PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Concluding Remarks

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Concluding remarks

By Alan H. Cook, F.R.S.

The idea of this meeting came to the organizers from the type of considerations set out by Dr Kelly in his opening remarks, namely that we see many apparent similarities between phenomena of large scale in geophysics and phenomena of small scale in metallurgy and we would like to understand their significance. Dr Kelly mentioned triple junctions between tectonic plates and between metal grains. Another example, which goes back many years, is that structures in mountains can be simulated by flow in materials such as plasticine, and Dr King has showed us how patterns of faulting look much the same over a wide range of scales. Yet another, by now well known, example is that lunar impact craters look almost indistinguishable over a range of sizes from a few micrometres up to hundreds of kilometres. Dr Kelly remarked to me this morning that the similarity between geophysics and metallurgy extends to terminology, for the geophysicist has his fault and the metallurgist his defect.

The discussion began with two sets of ideas that seem to me very important for understanding such similarities. In the first place, geometrical compatibility and the equilibrium of forces must be satisfied on all scales and so may impose similar patterns. Secondly, we had the idea that it is average stresses that are significant. Linked with that is the concept of the behaviour of an engineering component and it may be useful for geophysicists to look on parts of the Earth as engineering components. The remarks made by Dr Tozer in the discussion on Professor Weertman's paper were on these lines.

But if there are similarities between metallurgy and geophysics, there are also profound differences. In the first place, the scales are very different: geophysical lengths and times are about 10^8 times greater than in metallurgy, so that velocities are of the same order but accelerations are 10^8 times less. Inertial forces are thus much less important in geophysics, but body forces are more important, for the vertical attraction of gravity and the consequent hydrostatic pressure often dominate stress systems in geophysics.

A second important difference is that in metallurgy, as was mentioned in the discussion, we look at a two dimensional slice of a three dimensional process, whereas many geophysical phenomena are quasi two dimensional because the lithosphere is relatively thin and because gravity acts downwards.

Given the great difference of scale, we may wonder how similar are the mechanisms in metallurgy and geophysics. We have had here excellent descriptions of processes in the deformation of metals, but are they the significant ones on the geophysical scale? May it not be that there are, for example, processes involving the circulation of fluids and transport of materials that would lead to diffusion stress but on a scale of hundreds of metres rather than a few micrometres? Even so, Professor Ashby's maps might be as helpful in classifying large-scale geophysical mechanisms as they have been illuminating in metallurgy. If geophysical processes involve an activation energy and dependence on temperature through a Boltzmann factor, if the activation energy depends on pressure, if the idea of homologous temperature is important, then metallurgical ideas can be taken over into geophysics.

Thus, we may go a long way in geophysics without knowing much in detail about constitutive relations, but there is an important aspect, not mentioned in the discussion, for which we cannot ignore them. Very few attempts have been made to estimate the mechanical work done and the heat dissipated in, say, the formation of a mountain range, and to compare those estimates with the work available from the displacement of tectonic plates and with the heat flowing out of the Earth. To make such calculations, we do need to have some idea of the constitutive equations of geophysical processes.

A few other points may be worth remark. Water content strongly affects the behaviour of materials in geophysics; indeed one may go further and say that the distinctive tectonics of the Earth may well be determined by the presence of a permanent cover of liquid water in the oceans, a cover which almost certainly controls the thickness of the crust under the oceans. Secondly, geophysical materials are multiphase systems and we need to know more about how they may differ from single phase materials. Then I would draw attention to Dr Beeré's demonstration of negative stresses at grain boundaries. It may be compared with the suggestion that an increase of dilatancy in rocks indicates that an earthquake is about to occur, although it is by no means clear how reliable the indication is because earthquakes have also been found to be preceded by a decrease of dilatancy.

Lastly, I might remark that as a geophysicist I am greatly impressed by how much recent advances in metallurgical understanding owe to studies of reactor materials and to the development of metal-forming processes that involve very large strains.

It remains for me on behalf of the organizers and the Society to thank our speakers, chairmen, and all who have contributed to the discussions for a most stimulating meeting which I am sure has suggested many interconnections between our disciplines. We should like to feel that we have indeed advanced not geophysics, not metallurgy, but natural knowledge, which, as our President reminded us earlier, is the aim of the Society.

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