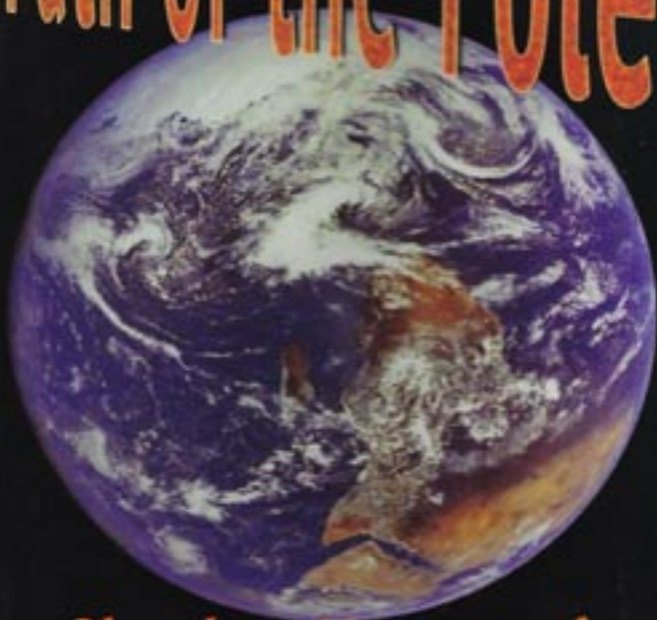


Path of the Pole



Charles Hapgood

Author of
Maps of the Ancient Sea Kings

Charles Hapgood
THE PATH OF THE POLE

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TO THE SPIRIT OF FREDERICK S. HAMMETT

Late Director, Cancer Research Center of the Lankenau Hospital of Philadelphia. A Pioneer in Science, a Champion of the Free Mind; An Artist in Intellectual Inquiry; A Fighter Against Those Blights of the Scientific Community: Smugness, Intolerance and Materialism.

Foreword

LIKE many people, I was introduced to *Earth's Shifting Crust* not by reading the original text nor through discussion in the technical journals, but through reading an abridged version in [*The Saturday Evening Post*](#). This was an unusual experience, to read something of scientific interest in a family magazine, but what I read was even more unusual. I found myself reading a reasonably plausible explanation—the first ever printed—of the major deformations that have racked the earth's crust. The abbreviated version so intrigued me that I acquired a copy of the complete work at the earliest opportunity. The full text proved to be even more stimulating than its abbreviated predecessor. That first edition of the book was introduced to the public, through its foreword, by the eminent scientist Albert Einstein. I must confess that this fact impressed me to a considerable degree. At the time it never occurred to me that I might be asked to present the second edition; in fact, this still strikes me as somewhat incongruous.

Perhaps at this point I should briefly introduce myself to the reader. I am a mining geologist and a passable mineralogist, engaged in recent years in teaching these subjects. Geology, like all branches of science, has become separated into a maze of specializations. The adherents of one specialization are certainly more than dimly aware of what is going on in other fields, but can hardly consider

themselves expert in any but their chosen field. I should not care to be accused of implying, through failure to admit the contrary, that I am a competent critic of Hapgood and Campbell's work. I most emphatically am not.

After carefully reading *Earth's Shifting Crust*, I began searching through the technical journals and other likely sources for the discerning criticism that I felt should be forthcoming from experts in the field. I should have known better than to expect it, I suppose, but hope springs eternal. A reaction came, of course, and largely it came from men who under ordinary circumstances are both rational and competent, but their reaction could hardly be described as rational; hysterical would be a better description. One observed, indignantly, that Hapgood was not a geologist. Admittedly this is a cardinal sin but hardly one punishable by scientific excommunication. Another cited, but failed to name, a scientist whose findings conflict with those of several world-renowned authorities selected by Hapgood as sources of technical data, and used this lack of agreement as an incontrovertible condemnation of the entire book.

I could continue with numerous examples, but this would be pointless. The fact is that almost without exception Americans commenting on the book couched their discussion in thick and unwarranted sarcasm, selecting trivia and factors not subject to verification as the bases for condemnation, seeking in this way to avoid the basic issues. Only the European reviewers were gracious enough to be fair, not that they accepted the theory without question, but they were prepared to offer it its day in court. Nowhere, in all that has been written about the book, have I found a single authority who has calmly and rationally offered a clear and documented criticism of the basic theory involved : that uncompensated masses on or in the earth may cause the earth's crust to slip over its core. Frankly, I wish someone would.

In the years since publication of the first edition of this work we have had, among other things, the benefit of the research of the International Geophysical Year. Incorporation of these and other data has had two extremely important effects upon Hapgood's theory: first to force a revision of the theory in relation to the mechanism of crustal displacement, and secondly to add tremendously to the weight of evidence supporting the thesis that crustal displacement has occurred. Regarding the first of these I believe that the author is to be congratulated for having the flexibility to adapt to new facts as they have become available. For the second, whereas there may have been a time when the occurrence of dislocations of the crust with respect to the earth's rotational poles could have been questioned, I personally feel that in the light of the data presented by Hapgood in this, the second edition of his book, such dislocations are no longer a matter of question.

Like many another engaged in teaching, I have grown weary of apologizing to my students for teaching time-worn theories whose logic, to use a kind word, is indefensible. The plain fact is that the logic of all previous theories of the earth's deformation is so obviously contrived, the holes are so gaping, that one is inclined to suspect that danger lurks there for the unwary. Now at last in Hapgood and Campbell's theory, actually a coalition of several older and poorly enunciated ideas, we find the first outwardly

reasonable explanation of the observed facts in several major geological fields. Now I ask—no, I implore—my colleagues, those most competent to assume the task, to attack this theory with the weapons of well-documented proof. Or, failing this, let them build upon it to a better, clearer understanding of the forces that have deformed this planet we live upon. Let us not bury this idea prematurely through prejudice, as so many valuable ideas of the past have been buried, only to be sheepishly exhumed in later years. If it is an unworthy thing let it be properly destroyed; if not, let it receive the nourishment that it deserves.

F.N. Earll
DEPARTMENT OF GEOLOGY
Montana College of Mineral Science and Technology

*The Mather and Einstein Forewords
to the First Edition*

THE most significant change in this book since Albert Einstein wrote his Foreword for the American edition and Professor Kirtley Mather wrote one for the British, Spanish, and Italian editions is directly related to the question on which they both expressed their strongest doubts : the ice-cap "mechanism" by which I proposed to account for displacements of the earth's outer shell. Their doubts have been vindicated by the progress of earth studies in the past decade. Advancing knowledge of conditions of the earth's crust now suggests that the forces responsible for shifts of the crust lie at some depth within the earth rather than on its surface.

Despite this change in the character of the proposed explanation of the movements, the evidence for the shifts themselves has been multiplied many fold in the past decade. The main themes of the book—the occurrence of the crust displacements even very recently in geological history, and their effects in forming the features of the earth's surface—therefore remain unchanged.

The Author

Foreword to the First Edition
British, Spanish, and Italian versions
by Kirtley F. Mather
Professor of Geology, Emeritus,
Harvard University; former president,
The American Association for the Advancement of Science

THE idea that the history of the earth involves the shifting of its thin "crust" from time to time and place to place is certain to receive increased attention in the next few years. Knowledge is rapidly accumulating concerning the spatial relations of the crust and the underlying "mantle." Information regarding the physical properties of these parts of the stratiform planet is being secured by geophysicists. Many specific facts are now available concerning local changes of level and of geographic position of points on the earth's surface. The geologic records of the past are replete with items that suggest significant differences between the latitude and longitude of many places in earlier epochs and those of the present time.

The need is clearly apparent for a synthesis of all these many data that would integrate them in a broadly inclusive scheme and give them unified meaning in relation to a general principle. In geology, indeed in all scientific disciplines, analysis must lead to synthesis which in turn must be followed by further analytical studies in the repetitive cycles of advancing knowledge and understanding. This is evidently the aim of this thought-provoking book. Its greatest value will be found in the stimulus it should give to discussion, debate and controversial argument.

The concept of crustal shifting as an important and frequently repeated episode in earth history is not new. But the marshaling of data from many diverse fields of study and their interpretation in causal terms are sufficiently novel to make the authors' ideas worthy of careful study and appraisal. Indeed, certain aspects of their application of the general concept are radically new and will undoubtedly lead to healthy controversy. I cannot, for example, accept as valid certain interpretations made by the authors of some of the facts they cite, but these are minor matters and do not necessarily invalidate their major argument. My own confidence in the principle of isostasy leads me moreover to discount the computation of tangential forces resulting from "off-center" ice caps, but this is certainly a matter for further study. The results of geophysical research must accord with the facts of earth history if they are to be accepted as completely trustworthy.

All of which means that the authors of this novel interpretation of crustal movements have made a distinctive contribution to geological lore which should be of interest to all geologists. The numerous unsolved problems to which Mr. Hapgood directs attention should be the subjects of intensified debate among scientists in every part of the world. It should moreover be noted that this book is

written in clear, nontechnical language. Mr. Hapgood has succeeded in bringing the thought within the reach of every educated layman. It is a readable survey of geological problems that too long have been the province of specialists alone.

Kirtley F. Mather
July 1, 1959

Foreword to the First Edition
by Albert Einstein

I FREQUENTLY receive communications from people who wish to consult me concerning their unpublished ideas. It goes without saying that these ideas are very seldom possessed of scientific validity. The very first communication, however, that I received from Mr. Hapgood electrified me. His idea is original, of great simplicity, and—if it continues to prove itself—of great importance to everything that is related to the history of the earth's surface.

A great many empirical data indicate that at each point on the earth's surface that has been carefully studied, many climatic changes have taken place, apparently quite suddenly. This, according to Hapgood, is explicable if the virtually rigid outer crust of the earth undergoes, from time to time, extensive displacement over the viscous, plastic, possibly fluid inner layers. Such displacements may take place as the consequence of comparatively slight forces exerted on the crust, derived from the earth's momentum of rotation, which in turn will tend to alter the axis of rotation of the earth's crust.

In a polar region there is continual deposition of ice, which is not symmetrically distributed about the pole. The earth's rotation acts on these unsymmetrically deposited masses, and produces centrifugal momentum that is transmitted to the rigid crust of the earth. The constantly increasing centrifugal momentum produced in this way will, when it has reached a certain point, produce a movement of the earth's crust over the rest of the earth's body, and this will displace the polar regions toward the equator.

Without a doubt the earth's crust is strong enough not to give way proportionately as the ice is deposited. The only doubtful assumption is that the earth's crust can be moved easily enough over the inner layers.

The author has not confined himself to a simple presentation of this idea. He has also set forth, cautiously and comprehensively, the extraordinarily rich material that supports his displacement theory. I think that this rather astonishing, even fascinating, idea deserves the serious attention of anyone who concerns himself with the theory of the earth's development.

To close with an observation that has occurred to me while writing these lines: If the earth's crust is really so easily displaced over its substratum as this theory requires, then the rigid masses near the earth's surface must be distributed in such a way that they give rise to no other considerable centrifugal momentum, which would tend to displace the crust by centrifugal effect. I think that this deduction might be capable of verification, at least approximately. This centrifugal momentum should in any case be smaller than that produced by the masses of deposited ice.

AUTHOR'S NOTE

Until a decade ago the idea that the poles had often changed their positions on the earth's surface was regarded as extreme, improbable, and unsound. It was advocated strictly by cranks. Nobody who was anybody in the scientific world would have anything to do with it.

Fashions change. Today every other book dealing with the earth sciences devotes space to polar wandering and continental drift.

Polar wandering is based on the idea that the outer shell of the earth shifts about from time to time, moving some continents toward and others away from the poles, changing their climates. Continental drift is based on the idea that the continents move individually.

Many scientists have come to the point of accepting both these ideas. The evidence on hand now seems to them to require that the earth's surface has shifted as a whole and that continents have also changed their positions relative to one another.

Up to the present those who have accepted both ideas have not connected them. They think of them as independent processes acting simultaneously. A few writers have suggested that perhaps continental drift causes polar wandering.

This book advances the notion that polar wandering is primary and causes the displacement of continents.

Those geologists who have accepted polar wandering and continental drift, or only continental drift, put the last such change at a long time ago.

This book will present evidence that the last shift of the earth's crust (the lithosphere) took place in recent time, at the close of the last ice age, and that it was the cause of the improvement in climate.

Two kinds of evidence are responsible for these changing ideas. New knowledge of geomagnetism, or the polarization of rocks of the earth's crust by the earth's magnetic field, has led to the discovery that the poles have changed their places on the surface of the earth at least 200 times since geological history began. There is little doubt now but that when we have the complete list it will be twice as long, or even longer.

The other new body of knowledge has come from new methods of dating events in the past by the use of radioactive isotopes of a number of elements. An isotope of carbon (C^{14} , called radiocarbon) has enabled us to find reliable dates for geological events back to about 65,000 years ago. Isotopes of other elements are good for dating events two or three hundred thousand years in the past. Still others date rocks hundreds of millions of years old.

With these radioactive dating methods it has been possible to reconstruct the climatic history of the earth in great detail for the last hundred thousand years. That is what I shall try to do in this book.

