

I. Note on Large Pyrites Found in East Swedish Morainic Deposits

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(With 3 text-figures and 1 plate)

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I. Introduction.

Large concretionary intergrowths of pyrite crystals are scarcely a common component of Swedish drift accumulations. However, in morainic deposits of an area somewhat E of Uppsala such pyrites or their derivative products are found now and then.

Attention was directed to this fact by the circumstance that a beautiful example of such pyritic intergrowth was sent to the Institute of Palaeontology of Uppsala by Mr E. FRANSSON, Almunge. The find had been made by Mr S. ZOTTERMAN.

This pyrite, remarkable on account of its mode of occurrence and its large size, was entrusted to me by Prof. G. SÄVE-SÖDERBERGH for a closer examination.

The examination performed attempted to find indications of the mother rock of the pyrite. The present paper is an account of this brief investigation.

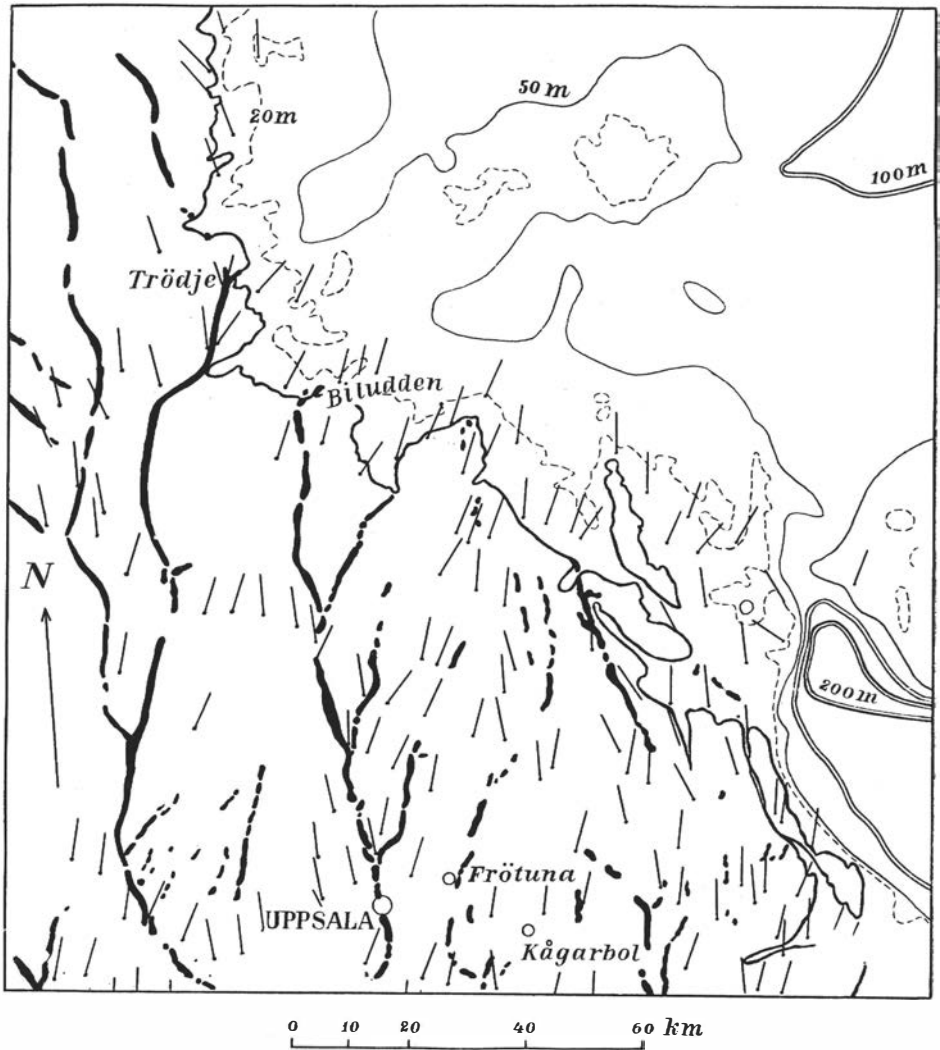


Fig. 1. Map showing the extension of the åses = eskers (broad lines) and the direction of the glacial striae (arrows) in the region concerned. Compiled from maps of WIMAN (1903) and LUNDQVIST 1935 (the glacial striae).

2. The pyrite and the pyrite-bearing formation.

The pyrite (Pl. I, Fig. 1) weighs 338 g. It forms a rounded lump of several repeatedly twinned crystals. The edges of the individual crystals are somewhat worn and rounded.

