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Job	Loc.	Est.	Set	Exp.
Supp.				
Elect.				
Engines				
Extern Eng.				
Konstr.				
Mechanik				
Millwork				
Plumbing				
Pres. b'n.				
Roofing				
X Vandalstad				

~~BAMBLE~~

~~and~~

~~TVEDESTRAND-LAGET DISTRICT~~

Order No. T.65078/HK.

Summer of 1970.

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M. J. Ryan.

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Introduction

During the period June 24 - September 15, 1970, M.J. Ryan and assistant P.M. Bowitz-Ihlen carried out field-work in Ringerike, Bamble and the Tvedestrand-Laget district of Aust-Agder under the directorship of Professor F.M. Vokes.

The work consisted of three parts:

- I. A continuation of the regional mapping and prospecting in Ringerike begun by Vokes and Vralstad in 1969. Also an investigation of the geology of certain areas shown by earlier geophysical surveying to have magnetic and electromagnetic anomalies.
- II. Mapping and prospecting in "Interesseområde 6, anomali 3154" of N.G.U. Rapport nr. 885 (in western Bamble).
- III. Prospecting in the Tvedestrand-Laget district in Interesseområder 1 and 3 of N.G.U. Rapport nr 885.

RINGERIKE

Introduction

The reconnaissance geological mapping of the Vaeleren-Soknadalen district done by Vokes and Vralstad in 1969 was extended to the west, east and northeast. Approximately 100 km² has been added to the 1969 map using the same 1:15,000 aerial photographs and 1:50,000 topographic maps mentioned in the 1969 report.

No new major rock groups were discovered and since historical aspects, general regional geology and descriptions of rock types were dealt with by Vokes and Vralstad, only brief descriptions need to be included here.

Structural observations add a third and possibly fourth set of folds to the two periods of folding already described in the 1969 report.

An area of sulphide-bearing schists and gneisses and thin pyrrhotite-bearing gabbro extends from the bridge over the Sokna river at Sandaker (extreme NE corner of map-area) upstream to the small bridge near Heiern (not the Heiern near Tyristrand) and rusty, sulphide-bearing schists etc. were seen north of the river in the railway cutting northeast of Tangen and in the Nökleby area.

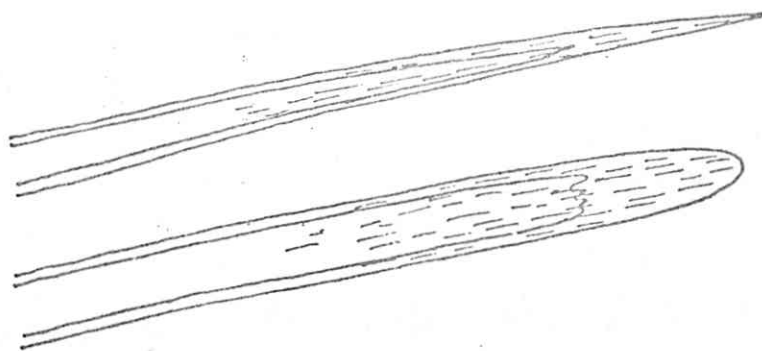
An attempt to relate magnetic anomalies to geology was hindered by the very poor exposure in the Tyristrand district. Some correlation with amphibolite/metagabbro can be observed.

Geology of Map-Area (Map I)

