SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C. Avhandlingar och uppsatser. N:o 536

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# A TELLURIDE ASSEMBLAGE IN THE RUDTJEBÄCKEN PYRITE ORE. VESTERBOTTEN, N. SWEDEN

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*Pris 1 krona*

STOCKHOLM 1954
KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER
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**Abstract.**

In a pegmatitic rock associated with compact pyrite-sphalerite-chalcopyrite ore in the Rudtjebäcken Mine, Skellefte District, N. Sweden, a mineral assemblage has been found, the most outstanding features of which is the occurrence of tellurides of lead, silver and gold. As compared with other compact sulphide ores of the Skellefte District the compact ores of Rudtjebäcken are particularly poor in arsenic, lead, antimony and precious metals. The telluride-bearing mineral assemblage thus represents a very interesting trend of fractionation.

## Introduction.

In the course of prospecting work in the Adak Area in Northern Sweden a mineral association was discovered, which, in some respects, is quite foreign to the normal mineralization of the area, the most outstanding characteristics being the occurrence of tellurides with lead, silver and gold. This assemblage is the more remarkable as it is connected with a sulphide ore which is particularly poor in lead, silver and gold. As compared with the main sulphide ore bodies the telluride mineralization appears to be quite insignificant and has no economic importance; from a genetical point of view, however, it is very interesting in some respects.

The Adak Area is situated in the north-western part of the vast region containing sulphide ores which is generally called the Skellefte District (3). Within a comparatively small area an extensive sulphide mineralization has been found, which has given rise to several ore deposits (the Adak Ores, the Karlsson Ore, the Lindsköld Ore, the Rudtjebäcken Ore). The three first-named deposits are copper ores with chalcopyrite, pyrrhotite and arsenopyrite as chief minerals and pyrite and sphalerite as subordinate constituents. The sulphide mineralization was preceded by hydrotermal alterations of the siliceous wall rocks. The minerals then formed indicate comparatively high temperatures of formation: Cordierite, cummingtonite, biotite, chlorite, almandite, andradite, diopside, hornblende.

The Rudtjebäcken Ore is different in several respects. The chemical alteration of the wall rocks was less pronounced, the most characteristic features being a replacement of biotite by muscovite and a general recrystallization leading to coarser grain sizes. The ore body is a compact sulphide mass, pyrite being by far the dominating mineral, pyrrhotite, chalcopyrite and sphalerite occurring in subordinate quantities.

The telluride-bearing mineral assemblage was found in a pegmatite cut by a drill hole (No. 7), and as yet only material from this drill hole is available

for examination. The pegmatite section cut by the drill hole is 2.1 metres wide. If the pegmatite runs parallel to the ore body and the layered structure of the wall rocks (as do minor pegmatites found in the tunnels of the mine), this would indicate a thickness of 1.9 metres. Nothing is so far known regarding the areal extension of the pegmatite.

## The Silicate Minerals of the Pegmatite.

The mineral composition of the pegmatite (disregarding the sulphides) is very simple: Quartz and microcline are the chief constituents. The large microcline individuals, sometimes pertitic, may contain small idiomorphic or hypidiomorphic plagioclase individuals (oligoclase). Biotite, small amounts of titanite and apatite also occur as »primary» constituents. The sulphides represent a later stage of mineralization and replace the silicates. The introduction of sulphides seems to have been accompanied by an addition of potash, which brought about a replacement of quartz by »secondary» microcline and muscovite. In such cases microcline forms an outer border around the masses or veinlets of muscovite. From this border potash and alumina has diffused into large quartz grains forming complicated intergrowths or small round spots of microcline in quartz which gradually disappear towards the centre of the quartz grains. In connection with the introduction of the sulphides some calcite, epidote and prehnite was also formed. Biotite was often transformed into chlorite.