In the niches between the crystals some scraps of the original mother rock was left. It consisted of a black shale substance. The shale scraps left were sufficient for a spectral analysis.

The pyrite was found in a partly fine-grained morainic matter just E of the Kågarbol farm, Almunge parish, about 25 km E of Uppsala. This deposit also contains drift boulders, inter alia, of *Ceratopyge* limestone. In pits dug in the morainic deposits close around Kågarbol several completely weathered concretions of pyrites, now limonitic, were observed during a short local examination. According to oral communication, pyritic concretions with a weathered wrapper but with a fresh core are now and then found in the morainic matter around Kågarbol. Entirely fresh concretions, like the present one, are rare, however. Its state of preservation is certainly due to its having been deposited in a very fine-grained protecting sediment.

Pyrites of the present type have been found earlier in the area somewhat E of Uppsala. The collections of the Institute of Mineralogy of Uppsala include a huge concretion of pyritic crystals weighing 547 g (Pl. I, Fig. 2). It was found at the Frötuna estate, situated about 15 km NW of Kågarbol (Fig. 1). This find must have been made long ago judging from the fact that it is labelled by GÖRAN WAHLENBERG who lived from 1780 to 1851 (identification of the handwriting by Mr V. JAANUSSON).

The Institute collections also include a very fine specimen of a concretion of several repeatedly twinned pyritic crystals found in 1716 on the shore at Edeholm, Värmdö parish, about 25 km E of Stockholm (Pl. I, Fig. 3; weight 105 g).

3. The spectral analysis.

As anticipated, there was so much left of the mother rock of the pyrite in the niches between the individual crystals (a black shale) that a spectral analysis could be performed. It was important to establish whether there were present affinities with certain other black shales with respect to some chemical trace elements which could disclose the original site of the pyrite.

For this purpose, shales from two localities N of Kågarbol were analysed, viz. Biludden in N Uppland, and Kallholn in the Siljan district of Dalarna.

Biludden (Bilskaten on Fig. 3) is a long and narrow peninsula formed by the northern end of the ås which traverses Uppland southwards past Uppsala. On Biludden there are a great many Lower Ordovician limestone boulders, but boulders and fragments of a black shale also occur (*Ceratopyge* shale according to WESTERGÅRD [SANDEGREN and other authors 1939, p. 52]).

The Kallholn shales are fillings of fissures within the so-called *Leptaena* reef limestone; they are of *Rastrites* age (THORSLUND 1932).

The analysis was performed by Dr P.-H. LUNDEGÅRDH.

The result of the analysis is presented in the following table. For comparison some analytical data of shales from the Island of Öland, and from Östergötland and Scania are also quoted (WESTERGÅRD and other authors 1944 *a* and *b*, 1947).

4. Discussion of results.

The conclusions which may be drawn on the basis of the analyses given, concerning the mother rock of the pyrite, are, as a matter of fact, not perfectly corroborative. The frequency of some elements is, however, of indicative importance in this respect.

Such elements as rubidium (not quantitatively determined) and magnesium (with a frequency similar in the Biludden and Kallholn samples but different from that of the mother rock of the pyrite) are of little orientating value. This is also the case of strontium, the content of which is rather equal in all the samples; the mother rock of the pyrite shows in this respect a slightly closer affinity for the Kallholn sample than for that of Biludden.

As regards aluminum and some elements which occur in very small quantities (cobalt, molybdenum and nickel), there is a closer connection of the mother rock of the pyrite with the Kallholn shale than with that of Biludden.

With respect to the other elements, they differ from those of the Kallholn shale but are akin to those of Biludden and other *Ceratopyge* shales.

The content of iron is practically identical in all the *Ceratopyge* shales quoted, but is quite different in the Kallholn shale and also in the *Dictyonema* and Olenid shales. Further, the mother rock of the pyrite reveals exactly the same content of titanium as the Biludden sample, but differs considerably from that of Kallholn. A great similarity also exists with respect to potassium, but in no wise with Kallholn. The content of vanadium, the very characteristic element of *Dictyonema* and *Ceratopyge* shales, closely corresponds to that of the Biludden sample and to the *Ceratopyge* and *Dictyonema* shales analysed, but is very different from that of Kallholn.

A fairly good correlation with the Biludden shale but a distinct deviation from that of Kallholn is shown by barium, manganese and chromium. The content of calcium is of about the same order as in the Biludden sample, but very much lower than in the Kallholn shale.

