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THE CLEAVAGE SURFACES OF GALENA[1]

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In general, the microscopic study of the sulphide minerals has been confined to the examination of surfaces that have been developed by grinding and polishing. The surfaces thus produced differ materially in some respects from those resulting from natural breakage or crushing, since they are the result of surface flowage and may therefore be considered as representing artificial surfaces.

This paper deals with the physical and structural characteristics of natural galena surfaces resulting from chipping or breaking pieces approximately one-half inch in diameter from large specimens and examining them by means of the reflecting microscope.

The samples studied were collected from a variety of sources but originated chiefly in the Joplin district, Missouri. They consisted of several types of the coarse crystalline galena, and the specimens varied in size from fairly uniform cubes approximately one inch in diameter to specimens up to ten inches in diameter.

The procedure followed was to chip off a fragment of galena with a sharp chisel in order to avoid extensive internal fracturing and at the same time procure a specimen having a surface approaching a plane. The specimens were then cleaved to approximately $\frac{1}{2}$-inch size for study with the reflecting microscope. Smaller pieces, of sizes down to +200 mesh, were also examined and were prepared for study by mounting them in a plastic clay.

Cleavage faces of galena are remarkable for their luster, which far surpasses that ordinarily attained on surfaces that have been prepared for microscopic study by grinding and polishing. When seen through the microscope, natural cleavage faces show many outstanding and interesting characteristics which may be of value to the metallurgist from the standpoint of ore treatment and are also worthy of consideration in the study of crystal structure.

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The galena specimen shown in Figure 1 illustrates the popular conception of "a perfect cube" which may be taken to mean that its form closely approaches that of the conventional illustration used in textbooks on mineralogy and crystallography. Presumably, such a cube may be considered by many to represent a unit or individual cube because examination of its surface shows no evidence to the contrary. Several specimens of this type, all from the Joplin district, were examined. All were smooth and no conception of their

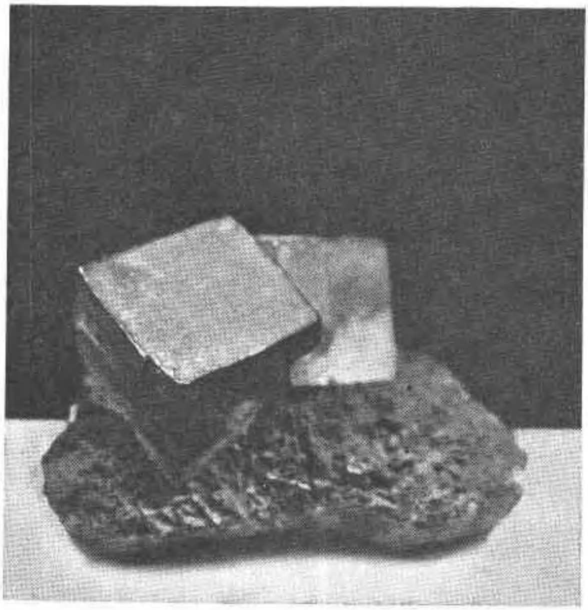

FIG. 1. Symmetrical cube of galena from the Joplin, Missouri district. Approximately natural size. These cubes show no surface indication that they are made up of innumerable, associated blocks or cubes of galena.

internal structure could be gained from surface observation. However, when the outer surface was removed by chipping with a chisel, it was apparent that such cube specimens were made up of innumerable smaller individual cubes.

Examination of the freshly cleaved surface by reflected light disclosed a variety of interesting surface characteristics. Some areas were apparently perfectly flat, highly reflective surfaces, free from pits or imperfections. In other cases, surfaces showed a well-defined "checkerboard" pattern of lines crossing each other at 90°

angles, obviously outlining the cleavage planes and marking the characteristic cubes which result when galena is subjected to crushing. If the visible striations on cleaved faces of galena are taken as a measure of the size of the component blocks, it is evident that these units are of extremely small size. In examining the finest sets of striation lines observed with an oil immersion objective at a magnification of 750 diameters the distance between lines was found to lie in a range from 0.005 mm. to 0.001 mm. (5 microns to 1 micron). Whether or not these dimen-

