

VIDENSKAPSSELSKAPET I KRISTIANIA

RESULTATER
AV DE NORSKE STATSUNDERSTØTTEDE
SPITSBERGENEKSPEDITIONER

BIND I

Nr. 3

**W. WERENSKIOLD AND IVAR OFTEDAL:
A BURNING COAL SEAM AT MT. PYRAMIDE
SPITSBERGEN**

WITH 7 FIGS. IN TEXT AND 1 PLATE

UTGIT PAA
DEN NORSKE STATS BEKOSTNING
VED SPITSBERGENKOMITEEN

REDAKTØR: ADOLF HOEL

KRISTIANIA
I KOMMISSION HOS JACOB DYBWAD
1922

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A BURNING COAL SEAM
AT MT. PYRAMIDE, SPITSBERGEN

BY

W. WERENSKIOLD AND IVAR OFTEDAL

WITH 7 FIGS IN TEXT AND 1 PLATE

I. Field Observations on the Geology of the Region and the Fire.

By

W. WERENSKIOLD

(WITH FIGS 1—5)

The great Ice Fjord on the west coast of Spitsbergen has several branches; the middle branch is called Klaas Billen Bay, and is about 30 kilometers long. This fjord runs towards NNE between flat-topped hills. To the west of the innermost bay lies Mt. Pyramide, which is about 900 meters high, and on the south side, this hill slopes down towards a valley, called "Mimers Dal", and is there furrowed by two

minor valleys, forming narrow and steep gullies. On the westward slope of the ridge between these gullies, a coalbed is actually a-fire, at a place about 360 meters above sea-level. In the year 1908, a Norwegian scientific expedition visited this region and made geological investigations. Some plant fossils collected at the base of Mt. Pyramide have been examined and described by professor NATHORST. In order to complete the work, the

same place was visited again, in August, 1921, by a party of the Norwegian Scientific Spitsbergen Expedition, including the author. Seeing the smoke from below, we climbed the steep talus slope up to the burning coal bed. Here we collected some minerals, which have been subjected to an examination at the Mineralogical-Geological Museum of the University of Kristiania, by Mr. OFTEDAL, who will communicate the results of his investigations in a special article, the description of the geological features having been left to me.

The geological features of the region in question may be briefly summarized thus: Devonian sandstone and schists have been tilted and denuded, and the lower carbonian Culm Sandstone has been deposited upon this plane of denudation, and lies discordantly upon the devonian rocks. The whole complex has been tilted again, and denuded once

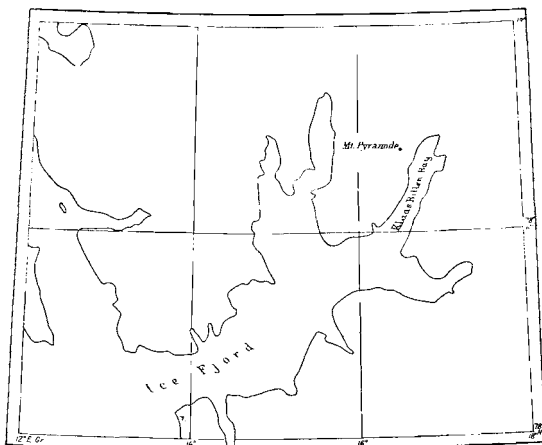


Fig. 1. Sketch map showing position of Mt. Pyramide.

more, and then the upper carbonian Cyathophyllum Limestone has been deposited in great thickness.

The devonian rocks are mostly red-coloured, and so is also the Culm Sandstone, in places where the material has been derived from the devonian beds. It is then often difficult to draw the line between these formations. But at most places the Culm consists of thick beds of a coarse, grey or whitish quartz sandstone, with some layers of dark shales. These are little conspicuous from a distance, being covered by heavy talus from the over-lying sandstone beds. The zones of shales contain seams or beds of coal, very variable both as to extent, thickness and quality. The coal beds of this formation seem to be best just in the above mentioned Mt. Pyramide. Several coal beds are here found,

