GALINA HALAHYJOVÁ-ANDRUSOVOVÁ

REFLECTIVITY OF GERSDORFFITE FROM DOBŠINÁ

(Figs. 1—6)

Abstract: Modern quantitative methode in reflected light, mainly measurements of reflectivity make possible more precise optical identification of ore mineral.

In the article are presented the results of study of the Dobšina gersdorffite with great chemical variability of the individual zones. Mineralogy and chemism of gersdorffite as member of the cobaltite order are briefly described. More in detail the applied methods of reflectivity measurement R are concerned. The conclusions for optical characterisation of gersdorffite as well as its individual zones completed with the results of microhardness measurement follow from it.

The presented studies do not lead to any essential solution of the diagnostics of gersdorffite and minerals akin to it but an attempt of tracing the optical values in reflected light in dependence on chemism is submitted. The applied methods are starting to be developed by us only.

Резюме: Новые квантитативные методы в отраженном свете, главным образом измерения отражательной способности, позволяют более точную идентификацию рудных минералов.

В настоящей статье приводятся результаты изучения добшинского герсдорфита, химическое сложение отдельных зон которого отличается большой изменчивостью. Вкратце описаны минералогия и химизм герсдорфита как члена ряда кобальтина. Подробно рассмотрена методика измерения, методика отражательной способности минералов. Оптическая характеристика герсдорфита и его зон, на основании приведенной методики, дополнена результатами измерения микротвердости.

Изучение оптических свойств герсдорфита в отраженном свете в зависимости от его химизма является у нас новым методом, который до сих пор еще не применялся.

Introduction

Gersdorffite from Dobšiná with its considerable chemical variability, interesting mineralogy as well as position on ore veins was the base for many studies. In the presented article the author comes back again to the problematics of Ni-Co minerals in Dobšiná (1959, 1961, 1964).

The obtained results are confronted with the results known from foregoing papers, mainly for elucidation of many questions not solved completely, concerning gersdorffite and other isotropic, white Ni-Co arsenides and sulfoarsenides. It is possible that the presented studies will not lead to essential complete solution of problems but it is an attempt, similarly as for instance in the case of the study of reflectivity of bravoite zones (S. Demirsoy, 1968), to trace changes, of reflection R with chemism and find the limit of reflectivity R values (further only R) of gersdorffite for diagnostic purposes.

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* RNDr. G. Halahyjová-Andrusovová, Department of Mineralogy and Crystallography of the Faculty of Natural Science at the Comenius University, Bratislava, Gottwaldovo nám. 2.

Mineralogy of Ni-Co Minerals

From the Ni-Co-Fe sulfoarsenides we take notice of gersdorffite and cobaltite as well as chloanthite, the most common Ni-Co minerals on the Dobšiná ore veins.

According the classification by H. Strunz (1962) gersdorffite and cobaltite crystallochemically belong to the cobaltite-ullmannite group, class of sulfides with ration R:S = 1:2! The cobaltite-ullmannite group includes two orders — a) of cobaltite, b) of ullmannite. The members of the cobaltite order are:

Cobaltite	$CoAsS$	$a_0 = 5.61$ Å
dzhulukulite	$(Co, Ni)AsS$	$a_0 = 5.57$ Å
gersdorffite	$NiAsS$	$a_0 = 5.71$ Å

According to the paper by P. Bayliss (1969) a_0 for samples from Dobšiná is equal 5.69—5.72 Å. Gersdorffite obtained synthetically with stechiometric formula NiAsS has $a_0 = 5.94$ Å. The mentioned minerals crystallize in the cubic system, didodecahedral class, T_{6h}. In this order isomorphism of Ni and Co has been ascertained. According to Peacock and Henry (1948 in H. Strunz, 1962) cobaltite and gersdorffite have pyrite structure with statistic distribution of As and S. Later structural-crystallographic studies of gersdorffite were published by P. Bayliss and H. C. Stephenson (1967, 1968). Cobaltite and gersdorffite very frequently contain Fe up to 12 % and more. In gersdorffite the content of Fe varies from negligible amounts to 16—17 % (Dobšiná, J. Goll 1937). Similarly the content of Co 1—2 % in gersdorffite as well as that of Ni in cobaltite may be found out in the same amount. On the basis of the study of gersdorffite from Dobšiná, which contains considerable % of Fe and according to anlyses mentioned by J. Goll (1937) the gersdorffite with higher Fe content was termed dobschauite with the formula $(Ni, Fe, Co)_2As_2S$ by Dana (1964). From the dobschauite further mineral varieties of gersdorffite were derived, plessite $(Ni, Fe, Co)_3As_3S_2$ and amoibite $(Ni, Fe)_9As_8S_6$. Later studies found out mixtures to be concerned and distinguishing of varieties as unsubstantiated. Therefore they were omitted as synonyms (C. Hintze, 1904; H. Strunz, 1962).

