

events are also the loci of gersdorffite mineralization, suggesting that gersdorffite is probably contemporaneous with stibnite and has the same hydrothermal origin.

Under the microscope, gersdorffite is seen in the form of white-colored small grains disseminated in a quartz matrix. It is generally isotropic but some grains exhibit weak anisotropism. It shows perfect cleavage parallel to (100) face (Photomicrograph 1).

Determination of Vickers microhardness

The procedure in determining microhardness is to press a known weight at a point on the mineral by means of a diamond-pointed needle, measure the diagonals of the square-based pyramid, and then to read the corresponding hardness from charts (Ref. 2 or Fig. 2). Vickers microhardness may be expressed by the following formula :

$$VH \text{ (kg/mm}^2\text{)} = \frac{1854.4 \times P}{d^2}$$

where P = test load in grams

d = mean diagonal in 0.001 mm

100 gr load was applied to several parts of the polished section, and the resulting diagonals were measured. The corresponding VH values were determined from Ref. 8 as follows :

Experiment I : Test load 100 gr

1 st diagonal reading 196 fillar microdivision	}	VH = 668
2 nd diagonal reading 204 fillar microdivision		

Experiment II : Test load 100 gr

1 st diagonal reading 175 fillar microdivision	}	VH = 874
2 nd diagonal reading 180 fillar microdivision		

As seen from these two experiments the hardness of the mineral is not the same everywhere in the section. In general, different values were found for different faces of the crystals. Hardness may vary depending on shape, size and smoothness of the polished surface. For this reason, in charts the VH values are given over a range. According to Ref. 9 for gersdorffite the lower limit is 520 and the upper limit is 907 and the values determined experimentally are within this range.

Determination of reflectivity

Reflectivity measurement involves comparison of the reflectivities of the unknown sample with a known one — the so-called standard. Under the microscope the reflectivity of the standard is measured twice. At the same time the reflectivity of the unknown mineral is also measured. Finally a measurement made on a dull-black surface is subtracted from the values of standard and unknown. As a rule the value for the dull-black surface should be zero. The reflectivity of the unknown sample is then determined by simple proportion of the reflectivity of the standard and that of the unknown mineral.

In measurements, a 5150 Å° green-colored monochromatic light and silicon carbide (SiC₂ with 20 % known reflectivity) standard have been used. With a Hillger & Watts type microscope, the reflectivity is measured as 20.7 % for stand-