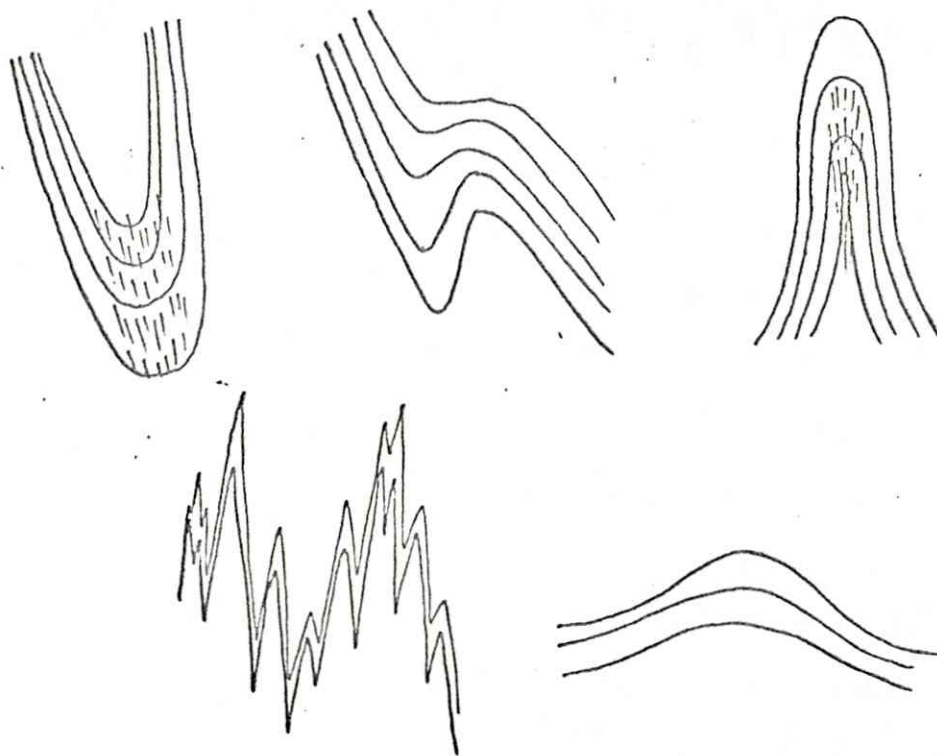
Structures: Mesoscopic and megascopic structures were seen best in the well exposed Tyrifjord coast section where most of the rocks are schistose and gneissose amphibolites and biotite-hornblende gneisses. The earliest structure was the primary, lithological layering (with perhaps volcanic structures in some amphibolites). This was folded by a first set of folds whose axial planes now strike mainly NNW. The first folds are invariably extremely tight/isoclinal with large amplitudes and short wavelengths (see fig. 1). In biotite gneiss they tend to have sharp pointed hinges while folded amphibolite layers exhibit rounded hinge zones. An axial plane foliation has developed which, because of the isoclinal nature of the folding, is more or less parallel with the lithological layering. It was the latter that was measured for 'dip and strike'.

The second folds have NW-NNW, steeply dipping axial planes and vary greatly in style. They may be gentle/open folds with rounded, unthickened hinges or tight/almost isoclinal folds with greatly enlarged hinge zones and streaked out limbs. A second axial plane foliation may develop, especially in the more feldspathic/micaceous rocks. Hornblendic gneisses

F₁ folds in gneiss (top) and amphibolite.



F₂ folds (steeply dipping, NW/NNW striking axial planes)



F₃ folds (NE striking axial planes).

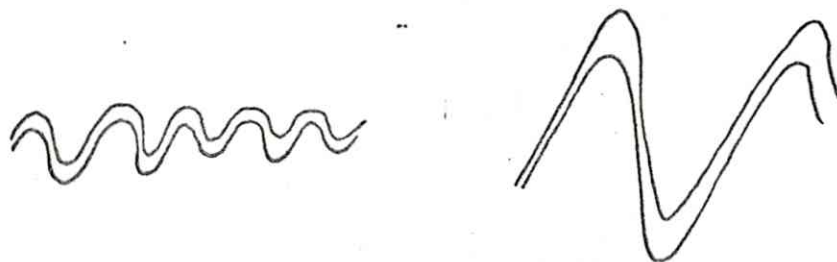


FIG. 1

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and amphibolites become strongly lineated, rodded rocks; axial plane pegmatites may occur. In some cases garnet development is synchronous with this second folding. One major NW fold closure can be seen around Tyristrand. The marked NNW 'grain' of the western half of the area is attributed to the development of tight second folds.

The third folds have NE/NNE striking, steeply dipping axial planes. On the Tyrifjord coast they can be seen as small-scale crenulations. These NE folds are more common in the northeastern quarter of the map-area where it can be seen that the strong NNW regional strike is not so characteristic as it is further west. Photointerpretation suggests closed dome/basin type structures and although time did not allow these to be checked, the suggestion seems reasonable in that interference of the second and third folds - both with steeply dipping axial planes that are approximately at right-angles - should give such structures.

In the eastern part of the map-area there is possibly a fourth set of folds with steeply dipping ENE to ESE axial planes which gently 'bend' or 'warp' the already steeply inclined NNW-striking foliation. It is difficult to decide whether these fourth 'folds' are really due to an earlier large scale 'pinch and swell'.