In 1958 N. I. Šiškin published an article about finding a new mineral of cobaltite order - dzhulukulite - with the formula (Co, Ni)AsS. The mentioned paper is quoted in the book by H. Strunz (1962) and in appendices to H. Hintze's „Handbuch der Mineralogie" (1960). Beside dzhulukulite is also known cobaltite with Ni content and gersdorffite with increased content of Co. This way an isomorphous order of minerals originates, gradually passing into each other from the chemical point of view:

cobaltite	dzhulukulite	gersdorffite
$CoAsS$ $CoAsS + Ni$	$(Co, Ni)AsS$ $NiAsS + Ni$	$NiAsS$

J. A. Dunn (1937) distinguished two varieties of gersdorffite α and β according to microchemical analyses. Regarding to distinct isomorphism of Ni and Co and also to variable content of As and S in gersdorffite as member of cobaltite order it is evident that delimitation of these two varieties is not right at present. Cobaltite—dzhulukulite—gersdorffite are only the principal members of the isomorphous order with great number of transitional types, to which also the mentioned varietes of gersdorffite belong. According to the studies by D. D. Klemm (1965) at the minerals cobaltite—gersdorffite—arsenopyrite there is a great possibility of isomorphism and formation of mixed crystals.

On the basis of the studies of analyses of the above mentioned minerals carried out up to now it is evident that pure cobaltite has not been known from literature and the formula varies in the limits $(Co.Fe.Ni)As_{1,05}S_{0,95}$—$(Co.Fe.Ni)As_{0,95}S_{1,1}$, however, whereat $(Co.Fe.Ni)_{0,98\,1,8}$ with maximum content 20 % mol. FeAsS and 25—30 % mol NiAsS. According to D. D. Klemm (1965) gersdorffite has tendency to greater content of metal in contrast to cobaltite and arsenopyrite as well as larger amount of As and S. The formula of gersdorffite changes from $(Ni.Fe.Co)As_{1,6}S_{0,4}$ to $(Ni.Fe.Co)As_{0,8}S_{1,2}$ where $(Ni, Fe, Co)_{1,4\text{-}0,9}$. Under microscope most frequently mixed crystals have inhomogeneous inclusions, what explains deflection from stechiometric formula of gersdorffite.

On the Dobšiná ore veins the mostly spread mineral and microscopically most typical is gersdorffite. It appears white with shade into yellow in reflected light. Homogeneous at first sight, observed under dry objective (A = 0.30, 10×) it is distinctly zonal, mainly at the rims of grains and aggregates. Under magnification 353×—475× (also with immersion) the individual zones may be studied more in detail optically. Zonality is shown by regular alternation of thin beds of various width differing in colour shade. Zones of white and violette colour alternate, visible more distinctly at the margins of veins and idiomorphic grains. Zonality of gersdorffite is treated more in detail in the article of G. Halahyjová-Andrusovová (1964).

In Dobšiná some zones of gersdorffite zones correspond to chloanthite from the group of skutterudite (G. Halahyjová-Andrusovová, 1963). Sometimes chloanthite overgrowths in branches with other minerals most likely belonging to this group of Ni-Co minerals. It is also found in the form of fringes at the edges of concentric reniform forms composed of niccolite, pararamelsbergite, followed by small crystals of arsenopyrite and löllingite in voids.

Chemism of Gersdorffite

Chemical composition of gersdorffite has been known from chemical analyses of former authors (Stromeyer, Zerjäu, Sipöcz in H. Hintze, 1904), analyses by J. Goll (1937) and according to the papers of the author of this article (1959, 1961).

In order to have chemism of the individual zones of gersdorffite more precise as base for measurement of reflectivity R the analysis by aid of electron microprobe was applied. At the same time also precision of chemical analyses of the Dobšiná gersdorffite published up to now has been indirectly verified. The analyses by electron microprobe were carried out in the BRGM in Orleáns (France) by G. Remond (1967). The presence and % of Ni-Co-Fe-As-S representation in the individual zones and the mineral generally were traced. Two samples from the Martiny Vein in the Dedičná štolňa (polished section 438, 122) were analysed. The grains for analysis were marked in advance microscopically. Both samples were metallized with Al at the surface with dimensions 200 Å. The sample 438 was moved slowly under the electron beam with the length of section 100 μ. The sample 122 was moved three times faster than the sample 438 along the whole length of analysed section 500 μ. Beside that on sample 438 planar registration (balayge) was carried out at a square with sides 300 μ. The results are of working character.

At both polished sections the concentric zonality of gersdorffite has the form of hexagons. In analyses by the microprobe considerable variability of some represented elements Co-Fe-S has been found out, what has permitted to carry out approximative analysis only (G. Remond, 1967):

polished section 438	polished section 122	
Ni — 32 %, very stable content	max. 31.4 %	min. 30.2 %
Co — 1.6 %, average value	max. 0.65 %	min. 0.34 %
As — 68 %, average value	max. 74 %	min. 56 %
S — from 10 to 12 %	max. 12.4 %	min. 6.1 %

The results of the analyses permit to conclude that zonality of gersdorffite is mainly caused by variability of Co and S. Less distinct is variability of As at the Dobšiná gersdorffite. The content of Ni is quite stable in both analysed samples. Fe is very irregularly distributed, its concentration changes from point to pint and therefore it cannot be expressed by numbers. Therefore the conclusion of relation of Ni and Fe content to reflection value was made as mentioned by M. Háber (1971).