From this survey it may appear that there is a great probability that the mother rock of the pyrite has been a *Ceratopyge* shale, belonging perhaps to the same formation as the shale fragments of Biludden.

Judging by the glacial striae which run mainly N—S in the area here considered, the pyrite is very likely to have derived from the submarine Cambro-Ordovician region in the Bothnian Gulf, but scarcely from any shale of the Siljan district (cf. Figs. 1 and 2; also cf. AMINOFF 1904).

However, it is a complex and difficult task to localize exactly the site of its origin.

It might be conceivable that the pyrite originates from some alum shale deposit in the land region somewhat N of Kågarbol. However, such layers are not known here, and do scarcely exist, inasmuch as no traces of alum shales have been observed, according to descriptions of the geological

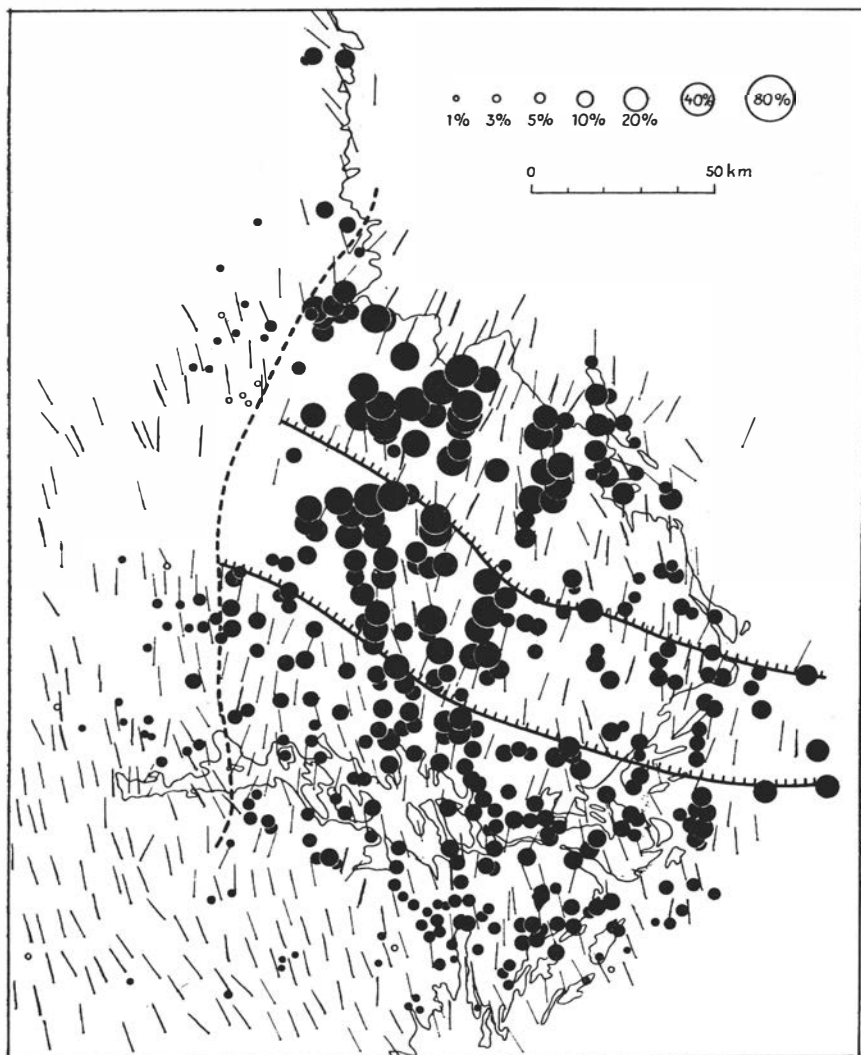


Fig. 2. Map showing the content of calcium carbonate in the clays and marls of the region concerned. The arrows show the glacial striation. The broken line marks the W limit of the young striae. The E limit of Älvdal porphyry drift boulders extends somewhat to the east of this line (cf. AMINOFF 1904). The two WNW—ESE lines indicate stationary positions of the retiring ice border. (From LUNDQVIST 1935.)

map sheets and special descriptions of the composition of the glacial deposits. In parts of the coastal district of N and NE Uppland, however, fragments of alum shales seem to occur, but they are obviously very scarce. One piece is reported from the map sheet Grisslehamn, viz. from glacial clay just S of Vaddö church (ERDMANN 1895, p. 31). Only on Biludden are fragments of alum shales more common. Occasionally, one or other piece is found somewhat S of Biludden; one boulder which later was shown to represent

the *Ceratopyge* shale (WIMAN 1903, p. 16) was reported by WAHLQVIST (1868, p. 37) from the southern continuation of the Biludden ås about 10 km S of Biludden.