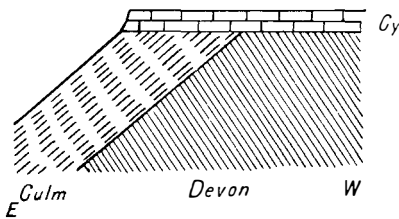


Fig. 2 Sketch of flat-topped hill south of Mimers Bay. Devon = devonian slates. Culm = culm sandstone. Cy = Cyathophyllum limestone (upper Carbonian).

about 100 meters above the base of the Culm system. The beds are inclined at an angle of about 30° to the east, and the coal-seams are seen outcropping here and there along the western slope of the ridge between the two small tributary valleys, mentioned before; the boundary between the devonian and the Culm follows approximately the river bed of the westernmost of these gullies. The geology of the district has been studied by Mr. BERTIL HÖGBOM, with special

regard to the value of the coal beds. HÖGBOM mentions some big dislocations or flexures; but during our short visit we did not notice any dislocations, only strongly tilted beds, and planes of discordance. A Swedish company has opened a mine on the coal bed, at a height of about 100 meters above the sea; but higher up, at some 250 meters, the outcrops are best exposed. As the succession of the various seams and beds is different at these places, it is believed by HÖGBOM, that there are two different beds, one about 30 to 40 meters above the other, and that the mine is worked on the uppermost, and thinnest one. The sinking of a shaft from the mine proved that the assumption of Mr. HÖGBOM was correct.

The coal is characterized as "splint-coal". The composition — a mean of 7 analyses, — is as follows:

$$\begin{array}{rcl} C = 75.7 \% & H = 4.6 \% \\ O + N = 9.22 \% & S = 0.48 \% \end{array}$$

Calorimetric value, 7000 Cal. Percentage of ashes, about 10 to 15. As seen from the section, there are many intercalated beds of shales and stone, which of course, make the beds less profitable, or partly useless. I have not as yet heard anything concerning the results of the provisional operations in the Swedish mine.

Below the thick coal bed, we observed some black bituminous shales. — At a place about 360 meters above sea level, the coal measures could be seen in a little ridge, that projected from the coarse talus of the sandstone. Here the coal was burning, and for a distance of about 60 meters had been burnt to ashes.

Mr. GRANHOLM, Director of the "Svenska Stenkolssaktiebolaget Spetsbergen", has kindly communicated, in a letter to Mr. HOEL, that the coal-seam was set a-fire in the year 1913, by a mining expert who had been engaged by a Swedish company ("Spetsbergens Svenska Kol-fält"). He reported that he made a fire with the coal, and added, that it burnt well. Mr. GRANHOLM does not think it worth while to try to

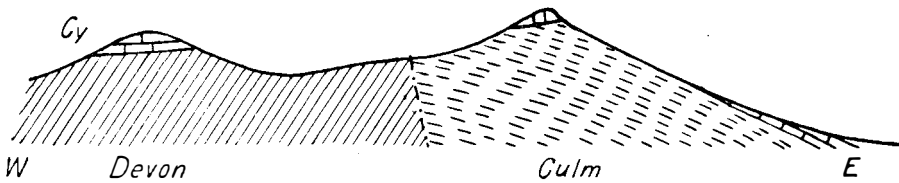


Fig. 3. Mt. Pyramide, section W—E, according to DE GEER.

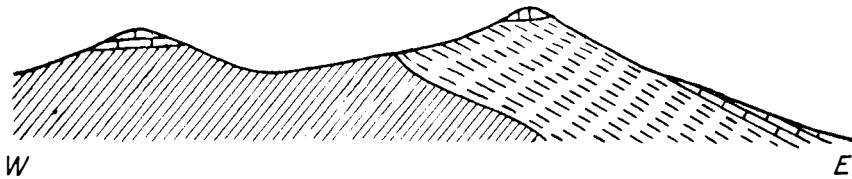


Fig. 4. Same section, as interpreted by the author.

extinguish the fire, as obviously only the uppermost few feet of the beds can be burnt. Furthermore, the ash content of this seam is so great that the coal has relatively little value. Lastly, it would at all events be rather difficult to put out the fire, — from want of water.

