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Bismutohauchecornite—new name: hauchecornite redefined

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SUMMARY. The name hauchecornite has been applied in the literature to a group of minerals with similar crystal structures and the general formula $(Ni,Co,Fe)_9ABS_8$, where A and B are As, Sb, Bi, and Te in two non-equivalent structural sites. A classification of the group is proposed based on the relative abundance of the elements As, Sb, Bi, and Te in the two sites. Hauchecornite is redefined as Ni_9BiSbS_8, the end-member being closely approximated by the composition of the material from the type locality, and a new name, bismutohauchecornite, is proposed for the $Ni_9Bi_2S_8$ end-member. The classification, redefinition, and the new name have been approved by the Commission on New Minerals and Mineral Names, IMA.

AN investigation of tučekite, the antimony analogue of hauchecornite (Just and Feather, 1978), prompted a detailed study of the literature on hauchecornite and its varieties. It was soon realized that the name hauchecornite was used to cover a whole group of closely related minerals with similar structures and chemical compositions that could be expressed in terms of relatively simple end-members. It therefore seems desirable to restrict the usage of the name of hauchecornite to an end-member that is closest to the chemical composition of hauchecornite from the type locality, i.e. Ni_9BiSbS_8, and to develop a classification scheme for other known or possible members of the group and also to name the end-members known from natural occurrences and described as varieties of hauchecornite. The name bismutohauchecornite is proposed for the $Ni_9Bi_2S_8$ end-member. The new name, the redefinition of hauchecornite, and the classification of the group, as described in this paper, have been approved by the Commission on New Minerals and Mineral Names, IMA.

Historical review. Only original works are reviewed. Hauchecornite was originally described by Scheibe (1888, 1893) from the Friedrich mine near Wissen a.d. Sieg in the Hamm a.d. Sieg mining district, Westphalia, Germany. The chemical analyses, which showed the presence of major Ni, Bi, Sb, and S and minor Fe, Co, and As, were interpreted as $(Ni,Co,Fe)_7(S,Bi,Sb,As)_8$ or $Ni_{14}SbBi_2S_{13}$. Although Scheibe's characterization of the morphology, physical properties, and chemical composition of the mineral was adequate, the mineral slowly slipped into the 'dubious' category and was even condemned as a mixture by some authors. The formula of the mineral also differed from paper to paper although no new analytical work was undertaken. Bateman (1927) mentioned an occurrence of hauchecornite in the Rio Tinto deposit in Spain. The mineral was identified only optically and no chemical data were given.

The first modern investigation was undertaken by Peacock (1950). His study of the physical properties and crystal structure confirmed Scheibe's data and fully rehabilitated the mineral. Peacock also proposed a new formula, $Ni_9(Bi,Sb)_2S_8$, the first one correctly reflecting the unit-cell content.

Williams (1958) described 'hauchecornite' from the Central Balstrup Lease, Zeehan, Tasmania. The identification was based on optical properties and an X-ray diffraction pattern, and no chemical tests were carried out because of the small grain size. The present author had the opportunity of examining these samples, and found that no Bi-bearing mineral was present. Electron microprobe analyses indicated that the mineral is, in fact, tučekite, $Ni_9Sb_2S_8$.

Gait and Harris (1972) published a paper on three 'varieties' of hauchecornite: antimonian, $Ni_9(Bi,Sb)_2S_8$, from the type locality; arsenian, $Ni_9(Bi,As)_2S_8$, from the Vermilion mine; and tellurian, $Ni_9(Bi,Te)_2S_8$, from the Strathcona mine, the last two localities both being in the Sudbury District, Ontario, Canada. All three minerals are fully characterized in terms of physical properties and chemical composition. The arsenian and tellurian 'varieties' have been subsequently renamed arsenohauchecornite and tellurohauchecornite respectively (Gait and Harris, 1980).

The crystal structure of hauchecornite was solved and published by Kocman and Nuffield (1974). Their work was done on material from the type locality, Wissen a.d. Sieg, and represents the basis for our redefinition of hauchecornite and for the classification of minerals of the hauchecornite group.

In 1975 Watkinson *et al.* mentioned a tentatively identified 'hauchecornite' with composition $Ni_9(Bi_{1.6}As_{0.1})S_8$ from the Zimmer Lake Area, Saskatchewan, Canada. In the same year Soeda and Hirowatari (1975) described 'hauchecornite' from the Tsumo and Mihara mines in Japan, with compositions close to $Ni_9(Bi_{1.4}As_{0.7})S_8$ and $Ni_9(Bi_{1.5}As_{0.5})S_8$ respectively.

