

# Thermodynamics of Rock-forming Crystalline Solutions

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14-2, p. 343, the pattern does not show up clearly.

I feel that I can recommend the book strongly for its synthesis of metamorphism, magmatism and structure within the framework of plate tectonics. The cosmopolitan view of metamorphism is a rare gift among modern petrologists. Readers of Professor Miyashiro's previous papers will be gratified to find a clear statement of his important views on metamorphism in a single volume in English. His summary of the metamorphic geology of Japan and other areas unfamiliar to the readers is of great value.

The book contains few typographic errors; I counted eight. There are a few other minor errors; for example, on p. 63, R. W. White did not demonstrate constancy of chemical composition with metamorphic grade.

My additional comments about the book are few. One reservation that I have is about the book's organization. For example, a person not versed in metamorphism will have to follow a series of cross-references to get a complete statement about the granulite facies. This will limit the usefulness of the book for some students.

I was surprised to find, that among the 800 references, Turner's book on metamorphic petrology published in 1968 and Winkler's paper on abolition of metamorphic facies (1970) were not cited. These works represent divergent views on the definition and usefulness of metamorphic facies. In addition, a paper on facies series by Hietanen (1967) was not commented upon.

With regard to most of Professor Miyashiro's views on definition of individual metamorphic facies I am in accord. His argument that a facies should be based on mineral paragenetic relationships and not field occurrence is particularly well taken.

His restricted definition of eclogite facies to assemblages of clinopyroxene (omphacite) + magnesian garnet + quartz (or kyanite) would exclude many eclogites from blueschist terranes, which often differ in chemistry from associated blueschist metabasalts.

Recognizing that such rocks may represent Ps-T conditions transitional to the eclogite facies, as defined above, is highly significant.

My personal view is that the blueschist facies is just as properly defined as any other metamorphic facies (p. 68), but the opposing view is held by several other authors other than Professor Miyashiro.

The metamorphism of the Akaishi Mountains, Japan (p. 140) is of the "burial type" and is inferred to have taken place under a geothermal gradient of 75-175°C. Km<sup>-1</sup>. Many petrologists have inferred that the source of heat in burial metamorphic rocks is internal not external. Consequently, many petrologists would probably not include geothermal gradients of this magnitude within the limits of burial metamorphism.

The book is a welcome addition to the science of metamorphic petrology. It comes at a particular appropriate time when many petrologists are speculating about the larger scale features of the earth and geophysicists and structural geologists are interested in the P-T constraints in tectonic belts. For these people, as well as the student who is interested in the interrelationships of metamorphism, magmatism and plate tectonics, this book is "must" reading.

## References

- Hietanen, A., 1967, On the facies in various types of metamorphism. *Jour. Geol.*, v. 75, p. 187-214.
- Turner, F. J., 1968, *Metamorphic petrology*. McGraw-Hill, New York, 386 p.
- Winkler, H. G. F., 1970, Abolition of metamorphic facies, introduction of the four divisions of metamorphic stages, and a classification based on isograds in common rocks. *Neue Jahrb. Mineral., Monatsh.*, v. 5, p. 189-248.

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## Thermodynamics of Rock-forming Crystalline Solutions

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by S. K. Saxena  
*Springer-Verlag, New York, 188 p., 1973.*  
 \$17.80.

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 London, Ontario*

This book is the ninth volume in the Springer series on minerals, rocks and inorganic materials. The topic considered is one of immense importance in modern petrology and one of more than usual difficulty. In the naturally complex chemical environment, the majority of minerals form from solutions or mixtures and are themselves mixtures. The products of igneous and metamorphic processes are normally solid solutions and the record of equilibrium factors is recorded in such solutions. This record is vital to the appreciation of pressure-temperature or tectonic history of rocks. Early work in experimental petrology was much concerned with simple systems but as we search for more precise information from rocks, it is the solid solutions that must be understood in detail.

The basic problem in the physical chemistry of all solutions is to find equations that will describe the chemical potential of all species present over all ranges of concentrations. From these we hope to extrapolate and interpolate from more limited data. It is quite impossible to do the infinite number of experiments required for natural mixtures. Thus, one must welcome a book that attempts to set out the present state of the art, an art which has developed rapidly with the common availability of computers.

The introductory parts of the book are devoted to the general principles of the problem and the description of the general relations for the various classes of solutions, ideal, regular, and the like. These relations lead to the general concepts of miscibility

relations, spinodal systems, distribution coefficients, activities and order-disorder phenomena. The final chapters are directed at more specific systems such as pyroxenes, olivines, feldspars and problems such as geothermometry. There is a small discussion of kinetic factors. Finally, there is a brief section on computer programmes.

