

SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 810    AVHANDLINGAR OCH UPPSATSER    ÅRSBOK 79 NR 4

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SVEN GAVELIN

THE BAGGETORP TUNGSTEN  
DEPOSIT  
SOUTHERN SWEDEN



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## ABSTRACT

Gavelin, Sven, 1985: The Baggetorp tungsten deposit, southern Sweden. Sveriges geologiska undersökning, Ser. C, No. 810, pp. 1-17, Uppsala 1985.

The Baggetorp tungsten deposit is situated about 40 km west of Norrköping in southern Sweden. The main ore minerals are wolframite and scheelite occurring in a quartz vein which cuts a heterogeneous veined gneiss intruded by granites. Wolframite is replaced and sometimes surrounded by scheelite. Molybdenite occurs as scattered flakes or is concentrated along the contacts of the quartz vein. Pyrite, chalcopyrite and bismuth minerals form the latest phases of mineralization. The quartz in the vein is intensely sheared, and the vein is cut by aplitic granites and pegmatites belonging to the post-Svecokarelian Småland granites, which are unaffected by shear deformation.

It is therefore concluded that the tungsten mineralization cannot be an end product of the Småland granites, but is localized to older shear zones, perhaps genetically connected with the veined gneisses. The latter were formed in the time interval between the emplacement of the older (synkinematic or primorogenic) granitoids and the younger (postkinematic) Småland granites.

## PREFACE

This presentation of the Baggetorp wolframite deposit in southern Sweden has been delayed for about 25 years for several reasons. My collection of data from the deposit was completed when the mining works were stopped, about 1958. My results therefore refer to the time 1944–1958. Some mineral determinations desirable at that time would have required a microprobe. Since we expected to have access to such an instrument in the near future, the final work was postponed. Later, I became completely occupied in research on the Västervik area in south-eastern Sweden, and the description of the Baggetorp deposits was put aside.

Unfortunately, my original specimens and polished sections were lost in a reorganization at the Mineralogical Institute, University of Stockholm, when I was retired. Therefore, the presentation that follows will in part be a summary of old notes and in part consist of new analyses and samples. The loss of the samples is unfortunate, as it makes further investigations impossible, especially on the post-wolframite alterations.

## POSITION

The Baggetorp wolframite deposit is situated on the 1:50 000 geological map-sheet "Tjällmo" (Stolpe 1881), in the County of Östergötland. It is located about 6 km east of Tjällmo church, where a small farm named Baggetorp is indicated on the map. Norrköping is the nearest larger city, lying 40 km east of Baggetorp. See also Hübner (1971) and Ohlsson (1979).

## HISTORY OF DISCOVERY

The discovery of the Baggetorp wolframite deposit was something of a fairy-tale. No experienced geologist would have proposed to look for a wolframite mineralization in the Baggetorp region at the time when it was found. In the spring of 1944, a farmer doing his military duties in guarding the Finspång railway station was invited by a friend for a cup of coffee. This friend worked at the Finspång railway station and was very interested in minerals and ores. He collected samples whenever he came upon deposits of interest and boasted about the weight of some of his ore samples. The farmer then replied that on his farm he had something that was even heavier. When they visited the place together they found black boulders which actually were very heavy. At first they thought that the boulders contained some manganese mineral. Later, however, a friend of theirs at a laboratory in Finspång discovered that tungsten was an essential constituent. It was then obvious that the heavy mineral must be wolframite. Samples were sent to various mining companies in Sweden; but in general the companies were a bit suspicious. Wolframite from Portugal was frequently imported by nearby Finspång indu-

stries. For this reason, it was thought that the samples presented might have originated from such loads. A sample was also sent to the Geological Survey of Sweden where the director at that time, P. Geijer, became interested. He travelled to Baggetorp and at once found that the samples of wolframite must have come from outcrops very close to the first find.