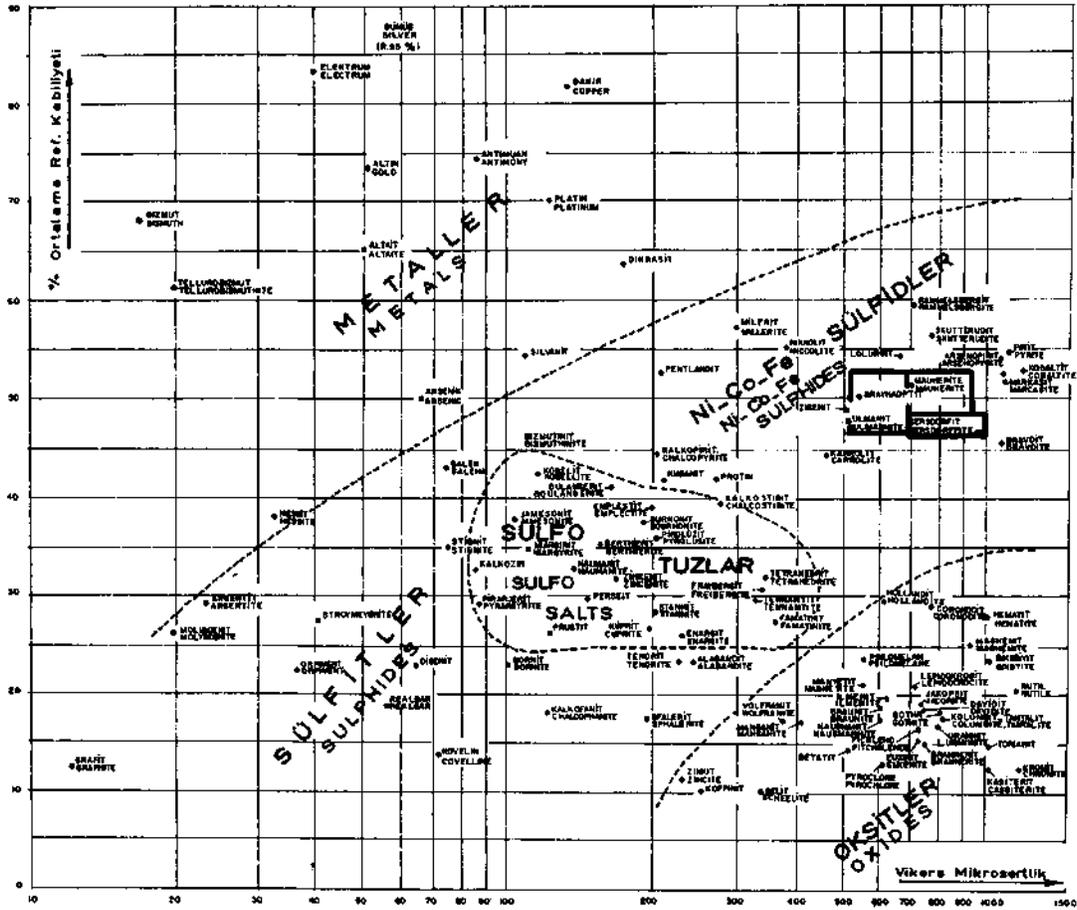


Fig. 2 - Distribution of opaque minerals according to their microhardness versus reflectivity (Bowir & Taylor, 1958).

ard, whereas for gersdorffite 46.3, 47.7, 47.6, 48.8, 48.5 % are noted at several points by digital voltmeter. From these values, that for a best polished part, 48.8 is taken and compared with the standard :

$$\frac{20.0}{x} = \frac{20.7}{48.8}$$

hence, the reflectivity of gersdorffite is determined as 47.1 %. The limit given for reflectivity of gersdorffite in Ref. 9 is in the range of 47.5-53.0 %. The reason why the value obtained is out of this range may be particularly due to the rough polishing of the sample and to a lesser extent due to the poor optical precision of the microscope.

X-ray diffraction

The sample which was determined microscopically as gersdorffite was also studied by the X-ray diffraction method (Fig. 3). Since the mineral is in disseminated form in a quartz matrix, the sarnrole prepared for analysis could not be totally separated from its quartz gangue and other impurities. For this reason, in the X-ray pattern quartz and annabergite peaks are seen simultaneously.

X-ray diffraction studies were carried out by using a Rieckermann-Seifert type generator with Cu-K α radiation and Ni-filter. The working condition was 40 kV, 20 mA with 1000 pulse; time constant was 2, the voltage of the Geiger-Müller counter being 1470 V. The pattern obtained is evaluated and compared with A.S.T.M. Data Card no. 10-470 (see Table 1).

Table - 1

<i>Gersdorffite (Ni, Fe, Co) . AsS</i>					
<i>Standard values given by A.S.T.M. Data Card no. 10-470.</i>			<i>Values measured from Fig. 3.</i>		
<i>Ref : R. M. Thompson, Univ. British Columbia, Vancouver, Canada.</i>			<i>Ref : Alabayır Tepe, Çukurören, Gediz.</i>		
dA°	I/I_1		θ	dA°	I/I_1
2.81	60		15.86	2.81	16
2.51	90		17.80	2.51	17
2.30	80		19.50	2.30	13
1.994	30		22.65	1.99	4
1.710	100		26.80	1.708	10
1.629	20		—	—	—
1.566	60		—	—	—
1.508	70		30.50	1.51	7
1.412	20		—	—	—
1.372	5		34.00	1.377	quartz + 18
1.331	5		—	—	—
1.296	10		—	—	—
1.264	20		—	—	—
1.233	40		—	—	—
1.204	20		—	—	—
1.157	30		42.00	1.15	6
1.088	70		45.50	1.079	6
1.051	40		—	—	—
1.033	30		—	—	—
1.001	60		49.50	1.01	5

Values of quartz and annabergite in this sample are as follows :

<i>Annabergite</i>			
dA° (A.S.T.M.)	θ	dA° (read)	I/I_1
7.82	5.63	7.85	6
6.58	6.70	6.60	28
4.33	10.20	4.35	10
3.18	14.00	3.18	6
2.97	15.10	2.956	6
2.43	18.35	2.44	25
1.96	23.10	1.96	13
1.66	27.60	1.66	14

