

**A beryllium-magnetite correlation
in the Hørtekollen—Grubeås area, Buskerud, Norway,
and its use for beryllium prospection.**

By

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Preface.

This paper is a result of a collaboration between Euratom and the Geological Survey of Norway on the prospecting for Beryllium and Scandium in Norway.

The first investigations of Norwegian Beryllium and Scandium deposits were started after the last war by H. Bjørlykke, and the deposit at Hørtekollen was studied by J. Hysingjord in 1951.

The collaboration work with Euratom in the field was carried out in the summer 1962. From the Geological Survey of Norway the state geologists Th. Sverdrup and J. Hysingjord were engaged in this work.

We very much appreciate the interesting co-operation with the scientists of the Euratom, which has given us many valuable informations on this prospecting work.

H. Bjørlykke

Summary.

A helvite-magnetite mineralization at Hørtekollen was studied for its beryllium and magnetite contents. Statistically, a close correlation between the magnetite and the beryllium contents was found to occur. Therefore a magnetic survey was made in the Hørtekollen—Grubeås area along the contact zone between the Drammen granite and the cambrosilurian metamorphic sediments in search of magnetite concentrations in which a similar relationship could exist.

A well-defined magnetic anomaly close to the surface was found, not far away from the mineralized lens of Hørtekollen. In this area, stream sediments also clearly indicate an abnormal beryllium content of more than ten to twelve times the background. Detailed magnetic measurements carried out with a nuclear procession magnetometer show that the magnetic anomaly is caused by some 1600 metric tons of magnetite. Due to its geologic setting as well as to its close proximity to the Hørtekollen mineralization, a similar relationship between magnetite and helvite can be expected to exist and this possibility warrants further investigations.

I. Introduction.

The geology of the Hørtekollen-Grubeås area was first described by Leopold von Buch in 1810 (1) and was also mentioned in the publications of M. C. Strøm, Keilhau, Kjerulf and Voigt. A more complete description of the geology and of the mineralogy of this area was given at the beginning of this century by W. Brøgger (2), J. Schetelig (3), and by V. M. Goldschmidt (4), the last also describing the helvite mineralization at Hørtekollen. The Drammen porphyritic granite is considered by the last author as a laccolithic intrusion with some apophyses in the sediments. The metamorphic sediments covering the granite, strike from N 50° 4' to N 70° E, with a slope of 5 to 10° SE. These rocks are formed mainly of metamorphic pelites (hornfels) with some lenses of silicified limestones.

The map (fig. 1) shows the contact between the Drammen granite and the metamorphic sediments on the east side of the Veslevassdal where a magnetic survey was made. All the area prospected is covered by forests. Outcrops are only locally found on the mountain slopes.

II. The Helvite-Magnetite Mineralization of Hørtekollen (fig. 1, point 1).

The helvite-magnetite mineralization of Hørtekollen forms a small-sized inclusion of metamorphic cambro-silurian limestones and pelites inside the Drammen granite. This lenticular inclusion occurs at about 15 meters from the main contact. The mineralization is composed mainly of magnetite, helvite, molybdenite, sphalerite, fluorite, with silicate minerals such as wollastonite, quartz, feldspars, biotite, orthite, epidote, garnet, pyroxene, etc. The outcrop was sampled systematically in order

to study the distribution of barious elements, mainly Be, Fe (magnetite), Mo, Sc and Zn. This study only concerns the distribution of Be and Fe (as magnetite), the latter being determined by the Frantz magnetic separator.

A laboratory beryllometer (5) with a gamma-source of Sb^{124} of about 100 mill-curies was used for the determination of the Be content of the various samples collected in the field. The results are given in table 1, together with the percentage of magnetite.

Table 1. *Beryllium and Magnetite Distribution in the Mineralized Inclusion of Hørtøkollen.*