North Eastern Area

Most of this region is composed of biotite gneiss ± garnet with thin, impersistent migmatised amphibolite layers. In the middle of the area, north of Aklangen, graphite was seen and again near Sandaker.

South of Ask on the Tyrifjord coast is a biotite gabbro which pre-dates a later metamorphism as the gabbro is in part sheared, metamorphosed, migmatised, amphibolitised etc. There is no sign of associated mineralisation.

Sulphides occur sporadically, associated either with thin amphibolites

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or with rusty biotite gneiss. At Ask (prospect no. 20) a small open mine worked pyrrhotite, pyrite, chalcopyrite in a $\frac{1}{2}$ - 1 m. dyke of gabbro, with blebs of sulphide, intrusive into mixed gneiss and amphibolite. Dark fine-grained amphibolite (? pyroxene granulite) also has sulphides as mineralised streaks along the foliation. The ore was taken from a $\frac{1}{2}$ - 1 $\frac{1}{2}$ m. wide zone. The gneiss of the Ask district contains several thin rust zones with pyrite and/or pyrrhotite. North of Ask towards Sandaker there is much drift and then at Sandaker rusty sulphide impregnated gneiss and schists outcrop.

East of the Sandaker bridge, Highway 7 road-cut exposures show sulphide-bearing biotite-graphite schists and west of the bridge, south of the road is an old, partly rubbish-filled prospect. Further west at the water-fall/weir locality a thin, 2-3 m. metagabbro 'dyke' containing pyrrhotite intrudes rusty, sulphide-bearing gneiss. Rusty, sulphide gneisses persist up to the small bridge about 500 m. west of the Sandaker bridge - thus with the foliation/lithological layering striking 155° - 170° , there is a sulphide bearing zone approximately 500 m. wide across the strike. Along the strike it may well link up with the sulphide-bearing gneisses around Ask and a rapid reconnaissance north of the Sokna river showed sulphide-bearing gneisses to the north, more or less along the strike.

Vaeleren-Soknadalen Belt

This zone, which contains most of the sulphide occurrences in the region, appears to lose its 'identity' to the south and possibly to the north. The elongate basic intrusives and "Finkornige mørke pyriclasitter med lyserøde feltspatiske gneiser" of the Vaeleren-Langdalstjern region are missing around Grefsrud where the rocks are gneissic (garnetiferous)

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amphibolites and migmatitic biotite (\pm garnet gneiss) gneisses (bandete amfibolittiske gneiser). The basic intrusive southeast of Grefsrud is strongly metamorphosed with coarse foliated garnet amphibolite margins and 'greens' of veined, migmatitic/agmatitic gneiss running through it. No sulphides are associated. To the north, the 'homogeneous dark amphibolites' become more gneissic and more like the 'banded amphibolitic gneisses' which make up the bulk of the map-area. Also pyriclasites lens but northwards - it may be that there is some genetic association between this seemingly isolated lens of pyriclasite and the sulphide-bearing basic intrusives around it.

Basic metamorphic and igneous rocks can be divided into groups - see Vokes and Vralstad (1969). Schistose and gneissose amphibolites in the Tyristrand district contain diopside-epidote, epidote-garnet lenses and lensoid structures that could well be relict pillow structure. Also structures resembling stretched volcanic bombs - unlike the more usual agmatitic amphibolite structures - can be seen along the Tyrifjord coast south of Tyristrand between Hagabru and Skarvhelletangen. This group of basic rocks must be a former volcanic series of tuffs, lavas, ashes, agglomerates etc. Occasionally the group contains rusty rocks with minor sulphides - pyrrhotite, pyrite and chalcopyrite may occur in amphibolite and associated biotite gneiss. An elongate massive amphibolite layer, sometimes with a massive, unfoliated garnetiferous core, concordant with the regional foliation/lithological layering occurs in the western part of the area. This rock is transitional between schistose amphibolite and the Elongate metagabbro bodies that occur in the Vaeleren-Soknadalen belt.

The Heiern Complex type - gabbro with purplish clouded feldspars and greenish ferromagnesian minerals and associated ultramafic layer -

resembles some of the bodies in Bamble (e.g. the complex east of Hullvatn) and must be distinguished from The Ertlia type - a discordant, fresh (? unmetamorphosed) norite.