Kovalenker *et al.* (1977) described 'hauchecornite' from the Oktyabr'skoe Cu-Ni deposit, Noril'sk District, USSR. The mineral has a composition very close to the ideal end-member $Ni_9Bi_2S_8$, and its physical properties are fully characterized. The authors correctly evaluated the role of partitioning Bi, Sb, As, and Te into the two sites and also predicted the possibility of the existence of other members of the group, but they considered these members to be only varieties of hauchecornite and suggested that the name hauchecornite should be retained for the 'pure bismuth variety'. The name bismutohauchecornite is here proposed for this species.

Also in 1977 Fillimonova *et al.* described 'arsenian hauchecornite' from the baryte-polymetallic deposit of Karagaily, Central Kazakhstan, USSR. This mineral has a chemical composition corresponding to $Ni_9(Bi,As)_2S_8$, similar to the material from the Strathcona mine. Its physical properties and chemical composition are well documented.

Just and Feather (1978) described tučekite, $Ni_9Sb_2S_8$, an antimony analogue of hauchecornite from Kanowna, Western Australia, and the Witwatersrand, South Africa.

In 1979 E. H. Nickel (priv. comm.) found bismuthian tučekite with a chemical composition close to $Ni_9(Sb_{0.7}Bi_{0.3})SbS_8$ at the Whim Creek deposit in Western Australia.

Crystal structure and chemical composition of the hauchecornite group minerals. Hauchecornite from the type locality, according to Kocman and Nuffield (1974), is tetragonal, has space group *P4/mmm*, and $a_0 = 7.300$ (3), $c_0 = 5.402$ (2) Å, with $Z = 1$. The structure contains 19 atoms in 6 non-equivalent types of sites. (Their notation will be used throughout to facilitate cross-reference): one $Ni(1)^{vi}$, eight $Ni(2)^{v}$, one Bi^{vi}, one M^{viii}, four $S(1)^{v}$, and four $S(2)^{v}$. For spatial arrangement of the sites see Kocman and Nuffield (1974). The Ni(1) and Ni(2) sites can accommodate Ni, Co, and Fe; no preferential ordering of any of these metals into a particular site has been reported. Sites S(1) and S(2) are occupied only by sulphur. Sites Bi and *M* can accommodate the Group V elements Bi, Sb, and As, as well as Te. Kocman and Nuffield concluded that the element with the less metallic character is ordered preferentially into the *M* site, which also means that the more metallic element is preferentially ordered into the Bi site. In the case of hauchecornite from the type locality, this ordering results in the Bi site being occupied only by bismuth, while the *M* site contains both bismuth and antimony in the ratio Sb:Bi = 7:2 Antimony is therefore the dominant element in the *M* site. The full empirical formula, based on the microprobe analysis by Gait and Harris (1972), is: $(Ni_{1.0}Co_{0.01})^{vi}(Ni_{8.0}Co_{0.09})^{v}Bi^{vi}(Sb_{0.7}Bi_{0.2})^{viii}S_4{}^{v}S_4{}^{v}$. As there is no known ordering in the $Ni(2)^{vi}$ and $Ni(2)^{v}$ sites, and the $S(1)^{v}$ and $S(2)^{v}$ sites are occupied only by sulphur, the empirical formula can be simplified to $(Ni_{9.0}Co_{0.1})Bi(Sb_{0.7}Bi_{0.2})S_8$, the ideal formula being Ni_9BiSbS_8.

Similar calculations can be carried out for all the other available analyses of the hauchecornite-type minerals. This leads to the empirical and ideal formulae given in Table I.

We can see here that the minerals fall into five different ideal formulae, each of which represents a different mineral species. As the material from the type locality corresponds closely to the ideal formula Ni_9BiSbS_8 the mineral hauchecornite is defined so as to cover naturally occurring minerals with the crystal structure as described by Kocman and Nuffield (1974) and with Ni dominant in the Ni(1) and Ni(2) sites, Bi dominant in the Bi site, Sb dominant in the *M* site, and S dominant in the S(1) and S(2) sites.