Samples	Be Content (ppm)	Magnetite Percentage
<i>Group I</i>		
(1) HØ/VW/4/1A-1D	175	0.5
(2) HØ/VW/4/1C-14	100	0.5
(3) HØ/VW/4/1B	830	5.5
<i>Group II</i>		
(1) HØ/VW/4/2A	2100	12
(2) HØ/VW/4/2B	130	1.1
(3) HØ/VW/4/2C	125	1.2
<i>Group III</i>		
(1) HØ/VW/4/3A	1830	9
(2) HØ/VW/4/3B	2630	15
(3) HØ/VW/4/3C	610	8
(4) HØ/VW/4/3D	6050	28
(5) HØ/VW/4/3E	210	0.1
(6) HØ/VW/4/3F	1030	5
(7) HØ/VW/4/3G	1530	9
(8) HØ/VW/4/3H	3730	18
(9) HØ/VW/4/3I	2900	12
(10) HØ/VW/4/3J	2210	8
(11) HØ/VW/4/3K	4300	3
(12) HØ/VW/4/3L	3900	32
(13) HØ/VW/4/3M	3470	14
(14) HØ/VW/4/3N	1820	2
(15) HØ/VW/4/3O	1400	16
(16) HØ/VW/4/01	2940	45
(17) HØ/VW/4/02	3900	48

The analysed samples were divided into three groups:

Group I : Western contact of the mineralized lens with the granite;

Group II : Western part of the lens;

Group III: Main part of the inclusion with strong Be mineralization.

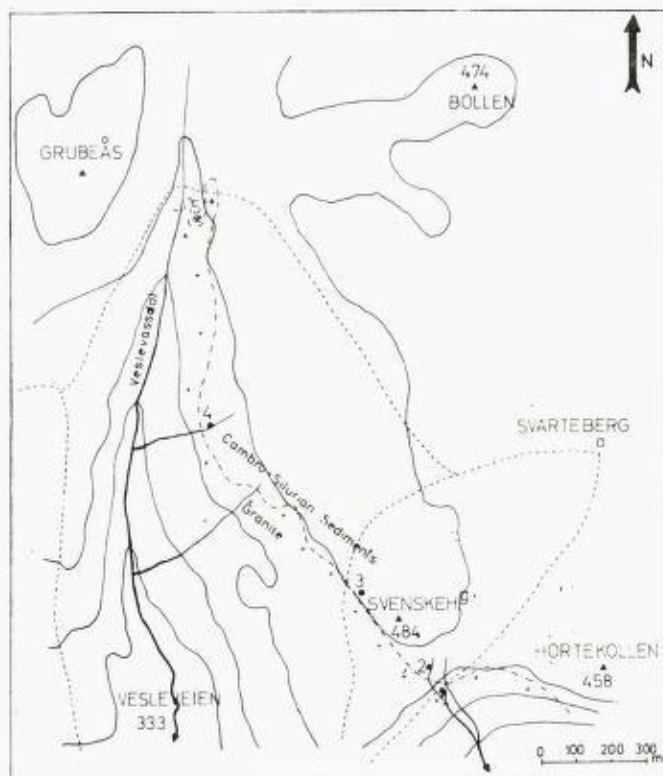


Fig. 1. Contact between the Drammen granite and the metamorphic Cambro-Silurian sediments.

Groups I and II form about $\frac{1}{5}$ of the total exposed surface. They are plotted on the fractile diagrams of fig. 2 (6). The broken line 1 suggests that we have sampled two populations with different beryllium contents. The fractile lines II and III respectively show the distribution of the Be content in groups I and II, and in group III. The median Be content of groups I and II is about 250 ppm (700 ppm BeO), whereas the median content of group III is 2400 ppm (6600 ppm BeO).

Groups I and II are mainly composed of metamorphic pelites with localized skarn lenses, whereas group III mainly contains silicified limestones (skarns), host-rocks, which are more favourable for mineral deposition.

