OCTAHEDRAL PARTING ON GALENA FROM BOULDER COUNTY, COLORADO

Ernest E. Wahlstrom,
University of Colorado, Boulder, Colorado.

Introduction

Octahedral parting or cleavage has been noted on galena from comparatively few localities. It is of interest because it offers a distinct contrast to the perfect cubical cleavage ordinarily observed on galena. The cause of the octahedral splitting has been more or less a subject of controversy; several different theories have been proposed to account for the phenomenon.

The literature on the subject prior to 1904 has been reviewed by Hintze,[1] according to whom galena with octahedral cleavage has been described from Vermland, Sweden, by Sjögren,[2] and from Lebanon County, Pennsylvania, by Cooke.[3] The galena from both places is changed upon heating, so that it displays only cubical cleavage. Galena from Habach with a difficult octahedral cleavage developed a pronounced cleavage after heating, according to Zepharovich.[4]

Some writers have suggested that octahedral cleavage results from polysynthetic twinning in galena; others, as for example Cooke,[5] believe that it is caused by pressure. Torrey[6] suggested that the galena is pseudomorphous after some mineral with an octahedral cleavage, or that it is a dimorphous form of galena. Sjögren suggested that the octahedral cleavage is related to the bismuth content that has been found in several analyzed specimens. His suggestion seems to be supported by the following analyses listed by Dana:[7] Habach, Salzburg, Bi_2S_3, 1.97%; Mont Blanc, Bi_2S_3, 1.0%; Nordmark, Sweden, Bi_2S_3, 0.91%.

Although early writers used the term "cleavage" to describe this splitting, recent textbooks describe it as "parting." Niggli[8] uses the term "parting" and ascribes it to systematically oriented crystal inclusions of bismuthinite in the galena. In the opinion of the present writer, Niggli's explanation probably applies to most of the known examples of bismuth-bearing galena with octahedral parting.

[1] Hintze, Carl, *Handbuch der Mineralogie*, vol. **1**, Part I, p. 461, 1904.
[2] Sjögren, H., *Geol. För. Förh.*, vol. **7**, p. 124, 1884.
[3] Cooke, J. P., *Am. Jour. Sci.*, vol. **35**, p. 126, 1863.
[4] Zepharovich, V., *Zeits. Krist.*, vol. **1**, p. 156.
[5] Cooke, J. P., *op. cit.*
[6] Torrey, J., *Am. Jour. Sci.*, vol. **35**, p. 127, 1863.
[7] Dana, *System of Mineralogy*, 6th Edition, p. 49, **1915.**
[8] Niggli, P., *Lehrbuch der Mineralogie*, Pt. **2**, p. 52, 1926.

Occurrence and Mineralogy of the Galena

The galena described in this paper is found in the hypothermal veins at Camp Albion, Boulder County, Colorado, associated with pyrite, chalcopyrite, sphalerite, and minor amounts of molybdenite. Gangue minerals are quartz, fluorite, feldspar, calcite, soda asbestos, and diopsidic aegirite. The veins occupy a fracture zone cutting the contact between a series of pre-Cambrian schists and gneisses, and a composite Tertiary igneous stock of monzonite and syenite. The veins have formed by fracture filling and by irregular replacement of the wall rocks of the fractures.

The proportions of metallic and gangue minerals vary considerably from place to place within a single vein, and from one vein to another. The galena is found most abundantly in the Snowy Range Mine in which a vein consisting chiefly of pyroxene and asbestos contains small scattered interstitial aggregates of galena. These aggregates display excellent, closely-spaced octahedral parting planes, with no indication of a cubical cleavage. The angles between the parting surfaces were measured with a reflecting goniometer and proved to be characteristically octahedral.

In a nearby mine, the Eureka, another vein containing large amounts of quartz and calcite, in addition to the pyroxene and asbestos, yielded galena with ordinary cubical cleavage. Inasmuch as the vein is genetically related to that in the Snowy Range Mine, it was thought desirable to analyze specimens from both veins in order to test the theory that the presence of bismuth may explain the octahedral parting. Analyses of the two types of galena from Camp Albion and two analyses of galena from other localities follow:

	I	II	III	IV
Pb	81.92	81.40	84.59	85.67
Bi	1.36	1.12	1.59	0.76
Zn	1.19	0.96	—	—
Ag	0.22[1]	0.12[1]	—	0.05
Fe	—	—	—	0.39
S	13.53[2]	13.25[2]	13.52[2]	13.59
Te	0.45	0.41	—	—
Insol. Impurity	1.30	1.32	—	—
Sol. Impurity	—	1.42[3]	—	—
	99.97	100.00	100.00	100.46

[1] Silver by cupellation.