The smoke issued only at the upper end of the area. Here black pitch-like crusts had been formed, that covered the white ashes, and the smoke came out of several holes, which were studded with sulphur crystals; it was much like some volcanic solfatara. We broke up and turned round some of the pitch crusts and discovered that they were embellished with a great many fine crystals on the lower side, some white or clear, some yellow. With some difficulty we succeeded in bringing some samples on board and getting them safely transported to the University of Kristiania. The ash was so hot at this place that we could cook a box of tinned meat on the surface. — Farther down we did not find these crystals; grey or reddish ashes lay between the sandstone blocks, but there was not much to be seen of any geological interest. As the coal beds are inclined at a rather great angle —

some 30° — and the fire seems to have been limited to the uppermost parts of the beds, the shales on both sides have not been metamorphosed to any considerable degree; as a matter of fact, the whole outcrop was so much covered by coal-dust and ashes and sandstone boulders that little could be seen as to the condition of the shales. — That the crystallized minerals were only found on the lower side of the pitch-crusts, where the smoke was pouring forth, is explained by the fact that the crystals are very brittle and in part easily soluble. The annual precipitation is very small, and most of it will fall as snow; the heat developed by the fire will cause the air to be very dry at the places where the crystals are found, but on the upper side of the pitch cakes the soluble matter is washed off.

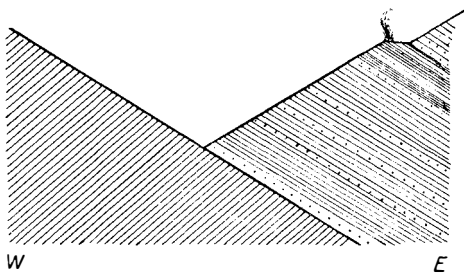


Fig. 5. Section of gully with burning coal beds in the culm shales and sandstones (right), resting discordantly upon devonian slates and sandstones (left).

Extensive beds of lignite have been burnt in North America and are still on fire for long distances. The most extensive report is rendered by Mr. J. A. ALLEN. The so-called Tertiary Lignite Formation is found over a great area about the upper Missouri River, and tributaries. "Throughout this extensive region the strata are nearly always horizontal in position, and consist of soft clays, marls and sands,

with occasional beds of soft, friable sandstone, and thin bands of indurated yellowish clay, interspersed with heavy seams of lignite. Owing to the yielding nature of these materials, the streams have excavated for themselves deep channels, and the country bordering them is deeply cut by innumerable gullies and ravines, extending back often for many miles from the principal water courses, forming the well-known and almost impassable "Bad Lands" of this region. These ravines vary in depth from one hundred to three or four hundred feet, and so extensive has been the denudation at many localities that only narrow ridges and isolated buttes, with their naked and almost vertical slopes, are left to indicate the former general level of the country. In consequence of this erosion the lignite beds are exposed at frequent points and for long distances. They vary in thickness from a few inches to six or eight, and even ten feet, and in quality from mere carbonaceous shale to that of a texture so compact and dense as to present the general appearance of cannel coal. The metamorphism resulting from the combustion of these beds varies, of course, in degree and extent with the thickness of the burned out beds. Over immense areas, embracing

hundreds and even thousands of square miles, the lignite beds seem, in some cases, to have been wholly consumed, all the ridges and buttes being either capped or banded with the reddened, indurated shales, that have resulted from the combustion.

The metamorphosed beds consist generally of, first, a thin stratum of grayish cinders and pumiceous matter, bearing a striking resemblance to the ashes, cinders and clinkers resulting from the combustion of coal in our grates, and varying from a few inches to two feet or more in thickness. Below this layer there is only a slight discoloration and hardening of the subjacent clay. Above the bed of cinders occurs a bed of indurated clay, of a brick-red colour, varying in thickness from a few feet to twenty or more; still above this are generally several feet of indurated reddened sandstone. The whole thickness of the strata showing more or less strongly the effect of heat, may amount to thirty or even fifty feet, but the more common thickness rarely exceeds eight to twelve. — — — Generally the metamorphism is limited to the hardening and change of colour of the superjacent clays and sands, but where the burned-out lignite beds were several feet in thickness, the strata immediately in contact with the lignite have been more or less fused or at least reduced to a more or less plastic condition. This is evident from the vitreous, porcellanic and vesicular structure of the different portions of these lower beds. At points where this igneous action has been most intense, we find almost every variety of scoriaeous material, undistinguishable in appearance from true volcanic lavas and pumiceous matter".

