

# Applications of Thermodynamics in Metamorphic Petrology

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gneisses) and treating in considerable detail its chronological evolution. In the four chapters which follow, outlines are given of the structural provinces which were affected by events during the early Proterozoic, viz. the Nagssugtoqidian, Rinkian and Ketildian Mobile Belts.

The next chapter by Emeleus and Upton presents an account of Gardar age (1330-1150 m.y.) activity in South Greenland, a period of ensialic sedimentation, volcanism and alkaline plutonism which was responsible for the production of some of the world's most spectacular and yet enigmatic igneous rocks, i.e., the Ilimaussaq intrusion.

Credible structural models for the formation of orogenic belts, and in the last few years, plate tectonic explanations, have been severely hampered by the lack of stratigraphic, bio-stratigraphic and structural detail on a local scale. In the three chapters which follow, Precambrian to Tertiary relationships in the East Greenland Caledonian and North Greenland fold belts are presented with abundant regional and more specialised local stratigraphic detail. As a result these chapters document not only the Precambrian history of the region but also its tectonic and lithological evolution during the formation of the Palaeozoic Proto-Atlantic Ocean (Iapetus), its subsequent closure to form the Caledonides and eventual fragmentation in the Mesozoic to generate the present Atlantic Ocean. Pertinent to this latter event are discussions of the East and West Greenland Tertiary igneous provinces.

The remaining chapters in the book which are by no means less important, include a discussion of the Quaternary geology of Greenland, a review of the metallogenic potential and organic fossil energy resources of Greenland, and an outline of fossil flora and palaeovertebrates. It concludes with an account of recently discovered kimberlites in Western Greenland.

The book is a scholarly and well edited work. It will certainly become one of the classics of regional geology and is a real bargain at approximately \$35.00.

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## Volcanism in Australia

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Edited by R. W. Johnson  
*Elsevier Scientific Publishing Company.*  
 405 p. 1976.  
 Price \$23.25

Reviewed by P. M. Clifford  
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This volume is an interesting assemblage of papers about volcanoes in Australasia. Most of us have scant idea about the range and continuity of activity there, and few of us have actually watched a volcano at work. This book enlightens us on both matters.

The 28 constituent papers are arranged as a "tour" clockwise from Australia via Papua-New Guinea to New Zealand. Six papers have a geochemical bias. Three of these deal with island arc situations, one with activity on a continental plate. All areas show a wide compositional range for their volcanic rocks and none lead to a satisfying petrogenetic model. Four papers cover odds and ends - an early Cambrian flood basalt province in northern Australia, long flows in Queensland, a model for ore deposits associated with andesitic strato-volcanoes, and a discussion of volcanic emanations in the Solomon Islands which supports the idea of exhalative ore deposition.

The bulk of the book, however, is concerned with physical studies. Eight deal with observed eruption patterns, four more discuss activity of volcanoes recently deceased, and four have to do with geophysical means of keeping a wary eye on potentially dangerous volcanoes.

Given the many active volcanoes in Australasia, and their tendency to violence, this emphasis is not surprising. Precise levelling, infra-red scanning, magnetic and thermal surveys and seismic monitoring are all yielding interesting and eventually useful results. But assessment of hazard based upon eruptive history and style is still the most common approach, and it is this that may be served by the volcanic histories, with their descriptions of repose patterns, and the style and products of individual

eruptions. These histories, too, are a valuable antidote to the disease of layer-cake thinking which can often afflict interpretations of ancient volcanic assemblages. These island-arc volcanoes are erratic in output, rarely providing an identifiable unit which is distributed all about the vent. When they come close to doing this (a pyroclastic eruption perhaps) but are not badly damaged by tectonic activity, there is the chance, as at Witori volcano on New Britain, to examine unaltered tephra and to see just how good correlation of units may be based upon such things as textural variations. Such studies link the currently alive to the long-since dead.

G. A. M. Taylor, in whose memory these papers are published, would, I suspect, have been pleased to see these accounts of the growth of work he began at Rabaul in 1950. For readers far removed from the area, the papers have interesting points to make, and are worth reading. But there is not really enough of general application to make it worth buying, except by the most avid volcanologists.

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## Applications of Thermodynamics in Metamorphic Petrology

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By Edgar Froese  
*Geological Survey Paper 75-43*  
*Printing and Publishing Supply and Services Canada*  
*Ottawa, Canada, K1A 0S9*  
 73 pages, 1976  
 Price \$3.00 in Canada,  
 \$3.60 in other countries

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This small and compact book fills neatly a serious gap that has developed between theoretical-experimental petrologists and more field-oriented chemical petrologists. Thermodynamic theory and calculation has been assuming an ever-increasing role in the

interpretation of metamorphic rocks and it has been clear for some time that a book was needed to enable the interested reader, with a background of some past exposure to physical chemistry and elementary calculus, to make use of these techniques. Edgar Froese's book can be recommended to accomplish this task. It would be possible to understand the book even without having once taken a course in physical chemistry, but one would not develop an overall understanding of the subject by this route.