The percentage content of Co does not attain as high values as in the analyses by J. Goll (1937) and former authors. It is sure that the high content of Co in these analyses is caused by present cobaltite. In contrast to theoretical composition of gersdorffite the results of analyses by electron microprobe show essentially higher content of As to the detriment of S, % content of which does not attain theoretical composition. However, it agrees with the results of the chemical analyses by J. Goll (1937) and G. Halahyjová-Andrusovová (1959, 1961).

The content of Ni is higher than shown in the analyses of gersdorffite from Dobšiná and lower compared to theoretical composition of Ni-As-S. A part of Ni isomorphously replaces Co and Fe.

The individual zones of idiomorphic gersdorffite crystals may be divided into three groups according to the content of Co and S:

maximum zone	% S 12.4	% Co 6.65
minimum zone	6.1	0.34
intermediary zone	9.2	—

That signifies minimum zones chemically rather approaching chloanthite. The maximum zone is nearest to gersdorffite and the intermediary zone is a transitional type if we do not take into regard concentration of Fe. If we compare distinguishment of zones according to chemism with observation under microscope, the minimum zones correspond to „whiter" zones, the maximum and intermediary zones to „grey" ones. The minimum zone (whiter) have more Ni, less Co and S, the maximum and intermediary zones (more grey) has unchanged amount of Ni, little Co and more S. The mentioned chemism influences values of R and microhardness VHN. Similar results are presented by H. Háber (1971) for gersdorffite from ore veins in the area between Gelnická Huta and Prakovce and S. Demirsoy (1968) for bravoites. D. D. Klemm (1965) found out zonality to be caused by various content of isomorphous Fe and Co in gersdorffite. This conclusion was confirmed by H. J. Gies (1968), who mentioned higher content of Fe and Co and relatively lower content of Ni in zones with lower R on the basis of electron picture of Fe, Ni, Co, Sb and microscopy. In zones with higher R the content of Fe and Co is minimum.

Reflectivity of Gersdorffite

As it is evident from the mentioned up to now, chemical variability of mineral reflecting in distinct zonality influences variability of optical properties.

R measurements of gersdorffite have to serve only for more precise diagnostics of the individual zones but also to find out the extent of variation of % R with the change of chemism.

Applied methods: Fundamental measurements were carried out in B.R.G.M. in Orléans (France) on photometric equipment with photomultiplier. The equipment was recalulated theoretically and constructed by J. Prouvost (1960) with employing the zero method. which permits to increase precision of measurement (C. Lévy, P. Picot 1961). The equipment consists of ore microscope Laborlux-Pol of the firm Leitz. Wetzlar with light source Monle lamp with low-volt glow lamp 6V, 5A trough transformer. The monochromator of the firm Trégor is prismatic with range 3800—8000 Å. constant deviation 180°. The dimension of used slot is 40/100 mm.

The measuring part is represented by photomultiplier with maximum sensitivity in the spectrum 5250 Å completed with galvanometer amplifier it is $2.6.10^{-1}$ a(mm)n with inner resistance 430 ohms.

In the optical part dry objective with aperture $A = 0.85$. magnification 45 × without inner tension of lenses was emplyoed. The iris diaphragm of the microscope was substituted by stable metallic plate with opening 1 mm.

As standard in measurement sphalerite from Santander (Spain) was employed. of which R was recalculated from the values n and k by J. Orcel (1930) mentioned in table 1.

Table 1. Reflectivity of Sphalerite Standard (Santander)

in nm	R in % S. Demirson, 1968	R in % data from B.R.G.M.
420		18,6
440	17,7	18,15
450	17,6	
460	17,4	17,82
470	17,3	
480	17,2	17,55
490	17,1	
500	16,9	17,32
510	16,8	
520	16,7	17,11
530	16,6	
540	16,5	16,98
550	16,5	
560	16,4	16,75
570	16,4	
580	16,3	16,60
590	16,2	
600	16,2	16,48
610	16,1	
620	16,1	16,35
630	16,0	

The measurements were carried out in visible spectrum from 420 nm to 640 nm in regular intervals up to 20 nm.

Curves of R dispersion were constructed on the basis of recalcutations of measurement results. The terminal results were corrected according to the curves of R dispersion. Measurements were carried out on fresh repolished sections. Relative error of measurements is approximately 2 %, mainly caused by the great difference of R standard and the measured mineral.

Controlling measurements were carried out on microphotometer of the firm Reichert Vienna attached to universal microscope MeF from the same firm. The controlling measurements were carried out by Viera Chrenová, preparing her diploma-work at the Faculty of Natural Science of the Comenius University, in the laboratories of the Uranium Industry in Příbram.

The photoelectric equipment consists of the photoelectric head with receiver, registration with galvanometer. The source of light was the lamp Lux U with low-volt glow lamp 6 V, 30 W with current stabilizator of Czechoslovak production. Photomultiplier of the firm Philips type AVP.