After this first investigation, Geijer advised the interested local people to take out mining claims over the area in question. This was when I was sent to Baggetorp to make further geological investigations. It was soon clear that the wolframite boulders were very local, being found only around a small field. North of the field, in the direction from which the wolframite boulders might have been transported by the inland ice, the bedrock was very well exposed. There, only granites (with some pegmatites) could be found, with no indication of either wolframite or scheelite. It was therefore obvious that the deposit itself must be situated not very far from the boulders. I proposed to the claim owners that they should dig a set of trenches. This work was, however, delayed. It was not until Joseph Berglund, at that time owner of the most important tungsten mine in Sweden, the Yxsjö scheelite deposit, had obtained the claims, that a systematic search for the outcropping wolframite was carried out. Further trenching exposed a quartz vein with large lumps of wolframite. After this initial discovery, prospecting could be carried out effectively.

### GENERAL GEOLOGY

The tungsten minerals occur in a quartz vein which cuts a type of veined gneiss that is fairly common in this part of Sweden. Pegmatoid or granitoid veins penetrate a lot of acid and intermediate supracrustal rocks, metabasites etc., which are not always possible to identify. Granites are found north and south of the gneisses. My investigations did not include any detailed study of the regional geology around the quartz vein, as this was not part of my assignment for the Geological Survey. My superficial investigations were in fairly good agreement with the later conceptions of Magnusson (1953), namely that the quartz vein was situated in a large block of gneiss surrounded by Småland granites. Anders Wikström, Geological Survey of Sweden (SGU), has recently made a provisional geological map of the area, which he has kindly placed at my disposal. His map is on a small scale, making it impossible to receive from it a detailed picture of the situation around the quartz vein. According to Wikström there is a belt of older granites north of the vein; but to the south the granites are younger (Småland granite). For the present discussion the age relations between parts of the surrounding granites are fairly irrelevant. Field data show that the quartz vein itself occurs in gneiss, and that this gneiss is surrounded by granites which at least in part belong to the younger (Småland) group, the end products of which are

pegmatites and aplites. It is possible to identify several different generations of pegmatites and aplites, all of which postdate the quartz vein. The youngest and clearly postkinematic aplites have a very gentle dip.

### THE QUARTZ VEIN

My first impression was that the wolframite-bearing vein represented a quartz filling in a tension crack. The vein cuts older structures and was first believed to represent an end product of a normal evolution: granite→ pegmatite→ quartz vein. Very soon it was evident, however, that such an explanation was not in accordance with the geological data. During the underground mining works it was found that the quartz vein did not always represent an "open fissure vein". In places it was seen to split up into small lenses. Examples were also found where the vein seemed to behave metasomatically and replace gneiss, as evidenced by remnants of gneissose structures in the quartz in the form of biotite streaks, oriented parallel to the gneissosity but discordant with the contact between the quartz vein and the gneiss. Quartz occurring in this manner generally seemed to be free from tungsten mineralization. On the other hand, where the quartz vein split up and terminated, tungsten was precipitated in the wall rocks instead of in the quartz.

Frequently the wolframite-bearing quartz was seen to be very intensely mechanically deformed. It displayed preferred orientation and was always strongly undulous. The same kind of deformation could sometimes be found in the wall rocks nearest the contact, where quartz had reacted plastically and "flowed" around, for example, large plagioclase crystals (Fig. 1). Therefore, it seems probable that the invasion of vein quartz was localized to a restricted zone of intense shearing, and that this shearing continued even after the emplacement of the quartz. The homogeneous granite which occurs in the area as well as the pegmatite and aplite veins cutting the quartz vein have not at all, or only weakly, been affected by mechanical deformation. Consequently, it is evident that the quartz-tungsten mineralization represents a process which cannot have been directly related to the so-called Småland granites and their pegmatitic or aplitic end products. The quartz vein must predate the emplacement of these rocks. The quartz-tungsten mineralization was probably a separate process which was combined with the formation of certain stresses within the crust. The tungsten mineralization might be more closely related to the development of gneisses than to the granites, which postdate the gneiss-forming processes. If this interpretation holds true, it has an important bearing on future prospecting for tungsten in southern Sweden. It means that such prospecting should not be concentrated to areas of late granite but instead to areas where specific structural conditions prevail.