## The Sulphide-Telluride-Mineralization.

### Chemical Composition.

The drill hole containing the Te-bearing minerals also cuts the main ore body. A series of analyses from various sections of this drill hole (No. 7) are given in Table 1:

**Table 1.**

Rudtjebäcken, drill hole 7

| | % S | % Cu | % Zn | % Pb | g/tAg | g/tAu |
|---|---|---|---|---|---|---|
| 165.39—166.91 m | 43.5 | 0.29 | 7.13 | 0.00 | 8 | 0 |
| 166.91—167.89 » | 33.5 | 3.29 | 2.16 | 0.00 | 21 | tr. |
| 167.89—169.62 » | 11.8 | 0.83 | 0.23 | 0.04 | 12 | tr. |
| 169.62—172.18 » | 25.0 | 0.52 | 0.35 | 0.01 | 11 | tr. |
| 172.18—174.25 » | 3.1 | 0.59 | 0.11 | 0.98 | 109 | 3.4 |
| 174.25—174.89 » | | | | | 3 | 0.2 |

The two first sections represent the compact pyrite ore body, the two next are from disseminated portions of the foot wall, the fifth (172.18—174.25) refers to the Te-bearing pegmatite. The low sulphur value demonstrates that in this section the total content of ore minerals is very low. It differs from the other sections by a remarkably high concentration of lead, silver and

gold. The analyses of the Te-bearing section were completed by determinations of As, Sb, Te, Se. Table 2 shows all the analyses performed (expressed in per cent and also in atomic proportions) and these figures give an idea of the proportions between the individual minerals of the assemblage.

**Table 2.**

| | S | Cu | Zn | Pb | As | Sb | Se | Te | Ag | Au |
|---|---|---|---|---|---|---|---|---|---|---|
| Per cent ..... | 3.1 | 0.59 | 0.11 | 0.98 | 0.28 | 0.014 | 0.013 | 0.07 | 0.0109 | 0.00034 |
| Atomic proportions .... | 965.7 | 92.8 | 16.8 | 47.3 | 37.4 | 1.15 | 1.65 | 5.49 | 1.01 | 0.017 |

## Sulphide Minerals.

The following minerals, in which sulphur is an essential constituent, have been observed (arranged according to decreasing quantity in the pegmatite section): Pyrite, chalcopyrite, arsenopyrite, galena, sphalerite, tetrahedrite.

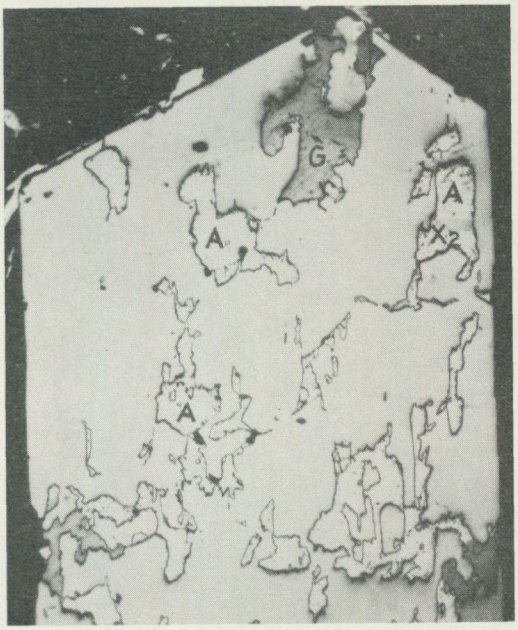


Fig. 1. Big crystal of arsenopyrite, partly replaced by galena (G), and altaite (A). In the upper right altaite area a band of mineral $X_2$. Green filter. Oil immersion. × 300.

Their mutual distribution is very irregular, however, and in polished sections, where the Te-minerals are comparatively abundant, also tetrahedrite occurs in greater quantities than elsewhere.

*Arsenopyrite* seems to have been the first mineral to crystallize. It may be replaced by all the other sulphides and also by the Te-minerals (see e. g. fig. 1). Even in large pyrite crystals small corroded remnants of arsenopyrite have been observed.

*Pyrite* may appear as well defined cubes but was often corroded and replaced by the later sulphides and tellurides.

*Sphalerite* and *chalcopyrite* are very irregularly distributed. In sphalerite small exsolution blebs of chalcopyrite are often found.

*Galena* and *tetrahedrite* show a closer relationship to the tellurides than the other sulphides. Intergrowths between the two minerals have sometimes been encountered. Pyrite, arsenopyrite and also sphalerite are often extensively replaced by them (figs. 2 and 3). Under the microscope the tetrahedrite is a

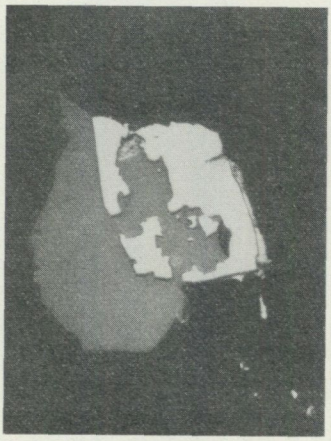

Fig. 2. Arsenopyrite (white) replaced by tetrahedrite (grey). Green filter. Oil immersion. × 400.