Some of the results of the chronology of the glacial epoch worked out here are surprising. For example, I have found evidence of three different positions of the North Pole in recent time. During the last glaciation in North America the pole appears to have stood in Hudson Bay, approximately in Latitude 60° North and Longitude 83° West. It seems to have shifted to its present site in the middle of the Arctic Ocean in a gradual motion that began 18,000 or 17,000 years ago and was completed by about 12,000 years ago.

The radioactive dating methods further suggest that the pole came to Hudson Bay about 50,000 years ago, having been located before that time in the Greenland Sea, approximately in Latitude 73° North and Longitude 10° East. Thirty thousand years earlier the pole may have been in the Yukon District of Canada.

These ideas are new, and they will at first seem strange, but if the reader will plow through the necessary factual detail presented in this book, he may find sufficient proof.

Acknowledgments

WHEN it comes time to write an acknowledgment of the assistance received from others in the preparation of a book, this job is sometimes accomplished in a perfunctory way; it is a job to be got over with but, at the same time, turned to advantage. I do not think that this is fair to the essentially social nature of science. The implication is usually obvious that the book is, in fact, the work of one or two perspiring and inspired persons, who, by themselves alone, have persevered against odds to complete an imperishable product. This distorts the process by which scientific and, indeed, all original work is done. Scientific research is essentially and profoundly social. Discoveries are not the product of single great minds illuminating the darkness where ordinary people dwell; rather, the eminent individuals of science have had many predecessors; they themselves have been merely the final organizers of materials prepared by others. The raw materials, the component elements that have made these great achievements possible, have been contributed by hundreds or thousands of people. Every step in the making of this book has been the result of contact with other minds. The work done by hundreds of writers over a number of centuries has been exploited, and the contributions of contemporary writers have been carefully examined. The product represents, I should like to think, a synthesis of thought; at the same time I hope its original elements will prove valid additions to the common stock of knowledge in the field.

Credit for the initiation of the research that led to this book belongs, in the first instance, to students in my classes at Springfield College, in Springfield, Massachusetts. A question asked me by Henry Warrington, a freshman, in 1949 stimulated me to challenge the accepted view that the earth's surface has always been subject only to very gradual change, and that the poles have always been situated precisely where they are today. As the inquiry grew, many students made valuable contributions to it in research papers. Among these I may name, in addition to Warrington, William Lammers, Frank Kenison, Robert van Camp, Walter Dobrolet, and William Archer.

Our inquiry first took organized form as an investigation of the ideas of Hugh Auchincloss Brown, and I am deeply indebted to him for his original sensational suggestion that ice caps may have frequently capsized the earth, for many suggestions for research that proved to be productive, for his generosity in sharing all his research data with us, and for his patience in answering innumerable letters.

In this early stage of our inquiry, when I was in every sense an amateur in many fields into which the inquiry led me, I received invaluable assistance from many specialists. These included several members of the faculty of Springfield College, especially Professor Errol Buker, without whose kindly sympathy our inquiry would have been choked in its infancy. Assistance with many serious problems was received from Dr. Harlow Shapley, of the Harvard Observatory, Dr. Dirk Brouwer, of the Yale Observatory, Dr. G.M. Clemence, of the Naval Observatory, and a number of distinguished specialists of the United States Coast and Geodetic Survey.

Our inquiry, in its third year, was involved in a difficulty that appeared to be insuperable, and from this dilemma it was rescued by an inspired suggestion made by my old friend the late James Hunter Campbell, who thereafter became my constant associate in the research project, and my collaborator. I must give credit to him for having taken hold of a project that was still an amateur inquiry, and transformed it into a solid scientific project.

When Mr. Campbell had developed his ideas far enough to assure us that the idea we had in mind was essentially sound, it became feasible to submit the results of our joint efforts to Albert Einstein, and we found him, from then on, a most sympathetic and helpful friend. Throughout an extended correspondence, and in personal conference, his observations either corroborated our findings or pointed out problems that we should attempt to solve. With regard to our inquiry, Einstein made an exception to his usual policy, which was to give his reactions to new ideas submitted to him, but not to offer his suggestions for their further development. In our case, with an uncanny sense, he put his finger directly upon problems that were, or were to be, most baffling to us. We had the feeling that he deeply understood what we were trying to do, and desired to help us. Our association with him represented an experience of the spirit as well as of the mind.

In the later stages of our inquiry, many distinguished specialists and friends helped us with particular problems. Suggestions were contributed by Professor Frank C. Hibben, of the University of New Mexico, Professor P.W. Bridgman, of Harvard, Dr. John M. Frankland, of the Bureau of Standards, Dr. George Sarton, Professors Walter Bucher and Marshall Kay of Columbia University, Dr. John Anthony Scott, Mrs. Mary G. Grand, Mr. Walter Breen, Mr. Stanley Rowe, Dr. Leo Roberts, Mr. Ralph Barton Perry, Jr., Mrs. Mary Heaton Vorse; Mr. Heaton Verse, Mr. Chauncey Hackett, Mrs. Helen Bishop, and Mrs. A. Hyatt Verrill. To Dr. Harold Anthony, of the American Museum of Natural History, our debt is enormous. It was he who afforded Mr. Campbell and me our first opportunity to discuss our theories with a group of specialists in the earth sciences, when he invited us to talk to the Discussion Group of the Museum. In addition, Doctor Anthony has helpfully criticized parts of the manuscript and has helped me to get criticism from other experts. Captain Charles Mayo, of Provincetown, Massachusetts, in many long discussions over the years, has contributed innumerable valuable suggestions.

One farsighted scientist without whose generous help this book in its present form would have been impossible is David B. Ericson, marine geologist of the Lamont Geological Observatory. He has contributed many vitally important bibliographical suggestions, has corrected numerous technical errors, and has provided needed moral support. I am equally indebted to Professor Barry Commoner, of Washington University, who not only read the manuscript to suggest improvements of content and style but also helped me in the preparation of special articles for publication in the technical journals. Mr. Norman A. Jacobs, editor of the *Yale Scientific Magazine*, published the first of these articles.

During the last year I have received enormous assistance from Mr. Ivan T. Sanderson, who, as a biologist, has read the manuscript with a critical eye for misuse of technical vocabulary and for weaknesses in presentation. I have received invaluable help from Professor J.C. Brice, of Washington University, who has criticized the whole manuscript from a geological standpoint. I am deeply indebted to my aunt, Mrs. Norman Hapgood, for the first complete translation from the Russian of the report of the Imperial Academy of Sciences on the stomach contents of the Beresovka Mammoth, to Mrs. Ilse Politzer for the translation from the German of Einstein's letter of May 3, 1953, and to Mrs. Maely Dufty for assistance with the translation of his foreword into English. To many personal friends, in addition to those mentioned, I owe thanks for encouragement and for suggestions that often turned out to have major importance. I am indebted to John Langley Howard for his assistance with the illustration of this book, to Mr. Coburn Gilman, my editor, for his innumerable constructive suggestions and his understanding spirit, to Mr. Stanley Abrons for his painstaking work in preparing the glossary, and to Mr. Walter Breen for preparing the index.

In the final typing of the manuscript Miss Eileen Sullivan has had to encounter and survive difficulties and frustrations that only she and I can have an idea of. I am very grateful for her help.

Grateful thanks are extended to all publishers and individuals who have consented to the use of selections or illustrations, and in particular to the following : Columbia University press, for quotations from George Gaylord Simpson, *Major Features of Evolution*; Thomas Y. Crowell Co., for a passage from Frank C. Hibben, *The Lost Americans*; Dover Publications, Inc., for quotations from Beno Gutenberg, *Internal Constitution of the Earth* (paperbound, \$2.45); W.H. Freeman & Co., for quotations from Krumbein and Sloss, *Stratigraphy and Sedimentation*; Alfred A. Knopf, Inc., for quotations from Hans Cloos, *Conversations With the Earth*; N.V. Martinus Nijhoff's *Boekhandel en Uitgeversmaatschappij*, The Hague, for quotations from J.H.F. Umbgrove, *The Pulse of the Earth*; Prentice-Hall, Inc., for quotations from R.A. Daly, *The Strength and Structure of the Earth*; *Science*, for quotations from various issues of this magazine; William Sloane Associates, Inc., for quotations from Thomas R. Henry, *The White Continent* (Copyright 1950 by Thomas R. Henry); University of Chicago Press, for quotations from various issues of the *Journal of Geology*.

Charles H. Hapgood
Keene Teachers College
OCTOBER, 1957.

In the new, revised edition of EARTH'S SHIFTING CRUST under the title *The Path of the Pole* I am especially indebted to Mr. Oppé and Mr. Delair for the great contribution they have made in researching the difficult field of Pleistocene history in South America, and to

Fred Earll for his foreword, to say nothing of his helpful advice in preparing this edition. I should also thank those hundreds of research workers who have, by their efforts in geophysical research and in the extension of our knowledge of the past through the new techniques of absolute dating, made possible my own work.

C.H.

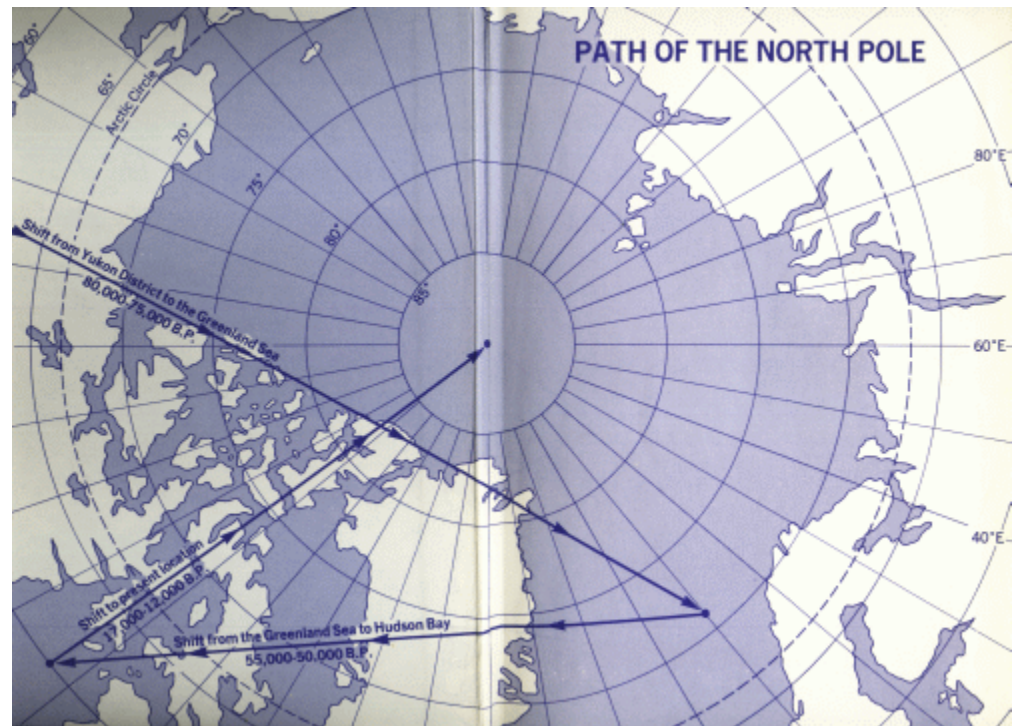
August, 1970

Charles Hapgood
The Path of the Pole

[previous](#)

14. Is the Pole Moving Now ?

Two rather curious pieces of evidence suggest that the lithosphere may be in motion at the present time. We have two observations of a movement of the North Pole with reference to the earth's surface. The first of these is cited by Deutsch (111a:37-38) on the authority of Munk and MacDonald. It suggests that the North Pole moved 10 feet in the direction of Greenland along the meridian of 45° West Longitude during the period from 1900 to 1960. This (according to Deutsch) would be at a rate of 6 centimeters (about two and a half inches) a year. The other finding, cited by Markowitz (292a), based on later data, suggests that the pole moved about 20 feet between 1900 and 1968 along the meridian of 65° West Long., and that it is now moving at the rate of about 10 centimeters (4 inches) a year. The difference between the two longitudes may not be particularly important, as the angular difference so near the pole is so small, but the difference in the two rates of motion may be very important. In the first place, it may be noted that a speed of 10 centimeters a year is two or three times the maximum speed usually estimated for subcrustal convection currents. This appears to imply that the displacement indicated as now occurring is not powered by convection currents. There is the suggestion of another mechanism at work.



A second point, possibly even more interesting, is that if both these observations were accurate when made, as we have every right to expect (in view of the eminence of the scientists involved), then we may have here evidence of a geometrical acceleration of the rate of motion. If the pole moved 10 feet between 1900 and 1960, but 20 feet between 1900 and 1968, then it moved 10 feet between 1960 and 1968, which would suggest an acceleration by a factor of about 8. The mechanism I have suggested above is based on a formula involving the geometrical progression of centrifugal effects, that is, the formula for calculating centrifugal force, which is a simple one (see p. 338).

chapter 2

THE FAILURE TO EXPLAIN THE ICE AGES

The evidence for displacements of the earth's outer shell is scattered over many parts of the earth and comes from several fields of science. It would not be justifiable to disregard this other evidence simply because the evidence from geomagnetism seems so strong. No other field furnishes so dramatic a confirmation of displacements as glacial geology. Here we review the facts that have led geologists, at various times during the last hundred years, to consider ideas of polar shift.