<i>Quartz</i>				
<i>dA° (A.S.T.M.)</i>	<i>I/I₁</i>	θ	<i>dA° (read)</i>	<i>I/I₁</i>
4.26	35	10.45	4.246	60
3.343	100	13.45	3.31	100
2.458	12	18.35	2.446	25 + annabergite
2.282	12	19.85	2.268	20
2.237	6	20.25	2.225	11
2.128	9	21.30	2.12	18
1.980	6	—	—	—
1.817	17	25.25	1.805	35
1.801	(1	—	—	—
1.672	7	—	—	—
1.659	3	27.60	1.66	14 + annabergite
1.608	(1	—	—	—
1.541	15	30.10	1.535	24
1.453	3	32.10	1.449	5
1.418	(1	—	—	—
1.382	7	—	—	—
1.375	11	34.00	1.377	18
1.372	9	—	—	—
1.288	3	—	—	—
1.256	4	38.00	1.251	11

It will be seen that most of the values of dA° (distance between $\langle hkl \rangle$ s according to Bragg's Law) in A.S.T.M. cards corresponds to the values of the analysed sample. Disagreements in intensities (I/I) are mainly due to:

- a. the poor method of sample preparation,
- b. the increasing values of θ angle.

ANNABERGITE ($Ni_3As_2O_8 \cdot 8H_2O$)

Apple-green-colored crystals, 2 mm in size, were determined to be annabergite by means of spectrographic and X-ray diffraction methods. It occurs in association with gersdorffite and as a crust around 1 cm long quartz crystals lining geodes.

Annabergite is a secondary mineral produced by oxidation of gersdorffite by means of meteoric waters. The flaky and fragile crystals are very soft; they show perfect cleavage parallel to (010). They are soluble in hydrochloric acid. The deep pinkish color of nickel is obtained by the dimethylgloxime test. Under the microscope, the mineral is slightly pleochroic from colorless to light green.

High Ni, As, Co, Fe, Si, Mg, Mn values are detected in spectrographic analysis of an annabergite-bearing sample. The unexpected anomalous values, such as of Si, Mn, Mg, Fe, Cr... etc. are most probably due to the impurities in the analysed sample. The results of two analyses are given in Table 2

Table - 2

Sample no.	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Sb	Si	Ti	Zn
I	?	2	3	0.5	3	—	2	3.5	4	3	5	2	3	5	2	1.5
II	?	2	4	—	3.5	3	2.5	4	4.5	3.5	5	—	—	5	2	1.5
Explanation :		4.5-5	.....		more than	10	%									
		4	.....			5	%									
		3.5	.....			1	%									
		3	.....			0.5	%									
		2.5	.....			0.1	%									
		2	.....			0.05	%									
		1.5	.....			0.01	%									
		1	.....			0.005	%									
		0.5	.....			0.001	%									

X-ray diffraction

X-ray diffraction determination was made by directing a monochromatic X-ray beam upon the powdered sample mounted on glass. The sample is placed opposite to the X-ray source and in the center of a goniometer fixed to a circular plate. The lights diffracted from crystals according to Bragg's Law ($n\lambda = 2d \cdot \sin(-)$) are noted by means of a counter fixed on the other side of the circular plate. The rate of speed of the goniometer is so arranged that while the sample rotates x degrees, the diffracted light rotates $2x$ degrees. The counter is set $20-4^\circ$ and connected to an automatic plotter. The counter is then driven at a constant angular velocity through increasing values of $2(-)$ until the whole angular range (up to 176°) is scanned. At the same time, the millimetric paper chart on the recorder moves at a constant speed, so that distances along the length of the chart are proportional to 2θ ; 1 cm corresponds to $0-1^\circ$. The result is a chart, such as Fig. 4, which gives a record of counts per second (proportional to diffracted intensity) versus diffraction angle 2θ .

The same type of generator and working conditions have been applied in analysis of annabergite as were used in analysis of gersdorffite. The pattern obtained reveals very few impurities and corresponds to the peaks given in A.S.T.M. Data Card no. 11-625 (see Table 3).

