Report on the Columbium Occurrence of the Fen Region Near Ulefoss in Southern Norway

by

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C O N T E N T S

List of Illustrations:

Sources of Information

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Summary

The Fen region covers an area of about 6 square kilometers. Practically all the rocks have a certain columbium content, generally from 0.05 to 0.1 percent Cb_2O_5.

Three occurrences with an average columbium content of 0.2 percent Cb_2O_5 or more are described in this report. Estimates of ore reserves only include ore with an average columbium content of 0.2 percent Cb_2O_5 more.

Diamond drilling and other surveys carried out are insufficient for calculating proven ore. Considering geologic factors, however, it is probable that the reserve estimates given represent minimum values.

The reserve estimates include only ore above the level of lake Nordsjø. Columbium mineralization undoubtedly extends to deeper levels except in the Cappelen occurrence.

The ore minerals are kopite (calcium columbate) and columbite (a low titanium iron columbate). The tantalum content of the ore is low. (Cb_2O_5: Ta_2O_5 = .20:1 for kopite and 100:1 for columbite.)

The principal ore of the Hydro occurrence and the Cappelen occurrence is a calcite (calcium carbonate) rock with 5 0 10 percent apatite (calcium phosphate) and small amounts of magnetite, biotite, pyrite, pyroxene and other dark minerals. There seem to be about equal amounts of kopite and columbite.

The principal ore of the Tufte occurrence is ankerite (calcium, magnesium, iron carbonate) rock with 10 - 15 percent apatite and small amounts of dark minerals. Columbite seems to be the chief ore mineral here, only a few crystals of kopite having been observed.

The Hydro occurrence is estimated to contain 750,000 tons of ore with an average content of 0.2 percent Cb_2O_5 (1500 tons Cb_2O_5). The Cappelen occurrence is estimated to contain 175,000 tons of ore with an average content of 0.25 - 0.30 percent Cb_2O_5 (450 tons Cb_2O_5). The Tufte occurrence is estimated to contain 4,000,000 tons of ore with an average content of 0.25 - 0.30 percent Cb_2O_5 (10,000 tons Cb_2O_5).

The ore of the three columbium occurrences considered contains about 400,000 tons of apatite (180,000 tons P_2O_5).

The reserves of ore with 0.05 to 0.1 percent Cb_2O_5 in the Fen region are probably several hundred 1,000,000 tons.

Location, Transport and Ownership

The columbium occurrences are within an area referred to by geologists as the Fen Region. This area covers some 6 square kilometers (3 kilometers in a northerly direction and 2 kilometers in an easterly direction). The western border of the Ren region is 1 kilometer to the southeast from Ulefoss, a village with some 1000 inhabitants. Ulefoss lies midway on the southwestern side of the 30 kilometers long lake Nordsjø in the county of Telemark. It is 110 kilometers in a straight line from Oslo Ulefoss can b e reached by train from Oslo to Lunde (on the Oslo-Kongsberg-Kristiansand railway). From Lunde there are 10 kilometers by road to Ulefoss. The highway Skien-Kongsberg-Oslo cuts the southern part of the Fen region. The nearest town is Skien, 30 kilometers by road to the southeast from Ulefoss. Skien lies on the Skien river, 10 kilometers from the estuary on the Oslo fjord.

Lake Nordsjø is 15 meters above sea level. It is connected with the sea by a lake and river system with slewses. The slewses can take boats up to 200 - 300 tons. From Ulefoss there are 24 kilometers by waterway to the port of Skien and 30 kilometers to the port of Porsgrunn further down the Skien river.

The landscape of the Fen region shows moderate relief with maximum height of 160 meters. The average height is 50 to 70 meters above sea level. The greater part of the Ren region is covered with fields and woods. Farming is the principle industry. In the western part of the region is the old Fen Iron mine which has been worked intermittently from 1652 to recent years.

The ground of the Fen region is to a great part owned by Søve Agricultural School, which belongs to the county of Telemark. The rest of the ground belongs to the Norwegian state and private farmers. The mining rights of columbium belongs to the Norwegian Department of Industry.

Geology of the Fen Region

The Fen region covers an area of about 6 square kilometers. It is built up of various so-called alkaline rocks and carbonate rocks. The region is younger than the surrounding bed rock formation which mainly consists of granitic gneiss.

Practically all rocks of the Fen region have a certain content of columbium. The ore minerals are kopite (calcium columbate) and columbite (a low titanium iron columbate). The tantalum content of the ore is low (Cb_2O_5:Ta_2O_5 = 200:1 for kopite and 100:1 for columbite). The columbium minerals are generally not recognizable to the eye. They occur as small crystals of a pinhead size or less. Under a magnifying lens the small cubes of kopite are easily distinguished.

There are few outcrops in the region. Analyses on samples from the outcrops, from the cores of diamond drill holes and from trenches indicate that the alkaline rocks in general have a content of 0.05 to 0.1 percent Cb_2O_5. The carbonate rocks in certain places have a content of 0.2 - 0.3 percent Cb_2O_5. Some samples show as much as 1 percent Cb_2O_5 and occasionally even more. Up to now, only the carbonate rocks have been considered as a potential columbium source.

The carbonate rocks generally contain 5 to 10 percent apatite (calcium phosphate) (2 - 4 percent P_2O_5). They are considered as a potential phosphate source.