1. The Failure of the Older Theories

A little more than a hundred years ago people were astonished at the suggestion that great ice sheets, as much as a mile thick, had once lain over the temperate lands of North America and Europe. Many ridiculed the idea, as happens with new ideas in every age, and sought to discredit the evidence produced in favor of it. Eventually the facts were established regarding an ice age in Europe and in North America. People later accepted the idea of not one but a series of ice ages. As time went on evidences were found of ice ages on all the continents, even in the tropics. It was found that ice sheets had once covered vast areas of tropical India and equatorial Africa.

From the beginning, geologists devoted much attention to the possible cause of such great changes in the climate. One theory after another was proposed, but, as the information available gradually increased, each theory was found to be in conflict with the facts, and as a consequence had to be discarded. In 1929, Coleman, one of the leading authorities on the ice ages, wrote :

Scores of methods of accounting for ice ages have been proposed, and probably no other geological problem has been so seriously discussed, not only by glaciologists, but by meteorologists and biologists : yet no theory is generally accepted. The opinions of those who have written on the subject are hopelessly in contradiction with one another, and good authorities are arrayed on opposite sides ... (87:246).

Recent writers, such as Daly (98:257), Umbgrove (419:285), and Gutenberg (194:205), agree that the situation described by Coleman is essentially unchanged. In January, 1953, Professor J.K. Charlesworth, of Queen's University, Belfast, expressed the opinion that

The cause of all these changes, one of the greatest riddles in geological history, remains unsolved; despite the endeavors of generations of astronomers, biologists, geologists, meteorologists and physicists, it still eludes us (75:3).

A volume on climatic change, edited by Dr. Harlow Shapley (375), while suggesting minor refinements for various older theories, proposes no new ones and in no way modifies the general effect, which is that down to the present time the theorizing about the causes of ice ages has led nowhere.

2. The Misplaced Ice Caps

One problem that writers on the ice ages have attempted to solve, sometimes in rather fantastic ways, but without success, is that of the wrong location of the great ice caps of the past. These ice caps have refused to have anything to do with the polar areas of the present day, except in a quite incidental fashion.

Originally it was thought that in glacial periods the ice caps would fan out from the poles, but then it appeared that none of them did so, except the ones that have existed in Antarctica. Coleman drew attention to the essential facts, as follows :

In early times it was supposed that during the glacial period a vast ice cap radiated from the North Pole, extending varying distances southward over seas and continents. It was presently found, however, that some northern countries were never covered by ice, and that in reality there were several more or less distinct ice sheets starting from local centers, and expanding in all directions, north as well as east and west and south. It was found, too, that these ice sheets were distributed in what seemed a capricious manner. Siberia,

now including some of the coldest parts of the world, was not covered, and the same was true of most of Alaska, and the Yukon Territory in Canada; while northern Europe, with its relatively mild climate, was buried under ice as far south as London and Berlin; and most of Canada and the United States were covered, the ice reaching as far south as Cincinnati in the Mississippi Valley (87:7-9).

With regard to an earlier age (the Permo-Carboniferous), Coleman emphasized that the locations of the ice caps were even further out of line :

Unless the continents have shifted their positions since that time, the Permo-Carboniferous glaciation occurred chiefly in what is now the southern temperate zone, and did not reach the arctic regions at all (87:90).

He is much upset by the fact that this ice age apparently did not affect Europe :

Unless European geologists have overlooked evidence of glaciation at the end of the Carboniferous or at the beginning of the Permian, the continent escaped the worst of the glaciation that had such overwhelming effects on other parts of the world. A reason for this exemption is not easily found (87:96).

One of the most extraordinary cases is that of the great ice sheet that covered most of India in this period. Geologists are able to tell from a careful study of the glacial evidences in what direction an ice sheet moved, and in this case the ice sheet moved northward from an ice center in southern India for a distance of 1,100 miles. Coleman comments on this as follows :

Now, an ice sheet on level ground, as it seems to have been in India, must necessarily extend in all directions, since it is not the slope of the surface it rests on that sets it in motion, but the thickness of the ice towards the central parts. ...

The Indian ice sheet should push southward as well as northward. Did it really push as far to the south of Lat. 17° as to the north ? It extended 1,100 miles to the Salt Range in the north. If it extended the same distance to the south it would reach the equator (87:110-11).

The great South African geologist A.L. du Toit pointed out that the ice caps of all geological periods in the Southern Hemisphere were eccentric as regards the South Pole, just as the Pleistocene ice caps were eccentric with regard to the North Pole (87:262). Is it not extraordinary that the Antarctic ice cap, which we can actually see because it now exists, is the only one of all these ice caps that is found in the polar zone ?

Coleman, who did a great deal of field work in Africa and India, studying the evidences of the ice ages there, writes interestingly of his experiences in finding the signs of intense cold in areas where he had to toil in the blazing heat of the tropical sun :

On a hot evening in early winter two and a half degrees within the torrid zone amid tropical surroundings it was very hard to imagine the region as covered for thousands of years with thousands of feet of ice. The contrast of the present with the past was astounding, and it was easy to see why some of the early geologists fought so long against the idea of glaciation in India at the end of the Carboniferous (87:108).

Some hours of scrambling and hammering under the intense African sun, in lat. $27^{\circ} 5'$, without a drop of water, while collecting striated stones and a slab of polished floor of slate, provided a most impressive contrast between the present and the past, for though August 27th is still early Spring, the heat is fully equal to that of a sunny August day in North America. The dry, wilting glare and perspiration made the thought of an ice sheet thousands of feet thick at that very spot most incredible, but most alluring (87:124).

When these facts were established, geologists sought to explain them by assuming that, at periods when these areas were glaciated, they were elevated much higher above sea level than they are now.

Theoretically, even an area near the equator, if elevated several miles above sea level, would be cold enough for an ice sheet. What made the theory plausible was the well-known fact that the elevations of all the lands of the globe have changed repeatedly and drastically during the course of geological history. Unfortunately for those who tried to explain the misplaced ice caps in this way, however, Coleman showed that they reached sea level, within the tropics, on three continents: Asia, Africa, and Australia (87:129, 134, 140, 168, 183). At the same time, W.J. Humphreys, in his examination of the meteorological factors of glaciation, made the point that high elevation means less moisture in the air, as well as lowered temperature, and is therefore unfavorable for the accumulation of great ice caps (231:612-13).

3. Worldwide Phases of Cold Weather

A widely accepted assumption with which contemporary geologists approach the question of ice ages is that the latter have occurred as the result of a lowering of the average temperature of the whole surface of the earth at the same time. This assumption has forced them to look for causes of glacial periods only in such factors as would tend to cool the whole surface of the earth at once. It has resulted in the assumption that glacial periods have always been simultaneous in the northern and southern hemispheres.

It is remarkable that this assumption has been maintained over a long period of time despite the fact that it is in sharp conflict with basic principles of physics in the field of meteorology. The basic conflict was brought to the attention of science at least seventy years ago; it has never been resolved. It consists essentially of the fact that glacial periods were periods of heavier rainfall in areas outside the regions of the ice sheets, so that this, together with the deep accumulations of ice in the great ice sheets, apparently must have involved a higher average rate of precipitation during ice ages. There is a great deal of geological evidence in support of this. Only recently, for example, Davies has discussed the so-called “pluvial” periods in Africa and has correlated them with the Pleistocene glacial periods (107).

Now, meteorologists point out that if precipitation is to be increased, there has to be a greater supply of moisture in the air. The only possible way of increasing the amount of moisture in the air is to raise the temperature of the air. It would seem, therefore, that to get an ice age one would have to raise, rather than lower, the average temperature. This essential fact of physics was pointed out as long ago as 1892 by Sir Robert Ball, who quoted an earlier remark by Tyndall :

... Professor Tyndall has remarked that the heat that would be required to evaporate enough water to form a glacier would be sufficient to fuse and transform into glowing molten liquid a stream of cast iron five times as heavy as the glacier itself (20:108).

William Lee Stokes has again called attention to this unsolved problem in an article entitled “Another Look at the Ice Age” in a statement that strongly suggests crust displacement :

Lowering temperatures and increased precipitation are considered to have existed side by side on a world-wide scale and over a long period in apparent defiance of sound climatological theory. Among the many quotations that could be cited reflecting the need for a more comprehensive explanation of this difficulty the following seems typical.

“In the Arequipa region [of Peru], as in many others in both hemi-spheres where Pleistocene conditions have been studied, this period appears to have been characterized by increased precipitation as well as lowered temperatures. If, however, precipitation was then greater over certain areas of the earth’s surface than it is at present, a corollary seems to be implied that over other large areas evaporation was greater than normal to supply increased precipitation, and hence in these latter areas the climate was warmer than normal. This seems at first to be an astonishing conclusion. ... We might propose the hypothesis that climatic conditions were far from steady in any one area, but were subject to large shifts, and that intervals of ameliorated conditions in some regions coincided with increased severity in others. The Pleistocene, then, may have been a period of sharper contrasts of climate and of shifting climates rather than a period of greater cold” (i95:815-16).

From a number of points of view, the foregoing passage is extremely remarkable. Stokes recognizes the fact that the basic assumption of contemporary geologists regarding the glacial periods is in conflict with the laws of physics. Then, in the passage he quotes, he draws attention to the implications, which if the theory of continental drift is rejected seem to point directly to crust displacement, for in what other way can we explain how one part of the earth's surface was colder and another, at the same time, warmer than at present ?

One of the arguments that are advanced in support of the assumption of worldwide periods of colder weather (which remains the generally accepted assumption of glaciologists) has its basis in geological evidence purporting to prove that ice ages occurred simultaneously in both hemispheres. A decade ago, however, Kroeber pointed to the essential weakness of this geological evidence when he showed the difficulty of correlating stratified deposits of different areas :

... There is plenty of geologic evidence, in many parts of the earth, of changes of climates, especially between wet and dry areas; and some of these happened in the Pleistocene. But the correlation of such changes as they occurred in widely separated regions, and especially as between permanently ice-free and glaciated areas, is an intricate, tricky, and highly technical matter, on which the anthropological student must take the word of geologists and climatologists, and these are by no means in agreement. They may be reasonably sure of one series of climatic successions in one region, and of another in a second or third region; but there may be little direct evidence on the correspondence of the several series of regional stages, the identification of which then remains speculative (257:650).

At the time that Kroeber remarked on the difficulty of correlating climatic changes in different parts of the world, we were not yet in possession of the data recently provided by the new techniques of radiocarbon and ionium dating. The effect of these new data has been to shorten very greatly our estimate of the duration of the last North American ice age. This estimate has been reduced, in the last few years, from about 150,000 years to about 50,000 years. Now, if we adopt the view that ancient glaciations, of which we know little, may reasonably be considered to have been the results of the same causes that brought about the North American ice age, then we must grant that they, too, may have been of short duration. But if this is true, how is it possible to establish the fact that they were contemporary in the two hemispheres ? A geological period has a duration of millions of years. An ice age in Europe and one in Australia might both be, for example, of Eocene age, but the Eocene Epoch is estimated to have lasted about 15,000,000 years. We can discriminate roughly between strata dating from the early, middle, or late Eocene, but we have no way of pinpointing the date of any event in the Eocene. Even with the new techniques of radiodating now being applied to the older rocks, it is possible to determine dates only to within a margin of error of about a million years. How, then, is it possible to determine that an ice sheet in one hemisphere was really contemporary with an ice sheet or an ice age in the other ?

The attempt to maintain the assumption of the simultaneousness of glaciations for the older geological periods is unreasonable. I shall show in what follows that it cannot be established even for recent geological time. It is my impression that the material evidence for the assumption was never impressive, and that the assumption was never derived empirically from the evidence but was borrowed a priori from the parent assumption; that is, the assumption of the lowering of global temperatures during ice ages, an assumption which is, as already pointed out, in conflict with the laws of physics.

If it is true that the fundamental assumption underlying most of the theories produced to explain ice ages is in error, we should expect that these theories, despite their many differences, would have a common quality of futility, and so it turns out. It is interesting to list the kinds of hypothetical causes that have been suggested to explain ice ages on the assumption of a worldwide lowering of temperature. They are as follows :

- a. Variations in the quantity of particle emission and of the radiant beat given off by the sun.
- b. Interception of part of the sun's radiation by clouds of interstellar gas or dust.
- c. Variations in the heat of space; that is, the temperature of particles floating in space which, entering the earth's atmosphere, might affect its temperature.
- d. Variations in the quantities of dust particles in the atmosphere. from volcanic eruptions or other causes, or variations in the proportion of carbon dioxide in the atmosphere.

There are serious objections to all these suggestions. So far as the variation of the sun's radiation is concerned, it is known that it varies slightly over short periods, but there is no evidence that it has ever varied enough, or for a long enough time, to cause an ice age. Evidence for the second and third suggestions is entirely lacking. The fourth suggestion is deprived of value because, on the one hand, no causes can be suggested for long-term changes in the number of eruptions or in the atmospheric proportion of carbon dioxide, and, on the other, there is insufficient evidence to show that the changes ever occurred.

I should make one reservation with regard to the fourth suggestion. There is at least one event that would provide an adequate cause for an increase in the atmosphere of both volcanic dust and carbon dioxide, and that is a displacement of the crust. The extremely far-reaching consequences of a displacement of the crust with respect to atmospheric conditions, and the importance of the atmospheric effects of a displacement for other questions, will be discussed in Chapter IX.