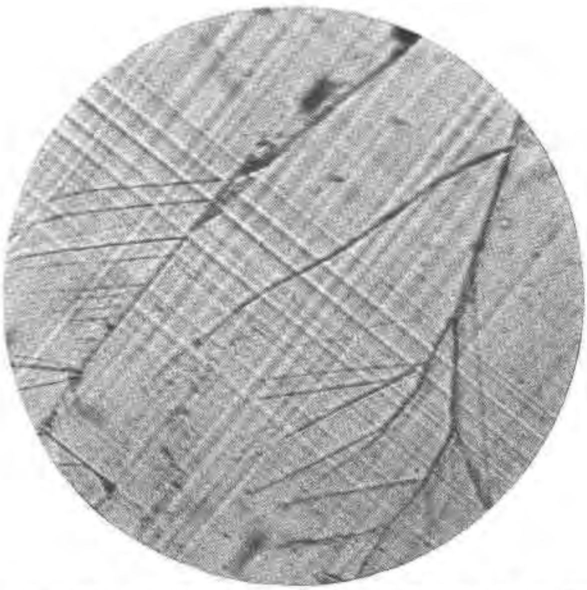

FIG. 2. (Magnification 400×). Shows "lattice structure" or outlines of cubic cleavage, also tree-like, surface indications of "slip planes," which in some cases are open and whose surfaces may be etched and non-reflective or smooth as in slickensides.

sions may be taken as that of the smallest unit cube is not certain. It is certain, however, that galena will break into cubes of the dimensions indicated. It is of interest to point out that the striations under discussion are in reality a manifestation of surface irregularities. As a matter of fact, it is due to the existence of surface irregularities that the striations are rendered visible. There are areas in which the preceding characteristics are well defined but in addition show another set of lines not so strongly marked, but clearly visible, extending diagonally across the cleavage lines at an angle of approximately 45°.

When viewed in reflected light, especially with the higher power objectives, the striated surfaces described exhibit surface characteristics strikingly similar to linen or other like material when viewed through a magnifier, *i.e.*, they are suggestive of a mesh-like or woven surface.

Reference to Figure 2 shows, in addition to the block cleavage, two sets of irregular, tree-like striations that are equally as well marked as the regular cube face outlines. Close examination of these forms suggests that they indicate planes along which slippage may have taken place and through which solutions or gases may have penetrated the cube mass. In some cases these channels are still open and when exposed by dissection show surfaces that present a pebbly appearance indicative of corrosion. Where these channels have "healed," *i.e.*, been filled in or cemented, they present surface irregularities similar to those of the cube blocks.

Although the galena cube under discussion was symmetrical in surface contour, examination of its interior structure showed that its component blocks did not parallel the surface planes. This deviation was more pronounced with increase in distance from the outer faces of the cube and amounted to a distinct curvature in the block arrangement. One of the cleaved faces, approximately one-half inch square, showed a distinct radiating arrangement of the component blocks from a central point which appeared to have resulted from exposure to a corrosive solution. The luster had been destroyed and the surface presented a "pebbly" appearance similar to that caused by acid attack. In addition, small block-shaped pits had been developed through the removal of cubes of galena. This removal had taken place along roughly symmetrical lines which gave the impression of a radiating structure on the surface affected. Crystals of lead carbonate had developed in several places on the corroded surface, undoubtedly formed by the decomposition of the galena. In general, the lead carbonate crystals were distinctly visible under a binocular microscope at a magnification of 5 diameters.

The occurrence of lead carbonate and lead sulphate associated with galena is common, but the presence of lead carbonate within a galena cube would not be expected.

Crystals of sodium chloride were commonly found oriented along striations on the galena surface (see Fig. 3). They ranged in size from 0.026 to 0.001 mm. The axes of the halite crystals generally paralleled the visible galena cubic structure, even when occurring along diagonal striations. This occurrence was observed in all specimens examined from the Tri-State district and leads to the belief that sodium chloride is a natural and common constituent of the galena in that region. In addition to whatever significance the occurrence of halite with galena may have from mineralogical and ore-dressing standpoint, it has a geologic interest worthy of men-

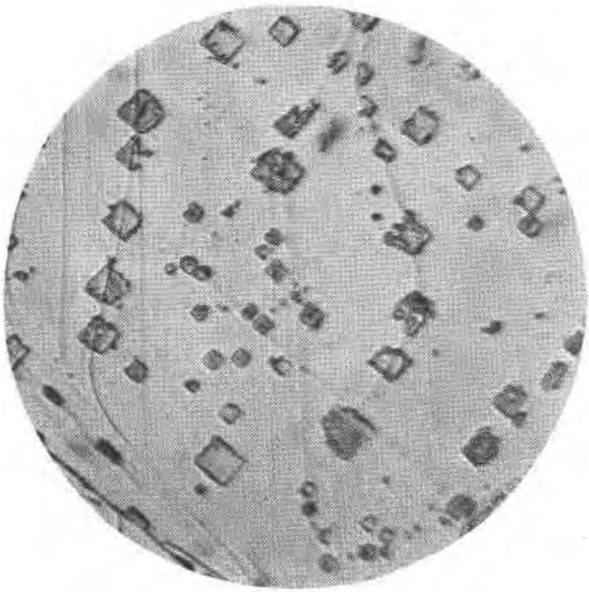

FIG. 3. Crystals of sodium chloride (halite) on natural cleavage face of galena from the Joplin district, Mo. The salt crystals range in size from 0.02 mm. to 0.001 mm. and appear to be a natural constituent of the coarsely crystalline galena from the Joplin region.