Fig. 3. Sphalerite (grey) with small blebs of chalcopyrite is replaced by tetrahedrite (white). Green filter. Oil immersion. × 400.

gray colour with an olive-green tint, which is in accordance with a normal copper-antimony-tetrahedrite. The analyses and the mineral association indicate a certain content of Ag and As, however. The size of the unit cell, $a_0 = 10.295 \pm 0.001$, supports this assumption (cf. the results of Machatschki (6)).

## Te-Minerals.

### Identification of the Te-Minerals.

The Te-minerals always appear in very close association and frequently intimately intergrown. The diagnostic characteristics of several of the Te-minerals with silver, gold and lead in polished sections are so vague, that it is frequently very difficult to obtain unequivocal identification. By means of X-ray powder data it is, however, generally possible to get definite information as regards a certain species, which has been shown, inter alia, by the

publications of Harcourt (5) and R. M. Thompson (13). In order to get a basis for comparisons a series of polished sections was prepared, in which the minerals could be confirmed by means of their powder patterns. Some of the minerals which were probable in the Rudtjebäcken mineral assemblage are easily identified merely by microscopical examination, others necessitate X-ray control (cf. appendix on the diagnostic properties of the minerals). In the

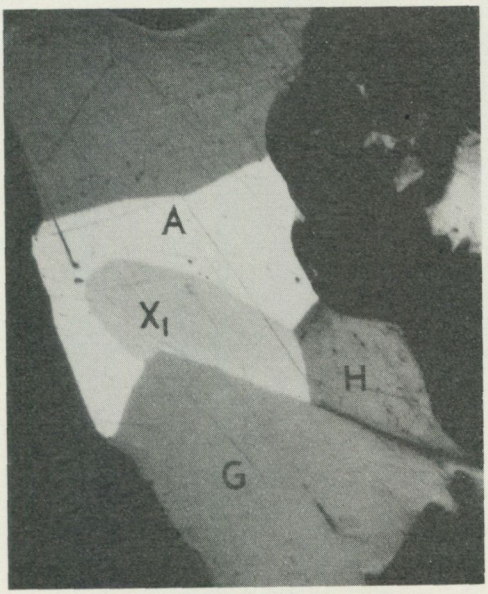


Fig. 4. Altaite (A), mineral $X_1$ ($X_1$), hessite (H), and galena (G) in silicates. Green filter. Oil immersion. × 450.

present case, however, the Te-minerals are so small and so intimately intergrown that from some of the minerals pure material could not be obtained. Two minerals in the assemblage could not be identified with Te-minerals so far known. These minerals are provisionally called $X_1$ and $X_2$.

## Description of Minerals.

The following minerals have been identified: Altaite (PbTe) (confirmed by its powder pattern), hessite ($Ag_2Te$) and petzite ($Ag_3AuTe_2$). As was mentioned above, these minerals and the additional minerals $X_1$ and $X_2$ always occur together and very often in association with galena or tetrahedrite. They may, however, also appear separately in the polished sections, spots up to 0.4 mm in size being encountered. In several cases these minerals are extremely finely distributed in a micaceous mass, the individual grains then being less than 0.001 mm.

*Altaite* is by far the dominating mineral among the tellurides. It is distinctly lighter than galena, which appears almost grey compared with altaite (figs. 4

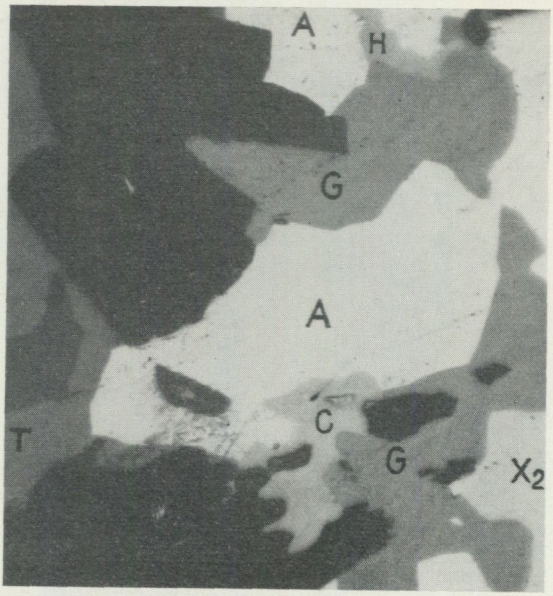


Fig. 5. Altaite (A), mineral $X_2$ ($X_2$), hessite (H), galena (G), tetrahedrite (T), chalcopyrite (C) and silicates (black). Green filter. Oil immersion. × 850.

