmatitic association, rather rare biotite partly altered into chlorite,felspar, and magnetite.

Samples 209. The first sample is a pink porphyric granite with quartz, microcline,a little oligoclase ,rather rare biotite,a little cordierite.

The second is the same porphyric granite crossed by dark folded stripes.It contains : quartz,microcline,a little myrmekite,much oligoclase,a great amount of biotite and green hornblend,big crystals of sphene.

The third is a dark gneiss containing :quartz,oligoclase, a little microcline,biotite,a little cordierite,many big crystals of sphene and zircon.

Samples 210. The first sample is a gray pink granite with quartz, oligoclase and microcline,green hornblend enclosing apatite,altered into biotite,chlorite,epidote,magnetite:a little cordierite.

The second is a very dark rock crossed by little lenticular aplitic beds.It contains: quartz, oligoclase,a great amount of dark minerals:
- bronzite altered into a kind of serpentine and into ouralite.
- green hornblend altered into chlorite,magnetite,sphene.

Shortly: These rocks have a variable mineralogical composition,now like the typic calcopotassic granite,now like the typic calcosodic gneiss,now intermediate.
The dark streaked rocks with quartz,oligoclase,biotite,hornblend,and pyroxenes,are very frequent.

THE CONTACT GRANITES- GNEISS.

This contact is observed easily in the following areas:

I). Raudtoknuten.

A cloudylike aplite crossed by dark folded stripes lies between the gray dark many folded gneiss, and the pink porphyric granite. This transition-rock takes place within a width of 100m.

II). Oksendal area.

The transition is clearly visible on the side of the cliff overhanganging the village. It consists of pink granite crossed by many dark stripes, which turns gradually into a tiny bedded gray gneiss.

III). Oftedal area.

The contact is situated on the side of the cliff overhanging the road of Haughom.
The foot of the cliff consists of granite with dip Eastwards; the upper part consits of tiny bedded gay gneiss with regular dip Eastwards.
The contact is marked by a little ledge hidden by vegetation.

IV). Around the Slettheie, and on the South of Haughom, the transition is similar.

Briefly, along the contact granites-gneiss, the transition is allways progressive. It consists chiefly of cloudy-like aplitic formations.
The granitic and gneissose formations have the same dip Eastwards. Indeed, the boundary-line makes a bend Eastwards, when it cuts the Avedal-valley.

SYNTHESIS OF FORMER PETROGRAPHIC STUDIES.

I°). Comparrison of granites and gneiss.

The former studies have disclosed the essential petrographic characters of the formations:

calcopotassic granite with prevailing microcline and oligoclase and biotite.

calcosodic gneiss with oligoclase, biotite, and silicates of metamorphism

The microscopical study shows clearly that the transition, in the point of view of mineralogical composition and the appearance, is gradual, between the typical gray gneiss(70,76) and the typical granites (A,B,C,), as shown by the samples I94, II3, I70, found about the boundary line.

II°). Comparrison of the granites enclosed in the gneiss.

The microscopical study points out that these granites have a variable mineralogical composition, i.e. allways biotite, sometimes oligoclase like the gneiss, sometimes prevailing microcline and a little oligoclase like the granites of Sirdalvatn.
The principal difference is the presence of green hornblend and the greater frequence of cordierite.

III°). Comparative study of the dark striped rocks in the granites.

These appearances are very frequent a mid the granites, alongside the Sirdalvatn, about the boundary line granites - gneiss; and also a mid the granites enclosed in the gneissose formation.
The microscopical study shows that the mineralogical composition of these rocks is very different from that of the granites and the gneiss. Indeed, microcline disappears gradually and is replaced by oligoclase, meanwhile green hornblend appears, allways accompanied with much biotite and sometimes with pyroxenes: augite and bronzite.

The dark minerals are often altered into various modifications:

I). The orthorhombic pyroxenes (bronzite) are altered into serpentine or sometimes ouralite.

II). The clinorhombic pyroxenes (augite) are changed into biotite chlorite, with magnetite and epidote or into ouralite.

III). Green hornblend is altered into biotite and chlorite with magnetite, sphene, epidote;

These chemical transformations are corresponding with a more complex alteration than that which is owed to weathering, and are certainly connected with the geological history of these rocks.

The usual alterations owed to weathering are:

alteration of the biotite into chlorite with magnetite or into felspars with magnetite.

alteration of sodico-calcic felspars into mica damourite and sometimes chlorite, of potassic felspars into kaolin and chlorite.

INTERPRETATION.

I have pointed out that the border of the granitic formation of the Sirdalvatn is marked by great transformations of the appearances of the gneiss.

To explain that, I have refered to different works of J. Sederholm and C. Wegman about the Precambrian of South -Finland and to works of Mrs. Roques and Demay about the Precambrian of Montagne-Noire on the South of Central Plateau of France.

Sederholm names "migmatites" the rocks, often already metamorphic, which are mixed with a granitic or aplitic or pegmatitic magma.

He distinguishes allways in these migmatites:

- the woof which is the remain of the original rock
- the "ichor" which is imbibing the woof.

The percentage of ichor is allways high: 50 to 80%.

On the average, the mineralogical composition is the same as this of a calco-alcalin (monzonitic) granite with oligoclase or andesine microcline, biotite frequently accompanied with amphiboles and pyroxene; the association of quartz and felspars are frequent: graphic micropegmatite, and chiefly myrmekite, which consists of small intricated threads of quartz amid crystals of felspars.

The great amount of cordierite and garnet almandin is characteristic for these migmatites.

In the countries where the migmatites take up large surfaces (Finland, South Norway, South of Central Plateau in France) a whole series is found going from gneiss and micaschistes (ectinites) to the deep aboriginal granite. It consits of:

I) embrechites: eye and striped gneiss with regular foliation.

II) anatexites: injected gneiss with undulated beds these foldings becomes marked and irregular (synmigmatitic foldings)

These injected gneiss are followed by leptynites
and nebulites (cloudylike aplitic rocks).
The anatexites contain granites of anatexy which
have a same composition as gneiss.

III). The cloudylike aplites and leptynites are turning
gradually into the deep aboriginal granite.

In the Knaben and Sirdalvatn areas, the granitic magma has risen along the planes of foliation of the gneiss whose dip is allways going eastwards. Further, this granite is sliced and its benches have the same dip as the gneiss. This kind of bearing is named "lacolithe".

In the Knaben area the transition between gneiss and granite has a limited width. The gneissose granites, leptynites, with dark stripes and cloudylike aplites represent the anatexites, and eye-gneiss, the embrechites.

In the Sirdalvatn area, the zone of anatexy has on average 3km width and a parallel direction with the granitic streak of Sirdalvatn.

The mineralogical composition has the same characters as these before pointed out by Sederholm, Roques, etc.:

The felspars are allways numerous :microcline, plagioclases similar to the typical oligoclase, but little more calcic; I have pointed out already the great frequency of the micropegmatitic associations and myrmekite .

The dark minerals are essentially :biotite, green hornblend, pyroxenes.

The cordierite is rather frequent, but the garnets are more rare.

The appearances are also similar to the descriptions of the Finish, Swiss, and French geologists: injected folded gneiss, leptynites, cloudylike aplites, granites enclosed in the anatexites etc. But as far as I have gone Eastwards ,I have never seen the eye-embrechites between the anatexites and the typical gray gneiss.

The Finish and French geologists think that these synmigmatitic foldings have been produced when the gneiss were still sticky during the raising of granites through them.

The aplitic or pegmatitic ichor has been injected through the gneissose formation along the planes of foliation.

The cloudylike appearances are probably owed to the streams ,perhaps through convection, a mid the melted rocks.

Mr Roques describes rocks with dark folded stripes, similar to these of the Sirdalvatn area ,a mid the migmatitic formations of Montagne Noire in France, but he does not explain why.

I have shown that the pyroxenes and amphiboles are entirely lacking in the typical granites, and I did not seen these minerals in the typical gneiss.

They are only observed in the dark stripes crossing the granites or the aplites in a parallel direction with the foliation of gneiss.

I think that ,during the granitization of gneiss, an aplitic ichor rich in felspars has been injected through the beds of basic rocks rich in amphiboles and pyroxenes.

These aplitic injections have had as result, the great enrichment in alcalin and calco-alcalin felspars and also the alteration of pyroxenes in ouralite, and of hornblend into biotite and chlorite.

This explanation would be satisfactory, if I had found a mid the typical gneiss, beds of amphibolitic rocks. But the thin sections of gneiss contain no amphiboles nor pyroxenes and further more ,on the outcrops, it is very difficult to distinguish easily the amphibolitic

beds from the dark tiny bedded gneiss.
However, I remind that, on the South of Knaben-gruver, several lenticular streaks or veins of amphibolites are enclosed a mid the granitic formation. Perhaps, these rocks existed a mid the gneiss before the granitization, and as usual for the amphibolites, their alteration has been slight.

STUDY OF MINERALIZATION.

Alongside the Sirdalvatn, as in the Knaben area, the mineralization is closely connected with the granitization of gneiss.
In the granitic formation of Sirdalvatn, contrary to the Knaben area the quartz and pegmatitic veins are rare, and the mineralization is allmost entirely lacking.
I point out however, the numerous big crystals of magnetite and also the titanomagnetite with inclusions of pyrite, probably aboriginal, visible in microscope. Further, in granite around Oftedal, the magnetite enclosed in rock, is easily visible with naked eye:
There is perhaps, a little molybdenite, but it is impossible to distinguish it from magnetite without metallographic microscope.
These minerals were contained originally in the magma before the solidification, but they have remained scattered in the rocks.
The mineralization is allways connected closely with quartzose and pegmatitic formations alongside the contact granites-gneiss in the zone of anatexy
The quartzose formations appears under two aspects:

I). Crust of cristallized quartz on the surface of anatexites, and masses of quartz a mid the folded beds of these rocks.

II). Straight white milked quartz veins cutting anatexites and also the quartz crusts.

These quartz veins are very often connected with pegmatitic veins which are allways bearing numerous masses of pure quartz.
The mineralization consists of masses of magnetite, and sulphides as molybdenite, pyrite, and chalcopyrite, filling hollows in quartz veins and anatexites or aplites.

MAGNETITE.

This oxide lies in little cristallized masses with cubic or octaedric shape. These crystals are sometimes altered into red hematite. Magnetite is chiefly enclosed in the quartz crusts on the surface of anatexites and in pegmatitic masses or veins.
I found this oxide in four areas:

on the South of Bergeheie and along the Kleivann,

on the South-East of Stakkhomfjeld,

on the North-East of Avedàl,

on the North of Slettheie.

Nowhere is the magnetite connected with the quartz veins,nor associated with the sulphides.

SULPHIDES.

Pyrite and chalcopyrite are allways enclosed in little hollows of quartz veins and never in pegmatitic veins.
Pyrite is more numerous than chalcopyrite.On account of their dispersion,these latter minerals are without economical importance;

Molybdenite.

