

# MINERALOGICAL MAGAZINE

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## Mechanisms of Reaction Meeting and Workshop

A MEETING on 'Mechanisms of Reaction' (convened by Drs B. Harte (Edinburgh University), T. J. B. Holland (Cambridge University), and B. W. D. Yardley (Leeds University) on behalf of the Metamorphic Studies Group) was held at Burlington House, London, on 22 May 1985. The meeting was followed on 23–4 May 1985 by a workshop or short course convened by Drs B. Harte and K. H. Brodie at Imperial College, London. The short course was given by Professors R. L. Joesten (University of Connecticut) and A. C. Lasaga (Yale University) and involved lectures and computer simulation practicals concerning mass transport, nucleation, and growth with particular relation to the development of mineral assemblage zoning and intra-mineral chemical zoning. The course was attended by approximately forty-five research workers and Ray Joesten's and Tony Lasaga's presentations were widely appreciated.

*Drs Bruce Yardley and Ben Harte have provided the following introduction to the published papers arising from the meeting.*

The meeting was organized with the objective of focusing attention on particular mineralogical and textural features of rocks which provide evidence of the controlling processes of metamorphism. Within the papers presented here there are discussions of the relative importance of mass transport (both diffusion and fluid flow), heat supply, nucleation and surface reaction in controlling reaction rates, together with references to the influence of deformation on these processes. In the first paper *Lasaga* introduces aspects of many of these controls, and discusses the theoretical basis for evaluating the relative importance of some of the rate-limiting steps with reference to experimental work on fluid–mineral reactions. In particular he shows that for many metamorphic reactions the surface reaction step may be more sluggish than mass transfer, and *Lasaga* goes on to model the

extent to which isograds may become widened into zones due to incomplete reaction when a realistic natural heating path is followed.

*Ridley* further examines the importance of the thermal budget on the extent of mineral reaction across rock layers by combining a model of progressive temperature–pressure evolution with estimates of heat absorption due to chemical reaction. He notes that appreciable reaction without further addition of heat may obtain, if nucleation occurs only after significant overstepping of equilibrium reaction temperatures. Using his model, *Ridley* shows that reactions may proceed either at fairly constant rates or in spurts, depending on heating rates and the controls of nucleation and growth. He considers how grain sizes and textures in rocks may reflect such situations.

In a detailed electron optical study, *Brearley* documents the complexities of nucleation and growth in a study of biotite breakdown under conditions of high temperature contact metamorphism. A series of steps from nucleation to crystal growth is identified. In addition he shows that the distribution of reaction products, with mullite becoming more abundant than corundum at the margins of the original biotite crystals, is controlled by the diffusion of Si from the matrix.

*Rubie* addresses the problems of interpreting variable extents of reaction in natural rocks with particular regard to the effects of fluid availability and the interplay of deformation and mineral reactions. He shows how the quantity of fluid in grain boundaries may be a major control on reaction kinetics, microstructural evolution and sometimes deformation. The duration of 'fluid present' rather than 'fluid absent' conditions during metamorphism is shown to be particularly important.

The varying extent of conversion of gabbros/dolerites to eclogites with pseudomorphic igneous fabric, allows *Mörk* to carefully document several reaction stages. Transient reaction stages with corona formation, large numbers of solid phases

and chemically zoned garnet are interpreted to imply restricted diffusion between original mafic and felsic domains. More extensive diffusion leads to omphacite in place of mafic minerals and garnet in place of plagioclase. She suggests that the strong Ca zoning seen in garnets in coronites is a result of progressive garnet growth towards the centre of original plagioclase crystals.

There then follow two papers in which zones of changing mineral assemblages around original minerals are examined and interpreted using irreversible thermodynamic models. *Foster* considers the detailed textures found in pelites showing replacement of staurolite and growth of sillimanite. Textures calculated from the models are shown to fit the mineral zones developed around staurolite in thin section, and *Foster* is further able to explain

why garnets may be both consumed and grow in different locations in the same rock.

In the second paper, using an irreversible thermodynamic approach, *Joesten* examines detailed coronite microstructure in the well-known Risør gabbro. He notes differences of layer sequence between coronas with primary microstructure and those with annealed microstructure. For the annealed coronas *Joesten* presents an irreversible thermodynamic model which predicts the modes and layer widths found in the natural samples. For the primary coronas *Joesten* suggests that an origin by intercumulus magmatic reaction and crystallization, rather than by sub-solidus metamorphism, is essential to explain his results. The controversial conclusion is challenged by *Ashworth* and further defended by *Joesten* in a Discussion and Reply.