The rocks met with in the Fen region and their apparent distribution are as follows. See fig. 1 and 2.

Fenite - This rock has been formed by alteration of the old granitic gneiss when the younger alkaline rocks were formed. It is mainly composed of alkali feldspars (sodium, potassium, aluminum silicate) and aegerine (sodium iron silicate). The rock is low in phosphorous some 1 percent P_2O_5, and the columbium content is generally less than 0.1 percent Cb_2O_5.

The fenite occurs in the peripheral parts of the Fen region. It forms a ring 100 to 400 meters broad along the greater part of the circumference of the region.

Alkaline Ricks - These rocks are mainly composed of the minerals nepheline (sodium, aluminum silicate : Na Al Si O_4) and aegerine deopside (a pyroxene mineral), in different proportions. They have a small content of apatite, calcite (calcium carbonate), titanite (calcium, titanium silicate), melanite (manganese garnet) and the columbium minerals kopite and columbite.

The chief types are urtite, ijolithe and melteigite. Urtite is an almost pure nepheline rock. Ijolithe consists of approximately equal amounts of nepheline and aegerine deopside. Melteigite has 30 percent or less nepheline and the rest is mainly aegerine diopside.

Vipetoite is a rock almost entirely composed of the dark minerals augite (calcium, magnesium silicate) and brown amphibole.

The southwestern part of the Fen region is built up of alkaline rocks. They probably cover some 1.5 square kilometers. The dominant types are ijolithe and melteigite. The amount of urtite seems to be negligible. Vipetoite probably do not cover more than 0.1 square kilometers.

The northwestern part of the Fen region is built up of a mixture of alkaline rocks, calcite rock (sövite) and other carbonate rocks. This part covers an area of about 1 square kilometers.

Damtjernite is a special type of rock which consists of large patches of biotite (a mica mineral) in a fine grained matrix. It is younger than the other rocks of the Fen region. It occurs in the form of dikes and pipes within the other rocks. It is also found outside the Fen region, in a distance of up to 50 kilometers from Ulefoss. The damtjernite probably covers an area of about 0.1 square kilometers.

The columbium content of the alkaline rocks is generally less than 0.1 percent Cb_2O_5. Vipetoite may have a higher columbium content. The content of phosphorous (in the form of apatite) in the alkaline rocks varies from 1 to 3 percent P_2O_5. In vipetoite the content of phosphorous is higher, some 4 percent P_2O_5.

Carbonate Rocks - There are three types of carbonate rocks: søvite, rauhaugite, and so-called red rock.

The søvite is a calcite (calcium carbonate) rock. It has generally 5 to 10 percent apatite and small amounts of magnetite, biotite pyrite, pyroxene and other dark minerals including the columbium minerals kopite and columbite. Søvite occurs in two small areas in the southern part of the Fen region and in the form of lenses cutting fenite in the northern part of the region (the Hydro and Cappelen occurrences). In the northwestern part of the Fen region (an area of about 1 square kilometer) søvite occurs intimately mixed with alkaline rocks.

Generally the content of columbium in the søvite seems to be less than 0.1 percent Cb_2O_5. However in the Hydro occurrence, the Cappelen occurrence, and partly in the Tufte occurrence it is higher: 0.2 to 0.5 percent Cb_2O_5 and occasionally 1 percent Cb_2O_5 and even more. The søvite generally contains 2 - 4 percent P_2O_5.

Rauhaugite is an ankerite (calcium, magnesium, iron carbonate) rock. It has also some calcite and apatite and small amounts of biotite and other dark minerals including columbite and kopite.

Rauhaugite covers an area of about 1.5 square kilometers in the northeastern part of the Fen region. It also occurs mixed with søvite and alkaline rocks, for instance in the Tufte occurrence.

In the Tufte occurrence the rauhuagite generally contains 0.3 to 0.5 percent Cb_2O_5. Here it is the chief columbium ore.

It is not possible to say anything about the columbium content of the large rauhaugite area in the northeastern part of the Fen region, only a few analyses having been made on samples from this area.

The content of phosphorous in the rauhaugite varies considerably. In the Tufte occurrence it is generally 3 to 5 percent P_2O_5. In the large rauhaugite area to the northeast it seems to be less.

The so-called red rock is composed of calcite and finely distributed haematite (Fe_2O_3). It may also have a certain content of ankerite. In some places there are considerable segregations of haematite. The red rock occurs in areas in the eastern part of the Fen region. Here the old Fen iron mine is situated. Some times the red rock occurs intimately mixed with alkaline rocks, sø vite and rauhaugite, e.g. in the Tufte occurrence.

Only a few analyses have been made on the red rock. Some analyses show 0,3 to 0,5 percent Cb_2O_5. The content of phosphorous in the red rock varies considerably, much in the same way as in rauhaugite.

So far only three columbium occurrences within the Fen region have been investigated in any detail. They are: the Hydro occurrence, the Cappelen occurrence and the Tufte occurrence.

The Hydro Occurrence

(See fig. 3)

The Hydro occurrence is a body of calcite rock (sø vite) about 500 meters long and with a maximum width of 50 meters, running in a southwesterly direction from the Hydro quarry at the shore of Lake Nordsjø in the northern part of the Fen region. It dips 50 degrees to 75 degrees to the southeast. The Hydro quarry is 300 meters north of the Sø ve agricultural school. This occurrence is generally referred to as the Hydro dike.

