The New View of the Earth

Moving Continents and Moving Oceans

新しい地球観：動く大陸・動く大洋

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Preface

This book is a translation of the original Japanese edition *Atarashii Chikyukan (The New View of the Earth)*, published in 1972. For the English version, I have made extensive additions, in both the text and the illustrations, to incorporate still more recent developments in our current understanding of the earth, and I have omitted some material that did not seem relevant to readers outside of Japan.

A number of my friends contributed to the initial writing of the book: in particular, Dr. Hiroo Kanamori, Dr. Kazuaki Nakamura, Dr. Masashi Yasui, and my wife Mutsuko Uyeda all had valuable comments to make on the Japanese edition, and Sir Edward Bullard and Dr. Frank Press had additional suggestions for this one. Dr. Allan Cox has gone through the text with meticulous care, and greatly improved both its science and its language. Robert Geller and Seth Stein read the proofs and suggested a number of important changes that I have incorporated into the final book. I also thank my translator Mrs. Masako Ohnuki and my editor Michele Liapes for their painstaking efforts.

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Seiya Uyeda

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Introduction

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Rapid Progress Versus Eternal Questions

In recent years truly dramatic discoveries in scientific research have unfolded, and progress has accelerated at a stunning pace. One reason is the advent of the electronic computer, which enables us to compile enormous amounts of data into meaningful categories, so that the multitudes of observations can be applied to the development of significant and universal concepts. The current abundance of new ideas is evident in the succession of papers now being written. Of the modern sciences, the field of earth science is beginning to be the most rapidly advancing. In particular, that area concerned with the solid part of the earth has recently undergone phenomenal changes of the sort that occur only rarely in any one field. They are remarkable changes—of interest to the layman as well as to the scientist—and I shall describe them in the chapters that follow.

The rapid progress does not mean, however, that all the questions have been completely resolved. In fact, recently, while still writing this book, I recalled an article of the late 1940s enumerating six important unresolved questions that were important at the time. It was not until I contacted my old friend Keiiti Aki of the Massachusetts Institute of Technology, with whom I had read and discussed the article so many years ago when both of us as undergraduates were looking for problems to tackle, that I was able to locate it. He promptly forwarded a copy to me, thanking me for reminding him of the memorable piece. It was a lecture entitled "Some Unsolved Problems of Geophysics" by L. H. Adams (1947) the president of the American Geophysical Union, and the six problems were the following:

(1) the origin of the mountain chains;
(2) the origin of geosynclines (deep basins filled with sediments);
(3) the cause of volcanoes and other igneous activity;
(4) the cause of deep earthquakes;
(5) the origin of the earth's magnetic field;
(6) the temperatures prevailing in the interior of the earth.

Although these problems were not the *only* existing questions of importance, all six were indeed significant. Furthermore, none of them have yet been completely solved; all of them remain as important as ever. To be sure, some people may argue, "Look at how many of these problems we *have* solved!" But have we really? This issue is going to be one of the main themes of this book. Indeed, as any earth scientist will agree, these problems have been considered crucial not only since the 1940s, but for hundreds of years. The progress of earth science may not be as rapid as it seems after all.

Some Peculiarities of Earth Science

How is it that, despite the rapid progress, we have not answered many fundamental questions about the earth? The fact is that many basic problems of earth science defy answer by means of direct experiments. This poses considerable difficulties for us. Consider, for instance, the sixth of Adams' problems—the temperature of the earth's interior. It is simply not possible—at least at the present time—to *measure* the temperature at the center of the earth. One can merely deduce it indirectly from other evidence.

Then, continental drift and movements within the earth—the central topics of this book—are beset by similar difficulties. The mere penetration of the deep interior of the earth would itself be a difficult task, but the measurement of movements at great depth is beyond the capability of any known instrument or method because of the vast scale of the deep movements and their extreme slowness. Consequently it is very difficult for us to prove by direct observation the actual existence of such phenomena. Even if we can eventually detect the present movements of the continents in relation to one another by precise geodetic measurements of distances, using such instruments as a laser reflector on the surface of the moon, this will in no way prove that similar continental movements occurred in the remote geological past. The continental shifts, splits, and collisions that have occurred throughout the earth's history are once-in-a-lifetime phenomena; and the components involved in these movements have been too massive, and the period of time too vast, for reproduction in the laboratory.