The tungsten-quartz vein does not always consist of pure quartz. It may contain

varying amounts of biotite, and sometimes even coarse microcline crystals. Frequently, the microcline is associated with concentrations of wolframite. Such microcline concentrations seem to represent local phenomena. They never give the vein a pegmatoidal character. More commonly, they resemble the coarsely crystalline microcline concentrations sometimes found in the gneisses.

The problems concerned with the kinematic deformation of the quartz vein and its immediate surroundings are complicated by the fact that the mechanical deformation was not evenly distributed throughout the rock mass, but was instead concentrated to certain shear zones. The fact that the late granites, their pegmatites and aplites have not been affected by this deformation, is proof that the tungsten mineralization was not an end product of the Småland granites.

### SURVEY OF THE ORE MINERALS

The only minerals in the deposit which have had any essential economic importance are *wolframite* and *sheelite*. In the beginning, even *molybdenite* was thought to be of some economic interest. However, it was soon found that this mineral was too scarce and unevenly distributed to be profitable. The formation of these three minerals seems to have been closely connected. For this reason, they are treated here as one group.

A second group, of purely mineralogical interest, is characterized by other sulphides than molybdenite. *Pyrite* is here the most common mineral. *Chalcopyrite* is also fairly widespread, although it generally occurs in very small amounts. Of particular interest is the appearance of *bismuth minerals*, which could be taken to represent a third group of mineralization. They are closely associated with chalcopyrite.

The presence of bismuth minerals was first indicated in the concentration process. On the shaking tables there appeared below the black mass of wolframite a white rim (heavier than wolframite), 3–4 mm wide. This rim was found to consist mainly of native bismuth, which evidently was fairly abundant, at least during the first stages of mining, when these observations were made. It is surprising that in the first seven polished sections (which are now lost) bismuth minerals were recorded in only one specimen. At least twelve additional specimens were polished, some of which contained visible copper-iron sulphides. Bismuth minerals were not observed in any of these. The explanation might be that bismuth mineralization was a very local phenomenon and localized to parts of the deposit which were mined during the first stages of the mining operations. *Magnetite*, sometimes altered into *hematite*, is fairly widespread in the sheelite margins.

Another quite unexpected mineral is *native antimony*. It was never observed in the microscope, but only in the waste after the concentration process, where it occurred as idiomorphic crystals, 1–1.5 mm long. The mineral was first thought to be

allemontite; however, analyses made by the Geological Survey of Sweden showed that no arsenic was present. The occurrence of antimony in connection with tungsten mineralization seems to be a fairly rare phenomenon. In the survey by Hobbs *et al.* (1973) only one example is presented, Yellows Pine mine, Idaho, where stibnite is mentioned. On the other hand, Bumhol *et al.* (1978) in their survey of tungsten deposits have recognized a special stibnite-bearing type, with examples from i.a. Bolivia and Spain. Stibnite is also found in some of the tungsten mineralizations of East Greenland (Hallenstein and Pedersen 1983).

## DESCRIPTION OF THE INDIVIDUAL ORE MINERALS

### WOLFRAMITE

Wolframite is the economically most important mineral and also that which first drew attention to the mineralized areas. The finds of wolframite boulders from the fields emanated from concentrations of almost compact wolframite in the foot wall of the quartz vein. They formed irregularly shaped masses several meters across. As my visits to the deposits were rather sporadic and the richer parts were removed very rapidly, I had no opportunity to take photographs of these concentrations. However, a sketch drawn from a photo gives a general idea of the pattern (Fig. 2). In several cases, it has also been found that thin veinlets of quartz penetrate large wolframite crystals. From these relations between quartz and wolframite, the latter mineral clearly seemed to predate quartz. From this it might be concluded that wolframite crystallized on the walls of an open fissure and quartz invaded the fissure later. Nevertheless, the fact that much wolframite is found to be completely surrounded by quartz and that wolframite also occurs in wall rocks, gneiss or even granitoid forms of the gneiss, is difficult to explain with such an interpretation. In addition, if one compares Baggetorp with similar deposits around the world, an overall pre-quartz wolframite crystallization seems even less probable.