tion, namely, the origin of the ore bodies of the Joplin, Missouri, district. This matter is discussed in detail by H. F. Bain,[3] and is briefly summarized by Waldemar Lindgren.[4] A theory advanced concerning the origin of the lead deposits of southeastern Missouri involves the transportation of the lead into the Cambrian sea by

[3] *Bull. U.S.G.S.*, No. **294**; Zinc and Lead Deposits of the Upper Mississippi Valley (1906).

[4] *Mineral Deposits.* McGraw-Hill Book Co., *New York*, **1919**, See pages 461–464.

flowing tributary streams, deposition with the Bonneterre dolomite, followed by concentration by surface waters after the subsequent formations were laid down.

Although the foregoing surface and structural features are described as existing in the symmetrical galena cube specimens, they are possessed in common by all the coarsely crystalline galena specimens from the Joplin district that were studied. In addition to the conditions described, other structural characteristics appear to be common to these coarsely crystalline varieties of galena.

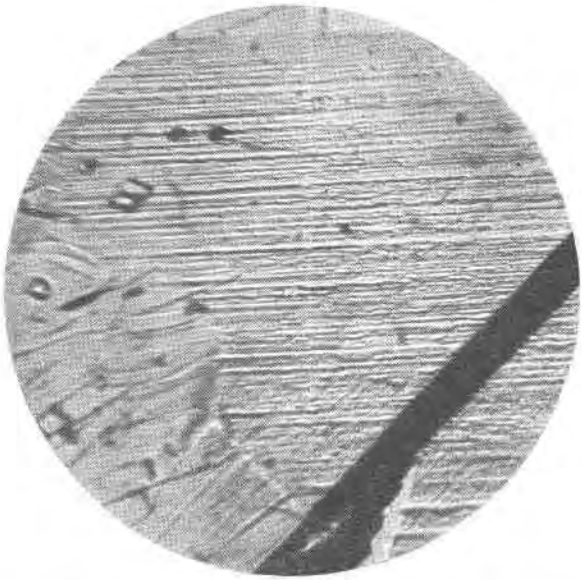

FIG. 4. Parallel striations extending across a natural cleavage face of galena at an angle of approximately 45° to the cubic cleavage. Magnification 225×. Tł e distance between the lines shown is approximately 0.004 mm.

In examining numerous cleaved faces of galena specimens, many slip planes were observed which undoubtedly indicate a condition of stress and strain within the mass. By dissection methods, material was removed along several of these planes. Two distinctly different types of surface were found to exist. In some instances the surfaces were smooth and highly reflective, approaching the condition of block cleavage surfaces. In others the surface of the slip plane was dull and lusterless and had the appearance of having been etched or corroded.

These two types of slip surfaces are probably the same, the differences in surface characteristics being due in the one case to the penetration and circulation of gas or solutions which attacked and destroyed the reflective surface, and in the other case to the absence of such a condition.

Voids are quite common in masses of galena made up of aggregates of blocks. These voids are usually irregular in shape and vary greatly in size. In some cases they are visible to the unaided eye, (1 mm. or more in diameter) but in others they are of microscopic size. Like the slip planes, their walls may be either reflective or dull (etched), probably due to the action of the same agencies—namely, corrosion by gas or solutions or their absence.

Summary

Perfect unit cubes of galena of any material size, *i.e.*, one-fourth inch, one-half inch or greater in dimensions, probably do not exist in nature. Such specimens as are found that appear to be homogeneous units are made up of a multiplicity of smaller units.

The existence of halite on galena surfaces is a matter that affords some grounds for amplification, at least theoretically. The mere fact of its presence is suggestive and might serve for entertaining the premise of the possible occurrence of other soluble or insoluble salts as natural surface constituents on sulphide minerals. Sodium chloride appears to be of common occurrence in certain galena samples from Missouri and it is not at all unlikely that further detailed study of galena and associated sulphide minerals from other mining districts may result in the finding and identification of salts of other elements such as calcium, magnesium, iron, etc.

The present study of galena, though incomplete, shows that galena possesses a variety of physical characteristics which may play some part in accounting for differences in the action of this mineral under variable flotation conditions and for differences between specimens from different localities.