Fig. 3 and table 1 show a good correlation between the beryllium and

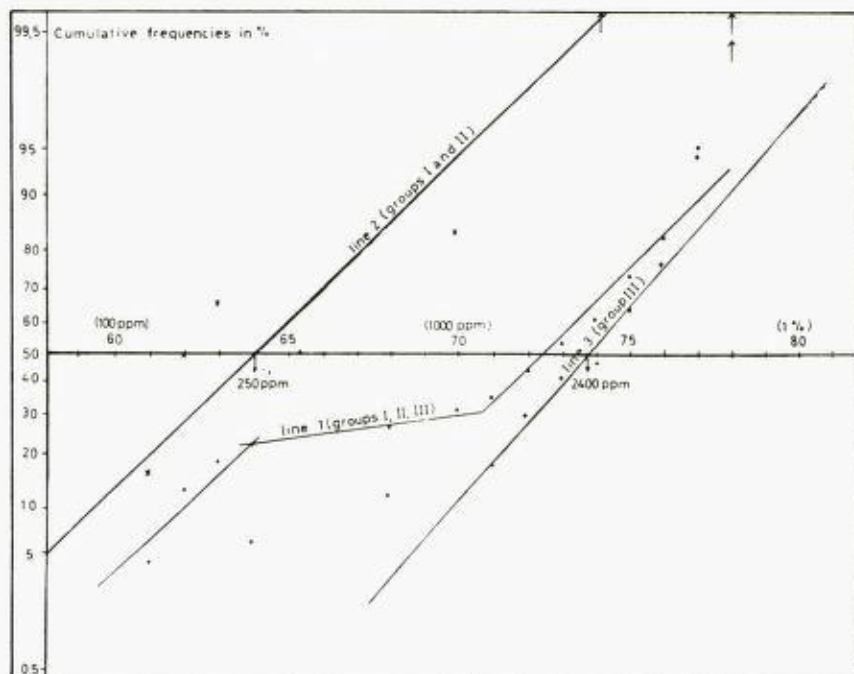


Fig. 2. Fractile diagrams of beryllium distribution in the different groups at Hørtekollen.

the magnetite contents. The correlation coefficient r has been computed with the classical formula:

$$r = \frac{\sum xy - (\sum x)(\sum y)/n}{\sqrt{[\sum x^2 - (\sum x)^2/n][\sum y^2 - (\sum y)^2/n]}}$$

where x and y respectively are the beryllium and the magnetite contents.

The correlation coefficient r is equal to 0.66 which is highly significant for (23-2) degrees of freedom. The probability that this correlation is due to hazard is under 0.001.

Stream sediments taken at various distances from the inclusion indicate an anomaly for Be up to a distance of about 50 m. Near the lens this value is 65 ppm Be. Due to the very small size of the mineralized lens, we observe a sharp diminution of the Be content in the stream sediments at a distance superior to 5 meters from the outcrop.

III. Magnetic Prospecting Along the Contact Zone.

Because of the short time we spent there – about two weeks – only the contact zone between the Hørtekollen mineralization and Grubeås up to the left bank of the Veslevassdal was surveyed.

The magnetic measurements were made with a nuclear precession magnetometer VARIAN M49A. This type of magnetometer is very practical for a rapid search for magnetic anomalies, especially in hilly countries. It measures the total magnetic field and not only one of the field components. Orientation and levelling of the magnetic equipment are no longer necessary. Moreover, measurements are made in absolute values and no corrections are necessary, with the exception of the diurnal

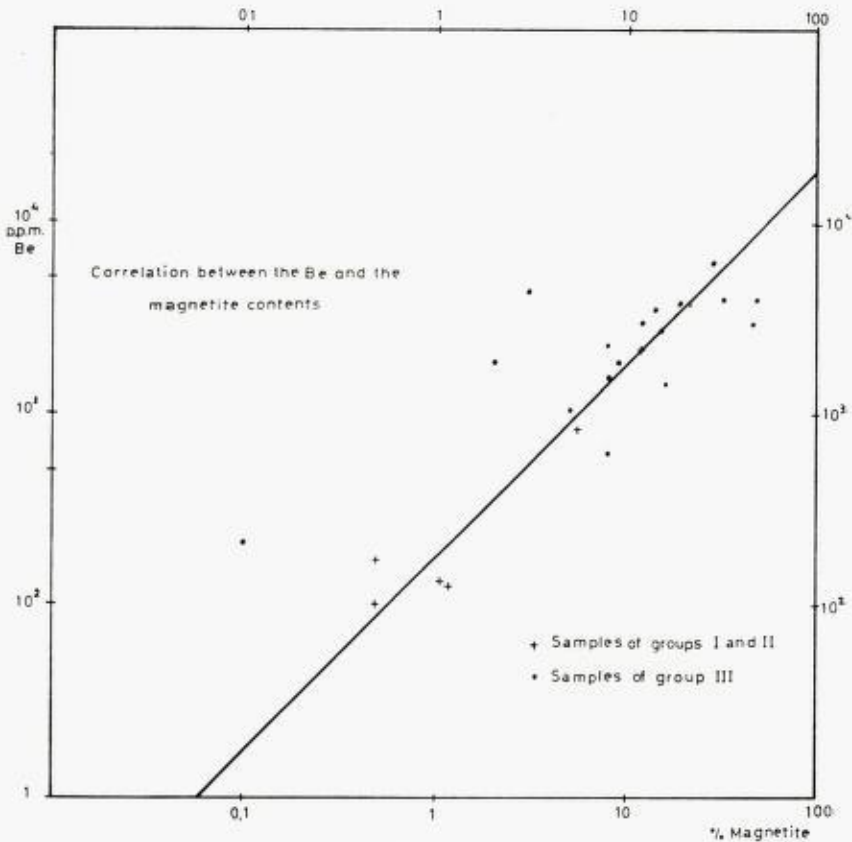


Fig. 3.

