Thermodynamics in Geology

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Thermodynamics in Geology

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PREFACE

It has long been realized that the mineral assemblages of igneous and metamorphic rocks may reflect the approach of a rock to chemical equilibrium during its formation. However progress in the application of chemical thermodynamics to geological systems has been hindered since the time of Bowen and the other early physical-chemical petrologists by the recurring quandary of the experimental geologist. His systems are complex and are experimentally intractable, but if they were not so refractory they would not be there to study at all. It is only recently that accurate measurements of the thermodynamic properties of pure, or at least well-defined minerals, melts and volatile fluid phases, combined with experimental and theoretical studies of their mixing properties, have made it possible to calculate the equilibrium conditions for particular rock systems.

Much work is now in progress to extend the ranges of composition and conditions for which sufficient data exist to enable such calculations to be made. Moreover the routine availability of the electron microprobe will ensure that the demand for such information will continue to increase.

The thermodynamic techniques required to apply these data to geological problems are intrinsically simple and merely involve the combination of appropriate standard state data together with corrections for the effects of solution in natural minerals, melts or volatile fluids. However the vocabulary of the subject often appears foreign to geologists and there has been a lack of up-to-date text books available for use in courses on thermodynamics in geology. The N.A.T.O. Advanced Study Institute, of which this volume is the Proceedings, set out to review some of the progress which has been made in the field, and to survey some topics of current research. In particular, however, the Institute functioned as a teaching medium in which the various review lecturers supplemented their talks with study problems worked out during afternoon teaching sessions.

The volume "Thermodynamics in Geology" is therefore more than just the proceedings of a conference, since each review lecturer was asked to write a chapter suitable for use as a teaching text. The book begins with a chapter on calorimetry (Navrotsky) followed by two chapters on the experimental determination of activity-composition relationships of mineral solid solutions by phase equilibrium experiments (Wood) and by high temperature solution calorimetry (Newton). After chapters on the nature of activity-composition relationships (Powell) and the expression of non-ideal behaviour using Margules' equations (Grover), a review of experimental techniques available for determining site occupancy is given (Whittaker).

The extraction of thermodynamic data from phase diagrams together with an analysis of accuracy and precision is considered by Anderson and Chatterjee and this section is followed by a discussion of the properties of volatile phases. The properties of supercritical solutions are reviewed by Holloway, and this is followed by a chapter on metamorphic solutions by Eugster and a review of studies of fluid inclusions is given by Touret.

Two specific examples of the application of thermodynamic methods to geological problems are considered by Wones and Dodge (biotites as monitors of granitic melts) and by El Goresy and Woermann (opaque minerals as oxygen barometers and geothermometers). These are followed by a section on the thermodynamic properties of melts. Following a review of the properties of "simple" molten salts (Kleppa) the nature and properties of silicate melts are considered by Fraser. This is followed by a chapter by Nicholls on the treatment of activities in natural silicate melts and a discussion of trace element behaviour by O'Nions and Powell.

Finally the kinetics of carbonate dissolution in sea-water are considered (Broecker and Takahashi) and a review of non-equilibrium thermodynamics in petrology is given by Fisher.

That so many authors should co-operate in this way to produce the collection of chapters in this volume, many provided with study problems and worked solutions, is a tribute to the enthusiasm and good-will of all those who participated in the Institute. We all hope that those reading the book will find it both useful and enjoyable.

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The Institute itself grew out of a number of one week vacation courses for British graduate students held in the Department of Geology, University of Manchester. These courses were organized and run by Drs. R.K. O'Nions, R. Powell, B.J. Wood and myself and I gratefully acknowledge their contributions which made the Institute possible. I particularly wish to thank Bernie Wood for his good advice on numerous occasions. I also thank the Natural Environment Research Council for financial support of the courses.

The Institute could not have been held without the good-will and co-operation of the technical and academic staff of the Department of Geology, University of Oxford and I thank them all for their assistance before, during and after the Institute. I particularly thank Valerie Miles for handling all the correspondence, Peter Deussen for help with draughting and design, and our conference secretary, Dominique, for her charm, good humour and cheerful efficiency.

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D.G.F.