The theories listed above were attacked by Coleman, who complained that they were entirely intangible and unprovable. He said :

Such vague and accidental causes for climatic change should be appealed to only as a last resort unless positive proof some time becomes available showing that an event of the kind actually took place (87:282).

Another group of theories attempts to explain ice ages as the results of changes in the relative positions of the earth and the sun. These are of two kinds: changes in the distance between the earth and the sun at particular times because of changes in the shape of the earth's orbit, and changes in the angle of inclination of the earth's axis, which occur regularly as the result of precession. The argument that precession was the cause of ice ages was advanced by Drayson in the last century (117). The argument based on these astronomical changes has been brought up to date in the recent work of Brouwer and Van Woerkom (375:147-58) and Emiliani (132). It now seems that these astronomical changes may produce cyclical changes in the distribution of the sun's heat, and perhaps in the amount of the sun's heat retained by the earth, but it is agreed, by Emiliani and others, that by itself the insolation curve or net temperature difference would not be sufficient to cause an ice age without the operation of other factors, and so Emiliani suggests that perhaps changes in elevation coinciding with the cool phases of the insolation curve may have caused the Pleistocene ice ages. One weakness of this suggestion is, of course, the necessity to suppose the accidental combination of two independent causes for ice ages.

There is another objection to be advanced against all theories supposing a general fall of world temperatures during the ice ages. We have seen that ice ages existed in the tropics and that great ice caps covered vast areas on and near the equator. This happened not once but several times. The question is, if the temperature of the whole earth fell enough to permit ice sheets a mile thick to develop on the equator, just where did the fauna and flora go for refuge? How did they survive? How did the reef corals, which require a minimum seawater temperature of 68° F. throughout the year, manage to survive? We know that the reef corals, for example, existed long before the period of the tropical ice sheets. Furthermore we know that the great forests of the Carboniferous Period, which gave us most of our coal, lived both earlier than and contemporarily with the glaciations of Africa and India, though in different places. Obviously this would have been impossible if the temperature of the whole earth had been simultaneously reduced, for the equatorial zone itself would have been uninhabitable, while all other areas were still colder. It is small wonder that W.B. Wright insisted, over a quarter of a century ago, that the Permo-Carboniferous ice sheets in Africa and India were proof of a shift of the poles (450).

4. The New Evidence of Radiocarbon Dating

The question of the causes of ice ages has been given increased importance by a recent revolution in our methods of dating geological events. In the course of the last twenty years all of our ideas regarding the chronology of the recent ice ages, their durations, and the speed of growth and disappearance of the great ice sheets have been transformed. This is altogether the most important new development in the sciences of the earth. The repercussions in many directions are most remarkable.

In order to get an idea of the extent of the change, let us see what the situation was only ten or fifteen years ago. As everybody is aware, geologists are used to thinking in terms of millions of years. To a geologist a period of 1,000,000 years has come to mean almost nothing at all. He is actually used to thinking that events that took place somewhere within the same 20,000,000-year period were roughly contemporaneous. As to the ice ages, the older ones were simply thrown into one of these long geological periods, but there was no way to determine their durations (except very roughly), their speeds of development, or precisely when they happened. It was convenient to assume that they had endured for hundreds of thousands or for millions of years, though no real evidence of this existed.

So far as the most recent division of geologic time, the Pleistocene, was concerned, geologists, with much more evidence to work from, saw that there had been at least four ice ages in a period of about 1,000,000 years. They consequently proposed the idea that the Pleistocene was not at all like previous periods. It was exceptional because it had so many ice ages. They may have been misled by failure to take sufficient account of the fact that glacial evidence is very easily destroyed, and that, as we go further back into geological history, the mathematical chances of finding evidences of glaciation, never very good, decrease by geometrical progression.

Down to twenty years ago it was the considered judgment of geologists that the last ice age in North America, which they refer to as the Wisconsin glaciation, began about 150,000 years ago and ended about 30,000 years ago, as I have already said.

This opinion appeared to be based upon strong evidence. The estimates of the date of the end of the ice age were supported by the careful counting of clay varves (6) and by numerous seemingly reliable estimates of the age of Niagara Falls. As a consequence, experts were contemptuous of all those who, for one reason or another, attempted to argue that the ice age was more recent. One of these was Drayson, whose theory called for a very recent ice age (117). His followers produced much evidence, but it was ignored. When the Swedish scientist Gerard de Geer established by clay-varve counting that the ice sheet was withdrawing from Sweden as recently as 13,000 years ago, the implications were not really accepted, nor were his results popularly known. Books continued to appear, even thirty years afterward, with the original estimates of the age of the ice cap.

Then, following World War II, nuclear physics made possible the development of new techniques for dating geological events. One of these was radiocarbon dating.

The method of radiocarbon dating was developed by Willard F. Libby, nuclear physicist of the University of Chicago. It uses an isotope of carbon (Carbon 14) which has a "half-life" of about 5,570 years. A half-life is the period during which a radioactive substance loses half its mass by radiation. Among the very numerous artificial radioactive elements created in nuclear explosions some have half-lives of millionths of seconds; others, occurring in nature, have half-lives of millions of years. For geological dating it

is necessary to have radioactive elements that diminish significantly during the periods that have to be studied, and that occur in nature.

Since radiocarbon exists in nature and has a relatively short half-life, the quantity of it in any substance containing organic carbon will decline perceptibly in periods of a few centuries. By estimating how much carbon was contained originally in the specimen and then measuring what still remains, the date of its geologic formation can be found to within a small margin of error.

When this method was first developed by Libby, it could date anything containing carbon of organic origin back to about 20,000 years ago. Since then the method has been improved, through the efforts of many scientists, and its range has been approximately tripled.

The first major result of the radiocarbon method was the revelation that the last North American ice sheet had indeed disappeared at a very recent date. Tests made in 1951 showed that it staged a readvance in Wisconsin as recently as 11,000 years ago (272:105). When this date is compared with other dates showing the establishment of a climate like the present one in North America, it seems that most of the retreat and disappearance of the great continental ice cap, at least in the United States, can have taken little more than two or three thousand years. We shall examine these dates in detail in Chapter IV.

What was the significance of this new discovery, besides showing how wrong the geologists had been before? The fact is that so sudden a disappearance of a continental ice cap raises fundamental questions. It contradicts some basic assumptions of geological science. What has become of those gradually acting forces that were supposed to govern glaciation as well as all other geological processes? What factor can account for this astonishing rate of change? It seems self-evident that no astronomical change and no subcrustal change deep in the earth can occur at that rate.

When this discovery was made, I expected that the next revelation must be to the effect that the Wisconsin ice sheet had had its origin at a much more recent time than was suspected, and that the whole length of the glacial period was but a fraction of the former estimates. I had a while to wait, because radiocarbon dating in 1951 was not able to answer the question. By 1954, however, the technique had been improved so that it could determine dates as far back as 30,000 years ago. Many datings of the earlier phases of the Wisconsin glaciation were made, and Horberg, who assembled them, reached the conclusion that the ice cap, instead of being 150,000 years old, had appeared in Ohio only 25,000 years ago (222:278-86). This conclusion has been so great a shock that some writers have sought to evade the clear implications by questioning the reliability of the radiocarbon method. Horberg betrays evidence of the intensity of the shock to accepted beliefs when he says that the results of the evidence are so appalling from the standpoint of accepted theory that it may be necessary either to abandon the concept of gradual change in geology or to question the radiocarbon method.

In this book I am not going to question the general reliability of the radiocarbon method. I intend merely to question the theories with which the new evidence is in conflict. Doctor Horberg says that the necessity to compress all the later stages of the Wisconsin glaciation into the incredibly short period of 15,000 or 20,000 years involves an acceleration of geological processes—snowfall, rainfall, erosion, sedimentation, and melting—that seems to challenge the principle laid down by the founder of modern geology, Sir Charles Lyell, over a century ago. Lyell’s principle, called “uniformitarianism,” stated that geological processes have always gone on about as they are going on now.

The Wisconsin ice cap went through a number of oscillations, warm periods of ice recession alternating with cold periods of ice readvance. Horberg is at a loss to see what could cause them to occur at the velocity required by the radiocarbon dates. These seem to require an annual movement of the ice front of 2,005 feet, “two to nine times greater than the rate indicated by varves and annual moraines” (222:283).^[1]

The fact that these new data call into question some basic ideas in geology is recognized by Horberg :

Probably only time and the progress of future studies can tell whether we cling too tenaciously to the uniformitarian principle in our unwillingness to accept fully the rapid glacier fluctuations evidenced by radiocarbon dating (222:285).

Recent geological literature shows that a rather desperate effort is being made to blur the significance of the new data. However, I would like to suggest some far-reaching implications. We have seen an ice sheet appear and disappear in—geologically speaking—a twinkling of an eye. There are three deductions to be made :

- a. Any theory of ice ages must give a cause that can operate that fast.
- b. If the last ice cap in North America appeared and disappeared in a short time, we cannot assume that the ancient ice caps lasted for longer periods.
- c. If other geological processes are correlated with ice ages, then their tempo must also have been faster than we have supposed, and a cause must be found for their accelerated tempo.

5. CONCLUSION

It is clear that none of the great glaciations of the past can be explained by the theories hitherto advanced. The only ice age that is adequately explained is the present ice age in Antarctica. This is excellently explained. It exists, quite obviously, because Antarctica is at the pole, and for no other reason. No variation of the sun’s heat, no galactic dust, no volcanism, no subcrustal currents, and no arrangements of land elevations or sea currents account for the fact. We may conclude that the best theory to account for an ice age is

that the area concerned was at a pole. We thus account for the Indian and African ice sheets, though the areas once occupied by them are now in the tropics. We account for all ice sheets of continental size in the same way.

Stokes has provided an excellent list of specifications for a satisfactory ice-age theory, every one of which is met by the assumption of crust displacements as the fundamental cause (395:815-16):

- a. An initiating event or condition.
- b. A mechanism for cyclic repetitions or oscillations within the general period of glaciation.
- c. A terminating condition or event.
- d. It should not rely upon unprovable, unobservable, or unpredictable conditions when well-known or more simple ones will suffice.
- e. It must solve the problem of increased precipitation with colder climate.
- f. The facts call for a mechanism that either increases the precipitation or lowers the temperature very gradually over a period of thousands of years.

It is evident that a displacement of the crust could initiate an ice age by moving a certain region into a polar zone, while a later displacement could end the ice age by moving the same area away from the polar zone. The increased precipitation and the oscillations of the borders of the ice sheets can be explained by the atmospheric effects that would result from volcanism associated with the movement of the crust. These effects will be discussed in later chapters.

chapter 3

THE FAILURE TO EXPLAIN CLIMATIC CHANGE

IN THE last chapter it was suggested that the ice ages can be explained by the assumption of frequent displacements of the earth's crust but that they cannot, at least for recent time (the Pleistocene Epoch) be explained by continental drift. The ice ages, however, represent only one side of the problem. If they are instances of extremely cold climates distributed in an unexplained manner on the earth's surface, there were also warm climates whose distribution is equally unexplained.

In connection with these warm climates in the present polar regions, there arises a contradiction of an especially glaring character. On the one hand there is evidence that the distribution of plants and animals in the past did not, as a rule, follow the present arrangements of the climatic zones. On the other hand, the trend of the new evidence is to show that climatic zones have always been about as clearly distinguished by temperature differences as they are today. This is in flat contradiction to the assumption, still widely held, that the earth, during most of geological history, did not possess clearly demarcated climatic zones. We are forced to conclude that, since many ancient plants and animals were not distributed according to the present climatic zones, the zones themselves have changed position on the earth's surface. This requires, as we have seen, that the surface shall have changed position relative to the axis of rotation. We shall now examine the evidence that supports this view.

1. Ages of Bloom in Antarctica

There have been many times during the history of the globe when the continent of Antarctica, now covered by a polar ice cap as much as two miles thick and covering an area of nearly 6,000,000 square miles, had warm climates.

So far as we know at present, the very first evidence of an ice age in Antarctica comes from the Eocene Epoch (52:244). This was barely 60,000,000 years ago. Before that, for some billion and a half years, there is no suggestion of polar conditions, though very many earlier ice ages existed in other parts of the earth. Henry, in *The White Continent*, cites evidence of the passing of long temperate ages in Antarctica. He describes the Edsel Ford Mountains, discovered by Admiral Byrd in 1929. These mountains are of nonvolcanic, folded sedimentary rocks, the layers adding up to 15,000 feet in thickness. Henry suggests that they indicate long periods of temperate climate in Antarctica :

The greater part of the erosion probably took place when Antarctica was essentially free of ice, since the structure of the rocks indicates strongly that the original sediment from which they were formed was carried by water. Such an accumulation calls for an immensely long period of tepid peace in the life of the rampaging planet (206:113).

Most sedimentary rocks are laid down in the sea, formed of sediment brought down by rivers from nearby lands. The lands from which the Antarctic sediments were brought seem to have disappeared without a trace, but of the sea that once existed where there is now land we have plenty of evidence. Brooks remarks :

... In the Cambrian we have evidence of a moderately warm sea stretching nearly or right across Antarctica, in the form of thick limestones very rich in reef-building *Archaeocyathidae* (52:245).