This excellent description shows clearly that the burning of coal beds in the Bad Lands leads to results quite different from those observed at Mt. Pyramide. In fact, the latter is quite an insignificant phenomenon, as compared with the immense areas of burnt lignite in America. Moreover, the inclination of the beds will prevent the combustion from reaching any depth, and only a superficial zone will be burned. The lignite does not burn farther than to a certain limit, when the covering beds have attained a thickness of about 100 feet.

The fire of the lignite beds of Upper Missouri started a very long time ago. The cross-sections of the valleys are narrowed, where the rivers pass through the hardened, burnt beds; these gorges stand in striking contrast to the open, grass-clad upper part of the valleys. The lava-like material is found as pebbles in river terraces, dating from pleistocene times. The fire has thus lasted for several thousand years. Most likely it has been started by spontaneous combustion at many different places.

Similar phenomena occur in Bohemia. The coal beds are found in several minor basins, in the Miocene, near Teplitz. Spontaneous

combustion of the lignite has caused extensive burning of the above lying loose shales and marls; at some places even quarternary clays and sands have been burnt, too. The products of the burning are red, hard brick-like slabs, black scoriæ or porcellain jasper. Pieces of this material are found in the gravels of the highest river terraces, dating from quaternary time. — The spontaneous combustion also here seems, to be connected with a period of rapid river erosion, by which process fresh coal beds were exposed to atmospheric agents.

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II. Minerals from the burning Coal Seam at Mt. Pyramide, Spitsbergen.

By

IVAR OFTEDAL

(WITH FIGS 6—7 AND PL. I)

At the request of Professor J. SCHETELIG, director of the Min.-Geol. Museum of the University, I undertook the examination of the minerals originated during the burning of a coal seam at Mt. Pyramide as mentioned in the preceding paper by WERENSKIOLD. The material is collected by A. HOEL and W. WERENSKIOLD in august 1921.

Although the material looks rather heterogenous, it proves to consist of only 3 mineral species, all showing the character of being easily sublimated.

The bulk of the material consists of *sal-ammoniac*, which was proved chemically and optically. The sal-ammoniac chiefly occurs in 2 different types as to habit of crystals. Exact measurements of the angles are not possible, the faces being mostly very much curved. — The first type shows as prevailing form the Tetragonal Trisoctahedron (211) in a rather regular development, and admitting measurements on goniometer, sufficiently exact for determination of the indices.

The second type is developed in cubes showing mostly very distorted shapes. These cubes seem to have grown on "stalks", turning a corner upwards. The faces are so strongly curved, that the right angles may be identified at the very point of the corner only. (See the Fig. 6, and Plate I, Fig. 2.)

A smaller number of the crystals shows a brighter or darker brown colour. These brown crystals are more regularly developed in cubes and show distinctly right angles. Yet they are often tabular. The brown colour is hardly due to iron compounds, as it might be expected, for the qualitative analysis of the brown crystals gives no iron. Probably it is due to coal dust or bituminous substance derived from the coal, on which the mineral is deposited. This probability is confirmed by some experiments on dry heating of the material.

Further *sulphur* occurs, in very small orthorhombic crystals. A crystal measured on goniometer showed the forms (111) and (101). The measurement gave the corresponding angles very exactly.

The *third mineral* crystallizes in fine yellow needles, sitting directly on the coal, partly covered by a crust of sal-ammoniac.

The mineral at once showed very striking properties. A determination of the specific gravity (with Clerici's liquid) gave the very low value of 1.43.

By means of the immersion method the refractive index α' was determined to 1.57. The refractive index γ' could not be determined directly, its value widely surpassing the upper limit of refractive indices reached with the scale of liquids available, which is $n = 1.74$. In liquids with $n = 1.74$ the mineral shows, in the α -direction, as well as in the γ -direction, very distinct Becke-lines, which are, naturally, of opposite characters. Assuming that these Becke-lines, as it seems, are of about the same strength, we may extrapolate the refractive index γ' to be located at about 1.9. Thus the birefringence — ($\gamma' - \alpha'$) — probably surpasses the unusually high value of 0.3.