The greater part of the Hydro occurrence is some 30 meters above the level of Lake Nordsjø. The occurrence is surrounded by fenite. On the surface the sø vite body has a maximum width of about 25 meters and shows sharp contact towards the fenite. Smaller bodies run parallel with the main body or branch off from the main body. At the level of Lake Nordsjø the main sø vite body is some 50 meters broad. Here it has a 10 meter broad marginal zone towards the fenite on either side. In the marginal zone the calcite rock is mixed with ankerite, feldspar, amphibole and manganophyl (manganese mica).

The reserves of calcite rock (sø vite) above the level of Lake Nordsjø is estimated at 300,000 cubic meters or about 750,000 tons.

The fairly homogeneous søvite of the Hydro occurrence is a coarsely crystalline marble composed of about 90 percent calcite, about 5 percent apatite and small amounts of magnetite, biotite, pyrite, pyroxene and other dark minerals including kopite and columbite. There seem to be about equal amounts of kopite and /columbite./

The survey of the Hydro occurrence includes 8 trenches and 7 diamond drill holes. The position of the holes and the trenches is shown on the map in fig. 2. Analyses of samples from the trenches and the cores of the diamond drill holes gave the following result:

Trench 1.	Average of 6	analyses	(Length 8	meters)	0.26% Cb_2O_5
Trench 2.	" " 12	"	" 19	"	0.21" "
Trench 3.&3b.	" " 11	"	" 16 + 2.5"		0.16" "
Trench 4.	" " 10	"	" 25	"	0.29" "
Trench 5.	" " 7	"	" 15	"	0.08" "
Trench 6.	" " 5	"	" 16	"	0.19" "
Trench 7.	" " 2	"	" 5	"	0.25" "
Trench 8.	" " 4	"	" 8	"	0.25" "
Hole 1.	" " 17	"	" 60	"	0.27" "
Hole 2.	" " 16	"	" 60	"	0.12" "
Hole 3.	" " 36	"	" 97	"	0.20" "
Hole 4.	" " 16	"	" 52	"	0.25" "
Hole 5.	Data missing		" 107	"	
Hole 6.	"	"	" 78	"	
Hole 7.	"	"	" 70	"	

In Appendix 1 the logs of the trenches and the diamond drill holes are given.

It seems justified to assume that the average columbium content of the Hydro occurrence is not less than 0.2 percent Cb_2O_5.

Calculating with 750,000 tons of ore above the level of Lake Nordsjø the total content of columbium is 1500 tons Cb_2O_5 in the form of kopite and columbite.

The søvite of the Hydro occurrence has an average content of 2 percent P_2O_5. The reserves of phosphorous in the form of apatite above the level of Lake Nordsjø is estimated at 15,000 tons P_2O_5.

The diamond drilling carried out is insufficient to allow estimation of ore reserves below the level of Lake Nordsjø. Indications are, however, that there are considerable ore reserves below this level.

The marginal zone of the søvite body and the fenite bordering the body also seem to have a considerable content of columbium. Stray analyses show that the columbium content of these rocks may be as much as 0.4 percent Cb_2O_5. This type of ore has not been investigated.

The Cappelen Occurrence

(See fig. 4)

The Cappelen occurrence is a rather flat-lying sǿvite body with a maximum length of 100 meters in an easterly direction. The body is 30 to 40 meters broad on the surface. It dips slightly to the south and is quickly thinning out in thid direction. The occurrence is surrounded by fenite. The occurrence is about 200 meters east of the Hydro quarry.

The reserves of sǿvite above the level of Lake Nordsjǿ is estimated to 60,000 cubic meters or 150,000 tons. The greater part of the lens is above the level of the lake. There are possibly an additional 50,000 tons below the level of the lake.

The sǿvite of the Cappelen occurrence is a crystalline marble composed of 80 to 85 percent calcite and 5 to 10 percent apatite. The rest is mainly magnetite. The ore minerals are kopite and columbite. Apparently there are about equal quantities of these two minerals.

The survey of the Cappelen occurrence includes two trenches and four diamond drill holes. Analyses of samples from the trenches and the holes gave the following result: (The position of the trenches and holes are indicated on the map in fig. 2).

Trench 1.	(Length 43 meters)	Average of 5 analyses:	0.4% Cb_2O_5	
Trench 2.	" 19 "	" " 2 "	0.27" "	
Hole 1.	" 35 "	" " 9 "	0.24" "	
Hole 2.	" 82.5 "	" " 20 "	0.28" "	
Hole 3.	" 60 "	" " 17 "	0.16" "	
Hoel 4.	" 120 "	5 analyses. Little ore.		

In Appendix 2 the logs of the trenches and the diamond drill holes are given.

The average columbium content of the sǿvite of the Cappelen occurrence can be estimated at 0.25 to 0.3 percent Cb_2O_5. The total reserves of columbium in the Cappelen occurrence in the form of the minerals columbite and kopite are estimated to about 400 tons Cb_2O_5.

The average content of phosphorous in the sǿvite of the Cappelen occurrence seems to be 4 percent P_2O_5. The reserves of phosphorous in the form of apatite are estimated at 6000 tons P_2O_5.

North of the main sǿvite body of the Cappelen occurrence are two smaller bodies which are estimated to contain 10,000 cubic meters of sǿvite or 25,000 tons. The average columbium content seems to be 0.2 percent Cb_2O_5. The average content of phosphorous seems to be about 2 percent P_2O_5.