and 5). It is slightly softer than galena[1] and perfectly isotropic. Its powder pattern is in very good agreement with the data given by Thompson (see Table 3).

**Table 3.**

| Rudtjebäcken | | Powder pattern of altaite (Thompson) | |
|---|---|---|---|
| I | d | I | d |
| 1 | 3.73 | 1 | 3.73 |
| 10 | 3.22 | 10 | 3.22 |
| 8 | 2.27 | 8 | 2.27 |
| 1 | 1.929 | 1 | 1.928 |
| 5 | 1.849 | 3 | 1.854 |
| 4 | 1.606 | 2 | 1.606 |
| 6 | 1.436 | 5 | 1.439 |
| 5 | 1.309 | 4 | 1.311 |
| 1 | 1.132 | 1 | 1.136 |
| 3 | 1.073 | 2 | 1.070 |
| 2 | 1.014 | 2 | 1.017 |
| 2 | 0.971 | 2 | 0.968 |
| 1 | 0.892 | 1 | 0.894 |
| 1 | 0.860 | 2 | 0.860 |

Altaite very often contains small amounts of the minerals $X_1$ and $X_2$, which are often lath-shaped but may also display quite irregular grain boundaries.

[1] When relative hardness is discussed, hardness is equal to resistance to polish.

At least $X_1$ has also been observed without direct connection with altaite, as minute inclusions in galena. The reflection power of $X_1$ is very similar to that of altaite; in air it is very easily overlooked when occurring in altaite. In oil the difference is more obvious, $X_1$ then appearing with a faint reddish tint (see figs. 1, 4 and 6). The mineral $X_2$ is slightly darker than $X_1$ (fig. 7) and looks more reddish grey in direct contact with $X_1$. $X_1$ displays a very distinct anisotropism but without any characteristic polarization colours, $X_2$ is very

Fig. 6. Altaite (white) with mineral $X_1$ (light grey). Green filter. Oil immersion. × 400.

weakly anisotropic. The order of hardness is: Haltaite $>$ $H_{X_2}$ $>$ $H_{X_1}$. The microscopical properties of $X_1$ agree in every detail with those of *calaverite* or *krennerite*, as found in the polished sections prepared for comparison and as given by Ramdohr (8). The colour, reflectivity and anisotropism of the mineral $X_2$ are in agreement with the properties of *melonite* ($NiTe_2$) as given by Ramdohr (8), but according to Stillwell (11), Ramdohr (8) and Thompson (13) melonite is distinctly harder than altaite, whereas mineral $X_2$ is found to be slightly softer than that mineral. As no other Ni-minerals have been found, the presence of a Ni-telluride is improbable. X-ray powder photographs do not clearly indicate the existence of either melonite or calaverite-krennerite in the assemblage. Pure material could not be obtained even by using a microdrill — admixture of altaite, tetrahedrite and/or galena could not be avoided — but some lines were found which contradict the presence of the possible minerals mentioned above. The following d-values have been found, which do not refer to altaite, tetrahedrite and galena and which can be taken for strong lines referring to a mixture of the minerals $X_1$ and $X_2$ = 3.47—3.49; 3.08—3.09; 2.77—2.83; 1.77—1.78, possibly also 1.65 and 1.54. The two strongest