Millions of years later, when these marine formations had appeared above the sea, warm climates brought forth a luxuriant vegetation in Antarctica. Thus, Sir Ernest Shackleton is said to have found coal beds within 200 miles of the South Pole (71:80), and later, during the Byrd expedition of 1935, geologists made a rich discovery of fossils on the sides of lofty Mount Weaver, in Latitude 86° 58' S., about the same distance from the pole, and two miles above sea level. These included leaf and stem impressions and fossilized wood. In 1952 Dr. Lyman H. Dougherty, of the Carnegie Institution of Washington, completing a study of these fossils, identified two species of a tree fern called *Glossopteris*, once common to the other southern continents (Africa, South America, Australia), and a giant tree fern of another species. In addition, he identified a fossil footprint as that of a mammallike reptile. Henry suggests that this may mean that Antarctica, during its period of intensive vegetation, was one of the most advanced lands of the world as to its life forms (207).

Soviet scientists have reported finding evidences of a tropical flora in Graham Land, another part of Antarctica, dating from the early Tertiary Period (perhaps from the Paleocene or Eocene) (364:13).

It is, then, little wonder that Priestly, in his account of his expedition to Antarctica, should have concluded :

... There can be no doubt from what this expedition and other expeditions have found that several times at least during past ages the Antarctic has possessed a climate much more genial than that of England at the present day ... (349d:210)

Further evidence is provided by the discovery by British geologists of great fossil forests in Antarctica, of the same type that grew on the Pacific coast of the United States 20,000,000 years ago (206:9). This, of course, shows that after the earliest known Antarctic glaciation in the Eocene, the continent did not remain glacial but had later episodes of warm climate.

Umbgrove adds the observation that in the Jurassic Period the floras of Antarctica, England, North America, and India had many plants in common (420:263).[\[2\]](#)

There is one group of theories for explaining these facts to which we cannot appeal because of their inherent and obvious weaknesses. These are the theories that try to explain warm and cold periods in Antarctica by changes in land elevations, changes in the directions of ocean currents, changes in the intensity of solar radiation, and the like. It is obvious, for instance, that no hypothetical warm currents could make possible the existence of warm climates in the center of the great Antarctic continent if that continent were at the pole, and if by some miracle Antarctica did become warm, how could forests possibly have flourished there deprived of sunlight for half the year ?

2. Warm Ages in the North

The Arctic regions have been more accessible, and consequently they have been more thoroughly explored, than the Antarctic. It was from them that the first evidence came of warm-climate floras in a polar region. Most of the theories developed by those defending the theory of the permanence of the poles were specially designed to explain these facts.

One method of explaining the evidence was to suggest that the plants and animals of past geological areas, even though they belonged to similar genera or families as living plants and animals, and closely resembled them in structure, may have been adapted to very different climates. This argument often had effect, for no one could exclude the possibility that, in a long geological period, species might make successful adjustments to different climatic conditions. Where single plants were involved such a possibility could not be dismissed. Where, however, whole groups of species, whole floras and faunas, were involved, there was increased improbability that they could all have been adjusted at any one time to a radically different environment from that in which their descendants live today. For this reason, and because the structure of plants has a definite relationship to conditions of sunlight, heat and moisture, biologists have abandoned this method of explaining the facts. Barghoorn, for example, says that fossil plants are reliable indicators of past climate (375:237-38).

It may be worthwhile to review, very briefly, some high points of the climatic history of the Arctic and sub-Arctic regions, beginning with one of the oldest periods, the Devonian, and coming down by degrees to periods nearer our own. (During this discussion the reader may find it helpful to refer to the table of geological periods, page 2.)

The Devonian evidence is particularly rich and includes both fauna and flora. Doctor Colbert, of the American Museum of Natural History, has pointed out that the first known amphibians have been found in this period in eastern Greenland, near the Arctic Circle, though they must have required a warm climate (375:256). Many species of reef corals, which at present require an all-year seawater temperature of not less than 68° F. (102:108), have been found in Ellesmere Island, far to the north of the Arctic Circle (389:2). Devonian tree ferns have been found from southern Russia to Bear Island, in the Arctic Ocean (177:360). According to Barghoorn, assemblages of Devonian plants have been found in the Falkland Islands, where a cold climate now prevails, in Spitzbergen, and in Ellesmere Island, as well as in Asia and America (375:240). In view of this, he remarks :

The known distribution of Devonian plants, especially their diversification in high latitudes, suggests that glacial conditions did not exist at the poles (375:240).

In the following period, the Carboniferous, we have evidence summed up by Alfred Russel Wallace, co-author with Darwin of the theory of evolution :

In the Carboniferous formation we again meet with plant remains and beds of true coal in the Arctic regions. *Lepidodendrons* and *calamites*, together with large spreading ferns, are found at Spitzbergen, and at Bear Island in the extreme north of Eastern Siberia; while marine deposits of the same age contain an abundance of large stony corals (435:202).

In the Permian, following the Carboniferous, Colbert reports a find of fossil reptiles in what is now a bitterly cold region : “Large Permian reptiles ... are found along the Dvina River of Russia, just below the Arctic Circle, at a North Latitude of 65°” (375:259). Colbert explains that these reptiles must have required a warm climate. In summing up the problem of plant life for the many long ages of the Paleozoic Era, from the Devonian through the Permian, Barghoorn says that it is “one of the great enigmas” of science (375:243).

Coming now to the Mesozoic Era (comprising the Triassic, Jurassic and Cretaceous Periods), Colbert reports that in the Triassic some amphibians (the labyrinthodonts) ranged all the way from 40° S. Lat. to 80° N. Lat. About this time the warm-water *Ichthyosaurus* lived at Spitzbergen (375:262-64). For the Jurassic, Wallace reports :

In the Jurassic Period, for example, we have proofs of a mild arctic climate, in the abundant plant remains of East Siberia and Amurland. ... But even more remarkable are the marine remains found in many places in high northern latitudes, among which we may especially mention the numerous ammonites and the vertebrae of huge reptiles of the genera *Ichthyosaurus* and *Teleosaurus* found in Jurassic deposits of the Parry Islands in 77° N. Lat. (435:202).

For the Cretaceous Period, A.C. Seward reported in 1932 that “the commonest Cretaceous ferns [of Greenland] are closely allied to species ... in the southern tropics” (373:363-71). Gutenberg remarks : “Thus, certain regions, such as Iceland or Antarctica, which are very cold now, for the late Paleozoic or the Mesozoic era show clear indications of what we would call subtropical climate today, but no trace of glaciation; at the same time other regions were at least temporarily glaciated” (194:195). This evidence, linked in this way with the problem of the ice ages we have already discussed, reveals the existence of a single problem. Ice ages in low latitudes, and warm ages near the poles, are, so to speak, the sides of a single coin. The correct explanation of one will probably involve the explanation of the other.

Following the Cretaceous, the Tertiary Period shows the same failure of the fauna and flora to observe our present climatic zones. Scott, for example, says : “The very rich floras from the Green River shales, from the Wilcox of the Gulf Coast and from the Eocene of Greenland show that the climate was warmer than in the Paleocene, and much warmer than today” (372:103).

In this Eocene Epoch we find evidence of warm climate in the north that is truly overwhelming. Captain Nares, one of the earlier explorers of the Arctic, described a twenty-five-foot seam of coal that he had thought was comparable in quality to the best Welsh coal, containing fossils similar to the Miocene fossils of Spitzbergen. He saw it near Watercourse Bay, in northern Greenland (319:II, 141-42). Closer examination revealed that it was, in reality, lignite. Nevertheless, the contained fossils clearly indicated a climate completely different from the present climate of northern Greenland :

The Grinnell Land lignite indicates a thick peat moss, with probably a small lake, with water lilies on the surface of the water, and reeds on the edges, and birches and poplars, and taxodias, on the banks, with pines, firs, spruce, elms and hazel bushes on the neighboring hills ... (319:II, 335).

Brooks thinks that the formation of peat bogs requires a rainfall of at least forty inches a year and a mean temperature above 32° F. (52:173). This suggests a very sharp contrast with present Arctic conditions in Grinnell Land.

DeRance and Feilden, who did the paleontological work for Captain Nares, also mention a Miocene tree, the swamp cypress, that flourished from central Italy to 82° N. Lat., that is, to within five hundred miles of the pole (319:II, 335). They show that the Miocene floras of Grinnell Land, Greenland, and Spitzbergen all required temperate climatic conditions with plentiful moisture. They mention especially the water lilies of Spitzbergen, which would have required flowing water for the greater part of the year (319:II, 336).

In connection with the flora of Spitzbergen and the fauna mentioned earlier, it should be realized that the island is in polar darkness for half the year. It lies on the Arctic Circle, as far north of Labrador as Labrador is north of Bermuda.

Wallace describes the flora of the Miocene. He points out that in Asia and in North America this flora was composed of species that apparently required a climate similar to that of our southern states, yet it is also found in Greenland at 70° N. Lat., where it contained many of the same trees that were then growing in Europe. He adds :

But even farther North, in Spitzbergen, 78° and 79° N. Lat. and one of the most barren and inhospitable regions on the globe, an almost equally rich fossil flora has been discovered, including several of the Greenland species, and others peculiar, but mostly of the same genera. There seem to be no evergreens here except coniferae, one of which is identical with the swamp-cypress (*Taxodium distichum*) now found living in the Southern United States. There are also eleven pines, two *Libocedrus*, two *Sequoias*, with oaks, poplars, birches, planes, limes, a hazel, an ash, and a walnut; also water lilies, pond weeds, and an *Iris* altogether about a hundred species of flowering plants. Even in Grinnell Land, within 8¼ degrees of the pole, a similar flora existed . (446:182-84).

It has been necessary to dwell at length on the evidence of the warm polar climates, because this is important for the discussion that follows.

3. Universal Temperate Climates—a Fallacy

The evidence I base presented above (and a great deal more, omitted for reasons of space) has long created a dilemma for geology. Only two practical solutions have offered themselves.^[3] One is to shift the crust, and the other is to suggest that climatic zones like the present ones have not always existed. It is often suggested that the climates have been very mild, virtually from pole to pole, at certain times. The extent to which the latter theory is still supported is eloquent evidence of the theory of the permanence of the poles. When one inquires as to the evidence for the existence of such warm, moist climates, a peculiar situation is revealed. There is no evidence except the fossil evidence that the theory is supposed to explain. Could there be a better example of reasoning in a circle? Colbert cites evidence that the Devonian animals were spread all over the world, and then remarks that therefore "... it is reasonable to assume ... that the Devonian Period was a time of widely spread equable climates, a period of uniformity over much of the earth's surface" (375:255). According to him, the same situation held true through the Paleozoic and Mesozoic and even much later periods (375:268). Other paleontologists reasoned in the same way. Goldring, for example, remarked: "The Carboniferous plants had a worldwide distribution, suggesting rather uniform climatic conditions" (177:362). She drew the same conclusions from the worldwide distribution of Jurassic flora (177:363).

Is this theory of universal temperate climates inherently reasonable? The answer is that it is not. It involves, in the first place, ignoring the astronomical relations of the earth and the sun. The theory requires us to assume the existence of some factor powerful enough to negate the variation of the sun's heat with latitude which, of course, is due to the angle of inclination of the earth's axis of rotation. As Professor George W. Bain, of Amherst, has pointed out, the result of this is that

... The thermal energy arriving at the earth's surface per day per square centimeter averages 430 gram calories at the equator but declines to 292 gram calories at the 40th parallel and to 87 gram calories at the 80th parallel ... (18:16).

What force sufficiently powerful to counteract that fact of astronomy can be suggested, and, more important, supported by convincing evidence?

It was thought at first that universal temperate climates might be accounted for by the theory of the cooling of the earth. Those who favored this theory (253, 292) argued that since, in earlier ages, the earth was hotter, the ocean water then evaporated much more rapidly, and it formed thick clouds that reflected the sun's radiant energy back into space. The cloud blanket shut out the sun's

radiation but kept in the heat that radiated from the earth itself, and this acted to distribute the heat evenly over the globe. The cloud blanket must have been thick enough to make the earth a dark, dank, and dismal place. Since, as Colbert shows, fossils are found outside the present zones appropriate to them even in recent geological periods, such conditions must have obtained during about 90 percent of the earth's whole history, and most of the evolution of living forms must have taken place in them.

For a number of reasons, including the difficulty of explaining how plants can have evolved in the polar regions without sunlight, this theory has been abandoned. We have also seen that the idea that the earth was ever hotter than now has recently been undermined. This has destroyed the dependability of the theory's basic assumption.

The fact that the theory never was reasonable is shown from Coleman's arguments against it, advanced more than a quarter of a century ago. He pointed out that not only are ice ages known from the earliest periods (from the Precambrian) but there is evidence that some of these very ancient ice ages were even more intensely cold than the recent ice age that came to an end 10,000 years ago (87:78), No less than six ice ages are known from the Precambrian (420:260). The evidence of one of these Precambrian or Lower Cambrian ice ages is interestingly described by Brewster :

In China, in the latitude of northern Florida, there is a hundred and seventy feet of obvious glacial till, scratched boulders and all, and over it lie sea-floor muds containing lower Cambrian trilobites, the whole now altered to hard rock (45:204).

It is obvious that such ice ages (and evidences of more of them are frequently coming to light) are in conflict with the theory of universal equable climates. Some of them are found right in the midst of periods thought to have been especially warm, such as the Carboniferous.