Western Area

This region is made up mainly of banded amphibolites and gneisses with the elongate massive amphibolite (? Sill) mentioned earlier. A major fold closure is postulated for the Sjumyra area in the southwest. Here homogeneous, strongly lineated biotite-hornblende-garnet gneiss occupies the thickened hinge zone with vertical or west-dipping layering to the east, and vertical or east-dipping layering to the west. Prospect nr 14 is an old Sphalerite 'mine' where a quartz-greenish grey coloured sphalerite - minor galena and pyrite - ? siderite vein, trending approx. 040, cuts amphibolite/garnet amphibolite/streaky amphibolitic gneiss. A cut max. 2½ m. deep, 2 m. wide and 15-20 m. long was made.

Prospect nr. 16 is a small 3 m. square pit in rusty, pyrrhotite-impregnated biotite gneiss.

BAMBLE

Introduction

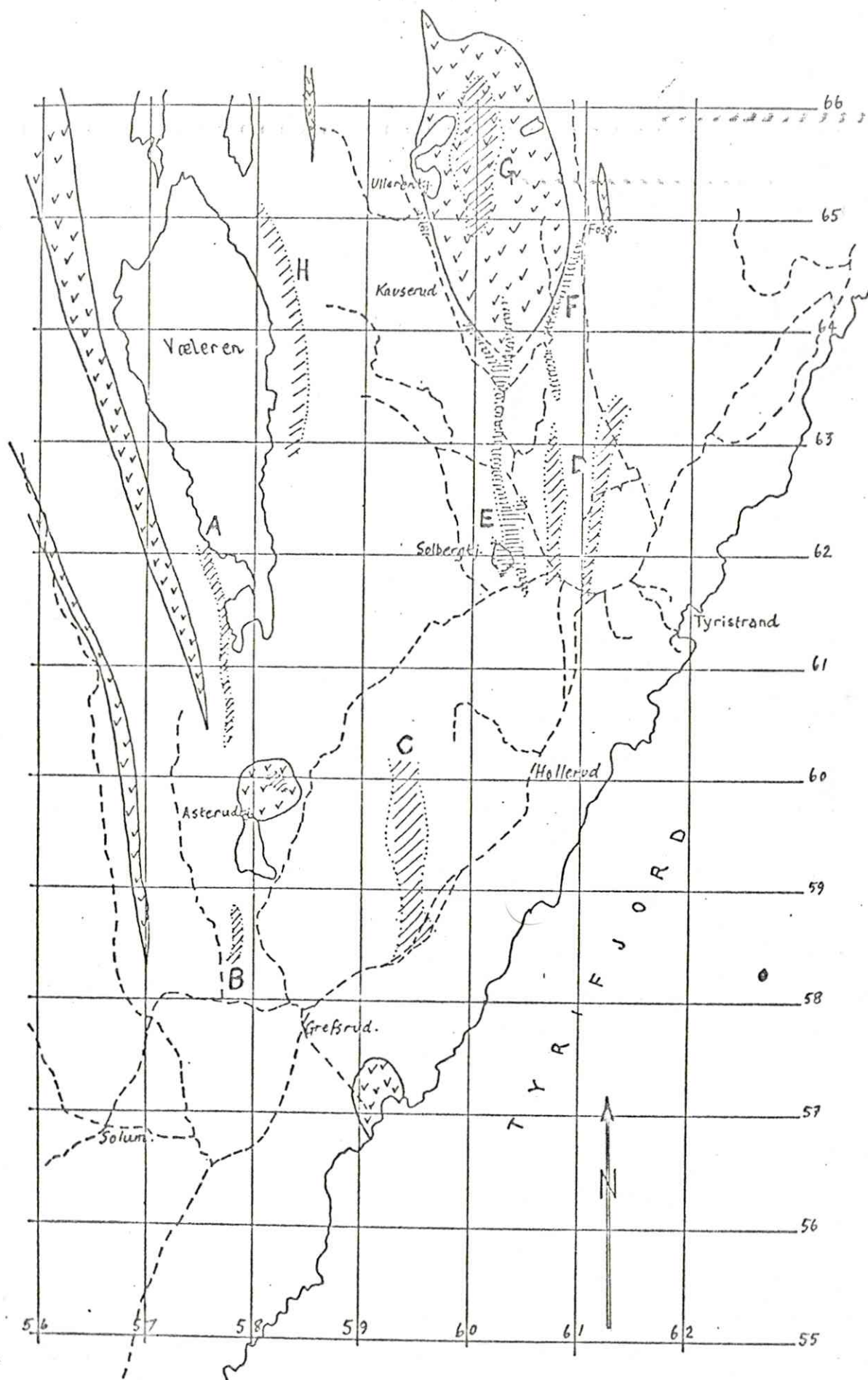
The basic intrusion east of Hullvatn (hereafter referred to as Intrusion H) and the one northeast of Grummestavdvatnet (Intrusion G), lying north of the head of Fossingfjord in western Bamble, were investigated in some detail and mapped from 1:10,000 scale aerial photographs.

