NUCLEAR RADIATION IN GEOPHYSICS

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Vorwort

Die Radioaktivität von Boden, Wasser und Luft ist ein klassisches Forschungsgebiet der Geophysik, aus dessen Ergebnissen diese von jeher reichen Nutzen zieht: Fragen nach der Wärmebilanz des Erdinnern, nach dem Alter der Erde und dem der Gesteine haben erst von hier aus eine befriedigende Lösung gefunden; Hydrologie und Balneologie verdanken der Radioaktivität entscheidende Bereicherung; im Rahmen der Prospektion und Bodenforschung hat sie ihren Platz; in der Physik der Atmosphäre bietet sie die wesentliche Grundlage zum Verständnis der atmosphärisch-elektrischen Erscheinungen; dem Meteorologen gibt sie neue Möglichkeiten zur Bearbeitung atmosphärischer Austausch- und Transportprobleme.

Die Möglichkeit der Injektion gewaltiger Mengen radioaktiven Materials in die Atmosphäre und das Auftreten künstlich-radioaktiver Elemente im geophysikalischen Bereich als Folge von Spaltprozessen oder Wirkungen der kosmischen Strahlung haben dieser engen Verbindung zwischen Radioaktivität und Geophysik neue Impulse verliehen. Die im letzten Jahrzehnt gewonnenen neuen Erkenntnisse und Fortschritte übertreffen bei weitem die in den rund 50 Jahren „klassischer" Periode erworbenen Einsichten und haben dazu neue Probleme, Aufgaben und Möglichkeiten aufgezeigt.

Angesichts dieser raschen Entwicklung schien es an der Zeit, eine Übersicht über die Rolle der natürlichen und künstlichen Radioaktivität — kurz der Kernstrahlungen im weitesten Sinne des Wortes — im geophysikalischen Rahmen zu geben mit dem Ziel, zu informieren und zu neuen Untersuchungen, Fortschritten und Anwendungen anzuregen. Dieser Plan einer umfassenden Darstellung der „Kernstrahlung in der Geophysik" wurde von den zur Mitarbeit angesprochenen Kollegen lebhaft begrüßt. So war es möglich, die einzelnen Teilgebiete jeweils aus der Sicht und Feder eines Spezialisten zur Bearbeitung kommen zu lassen.

Obwohl hierbei mit gelegentlichen Überschneidungen und Verschiedenartigkeiten in der Auffassung und Darstellung zu rechnen war, haben wir dies bewußt in Kauf genommen,um neben der Individualität der Beiträge die Lebendigkeit und Dynamik des gesamten Fragenkomplexes fühlbar werden zu lassen. Um der Originalität der Beiträge willen wurde auch Zweisprachigkeit angestrebt (Deutsch und Englisch), wobei eine Zusammenfassung zu Anfang eines jeden Kapitels in der jeweils anderen Sprache als Erleichterung dienen möge. Ein zweisprachig angelegter Index soll gleichzeitig Wörterbuch für die Fachausdrücke sein.

Wir möchten auch an dieser Stelle allen Mitarbeitern unseren verbindlichsten Dank für die Mühe und Sorgfalt bei der Abfassung ihrer Beiträge aussprechen. Einigen von ihnen danken wir besonders für die Geduld, die sie angesichts der bei einer solchen Gemeinschaftsarbeit leider nicht zu vermeidenden Verzögerungen in der Fertigstellung des Manuskriptes und damit der Drucklegung aufbringen mußten. Unser Dank gilt in gleicher Weise dem Verlag für sein großes Verständnis und sein stets entgegenkommendes Verhalten allen unseren Wünschen gegenüber sowie für die Ausgestaltung des Buches.

Weihnachten 1961

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Preface

The "radioactivity of soil, water, and air" is a classical research field of geophysics. Many important discoveries and informations are based on its extended use. Questions concerning the heat balance of the earth's interior or the age of the earth and of different rocks have found satisfactory solutions on this basis; hydrologic, oceanographic and balneologic research, prospecting geology, atmospheric-electric phenomena connected with problems of the physics of the atmosphere as well as meteorologic transport- and exchange-problems have profited from and prospered under its protectorate.

The technical possibilities to inject tremendous amounts of radioactive materials into the atmosphere and the occurence of artificial-radioactive elements in the geophysical sphere as a consequence of world-wide application of fission processes and effects of cosmic radiations have given new impulses to this close connection between radioactivity and geophysics. The progress and tremendous advances in this field and its impact on other areas of geophysics in the last decade surpass by far the experiences and information collected during the roughly 40 to 50 years of the "classical" period and have opened new avenues for geophysical research.

It has seemed timely, therefore, to attempt a summary statement on the role of natural, artificial, and man-made radioactivity—of nuclear radiations in the broadest sense of the word—in the geophysical area with the goal to sketch the essential features of our science, the principal directions of current inquiries and of future research.

The response to this plan of a review on "Nuclear Radiation in Geophysics" by the colleagues asked for their advice was so enthusiastic that each individual chapter of the survey could be presented by an expert in the proper field in his own style and his own words. Such an approach could be expected to lead to occasional overlapping, differences in presentation and in interpretation. However, in order to exhibit the dynamic of the whole project and to preserve the originality of the contributions this challenge was accepted, being sure that science is often "most stimulating and convincing, when it is least dogmatic". For the same reason also the two languages—German and English—were accepted; a short summary at the beginning of each chapter in the complementary language and a subject index in the two languages will facilitate the study of the book.