The colour of the mineral is greenish-yellow, and the absorption is much stronger in the γ -direction than in the α -direction. α is located in the longitudinal direction of the crystal needles.

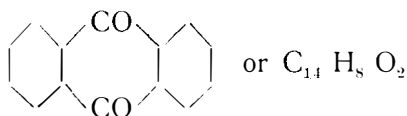
Extinction parallel.

Cleavage observed in a longitudinal direction.

On a crystal needle, measurable on goniometer in spite of its minute dimensions, I found one angle only, and its supplement, in the prism-zone. The average value of this angle was $51^\circ 40'$. This measurement, in connection with the parallel extinction, makes it probable that the mineral belongs to the orthorhombic system. Top faces have not been observed on any crystal.

Also in other respects the mineral shows unusual properties. On heating, it sublimates very easily, and deposits again in beautiful long crystal needles. To different reagents it is very resistant. Thus it may be dissolved in concentrated sulphuric acid and regenerated from the solution on dilution with water. Further it is easily soluble in chloroform, and somewhat less easily in benzol. The solutions are all yellow.

Many of the properties mentioned above, especially the low specific gravity and the solubility in organic solvents, strongly point towards the organic section of the chemical compounds. Further the unusual optical properties seem to point in the direction of more complex substances. Because of the occurrence of the mineral in connection with coal, I looked over descriptions of substances derived from coal-tar, and found out that all the properties mentioned could agree with those of *anthrachinone*:



The data given in the literature concerning anthrachinone, however, being partly little exact, I applied to Professor H. GOLDSCHMIDT, director of the section A of the Chemical Laboratory of the University, who kindly handed me some pure artificial anthrachinone. Thus a comparison could be made between the properties of the mineral on the one hand and the data given in the literature, supplemented by properties determined on the artificial material, on the other. The following table shows some of the properties of the mineral, compared with data given for anthrachinone in the literature.¹ (See also the Fig. 7.)

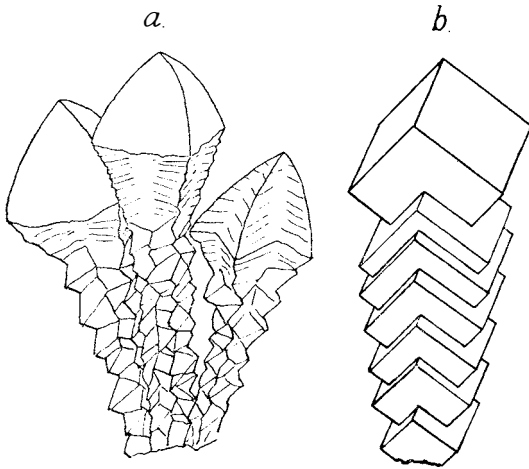


Fig. 6. a) Sal-ammoniac. Drawn from nature. b) Scheme of a).

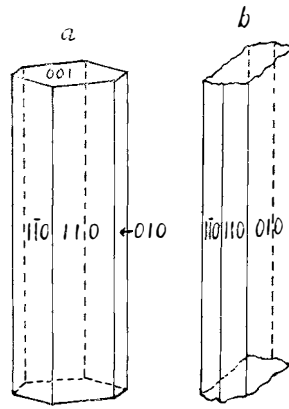


Fig. 7. a) Anthrachinone. Simple development. From Friedländer. b) Crystal of the yellow Spitsbergen mineral. From observations under the microscope.

Mineral, Spitsbergen.

Long crystal needles.
 System: orthorhombic (?).

 One angle in the prism-zone
 = $51^{\circ} 40'$.

 Cleavage: in a longitudinal
 direction.
 Sp. G. = 1.43.
 Colour: greenish-yellow.
 Birefringence: about 0.3.

Anthrachinone.

Long crystal needles.
 System: orthorhombic.
 c-axis parallel to the longitudinal
 direction.
 $110 \wedge 010 = 51^{\circ} 20'$.
 (My own measurement gave
 $51^{\circ} 23'$)
 Best cleavage: 100.