Lang years ago,many surficial investigations have been tried over Avedal and also on the South of the Bergeheie,where the mineralization appears rather expanded on the surface.
The ore lies in hollows of quartz veins and fills numerous little fissures of rock,sometimes in pegmatitic veins ,but never in connexion with the crusts of quartz.
The mineralization is interesting only in the complex of anatexy constituted by folded gneiss,aplites and granites;outside these areas molybdenite is very scattered.
I will point out two interesting outcrops:

N° 73.(South of Vardefj): a big pegmatitic vein crosses the gray tiny bedded gneiss;it contains numerous masses of pure quartz and ends by a big quartz vein.

Molybdenite is very frequent in the hollows of the masses and of the quartz vein.
It is more scattered in pegmatite and also in fissures of the surrounding gneiss.

N° 173.(North of Raudtoknuten); molybdenite is scattered a mid a dark gneiss rich in ferromagnesian minerals while in the Knaben area, molybdenite is never connected with the rocks rich in dark minerals.

Shortly;the mineralized points are distributed irregularly on a streak of 3km width along the contact granites-gneiss and are allmost,lacking in the granitic formation.
It is likely that the mineralization of Sirdalvatn area extends more to South of Oftedal.I could not make sure of that for lack of time.
It appears that the mineralization of this area is less important and more scattered than that of Knaben area.
To get a more exact opinion about the percentage of molybdenite,it would be necessary to continue the old surficial investigations alongside the contact granites-gneiss from North to South chiefly in the anatexites.

However, even if the percentage is interesting for being operated, it would be impeded by the great difficulty of access resulting of the height of the cliffs.

INTERPRETATION.

The study on all the deposits of molybdenite discloses that they are allways connected with an intrusion of acid magma, either in sedimentary formations or in series of metamorphic rocks.
There are essentially two kinds of deposits:

I) Contact deposit (pyrometasomatic type) on the border of the granitic intrusions or in the granit it self.

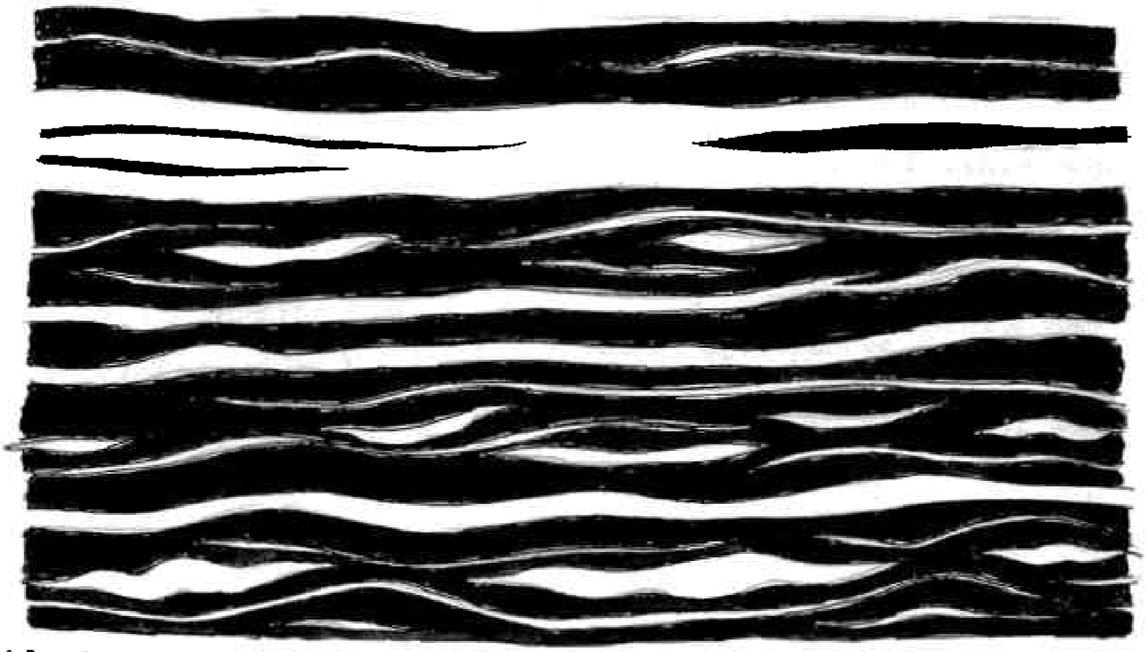
II). Pneumatolitic deposits (pegmatitic veins) where molybdenite is connected with wolframite and cassiterite and minerals bearing Fluorin and Lithium as tourmaline, lepidolite.
Rarely in hydrothermal deposits (quartz veins) where molybdenite is accompainied with pyrite and other sulphides

The two deposits of Knaben area and Sirdalvatn area are connected with a granitic lacolith raising through a great formation of gray gneiss.
I remind that at Knaben, only the intruded granites are mineralized by sulphides without magnetite, and on the contrary, in the Sirdalvatn area, the mineralization consists of magnetite and sulphides only localized in the contact zone.
In his publication "Magmas and igneous ore deposits" (Economic Geolgy May 1926) Mr J.H. Vogt etablishes a classification of Sn, W, Mo, deposits. He cites some deposits of Telemark connected with precambrian granites and allways free of cassiterite and wolframite, bearing molybdenite accompainied with a feeble percentage of pyrite and chalcopyrite.
This description corresponds exactly with the two deposits of Knaben and Sirdalvatn.
It is likely that molybdenite and pyrite and magnetite were already originally in the intruded magma. According to Mr Vogt, the average percentage of molybdenite in granitic magma is 0,0001%.
Further, many little inclusions of original magnetite, pyrite and perhaps molybdenite are clearly visible in the microscopical examination.
Lindgren and Vogt think that these minerals have been extracted from magma by Fluorin, Chlorin, or Sulphur to form volatile compound which have a low boiling and critical point.
I believe that Fluorin did not play a part in this reactions, because I never found fluor-bearing minerals like tourmaline in the pegmatites

It is possible to distinguish several periodes during the solidification of the intruded granitic magma.
The usual constituants of granite,quartz,felspars,micas are cristallizing at first.Then, the constituants of pegmatites are cristallizing from gazeous compounds (pneumatolitic periode) with graphic association of quartz and felspars.
Finally,happens the hydrothermal periode with the filling by quartz of fissures,which are crossing the granites and the surrounding rocks Larsen and Wright have poited out that quartz connected with felspars in graphic association is the allotropic kind quartz β cristallizing at 600 or 700°,while the quartz of masses enclosed in pegmatitic vein is the kind quartz α cristallizing at lower temperature about 500°.
That proves that the quartz veins and quartz masses have come later than the pegmatitic veins.
Lindgren has shown clearly that it is magnetite which crystallises more often first at high temperature,and that the sulphides come only after in following order: pyrite,mispickel,chalcopyrite.
I remind that in Sirdalvatn area,magnetite appears chiefly in the crusts of quartz on the surface of the anatexites and sometimes in pegmatitic veins,never connected with other sulphides.
Its crystallization has happened during the first periode (solidifisation of anatexites) and overlaps also on the second periode (pneumatolitic periode)
Lindgren points out that molybdenite crystallizes in various periodes according to the deposits.
In Sirdalvatn area,molybdenite appears in pegmatitic vens but chiefly in the hollows of quartz veins and the fissures of rock in the vicinity of these veins.Its crystallization has happened during the second periode (pneumatolitis periode) and chiefly during the third (hydrothermal periode).
The other sulphides,pyrite and chalcopyrite are found only in quartz veins and sometimes in impregnation amid the surrounding rocks.
Their crystallization has happened only during the third periode.
The following table condenses the priceding results which give a likely interpretation of all my observations.

magnetite ↕	I. Crystallization of granitic magma (quartz crusts)
molybdenite ↕	II. Pneumatolitic periode (pegmatitic veins)
pyrite, chalcopyrite ↕	III. Hydrothermal periode (quartz veins and masses)

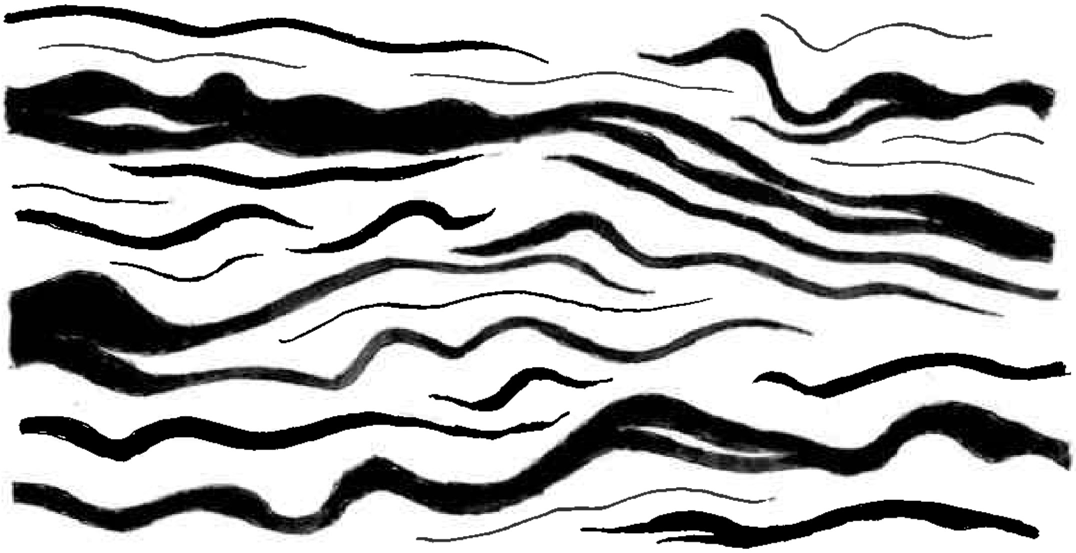
INJECTED AMPHIBOLITES OF TONSTADT ROAD.



black:amphibolitic beds.
white:aplitic beds.