The reserves of columbium in these bodies are estimated at 50 tons of Cb_2O_5 and the reserves of phosphorous to 500 tons P_2O_5.

The Tufte Occurrence

(See fig. 5)

The ore of the Tufte occurrence is a mixture of sǿvite (calcite rock), rauhaugite (ankerite rock) alkaline rocks, and a little red rock, rauhaugite being the principle ore type.

The Tufte occurrence is near the Tufte farms about 700 meters south from Sǿve agricultural school. It is close to the main road from Ulefoss to the town of Skien. The area which has been surveyed is about 40,000 square meters (about 300 meters in a northerly direction and about 150 meters in an easterly direction).

The Tufte occurrence has an average height of about 75 meters above sea level. The occurrence has no geologic border. It is surrounded by the same type of rocks as in the occurrence proper, but apparently the surrounding rocks have less columbium content.

The Tufte occurrence is fairly well exposed. The dominant rock types are sǿvite (calcite rock), biotite, calcite rock and chlorite calcite rock (the two latter often being referred to as greenstone) and rauhaugite (ankerite rock). There are probably not more than 25 percent of alkaline rocks (sodium silicate rocks) in the total rock mass of the Tufte occurrence.

The various rocks occur in an intimate intermixture. They form "schlieren" which mostly run in a northerly or northeasterly direction, generally with a steep dip. In some places there are large and fairly homogeneous masses of calcite rock (sǿvite) e.g. in the Tufte quarry, and in other places there are large and fairly homogeneous masses of rauhaugite (ankerite rock).

Rauhaugite has the largest columbium content of the rocks in the Tufte occurrence. It has generally from 0.3 to more than 1 percent Cb_2O_5. The calcium carbonate rocks at the Tufte occurrence (sǿvite and greenstone) and the alkaline rocks generally have a columbium content of less than 0.1 percent Cb_2O_5. However, the sǿvite of the Tufte quarry has a larger content of columbium, up to 1 percent Cb_2O_5.

The columbium of the Tufte occurrence is largely confined to columbite. Very little kopite has been observed.

The carbonate rocks of the Tufte occurrence seem to have an average content of phosphorous of 4 percent P_2O_5 (8 to 10 percent apatite). Locally it may be higher, up to 20 percent apatite and

even 60 percent apatite in certain "schlieren". The alkaline rocks seem to have an average content of phosphorous of 2 - 3 percent P_2O_5.

The survey of the Tufte occurrence includes 6 trenches and 5 diamond drill holes. The position of the holes and the trenches is shown in the maps in figures 2 and 5. Analyses of samples from the trenches and the cores of the diamond drill holes gave the following results:

Trench A.	(Length 50 meters)	Average of 5	analyses	0.28 %	Cb_2O_5
Trench B.	" 20 "	"	" 3 "	0.30 "	"
Trench C.	" 100 "	"	" 14 "	0.33 "	"
Trench D.	" 65 "	"	" 4 "	0.26 "	"
Trench E.	" 15 "	"	" 1 "	0.18 "	"
Trench F.	" 40 "	"	" 3 "	0.28 "	"
Hole 1.	" 65 "	"	" 16 "	0.39 "	"
Hole 2.	" 50 "	"	" 14 "	0.13 "	"
Hole 3.	" 80 "	"	" 18 "	0.20 "	"
Hole 4.	" 62 "	"	" 13 "	0.26 "	"
Hole 5.	" 50 "	"	" 10 "	0.20 "	"

The logs of the trenches and the diamond drill holes are given in Appendix 3.

The logs show that in Hole 1 there is a zone of 30 meters length having a columbium content of 0.28 to 1.10 percent Cb_2O_5. In Hole 2 there is a zone of 10 meters length having a columbium content of 0.20 percent to 0.40 percent Cb_2O_5. In Hole 3 there is a zone of 30 meters length having a columbium content of 0.21 to 0.72 percent Cb_2O_5. In Hole 4 there is a zone of 23 meters length having a columbium content of 0.36 to 0.76 percent Cb_2O_5. In Hole 5 there is a zone of 23 meters length having a columbium content of 0.27 to 0.66 percent Cb_2O_5. These high contents of columbium are largely confined to the rock rauhaugite.

The investigations carried out on the Tufte occurrence are insufficient to justify any calculation of the ore reserves. However, we can make a very rough estimate.

The rock mass of the Tufte occurrence to the level of Lake Nordsjø can be estimated to about 6,000,000 tons. It seems likely that about 1/3 of this rock mass, or 2,000,000 tons, consists of rauhaugite. It seems justified to assume that the rauhaugite of the Tufte occurrence has an average columbium content of 0.4 - 0.5 percent Cb_2O_5. This would give a total reserve of columbium (mainly in the form of columbite) of 8,000 - 10,000 tons Cb_2O_5 in the rauhaugite.

It will generally not be possible to mine the rauhaugite without considerable contamination of other rocks with a lower columbium content. The effective tenor of columbium will thus be

less than 0.5 percent Cb_2O_5. There are probably about 4,000,000 tons of rock with an average content of 0.25 - 0,3 perdent Cb_2O_5 above the level of Lake Nordsjø (10,000 tons Cb_2O_5).

Without doubt the columbium mineralization extends below the level of Lake Nordsjø. It may thus be large additional ore reserves in this occurrence.