The explanation to the complexities here could be twofold. Either the first wolframite mineralization is contemporaneous with the precipitation of quartz, which then continued after the crystallization of wolframite, or, the brecciation of wolframite by quartz is the result of a strong mechanical deformation which caused the quartz to flow. The ability of quartz to flow in the present area can be verified by its behaviour in Fig. 1. This texture suggests that strong post-wolframite deformation caused intense fracturing (in part along the cleavage planes) in wolframite and plastic flow in quartz.

On the other hand, thin sections of quartz veins of the same kind as shown in Fig. 2 display very weak indications of "flow". Of course they might have been



Fig. 1. Strongly sheared gneiss close to the quartz vein. Quartz shows plastic flow structure around a plagioclase megacryst. Thin section, 2 nic., 28x.

recrystallized after the flow. However, this seems fairly unlikely. Perhaps the most probable explanation is still that precipitation of quartz extended over a rather long period. Quartz continued to crystallize after deposition of the first quartz mass with wolframite, and even after the first deformation and crushing of wolframite.

Wolframite crystals vary considerably in size, from a few millimeters in breadth up to single specimens reaching the size of  $12 \times 7 \times 7$  cm.

The chemical composition of wolframite is given by analysis No. 1.

Analysis No. 1. Wolframite, Baggetorp tungsten deposit. Received in 1974 from the mining company (F. Swedberg).

	Weight %	Mol. proportion of oxide
WO <sub>3</sub>	75.53	0.320
MoO <sub>3</sub>	0.07	
MnO	8.15	0.115
FeO	14.73	0.205
MgO	0.78	0.014
SiO <sub>2</sub>	0.04	0.007
SnO <sub>2</sub> , Nb <sub>2</sub> O <sub>5</sub>	0.39	
H <sub>2</sub> O	0.14	
Total	99.83	

Of special interest is the ratio  $\text{Fe}^{2+}:\text{Mn}^{2+}$ , which is 0.66:0.34 (about 2:1). Two microprobe analyses of other wolframite samples made at the SGU show  $\text{Fe}^{2+}:\text{Mn}^{2+}$  ratios of about 3.5:1. The Mo content is low;  $\text{MoO}_3$  in analysis No. 1 is 0.07%, in two microprobe analyses 0.05–0.07%.