Scale: 1 m

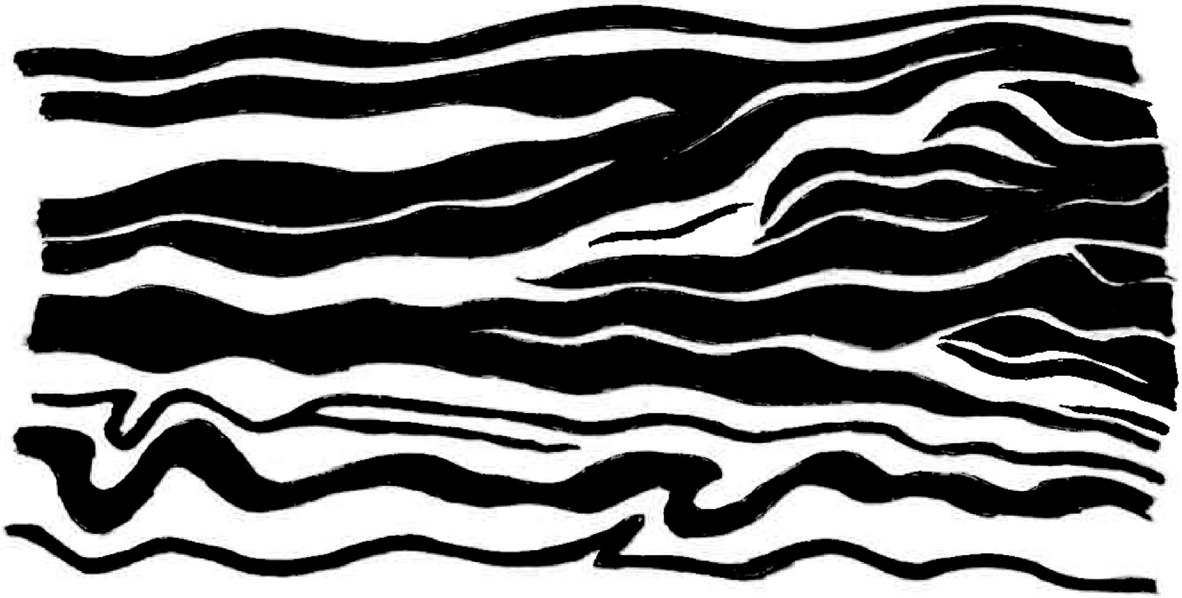
INJECTED AMPHIBOLITES OF TONSTADT ROAD



black: amphibolitic beds
white: aplitic beds

Scale: 1 m

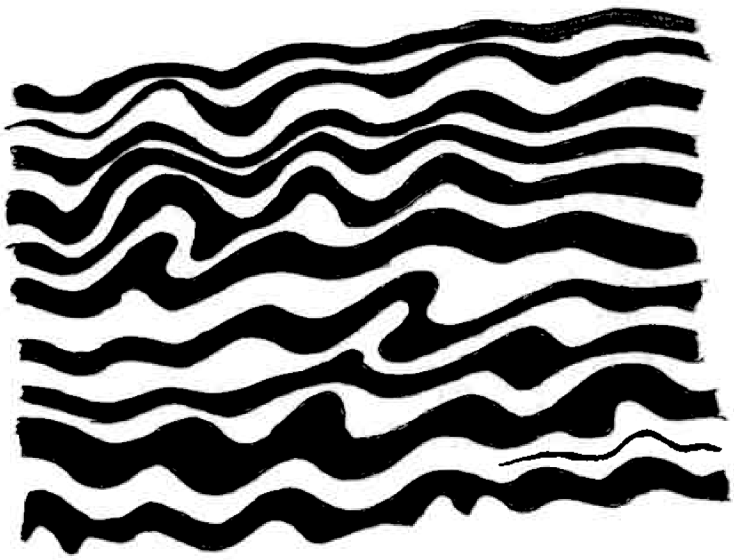
INJECTED AMPHIBOLITES OF TONSTADT ROAD.



black:amphibolitic beds.
white:aplitic beds.

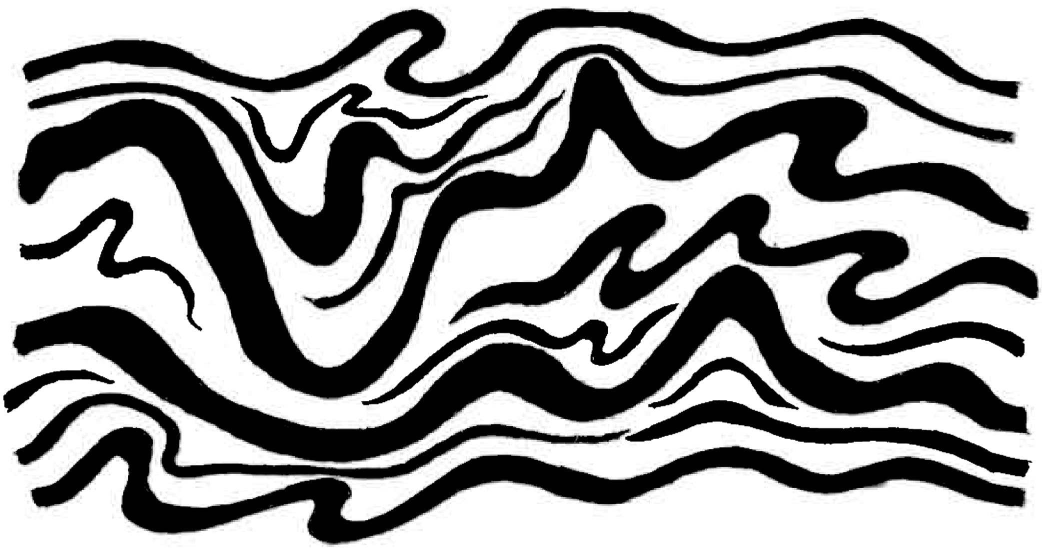
Scale: 1 m

INJECTED GNEISS OF SLETTHEIE.



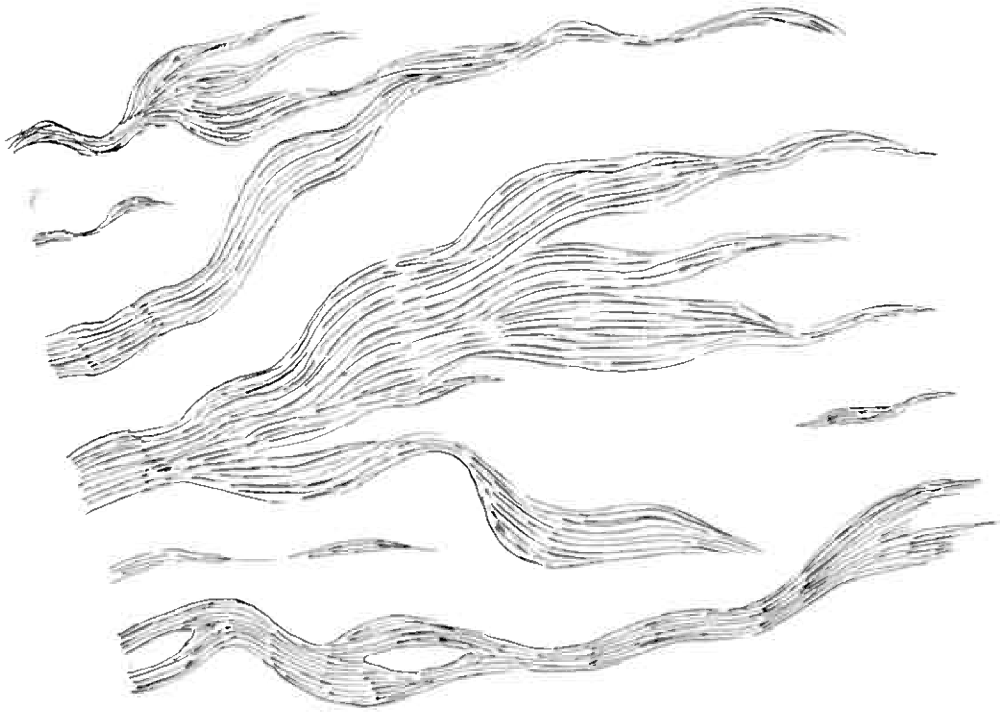
Scale: 20 cm

INJECTED GNEISS OF SLETTHEIE.



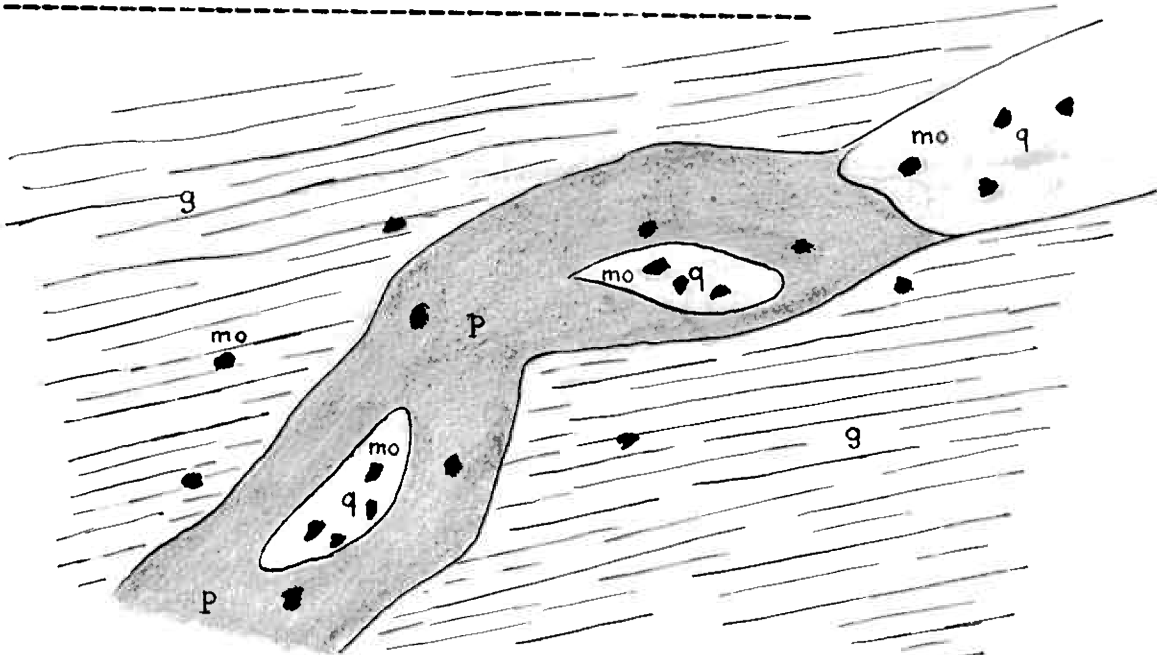
Scale: 20 cm

NEBULITE OF STAKKHOMFJELLE.



Scale: 1 m

PEGMATITE VEIN (outcrop Nº 73.) STOREHEIE.



p: pegmatite.
q: quartz.
g: gneiss
mo: molybdenite.

Scale: 50 cm

GEOLOGICAL MAP OF THE SIRDALSVATN AREA.

Scale I/50000.

- typical granite
- granite of anatexy
- injected amphibolites
- typical gneiss
- anatexites: folded gneiss

Mineralization.

- ● molybdenite
- ■ magnetite

RESULT OF MICROSCOPICAL EXAMINATION OF SAMPLES

WITH POLARIZING LIGHT

In all this study, the plagioclasic felspars have been deter minated according to the method of French mineralogist A.M. Levy on the sections perpendicular to the crystallographic direction g1.

All the drawings are executed from the examination with the polarizing light with magnifying 20.

I°. GRANITES OF SIRDALVATN.

SAMPLES A, B, C, I70.

SAMPLE A.

Light gray granite with big white felspars.
It contains:
many xenomorph quartz crystals.
prevailing microcline.
oligoclase often altered into damourite (a kind of white mica).
micropegmatitic association and myrmekite.
rather numerous crystals of biotite often altered into felspars or chlorite and magnetite along the cleavages.
big crystals of magnetite enclosing pyrite.
titanomagnetite altered into sphene.
epidote, apatite.

SAMPLE B.