The content of phosphorous in the estimated 2,000,000 tons of rauhaugite is about 80,000 tons P_2O_5. In the estimated 4,000,000 tons of ore of the Tufte occurrence (to the level of Lake Nordsjø) the content of phosphorous is about 160,000 tons of P_2O_5.

The area north of the Tufte occurence to the small farms Grua and Norenda is geologically very much like the Tufte occurrence, only there seem to be considerably more rauhaugite. However, it seems that the rauhaugite of this area has not the high content of columbium that is characteristic for the rauhaugite of the Tufte occurrence.

This area is poorly exposed. The survey includes the diamond drill holes Søve 1, 2, 3 and 5 and the trenches G and H. About 80 analyses have been made of the cores of the diamond drill holes and about 50 analyses on samples from the trenches. Very few of these analyses show a columbium content over 0.1 percent Cb_2O_5.

Other Occurrences

The area east of Søve agricultural school to the Søve bay has been surveyed by the diamond drill hole Søve 4 and by the trenches Søve B, C-D, E and F. The rocks are the same as in the Tufte occurrence, an intimate mixture of søvite, rauhaugite and alkaline rocks with occasional "schlieren" of red rock. The columbium content of the søvite and the alkaline rocks are generally less than 0.1 percent Cb_2O_5. In the rauhaugite and in the red rock the columbium content is occasionally high, up to 0.5 percent Cb_2O_5. However, most of the analyses of the rauhaugite and the red rock also show columbium contents of less than 0.1 percent Cb_2O_5. The rocks of this area have a content of phosphorous varying from 2 to 4 percent P_2O_5.

The søvite area Vipeto south of the farms in the southern part of the Fen region (see map in fig. 1) is surveyed by the trenches Vipeto A and B and a few stray samples. Twenty-three analyses have been made on samples from the trenches. Most of

the analyses show a columbium content of less than 0.1 percent Cb_2O_5. A few analyses show 0.2 percent Cb_2O_5 and one single analysis 0.3 percent Cb_2O_5. This area is about 50,000 square meters.

The sövite area east of the farms Vipeto (covering an area of about 10,000 square meters) has not been investigated.

Only a few samples have been taken from the large areas of rauhaugite and red rock in the eastern part of the Fen region. These stray samples generally show a low columbium content, about 0.1 percent Cb_2O_5. This area ought to be properly surveyed, considering the fact that rauhaugite and red rock are the rocks showing the highest content of columbium in the Tufte occurrence.

Ore Reserves

The exploratory work carried out in the Fen region has been concentrated at three places: The Hydro occurrence, the Cappelen occurrence and the Tufte occurrence. The drilling and trenching are not sufficient for calculating proven ore. Considering geologic factors, however, it is probable that the reserve estimates given below represent minimum reserves.

The ore minerals are columbite and kopite. The columbium tantalum ratio in the two minerals is: $Cb_2O_5:Ta_2O_5$ = 200:1 for kopite and 100:1 for columbite.

The reserve estimates only include ore with an average content of 0.2 percent Cb_2O_5 or more. It should be emphasized that the columbium ore is generally not a homogeneous ore. The columbium content varies from 0.05 percent Cb_2O_5 to more than 1 percent Cb_2O_5 in different parts of the ore bodies. (See Appendices 1, 2 and 3.) In some cases, particularly in the Tufte occurrence, it will probably be possible to mine some of the richer parts of the ore body separately, thus getting a certain tonnage of ore with 0.4 to 0.5 percent Cb_2O_5.

The lower limit reached by drill tests approximates the level of Lake Nordsjø. Columbium mineralization undoubtedly extends considerably below this level except in the Cappelen occurrence.

The reserve estimates given below only include ore above the level of Lake Nordsjø:

Hydro occurrence: 750,000 tons of ore with an average content of 0.2% Cb_2O_5 ..... 1500 tons Cb_2O_5

Cappelen occurrence: 175,000 tons of ore with an average content of 0.25-0.3% Cb_2O_5 .... 450 tons of Cb_2O_5

Tufte occurrence: 4,000,000 tons of ore with an average content of 0.25-0.3% Cb_2O_5 .... 10,000 tons of Cb_2O_5

TOTAL ... about 5,000,000 tons of ore ... about 12,000 tons Cb_2O_5

The reserve estimates of phosphorous in the form of apatite in the ore are:

Hydro occurrence: 750,000 tons of ore with an average content of 2% P_2O_5 ..... 15,000 tons P_2O_5
Cappelen occurrence: 175,000 tons of ore with an average content of nearly 4% P_2O_5 ..... 6,500 " "
Tufte occurrence: 4,000,000 tons of ore with an average content of 4% P_2O_5 .....160,000 " "

TOTAL ..... about 180,000 tons P_2O_5

Practically all rocks in the Fen region have a certain content of columbium, generally between 0.05 and 0.1 percent Cb_2O_5. reserves of this type of ore are probably several hundred million tons.

Geologic features indicate that important occurrences of ore with 0.2 percent Cb_2O_5 or more may be found in the area east of Søve agricultural school and in the rauhaugite- red rock area in the eastern part of the Fen region.

Basis for Reserve Estimates

The figures given for reserves of columbium are merely estimates. They are based on estimates of the volume of the columbium mineralized rock mass in the three occurrences considered in this report (to the level of Lake Nordsjø) and estimates of the average content of columbium in the occurrences.