Table - 3

<i>Annabergite (Ni₃As₂O₈ · 8H₂O)</i>					
<i>Standard values given by A.S.T.M. Data Card no. 11-625. Ref: Nat. Bur. Standards Circ. 539 10 8 (1960).</i>			<i>Values measured from Fig. 4. Ref: Alabayır Tepe, Çukurören, Gediz. M.T.A. Natural History Museum</i>		
<i>dA°</i>	<i>I/I₁</i>		<i>θ</i>	<i>dA°</i>	<i>I/I₁</i>
7.82	25		5.65	7.82	13
6.58	100		6.72	6.58	100
4.87	8		—	—	—
4.33	20		10.25	4.33	10
4.01	4		11.00	4.00	10
3.86	4		—	—	—
3.18	26		14.00	3.18	30
2.98	30		15.00	2.976	17
2.71	18		16.50	2.71	15
2.67	14		16.70	2.68	23
2.63	8		17.05	2.627	9
2.52	8		17.75	2.52	16
2.43	12		18.45	2.43	9
2.29	12		19.60	2.29	21
2.17	8		20.80	2.169	7
2.06	6		21.90	2.06	14
1.96	4		—	—	—
1.93	4		—	—	—
1.89	4		—	—	—
1.66	6		27.65	1.659	70 + quartz
1.64	7		—	—	—

Values of quartz peaks in this sample are as follows :

<i>Q u a r t z</i>			
<i>dA° (A.S.T.M.)</i>	<i>θ (read)</i>	<i>dA°</i>	<i>I/I₁</i>
3.343	13.45	3.31	60
2.237	20.40	2.209	20
1.983	22.85	1.983	6
1.659	27.65	1.659	70

R E F E R E N C E S

- 1 — ARAL, Halil (1970) : Geology and antimony deposits of Göynük-Çukurören region-Gediz-Kütahya. *M. Sc. thesis. M.E.T.U.* (unpublished).
- 2 — BASTIN, Edson (1931) : Criteria of age relations of minerals with polished sections of ores. *Econ. Geol. Bul.*, vol. 26, p. 561.
- 3 — BAYLISS, P. & STEPHENSON, N. C. (1967) : The crystal structure of gersdorffite. *Mineralogical Magazine and Journal of the Mineralogical Society*, vol. 36, pp. 38-41.
- 4 — BOWIE, S. H. & TAYLOR, K. (1958) : A system of mineral identification. *Mining Magazine*, London, vol. 99, pp. 265-267, 337-345.
- 5 — CULLITY, H. D. (1967) : Elements of X-ray diffraction. *Adison Wesley Co.*
- 6 — EDWARDS, A. B. (1947) : Textures of ore minerals and their significance. *Australian Inxt. Min. Metall.*, Melbourne, p. 185.
- 7 — EUGENE, N. Cameron (1961) : Ore microscopy. *John Wiley and Sons, Inc.*
- 8 — Instruction hardness testing equipment book for M 73-74 microscopes. *Vickem Limited, York.*
- 9 — McLEOD, C. R. & CHAMBERLAIN, J. A. (1969) : Reflectivity and Vickers microhardnns of ore minerals. *Geol. Survey of Canada*, paper 68-64.



Photomicrograph 1 - Polished section of gersdorffite showing perfect cleavage parallel to (100).

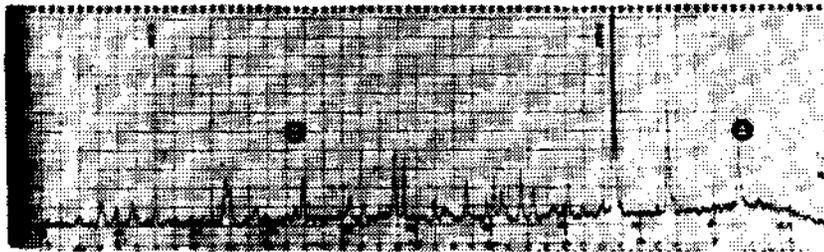


Fig. 3 - Automatically recorded X-ray diffraction pattern of gersdorffite.

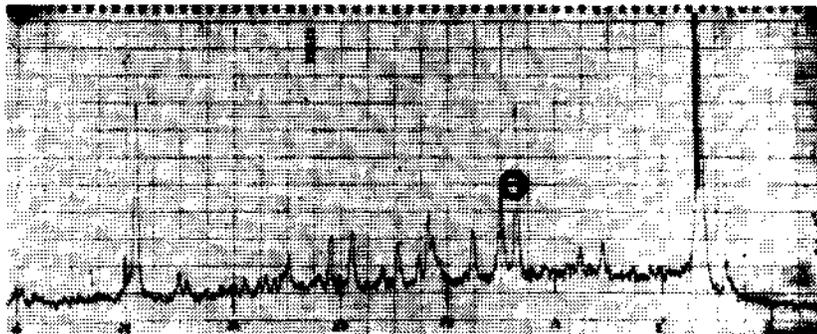


Fig. 4 - X-ray diffraction pattern of annabergite.