Light gray tiny grained granite.
It contains:
xenomorph crystals of quartz.
prevailing microcline.
a little oligoclase.
micropegmatite and myrmekite.
rather numerous brown biotite enclosing zircons.
a very little muscovite.
big crystals of magnetite altered into red hematite and enclosing pyrite
titanomagnetite altered into sphene.
apatite and big scattered crystals of zircon.

SAMPLE C.

Light gray granite with a few little beds of mica.
It contains:
many xenomorph quartz crystals.
prevailing microcline with sometimes Carlsbad twin.
a little oligoclase.
brown biotite enclosing zircons, often altered into chlorite.
a little cordierite.
magnetite enclosing pyrite.
apatite.

SAMPLE I70.

Light gray granite allmost aplitic. It contains:
numerous quartz crystals.
prevailing microcline, myrmekite.
rather rare biotite chloritized or partly altered into felspars and magnetite.

INJECTED AMPHIBOLITES OF TOMSTADT ROAD.

SAMPLES D,E,F,G,H,I,J,K.

SAMPLE D.

The thin section shows a little aplitic bed crossing a dark rock.
The aplitic bed contains quartz and felspars oligoclase with microp. pegmatitic association and myrmekite.
The dark part contains:
quartz
oligoclase.
a little biotite often altered into chlorite and magnetite.
big numerous crystals of green hornblend (twin h1) altered into biotite,chlorite,magnetite,sphene and epidote.
many crystals of magnetite enclosing pyrite.
scattered crystals of zircon,apatite included in hornblend.

SAMPLE E.

Alternacy of dark and aplitic beds with big eyes of felspars.
The sample EI(dark bed)contains:
quartz
prevailing oligoclase.
a little microcline.
myrmekite and micropegmatitic association.
a little biotite.
numerous crystals of green hornblend (twin h1)altered into biotite and sphene.
magnetite enclosing pyrite.
titanomagnetite altered into sphene/
apatite/
The sample E2 (aplitic bed) contains:
quartz.
oligoclase often altered into damourite ,microcline
myrmekite and micropegmatite.
a little magnetite and red hematite.

SAMPLE F.

Light gray granite crossed by little lenticular dark beds enclosin big eyes of felspars.
It contains: quartz ,prevailing oligoclase ,microcline.
myrmekite and micropegmatite.
brown biotite enclosing zircons.
green hornblend (twin h1).
apatite,big crystals of zircon,sphene.

SAMPLE G.

Succession of tiny dark beds and light aplitic beds.
It contains:
quartz .
prevailing oligoclase,microcline.
myrmekite and micropegmatite.
big crystals of green hornblend (twin h1) often altered into biotite,chlorite,magnetite,sphene.
biotite altered into chlorite,magnetite,felspars.
a little cordierite.
magnetite enclosing pyrite.
titanomagnetite altered into sphene.

SAMPLE H.

Dark rock with thin aplitic beds.
It contains:
quartz.
much oligoclase.
much green hornblend altered into biotite,chlorite,sphene.
biotite.
apatite included in hornblend.
magnetite, titanomagnetite.
big crystals of sphene.

SAMPLE I.

Dark rock crossed by irregular wide aplitic beds.
It contains:
quartz.
oligoclase.
much biotite enclosing zircons.
green hornblend with twin hI and alteration in biotite and sphene.
a little cordierite.
many big crystals of magnetite,titanomagnetite altered into sphene.

SAMPLE J.

Light gray rock with irregular dark beds.
It contains:
quartz and oligoclase.
much biotite partly altered into chlorite,felspars and magnetite.
green hornblend enclosing apatite and altered into biotite,chlorite and epidote.
magnetite and titanomagnetite.

SAMPLE K.

Allmost entirely dark rock with little lenticular aplitic beds.
It contains:
quartz.
much oligoclase.
myrmekite and micro-pegmatite.
many pyroxenes: bronzite.
augite often altered into biotite and chlorite.
many big crystals of magnetite and titanomagnetite.

III°. TYPICAL GNEISS.

SAMPLES 76,70,I94,II3 ,209c.

SAMPLE 76.

Thin bedded gray gneiss containing numerous red garnets.
The bedding is not visible in the microscope.
It contains:
numerous xenomorph quartz crystals.
much oligoclase.
much biotite often altered into chlorite along the cleavages.
numerous big crystaks of garnet almandin enclosing little quartz crystals.
a little cordierite.
rare magnetite,epidote.

SAMPLE 70.

Thin bedded gray gneiss.
It contains:
puzzle of little quartz crystals.
much oligoclase.
numerous crystals of biotite parallel with the bedding.
a little cordierite.
a little magnetite.
apatite.

SAMPLE I94.

Thin bedded dark gneiss.
The bedding is clearly visible in the microscope.
It contains:
puzzle of little quartz crystals.
prevailing oligoclase often damouritized, a little microcline.
frequent micropegmatitic associations and myrmekite.
biotite often altered into chlorite and felspars.
magnetite.
I point out two beds of stringy biotite enclosing a puzzle of little quartz crystals with magnetite.The felspars are entirely lacking. That is like to a fragment of micaschist a mid the gneiss.

SAMPLE II3.

Thin bedded gray gneiss.
It contains:
quartz.
much oligoclase ,a little microcline.
myrmekite and micropegmatite.
green brown biotite partly chloritized or altered into felspars and magnetite.

much magnetite altered into red hematite.
epidote sphene.

SAMPLE 209c.

Dark folded gneiss.
It contains:
quartz.
much oligoclase,a little,microcline.
myr mekite and micropegmatite.
brown green biotite enclosing big crystals of zircon,and altered into chlorite along the cleavages or into felspars.
a little cordierite.
a little titanomagnetite altered into sphene and red hematite.
big scattered crystals of zircon.

IV. GRANITES OF ANATEXY ENCLOSED IN THE GNEISS.

SAMPLES a,b,c,d,e,f,g, 204 ,235, 24I ,I76 ,II3$_1$,II3$_2$;209a,209b,210a

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SAMPLE a.

Tiny grained gray granite.
It contains:
numerous quartz crystals.
much oligoclase;
a little microcline.
myrmekite and micropegmatite.
green brown biotite partly altered into felspars.
a little cordierite.
rare magnetite,a little sphene.

SAMPLE b.

Light gray ganite allmost aplitic.
It contains:
quartz.;
much microcline.
myrmekite and micropegmatite.
many crystals of biotite enclosing zircons.
a little codierite.
magnetite enclosing pyrite partly altered into red hematite.
titanomagnetite altered into sphene.

SAMPLES c.

Light gray tiny grained granite.
quartz.
much oligoclase,a little microcline.
myrmekite and micropegmatite.
much biotite enclosing zircons.
a little cordierite.
much magnetite.
titano-magnetite altered into red hematite.and sphene.

SAMPLE g.

Light gray granite with scattered dark minerals.
It contains:
quartz.
oligoclase.
myrmekite and micropegmatite.
rare biotite enclosing zircons.
a little green hornblend.
a little magnetite.

SAMPLE d.

Gray granite crossed by dark stripes.
It contains:
a great amount of quartz.
oligoclase.
much green brown biotite enclosing big crystals of zircon. and often altered into chlorite and felspars.
big crystals of green hornblend enclosing crystals of apatite.
magnetite enclosing pyrite and altered into red hematite.
sphene.

SAMPLE e.

Very dark rock crossed by few aplitic beds.
It contains:
quartz.
oligoclase.
green hornblend.
pyroxenes: bronzite.
augite altered into ouralite and biotite with epidote.
big crystals of magnetite.
titanomagnetite altered into red hematite and sphene.

SAMPLE f.

Alternacy of dark and aplitic beds.
It contains:
oligoclase.
quartz.
biotite enclosing zircons.
green hornblend enclosing apatite and altered into biotite, epidote and sphene.
magnetite.

SAMPLE 235.

Gray granite with little irregular dark beds.
It contains:
quartz;
prevailing microcline .
a little oligoclase.
biotite enclosing zircons,altered into chlorite or felspars with magnetite.
green hornblend enclosing apatite,altered into biotite,chlorite,epidote.
Magnetite.
sphene.

SAMPLE 24I.

Light pink granite.
It contains:
quartz;
prevailing microcline (Carlsbad twin).
a little oligoclase.
myrmekite and micropegmatite.
biotite enclosing zircons,altered into chlorite or felspars with magntite
magnetite,titanomagnetite.
apatite ,sphene.

SAMPLE I76.

Dark porphyric granite with big white felspars.
It contains:
quartz.
microcline and oligoclase.
myrmekite on the border of the microcline crystals.
biotite enclosing zircons,often altered into chlorite,or felspars.
big crystals of magnetite.
titanomagnetite altered into sphene.
apatite,zircons.

SAMPLE 204.

Pink tiny grained granite.
It contains:
quartz.
microcline,oligoclase aalmost entirely damouritized.
micropegmatitic association.
biotite often chloritized or altered into felspars.
magnetite altered into red hematite,titanomagnetite:crystals with geometrical shape altered into sphene.

SAMPLE II3.a

Light gray granite crossed by rare dark folded stripes.
The light gray part contains :
quartz
oligoclase , rare myrmekite
chloritized and altered into felspars and magnetite biotite
magnetite, titano-magnétite altered into sphene
many scattered crystals of sphene

SAMPLE II3$_3$

dark rock, crossed by small white aplitic beds.
It contains :
quartz
oligoclase (albite and pericline twins)
pyroxenes: bronzite
augite, which is sometimes altered into biotite and chlorite

rare chloritized biotite
magnetite altered into red hematite
sphene.

SAMPLE 209 a:

Red porphyric granite with big pink felspars.
It contains :
quartz
microcline
rare oligoclase , myrmekite, micropegmatite
often chloritized biotite.
rare cordierite
magnetite, altered into sphene titano-magnetite
epidote

SAMPLE 209 b :