The volume of the three occurrences are estimated by measuring the surface area of the occurrences, the maximum width and the depth. The two latter figures have been obtained by diamond

drilling. The estimates of the average content of columbium in the occurrences are based on assay (spectrographical analyses) of cores of diamond drill holes and samples from trenches (channel sampling).

At the Hydro occurrence 7 diamond drill holes and 8 trenches were made, in the Cappelen occurrence 4 holes and 2 trenches, in the Tufte occurrence 5 holes and 6 trenches. The general plan for drilling has been to establish profiles across the prevailing rock structure.

In Appendices 1, 2 and 3 is a record of the exploratory work carried out in the Hydro occurrence, the Cappelen occurrence and the Tufte occurrence respectively.

The total exploratory drilling in the Fen region is 22 holes, 50 to 120 meters long. Total length of holes is about 1700 meters. About 300 meters of trenches have been made.

The assay of the diamond drill cores and samples from the trenches were generally made in 1 to 3 meter intervals, occasionally greater intervals. The diamond drill core was split and one-half of the core was filed for future reference.

The columbium content was determined by means of spectrographic analyses. The greater part of the analyses have been made at Statens Raastofflaboratorium (Mineral resources laboratory of the State). Some analyses, particularly on samples from the Hydro occurrence, were made at the laboratory of the Norsk Hydro-Elektrisk Kvaelstofaktieselskap in Rjukan. The analyses made by Statens Raastofflaboratorium are more reliable than those made by the Hydro firm, the former laboratory having the better equipment. Mr. Hvalheim, the director of the Statens Raastofflaboratorium, maintains that the spectrographic analyses are accurate to plus or minus 10 percent. Some of the spectrographic analyses of the Hydro occurrence were checked by gravimetric analyses.

The content of phosphorous in the ore was also determined by means of spectrographic analyses.

Past Production

The Hydro and Cappelen occurrences have been worked intermittently on a small scale for calcite rock (søvite) production. A few hundred tons of calcite rock have been produced at both occurrences. The Hydro quarry is an opening about 10 meters wide, 10 meters deep and 5 meters high. The Cappelen quarry is a shallow opening about 7 meters wide and a few meters high.

The Tufte quarry was opened in 1943. It is an opening about 30 meters long and 10 meters high. About 2000 tons of søvite was produced in that year. It was ground to søvite flour, sold for its phosphate content, and then used as a fertilizer.

In 1943 the Germans started surveying the Fen region for columbium. The work was carried out on behalf of I.G. Farbenindustrie A.G. Up to the time of the German capitulation in Norway, May 1945, one million Norwegian kroner (about $200,000 at the rate current at that time) had been spent. The Germans had planned to start production of columbium concentrates in the autumn of 1945. Most of the drilling described above was done on German initiative. They made concentration experiments on a pilot plant scale and also did some metallurgical work.

Survey Carried Out in the Fen Region
(March 1950)

The Tufte Occurrence

Diamond drill holes:	Length in Meters	Number of Columbium Analyses
Tufte 1	65	16
Tufte 2	50	14
Tufte 3	80	18
Tufte 4	62	13
Tufte 5	50	10
Trenches:		
Trench A	50	5
" B	20	3
" C	100	14
" D	65	4
" E	15 + 5	1
" F	40	3

The Hydro Occurrence

Diamond drill holes:		
Hydro 1	60	18
Hydro 2	60	16
Hydro 3	97	36
Hydro 4	51	16
Hydro 5	107	Data missing
Hydro 6	78	" "
Hydro 7	70	" "
Trenches:		
1	8	6
2	19	12
3b	2.5	2
3	16	10
4	25	10
5	15	7
6	16	5
7	5	2
8	8	4

(March 1950 cont.)

The Cappelen Occurrence

Diamond drill holes:

Cappelen 1	35	9
Cappelen 2	82.5	20
Cappelen 3	60	17
Cappelen 4	120	5

Trenches:

1	43	5
2	19	2

Other Areas

6 diamond drill holes: Søve 1 - 6
9 trenches

The Hydro Occurrence

Columbium Content of Diamond Drill Cores

Hole 1 (H1)

Length in Meters	Percent Cb_2O_5
24 - 26	0.3
26 - 28	0.3
28 - 30	1.0
30 - 32	0.2
32 - 34	0.2
34 - 36	0.2
36 - 38	0.1
38 - 40	0.1
40 - 42	0.1
42 - 43	<0.1
43 - 45	0.2
45 - 47	0.4
47 - 49	0.25
49 - 51	0.5
51 - 53	0.2
53 - 55	0.4
55 - 57	0.1
57 - 59	0.2
Average content	0.27

Appendix I.