In the optical part objective PLAN-16 x with aperture A = 0,20 and ocular PLAN 10 x were used. The aperture diaphragm was of the value 6,8, the diaphragm of photometer 2,5 and the diaphragm of field of vision was closed with stroke. The size of the measured field was 19,3 microns. As standard was used the intrenational standard SIKA No. 200, the values R of which are mentioned in table 2. The measurements were carried out in visible spectrum, wave length from 440 nm to 660 nm after each 20 nm of wave length without polariser. The error of measurements is less in the Reichert equipment at these controlling measurements because the apparatus is of more modern construction and in the measurements a standard of better quality distributed by the International Commission IMA for ore microscopy (IMA/COM) calibrated in the Netherlands was employed by M. Háber.

Table 2. Reflectivity of SIKA Standard No. 200

in nm	R in % (M. Háber)	R in % (Pijpekamp)	R in % (N. F. M. Henry)
440	21,1		
460	21,0		
470			21,1
472		20,95	
480	20,8		
500	20,7		
520	20,6		
540	20,4		20,6
546		20,47	
560	20,3		
580	20,2		
589		20,28	
600	20,1		
620	20,05		
622			20,2
640	20,0		
650		20,09	
660	19,95		

In comparing the results of R measurements of gersdorffite also the differences of the applied equipments and standards should be taken into consideration.

Results of measurements: R measurements were intended in detail to zonal gersdorffite. Within the limits of distinguishing ability the „more grey" and „whiter" zones of gersdorffite as well as the core of zonal grains were re-measured. The „whiter" zones are shown to have always higher R values than the „more grey" zones. There is not only a difference of $\%$ values of R in the individual wave lengths but we also observe different course of R dispersion curves. The R dispersion curves of gersdorffite are of anomalous type characteristic for minerals with high absorption.

The predominating part of curves of R dispersion of the „whiter" zones has their maximum in the yellow spectrum, the minimum in the violette and red sprectrum. The „grey" zones have essentially lower R values and somewhat different course of R dispersion curves (table 3, 4, figs. 1—4).

Table 3. Reflectivity Values of Gersdorffite from Dobšiná

	in nm										
	420	440	460	480	500	520	540	560	580	600	620
whiter zone n. 438	56,8	60,5	62,4	63,4	63,9	64,1	64,3	64,9	64,0	63,4	61,4
whiter zone n. 158, average	46.2	47,7	48,9	49,9	50,8	51,0	51,0	51,0	51,0	51,8	52,4
whiter zone n. 158	45,2	46,0	46,7	47,2	47,6	48,0	48,4	48,8	49,1	49,3	48,3
more grey zone n. 438, average	51,1	55,0	57,5	58,3	58,7	58,9	59,1	59,2	59,2	59,2	58,6
more grey zone n. 158, average	45,4	46,9	47,9	48,6	49,2	49,7	50,0	50,2	50,3	49,8	49,6
more grey zone n. 122, average	46,2	47,3	48,1	48,7	49,5	50,0	50,2	50,3	50,3	50,2	50,4
more grey zone n. 473, average	51,2	51,7	52,2	52,6	52,8	52,9	53,3	53,5	53,6	53,9	53,9
grain core n. 122, average	53,3	54,4	55,4	56,5	57,2	57,9	58,4	58,2	58,9	59,0	59,3

The measurements f R in minerals of the cobaltite order and skutterudite group have been so far rare and the results relatively different. Many measurements were carried out without nearer indication of wave length of light. If we try comparison with published results of R measurements of the above mentioned Ni-Co minerals, it is to be seen that R dispersion curves of the „grey" zones and R values approach values of gersdorffite (I. M. Gray, A. P. Millman, 1962) respectively are somewhat higher. The higher values of the „grey" zones are caused by the presence of Co and Fe. The higher content of Ni results in lower R and more grey colour, for instance in bravoites as mentioned by S. Demirsoy (1968). As mentioned by M. Háber (1971) from R measurements of gersdorffite from the area between Gelnická Huta and Prakovce which has equable per cent of Fe in the zones, the iron content of the individual zones may be identified. $\%$ content of other elements in the zones is precisely known and distribution more homogeneous than in the zones of the Dobšiná gersdorffite and

Table 4. Reflectivity of Gersdorffite (V. Chrenová, 1971)

