occur below the depth marked by point k and recrystallization below the depth of point m.

The increased temperature should cause plastic flow of all three minerals to occur at depths shallower than those shown. At the present time there appears to be no quantitative information on this point. The stress differences required to initiate plastic flow at the minimum confining pressures required at 25° C are reduced at increased temperatures. This has been discussed for galena. Data are less satisfactory for chalcopyrite, but the trend of the curve for intrusion suggests that a relation between stress difference for plastic flow in triaxial compression and applied pressure in intrusion experiments may be similar. There is no experimental evidence bearing on this relation for sphalerite, but it appears to be reasonable to assume analogous behavior.

Information from Roberts (Gill, 1969) indicates that recrystallization does not occur in sphalerite as readily as in chalcopyrite.

Results obtained by H. C. Heard in his experiments on Yule Marble (1963) suggest that, at much lower strain rates, a steady state of deformation of galena, sphalerite or chalcopyrite could be attained at stress differences well below the maxima shown in Figure 1. At elevated temperatures the stress differences required would be still lower.

The curves shown for galena and chalcopyrite intrusion on Figure 3 are based on the results of experiments lasting only about 2½ hours each. R. L. Stanton and Helen Gorman (1968) have studied the textural results of heating natural polycrystalline sulfide ores in sealed, evacuated glass capsules for periods up to 90 days. They obtained clear evidence of grain boundary migration in galena, sphalerite and chalcopyrite and deduced, by projection of graphs, that this process could start in galena at around 20° C and in sphalerite at 60° C. No figure was obtained for chalcopyrite.

The minor adjustments studied by Stanton and Gorman could, if accompanied by persistent slow strain, result in substantial changes over long periods of time. They could not in themselves produce the textural effects of major plastic flow, nor could they replace an old, dimensionally oriented texture by a new mosaic of more or less equidimensional grains, as occurs with recrystallization.

The information now available indicates that if a mixture of galena, sphalerite, chalcopyrite and pyrite at a depth of 3 km in the continental crust were subjected to increasing stress, galena would flow at a stress difference of about 700 bars, continuing until the movement brought grains of stronger minerals into contact. If the strain rate were relatively high, galena could fail by rupture before this occurred.

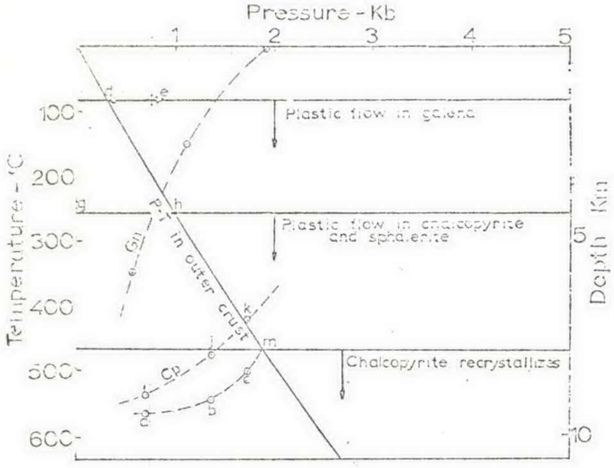

FIG. 3. Similar to Figure 2, but with a steeper temperature gradient. Data from intrusion experiments on chalcopyrite are added. Line i j k marks the beginning of appreciable plastic flow. Line a b c marks the start of recrystallization. The levels shown for the start of plastic flow may be adjusted upward when more experimental data are available. Data from Davies (1965), Krishnamurthy (1967), Siemes (1967), Saynisch (1967) and Lang (1968).

If the strain rate were very low, rupture of galena would probably not result. If the deformation of galena were to transfer the bulk of the load to sphalerite or chalcopyrite, they would fail by shearing at stress differences of around 600 bars, and galena could be forced into any openings created. If stress were then transferred to pyrite, rupture of pyrite would occur at a stress difference of around 6,000 bars. Galena and/or granulated sphalerite or chalcopyrite, or a mixture of these would be forced into the cracks or around fragments of pyrite.

At a depth greater than 5 km galena would flow first. At rapid strain rates it should shear at a stress difference of around 3 kilobars. If the rearrangement were to transfer the increasing load to sphalerite, this would start to flow at a stress difference of around 4 kilobars, and chalcopyrite would flow at about 5.5 kilobars. Either could move plastically to positions of reduced pressure created by complexities of transmission in such a mixture. At rapid strain rates sphalerite could shear at a stress difference of 6 to 6.5 kilobars, and chalcopyrite could shear at 7 to 7.5 kilobars. At low strain rates flow would continue until the stress build-up was transferred to pyrite. Continued increase in stress would ultimately cause rupture of pyrite. Galena, sphalerite and chalcopyrite should then penetrate rupture surfaces and flow around pyrite fragments. If the temperature were raised to 560° C, chalcopyrite would recrystallize to a mosaic texture and flow would be relatively rapid. In these circumstances the mobility of sphalerite and chalcopyrite may be in a reverse relationship to that at the start