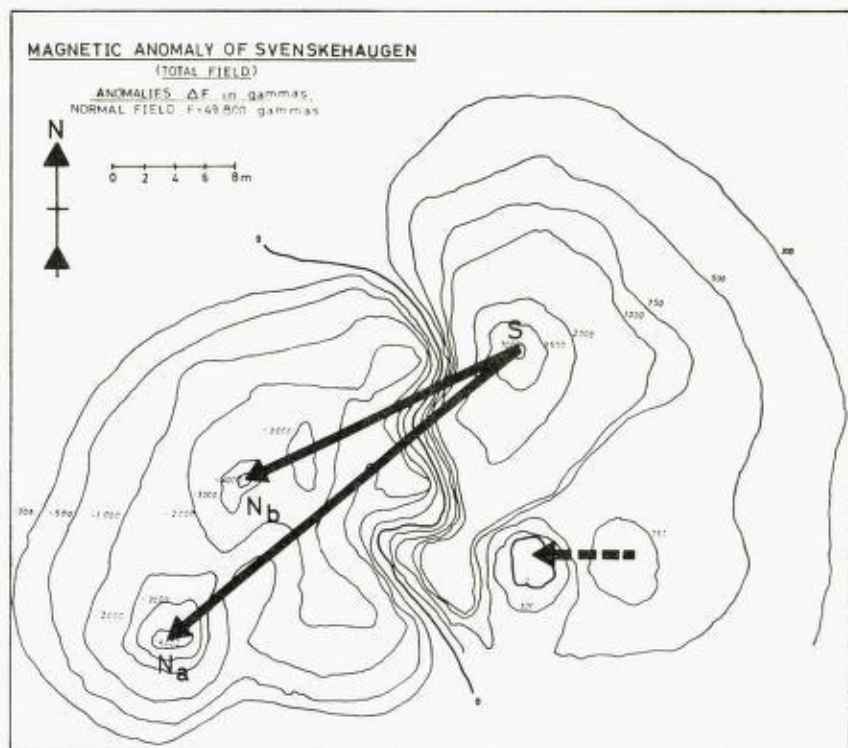


Fig. 4.

variations of the total magnetic field. In the present case, diurnal variations are not considered significant, with respect to the anomalous values found in the surveyed country. The normal total magnetic field for the country is $F = 49,800$ gammas. This value was measured at several points where no field gradient was found. During our survey several magnetic anomalies from 400 to 500 gammas were detected (Points 1, 2, 3, 4 and 5 on the map, fig. 1). Only one of them (Point 2 on the same map), deserved out attention because of its high intensity. This anomaly is located on the south-eastern slope of Svenskehaugen at about 70 m from the mineralization of Hørtøkollen. Point 5 corresponds to a small Mn-Fe-Zn mineralization.

IV. Analysis of the Magnetic Anomaly of Svenskehaugen.

IV. *Analysis of the Magnetic Anomaly of Svenskehaugen*

The magnetic anomaly found on the south-eastern slope of Svenskehaugen has a surface area of about 1000 m² and was surveyed with a grid spacing varying from 2 to 5 meters, depending on the gradient's variations.

The magnetic map is reproduced on fig. 4. All values were measured at a height of 8 feet above the surface.

Here follows a summary of the interpretation of the results:

Physical Interpretation of the Map

1. *Hypothesis*

We shall interpret the map assuming that each pole of the magnetic mass acts separately at the point laying over that pole at the surface level. Although the anomaly is small in area, such a rough approximation seems to be sufficient because of the lack of depth of the buried mass causing

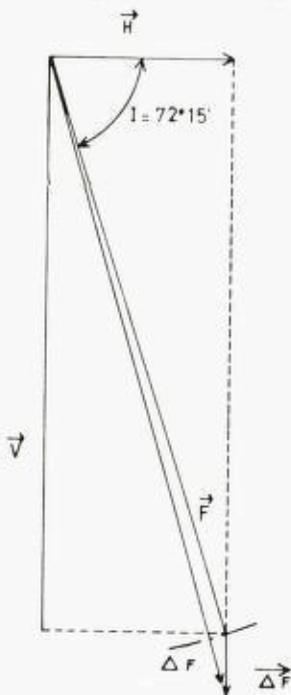


Fig. 5. Vectorial scheme of the total field \vec{F} and of the anomaly ΔF in this case $|\Delta \vec{F}| \approx 0,1 F$.

the anomaly. Accordingly, our numerical results cannot be considered more than a rough estimation.