The Hydro Occurrence

Columbium Content of Diamond Drill Cores

Hole 2 (H2)

Length in Meters	Percent Cb_2O_5
15 - 16	0.3 - 0.4
19 - 20	0.25
32 - 34	<0.2
34 - 36	0.3
36 - 38	<0.2
38 - 40	0.25
40 - 42	0.1
42 - 44	<0.1
44 - 46	0.1
46 - 48	<0.1
48 - 50	0.1
50 - 52	0.1
52 - 54	<0.1
54 - 56	0.2
56 - 58	0.15
58 - 60	<0.1
Average content (32 - 58)	0.12

Appendix I

The Hydro Occurrence

Columbium Content of Diamond Drill Cores
Hole 3 (H3)

Length in Meters	Percent Cb_2O_5
21 - 23	0.2
23 - 25	0.1
25 - 27	0.1
27 - 29	0.1
29 - 31	0.1
31 - 33	0.5
33 - 35	0.5
35 - 37	0.5
37 - 39	0.3
39 - 41	0.4
41 - 43	0.4
43 - 45	0.3
46 - 48	0.2
48 - 50	0.1
50 - 52	0.1
52 - 54	<0.1
54 - 56	<0.1
56 - 58	0.2
58 - 60	0.2
60.5 - 62	0.5
62 - 64	0.5
64 - 66	>1.0
66 - 68	0.05
68 - 70	0.3
70 - 72	0.05
72 - 74	0.05
74 - 76	0.25
76 - 78	0.15
78 - 80	<0.1
80 - 81	0.1
83 - 84	<0.1
86 - 87	<0.1
89 - 90	<0.1
90.5 - 92.7	0.1
93 - 95	<0.2
96 - 97	<0.2
Average content (31 - 77)	0.29

Appendix 1

The Hydro Occurrence

Columbium Content of Diamond Drill Cores

Hole 4 (H4)

Length in Meters	Percent Cb_2O_5
12 - 14	0.5
14 - 16	0.1
16 - 17	0.5
19 - 21	0.5
21 - 23	0.1
23 - 25	0.3
25 - 27	0.1
27 - 29	0.2
29 - 31	0.2
31 - 33	<0.1
33 - 35	<0.1
35 - 37	0.5
42.6 - 43.6	0.1
45.4 - 47.4	0.5
47.4 - 49.4	0.2
49.4 - 51.4	0.5
Average content	0.25

Appendix 1

Columbium Content of Trenches at the Hydro Occurrence

Trench 1

Analysis No.	Meters North or South of Reference Line	Percent Cb_2O_5
1	4.50 m north	<0.1
2	5.50 " "	0.7
3	6.50 " "	0.6
4	7.50 " "	0.1
5	9.50 " "	<0.1
6	10.50 " "	<0.1
Average content		0.26

Trench 2

1	14.5 m south	<0.1
2	12.0 " "	0.2
3	10.0 " "	0.1
4	9.0 " "	0.2
5	6.5 " "	0.1
6	4.5 " "	<0.1
7	3.0 " "	0.1
8	2.0 " "	0.1
[illegible]	0.5 " north	>1.0
[illegible]	2.5 " "	0.1
11	3.5 " "	0.2
12	5.5 " "	0.3
Average content	[illegible]	0.21

Appendix 2

Columbium Content of Trenches at the Hydra Occurrence

Trench 3b.

Analysis no.	Meters North or South of Reference	Percent Cb_2O_5
1	20.0 m south	0.3
2	18.5 m "	0.2

Trench 3

1	21.0 m south	0.2
2	18.0 m "	0.2
3	17.0 m "	<0.1
4	16.0 m "	0.2
5	15.0 m "	0.2
6	13.0 m "	0.1
7	10.0 m "	<0.1
8	9.0 m "	0.3
9	7.5 m "	0.1
10	m "	<0.1
Average content (3 and 3b)		0.16

Trench 4

1	20.5 m south	0.3-0.4
2	19.5 m "	0.4
3	18.0 m "	1.0
4	16.5 m "	0.1
5	15.0 m "	<0.1
6	13.0 m "	0.1
7	11.5 m "	<0.1
8	9.0 m "	0.15
9	5.5 m "	0.6
10	3.5 m "	0.1
Average content		0.29

Trench 5

1	9.0 m south	<0.1
2	8.0 m "	<0.1
3	5.0 m "	<0.1
4	3.0 m "	<0.1
5	1.0 m north	<0.1
6	7.0 m "	0.1
7	8.5 m "	0.2
Average content		0.08

Trench 6		
1	8.5 m south	<0.1
2	7.0 m "	0.4
3	3.0 m north	0.2
4	4.0 m "	0.1
5	6.0 m "	0.2
Average content		0.19
Trench 7		
1	3.0 m south	0.4
2	0.5 m "	0.1
Average content		0.25
Trench 8		
1	17.0 m south	<0.5
2	15.0 m "	0.1
3	13.0 m "	0.4
4	11.0 m "	<0.1
Average content		0.25

Appendix 2

The Cappelen Occurrence

Columbium Content of Diamond Drill Cores

Hole C 1

Analysis no.	Length in Meters	Percent Cb_2O_5
1	15 - 16	0.2
2	19 - 21	0.1
3	21 - 23	0.2
4	23 - 25	0.4
5	25 - 27	0.5
6	27 - 29	0.4
7	29 - 31	<0.1
8	31 - 33	0.2
9	33 - 35	0.1
Average content		0.24

Appendix 2

The Cappelen Occurrence

Columbium Content of Diamond Drill Cores

Hole C 2

Analysis no.	Length in Meters	Percent Cb_2O_5
1	10.5	0.08
2	13.0	0.40
3	16.5	0.58
4	22.5	0.29
5	30.2	1.12
6	30.5	0.56
7	32.6	0.34
8	38.6	0.22
9	41.0	0.05
10	45.0	0.05
11	48.2	0.06
12	49.5	0.03
13	50.3	0.11
14	55.5	0.08
15	59.6	0.43
16	63.2	0.07
17	64.2	0.04
18	65.5	0.47
19	69.0	0.19
20	73.3	0.12
	82.5	
Average content		0.28