SAME GRANIte as the preceding, but crossed by many dark folded stripes

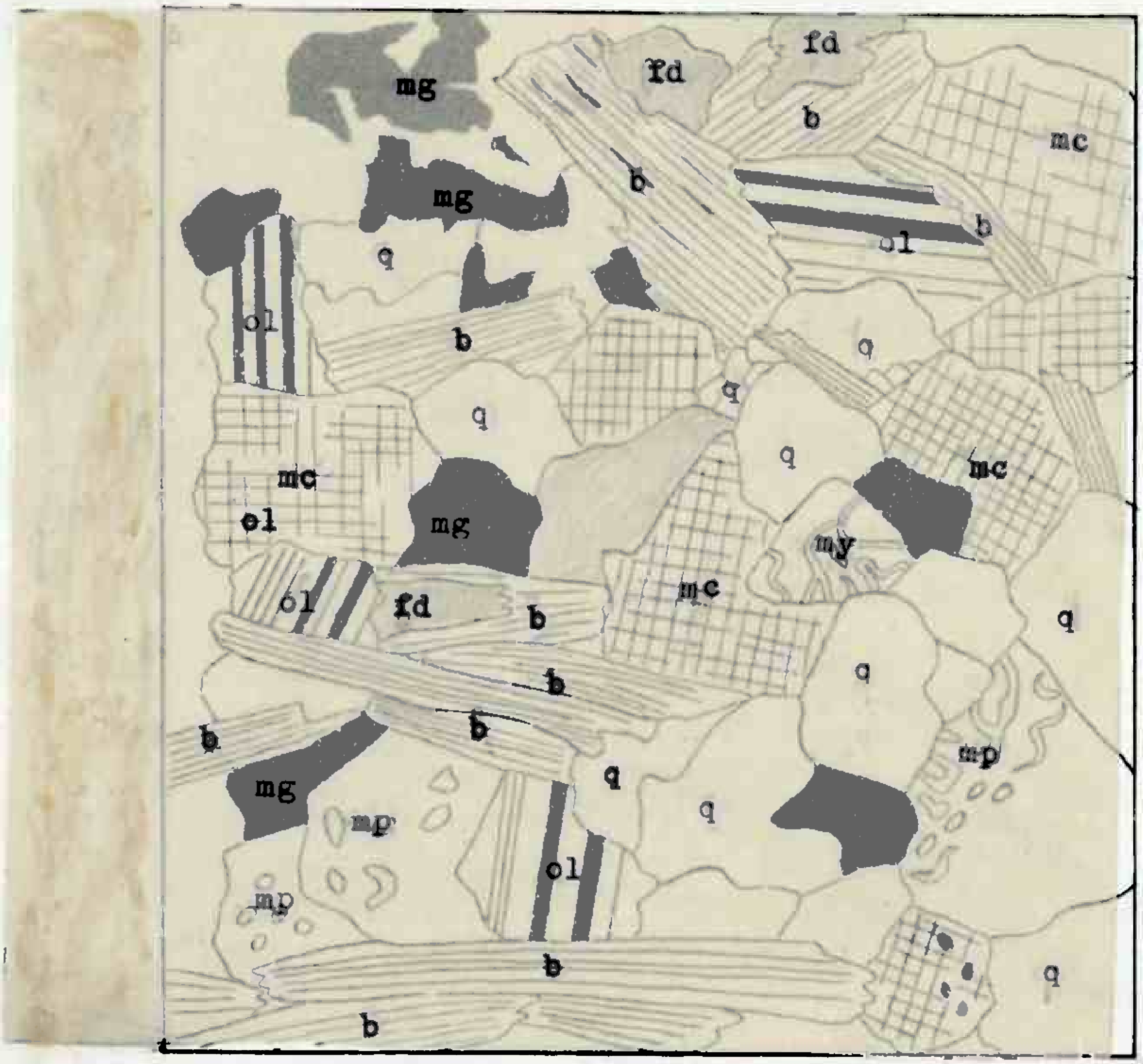
The dark streaks contain :
quartz
numerous crystals of oligoclase
frequent association : myrmekite and micropegmatite
many beds of biotite enclosing zircons
many beds of big crystals of green hornblend altered into chlorite and magnetite

many big crystals of titanomagnetite partly altered into sphene. The granite has the same mineralogical composition as the granite 209a.

SAMPLE 210a .

Light pink granite with little scattered masses of dark minerals.
It contains:
quartz.
oligoclase allmost entirely altered into damourite.
myrmekite and micropegmatite.
big crystals of green hornblend enclosing apatite and altered into epidote,sphene,magnetite,and chlorite.
biotite entirely altered into chlorite or felspars.
big crystals of magnetite.
titanomagnetite altered into sphene.

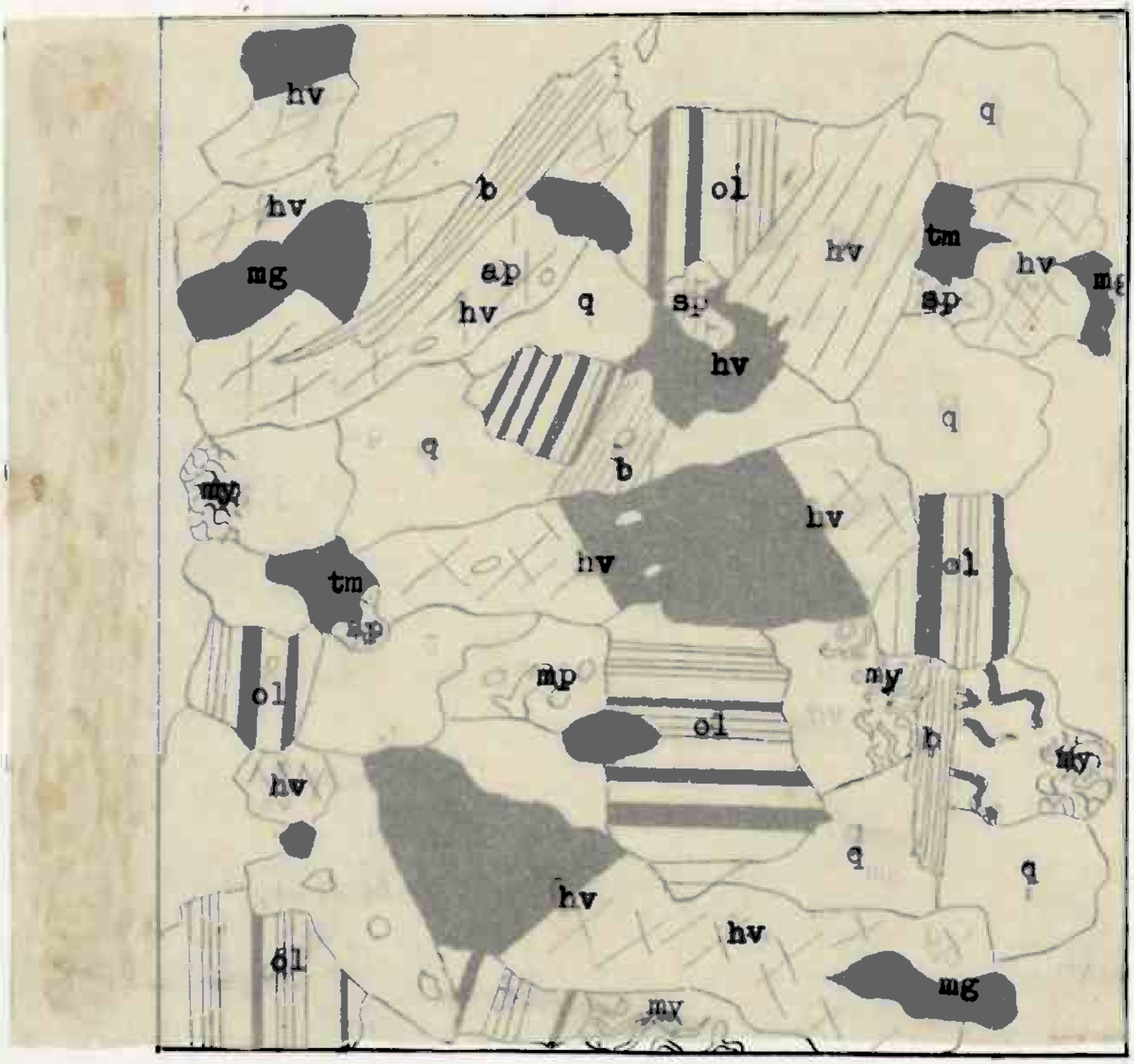
SAMPLE A .GRANITE OF SIRDALVATN.



q: quartz
fd: damouritized felspar
mi: microcline
ol: oligoclase
my: myrmekite

mp: micropegmatite
b: biotite
mg: magnetite
ep: epidote

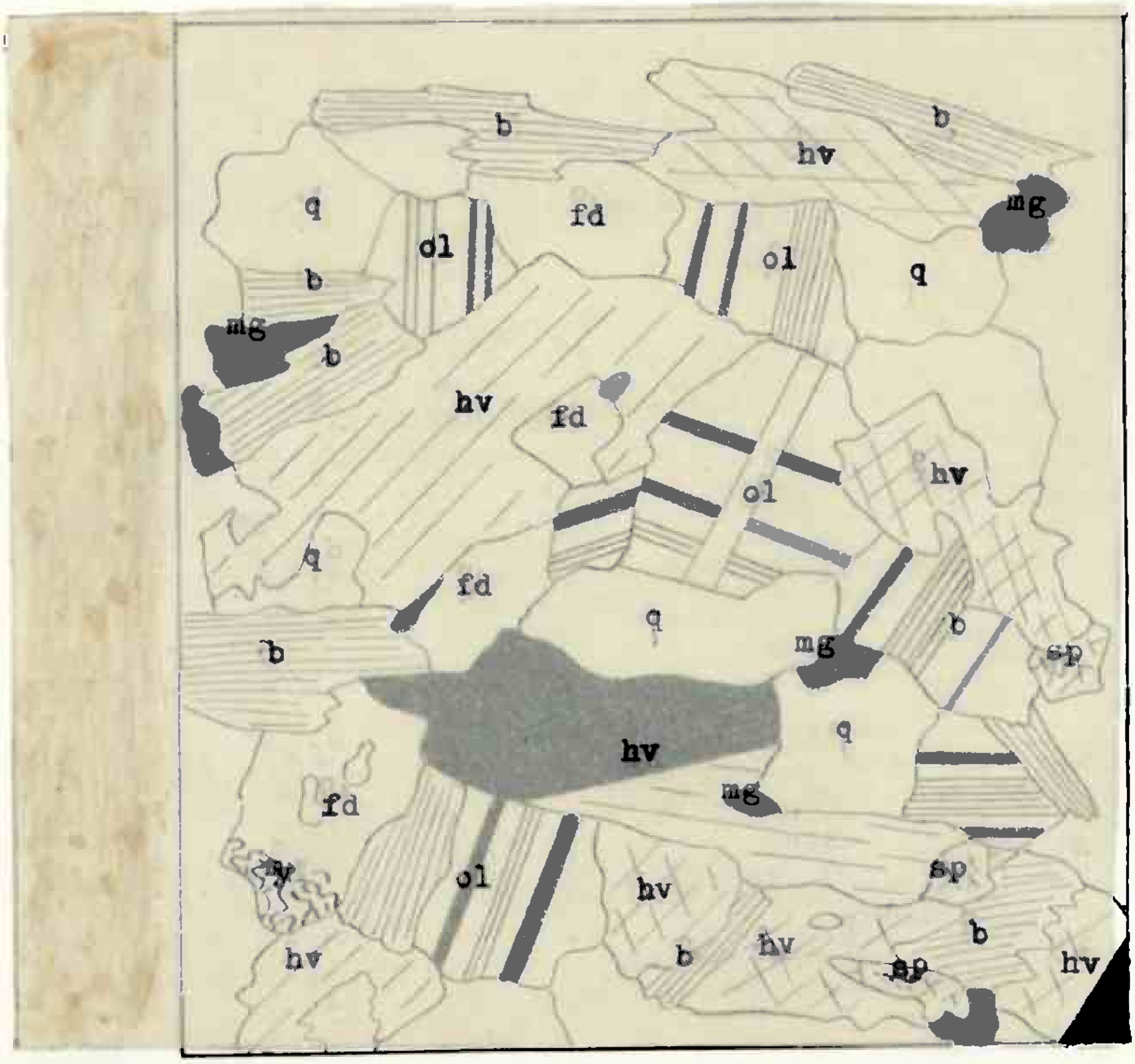
SAMPLE D.INJECTED AMPHIBOLITE OF TONSTADT ROAD.