	R in %									
	440 nm	460 nm	480 nm	500 nm	520 nm	540 nm	560 nm	580 nm	600 nm	620 nm
1	45,2	45,9	48,0	48,6	48,5	48,8	48,7	49,7	51,5	55,1
2	42,2	44,6	47,3	47,7	48,1	48,5	48,7	49,2	51,5	55,1
3	45,2	47,2	50,2	49,9	49,8	49,2	49,2	49,7	51,5	55,1
4	45,2	47,2	48,7	49,0	48,1	48,5	48,7	49,7	52,7	60,1
5	45,2	45,9	48,0	48,1	47,8	48,3	48,7	49,7	52,7	60,1
6	45,2	47,2	48,5	48,7	49,0	49,3	49,2	49,4	50,2	55,1
7	45,2	45,9	46,4	47,4	49,0	49,3	51,5	53,1	55,2	55,1
8	48,2	48,5	49,2	49,6	50,3	50,7	50,7	51,0	52,7	55,1
9	49,5	45,9	46,4	47,4	47,5	47,5	49,2	49,4	50,2	55,1
10	45,2	47,2	47,8	48,0	48,7	48,9	49,6	49,9	50,2	50,1
11	45,2	45,9	46,4	49,0	49,4	49,7	51,5	52,1	54,0	55,1
12	45,2	47,2	47,8	48,1	48,7	49,1	50,7	51,0	51,5	55,1
13	45,2	45,9	46,4	47,2	48,4	48,5	50,2	50,5	51,5	50,1
14	45,2	47,2	47,8	48,1	48,7	48,8	49,6	49,9	50,2	50,1
15	45,2	47,2	47,8	49,0	49,7	50,5	51,5	52,6	55,2	55,1
16	45,2	47,2	48,7	49,9	50,1	49,5	50,3	50,8	51,5	55,1
17	48,2	48,5	49,5	50,3	50,5	50,0	50,7	51,2	52,7	55,1
18	48,2	48,5	48,7	49,9	50,1	51,1	53,5	54,0	55,2	55,1
19	48,2	49,8	52,3	52,1	51,8	52,4	54,6	55,1	55,2	55,1
20	45,2	47,2	48,0	48,6	48,8	49,1	49,5	50,2	51,2	50,1
21	48,2	52,5	53,3	53,7	53,6	53,4	53,4	53,1	54,0	55,1
22	45,2	45,9	49,2	49,7	51,0	51,0	51,8	51,5	51,5	55,1
23	48,2	52,5	52,0	52,8	52,3	52,5	52,6	52,6	52,7	55,1
24	48,2	52,5	52,7	52,8	53,3	53,1	53,0	53,1	54,0	55,1
25	51,2	51,1	52,0	52,4	53,3	53,4	54,1	54,2	55,2	60,1
×	46,2	47,8	48,9	49,5	49,8	50,0	50,8	51,3	52,6	54,9
+	—	—	—	—	—	50,1	50,6	—	52,7	—

× average value of reflectivity of gersdorffite calculated from 25 measurements
+ adjusted values according to the graph of R dispersion curve of gersdorffite

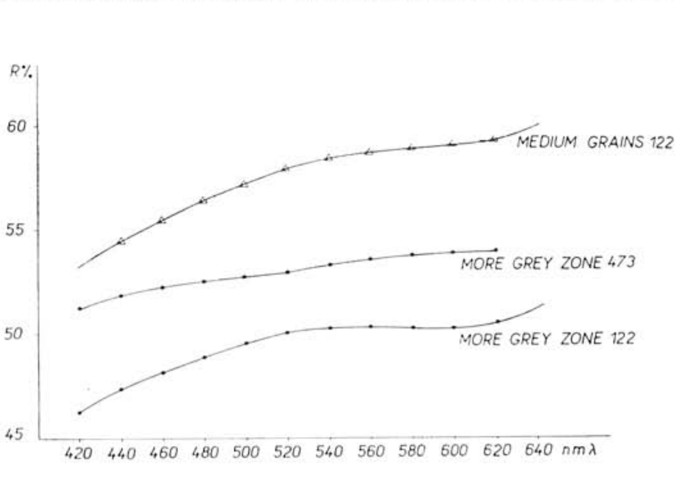

Fig. 1. Gersdorffite from Dobšiná.

therefore better conclusions may be drawn than in R measurements of the Dobšiná gersdorffite (table 5, fig. 5).

The results of R measurements of not zonal gersdorffite from Rudňany show the course of R dispersion curves and R values to be indentical with the values and courses of R dispersion curves of „grey" zones.

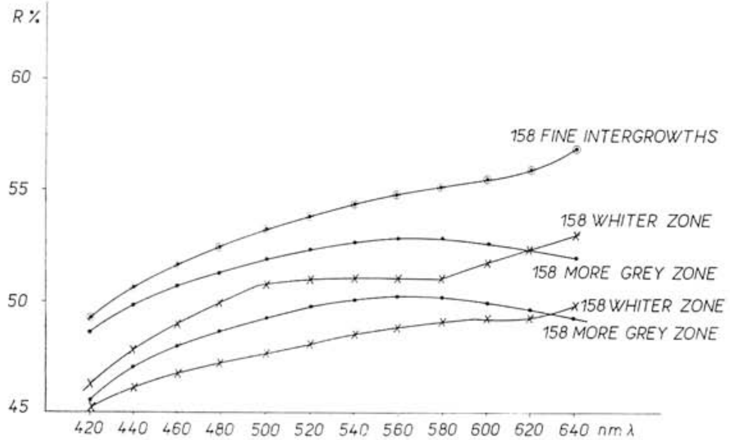

Fig. 2. Gersdorffite from Dobšiná.