There is no doubt that the Biludden shale fragments as well as the scattered ones occasionally found along the coastal district of N and NE Uppland derive from shale deposits on the bottom of the Bothnian Gulf.

Concerning the Kågarbol pyrite, it was mentioned that no concealed shale deposit in the area N of Kågarbol seems to exist. The pyrite may be considered to have been transported from a shale deposit at a greater distance, most likely situated on the bottom of the Bothnian Gulf. The fact that there is no shale substance but many pyrites in the morainic matter around Kågarbol favours this assumption. The pyrites with their hardness of 6–6.5 may very well have endured a transport of this length, but by no means the easily crumbling shaly matter.

The question now is whether the Kågarbol pyrite derives from exactly the same deposit as do the alum shale drifts of the N and NE coastal districts. In this case the localization of the site of the origin of the shale fragments of Biludden is of importance.

WESTERGÅRD (SANDEGREN and other authors 1939, p. 52) is of the opinion that a submarine shale deposit possibly exists just in the proximity from where the fragments are brought to the shore by the activity of waves. This may scarcely be tenable, however, judging from the fact that pieces of shales as well as fairly large, flattened boulders occur in the ås itself. Thus the pieces along the shores of the peninsula may have been eroded from the ås, for the most part from its submarine section.

The shale deposit may thus be searched for somewhere in the sea in the continuation of Biludden. Biludden points between NE and ENE, and its about 3 times longer submarine continuation (the so-called Slangrevet and a row of shoals off the end of the reef) points in the same direction. The seawards reconstructed continuation of this partly supramarine and partly submarine ås is intersected by the reconstructed continuation of the East Uppland åses only 15–20 km off the point of the Slangrevet. The glacial striae also point toward this area, which forms a depression of the seabottom.

This depression may have been formed by glacial exaration. An important part of its rocks has certainly been redeposited in the Biludden ås. Thus there is reason to assume that the shale pieces in the ås are derived from this area.

The Kågarbol pyrites may also be assumed to originate there, since it is scarcely probable that shale deposits exist in the more adjacent bay of Öregrundsgrepen. If this were the case, shale fragments would likely occur in the Östhammar ås, which, however, does not seem to be true. Alum shales are, in fact, not very resistant, but such comparatively short a trans-

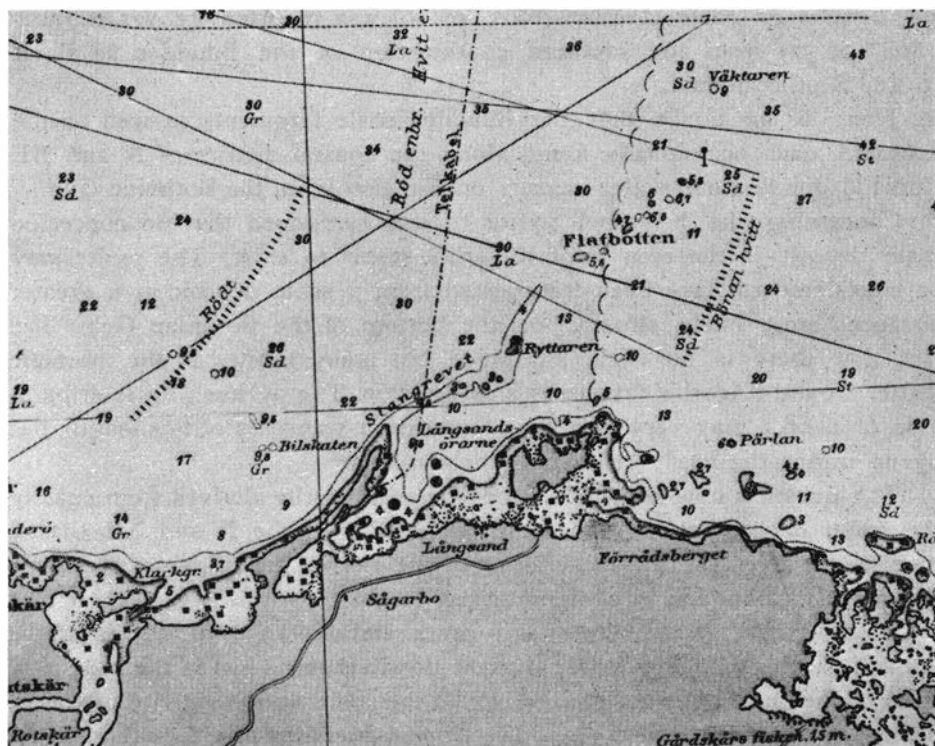


Fig. 3. The Biludden ås and its submarine continuation. From the nautical chart. 1 : 100 000.