It was already known from earlier mapping by Ryan and Batey (research student map-areas) that Intrusion G lay in a positive magnetic anomaly belt whose rocks consisted of granitic gneisses with amphibolites and other basic igneous bodies. Further northeast in that belt, along the regional strike, Nickel deposits occur at Meikjaer and Nystein. With a very high positive

Fig. 4.

EM anomalies : horizontal shading

MAG. anomalies: oblique shading.



Geophysical Anomalies in Ringerike

Fig. 4 shows the location of the 'EM' and 'MAG' anomaly areas in the Vaeleren-Heieren-Tyristrand-Grefsrud district.

Anomaly A: trends parallel with, but is displaced east of the elongate metagabbro body to the west of Vaeleren. The area consists of mixed amphibolites and massive homogeneous pink biotite gneiss. Amylonite zone running parallel with the western shore of Vaeleren separates the migmatitic amphibolites, "metadolerite/gabbro" ? pyroxene granulites (massive, non-foliated rocks, veined with garnetiferous pegmatites which may be foliated) and gneisses with discordant amphibolite of the S.E. Vaeleren peninsula from the banded, amphibolitic gneisses of the "mainland". Prospect 13 was not located.

Anomaly B: South of Asterudtjern consists of mixed amphibolites and garnetiferous gneisses - part of the banded amphibolitic gneiss group.

Anomaly C: contains relatively little basic rock - the area is composed mainly of homogeneous biotite gneiss with occasional magnetite-bearing pegmatite lenses, hornblende-biotite \pm garnet gneiss and thin agmatitic amphibolites.

Anomalies D: lie in the very poorly exposed area west of Tyristrand. As far as one can see from the small, scattered exposures the area is again made up of typical banded, gneissic amphibolite, with very minor pyrite and occasional chalcopyrite.

Anomaly E: is one of very poor exposure also. 40 m. to the east of Solbergstjern and again approximately 180 m. north of the lake, coarse-grained, massive garnetiferous metagabbro outcrops. Elsewhere in the area the rocks are biotite gneisses.

Anomaly F: on the SE margin of the Heieren Complex, is again in a poorly exposed area. Scattered exposures show mainly biotite schist and gneiss with garnet amphibolites. In the road cuttings south of Foss there is a marked rusting, but elsewhere there are few signs of sulphides.

Anomalies G and H: were not investigated, because of lack of time.

Conclusions

a) Ringerike

The map area can be divided into three broad, roughly N-S trending divisions. Minor sulphide occurrences and rust zones are scattered throughout the whole area but the central Vaeleren-Soknadalen belt contains the most important deposits and the majority of the basic igneous rocks occur here. A broad rust zone containing thin gabbro 'dykes' and sulphides occurs at Sandaker and the sulphides around Ask may be the southern continuation of this poorly exposed zone. No areas of real economic importance have emerged but northward extensions of the Vaeleren-Soknadalen belt and Ask-Sandaker zone may exist. Reconnaissance geological mapping north of the Sokna river is recommended as the first stage in any future operations.

b) Bamble

The Hullvatn-Grumnestavdvatn area appears unlikely to contain economic concentrations of sulphides at or near the surface. The large Hullvatn intrusion contains several generations of sulphides - as blebs scattered throughout the rock or concentrated in the pore-space material or associated with late stage scapolite-sulphide mineralisation.

c) Tvedestrand-Laget District

The most interesting area in this district would appear to be the Østeravatnet-Royvatn-Skuggevik area where there may exist a structural control/gabbro intrusion relationship. The probability of finding economic concentrations of sulphides at or near the surface appears low, but the area ought to be considered for detailed geological mapping and geophysical investigation as it could provide a useful case history.