q: quartz
fd: damouritized felspar
ol: oligoclase
my: myrmekite
b: biotite
hv: green hornblend

ap: apatite
zr: zircon
mg: magnetite
tm: titanomagnetite
sp: sphene

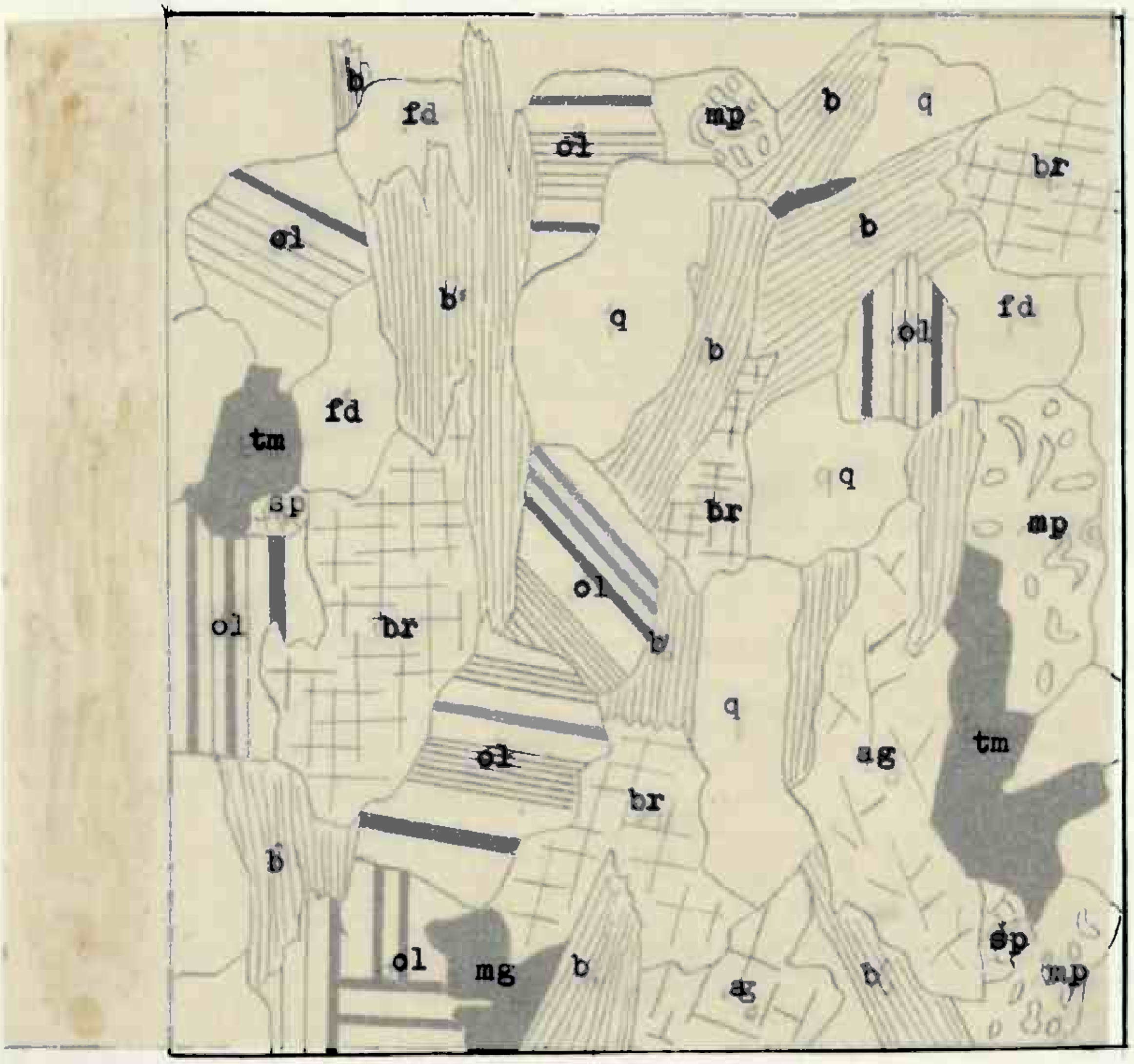
SAMPLE G. INJECTED AMPHIBOLITE OF TONSTADT ROAD.



q: quartz
ol: oligoclase
hv: green hornblend
mg: magnetite
ap: apatite

fd: damouritized felspar
my: myrmekite
b: biotite
sp: sphene

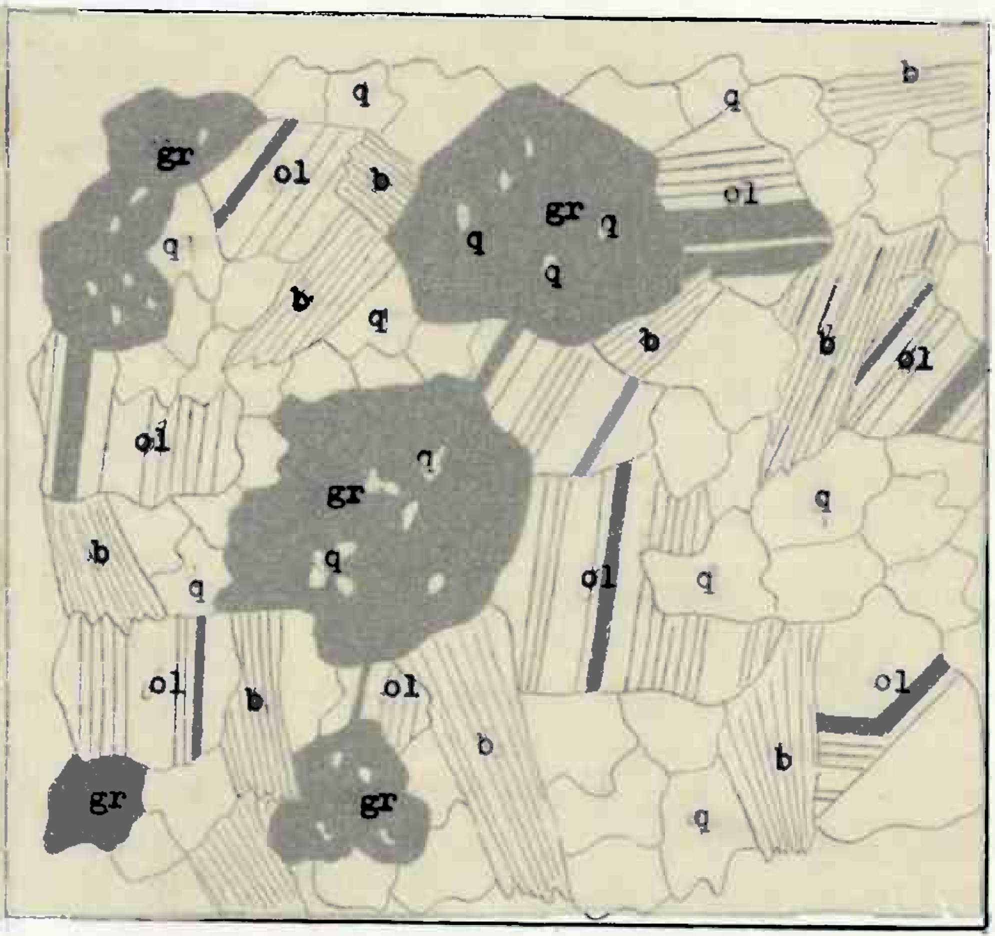
SAMPLE K. INJECTED AMPHIBOLITE OF TONSTADT ROAD.



q: quartz
ol: oligoclase
b: biotite
ag: augite
tm: titanomagnetite
ep: epidote

fd: damouritized felspar
mp: micropegmatite
br: bronzite
mg: magnetite
sp: sphene

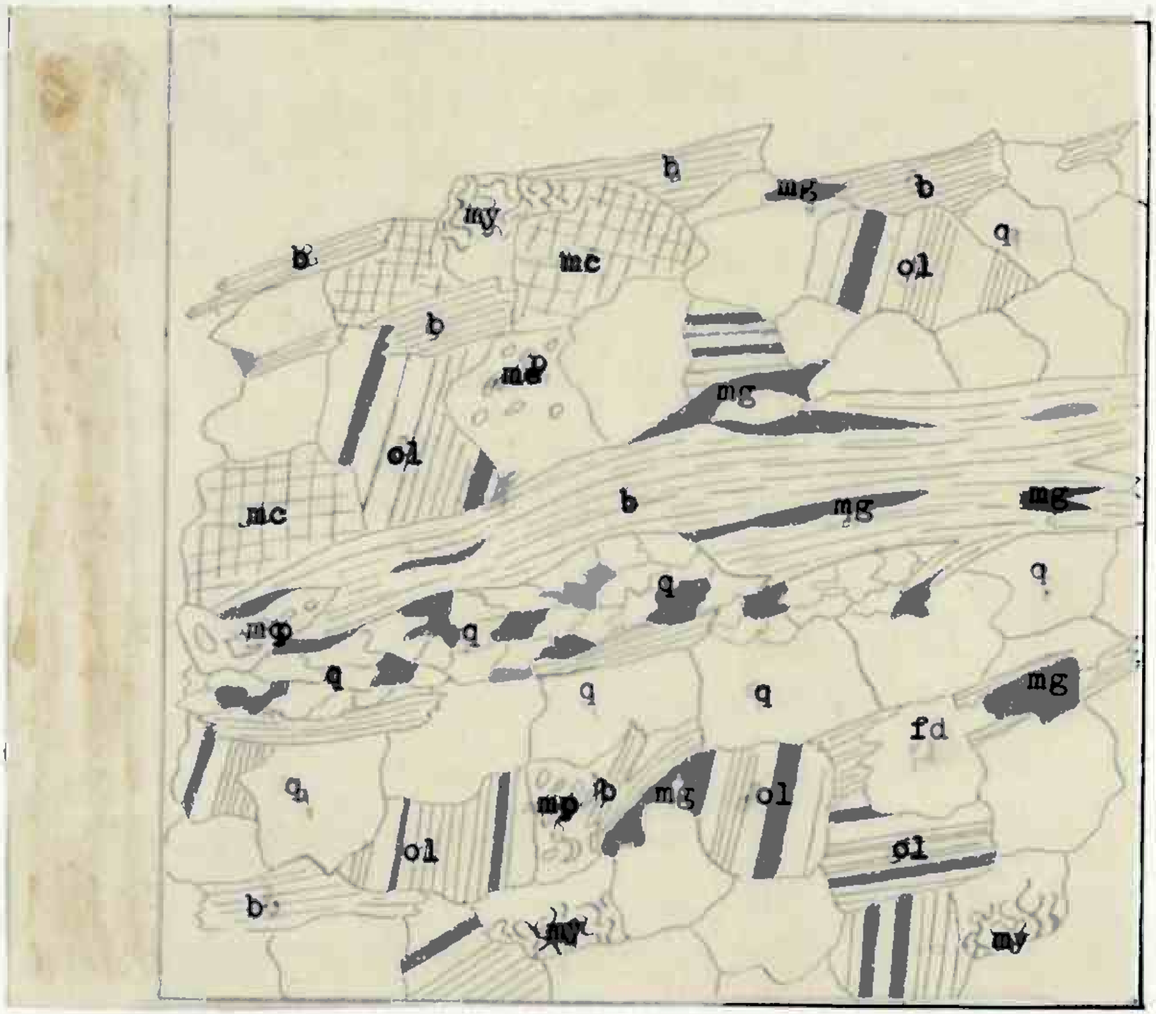
SAMPLE 76. TYPICAL GNEISS.



