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Further Notes on the Deformation of Sulfides

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Abstract

Results of recent triaxial compression experiments on sulfides, performed in the laboratories of the Technischen Hochschule Aachen (Siemes, 1967; Saynisch, 1967; Lang, 1968), show that galena, sphalerite and chalcopyrite can be made to flow plastically under ordinary laboratory temperatures if the confining pressure is above 300 bars for galena and above 1,000 bars for sphalerite and chalcopyrite. These results are used with those obtained from intrusion experiments at McGill University (see Gill, 1968) to arrive at a view of the behavior of each of these sulfides when stressed at various depths within the outer part of an average continental crust. This leads to a consideration of textural changes expectable as a result of mechanical deformation of sulfide orebodies including these minerals. The results would depend on the composition and texture of the original ore, and could differ markedly because of differences in confining pressure (depth), stress difference, strain rate or temperature.

SINCE publication of the article entitled "Experimental Deformation and Annealing of Sulfides and Interpretation of Ore Textures," I have received from the Institut für Mineralogie und Lagerstättenlehre of the Technischen Hochschule Aachen through the courtesy of Dr.-Ing. Heinrich Siemes the results of recent deformation experiments on polycrystalline galena, sphalerite and chalcopyrite at ordinary laboratory temperatures (Siemes, 1967; Saynisch, 1967; Lang, 1968). These were performed with triaxial compression equipment using confining pressures up to 5,000 bars and stressing to failure at strain rates of 0.3×10^{-8} sec^{-1} to 0.3×10^{-5} sec^{-1}. Some of the results of significance in relation to the interpretation of ore textures are shown graphically in Figure 1. The data chosen were obtained from tests on the purest material used in each set of tests.

Textures of all test specimens were investigated before and after deformation, and it was found that original textures were progressively superceded by others with marked lineation parallel to the axis of greatest pressure. X-ray studies showed that the crystallographic direction with this preferred position was [110] in all three minerals.

A few experiments on fine-grained pyrite from Rio Tinto failed to produce pervasive plastic flowage. Strengths ranged from 7,500 bars stress difference at 1,000 bars confining pressure to 15,000 to 17,000 bars at 5,000 bars confining pressure. Handin had previously reported ultimate strengths for pyrite from Utah at 24° C as 1,470 bars with no confining pressure and 5,000 bars with 490 bars confining pressure (Handin, 1965, p. 263).

Figure 2 was designed to represent average P-T conditions in continental crust and to relate results of the Aachen and McGill experiments to them. The depth scale is distorted slightly to preserve uniform pressure and temperature scales. Line e d m shows one estimate of average P-T in relation to depth below the earth's surface. Points a, b and c were obtained by projecting curves from intrusion experiments on galena as described in the paper referred to above (Gill, 1969, Fig. 8) to zero intrusion. Their positions are approximate, especially that of c, but the general position and shape of the curve must be about as shown. Its intersection with e d m, point d, marks the level in the crust below which intrusion into tubular openings 1.6 mm in diameter could occur.

At a depth of 1.25 km the confining pressure is 300 bars (o e in Fig. 2) and the temperature 25° C. From Figure 1 it is seen that plastic flow in galena starts where the stress difference exceeds 750 bars. This is plotted as e f in Figure 2. At the same temperature o k is the best estimate now possible of the applied pressure required for intrusion flow. It should be possible to work out a precise mathematical expression relating the stress difference required to initiate plastic flow in triaxial compression experiments to the applied pressure required to initiate plastic intrusion into openings of a specified size. This has not been done, but it seems clear that the stress difference required would be less at higher temperatures, so in Figure 3, line f g h has been drawn on the assumption that, at any given temperature, the stress difference required to produce flow in triaxial compression experiments is related to the applied pressure in the McGill intrusion experiments by a constant factor given by ef/ok = 0.4.

Figure 1 shows that the stress difference required to initiate plastic flow in galena also varies with the confining pressure. Line f i j in Figure 2 was