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Radiogenic Isotope Geochemistry of Sedimentary and Aquatic Systems

With 144 Figures and 14 Tables

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Preface

This book is based on the script of a lecture course in isotope geochemistry, which is given at the University of Strasbourg, France and at the Eidgenössische Technische Hochschule (ETH), Zurich, Switzerland by Peter Stille. It is intended to be read by geologists, hydrologists, geochemists and any researchers and students from the broad field of environmental science. Its purpose is to enable readers to venture safely into the often mirky realms of radiogenic isotope geochemistry applied to sedimentary and aquatic systems. The authors have strived to construct the book in such a way that it can be read and understood by those readers, especially students, who have no background in geochemistry. 7 chapters take the reader through the rock cycle from weathering on the continent to eventual deposition in the sea, looked at largely from the perspective of radiogenic isotope geochemistry.

Isotope geochemistry has become the most important field of speciality in geochemistry and is being applied increasingly to the study of chemical processes in natural water bodies, the atmosphere and to other aspects of our environment. By integrating various isotope systems we can demonstrate that chemical exchange or movement of material has taken place in, for example, waste dumps or during natural sedimentation processes. (including weathering, erosion and diagenesis) as a result of water-rock exchange. The study of isotope systems can yield important information which allows us to determine the origin of migrating fluid phases, the water-rock ratio necessary for such exchange and the mechanisms which have led to the mobility of elements.

This book attempts to shed some light on the entire field of sedimentary isotope geochemistry, including the isotope geochemistry of natural water bodies, and objectively discusses important results of previous research in the various sub-fields. Readers are thus given the opportunity to critically assess this research, allowing them to apply isotopes in their own particular fields. In order to do this, we will deal especially with the geochemical and environmental questions which can be and have been solved through the application of an isotopic study.

The sequence of chapters reflects the rock cycle. Weathering and erosion contribute significantly to sediment formation and are discussed in chapter 2.

In chapter 3, the fluvial transport of these weathering products into the sea is looked at in some detail. The rivers transport large quantities of chemical elements into the ocean basins either in dissolved form or associated with the suspended load. Knowledge of these transport mechanisms allows us to establish mass balances for the oceans. Isotope studies help us also to reconstruct chemical exchange processes between the suspended load, river water and river basin sediments as well as determining the origin of toxic elements. Isotope geochemistry comes into its own when used to identify the sources of contamination in river water and to trace the transport routes of unwelcome chemical substances.

Chapter 4 concerns the application of various isotopic systems to the investigation of our heavily polluted biosphere. It is designed especially to encourage environmental researchers to explore the application of isotope geochemistry to their studies. Problems of source, mobility and exchange characteristics of heavy metals in contaminated soils and natural water bodies are discussed here.

Chapters 5, 6 and 7 are all concerned with the marine environment. The oceans represent the most important sedimentary environment. River loads end up here and authigenic minerals (e.g. phosphates, carbonates, clay minerals, FeMn-ore bodies) are formed here. Knowledge of the isotopic composition of oceans today and in the past is of the greatest importance not only for understanding the processes of exchange between sediments and seawater and during diagenesis but also for the reconstruction of the paleo-environment. Residence times of elements in seawater are explained in Sect. 5.3. Elements with long residence times (relative to the ocean mixing time) can be used for high resolution chemostratigraphy (e.g. Sr) whereas those with short residence times can be used to trace ocean currents and reconstruct ocean circulation patterns in the past (e.g. Nd, Pb, Ce, O). As well as looking in detail at the application of the Rb-Sr and the Sm-Nd systems to stratigraphy and paleoceanography, this chapter introduces less intensely researched isotope systems such as the U-Th-Pb, Re-Os and La-Ce systems and their potential for future marine research.

While chapter 5 concentrates on seawater and authigenic mineral isotope geochemistry, chapter 6 deals more especially with detrital and authigenic clay minerals in marine sediments for dating and for constraining mechanisms of exchange during deposition and diagenesis. The Rb-Sr and K-Ar isotope systems of clay-rich rocks are explored here. Special attention is paid to the formation and dating potential of glauconite.

Chapter 7 concerns the behaviour of the Sm-Nd isotope system in marine sediments during diagenesis. Chemical and isotopic exchange mechanisms leading to Nd isotopic homogenization between authigenic clay minerals in phosphate-rich, detrital sediments and bituminous shales are discussed. Knowledge of these mechanisms is of great importance, not only for the reconstruction of diagenetic evolution in a sedimentary basin, but also for dating these diagenetic processes. However, as was shown recently, knowledge of the Sm-Nd isotopic system can also be important for petroleum exploration, since neodymium isotopic equilibrium may occur between authigenic clay minerals, ambient waters, source rocks and petroleum.

We have benefited from many discussions with, and helpful comments from, several of our colleagues and friends. Peter Stille would like to express his gratitude to Emilie Jäger (Bern) and Mitsunobu Tatsumoto (Denver) who were undoubtedly the greatest influences during his formative years in science. Thanks go to Norbert Clauer (Strasbourg) for first introducing Peter Stille to sediments. We are also grateful to François Gauthier-Lafaye, Regis Bros, Marc Steinmann, Miriam Andres, Urs Schaltegger, Horst Zwingmann and Jost Eikenberg. Especial thanks go to Claude Hammel who drafted all the figures.

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