q: quartz
b: biotite
mg: magnetite

ol: oligoclase
gr: garnet

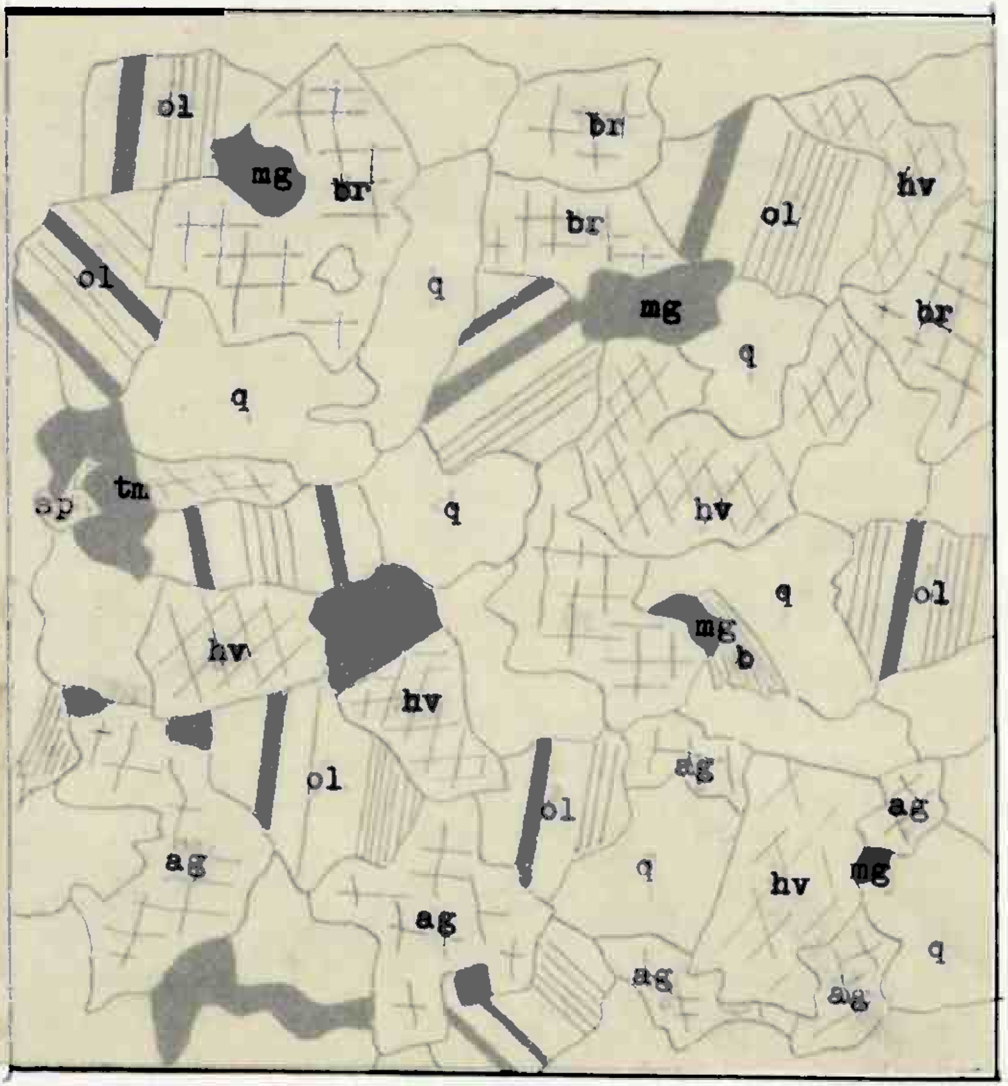
SAMPLE I94. TYPICAL GNEISS.



q: quartz
mp: micropegmatite
mc: microcline
mg: magnetite

ol: oligoclase
my: myrmekite
b : biotite

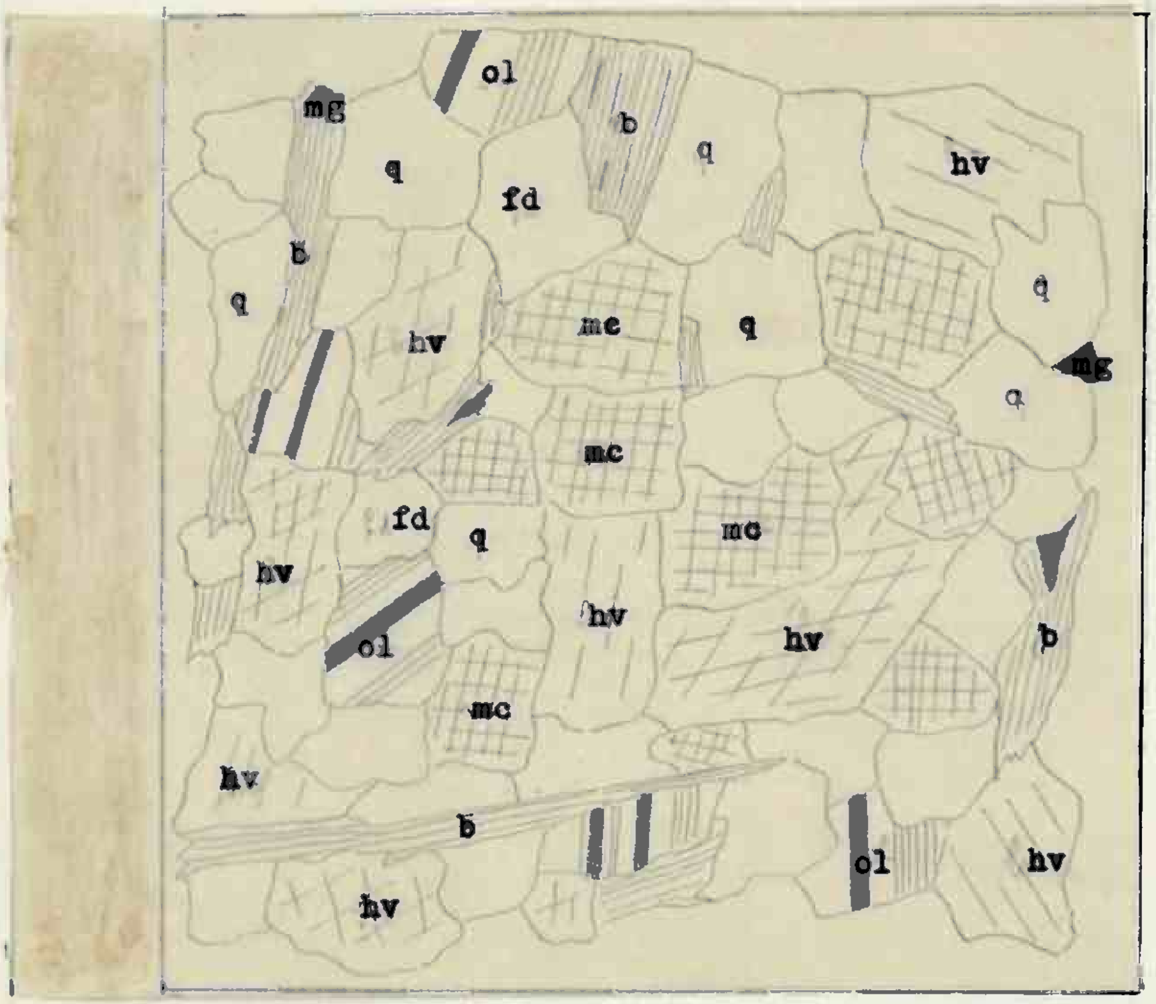
SAMPLE d. GRANITE OF ANATEXY.



q: quartz
br: bronzite
hv: green hornblend
mg: magnetite
sp: sphene

ol: oligoclase
ag: augite
b: biotite
tm: titanomagnetite

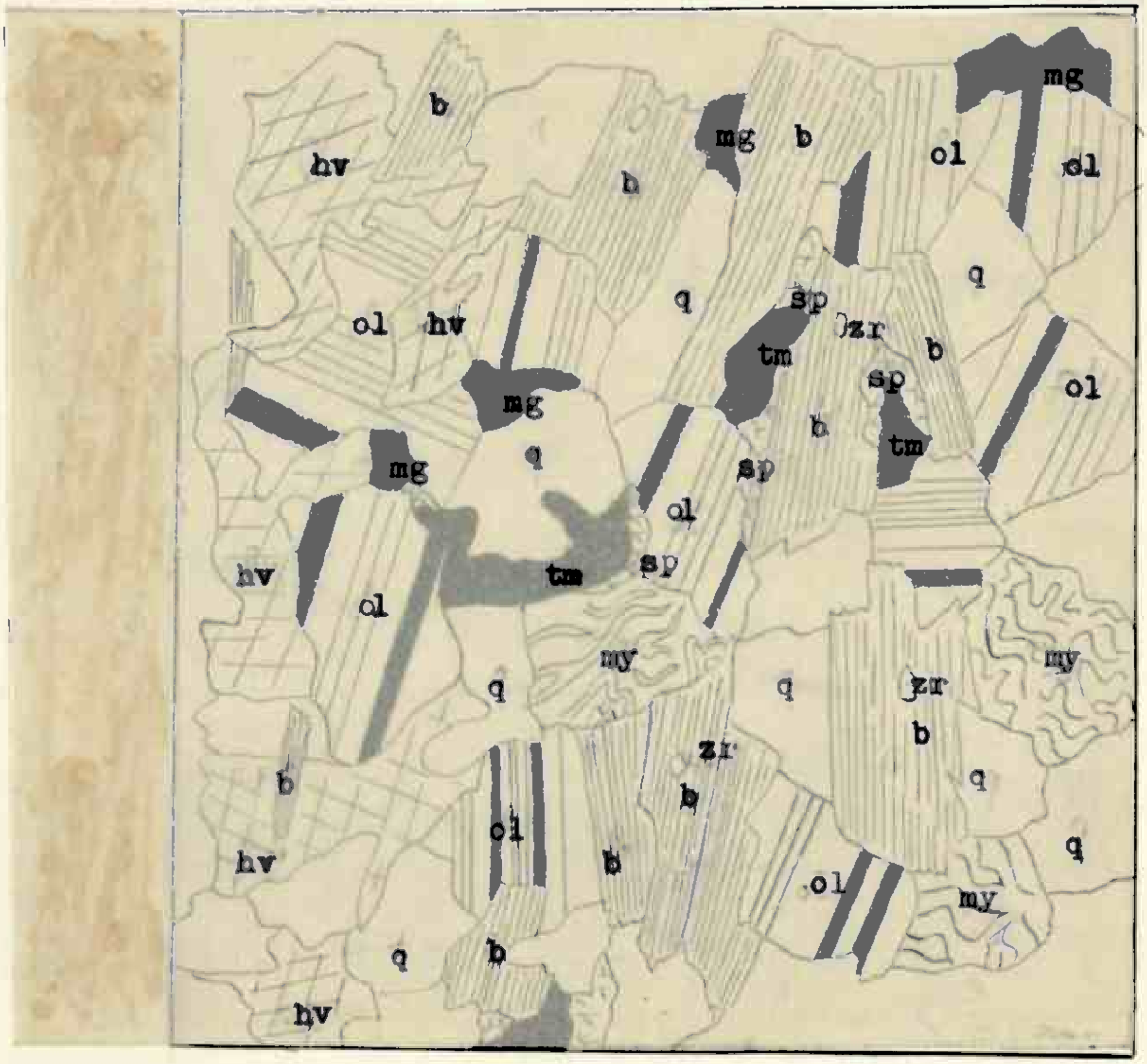
SAMPLE 235. GRANITE OF ANATEXY.