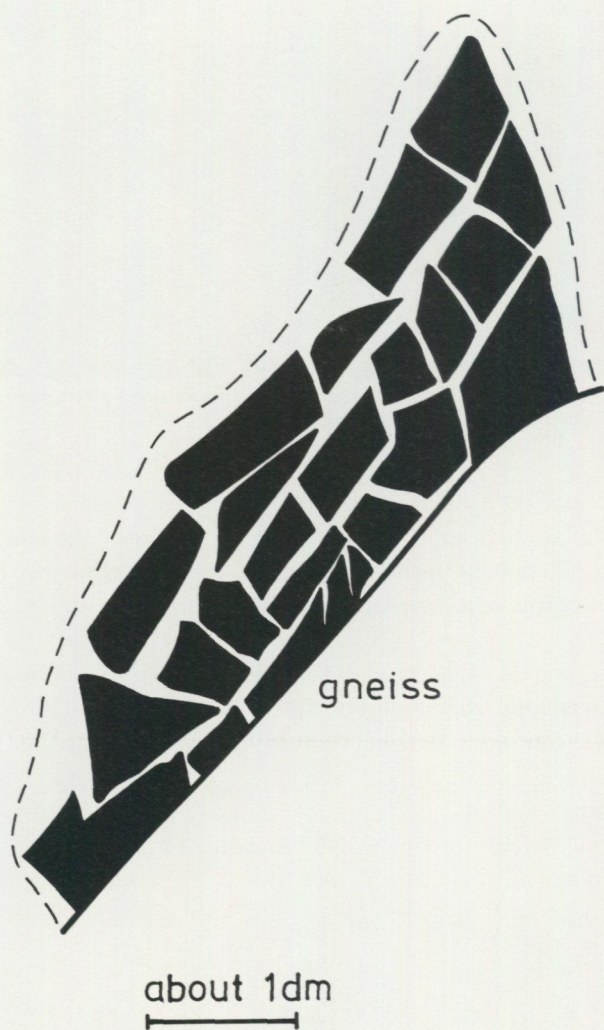


Fig. 2. Quartz (white) penetrating wolframite (black), mainly along cleavage planes. Drawn from a photo of outcropping wolframite concentrations.

## SCHEELITE

Scheelite clearly crystallized later than wolframite and frequently replaces the latter mineral. Very often it forms regular border zones around wolframite individuals (Figs. 3 and 4). If scheelite actually replaces wolframite, this must involve calcium metasomatism. Scheelite crystal margins frequently contain abundant iron oxides (magnetite and sometimes hematite), which could indicate that the iron content of the wolframite was at least partly retained during the recrystallization. The role of manganese is somewhat uncertain. Veinlets in wolframite containing minerals with lower reflectivity were first believed to represent secondary manganese minerals. Microprobe analyses, however, disclosed that they contain no manganese. In some cases they turned out to be scheelite. In one specimen, where bismuth minerals occur, a crystal of either hausmannite or manganite was observed. Unfortunately, this was part of the lost material and the determination cannot be verified now.

From the mining company I also received an analysis (No. 2) of "pure scheelite".

Analysis No. 2. Scheelite, Baggetorp tungsten deposit.

	Weight %	Oxide	Weight %	Mol. proportion of oxide
Ca	12.4	CaO	17.4	0.310
Fe	0.90	Fe <sub>3</sub> O <sub>4</sub>	1.2	
Mo	0.093	MoO <sub>3</sub>	0.14	
Mn	0.034			
W	57.5	WO <sub>3</sub>	72.4	0.313
SiO <sub>2</sub>	10.1	SiO <sub>2</sub>	10.1	

The analysis was reported in percentages of metal atoms (with the exception of SiO<sub>2</sub>). From the values given, the oxides of the elements and the molecular proportions were calculated (see the table). It is evident that the analysed material was not pure scheelite. SiO<sub>2</sub> certainly represents impurities of quartz and Fe<sub>3</sub>O<sub>4</sub> of magnetite. As can be seen, the molecular proportion CaO:WO<sub>3</sub> is close to unity in agreement with the theoretical formula for scheelite, CaO:WO<sub>3</sub>.

Molybdenum is low in the analysis (MoO<sub>3</sub>=0.14%). This is in accordance with the fluorescence colour which is generally white with a slightly bluish tint. However, microprobe analyses show that the Mo content may vary considerably from one place to another. This is also in accordance with the fluorescence colours. One can sometimes discern a slightly yellowish tint. Microprobe analyses of some scheelites may show between 0.5 and 0.9% MoO<sub>3</sub>. In one case, where scheelite with a clearly yellow tint surrounds wolframite, MoO<sub>3</sub> was found to be 5.6%. In addition, there are coatings on fine fissures with a strong yellow fluorescence, which must represent true molybdoscheelite. The mode of the occurrence indicates that the coatings are related to the introduction of molybdenite.