[2] Calculated.

[3] Chiefly calcite; by difference.

I. Galena with octahedral parting, Snowy Range Mine, Boulder County, Colorado. Analyst: E. E. Wahlstrom.
II. Galena with cubical cleavage, Eureka Mine, Camp Albion, Boulder County, Colorado. Analyst: E. E. Wahlstrom.
III. Galena with octahedral parting, Habach, Salzburg; described by v. Zepharovich. Analyst: Weselsky.
IV. Galena with octahedral parting; described by Sjögren. Analyst: Wallroth.

The impurities in the analyzed specimens were found microscopically to consist of mechanically intermixed gangue minerals and sphalerite. Upon correcting for impurities and allotting tellurium to bismuth to form tetradymite, the following percentages of mineral molecules were obtained:

	I	II
PbS	97.49	98.08
Ag_2S	0.36	0.15
$Bi_2(S, Te)_3$	2.15	1.77
	100.00%	100.00%

An inspection of the analyses shows that the two types of galena from Camp Albion are chemically nearly equivalent. This similarity of composition is offered as proof that bismuth-bearing galena may or may not have an octahedral parting, and that other factors must be considered in explaining the phenomenon. The percentages of bismuth come well within the upper and lower limits of bismuth in analyzed specimens of galena with octahedral parting from other localities.

Polished Section Data

A study of several polished sections of the ores was made to obtain further information bearing on the problem. It was determined that the parting planes are controlled by tetradymite inclusions which are oriented in closely spaced laminae paralleling the octahedral directions of the galena. The tetradymite laminae are about .005 mm. thick and spaced, on the average, about 0.2 mm. apart; the mineral cannot be observed until the polished surface has been etched. A geometrical pattern consisting of polygons formed by the traces of intersecting layers then stands out in strong relief. The shapes of the polygons are determined by the direction of the surface of the polished section with reference to the octahedral planes. The polygons most frequently seen are either triangular or quadrilateral.

It should be emphasized that on the polished surface the tetradymite forms regularly-spaced continuous lines of uniform width and does not form lenticular linear structures such as are frequently observed in bornite-chalcocite intergrowths or in hematite-magnetite mixtures as recently described by Greig, Merwin, and Posnjak.[9] The uniform distribution of tle tetradymite and the lack of structures that might be interpreted as of replacement origin suggest that the tetradymite layers are formed by exsolution. This conclusion is substantiated by the chemical analyses given above, which show that the bismuth content does not vary greatly from specimen to specimen, despite the fact that the specimens are found in different veins and outwardly have a different appearance.

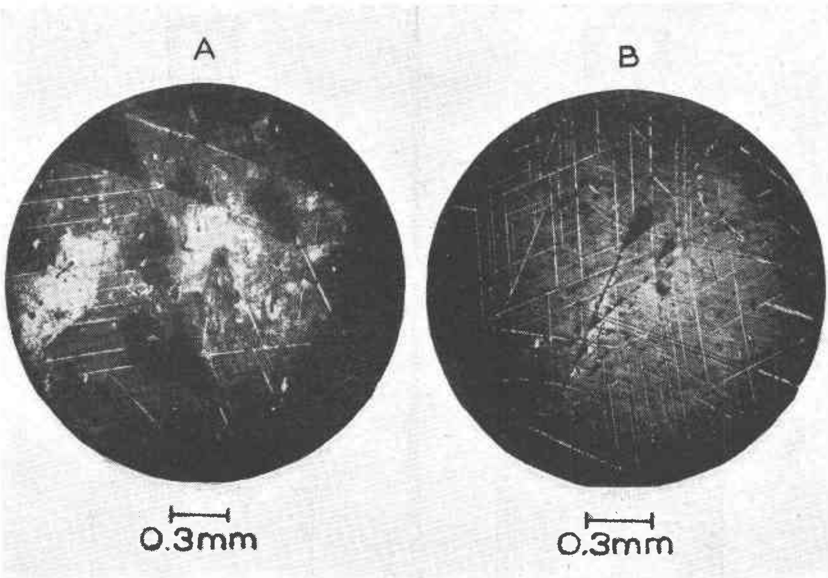

Fig. 1. A. $FeCl_3$ etched polished surface of galena with octahedral parting from Camp Albion, Boulder County, Colorado. The white lines are the traces of tetradymite plates which parallel the octahedral directions of the galena. The black triangular figures are pits formed during grinding; these are controlled by the tetradymite plates.