These, then, are the problems that make the basic issues of earth science so difficult to resolve despite the new discoveries that have been made and the storehouse of information that is now accumulating. Indeed, they might lead us to wonder if research in such a field has any validity at all. The potential solution to a problem sometimes seems to become more elusive as research advances, so that the gap between them remains virtually unchanged. However progress *is* being made because our understanding of the scope and significance of the basic problems in earth science is becoming more profound. Perhaps we are not learning to ask better questions, but at least we are beginning to understand more clearly the meanings of our questions.

The difficulty of direct verification is a serious one in earth science, and almost inherent in the field. Yet advances in observation and theory justify more and more the use of indirect verification and bring us increasingly nearer to the truth.

The Uniqueness of Earth Science

Paradoxically, the fact that solutions to these problems have been hard to come by may have helped earth scientists. We have been obliged to examine and observe patiently many seemingly unrelated phenomena. These observations have led us to propose daring new hypotheses. Then, to prove them, we have had to seek additional and unshakable observations to support them, no matter how indirect such observations might be. The successful combination of the basic field work of earth science with the more abstract concepts of physics and chemistry has been a triumph that geologists savor. The unknown mechanisms—such as those responsible for the origin of the earth, for convection within the mantle, for the origin of the earth's magnetic field, and for deep-focus earthquakes—seem to offer a special challenge and appeal to the earth scientist. The approaches to this challenge vary widely, as do the intellectual tastes and motivations of individuals: for there are many types of people, and human wisdom is advanced by the efforts of all of them.

Insight

Scientific research includes various types of work. At least two processes are necessary—(1) the accumulation of data by experiment and observation, and (2) the analysis and theorization of that data. Many individual researchers tend to focus on one or the other of these processes, depending on their own inclinations. The modern age demands highly refined skills in any one aspect of the work, thereby creating niches for people who specialize in one of the following categories: experimentation, observation, analysis, or theory. Such specialization is unavoidable to a certain extent. A true researcher, however, should not allow himself to become immersed in one to the exclusion of the others. For example, it is possible for one to get so absorbed in taking measurements day and night, that he forgets to think. But if his work is to be really valuable, he must back his efforts by sound reasoning.

Indeed, good research requires a deep understanding of the scope of basic problems and a high degree of trained perception. Only too often superficial ideas and notions are mistaken for genuine creative thought. Although such ideas in themselves should not be discouraged, what the theoretician really needs is the special ability called *insight*—that capacity to select the genuinely promising idea from the others and to develop it into a theory or a set of predictions that can be experimentally verified. It is the most important quality a scientist can have.

The concepts treated in this book are the results of true scientific insight. It was insight that produced an important shift in our perspective of the earth—from a *fixist* view of an unchanging and stable body to a *mobilist* view of drifting land masses and ocean basins.

Outline of the Book

Throughout the book, general background in earth science will be provided for lay readers. In the first chapter we will discuss the history of the theory of continental drift, first introduced by Alfred Wegener. It was a theory that enjoyed temporary popularity after its introduction, followed by denunciation and rejection as an almost heretical idea. It then experienced a dramatic revival after World War II, owing to the introduction of paleomagnetism, which is the study of the history of the earth's magnetic field by means of the natural magnetization of rocks.

In the second chapter we will outline the findings in ocean floor geology that helped to revive the theory of continental drift. In this field, too, fantastic progress has been made since World War II, yielding an enormous amount of information that we could not have obtained from research limited to the land.

The theories of sea-floor spreading and plate tectonics will be outlined in the third and fourth chapters. The theory of sea-floor spreading is based on the idea that the ocean floor is created at the mid-oceanic ridges, spreads out horizontally, and disappears in the deep trenches. This theory was a remarkable synthesis of numerous independent data, and its dramatic success resulted in the even more fascinating concept of plate tectonics. Basically, the earth's surface is thought to consist of about 10 plate-like solid blocks, approximately 70 kilometers thick, which interact with one another. A further application of this concept to the past suggests that such interactions have been the primary cause of mountain building and other large-scale movements of the earth's crust throughout the earth's geologic history.

In Chapter 5 we shall examine island arcs from the new perspective of plate tectonics, using Japan as an example. The Japanese island arcs form part of a circum-Pacific belt of volcanoes, large earthquakes, deep trenches, and faults that are assumed to have been caused by the underthrusting of the floor of the Pacific Ocean beneath the Asian continent.

In the last chapter, we will describe the transition from the so-called fixist to the mobilist view of the earth, along with the possible driving mechanisms of plate tectonics.