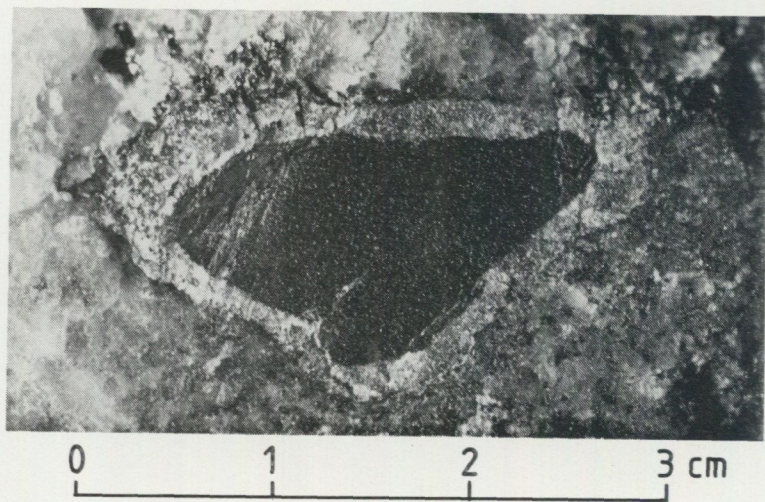


Fig. 3. Big wolframite crystal surrounded by a scheelite rim.

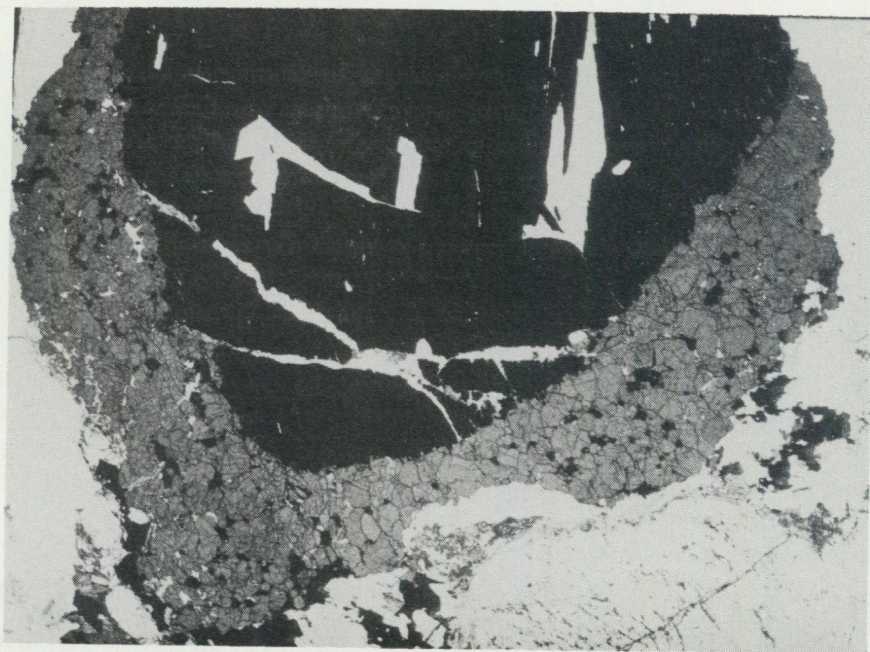


Fig. 4. Scheelite rimming wolframite. Fine veinlets of quartz (white) in the wolframite. Thin section. 1 nic., 6.5x.

## MOLYBDENITE

Molybdenite occurs irregularly distributed in the quartz and clearly postdates both wolframite and scheelite. However, the most conspicuous concentrations are found along the 1–2 mm thick chlorite-mica coatings, which sometimes border the quartz vein. Molybdenite is apparently closely connected with the tungsten mineralization, as evidenced by its sporadic occurrence together with the tungsten minerals.

## IRON-COPPER SULPHIDES

Among iron-copper sulphides *pyrite* is the most common mineral. It may occur as small separate crystals, as aggregates a few millimetres across, or even as winding veinlets of fine-grained pyrite which cut through wolframite, scheelite or molybdenite (Fig. 5). Of particular interest is the fact that in this figure the fissures filled with pyrite also contain a low-reflectivity mineral. Comparison with somewhat wider veins, which have been shown by microprobe analysis to contain scheelite, suggests that the veins in Fig. 5 are also of scheelite type. The fine fissure-coatings of scheelite often display a yellow fluorescence, probably due to admixture of