 Sp. G. = 1.419-1.438.
 Colour: sulphur-yellow.
 Birefringence: strong.

¹ The physical and crystallographic data are taken from Groth: Chemische Kristallographie, Bd. V.

Very resistant to different reagents.	Very resistant to oxidizing reagents.
Sublimates very easily.	Sublimates very easily.
Soluble in benzol.	Soluble in benzol.
Occurrence: in connection with burning coal.	Obtained from coal-tar.

Further I have determined the following properties of the mineral and also of the artificial anthrachinone and found perfect agreement between both sets of determinations:

Absorption: $\gamma > \alpha$.

Vibration of α in the longitudinal direction.

Refractive index $\alpha' = 1.57$.

Refractive index γ' very much higher than 1.74.

Soluble in concentrated sulphuric acid.

Soluble in chloroform.

Some other properties of anthrachinone, according to the literature are:

Optic axial angle small.

Acute bisectrix: c-axis.

Plane of optic axes: (100).

These properties I have not been able to determine definitely in any one of the two substances. Yet they are not at all in conflict with my observations. Assuming the plane of optic axes to be parallel to (100), we may draw the following conclusions, concerning both the substances:

The crystal needles being somewhat tabular in the a-c-plane (Fig 7b.), they will mostly rest with the face (010) on the object-glass. Thus a bisectrix will be seen in convergent light. Observations of the extremely indistinct interference figure caused by this bisectrix, show that it can not at all be distinguished from the interference figure caused by an optic normal. The bisectrix observed therefore must be the obtuse one, and we may add, that the optic axes must be located very near the crystallographic c-axis, that is: acute bisectrix = c, optic axial angle small. It follows further that the measured refractive index α' (= 1.57) must be identical with the principal refractive index β , and that the principal refractive index α cannot be very much lower than 1.57. The last conclusion also is confirmed by the fact that α' *always* shows the value of 1.57, in spite of the probability that not *all* the crystal needles are resting exactly with (010) on the object-glass. The principal refractive indices α and β thus being only a little different, and γ being very much higher, we may draw the conclusion, that the substances are optically positive.

In hand books of organic chemistry a reaction very characteristic of anthrachinone is given. The anthrachinone is reduced by means of Zn and NaOH, and characteristic changes of colour are observed.

This reaction I tried, on the Spitsbergen-mineral as well as on the artificial anthrachinone, and it passed off quite identically in both cases. Also another reaction I have tried on both the substances, and with the same result.

As melting-point of anthrachinone, the literature gives 273° to 277° . A determination of the melting-point of the mineral failed, because of impurities of organic nature. These impurities also somewhat darken the colour of the mineral. The pure anthrachinone is considerably brighter.

At the suggestion of Mr. A. RØDLAND, chief chemist of the Mineralogical Institute of the University, to whom I am indebted for much valuable advice, I now treated the mineral exactly as anthrachinone intermixed with other organic substances, and let it pass through a purifying process, especially prescribed for anthrachinone in analytic chemistry. This process is carried out by means of chromic acid, that wholly oxidizes all organic compounds except anthrachinone and related substances. Anthracene, in the event of it being present, is oxidized to anthrachinone. As a result of this process I got a very pure preparation, showing the bright yellow colour of the pure anthrachinone. The melting point of this pure substance proved to differ at most 2° to 3° from that of the pure anthrachinone, — a very good agreement.

I sent the purified substance, 45 milligrammes, to the Pharmacological Institute of the University (director Professor E. POULSSON) to be analyzed. The analysis was very kindly made by the 'amanuensis' Mr. GUNNAR WEIDEMANN, and the result was the following:

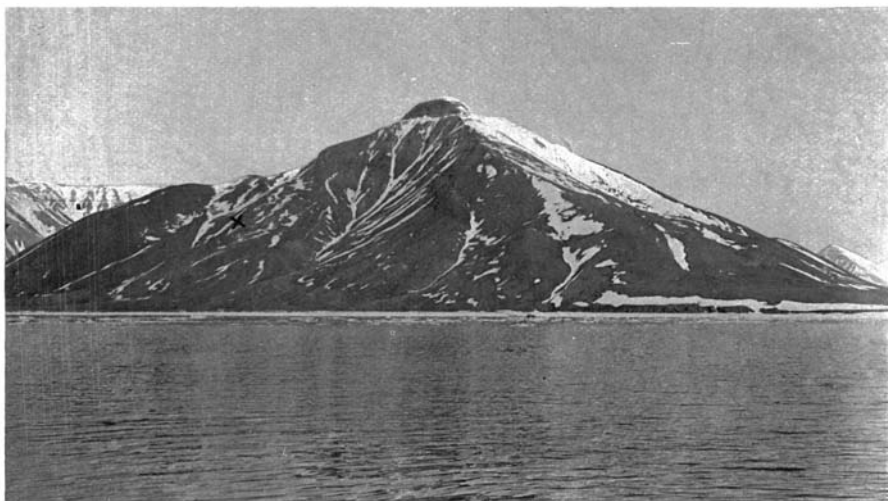
<i>Analysis.</i>	<i>Calculated from the formula of anthrachinone.</i>
C . . . 80.1 per cent.	80.7 per cent.
H . . . 4.5 " "	3.9 " "
(O . . . 15.4 " ")	(15.4 " ")

The small disagreements are easily explained. My substance may have been a little damp, or it may have been intermixed with traces of substances related to anthrachinone. In both cases the analysis will give a too high amount of H. At any rate, the analysis offers no objection to the identity of the substance analyzed and anthrachinone, and in consideration of all the facts mentioned above, concerning the two substances, it must be correct to conclude that the Spitsbergen mineral is anthrachinone, somewhat intermixed with other organic substance.

Anthrachinone, originated by a natural process, has thus been observed for the first time. It therefore has to be classed in the system of mineralogy among the organic minerals. As a mineral-name for

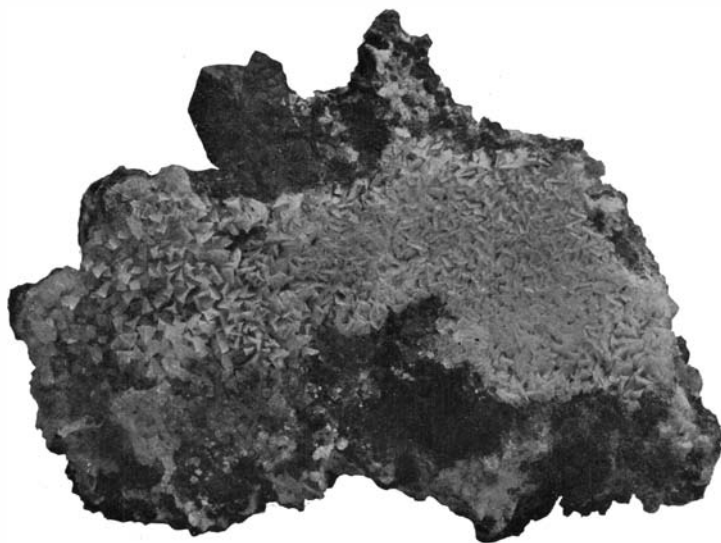
anthrachinone I will propose *Hoelite*, after ADOLF HOEL, the present leader of the Norwegian Scientific Expeditions to Spitsbergen.

As to the origination of the Hoelite, I am in lack of material for a detailed discussion. Generally, it is well known, that anthrachinone is formed by oxidizing of anthracene, which is a constituent of the coal-tar. Thus the general features seem to be clear. The burning of the coal is going on under a cover of gravel, admitting only a scarce supply of oxygen, — and a partial distillation of the coal takes place. The anthracene thus originated has then been oxidized to anthrachinone in a manner hitherto unknown. Anthrachinone also originates in other ways, but in our case it seems most likely that anthracene has been the primary substance.



Adolf Hoel fot. 18/7 1908.

Fig. 1. Mt. Pyramide seen from Klaas Billen Bay. × indicates the place where the coal-seam is burning.



Borghild Larssen fot.

Fig. 2. Sal-ammoniac. Typical specimen.