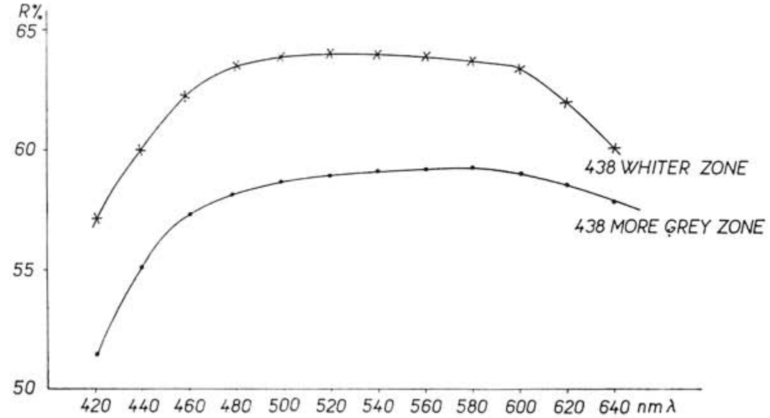

Fig. 3. Gersdorffite from Dobšiná.

In comparison of the R values and R dispersion cuves obtained with fundamental and controlling measurements the values of controlling measurement (V. Chrenová, 1971) are lower than those of fundamental measurement. The course of R dispersion curves of both measurements is identical from 440 nm to 580 nm, great differences are in the range from 400 nm to 440 nm and from 580 to 640 nm, where sensibility of the photomultipliers of employed equipments was different. Some gersdorffite zone approach

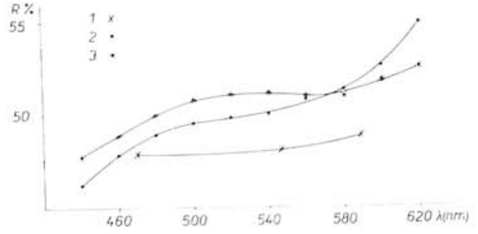

Fig. 4. Gersdorffite. 1 — A. E. Burke (1970), 2 — V. Chrenová (1971), 3 — author's measurement.

Table 5. Reflectivity and Microhardness Values of Gersdorffite from the Area Gelnická huta — Prakovce (M. Háber, 1971)

Sample No.	R_{470} nm	R_{546} nm	R_{589} nm	R_{650} nm	VHN 2 kp/nm	Remark
11	52,3	52,9	53,3	53,9	753	standard silicon
13	52,3	52,7	53,35	54,0	750	
7	50,6	50,2	51,9	52,6	785	
4	48,4	49,2	49,1	50,4	820	
2	49,5	50,1	50,2	51,2	773	
6	48,4	49,1	49,5	50,05		
10	50,0	50,4	51,0	52,9	812	
12	46,2	46,7	47,5	48,6	874	

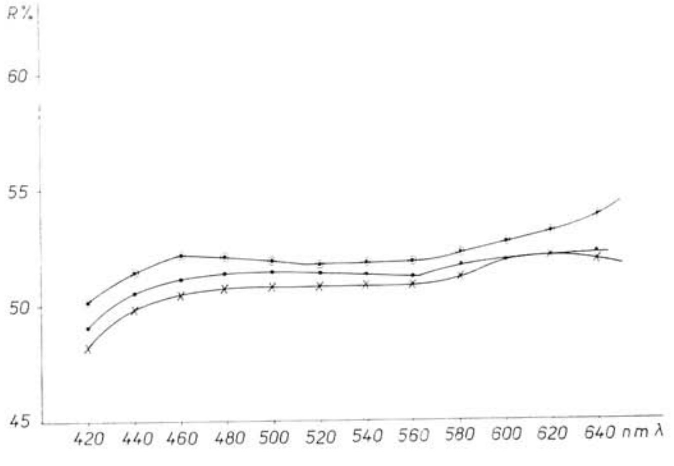

Fig. 5. Gersdorffite from Rudňany.

in their values chloanthite, however, according to R dispersion curves precise identification cannot be made (Tab. 6.)

Finally α and β gersdorffite should be mentioned: In their article I. V. Ľachnickaja, M. J. Šumskaja (1966) are dealing with the β variety of gersdorffite and try to substantiate optically the existence of this gersdorffite variety on the basis of R values

Table 6. Reflectivity Values of Ni-Co Minerals

in nm	gersdorffite	cobaltite	skutterudite	author
460			60,5	Orcel
470	47,9			Burke
546	48,1			Burke
589	48,8			Burke
598				Orcel
650	48,5		61,9	Burke
white light	53/47,5	52,5/52,7	55,8	Folinsbee Bowie
green filter	49,5ˣ	52	60	Ramdohr
orange filter	42,5ˣ	52,5	53,5	x) too low
red filter	42ˣ	48	51,5	remark of Ramdohr

and the course of dispersion curves (fig. 6). It seems that the experiences about the minerals of the cobaltite and skutterudite group and the R measurements obtained up to now make possible to consider gersdorffite varieties, which may be recognized by aid of R.