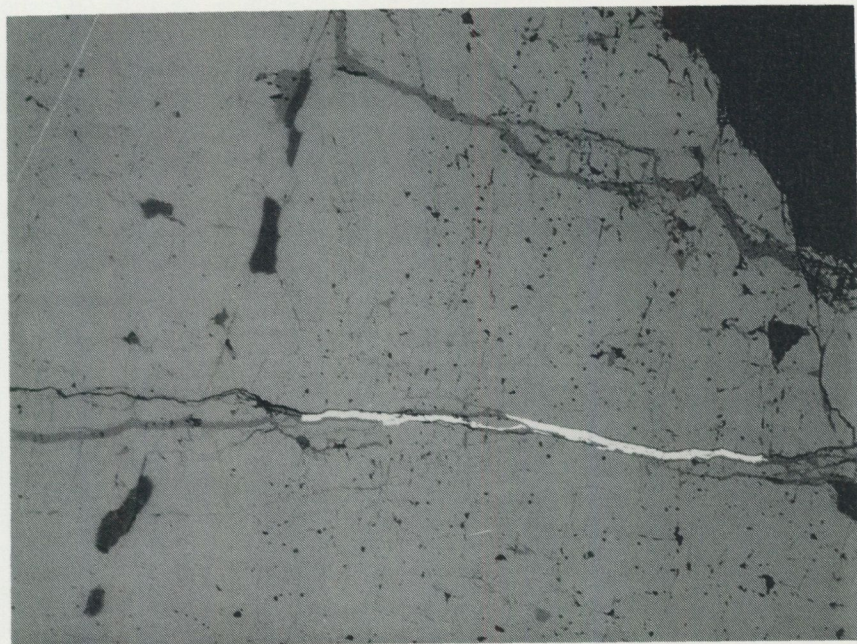


Fig. 5. Narrow veinlet of pyrite (white) in wolframite. Veinlets with lower reflectivity than wolframite probably consist of molybdoscheelite. Polished section. 1 nic., 28x.

molybdoscheelite. If this interpretation is correct, the picture in Fig. 5 is proof of the intimate relationship between the various steps of mineralization.

*Chalcopyrite* is fairly common, but always occurs in very small amounts. It postdates pyrite where the two minerals are found together.

#### BISMUTH MINERALS

Among bismuth minerals *bismuthinite* och *native bismuth* are most common, the latter being a transformation mineral from the former. *Wittichenite* and *empletite* have also been identified by X-ray analysis.

#### OXIDES AND OTHER SECONDARY MINERALS

As was mentioned before (p. 11) magnetite is frequently observed in scheelite surrounding wolframite. Rarely, magnetite has been altered to hematite. More extensive oxidation has been recorded only in the specimen characterized by bismuth minerals. The introduction of the latter was apparently rather special in the mineralization process.

#### SUMMARY

From the above it is evident that the formation of the Baggetorp tungsten deposit should not be considered to be related to the crystallization history of the Småland granites. It predates these granites and was closely connected with the gneiss forming processes that preceded the intrusion of the granites. In connection with the mineralization local tension must have occurred, which gave rise to situations favouring the wolframite-quartz mineralization. If this holds true, it means that future prospecting for tungsten in this region should not be concentrated to the so-called Småland granites but rather to areas with certain structural peculiarities. These circumstances might explain why very intense prospecting in granite areas (prospecting, in which I myself was active in that time) gave no positive results. For a successful prospecting it would therefore seem advisable in the future to consider structural features rather than petrological or chemical indications.

My interpretation of the geological evolution is as follows:

1. Intense shearing of early Svecofennian (Svecokarelian) gneisses.
2. Precipitation of quartz in a shear zone with contemporaneous crystallization of wolframite.
3. Continued shearing, mobilization of quartz (or continued crystallization from fluids), possibly combined with Ca-metasomatism, replacement of wolframite by scheelite and probably formation of magnetite, hematite and possibly some manganese minerals.