Further, the field measured just over a pole considered as one point is approximately the algebraic sum of the normal geomagnetic field and the true anomalous field. This results from the high dip of the local geomagnetic field ($I = 72^\circ 15'$) (fig. 5).

2. Determinations of the Poles

The pole depths are readily found by measuring the field strength at different levels above the ground. A very convenient feature of the nuclear magnetometer is that it can be elevated up to 20 feet in the air using a set of 2-foot aluminium extension staffs.

a) South Magnetic Pole

Two measurements at 2 ft and 10 ft above the ground were made. Taking x_s as the depth of the pole in feet, we receive:

Level of the sensing head above the ground	Level of the sensing head above the pole	Local measured total field F (gammas)	Anomaly F (gammas)
2	$x_s + 2$	54.700	4.900
10	$x_s + 10$	52.350	2.550

From this:

$$\left(\frac{x_s + 10}{x_s + 2} \right)^2 = \frac{4,900}{2,500} \approx 1.4^2$$

$$x_s \approx 18 \text{ ft} \approx 5.50 \text{ m}$$

Pole strength p :

$$p = \Delta F_{10} (x_s + 10)^2$$

$$x_s + 10 \approx 28 \text{ ft} \approx 854 \text{ cm}$$

$$\Delta F_{10} = 0.0255 \text{ Ö}$$

$$p = 1.86 \pm 10^4 \text{ c.g.s. units}$$

b) North Magnetic Pole

According to the configuration of the magnetic field (fig. 4), we consider the North pole as divided into two points N_a and N_b , respectively respectively 30 and 20 meters distant from the South pole S .

i) Pole N_a

The depth was calculated from two extreme measurements at 6 ft and 20 ft above the ground (x_{N_a} in ft).

Level of the sensing head above the ground	Level of the sensing head above the pole	Local measured total field F (gammas)	Anomaly ΔF (gammas)
6	$x_{N_a} + 6$	48.280	-7.520
20	$x_{N_a} + 20$	42.160	-1.640

From this:

$$\left(\frac{x_{N_a} + 20}{x_{N_a} + 6} \right)^2 = \frac{7,520}{1,640}$$

$$x_{N_a} = 6.3 \text{ ft} \simeq 1.9 \text{ m}$$

Pole strength:

$$p_a = \Delta F_{20} (x_{N_a} + 20)^2$$

$$x_{N_a} + 20 \simeq 26 \text{ ft} \simeq 800 \text{ cm}$$

$$\Delta F_{20} = 0.0164 \text{ } \ddot{\text{o}}$$

$$p_a = 1.05 \pm 10^4 \text{ c.g.s. units}$$

ii) Pole N_b

The pole strength is obtained by difference:

$$p_b = p - p_a = (1.86 - 1.05)10^4$$

$$= 0.8 \pm 10^4 \text{ c.g.s. units}$$

Pole depth:

$$(N_b + 8)^2 = \frac{bP}{\Delta F_b}$$

$$\Delta F_b = 0.034 \text{ } \ddot{\text{o}}$$

$$(x_{N_b} + 8) \text{ ft} = 485 \text{ cm}$$

$$x_{N_b} = 8 \text{ ft} = 2.4 \text{ m}$$

3. Magnetic Moments M

Considering the lengths of the two branches:

$$L_a = SN_a = 30 \text{ m} \qquad L_b = SN_b = 20 \text{ m}$$

$$M_a = p_a L_a = 1.05 \pm 10^4 \pm 3000 = 3.15 \pm 10^7 \text{ c.g.s. units}$$

$$M_b = p_b L_b = 0.8 \pm 10^4 \pm 2000 = 1.6 \pm 10^7 \text{ c.g.s. units}$$

$$M_{\text{tot}} = M_a + M_b = 4.75 \pm 10^7 \text{ c.g.s. units}$$

4. Intensity of Magnetisation

This depends of course on the susceptibility of the rock which is unknown here.