Also here we wish to acknowledge our deep appreciation to all coworkers for their interest, their efforts, their advice and criticism as well as for their patience in connection with some delay in the final formulation of the manuscript. Our sincere thanks are also due to the publisher for helpful understanding and generous support of our many wishes.

Christmas 1961

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Introduction

The tremendous advances of nuclear physics in the last three decades have provided new knowledge and new techniques which have found practical applications in substantially all fields of science and engineering.

The application of radioactive tracers and other nuclear techniques to problems in medicine and the life sciences has produced dramatic advances which affect the lives of nearly all of us. In a parallel manner the application of newer and improved nuclear methods to problems in the earth sciences is rapidly accelerating our acquisition of knowledge and understanding concerning the lithosphere, hydrosphere, atmosphere, and even space. This volume provides a welcome review of many of the newer findings, especially those of the last decade. It also focusses attention on some important problems in the earth sciences whose solutions are tasks for the future.

Reciprocally, we need to be on the alert for observations in the earth sciences which can contribute to the growth of our understanding of nuclear physics. The collaboration between the earth sciences and the nuclear sciences is a two-way street. Recall that the presently accepted value of the half-period of K^{40} (and hence part of our physical theory of highly forbidden β-ray transitions) is the result of reinvestigations which were directly stimulated by FRANCIS BIRCH's comments in 1947 on the geothermal implications of the heat which would have been generated by potassium in Pre-Cambrian times. The more classical examples are of course the discovery of the effects of radioactivity in rocks and minerals even before the discovery in 1896 of radioactivity, and hence before the birth of nuclear physics. These include the discovery by ROSENBUSCH in 1873 of pleochroic halos in mica (explained by JOHN JOLY in 1907 as α-ray damage from minute uranium inclusions) and the discovery through the work of HILLEBRAND in 1891, of RAMSEY and of LOCKYER in 1895 of the first known terrestrial helium in the uranium mineral cleveite (explained by RUTHERFORD and ROYDS' unequivocal identification of α-rays as a helium nuclei, about ten years later).

The extensive bibliographies which are in this book will prove especially valuable, even to veteran workers. This is because the literature in the earth sciences is widely scattered in many periodicals, in technical reports from various atomic energy agencies, in Congressional hearings, in Geneva Conference reports, and in reviews and symposia which have small circulations. The reader will find that much has been accomplished since the appearance in 1954 of the excellent text on *Nuclear Geology* edited by HENRY FAUL. To new workers in the earth sciences a word of warning is in order. Several of the chapters in the present book deal with advances in a given topic during only the last 10 to 15 years, due to page limitations. The earlier literature, some of which is important, will have to be searched out by consulting bibliographies given in the earliest papers which are discussed herein.

There was a marked quickening of the application of nuclear physics to the earth sciences in the 1930's. This was the outgrowth of the discovery in that decade of the neutron, of the positron, of deuterium, of induced radioactivity, and of nuclear fission, together with substantial improvements in instrumentation. It became clearly recognized in the 1930's that, at least in the oceans, the members of a decay series such as uranium, ionium, and radium are not in radioactive equilibrium. Subsequently the quantitative study of cases of "disequilibrium" has illuminated many problems in geochronology and in the study of such dynamic processes as sedimentation, biochemical effects, and oceanic circulation.

The 1940's saw the development of nuclear reactors and of nuclear bombs, with their greatly increased productivity of radioactive nuclides. These nuclides have provided the material for radioactive tracer observations of dynamic processes in the hydrosphere and atmosphere on a global scale. Public concern for an evaluation of the alleged health hazards of some of these radioactive nuclides has made substantial financing available for the study of their distribution, from the stratosphere to the oceanic depths.

The pace of research in the application of nuclear physics to the earth sciences has accelerated tremendously in the 1950's. Among the contributing factors which can be recognized are: (1) an increased scientific interest in geophysics, geochemistry, oceanography, meteorology, and space, (2) the practical problems of exploration for mineral deposits, especially for uranium and for petroleum, (3) the availability of radioactive tracers from tests of nuclear weapons and nuclear devices in the air, in the oceans, and underground, (4) the identification of a number of radioactive nuclides produced in meteorites, in the atmosphere, and in the lithosphere by cosmic rays, including H^3, Be^7, Be^{10}, C^{14}, Na^{22}, P^{32}, P^{33}, and S^{35}, (5) the substantial improvements in mass spectrometers and radiation detection instruments capable of quantifying these nuclides, such as NaI-γ-ray spectrometers and solid-state detector systems, and (6) money.

The earth scientist must beware of taking all quantitative physical and chemical results at face value. Subtle errors of sample selection, sample preparation, analysis, calibration, or interpretation can arise easily. The importance of interchecking results by measuring the same or similar samples in two or more laboratories, and if possible by two or more methods, cannot be overemphasized. It was, for example, a sobering experience when the first such interlaboratory comparisons were made on helium-age measurements and resulted in 1939 in lowering the helium-age scale to about one-half of its former value. The physical sciences and the earth sciences are complex and involve many subtleties. Scientific teams which include profound specialists in both areas usually produce results which involve minimum opportunity for errors in conception, execution, and interpretation.

As knowledge accumulates, the storage and retrieval of scientific information becomes a serious problem, especially in a widely diffused field. Like the nuclides which we study, there is a world-wide distribution of nuclear earth scientists, and at a small but increasing concentration. This book will contribute greatly to the retrieval of information which is currently in storage but which needed to be gathered for reexamination and for the guidance of future research.

October 1961

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