4. Formation of molybdenite, sometimes directly connected with the wolframite mineralization, sometimes concentrated to micaceous border zones along the quartz vein.
5. Introduction of other sulphides:
  - a) *Pyrite* in various forms. Always postdating wolframite, scheelite and molybdenite.
  - b) *Chalcopyrite*, postdating pyrite.
  - c) *Bismuth minerals*. Dominating are *bismuthinite* and *native bismuth*, the latter formed from the former as an alteration product. In addition, the minerals *emplektite* and *wittichenite* have been observed and have also been verified by X-ray analysis. This bismuth mineralization is fairly rare, although not quite unique in tungsten deposits.

### COMPARISON WITH SIMILAR DEPOSITS

A survey of tungsten occurrences from all over the world generally gives the impression that such deposits can be divided into two groups. One represents skarn deposits where scheelite is the main economical mineral, and the other consists of "vein deposits", where both wolframite and scheelite occur. Since the latter is the one which is of interest for the present study, the following discussion will be limited to this group.

A large number of papers on tungsten deposits have been published, but I will here refer substantially to Little (1959) and Hobbs and Elliott (1973) who, in addition to their primary purpose of giving a survey of some limited regions, also give brief surveys of world-wide regional occurrences. Since we are mostly interested in the quartz vein deposits we will start by referring to the mineralogy of such deposits. In addition to wolframite and scheelite, molybdenite is generally recorded. Pyrite and chalcopyrite are frequently reported sulphides. All these minerals are found in the Baggetorp deposit. Arsenopyrite and sphalerite are frequently mentioned, but these minerals have not been observed in the Baggetorp deposit.

More interesting is the fact that many of the deposits contain bismuth minerals such as native bismuth and bismuthinite. This verifies the assumption that tungsten mineralization is sometimes intimately combined with bismuth mineralization. The fact that we also find some copper-bismuth minerals at Baggetorp does not contradict such an assumption. At Baggetorp these minerals were identified in one single case. Similar minerals may easily have been overlooked in other deposits. In the main, the geology and mineralogy of the Baggetorp deposit have much in common with similar deposits around the world. It is worthwhile, however, to make a comparison with an adjacent wolframite deposit fairly close to the present one. In southern Norway there is the Ørdsalen tungsten mineraliza-

tion (Heier 1955), which in many respects seems to be very similar to the Baggetorp deposit. Many features in Ørdsdalen are exactly the same as in Baggetorp, for example wolframite individuals surrounded by rims of scheelite. The two mineralizations are probably of fairly similar age.

Surveys of tungsten deposits in central Sweden have been presented by Hübner (1971), Ohlsson (1979) and Hellingwerf and Baker (1984), where wolframite is also reported in one pegmatitic development of tungsten mineralization. In the mentioned publications some new finds of tungsten in Sweden have been reported, but these seem to be rather small in size and do not appear to contribute to the understanding of the Baggetorp deposit.

After the present manuscript had been sent to the printer for a first proof, I was informed by Dr Sigvard Ljung from "Nämnden för Statens gruvegendom" (The State Prosperity Commission) that several new finds of wolframite in quartz have been reported in Sweden during the last 4–5 years. Two of these are particularly interesting since mineralogically they are fairly similar to the Baggetorp deposit:

1. "*Storträsket*", 25 km ESE of Storuman. Swarms of quartz veins, up to two decimeters wide, containing wolframite, scheelite, some molybdenite, arsenopyrite, pyrite, pyrrhotite and chalcopyrite. Native bismuth was also observed.
2. "*Stubburbäcken*", about 30 km north of Storuman. Also quartz veins with wolframite (main tungsten mineral), scheelite, arsenopyrite, löllingite and native bismuth, further pyrite, pyrrhotite, chalcopyrite and galena.

As can be seen, these two mineral deposits show much in common with the Baggetorp deposit. However, they are too small to be of any economic interest. Ljung also states that there exists a group of scattered deposits from the far north (Jokkmokk, Arjeplog) southwards to Baggetorp, most of them representing scheelite deposits (see also Hellingwerf and Baker 1984).

#### ACKNOWLEDGEMENTS

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