The author clearly states in his introductory remarks that the book is for advanced students and research workers and I must agree. Perhaps the problem that is at the core of this subject, and most approaches to it, is that solution equations are not directly derived from basic thermodynamic laws. The equations can be put into the class of intelligent guesses. At best, some of the most simple, may be "derived" or shown to have some basis in the postulates of classical and statistical thermodynamics. The subject is not simple or straight forward and there is much room for misconception and misuse.

From my reading of Saxena's approach, it is clear that this book is only for the specialist and those with a firm grasp of thermodynamics. I am tempted to comment that those who do not have a firm grasp of a good treatment such as Denbigh "Principles of Chemical Equilibrium" are best advised to leave Saxena alone.

In fact, I was a little disappointed in this book. I think the introductory level could have been set a little lower. From my experience of graduate students in this field, and many research workers, the fundamentals are passed over much too lightly and I see many places where misconceptions will arise. So the book is useful as a summary for the well versed. But do they need it? Of course, this is the eternal problem of all who write books.

Early in the book (p. 6) the reader meets the equation for the ideal entropy of mixing; the core concept in all solution theory. I think Saxena could have expanded this section. If the student of solution theory does not firmly appreciate the meaning of chemical potential and the equation

$$\Delta S = -R(x_A \ln x_A + x_B \ln x_B)$$

then he will be lost from there on. If he

does, then the text will become more useful. The next great problems, and often misconceptions involve the precise way in which chemical potentials are described. Saxena appears to fumble on this topic. For example, if there is a mixture XO-YO, one can define  $\mu_{XO}$  as:

$$\mu_{XO} = \left( \frac{\partial G}{\partial n_{XO}} \right)_{P,T,n_{YO}}$$

This has an exact and operational meaning. If I write  $\mu_X$  and mean  $\mu_{XO}$  confusion may arise for

$$\mu_X = \left( \frac{\partial G}{\partial n_X} \right)_{P,T,n_{XO},n_{YO}}$$

also has an exact and operational meaning and is quite distinct. In teaching students, I have always found that it is from this type of problem that their difficulties arise. Saxena is often not sufficiently clear about such things.

Should a future edition arise, I feel that Saxena might well fill out some of these gaps even if some more sophisticated applications were neglected. Applications of many aspects, for example the Gibb's phase rule, are weak or even suspect (p. 46-49).

In many places I felt serious gaps for a book that should be useful. I was surprised to see topics like crystal or ligand-field theory left out when transition-metal solutions are so important. Very important modern works on such topics are not in the bibliography. New techniques for the study of some solutions and the results from electron diffraction and Mossbauer spectroscopy are not mentioned. They are at the centre of modern observations. The discussion on kinetics is quite inadequate yet vital to the subject. Before one plays the complex games of equilibrium, it is well to reflect at length as to whether or not the data warrant the effort.

In summary, I was disappointed. The experimentalist may find the book of some use but not many others. I do not think this book conveys the modern state of a complex, difficult, but important subject.

MS received, April 5, 1974.

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## The Persian Gulf

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Edited by B. H. Purser  
Springer-Verlag, New York,  
471 p., 1973.  
\$29.70.

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Subtitled "Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea", this book contains 22 papers, most describing new data collected by research teams from Dutch Shell Research, Imperial College of London, and Kiel University. Some of the papers were first presented orally at the International Sedimentological Congress in Heidelberg, 1971.

No region of modern carbonate deposition is more important than the Persian Gulf. The area of accumulation is vast and complex, and its tectonic setting, between the Zagros Orogenic Belt to the north and the Arabian Foreland to the south, is directly analogous to many ancient sedimentary basins. Both the setting and the hot-arid climate differ from the well-known areas of modern carbonates in the Caribbean, and knowledge of both regions is therefore complementary.

The book is directed to the specialist, and only a handful of readers of *Geoscience Canada* will wish to purchase a personal copy. However, there are several papers all sedimentologists should note beyond reading the remarks that follow.

"Regional Sedimentation along the Trucial Coast" (p. 211-231) by B. H. Purser and G. Evans is by far the best introduction to this classic area of *sabkha* evaporites, algal tidal flats, lime mud lagoons, ooid tidal deltas and fringing reefs. Especially welcome to those working ancient carbonates is the portrayal of vertical sequences of facies deposited in each environmental setting.

"Sedimentation around Bathymetric Highs" (p. 157-177) by Purser is required reading for those concerned