q: quartz
ol: oligoclase
hv: green hornblend
mg: magnetite

mc: microcline
fd: damouritized felspar
b: biotite

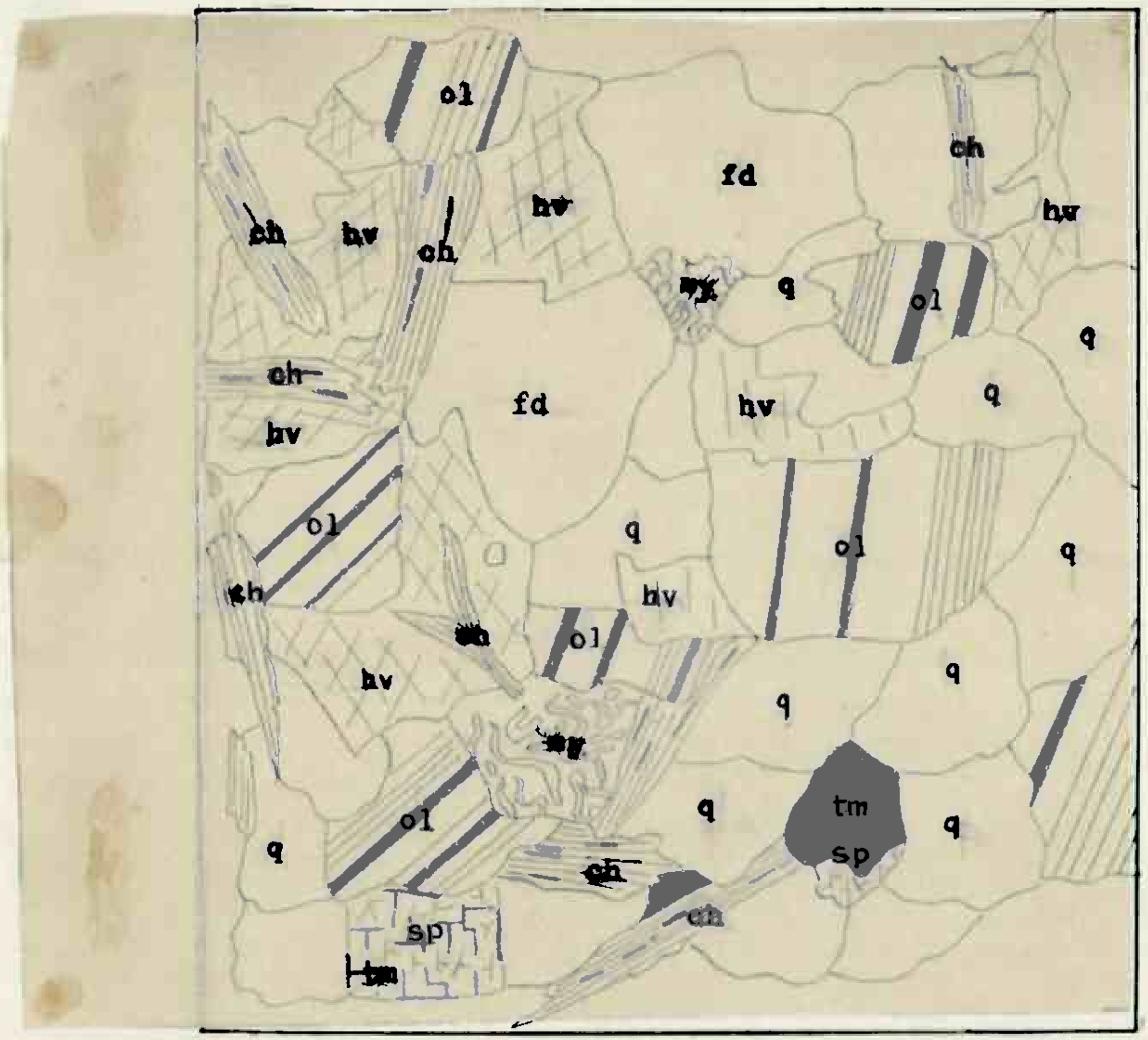
SAMPLE 209b. GRANITE OF ANATEXY.



q:quartz
my:myrmekite
hv:green hornblend
mg:magnetite
sp:sphene

ol:oligoclase
b:biotite
zr:zircon
tm:titanomagnetite

SAMPLE 210a. GRANITE OF ANATEXY.



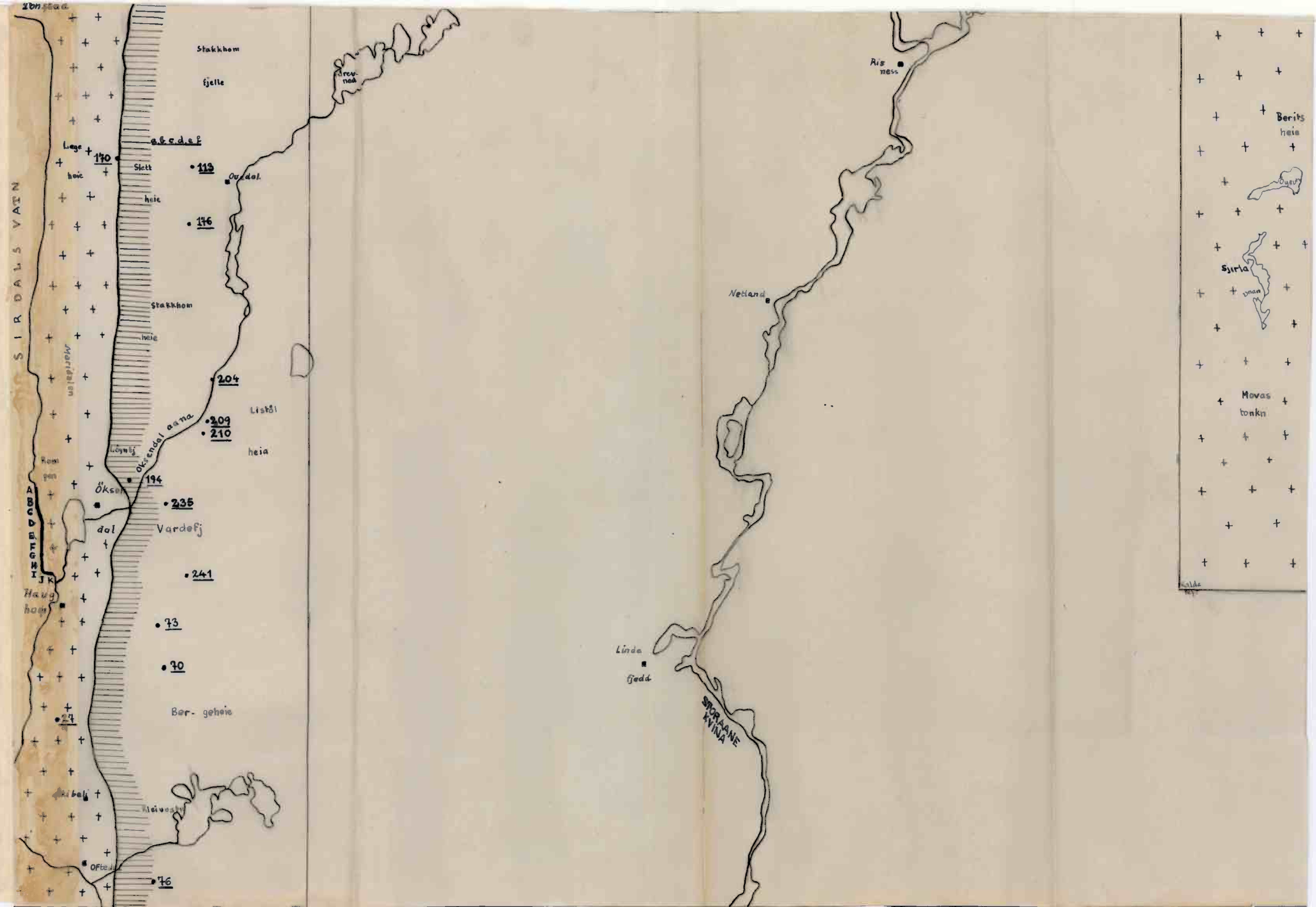
q:quartz
fd:damouritized felspar
hv:green hornblend
ap:apatite
mg:magnetite

ol:oligoclase
my:myrmekite
ch:chlorite
tm:titanomagnetite

SITUATION OF THE TWO SURVEYED AREAS.

MAP OF COLLECTED SAMPLES.

Scale: I/50000.




KART
over
MOLYBDENFELTET
Knaben Gruber - Björnevann
Målestokk = 1/10000
Ekv = 30 m
Forstöret efter Norges Geogr. Opmålings
originalkart i målestokk 1/25000
Molybdenite
Pyrite
Quartz veins
Forstörelsen og tegningen utfört av
E. Dårstad
7-4-1938
S.N.
St. Knabetj
Knabeelv
Vannmagasin
Knaben Gruber
Knabel
Svoen
Berits-
heie
Aljakdalen
Bragøl
Hommen
Barøkke
Benkeheie
Öyvasskn
Lille
Smedsvann
Store
Smeds-
vann
Öyevann
Litleddalsseter
Øvre
Litleddalsvn
Litleddalsvn
Skakketj
Reins-
fjell
Glenndalen
Sjirla-
vatnan
Gradevann
Saghytta
Ljörestokkvne
Ljörestokk-
heie
Skarke-
Glaveen
Borkn-
hom-
knattan
Grunnatj
Movastökn
Botnavann
Berge-
rinnen
Pråmvann
Movas-
rona
Bergerinntj
Lirings-
knudan
Heddals-
heie
Liringstj
Heddalen
Stedjan
Fjeddan
Hauk-
hommen
Kaldalsryggen
Kaldalen
Björnevasslien
Björnevann
Akroken
Sollisleinen
Gjeleskar St
Kalde-
Lieseter
Myr