Classification of the hauchecornite-group minerals. The classification of the hauchecornite-group minerals is based on elements dominant in the Bi and the *M* sites while it is assumed that Ni is dominant in the Ni(1) and Ni(2) sites, and sulphur in the S(1) and S(2) sites. Applying the abovementioned ordering rules, we can see that there are ten possible end-members (Table I) and each of them should be given full species status when found as a naturally occurring mineral (or more accurately, as a mineral in which the end-member predominates). After recalculating the analysis to 8 sulphur atoms, the elements Bi, Sb, As, and Te should be partitioned into the appropriate sites by allocating the elements to the Bi site, starting with the element with the most pronounced metallic character, i.e. in the order Bi-Te-Sb-As. Any small surplus or deficit could perhaps be evenly distributed among the sites (a large departure from $Bi+M = 2$ would indicate analytical error). In this way a quantitative analysis is enough to classify

TABLE I. *Formulae of hauchecornite-group minerals from analyses recalculated to eight sulphur atoms*

Site	$Ni(1)^{vi}Ni(2)^{v}$			Bi,Te,Sb,As^{vi}				Bi,Te,Sb,As^{viii}					
Ref.	Ni	Co	Fe	Bi	Te	Sb	As	Bi	Te	Sb	As	Ideal end-member	Name
1	8.90	0.15	0.04	1.0				0.92			0.08	Ni_9BiBiS_8	bismutohauchecornite
2	8.9	0.1		1.0				0.5			0.1	Ni_9BiBiS_8	bismutohauchecornite
3	8.4	0.7	0.1	1.0				0.48			0.46	Ni_9BiBiS_8	bismutohauchecornite
4	9.1	0.1		1.0				0.2		0.7		Ni_9BiSbS_8	hauchecornite
5	8.9	0.1	0.3	1.0				0.5			0.7	Ni_9BiAsS_8	arsenohauchecornite
6	8.66	0.51		1.0				0.45			0.70	Ni_9BiAsS_8	arsenohauchecornite
7	9.1	0.1	0.1	1.0				0.4			0.7	Ni_9BiAsS_8	arsenohauchecornite
8	8.8	0.2	0.2	1.0				0.3	0.8			Ni_9BiTeS_8	tellurohauchecornite
9	8.2	0.2	0.7	0.1		0.9				0.9	0.1	Ni_9SbSbS_8	tučekite
10	8.3		0.7			1.0				0.9	0.2	Ni_9SbSbS_8	tučekite
11	8.3		0.6			1.0				0.9	0.2	Ni_9SbSbS_8	tučekite
12	8.1	0.4	0.4	0.3		0.7				1.0		Ni_9SbSbS_8	tučekite
	9.0					1.0					1.0	Ni_9SbAsS_8	
	9.0						1.0				1.0	Ni_9AsAsS_8	
	9.0				1.0				1.0			Ni_9TeTeS_8	
	9.0				1.0					1.0		Ni_9TeSbS_8	
	9.0				1.0						1.0	Ni_9TeAsS_8	

1. 'Hauchecornite', Oktyabr'skoe Deposit, USSR, Kovalenker *et al.* (1972).
2. 'Hauchecornite', Zimmer Lake, Canada, Watkinson *et al.* (1975).
3. 'Hauchecornite', Mihara Mine, Japan, Soeda and Hirowatari (1975).
4. Hauchecornite, Friedrich Mine, Germany, Gait and Harris (1972).
5. 'Arsenian hauchecornite', Vermilion Mine, Canada, Gait and Harris (1972): arsenohauchecornite, Gait and Harris (1980).
6. 'Arsenian hauchecornite', Karagaily, USSR, Filimonova *et al.* (1972).
7. 'Hauchecornite', Tsumo Mine, Japan, Soeda and Hirowatari (1975).
8. 'Tellurian hauchecornite', Strathcona Mine, Canada, Gait and Harris (1972): tellurohauchecornite, Gait and Harris (1980).
9. Tučekite, Kanowna, W. Australia, Just and Feather (1978).
10. Tučekite, Witwatersrand, S. Africa, Just and Feather (1978).
11. 'Hauchecornite', Zeehan, Tasmania, Williams (1958); anal. Just (this paper).
12. Tučekite, Whim Creek, W. Australia, Nickel (priv. comm.).

the mineral and a structural study is not necessary. It is the author's opinion that the differences between the simple lattice given by Kocman and Nuffield and the supperlattice (with *a* and *c* doubled and Z = 8) given by Gait and Harris, and by Kovalenker, are small enough for the two structures to be viewed as structural polytypes and do not warrant the introduction of a new special name if both structural types are found for material with the same chemical composition.

The theoretical end-members and their natural equivalents (when known) are given in Table I.

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