Coleman presents other geological evidence against the theory. The fact that most of the fossils found are those of warm-climate creatures is, he thinks, misleading. Plants and animals are more easily fossilized in warm, moist climates than they are in cold, arid ones. Fossilization, even under the most favorable conditions, is a rare accident. The fauna and flora of the temperate and arctic zones of the past were seldom preserved (87:252). Thus, while the finding of fossils of warm-climate organisms all over the earth is an argument against the permanence of the present arrangement of the climatic zones, it is not an argument for universal mild climates.

Another argument against such climates may be based upon the evidences of desert conditions in all geological periods. These imply worldwide variations in climate and humidity. Both Brooks (52:24-25, 172) and Umbgrove (420:265) stress the importance of this evidence. One of the most famous formations of Britain—the Old Red Sandstone—is apparently nothing but a fossil desert. Coleman

points to innumerable varved deposits in many geological periods as evidence of seasonal changes (87:253), which, of course, imply the existence of climatic zones.

Ample evidence of the existence of strongly demarcated climatic zones through the earth's whole history (at least since the beginning of the deposition of the sedimentary rocks) comes from other sources. Barghoorn cites the evidence of fragments of fossil woods from late Paleozoic deposits in the Southern Hemisphere that show pronounced ring growth, indicating seasons; he also points out that in the Permo-Carboniferous Period floras existed that were adapted to very cold climate (375:242). Colbert himself reports good evidence of seasons in the Cretaceous Period, in the form of fossils of deciduous trees (375:265).

Umbgrove cites the geologist Berry, who states that the fossilized woods from six geological periods, from the Devonian to the Eocene, show well-marked annual rings, indicating seasons like those of the present time. Furthermore, Berry goes on to say :

Detailed comparisons of these Arctic floras with contemporary floras from lower latitudes ... show unmistakable evidence for the existence of climatic zones ... (420:266).

Brooks concludes, on the basis of Berry's evidence, that climatic zones existed in the Eocene (52:24). Ralph W. Chancy, after a study of the fossil floras of the Tertiary Period (from the Eocene to the Pliocene), concluded that climatic zones existed (72:475) during that whole period. The distinguished meteorologist W.J. Humphreys, whose fundamental work, *The Physics of the Air*, remains a classic, remarked in 1920 that there was no good evidence of the absence of climatic zones at any time from the beginning of the geological record. Finally Dr. C.C. Nikiforoff, an expert on soils (both contemporary and fossil soils), has stated that "in all geological times there were cold and warm, humid and dry climates, and their extremes presumably did not change much throughout geological history" (375:191). We will return, below, to the significance of fossil soils and present other evidence showing persistence of sharply demarcated climatic zones during the earth's whole history. But where, at this point, does the evidence leave us ?

On the one hand, the evidence shows that the plants and animals of the past were distributed without regard to the present direction of the climatic zones. I have been unable to do more than suggest the immensity of the body of evidence supporting this conclusion. On the other hand, the attempt to deny the existence, in the past, of sharply demarcated climatic zones like those of the present has failed. It may even be said to have failed sensationally. There is no scrap of evidence for it except the evidence it is supposed to explain, while, on the other hand, it is in contradiction with both the fundamentals of astronomy and the preponderance of the geological facts.

So we are left with a clear-cut conclusion: Climatic zones have always existed, but they have followed different paths on the face of the earth. If changes in the position of the axis of rotation of the earth, and of the earth upon its axis, are equally impossible, and if the

theory of continental drift provides no satisfactory solution for reasons already discussed (Chapter I), then we are forced to the conclusion that the surface of the earth must often have been shifted over the underlying layers.

4. The Eddington-Pauly Suggestion

Another suggestion for displacements of the earth's crust, to which I have already referred, is that of Karl A. Pauly, who has contributed new lines of evidence in support of such shifts. He has based his theory on Eddington's suggestion that the earth's crust may have been gradually shifted through time by the effects of tidal friction. The evidence for displacements presented by Pauly is most impressive.

Pauly finds, from a study of the elevations above sea level of the terminal moraines of mountain glaciers in all latitudes, that there is a correlation of elevation with latitude. While it is true that many factors influence the distance a mountain glacier may extend downward toward sea level, latitude is one of them, and by using a sufficient number of cases it is possible to average out the other factors and arrive at the average elevation of mountain glacier moraines above sea level for each few degrees of latitude from the equator toward the poles. This gives us a curve that makes it possible to compare the elevations of the terminal moraines of mountain glaciers that existed during the Pleistocene Epoch. Pauly finds that these moraines do not agree with the curve, indicating unmistakably a displacement of the earth's crust (342:89).

Pauly cites another impressive line of evidence in support of displacements of the lithosphere. He has compared the locations of the coal deposits of several geological periods (many of which are now in polar regions) with the locations of ice caps for the same periods. He lists 34 coal deposits regarded as of Jurassic-Liassic age and 17 of Triassic-Thaetic age, and finds that, if it is assumed that the centers of the ice caps of that time were located at the poles, then these coal deposits would have been located within or just outside the tropics, as would be correct. He says :

The very definite location of these coal deposits within the Trias-Jura tropical and subtropical zones cannot be mere coincidence. The distribution indicates the lithosphere has shifted (342:96).

Of the Permo-Carboniferous coal deposits, very widely distributed over the earth, he says that "95 out of 105 listed in *The Coal Resources of the World* lie within or just outside of the tropics as determined by the assumption that the North or South Pole lay under the center of one of the Permo-Carboniferous ice sheets" (342:97).

5. The Contribution of George W. Bain

Professor Bain has gone considerably beyond the categories of evidence that we have so far discussed. He has considered the specific chemical processes controlled by sunlight and varying according to latitude, and the remanent chemicals typical of soils developed in the different climatic zones. He has extended this sort of analysis also to marine sediments.

Bain's approach to the problem has many advantages. It circumvents, for one thing, the argument that plants of the past may have been adjusted to climates different from those in which their modern descendants live. He begins with a precise definition of each climatic zone in terms of the quantities of the sun's heat reaching the earth's surface. He points out that, as is known, the seasonal variation of this heat increases with distance from the equator (18:16). He then describes the global wind pattern resulting from this distribution of the sun's energy, defining clearly the conditions of the horse latitudes, in which most of the earth's deserts are found, and the meteorology of the polar fronts. He shows that there are distinct and different complete chemical cycles in each of these areas, and corresponding cycles in the sea. Many of the chemical compounds produced in each of these areas are included, naturally, in the rocks formed from the sediments, and they remain as permanent climatic records.

It is impossible, because of limitations of space, to do justice to Bain's comprehensive approach to this question. He establishes that great differences exist between the mineral components of the rocks in different climatic zones, resulting from the difference in the amount of the sun's radiant heat. With regard to the polar soils, he found that they are developed in circles on the earth's surface rather than in bands. Temperate and tropical soils are, of course, found in bands, since the zones are bands that encircle the earth.

It is clear that Bain has established a sound method for the study of the climates of the past. He has applied his method to the study of the climates of five periods, the Cambrian, Ordovician, Silurian, Devonian, and Permian (19a) (Figs. 11, 12, 13, 14, and 15, pp. 74-78), with significant results. He concludes, first, that climatic zones, representing the different distributions of solar heat, existed in those periods just as at present. This is proved by the specific remanent chemicals included in these rocks, which differ exactly as do the sediments of the different zones at the present time. This is, of course, fatal for the theory of universal equable climates.

His second conclusion is that the directions of the climatic zones have changed enormously in the course of time. He finds the equator running through the New Siberian Islands (in the Arctic Ocean) in the Permo-Carboniferous Period, and North and South America lying tandem along it (18:17). The evidence he uses seems to establish his essential point (and ours) that the climatic zones themselves have shifted their positions on the face of the earth.

Bain has drawn some interesting further conclusions. He states that the earth's crust must have been displaced over the interior layers and that "fixity of the axis of the earth relative to the elastic outer shell just is not valid. ..." (18:46). He points to the fossil evidence of the cold zones (distributed in circular areas) and says, "... The recurrent change in position of these rings through geologic time can be accounted for now only on the basis of change in the position of the elastic shell of the earth relative to its axis of rotation" (18:46).

Even without the evidence of geomagnetism, or even if that evidence should someday be discredited, the evidence produced by Bain would be sufficient to establish the truth of displacements of the lithosphere. However, the mechanism he suggests does not seem satisfactory. He depends upon the effects of erosion. He points out that at the present time the balance of the sediment transfer by rivers is toward the equator. The mass thus added to the lithosphere on the equator has been given increased velocity by the fact of being moved equatorward, and this would tend to accelerate the rotation, but the gyroscopic effect of this, he thinks, would be to cause the rotating globe to precess in a direction at 90° to the direction of the rotation. The crust alone, however, not the entire globe, would be shifted (19a:128-129).

There seem to me to be three objections to this mechanism. In the first place, it seems probable that isostatic adjustment of the lithosphere to the transfer of sediments would eliminate the effect. A poleward flow of material under the lithosphere would roughly equal the equatorward movement of sediment. A second objection is that there is no reason to suppose that with every position of the lithosphere the balance of sediment transfer would be toward the equator. This would require changes in the drainage systems of all the continents with each shift of the crust. The third objection is that the geomagnetic evidence suggests polar shifts were far more frequent than indicated by Bain. Bain makes no use of the continental-drift hypothesis.

6. The Contribution of T.Y.H. Ma

Bain has pointed out (18) that among other indications of latitude, sea crustaceans and corals may indicate latitude either by the presence or absence of evidence of seasonal variations in growth. It happens that corals have been very thoroughly investigated from precisely this point of view.

By a remarkable parallelism of development, another theory of displacement of the earth's crust took shape on the opposite side of the earth at about the same time that Mr. Campbell and I started on our project. Professor Ting Ying H. Ma, an oceanographer, then at the University of Fukien, China, came to the conclusion, after many years of study of fossil corals, that many total displacements of the earth's lithosphere must have taken place. I did not become aware of Ma's work until I was introduced to it by David B. Ericson, of the Lamont Geological Observatory, in 1954. Ericson has, in fact, taken a leading role in introducing Ma's work to American scientists.

For about twenty years previous to the time I mention, Ma had intensively pursued the study of living and fossil reef corals. He very early noticed the special characteristic of reef corals referred to by Bain but hitherto ignored by writers on corals. He saw that, at distances from the equator, there were seasonal differences in the rates of coral growth and that the evidences of these were preserved in the coral skeleton. Specifically he observed that in winter the coral cells are smaller and denser; in summer they are larger and more porous. Together these two rings make up the growth for one year.

Studying living coral reefs in various parts of the Pacific, comparing, measuring, and tabulating coral specimens of innumerable species, making photographic studies of the coral skeletons, Ma established that the rates of total annual coral growth for identical or similar species within the range of the coralline seas increased with proximity to the equator, and that seasonal variation in growth rates increased with distance from the equator.

Other writers on corals have pointed out that there are numerous individual exceptions and irregularities in coral growth rates, deriving from the fact that the coral polyps feed upon floating food, which may vary in quantity from place to place, from day to day, and even from hour to hour (125:20-21; 298:52-53). Ma, however, has guarded himself against error by a quantitative and statistical approach. In several published volumes of coral studies (285-Z90) he has compiled tables running into hundreds of pages, and his studies have involved thousands of measurements.

When this indefatigable oceanographer had worked out the relations of coral growth with latitude, he possessed an effective tool with which to investigate the climates of the past. He studied specimens of fossil corals from many geological periods. He devoted separate volumes to the Ordovician, Silurian, Devonian, Cretaceous, and Tertiary Periods (285-289).

As Ma assembled the coral data for these periods, it became clear that the total width of the coralline seas had not varied noticeably from the beginning of the geological record. Not only was the existence of seasons in the oldest geological periods clearly indicated; it was also indicated that the average temperatures of the respective zones were about the same as at present.

The second result of Ma's studies was to establish that the positions of the ancient coralline seas and, therefore, of the ancient equators were not the same as at present. They had evidently changed from one geological period to another. Ma first believed that this could be explained by the theory of drifting continents. Down to about 1949 he sought to fit all the evidence into that theory. By 1949, however, the accumulated evidence forced him to adopt a theory of total displacements of all the outer shells of the earth over the liquid core. By an instinct of conservatism, however, he did not abandon the theory of floating continents but combined it with the new theory.

Ma's coralline seas ran in all directions (Figs. 16, 17, 18, 19, and 20, pp. 82-86); one of his equators actually bisected the Arctic Ocean. But he had great difficulty in matching up his equators on different continents. If, for example, he traced an equator across North America, he could not match it with an equator for the same period on the other side of the earth to make a complete circle of the earth. He therefore supposed that the continents themselves had been shifting independently and this had had the effect of throwing the ancient equators out of line. He therefore allowed, for each period, enough continental drift to bring the equators into line, and it seemed, when he did this, that in successive geological periods he did have increasing distances between the continents, as if the drift had been continuous.

Subsequently Ma developed his theory into a complete system, which is most interesting, and yet to which I think serious objections may be raised.

Corals are, according to Ma, excellent indicators of the climate for the time in which they grew, but by the nature of the case, since corals grow only in shallow water and grow upwards only as far as the surface, the period of time represented by a single fossil coral reef is of the order of a few thousand years only, as compared with the millions of years embraced by a geological period.

