Radiogenic Isotope Geology

Modern isotope geochemistry is a rapidly expanding field that has a part to play in a broad range of Earth and planetary sciences – from extra-solar-system processes to environmental geoscience. This new edition of a popular textbook is completely updated and places more emphasis on the uses of radiogenic isotopes in environmental Earth science.

The author reviews the field of radiogenic isotope geology in a concise and visual manner to provide a comprehensive introduction to the subject and its wide variety of applications. For each technique, current ideas are presented in their historical context to allow the reader to understand the development of the theory. The latest ideas and methods, classic papers and case studies all come under scrutiny within this book.

An accessible introduction for scientists from other disciplines and an important reference for students and researchers working in isotope geology.

ALAN DICKIN has held a teaching position at McMaster University for 18 years. The first edition of this textbook was published in 1995, and has become widely established as the standard reference in the field.

Radiogenic Isotope Geology

Second Edition

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PREFACE

The objective of this book is to review the field of radiogenic isotope geology in a concise manner, in order to give readers an overview of the subject and to allow them to critically assess the past and future literature.

The approach is historical for three reasons: firstly, to give an impression of the development of thought in the field so that the reader can understand the origin of present ideas; secondly, to explain why past theories have had to be modified; and thirdly, to present 'fall back' positions lest current models be refuted at some future date. The need for this type of approach has been illustrated by several recent papers that have attempted to 'resurrect' old theories that had been discarded in the face of apparently strong evidence against them. Hence, we see that a knowledge of the 'classic work' in the field is an important starting point for current research.

The text is focussed on three types of literature. Firstly, it attempts to give accurate attribution of new ideas or methods; secondly, it reviews classic papers, although these may not have historical precedence; and thirdly, it presents case studies that have evoked controversy in the literature, as examples of alternative interpretations of data.

The radiogenic isotopic systems described in this book offer an analytical 'tool-box' of methods. The varied physical and chemical properties of different parent–daughter pairs suit them to a range of different dating and tracing tasks. Together, they allow constraints to be placed on the behaviour of complex natural systems in the solid and environmental Earth sciences.

The book is organised so that each chapter is a nearly free-standing entity covering one segment of the field of radiogenic isotope geology. However, the reader may benefit from an understanding of the thread, which, in the author's mind, links these chapters together.

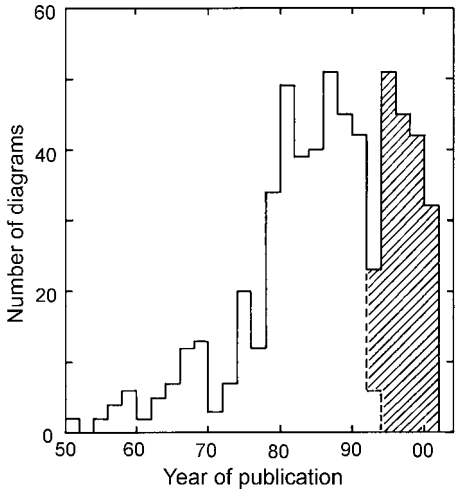
Chapter 1 introduces radiogenic isotopes by discussing the synthesis and decay of nuclides within the context of nuclear stability. Decay constants and the radioactive decay law are introduced. Chapter 2 then provides an experimental background to many of the chapters that follow by discussing the details of mass spectrometric analysis (TIMS and ICP-MS) together with isochron regression fitting.

The next three chapters introduce the three pillars of lithophile isotope geology, comprising the Sr, Nd and Pb isotope methods. The emphasis is on their applications to geochronology and their evolution in terrestrial systems. Chapter 3 covers the Rb–Sr system, since this is one of the simplest and most basic dating methods. Chapter 4 covers the Sm–Nd system, including the use of Nd model ages to date crustal formation. Chapter 5 examines U–Pb geochronology and introduces the complexities of terrestrial Pb isotope evolution in a straightforward fashion. Each chapter ends with an examination of these isotopes as environmental tracers, focussing particularly on the oceans.

Chapters 6 and 7 apply Sr, Nd and Pb, as geochemical tracers, to the study of oceanic and continental igneous rocks. This is appropriate, because these isotopes are some of the basic tools of the isotope geochemist, which together may allow an understanding of the complexities of mantle processes and magmatic evolution. These methods are supplemented in Chapters 8 and 9 by insights from the Re–Os, Lu–Hf and other lithophile isotope systems, arising from their distinct chemistry.

Chapter 10 completes the panoply of long-lived isotopic dating systems by introducing the K–Ar and Ar–Ar methods, including their applications to magnetic and thermal histories. This leads us naturally in Chapter 11 to the consideration of rare gases as isotopic tracers, which give unique insights into the degassing history of the Earth.

Chapter 12 introduces the short-lived isotopes of the uranium decay series, covering classical and recent developments in the dating of Quaternary-age sedimentary rocks. This prepares us for the complexities of Chapter 13, which examines U-series isotopes as tracers in igneous systems. Short-lived processes in



Histogram of the numbers of figures used in the second edition of *Radiogenic Isotope Geology* according to their publication dates (in biennial samples). The hatched area represents new material added since the publication of the first edition.

mantle melting and magma evolution are the focus of attention.

Chapter 14 examines the most important of the cosmogenic isotopes. These are not 'radiogenic' in the strictest sense, but represent a vast and growing field of chronology and isotope chemistry that is especially pertinent to environmental geoscience.

Finally, in Chapters 15 and 16, we examine two specialised fields that are on the fringes of radiogenic isotope analysis, but which provide powerful geological tools. The 'extinct' nuclides discussed in Chapter 15 are used to throw light on the early evolution of the solar system. Lastly, Chapter 16 examines the use of (radiogenic) fission-track analysis as a specialised dating tool for low-temperature thermal histories.

The text is gathered around a large number of diagrams, many of which are classic figures from the literature. Because of the centrality of these figures in the text, they give an indication of the historical coverage of the field in this book. The adjacent figure shows a 'snap-shot' of this data set, in the form of a histogram of the numbers of diagrams used from a series of two-yearly periods over the past fifty years. This analysis shows a 'period of emergence' of isotope geology in the first thirty years, followed by a 'mature period' with essentially uniform coverage over the last twenty years. The period of coverage ends in December 2002. Material from 2003 and subsequent years will be reviewed on the web site that supports this book (radiogenic.com).

I am very grateful to Conrad Guettler for his encouragement to begin this work, and to subsequent CUP editors Matt Lloyd and Sally Thomas for their ongoing assistance with the updating of the text. I also thank the many members of the geological community who gave helpful comments on the text during its evolution, and acknowledge the many authors and publishers for permission to reproduce their classic figures. Finally, and especially, I thank my family for their support and encouragement over the years, without which this book would not have been completed.

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