portation as in this case should scarcely have crumbed down the shale pieces. The above-mentioned find of *Ceratopyge* shale in the ås about 10 km S of Biludden is situated at a distance of about 15 km from the N end of the peninsula; its total distance of transportation is, of course, longer.

The submarine area where shale deposits may exist or may have existed before having been destroyed by glacial action is certainly only a part of a larger such area. As a matter of fact, it is difficult to arrive at more definite conclusions concerning its extension. Large concretions of pyrite have been found in the Åland Islands. However, those I have seen are different from the Uppland drift pyrites and also from other alum shale pyrites which I have observed (cf. Pl. I, Figs. 4—5—6). They consist of much smaller crystals and have a somewhat reniform appearance (Pl. I, Figs. 7—8), and adhering fragments of the mother rock, prove them to be formed in a Cambrian sandstone. This type of pyritic concretions is common in the Cambrian sandstone of Estonia (oral communication by Mr V. JAANUSSON).

The presence of these pyrites in the Åland Islands shows that Cambrian sandstone strata exist N of Åland on the bottom of the Bothnian Gulf.

According to a verbal communication by Prof. H. G. BACKLUND, large concretions of pyritic crystals are now and then found in the Åbo skärgård. Such pyrites have not been examined with respect to their primary origin, but Prof. BACKLUND has stated that they are partly of the alum shale type, partly of the Cambrian sandstone type. This indicates that deposits both of alum shales and Cambrian sandstones occur on the bottom of the eastern part of the Bothnian Gulf (cf. BACKLUND 1937, p. 260, Fig. 12).

On the Swedish side, alum shales seem to extend towards the north beyond the Gävle Bay. The occurrence of large boulders of *Ceratopyge* shales at Trödje about 18 km N of Gävle is of interest in this connection.

The boulders occur in an NE ås. Another ås running N—S and joining the NE ås at Trödje does not contain any Cambro-Ordovician boulders (SANDEGREN and other authors 1939, p. 91). The boulders of alum shale have been suggested to derive from a concealed shale deposit in the proximity of Trödje, but, as pointed out by SANDEGREN (op. cit. p. 92), this has not been proved. WESTERGÅRD (op. cit. p. 63) leaves this question open.

The assumption that the Trödje boulders should originate from a submarine shale deposit is rejected on account of the fact that Cambro-Ordovician drift boulders are absent on the shores in the vicinity. However, it may be of interest to make a comparison between the Trödje and the Biludden åses. Both contain pieces of alum shales, and both have mainly the same direction. Furthermore, within a short distance and in the direct continuation of the åses the sea bottom is depressed. As regards the shale boulders and fragments of Biludden, they were suggested to be derived from the depression corresponding to the Biludden ås. It seems conceivable that the Trödje shale boulders are derived in a similar way, i. e. that they have been transferred from shale deposits in the submarine depression just NE of the NE branch of the Trödje ås.

The beautiful Värmdö pyrite which was mentioned on p. 3 and which is shown in Pl. I, Fig. 3 is obviously an alum shale pyrite. Judging by the fact that the edges are scarcely worn at all, it may have been transported by an iceberg. For this reason it is impossible to trace its origin, but it is most likely derived from the submarine alum shale deposit of the Bothnian Gulf.

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Explanation of the Plate.

All figures natural size. Coll. M. I. = Collection of the Institute of Mineralogy of Uppsala.

1. The Kågarbol pyrite. 2. The Frötuna pyrite (Coll. M. I. $\frac{64}{214}$). 3. The Värmdö pyrite (Coll. M. I. $\frac{64}{366}$). 4-5-6. Pyrites from the Andrarum alum shale quarry, Scania (Coll. M. I.: 4-5 not registered; 6: $\frac{64}{129}$). 7-8. Cambrian pyrites from Åland; 7 from Bostaholm (7: Coll. M. I. $\frac{64}{157}$; 8: Coll. M. I. $\frac{64}{89}$).

