Crustal Heat Flow A Guide to Measurement and Modelling

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Reviewed by Ted Lilley

Not knowing this book was in preparation, it was a delightful surprise when a copy arrived on my desk in October 2001. A surprise also because while in many geophysics texts, heat flow is typically given its own chapter, to this reviewer there has been no book quite like this one before. Consistent with the title, the whole book is devoted to heat flow.

Both authors have been closely concerned with heat flow throughout their respective careers, and this volume brings together in a coherent and useful way much of their work.

Heat flow is one of the fundamental quantities in geophysics. Its study has featured prominently in Australian geophysics since the influential role played by J. C. Jaeger half a century ago, following Jaeger's collaboration with Carslaw, which produced the book (by Carslaw and Jaeger) 'Conduction of Heat in Solids'. The present book has Australian examples and case histories very much to the fore, which is refreshing when many Earth science books come with northern hemisphere examples.

The present book deals with subjects as widely spaced as climate change recorded in thermal profiles in the crust, to fission track thermochronology. There is a useful summary at the end of each chapter.

The book is in three logical parts.

Part 1, on the Thermal State of the Earth, describes, in Chapter 1 (Terrestrial Heat), the present understanding of the Earth's thermal state, and in so doing introduces the units, which will be used throughout the book. SI units are used, perhaps now taken for granted, but at their best in this type of geophysics. The second chapter is the crucial one on Heat Generation (mainly radioactivity, but certain other processes also rate a mention), and the physics is again well introduced.

Part 2 then addresses Measurement Techniques, and the natural elements thereof. Chapter 3 is on Thermal Gradients, and details of measuring this most fundamental quantity on both land and sea. Chapter 4 is then on Thermal Conductivity, the quantity needed for combination with thermal gradient values; wider aspects of the physics of heat conduction in rocks are also discussed. Chapter 5 is on Thermal Maturity, and here there is specialist treatment of the maturation of hydrocarbons in sedimentary basins as measured, for example, by vitrinite reflectance.

Part 3 deals with modelling techniques. Chapter 6, entitled Heat Flow, addresses how actual observed heat flow values are interpreted in terms of geological structures on both local and regional scales. Chapter 7 describes Lithospheric Models in the framework of present plate tectonic theories, in particular returning to the effects expected in boreholes in sedimentary basins (echoing the hydrocarbon exploration theme of the book). Chapter 8 addresses the Numerical Modelling of steady-state heat conduction in three dimensions, as for a known geologic structure in a sedimentary basin.

The book concludes with Chapter 9, entitled Unravelling the Thermal History of Sedimentary Basins. Here the strategy is to use physical data from a basin to deduce its heat-flow history. The passage of time is now introduced, with the simplification pointed out that thermal equilibration in a basin is rapid compared to the lithosphere as a whole. Again there is a return to the theme of the generation of petroleum.

The book thus ranges from detailed technical applications to wide fundamental principles. In so doing, it should please the minds of both practitioners in the subject, and also students who find satisfying the basic physics displayed in this grand piece of apparatus which we call Earth.

In fact the book demonstrates that heat flow can form a worthy basis for a whole introductory geophysics course. Using the present text as a base, a lecturer could steer a route through much of solid-earth geophysics. There are excellent worked examples.

In following such a course, students would find the book presented 'benchmark' papers in subjects such as mantle convection, which could then be followed into the literature to find the latest discussions of the subject. Two other examples where these remarks apply are seismic tomography (there have been important developments in Australia since the references given) and the use of electromagnetic methods to determine deep electrical conductivity profiles, and thus thermal state. In this broader view of geophysics, the examples given in the book may be regarded as 'sample' papers, which can lead into a wider literature search where that is required.

The book provides ample and interesting connections to relevant history. The authors' humour is revealed also, in such cameos. Amongst the quotations from the great geologists of the 19th century, in their period-piece style, we suddenly (at the start of Chapter 8) come across a most delightful modern one, which could not be more topical or appropriate! (When I model I pretty much blank. You can't think too much or it doesn't work. Paulina Porizkova, actress and model.)

The book is well produced (consistent with the best CUP standards), and the cover attractive. The cover, indeed, emphasises the whole-Earth nature of heat flow. My copy, paper-back, seems well bound and very workable for its 324 pages. The book gives the impression of being free of printing errors (the most I can point out is that the journal of the Hyndman and Everett (1968) paper, the Geophysical Journal of the Royal Astronomical Society, is given as Geophysics Journal.)

Finally, this book is a book of its time. It has a website as an ongoing source of support, in addition to the information and concepts in the text. The website is: http://www.earth.monash.edu.au/heatflow/

For a price of A$80, it is in my view, very good value. There is a great deal which can be learned from this book. With its emphasis on sound physics and quantitative examples, the approach or philosophy is admirable and comes across clearly.