The style of writing is, for the most part, clear and unambiguous, and easy to follow, and while Froese is careful to state matters rigorously there is little sign of rigor concealing the meaning of the sentences. I found only three minor typographical errors and the quality of printing and reproduction of figures is uniformly excellent. In many ways, the heart of the presentation lies in the profusion of figures, with 33 figures in 37 pages. Each figure serves to illustrate graphically one or more of the important equations around which the calculations are built, with the result that the reader need never feel lost in a maze of equations. There is always an illustration that shows graphically the meaning of each equation.

In addition to the extensive use of figures Froese has used detailed numeric examples to illustrate the application of the equations to problems of metamorphic petrology, some of which have been published elsewhere, and some of which are given for the first time in this paper. The examples are well-chosen so as to illustrate a variety of principles, ranging from simple calculation of univariant equilibrium, through ideal solution models applied to the displacement of equilibria, to consideration of non-ideal solid solutions and partial melting. This is an ambitious array of subjects for so short a book and it is inevitable that some parts of the subject of thermodynamics and some good examples have been omitted. However, there is at least one example of most kinds of equilibrium calculation and the reader who works his way through all of them will become sufficiently adept with the subject to progress the rest of the way on his own.

Attention should be drawn to some of the aspects this reviewer found most rewarding. Particularly good treatment is

afforded to thermodynamic temperature scales, to the minimization of free energy at equilibrium, to the derivation and use of the equilibrium constant, and to the problems of standard states. Excellent illustrations will help the reader understand the different standard and reference states and the meanings of the different terms needed in finding the free energy of water at different pressures and temperatures. Clear but rather compact treatment is given to equilibria between sulphides and silicates, and all chemical petrologists should become aware, via this approach, of the importance of 'opaques' in the understanding of metamorphic mineralogy.

It is always possible to find something to criticize in a short presentation of a large subject, particularly when similar problems can be treated by a variety of approaches even though the numerical results must finally all agree. For example, there is no derivation nor use made of the Gibbs phase rule, and no attention given to Schreinemakers' rules, presumably because these are a necessary though unstated consequence of the fundamental equations that are used. Similar reasoning must have excluded the representation of equilibria in  $\text{CO}_2$ - $\text{H}_2\text{O}$  mixtures by means of diagrams plotting gas composition against temperature ( $T$ - $x$  diagrams). The treatment of ideal site-mixing and the Temkin model of ideal site-substitution is rather short and essentially phenomenological, with no reference to the probabilistic nature of the entropy of ideal solution. This is not really a criticism but a reflection of different taste in development.

In summary this is a good book, and at the price of \$3.00 an outstanding bargain. I recommend it to students of petrology at all levels, particularly undergraduates in their final year and graduate students in their first year. Readers who have been away from academic subjects for some years should also be able to read the book and use the results, although they need occasional reference to one of the standard texts of physical chemistry cited in the bibliography.

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## Ice Ages: Ancient and Modern

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Edited by A. E. Wright and F. Moseley  
*Geological Journal Special Issue No. 6,*  
*Seel House Press, Liverpool, 320 p.,*  
*1975*  
£ 12.00

Reviewed by Aleksis Dremanis  
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This volume containing 15 papers and two brief tributes to Leonard J. Wills on his 90th birthday and Frederick W. Shotton on his retirement after 24 years as Head of the Department of Geology, University of Birmingham, is an outgrowth of the 21st Inter-University Congress organized by the students of the Lapworth Society at Birmingham, U.K., in January, 1974. It deals with two groups of topics: the Quaternary and the pre-Quaternary glaciations - both of considerable interest to the Canadian earth scientists.

The first paper is F. W. Shotton's "Introduction to the Quaternary", discussing various lines of evidence that have been used to deduce and date the Quaternary climatic cycles, but also warning that not all of them are applicable to the earlier 'Ice Ages'. G. S. Boulton discusses processes and patterns of subglacial erosion, deformation and sedimentation by applying theoretical approach based upon direct observations at the present-day glaciers and the theories developed mainly by physicists, glaciologists and engineers. In conclusion he cautions, however, that his "predictions cannot be readily tested", as "there is as yet no consensus about the patterns of erosion and deposition produced by ancient ice sheets". E. A. Francis presents a review on glacial sedimentary deposits, their definitions and nomenclatures. He also proposes recommendations "in an attempt to simplify classification and to relate deposits to genesis and environment". While achieving this goal successfully re- several terms, Francis unfortunately does not assist in solving the already existing confusion on the international usage in one of the basic terms - moraine, by suggesting "that