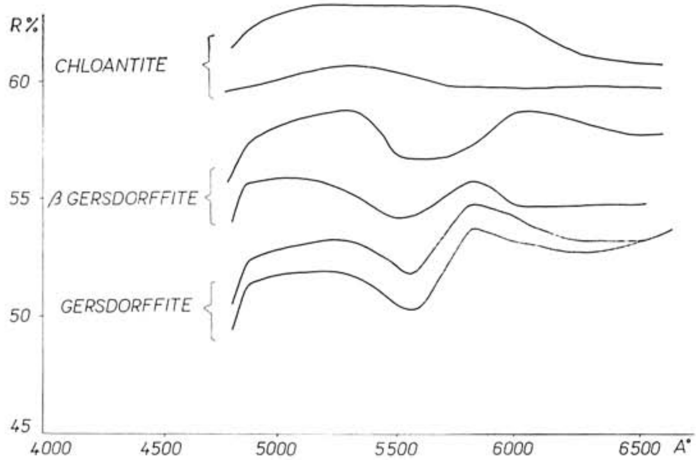

Fig. 6. Dispersion R curves of arsenides from Berikulskoe ore deposit (I. V. Lachnickaja, M. J. Šumskaja 1966)

Microhardness of Gersdorffite

The variability of the chemism of mineral is not only reflected in optical properties but also in % of other physical properties. Microhardness measurements of the Dobšiná gersdorffite confirm it. Microhardness measurements were carried out on Soviet microhardness-meter PMT-3 with Vickers' pyramid employing 100 g weight. The time of impression of the pyramid into the mineral polished section was 15 sec. On each polished section 10 measurements were made. The measured values were recalculated to microhardness value in kp/mm^2

The great variability of chemism of the Dobšiná gersdorffite is reflected in the results of meirohardness VHN. At the polished section from the Martini Vein the core of the zonal grain has the value VHN = 782 kp/mm^2. At the edge of the „whiter" zones the values vary VHN = 782—933 kp/mm^2. At the polished section 438 from the same locality the grain core has values VHN = 907—933 kp./mm^2. The outer „whiter" zones have VHN = 673—724 kp./mm^2. The „more grey" zones have values VHN = 724—782 kp./mm^2. The measured gersdorffite has great dispersion of microhardness values VHN = 673—933 kp./mm^2 on an average.

The impressions after the diamond pyramid were, naturally, not always in the limits of one zone for their negligible dimensions, what causes variation of VHN at one type of zone.

In microhardness measurements of gersdorffite we compared the data with the measurements on gersdorffite from Rudňany, where the results are always VHN = 698 kp/mm^2.

If we compare the measured values VHN of gersdorffite with the data in literature and the results of chemism study, we may state the following: the core of gersdorffite grains and the nearest zones have the highest hardness. According to distribution of Co in zones with higher content the value of microhardness increases. The values VHN of gersdorffite, mainly of grey zones agree with the data for gersdorffite in literature. A good agreement is to be seen with the data of Burke (1966—1967), Bowie and Taylor (1958 in B. B. Young, A. P. Millman 1964). The whiter zones with smaller content of S approach chloanthite or skutterudite, what agrees with the data VHN for these minerals in literature.

Conclusion

Chemical variability of the Dobšiná zonal gersdorffite influences reflectivity R, measured in the the individual zones in the limits of microscopic distinguishing possibility — core of grains, „more grey" zones, „whiter" zones. The curves of R dispersion and values of R in % of „grey" zones approach R values of gersdorffite published in literature. The higher values of R are caused by the presence of Fe and Co. The values of R and R dispersion curve of gersdorffite from Rudňany agree with R of „grey" zones of the Dobšiná gersdorffite. The „whiter" zones approach R of chloanthite and Fe skutterudite in their R values, what agrees with the results of analysis by electron microprobe.

The difference in R between the „grey" and „whiter" zones is not only in R values in the individual wave lengths of the visible spectrum but also in the course of R dispersion curves of these zones.

The results of R and microhardness measurements confirm that the distinctly zonal Dobšiná gersdorffite is not only gersdorffite but zones of gersdorffite, chloanthite and transitional types of cobaltite order alternate. Same grain cores and marginal parts approach cobaltite. Regarding to little knowledge of optical properties of Ni-Co-Fe arsenides and sulfoarsenides at present and the lack in literature data evaluation of R in zonal gersdorffite is not possible and precise.

Up to present experiences in application of modern quantitative methods in reflected light show them to be important diagnostic aid in determination of ore minerals and development of these methods very necessary by us.

Acknowledgement

A part of the laboratory works was carried out in B.R.G.M. in Orléans; France, with kind permission by Prof. C. Lévy. I beg to express my thanks Mr. R. Cay for the help in R measurement and Mr. G. Remond for the analyses by electron microprobe. I also thank Mr. H. Háber for his help in measurements of microhardness of the studied samples. Further I thank the members of the Uranium Industry in Příbram for permitting R measurement in their laboratories.

Translated by J. PEVNÝ.

REFERENCES

BAYLISS, P., STEPHENSON, N. C., 1967: The crystal structure of gersdorffite. Min. Mag. 36, p. 38.

