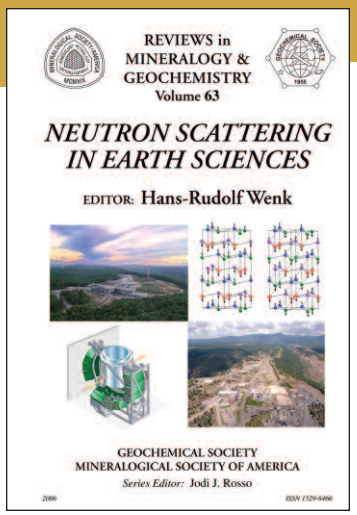
Neutron Scattering in Earth Sciences[1]



The availability of specialised structural and analytical techniques at central facilities (e.g. synchrotron and neutron laboratories) has revolutionised materials (*sensu lato*) research over the last 10–20 years, but Earth scientists as a whole have been slow to 'dip their toes' into such exciting waters. However, the synchrotron radiation, element-specific X-ray absorption spectroscopic technique (EXAFS) is becoming increasingly popular among environmental scientists studying the cycling of toxic elements. By contrast, some mineral physicists carry out challenging synchrotron X-ray and/or neutron diffraction experiments, often at controlled temperatures and pressures. However, the time is ripe to emphasise the wider importance of neutron methods for a wide range of Earth science research and to expand the user-base. Thus the short course entitled Neutron Scattering in Earth Sciences (December 2006) was held to try to stimulate new research areas and to attract more Earth scientists to this exciting cross-disciplinary research community.

The book contains 17 chapters with an impressive list of authors covering a wide range of scientific and experimental expertise but, perhaps inevitably, not many have a mainstream Earth science background. Chapter 1 (Parise) is an excellent introduction to the special properties of neutron radiation and emphasises the advantages compared to equivalent X-ray techniques. Chapter 2 (Vogel and Priesmeyer) provides background information on neutron sources and associated equipment, distinguishing between reactors and spallation sources and between monochromatic and polychromatic (time-of-flight) techniques. These articles introduce terminology, concepts and experiment types which are more fully covered in the other contributions.

Chapter 3 (Ross and Hoffmann) deals with single-crystal diffraction and gives useful examples for location of light elements (mainly hydrogen and deuterium). The low-key nature of this article perhaps reflects the paucity of single-crystal mineralogical studies using neutron diffraction. Chapter 4 (Von Dreele) describes how Rietveld refinement of powder data can be used to obtain full structures, and this analysis method provides the basis for the contributions given in chapters 5 (Knorr and Depmeier) and 7 (Redfern), the latter reviewing studies of the temperature dependence of cation order–disorder in a range of petrologically important minerals. Chapter 6 (Harrison) is an authoritative treatment of neutron diffraction of magnetic minerals, providing useful summaries for magnetite spinels and hematite–ilmenite solid solutions.

Chapter 8 (Kuhs and Hansen) is another excellent contribution which deals with time-resolved, controlled pressure/temperature studies of water ices and clathrates. The higher flux from a reactor source with a specialised beamline (D20 at ILL) allows reactions to be studied on sub-second time scales. Chapter 9 (Parise) also deals with water-ice polymorph stabilities as part of a useful review of high-pressure experimental equipment. The final section is particularly interesting and deals with new plans and developments, particularly on the SNS at Oak Ridge. In the next chapter, Chun-Keung Loong shows that neutron inelastic scattering provides information on spatial–temporal interactions of atoms and electrons. The next three chapters deal with studies of disordered/amorphous solid materials and fluids. Chapter 11 (Proffen) shows how total-scattering methods and pair-distribution functions can be used to obtain 'true' atomic structures for amorphous and poorly crystalline or strained materials. Chapter 12 (Wilding and Benmore) summarises neutron-diffraction and data-reduction methods used in the study of silicate glasses. The use of levitation techniques for in situ studies of oxide melts seems particularly promising. The next chapter (Cole, Herwig, Mamontov and Larese) is wide ranging and shows how neutron diffraction has been used to provide important data on the structure of liquid water and aqueous electrolyte solutions.

The last few chapters deal with macro- and micro-structural features of 'real' rocks and related mineralogical samples. In chapter 14 (Radlinski), the technique of small-angle neutron scattering (SANS and ultra-SANS) is described, and it is shown how these techniques can be used to characterise the porosity (and fractal properties) of sandstones and coal, and to study micro-structures of shales and clays at length scales between 1 nanometre and 20 microns. Chapter 15 (Wenk) is the most persuasive, which is appropriate as it is written by the editor of this book – a pioneer in the use of neutrons for studying textures of deformed rocks. Examples of work dealing with real petrological problems are clearly explained. In chapter 16 (Daymond), the study of deformed aggregates is described with the example of in situ measurements of strain partitioning in multi-phase mineral mixtures being particularly interesting. In the last chapter (Winkler), applications of neutron radiography and tomography are covered, with examples including study of rock cores, experiments to measure melt viscosity, and fossil conifers. These techniques have a huge potential in Earth science, and this chapter is just too brief.

This is a typical volume in the Reviews in Mineralogy and Geochemistry (RiMG) series – it is packed with important information and is excellent value at $40. However, it is not user friendly, as there is much repetition of basic concepts, and background information is scattered through the different articles in the volume. The lack of an index makes it difficult to dip into and cross-check between chapters.

It is pertinent to compare this book with the thematic issue of the *European Journal of Mineralogy* (*Neutron Scattering in Mineral Sciences*, editor R. Rinaldi, *EJM*, volume 14(2), 2002). On the whole, the *EJM* papers are authored by mainstream mineralogists and, overall, this is reflected in a better coverage of significant mineralogical examples. However, the RiMG book has a wider scope and includes chapters dealing with amorphous materials (glasses, melts and fluids) and magnetic samples, and has more detailed information on techniques. Potential users could consult both of these, but wise researchers might already have RiMG volume 63 on their shelves along with the rest of this excellent series.

C. Michael B. Henderson
School of Earth, Atmospheric and Environmental Sciences
The University of Manchester, Manchester M13 9PL, UK
and
Synchrotron Radiation Source
STFC Daresbury Laboratory
Warrington WA4 4AD, UK

[1] Wenk H-R (editor) (2006) *Neutron Scattering in Earth Sciences*. Reviews in Mineralogy & Geochemistry 63, Mineralogical Society of America Chantilly, VA, USA, ISBN: 978-0-939950-75-1, 471 pages, US$40 25% discount for MSA and GS members