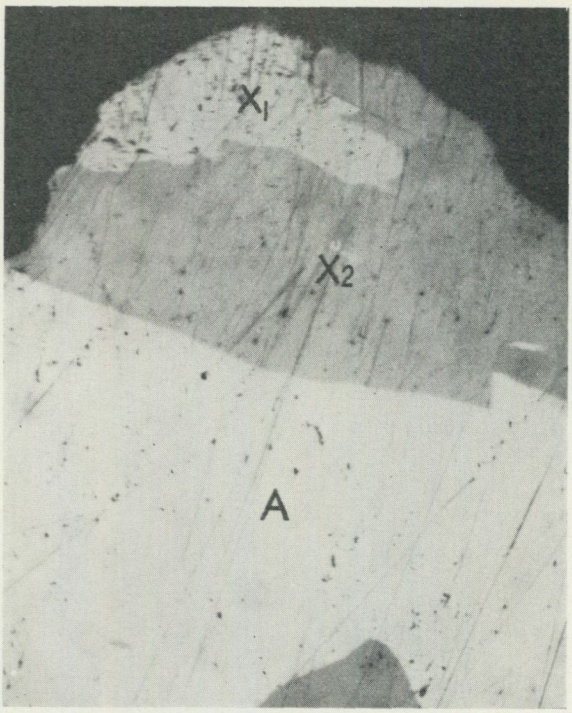


Fig. 7. Altaite (A) with the minerals $X_1$ and $X_2$. Green filter. Oil immersion. × 850.

lines of melonite, 2.81 (10) and 1.54 (6) (Thompson (13)), are in accordance with the lines found in the Rudtjebäcken minerals, but the two next strongest lines, 2.05 (5) and 1.91 (5), have not been observed. The strongest line of krennerite, 3.05 (10) (Thompson (13), Harcourt (5)) or 3.03 (Tunell and Murata (14)), is not very far from the line 3.08. The next strongest lines 2.11 (5), 2.96 (4) and 2.24 (4) have not been observed, but this may of course be due to the extremely small quantities available for X-ray analyses. A certain distortion of the pattern due to a partial replacement of Te by Se may also be possible. However that may be the microscopical characteristics of the mineral $X_1$ are strongly in favour of krennerite, which is also very plausible from a paragenetic point of view.

*Hessite* is easily recognized by its microscopical properties.

Its reflectivity is distinctly lower than that of the above-mentioned tellurides (figs. 4 and 5). Anisotropism is distinct with characteristic yellow-brown polarization colours. All grains display a very characteristic confused lamellar twinning. The mineral has always been found in connection with altaite (and the other tellurides), forming irregular grains at the borders of the altaite spots. Quantitatively it seems to be somewhat subordinate to the minerals $X_1$ and $X_2$.

*Petzite* has been observed only as two minute grains in connection with

altaite and some hessite. Its reflectivity and colour are very similar to those of hessite. In accordance with the observations in the polished sections confirmed by powder photographs it is slightly harder than altaite and isotropic.

### Comparisons and Discussion.

Tellurides with lead, silver and gold are a characteristic association known from several mining districts in the world. As is evident from the above description, there is little similarity — if the characteristic features of the whole districts and the geologic settling are considered — between the Rudtjebäcken assemblage and the tertiary telluride paragenes classified as subvolcanic by Schneiderhöhn (e. g. the famous mining district in Transylvania). A more likely comparison is one with the Canadian archean gold veins, in which tellurides have frequently been found, in some deposits even as ore minerals of economic importance (12). The resemblances between these mining districts of Canada and those of the Skellefte Field have been stressed on several occasions (e. g. Ödman (7)), and the Rudtjebäcken mineralization may therefore be taken as an additional support of this resemblance. The Australian mining district of Kalgoorlie is also of interest in this connection, the telluride-bearing associations of that area being described by Stillwell (11).

In Finland, in the so-called Tammerfors region, a mineralization with sulpho-minerals and gold and accompanied by a marked sericitization has been described by Saksela (9). The analogies between this mineralization and certain types of mineralization in the Skellefte District were also emphasized by Saksela. From this Finnish district tellurides, too, have been reported (tellurbismuth and a gold telluride, not more closely identified, by Saksela (9) and hessite by Paarma, see Eskola (2)).

In the Skellefte District tellurides of gold, silver and lead have not yet been identified with certainty. However, bismuth tellurides have been found in considerable concentrations in two deposits, Boliden (7) and Mångfallberget (4), where tetradymite and tellurbismuth were found. Analyses of Bi-tellurides in Boliden have caused Ödman (7), to conclude that the existence of altaite is very probable, even if it has not been observed in the microscopical examination. He mentions, in addition, two not-defined minerals which on account of their paragenetic appearance are supposed by him to be gold tellurides.