BAYLISS, P., STEPHENSON, N. C., 1967—1968: The crystal structure of gersdorffite (III) a distorted and disordered pyrite structure. Min. Mag. *36*, p. 940.

BAYLISS, P., 1969: X-ray data, optical anisotropism and thermal stability of cobaltite, gersdorffite and ullmannite. Min. Mag. *37*, 285, p. 26.

BOWIE, S., HENRY, N. F. M., 1964: Quantitative measurements with reflecting polarizing microscope. Trans. Min. Metall. *73*, p. 467—478.

DANA, J. D., DANA, E. S., PALACH, CH., BERMAN, H., FRONDEL, C., 1837—1892: The system of mineralogy. 7. ed. (1946), I/1, 520 p.

DEMIRSOY, S., 1968: Untersuchungen über den Einfluss der chemischen Zusammensetzung auf die spektralen Reflexionsfunktionen und Mikrodrückhärte im Spinell-Dreistoffsysteme. Disertation-theses, Aachen, 216 p.

DUNN, J. A., 1937: Microscopical study of Bawdwin ores. Records of the Geol. Survey of India *72*, 3, p. 333—359.

GOLL, J., 1937: Metalografická studie o niklových rudách od Dobšiné. Rozpravy české akad. věd a umění, tř. II, *47*, Praha.

GIES, H. J., 1968: Zur Paragenese von Gersdorffit und Ullmanit — ein Vergleich von mikroskopischen u. Mikrosonde-Untersuchungen. Freiberger Forschungshefte C *230*, I, p. 367—376.

GRAY, I. M., MILLMAN, A. P., 1962: Reflections characteristics of ore minerals. Econ. Geol. *57*, p. 325—340.

HÁBER, M., 1971: Mineralogicko-geochemický a paragenetický výskum hydrotermálnych žíl v oblasti medzi Prakovcami a Kojšovom. Manuscript. Archív Prír. fakulty UK, Bratislava, 200 p.

HALAHYJOVÁ-ANDRUSOVOVÁ, G., 1959: Mineralogické a paragenetické štúdium rudných ložísk v okolí Dobšinej. Manuscript, 166 p.

HALAHYJOVÁ-ANDRUSOVOVÁ, G., 1961: Mineralogické a paragenetické štúdium rudných ložísk v okolí Dobšinej. Manuscript. Archív Prír. fakulty UK, Bratislava, 190 p.

HALAHYJOVÁ-ANDRUSOVOVÁ, G., 1964: O genéze dobšinských rudných žíl. Geol. práce, Zprávy *33*, Bratislava, p. 53—67.

HINTZE, C., 1904: Handbuch der Mineralogie I/1, Leipzig, 1208 p.

HINTZE, C., CHUDOBA, K. F., 1960: Handbuch der Mineralogie, Ergänzungsband II, 958 p.

CHRENOVÁ, V., 1971: Odrazivosť niektorých rudných minerálov. Manuscript, Archív Prír. fakulty UK, Bratislava, 46 p.

KLEMM, D. D., 1965: Synthesen und Analysen in den Dreiecksdiagramm FeAsS-CoAsS-NiAsS und FeS_2-NiS_2-CoS_2. N. Jhb. Min. Abh. *103*, 3, p. 205—255.

KLEMM, D. D., WEISER, T., 1965: Hochtemperierte Glanzkobalt-Gersdorffit Mischkristatte von Outokumpu (Finland). N. Jhb. Min. Monatshft. *8*, p. 236—242.

ĽACHNICKAJA, I. V., ŠUMSKAJA, M. J., 1966: O novoj raznovidnosti gersdorffita v Berikuľskom mestoroždenii. Zap. vses. min. ob. *5*, p. 567—570.

LÉVY, C., PICOT, J., 1961: Nouvelles données sur les composés iridiumosmium. Existence de l'osmium natif. Bull. Soc. Franc. Minér. Crist. *84*, p. 312.
ORCEL, J., 1930: La mesure du pouvoir réflecteur des minéraux opaques a l'aide de la celullephotoélectrique et ses applications. Bull. Soc. Franc. Minér. Crist. *53*, p. 272—360.
PROUVOST, J., 1960: Transformation experimentales des sulfures métalliques naturales, études de leur mécanisme. Bull. Soc. Franc. Minér. Crist. *83*, p. 265—294.
REMOND, G., 1967: Etude d'echantillon Ni-As-S. B. R. G. M., Orléans, 25 p.
lin, 1089 p.
REMOND, G., 1967: Étude d'echantillon Ni-As-S. B. R. G. M., Orléans, 25 p.
STRUNZ, H., 1962: Mineralogičeskije tablici (russ. translation). Gos. nauč. techn. izdat,, Moskva, 531 p.
VOLYNSKIJ, I. S., 1949: Opredelenije rudnych mineralov pod mikroskopom III, I. ed., Gosgeolizdat, Moskva, 338 p.
YOUNG, B. B., MILLMAN, A. P., 1964: Microhardness and deformation of ore minerals. Bull. Inst. Min. Met. Trans *73*, p. 437—466.

Review by M. BENEŠOVÁ and M. KODĚRA.