How short the continuous growth of a coral reef may be is indicated by numerous studies of the coral reefs of the Pacific. A.G. Mayor, for example, says :

... The modern reefs now constituting the atolls and harriers of the Pacific could readily have grown upward to sea-level from the floors of submerged platforms since the close of the last glacial epoch (298:52).

At Pago Pago harbor borings were made down to the basalt underlying the reef, and after estimates of the growth rate were arrived at, the age of the reef (Utelei) was estimated at 5,000 years. When these spans are compared with those of entire geological periods of the order of 20,000,000 or 30,000,000 years, it is clear how fragile must be any conclusions based on the assumption that a given coral reef in Europe was contemporary with another one in North America. It is quite impossible in the present state of our knowledge to decide that they were in fact contemporary.

This means that Ma's corals for a period like the Devonian may be indications of different equators that existed at different times during that period of 40,000,000 years. Therefore it is obvious that thousands of coral specimens would be required to give any certainty as to the actual climatic history of an entire geological period.

Very possibly Ma could have avoided combining the two different theories—the slipping of the shell of the earth and the drifting of continents—if he had supposed a sufficiently frequent slipping of the crust. The frequency of the displacements suggested by the

theory presented in this book, which would involve many different equators in a single geological period, might remove his difficulties. As it is, he has to face all the geophysical and geological objections to the drifting-continent theory as well as difficulties with his displacement theory.

7. On the Rate of Climatic Change

Studies appear from time to time in which attempts are made to trace climatic changes in specified areas over periods of millions of years. In one of these, for example (72), the conclusion is reached that there was a gradual cooling of the climate during a great many million years of the Tertiary Period. It is true that no cause of such a progressive cooling can be pointed to; neither is there any explanation as to why the climatic change had to be so gradual. It is simply assumed that the climatic change had to be gradual and that the cause of the change had to be such as to explain gradual changes.

It is important to define the evidence on which these conclusions are based. In the example I am considering, the facts are as follows :

- a. The period of time involved is of the order of 30,000,000 years.
- b. Wherever reference is made to the specific strata of rock selected for analysis of the climatic evidence (consisting of included fossils), it is clear that the time required for the deposition of any particular layer was of the order of 10,000 years.
- c. It follows that during 30,000,000 years it would have been possible to have about 3,000 different layers of sedimentary rock.
- d. A vast majority of these layers cannot be sampled, either because they no longer exist, or because they do not contain fossils, or simply because of the amount of work involved.
- e. As a result, only spot checking is possible. Perhaps a dozen strata out of 3,000 may be studied, and from these it must be obvious that no dependable climatic record can be established.
- f. Even with the unsatisfactory spot checking so far attempted, reversals of climatic trends have been observed (72).
- g. Climatic conditions indicated by a layer of sediments deposited during a brief period of time in one location cannot be assumed to indicate the direction of climatic change over a great region or over the whole earth. It seems quite as reasonable to suppose that

climatic change in other regions at the same time could have been in a different direction. Furthermore it cannot be assumed that two sedimentary deposits in different areas are of the same age because they both indicate climatic change in the same direction.

It may be concluded that claims for gradual climatic changes in the same direction over long periods of time and over great areas are unsupported by convincing evidence. They are supported by no reasonable hypothesis. We are left free to conclude that climatic change may have taken place in relatively short periods of time, and possibly in opposite directions at the same time, as the consequence of displacements of the lithosphere.

chapter 4

EVIDENCE FOR THE NORTH POLE IN HUDSON BAY

IN THE preceding chapters much evidence has been presented to support the assumption of the displacement of the earth's outer shells over the inner body, displacements that may have occurred rather frequently during the history of the earth. It is now time to tie down this assumption with concrete evidence that such a displacement has occurred, not in the remote past of the planet's history but in very recent time, and not once but at least three times in that recent epoch that we call the Pleistocene. I will ask the reader's indulgence for my descending to details in the examination of the evidence. This is not the sort of thing that he who runs may read, but, although the evidence is detailed, it is not particularly technical. It is the sort of evidence that murder-trial lawyer Perry Mason might

ward. And the sea level would be stable, except for very minor fluctuations.

Barrell himself suggests that subsidence of continental areas would be aided by liquid intrusions, "the weight of magmas of high specific gravity rising widely and in enormous volume from a deep core of greater density into these portions of an originally lighter crust. ..." (420:235-36).

Barrell's suggestion points to the chief weakness of the geophysical argument in favor of the permanence of the continents, whether or not they drift. As I have already pointed out, geophysicists seem, too often, to take as the frame of reference only the outermost ten miles or so of the lithosphere. Theoretically they base their calculations on the full depth of the lithosphere, but practically this assumption is canceled out by the assumption that the lithosphere is arranged in layers of equal density, so that significant changes of density in depth are excluded. But if the real possibilities of changes of average density in the full depth of the lithosphere are taken into account, the difficulties in the face of the subsidence and elevation of continents vanish, and the theory of continental drift becomes superfluous.

chapter 10

THE EXTINCTION OF THE MAMMOTHS AND THE MASTODONS

When this theory of crustal displacements was first presented to a group of scientists at the American Museum of Natural History, on January 27, 1955, Professor Walter H. Bucher, former President of the Geological Society of America, made an interesting observation. I had presented evidence to support the contention that North America had been displaced southward and Antarctica had been moved farther into the Antarctic Circle by the movement of the crust at the end of the ice age. Professor Bucher pointed out that, if this were so, there must have been an equal movement of the crust northward on the opposite side of the earth. He asked me whether there was evidence of this. I said I thought there was. I am presenting the evidence here.

1. The Extinction of the Mammoths

The closing millennia of the ice age saw an enormous mortality of animals in many parts of the world. Hibben estimated that as many as 40,000,000 animals died in North America alone (212:168). Many species of animals became extinct, including mammoths, mastodons, giant beaver, sabertooth cats, giant sloths, woolly rhinoceroses. Camels and horses apparently became extinct in North

America then or shortly afterward, although one authority believes a variety of Pleistocene horse has survived in Haiti (365). The paleontologist Scott is enormously puzzled both by the great climatic revolution and by its effects :

The extraordinary and inexplicable climatic revolution had a profound effect upon animal life, and occasioned or at least accompanied, the great extinctions, which, at the end of the Pleistocene, decimated the mammals over three-fifths of the earth's land surface (372:75).

No one has been able to explain these widespread extinctions. I shall attempt to explain them as consequences of the last displacement of the crust, but, since the extinctions took place both in North America and in Asia—that is, both in the area presumably moved southward and in the area presumably moved northward—I shall concentrate first on Asia. There we shall find no difficulty in producing evidence to show that the climate of eastern Siberia grew colder as North America grew warmer, just as the theory requires.

Among all the animals that became extinct in Asia, the mammoth has been the most studied. This is because of its size; because of the great range of its distribution, all the way from the New Siberian Islands in the Arctic Ocean, across Siberia and Europe, to North America; because pictures of it drawn by primitive man have been found in the caves of southern France and Spain; but most of all, perhaps, because some well-preserved bodies of mammoths have been found frozen in the mud of Siberia and Alaska. Ivory from these frozen remains has provided a supply for the ivory trade of China and Central Europe since ancient times.

A study of the reports on the frozen mammoths reveals some very remarkable facts. In the first place, they increase in numbers the farther north one goes, and are most numerous in the New Siberian Islands, which lie between the Arctic coast of Siberia and the pole. Secondly, they are accompanied by many other kinds of animals.

Thirdly, although ivory is easily ruined by exposure to the weather, uncounted thousands of pairs of tusks have been preserved in good enough conditions for the ivory trade. A fourth point is that the bodies of many mammoths and a few other animals have been preserved so perfectly (in the frozen ground) as to be edible today. Finally, astonishing as it may seem, it is not true that the mammoth was adapted to a very cold climate. I shall first take up this question of the mammoth's alleged adaptation to cold.

2. The Mammoth's Adaptation to Cold

It has long been taken for granted, without really careful consideration, that the mammoth was an Arctic animal. The opinion has been based on the mammoth's thick skin, on its hairy coat, and on the deposit of fat usually found under the skin. Yet it can be shown that none of these features mean any special adaptation to cold.

To begin with the skin and the hair, we have a clear presentation of the facts by the French zoologist and dermatologist H. Neuville. His report was published as long ago as 1919 (325). He performed a comparative microscopic study of sections of the skin of a mammoth and that of an Indian elephant, and showed that they were identical in thickness and in structure. They were not merely similar; they were exactly the same. Then he showed that the lack of oil glands in the skin of both animals made their hair less resistant to cold and damp than the hair of the average mammal. In other words, the hair and fur of the mammoth showed a negative adaptation to cold. It turns out that the common, ordinary sheep is better adapted to Arctic conditions :

We have ... two animals very nearly related zoologically, the mammoth and the elephant, one of which lived in severe climates while the other is now confined to certain parts of the torrid zone. The mammoth, it is said, was protected from the cold by its fur and by the thickness of its dermis. But the dermis, as I have said, and as the illustrations prove, is identical in the two instances; it would therefore be hard to attribute a specially adaptive function to the skin of the mammoth. The fur, much more dense, it is true, on the mammoths than on any of the living elephants, nevertheless is present only in a very special condition which is fundamentally identical in all of these animals. Let us examine the consequences of this special condition, consisting, I may repeat, in the absence of cutaneous glands. The physiological function of these glands is very important. [Neuville's footnote here : It is merely necessary to mention that according to the opinion now accepted, that of Unna, the effect of the sebum is to lubricate the fur, thus protecting it against disintegration, and that of the sweat is to soak the epidermis with an oily liquid, protecting it also against desiccation and disintegration ... the absence of the glandular secretions puts the skin in a condition of less resistance well known in dermatology. It is superfluous to recall that the sebaceous impregnation gives the fur in general its isolating properties and imparts to each of its elements, the hairs, its impermeability, thanks to which they resist with a well-known strength all disintegrating agents, and notably those which are atmospheric. Everyone knows to what degree the presence of grease produced by the sebaceous glands renders wool resistant and isolating, and to what degree the total lack of this fatty matter lessens the value of woolen goods....] (325:331-33).

Neuville points out both that the mammoth lacks sebaceous glands and that the oil from these glands is an important factor in the protection of an animal against cold. It is probable that protection from damp is more important than protection from low temperature. Oil in the hair must certainly impede the penetration of damp. The hair of the mammoth, deprived of oil, would seem to offer poor protection against the dampness of an Arctic blizzard. Sanderson has pointed out that thick fur by itself means nothing: Many animals of the equatorial jungles, such as tigers, have thick fur (365). Fur by itself is not a feature of adaptation to cold, and fur without oil, as Neuville points out so lucidly, is a feature of adaptation to warmth, not cold.

The question of the importance of oily secretions from the skin for the effectiveness of resistance of fur or hair to cold and damp is, however, highly involved. Very many inquiries directed to specialists in universities, medical schools, and research institutes over a period of more than five years failed to elicit sufficiently clear and definite answers until, finally, Dr. Thomas S. Argyris, Professor of Zoology at Brown University, referred me to the Headquarters Research and Development Command of the United States Army. This agency, in turn, very kindly referred me to the British Wool Industries Research Association. I addressed an inquiry to them regarding the effects of natural oil secretions from the skin on the preservation of wool. They replied in general confirmation of Neuville:

... Those interested in wool assume that the function of the wool wax is to protect the wool fibres from the weather and to maintain the animal in a dry and warm condition. Arguments in this direction are of course mainly speculative. We do know, however, that shorn wool in its natural state can be stored and transported without entanglement (or felting) of the fibres, while scoured wool becomes entangled so that, during subsequent processing, fibre breakage at the card is significantly increased. It seems reasonable, therefore, to assume that the wool wax is responsible not only for conferring protection against the weather but also for the maintenance of the fleece in an orderly and hence more efficacious state (447).

It appears that there has been no scientific study of the precise points at issue here; no one has measured in any scientific way the quantitative effect of oily secretions in keeping heat in or moisture out. Despite this fact, however, we are at least justified, on the basis of the facts cited above, in rejecting the claims advanced for the hair of the mammoth as an adaptive feature to a very cold climate.

Neuville goes on to destroy one or two other arguments in favor of the mammoth's adaptation to cold :

... It has been thought that the reduction of the ears, thick and very small relatively to those of the existing elephants, might be so understood in this sense: such large and thin ears as those of the elephants would probably be very sensitive to the action of cold. But it has also been suggested that the fattiness and peculiar form of the tail of the mammoth was an adaptive character of the same kind; however, it is to the fat rumped sheep, animals of the hot regions, whose range extends to the center of Africa, that we must go for an analogue to the last character.

It is therefore, only thanks to entirely superficial comparisons which do not stand a somewhat detailed analysis, that it has been possible to regard the mammoth as adapted to the cold. On account of the peculiar character of the pelage the animal was, on the contrary, at a disadvantage in this respect (325:331-33).

There remains the question of the layer of fat, about three inches thick, which is found under the skin of the mammoth. This fat is thought to have provided insulation against the bitter cold of the Siberian winter.