For pure magnetite ($k \sim 0.3$) it would be:

$$I = k.F = 0.3 \pm 0.5 = 0.15 \text{ c.g.s. units}$$

5. Polar Cross Sections

Inversely proportional to the intensities of magnetisation, these cross sections would be minimal if pure magnetite were to be considered. In this case:

$$A_a = \frac{p_a}{I} = \frac{1.05 \times 10^4}{0.15} = 7 \times 10^4 \text{ cm}^2 = 7 \text{ m}^2$$

$$A_b = \frac{p_b}{I} = \frac{0.8 \times 10^4}{0.15} = 5 \times 10^4 \text{ cm}^2 = 5 \text{ m}^2$$

$$A_{\text{tot}} = 12 \text{ m}^2$$

6. Equivalent Volume of Pure Magnetite

$$V = \frac{M_{\text{tot}}}{I} = \frac{4.75 \times 10^7}{0.15} = 3.17 \times 10^8 \text{ cm}^3 = 317 \text{ m}^3$$

This can also be found from the polar cross sections and the lengths L . This value is of course the minimum one for the actual mass causing the anomaly.

7. Tonnage of $Fe_3 O_4$

Assuming the density of the magnetite being 5,

$$T = 317 \pm 5 = 1585 \text{ T}$$

This value however does not depend on the actual magnetite concentration of the rock, since susceptibility is proportional to volume concentration in magnetite.

8. *Conclusions of the Magnetic Measurements*

- The anomaly results from a superficial magnetite mineralization (sub-outcrop);
- The magnetic mass is divided into two branches approximately striking NE-SW and rejoining at the common south pole. The lengths of the branches are 30 m and 20 m;
- The mineralization contains about 1600 T of magnetite;
- It should be mentioned that the south magnetic pole lays at a deeper level than the north poles and further that the magnetic axis does not strike parallel to the actual local geomagnetic meridian. This indicates a high remanent polarisation of the mass.

V. **Geochemical Assays for Be in the Magnetic Anomaly.**

Stream sediments derived from the magnetic zone give a Be content of 17.5 ppm, which is more than ten to twelve times the normal background (1.4 ppm Be) of stream sediments in this area. The measurements were made by J. W. Brinck (see report 7).

VI. **Conclusions.**

The contact zone between the Drammen granite and the cambrosilurian sediments along the Tyrifjorden constitutes a favourable area for a possible new mineralization of Be and other metallic elements such as Zn, Mo, Fe, etc.

A study of the Be distribution in the mineralized lens of Hørtekollen indicates a high Be Content as well as correlation between Be and magnetite.

Magnetic and geochemical surveys were used in the Hørtekollen-Grubeås area in search of possible new mineralizations and have led to the discovery of a small area in which the probability of finding a similar correlation between Be and magnetite mineralizations is very great. However, from the surface area of the anomaly, it is indicated that the potential tonnage of this possible mineralization is substantially greater than that of the mineralized inclusion of Hørtekollen.

We wish to express our thanks to the Norwegian Government, to Dr. Bjørlykke, Director of the Norwegian Geological Survey, and to the Directorate of Euratom for their kind support.

Bibliography.

- 1) *L. von Buch*, 1810, "Reise durch Norwegen und Lappland", Bd. I, p. 118.
- 2) *W. C. Brøgger*, 1894, "Eruptivgesteine", Band II, p. 127.
- 3) *W. C. Brøgger and J. Schetelig*, 1900, "Geologisk Kart Kristiania".
- 4) *V. M. Goldschmidt*, 1911, "Die Kontaktmetamorphose im Kristianagebiet.", Vidensk. skr. I, Math.-Nat. Kl. no 1, p. 91-94.
- 5) *S. H. U. Bowie, H. Bisby, K. C. Burke and F. H. Hale*, 1960, "Electronic Instruments for Detecting and Assaying Beryllium Ores.", Trans. Inst. Min. and Met. Vol. 69 pt. 7.
- 6) *A. Hubaux*, 1961, "Représentation graphique des distributions d'oligoéléments.", Ann. Soc. Géol. de Belgique, T LXXXIV, Mars pp. 279-296, Rapport EUR 42 f.
- 7) *J. W. Brinck, A. Hofmann*, 1963, "Distribution of Be in the Oslo Region. A Geochemical Stream Sediments Study.", to be published in Economic Geology.