Appendix 2

The Cappelen Occurrence

Columbium Content of Diamond Drill Cores

Hole C 3

Analysis no.	Length in Meters	Percent Cb_2O_5
1	0 - 5.95	0.07
2	5.95 - 10.8	0.27
3	10.8 - 14.7	0.28
4	14.7 - 19.8	0.48
5	19.8 - 24.1	0.27
6	24.1 - 25.5	0.07
7	25.5 - 28.5	0.11
8	28.5 - 33.0	0.05
9	33.0 - 36.0	0.12
10	36.0 - 38.2	0.07
11	38.2 - 40.2	0.15
12	40.2 - 43.7	0.21
13	43.7 - 46.2	0.23
14	46.2 - 49.5	0.08
15	49.5 - 53.7	0.07
16	53.7 - 55.8	0.09
17	55.8 - 60.2	0.08
Average content		0.16

Hole C 4

Average content	0.1

Appendix 2

The Cappelen Occurrence

Columbium Content of Trenches

Trench 1.	Meters North or South of Reference Line	Percent Cb_2O_5
1	10.0 m south	0.5
2	15.0 m "	0.4
3	1.5 m north	0.3
4	9.0 m "	0.4
5	15.0 m "	0.4
Average content		0.4
Trench 2		
1	0.5 m north	0.5
2	4.5 m "	<0.1
Average content		0.27

Appendix 3

The Tufte Occurrence

Columbium Content of Diamond Drill Cores

Hole Tufte 1 (T 1)

Length in Meters	Percent Cb_2O_5
0 - 2.4	0.55
2.4 - 3.45	<0.07
3.45 - [illegible]	0.69
[illegible] - 8.80	0.28
8.80 - 9.75	0.44
9.75 - 15	0.42
15 - 20	0.55
20 - 25	0.80
25 - 30	0.68
30 - 35	1.10
35 - 40	≤0.07
40 - 45	<0.07
45 - 50	0.32
50 - 55	0.08
55 - 60	<0.07
60 - 65.20	<0.07
Average content	0.39

Appendix 3

Hole Tufte 2 (T 2)

Length in Meters	Percent Cb_2O_5
0 - 0.5	0.25
0.5 - 6	0.40
6 - 9.40	0.20
9.40 - 10.80	<0.07
10.80 - 12.90	≦0.07
12.90 - 15.50	<0.07
16.22 - 20	0.15
20 - 25	≦0.07
25 - 30	<0.07
30 - 35	≦0.07
35 - 39.50	0.18
39.50 - 45	<0.07
45 - 49.30	<0.07
49.30 - 50.20	≦0.07
Average content	0.13

Appendix 3

Hole Tufte 3 (T 3)

Length in Meters	Percent Cb_2O_5
0 --- 4.50	0.30
4.50 - 6.53	0.32
6.53 - 10	<0.07
10 - 15	<0.07
15 - 20	<0.07
20 - 25	0.21
25 - 30	≤0.07
30 - 35	≤0.07
35 - 40	0.15
40 - 45	≤0.07
45 - 50	<0.07
50 - 53.45	0.21
53.45 - 59.30	0.38
[illegible] - 63.35	0.72
[illegible] - 68.85	0.44
68.85 - 71.60	≤0.07
71.60 - 74.50	≤0.07
74.50 - 79.63	0.35
Average content	0.20

Appendix 3

Hole Tufte 4 (T 4)

Length in Meters	Percent Cb_2O_5
0 - 5	0.17
5 - 10	≦0.07
10 - 15	0.10
15 - 20.70	0.15
20.70 - 27.80	0.12
31.80 - 33.20	≦0.07
34.90 - 36.45	<0.07
36.45 - 40	0.36
40 - 44.70	0.62
44.70 - 50	0.40
50 - 56.20	0.39
56.20 - 59.80	0.76
59.80 - 61.96	<0.07
Average content	0.26

Appendix 3

Hole Tufte 5 (T 5)

Length in Meters	Percent Cb_2O_5
[illegible] - 5	0.30
5 - 10	0.30
10 - 15	0.27
[illegible] - 20	0.66
20 - 23.30	0.40
2[illegible]45 - 31.60	<0.07
31.60 - 36.65	<0.07
36.65 - 40	<0.07
40 - 45	<0.07
45 - 49.80	<0.07
Average content	0.20

Appendix 3

Columbium Content of Trenches at the Tufte Occurrence

		Percent Cb_2O_5
Trench A		
Analyses:		
	1	0.08
	2	0.43
	3	0.30
	4	0.18
	5	0.41
	Average content	0.28
Trench B		
	1	0.15
	2	0.19
	3	0.55
	Average content	0.30
Trench C		
	1	0.22
	2	0.61
	3	0.46
	4	0.43
	5	<0.07
	6	<0.07
	7	0.24
	8	0.42
	9	0.16
	10	0.45
	11	0.45
	12	0.33
	13	0.47
	14	0.24
	Average content	0.33
Trench D		
	1	0.40
	2	0.46
	3	0.09
	4	<0.07
	Average content	0.26
Trench E		
	1	0.18
	Average content	0.18
Trench F		
	1	0.14
	2	0.31
	3	0.40
	Average content	0.28