The comparison between the above-mentioned mining districts and the Rudtjebäcken Te-bearing mineral assemblage is founded on certain analogies in the »ore minerals». If, on the other hand, gangue minerals and geologic settling are also considered, certain dissimilarities are conspicuous. In Rudtjebäcken the gangue minerals are those of a normal pegmatite, whereas for instance in the majority of the Canadian and Australian occurrences quartz is the chief gangue mineral. In some Canadian deposits, however, minerals characteristic of pneumatolytic assemblages also have been found (tourmaline, molybdenite, scheelite).

In most of the occurrences referred to there seems to exist no intimate rela-

tionship between the Te-minerals and compact sulphide deposits; Boliden, for instance, in N. Sweden and Noranda in Canada are exceptions. Of course it is not possible to find definite evidence of an intimate connection between the formation of the compact sulphide mass and the insignificant Te-mineralization even at Rudtjebäcken, but the close connection in the field and the fact that in pegmatites somewhat more distant from the main ore only arsenopyrite and some pyrite have been found but no sign of more »precious» minerals, strongly favours the assumption of an intimate genetic relationship. Such a relationship lends the Te-bearing assemblage an interest beyond the mineralogical features, as it demonstrates a peculiar type of fractionation of the metals in the original ore-bearing fluid.

We shall first establish the characteristics of the compact sulphide ore body at Rudtjebäcken as compared with other compact sulphide ores of the Skellefte District. As was mentioned in the introduction, the compact Rudtjebäcken ore body is chiefly a pyrite mass with subordinate pyrrhotite, sphalerite and chalcopyrite (on an average about 10, 7 and 3 per cent respectively). Such proportions are very common in, or even characteristic of, many other ore bodies in the Skellefte District. In the majority of the ores of such a composition, however, more or less galena is present in the zinc-rich portions, and together with galena are generally found tetrahedrite and sulpho-minerals with considerable contents of silver. Arsenopyrite is in addition, a common constituent, in part as separate, dense ore portions, in part more dispersedly distributed in the pyrite mass.

We may thus state that the Rudtjebäcken ore, as compared with other pyrite ores of the Skellefte District, is

a) poor in arsenic

b) poor in lead, antimony and precious metals.

As was shown above, these very metals are concentrated in the Te-bearing mineral assemblage. According to our present experience of the fractionation of metals at the formation of the Skellefte field ores, a coexistent concentration of arsenic and gold is common, and the same is true of a concentration lead, antimony and silver together. At least in the cases where these five constituents are quantitatively of minor importance in the ores, gold and arsenic are precipitated before, lead, antimony and silver after the crystallization of the main pyrite ore bodies (with their subordinate constituents of copper and zinc). In the Te-bearing mineral association at Rudtjebäcken we find all five metals contemporaneously concentrated. Geochemically this involves a certain analogy with the first two stages of mineralization in the Boliden deposit, the arsenopyrite stage and the quartz-tourmaline stage, which both precede the formation of solid pyrite ore (7). It is remarkable that also the Boliden mineralization differs from other ore bodies in the Skellefte District by an unusual concentration of Te (and Se) in the earlier stages of the mineral formation. It might be surmised that the presence of these elements in the ore-forming fluids may have had a significant influence on the course of fractionation during the mineralization process.

## Appendix.

### Note on the Diagnostic Properties of Certain Tellurides in Polished Sections.

Determination of the various minerals in polished sections of polymineralic telluride assemblages is sometimes a precarious task. It consequently seems suitable to publish some data from the polished sections made for comparison, where the tellurides were confirmed by their X-ray patterns. In the tables and descriptions supplied by Ramdohr (8), Schneiderhöhn (10) and Uytenbogaardt (15) hardness (= »resistance to polish») is taken as a primary basis of classification. In one respect my experience is contradictory to the statements in earlier publications on this matter (Borchert (1, p. 460)): *Altaite* is said to be very soft and next to hessite the softest telluride. In one polished section where petzite, hessite, altaite and calaverite or krennerite occur together (the three first mentioned minerals being confirmed by their X-ray pattern) the following series of hardness could be established: H (altaite) > H (calaverite or krennerite) > H (petzite) > H (hessite). As regards *petzite* I could (in accordance with Borchert and Stillwell (11)) not discern any kind of anisotropism. Other observations were in harmony with the data given in the literature cited and need not be discussed.

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