years or decades. When models are calibrated, it generally is assumed that the aquifer system is in a natural steady state condition prior to human influence. Papers presented during this symposium demonstrate the fallacy of this assumption in many situations.

Many of the talks showed that groundwater flow systems can change dynamically over geologic time in response to changing boundary conditions, hydraulic stresses, or aquifer properties. Such changes can be caused by long-term climatic changes, sea level changes, glacial loading or unloading, tectonic forces, mineral dissolution or precipitation, and deposition or erosion of sediments. Each of these processes was addressed by one or more speakers.

Perhaps the single most important and pervasive theme was that modern groundwater systems may still be undergoing slow transient responses to changes in stresses that now appear constant or to processes that are no longer active. This may be manifested by anomalous hydraulic heads or by inconsistencies between modern hydraulic gradients and the distributions of solutes, isotopes, or temperature. For example, several papers showed that the present position of the freshwater-saltwater interface (or transition zone) in coastal aquifers on both th%⅔tlantic and Pacific coasts of the United States are not now in equilibrium with sea level. Freshwater extends farther offshore than can be explained by present-day sea level, and the interface reflects a long-term average sea level at about 15–30 m lower than present. Consequently, the interface is migrating naturally toward the land. This type of natural transient change must be recognized and differentiated from artificially induced effects if accurate predictions of future changes in groundwater flow and quality are to be made.

Several papers focused on the western United States, where geologically recent climatic changes have altered recharge patterns to aquifers. The change in recharge, in turn, causes changes in the flow systems, which then affect water quality. Other papers discussed longer-term geological processes related to sedimentation and erosion. Erosional unloading and topographic changes can have strong influences on groundwater flow patterns in low-permeability environments. There, significant underpressuring is caused by adjustment times on the order of several millions of years. Conversely, high depositional rates and sediment compaction, such as occurs in the Gulf Coast basin, can lead to significant overpressuring. In certain cases, it might be possible for a high-temperature basalt intrusion to induce pressure anomalies in sediments that are retained for thousands of years after the intrusion's heat has dissipated. Some of the other papers noted the potentially important role of groundwater flow in controlling the migration and accumulation of oil. Understanding the evolution of groundwater flow through petroleum source beds and traps can lead to improvements in exploration and development strategies.

A common feature among most of the reported studies was the use of numerical simulation models to aid in analysis. Groundwater flow, solute-transport, and heat-transport models were consistently used to simulate processes over periods of thousands of years to millions of years.

In summary, the papers demonstrated that understanding long-term climatic and geologic processes can aid in the analysis of groundwater flow systems and help explain observed anomalies in head and water quality. Conversely, a knowledge and understanding of the dynamics and evolution of groundwater flow systems may help in explaining or interpreting certain geologic features and processes, such as diagenesis, ore deposition, permeability, and porosity enhancement, and petroleum migration.

This report was contributed by Leonard F. Konikow, U.S. Geological Survey, Reston, Va. and Donald I. Siegel, Department of Geology, Syracuse University, Syracuse, N.Y.

Books

Elements, Oxides, Silicates: High Pressure Phases With Implications for the Earth's Interior

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Lin-gun Liu and William A. Bassett, Oxford University Press, New York, xi + 250 pp., 1986, $49.95.

Reviewed by Thomas J. Ahrens

A vitally important aspect of understanding the composition, structure, and processes acting within the solid Earth is obtaining a complete as possible knowledge of the fields of stability of the Earth's component minerals and their high-pressure polymorphs with respect to pressure and temperature. Liu and Bassett's book is the first effort which has focused on bringing together the available phase diagrams for the elements, oxides, and silicates that are relevant to the understanding of Earth's and the other terrestrial planetary interiors. Since the book also covers the elements and compounds important to the shallow region of the mantles of the major planets (e.g., H_2, He, C, and H_2O), it is an invaluable source of data for scientists studying the interiors of these planets as well.

An initial introductory chapter lays out, in very condensed form, the relation of phase diagrams to thermodynamic properties. Crystal chemical principles are summarized, as well as the main features of the techniques and apparatus employed to obtain the data summarized in the remainder of the book. Although references to apparatus papers are numerous and well chosen, references to works which relate thermodynamic properties to contruction of phase diagrams are lacking. Table 1.3, a summary of the ionic radii of elements in different coordinations appears to me to be the most valuable part of Chapter 1.

Chapters 2, 3, and 4, in which the phase diagram of the elements, oxides, and silicates are summarized, are the heart of this book. The pressure range covered varies from 40 to 50 kbar for materials whose phase diagrams were studied with a piston cylinder apparatus and up to 3000 kbar for the case of iron which has been studie using shock wave techniques. Similarly, the temperature ranges of the phase diagrams vary from $\sim 10^{2\circ}$K to $10^{3\circ}$K, depending on the range over which the melting point has been explored. The crystal structures of most of the solid polymorphic phases are reported on the basis of in situ and quenched X ray diffraction measurements conducted in multianvil and diamond anvil pressure apparatus during the last 20 years.

In general, the huge task of compiling and critically reviewing phase equili⅛brium data for hundreds of materials has been carried out extremely well. Interspersed with phase diagrams are some useful tables and figures providing crystallographic data for groups of compounds and demonstrating the systematics of molar volume versus cation-anion distance for related compounds and structures.

A technical flaw in the book, which is easily corrected, is a missing phase diagram for $PbCrO_3$ (p. 143). Unfortunately, the caption is not missing and, as a result, the next 51 phase diagms have the wrcng caption. This problem is not sorted out until pp. 178 and 179, where the phase diagram of $K_2Cr_2O_7$ is given twice (on p. 179 with the correct caption).

In discussing successive phase transformation of the silicates with pressure (either in Chapter 4 or 5) it would have been helpful to the reader to have provided a detailed series of observed and/or theoretical seismic velocity versus depth profiles for the transition region of the Earth. The relation of sharp seismic velocity increases to phase transformation in the 200- to 700-km-depth range of the Earth are extensively discussed in Chapter 5. Also in Chapter 5, several detailed mantle model compositions are given in a series of tables. Their significance would be easier to comprehend if the tables specifying these (5.1–5.10) had captions. A summary of cosmochemical constraints and the relation of mantle models to the observed chemistry of crustal rocks derived from partial melt processes would have made this last chapter more complete.

In spite of the minor deficiencies in the present printing, this monumental work is a highly useful and long-needed book which will serve solid Earth scientists for many years.

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