B. $FeCl_3$ etched polished surface of galena with cubical cleavage from Eureka Mine, Camp Albion, Boulder County, Colorado. The lines are the traces of tetradymite plates which parallel the octahedral directions of the galena. The small triangular patches are pits controlled by cubical cleavage. The sides of the pits do not parallel the tetradymite plates as in Figure 1A.

[9] Greig, J. W., Merwin, H. E., and Posnjak, E. Separation planes in magnetite: *Am. Mineral.*, vol. **21,** p. 504, 1936.

The exsolved tetradymite is found in both types of galena. In polished sections of the galena with octahedral parting the sides of the polygons parallel the sides of the pits formed by the breaking out of pieces of galena during grinding and polishing. In the galena with the cubical cleavage the exsolved plates again parallel the octahedral directions but the pits are in this case controlled mainly by the perfect cleavage, and the tetradymite polygons do not generally coincide with the outlines of the pits. A very few triangular pits which are controlled by the tetradymite layers, as in the type exhibiting only the parting, were observed. Photomicrographs of etched polished sections are shown in Fig. 1.

The observation of the exsolved tetradymite is best made after a brief application of 20% $FeCl_3$ solution or 1:1 HCl. Although the galena and tetradymite give similar etch reactions, the tetradymite is attacked less vigorously by the reagents than the galena, and stands out in relief, if not exposed too long to the etching solutions.

Following are the etch tests obtained from several specimens of both types of galena and the tetradymite.

	Galena (cubical and octahedral)	*Tetradymite*
	Isotropic	Anisotropic
	Hardness B	Hardness B (estimated)
	Color: galena white	Color: galena white
Etch tests:		
HNO_3	Stains black; fumes tarnish	Stains black with slow effervescence
HCl	Tarnishes iridescent	Slowly tarnishes iridescent
KCN	Neg.	Neg.
$FeCl_3$	Tarnishes iridescent	Slowly tarnishes iridescent
KOH	Neg.	Neg.
$HgCl_2$	Neg.	Slowly tarnishes iridescent

Microchemical tests on small amounts of material reveal the presence of lead only, as it is necessary to use comparatively large amounts of material to obtain positive tests for bismuth and tellurium. For these tests it is best to leach with HCl the residue of a fragment of galena at least 2 mm. in diameter that has been decomposed with 1:1 HNO_3. Selenium is absent.

Origin of the Parting

The fact that the galena from the Snowy Range veins shows only parting, whereas that from the Eureka vein displays a cubical cleavage is not easily explained. It is probable that the galena with the parting is in a metastable state, resulting from peculiar conditions that obtained after precipitation of the minerals from solution. Inasmuch as the two veins from which specimens were collected contain different proportions of gangue minerals, it might be suggested that the chemical environment was the controlling factor in either vein. However, it seems more probable to the writer that mechanical stresses active during or after the ore-forming period account for the observed features. This conclusion is supported by the fact that the galena with the octahedral parting loses this property upon being heated in a closed tube, and changes to a form with cubical cleavage. Apparently the stresses set up in the mineral during heating cause the development of minute fractures along the cube directions. Presumably the change during heating is mechanical and not chemical.

Conclusions

In summary, the following conclusions have been reached: the octahedral splitting in galena from Camp Albion, Boulder County, Colorado, is parting and not cleavage. The parting is primarily controlled by closely spaced layers of tetradymite which parallel the octahedral directions of the galena. The tetradymite probably formed by exsolution from galena that was originally bismuth-bearing.

A bismuth-bearing galena may show either cubical cleavage, or octahedral parting, or both, depending on the nature of mechanical stresses in the material after precipitation from solution. Probably the galena with octahedral parting is in a metastable state, and if subjected to the proper stresses, it will change to the form ordinarily seen.

Acknowledgments

The writer wishes to express his thanks to Professors R. D. Crawford and P. G. Worcester who critically read the paper, and to Dr. W. O. Thompson who carefully criticized the manuscript.