The best opinion of physiologists is opposed to the view that the storage of fat by animals is a measure of self-protection against cold. The consensus is, on the contrary, that large fat accumulation testifies chiefly to ample food supply, obtainable without much effort, as indeed is the case with human beings. Physiologists agree that resistance to cold is mainly a question of the metabolic rate, rather than of insulation by fat. Since the length of capillaries in a cubic inch of fat is less than the length of capillaries in a cubic inch of muscle, blood circulation would be better in a thin animal. We might ask the question, Which would be more likely to survive through a Siberian winter, a man burdened with fifty or a hundred pounds of surplus fat or a man of normal build who was all solid muscle, assuming that winter conditions would mean a hard struggle to obtain food ? Dr. Charles P. Lyman, Professor of Zoology at Harvard, remarked regarding this question of fat :

It is true that many animals become obese before the winter sets in, but for the most part it seems likely that they become obese because they have an ample food supply in the fall, rather, than that they are stimulated by cold to lay down a supply of fat. Cold will ordinarily increase the metabolic rate of any animal which means that it burns up more fuel in order to maintain its ordinary weight, to say nothing of adding weight in the form of fat. The amount of muscular activity in the daily life of either type of elephant is certainly just as important as the stimulus of cold as far as laying down a supply of fat is concerned (284).

This statement suggests that there is no basis for the assumption that the fat of the mammoths adapted them to an Arctic climate. On the other hand, it is quite true that the storage of fat in the fall may help animals to get through the winter when food is scarce. The winter does not, however, have to be an Arctic winter. A Winter such as we have in temperate climates is quite cold enough to cut the available food supply for herbivorous animals. It seems that under favorable circumstances even the African and Indian elephants accumulate quite a lot of fat. F.G. Benedict, in his comprehensive work on the physiology of the elephant, considers it a fatty animal (26).

The resemblances between the mammoth and the Indian elephant extend further than the identity of their skins in thickness and structure, and the fact that they were both fatty animals. Bell suggests that they were only two varieties of the same species :

Falconer insists on the importance of the fact that throughout the whole geological history of each species of elephant there is a great persistence in the structure and mode of growth of each of the teeth, and that this is the best single character by which to distinguish the species from one another. He finds, after a critical examination of a great number of specimens, that in the mammoth each of the molars is subject to the same history and same variation as the corresponding molar in the living Indian elephant (25).

It is clear that the similarities in the life histories of each of the teeth of these two animals were more important than the differences in the shapes of the teeth, which were such as might easily occur in two varieties of the same species. It cannot be denied that two

varieties of the same species may be adapted to different climates, but it must be conceded that the adaptation of two varieties of the same species, one to tropical jungles and the other to Arctic conditions, is against the probabilities.

3. The Present Climate of Siberia

The people who lay the greatest stress on the adaptation of the mammoth to cold ignore the other animals that lived with the mammoths. Yet we know that along with the millions of mammoths, the northern Siberian plains supported vast numbers of rhinoceroses, antelope, horses, bison, and other herbivorous creatures, while a variety of carnivores, including the sabertooth cat, preyed upon them. What good does it do to argue that the mammoth was adapted to cold when it is impossible to use the argument in the case of several of the other animals ?

Like the mammoths, these other animals ranged to the far north, to the extreme north of Siberia, to the shores of the Arctic Ocean, and yet farther north to the Lyakhov and New Siberian Islands, only a very short distance from the pole. It has been claimed that all the remains on the islands may have been washed there from the mouths of the Siberian rivers by spring floods; I shall consider this suggestion a little later.

So far as the present climate of Siberia itself is concerned, Nordenskjöld made the following observations of monthly averages of daily Centigrade temperatures during the year along the Lena River (334):

January -48.9 (-56 F.)
February -47.2 (-52F.)
March -33.9 (-40 F.)
April -14 (+ 7F.)
May - 0.4 (+32F.)
June +13.4 (+56F.)
July +15.4 (+60 F.)
August +11.9 (+53F.)
September + 2.3 (+36 F.)
October -13.9 (+ 7F.)
November -39.1 (-36F.)
December -45.1 (-49F.)

The average for the whole year was -16.7 (+2° F.). It appears that only three months out of the year are reasonably free from frost. Even so there must be frequent frosts in July, notwithstanding the occasional high midday temperatures. High temperatures on some days would bring the monthly mean down, even if night frosts continued through July.

No doubt it was knowledge of these conditions that caused the great founder of modern geology, Sir Charles Lyell, to remark that it would doubtless be impossible for herds of mammoths and rhinoceroses to subsist throughout the year, even in the southern part of Siberia.

If this is the case with Siberia, what are we to think when we contemplate the New Siberian Islands? There the remains of mammoths and other animals are most numerous of all. There Baron Toll, the Arctic explorer, found remains of a sabertooth tiger, and a fruit tree that had been ninety feet tall when it was standing. The tree was well preserved in the permafrost, with its roots and seeds (113:151). Toll claimed that green leaves and ripe fruit still clung to its branches. Yet, at the present time, the only representative of tree vegetation on the islands is a willow that grows one inch high.

Now let us return to the question of whether all these remains were floated out to the islands on spring floods. Let us begin with a backward view at the history of these islands. Saks, Belov, and Lapina point to evidence that there were luxuriant forests growing on the New Siberian Islands in Miocene and perhaps Pliocene times (364). At the beginning of the Pleistocene the islands were connected with the mainland, and the mammoths ranged over them. In the opinion of these writers the vast numbers of mammoth remains on Great Lyakhov Island indicate that they took refuge on the island when the land was sinking (364:4, note). There is no evidence that they were washed across the intervening sea.

The improbabilities in this suggestion of transportation of these hundreds of thousands of animal bodies across the entire width of the Nordenskjöld Sea, for a distance of more than 200 miles from the mouth of the Lena River, are simply out of all reason. Let us see exactly what is involved.

First, we should have to explain why the hundreds of thousands of animals fell into the river. To be sure, they did not fall in all at once; nevertheless they must have had the habit of falling into the river in very large numbers, because only one body in a very great many could possibly float across 200 miles of ocean. Of those that floated at all only a few would be likely to float in precisely the correct direction to reach the islands. Islands, even large ones, are amazingly easy to miss even in a boat equipped with a rudder and charts. The Lena River has three mouths, one of which points in a direction away from the islands. The two other mouths face the islands across these 200 miles of ocean. Occasionally a piece of driftwood might float across the intervening sea. Occasionally perhaps an animal—if for some reason it did not happen to sink, if it were not eaten by fishes—might be washed up on the shore of

one of the islands. It seems probable that only a very powerful current could transport the body of a mammoth across 200 miles of ocean.

But let us suppose that somehow the animals are transported across the ocean. What then ? The greatest of the New Siberian Islands is about 150 miles long and about half as wide. Not one single account of the explorations on these islands has mentioned that the animal remains are found only along the beaches. They are obviously found also in the interior. Are we to suppose that the floods of the Lena River were so immense that they could inundate the New Siberian Islands, 200 miles at sea ? It is safe to say that all the rivers of Europe and Asia put together, at full flood, would fail to raise the ocean level 200 miles off the coast by more than a few inches at most.

But, again, let us suppose that the remains were merely washed to the present coasts and not into the interior. How then were they preserved ? How were hundreds of thousands of mammoths placed above high-water mark ? Storms, no doubt, but whatever storms can wash up, other storms can wash away. No accumulation of anything occurs along the coasts because of storms. All that storms can do is to destroy; they can grind up and destroy anything. And they would have ground up and destroyed all the bodies, including, of course, the 90-foot fruit tree with its branches, roots, seeds, green leaves, and ripe fruit.

I think it is plain that the only reason suggestions of this kind are advanced is that there is need to support some theory that has been developed to explain some other part of the evidence, some local problem. Moreover there is need, always need, to discredit the evidence that argues for drastic climatic changes.

Naturally the knowledge that the Arctic islands, though they are now in polar darkness much of the year, were in very recent geologic times able to grow the flourishing forests of a temperate climate eliminates any need to insist that they were always as cold as they are today. Thus it is not a question at all of whether the climate grew colder but merely a question of when the change occurred.

Campbell has contributed a suggestion with regard to the alleged floating of hundreds of thousands of bodies across the Nordenskjöld Sea. He notes that bodies ordinarily float because of gas produced by decomposition. Decomposition is at a minimum in very cold water, and therefore bodies ordinarily do not float in very cold water. As an example of this he points to a peculiarity of Lake Superior. The waters of this lake are very cold. There is an old saying in the lake region that "Lake Superior never gives up its dead." The Arctic Ocean is much colder than the waters of Lake Superior. The water of the Lena would not be warm even in midsummer, but during the spring floods—when the Lena would be swollen with the melt water of the winter snows—the water would be frigid, and the bodies of animals drowned in it would not decompose, nor would they float. They would tend to sink, instead, into the nearest hole and perhaps never come to the surface.

4. A Sudden Change of Climate ?

We may reasonably conclude that the climate of Siberia changed at the end of the Pleistocene and that it grew colder. Our problem is to discover what process of change was involved. On the one hand, our theory of displacement of the crust involves a considerable period of time and a gradual movement; on the other hand, the discovery of complete bodies of mammoths and other animals in Siberia, so well preserved in the frozen ground as to be in some cases still edible, seems to argue a cataclysmic change.

To those who, in the past, have argued for a very sudden catastrophe, the specialists in the field have offered opposing theories to explain the preservation of the bodies. One of these was that as the mammoths walked over the frozen ground, over the snowfields, they may have fallen into pits or crevasses and been swallowed up and permanently frozen. Or, again, they might either have broken through river ice and been drowned or have got bogged while feeding along the banks.

There is no doubt that a certain number of animals could have been put into the frozen ground in just the manner suggested above. That this is the explanation for the preservation of the mammoths' bodies generally, however, is unlikely for a number of reasons.

It is not generally realized, in the first place, that it is not merely a matter of the accidental preservation of eighty-odd mammoths and half a dozen rhinoceroses that have been found in the permafrost. These few could perhaps be accounted for by individual accidents, provided, of course, that we agreed that the animals concerned were Arctic animals. The sudden freezing and consequent preservation of the flesh of these animals might be thus explained. But there is another factor of great importance, which has been consistently neglected. It has been overlooked that meat is not the only thing that has to be frozen quickly in order to be preserved. The same is true of ivory. Ivory, it appears, spoils very quickly when it dries out.

Tens of thousands of skeletons and individual bones of many kinds of animals have been discovered in the permafrost. Among them have been found the enormous numbers of mammoths' tusks already mentioned. To be of any use for carving, tusks must either come from freshly killed animals or have been frozen very quickly after the deaths of the animals and kept frozen. Ivory experts testify that if tusks are exposed to the weather they dry out, lose their animal matter, and become useless for carving (280:361-66).

According to Lydekker, about 20,000 pairs of tusks, in perfect condition, were exported for the ivory trade in the few decades preceding 1899, yet even now there is no end in sight. According to Digby, about a quarter of all the mammoth tusks found in Siberia are in good enough condition for ivory turning (113:177). This means that hundreds of thousands of individuals, not merely eighty or so, must have been frozen immediately after death and remained frozen. Obviously it is unreasonable to attempt to account for these

hundreds of thousands of individuals by the assumption of such rare individual accidents as have been suggested above. Some powerful general force was certainly at work. Lydekker gives many hints of the nature of this force in the following passage :

... In many instances, as is well known, entire carcasses of the mammoth have been found thus buried, with the hair, skin and flesh as fresh as in frozen New Zealand sheep in the hold of a steamer. And sleigh dogs, as well as Yakuts themselves, have often made a hearty meal on mammoth flesh thousands of years old. In instances like these it is evident that mammoths must have been buried and frozen almost immediately after death; but as the majority of tusk appear to be met with in an isolated condition, often heaped one atop another, it would seem that the carcasses were often broken up by being carried down the rivers before their final entombment. Even then, however, the burial, or at least the freezing, must have taken place comparatively quickly as exposure in their ordinary condition would speedily deteriorate the quality of the ivory (280:363).

He continues:

How the mammoths were enabled to exist in a region where their remains became so speedily frozen, and how such vast quantities of them became accumulated at certain spots, are questions that do not at present seem capable of being satisfactorily answered; and their discussion would accordingly be useless. ... (280:363).

Lydekker was not alone in feeling the futility of considering these mysterious facts. For many years, in this field as in others, there has been a tendency to put away questions that could not be answered. However, we shall return to his statement. I shall try to show later on how all the details of the phenomena he describes can be made understandable. For the moment, I would like to point out simply that some sort of abrupt climatic change is required. This conclusion is reinforced by the results of recent research in the frozenfoods industry. This has produced evidence that throws additional doubt on the theory of the Preservation of the bodies of mammoths by individual accidents. It seems that the preservation of meat by freezing requires some rather special conditions. Herbert Harris, in an article on Birdseye in *Science Digest*, writes :

What Birdseye had proved was that the faster a food can be frozen at "deep" temperatures of around minus 40 degrees Fahrenheit, the less chance there is of forming the large ice crystals that tear down cellular walls and tissues leaving gaps through which escape the natural juices, nutriment and flavor (202:3).

Harris quotes one of Birdseye's engineers as saying :

... take poultry giblets; they can last eight months at 10 below zero, but "turn" in four weeks above it. Or lobster. It lasts 24 months at 10 below but less than twenty days at anything above. ... (202:5).

In the light of these statements the description of the frozen mammoth flesh given by F.F. Herz is very illuminating. Quoted by Bassett Digby in his book on the mammoth, Herz said that "the flesh is fibrous and marbled with fat" It "looks as fresh as well frozen beef." And this remark is made about flesh known to have been frozen for thousands of years ! Some people have reported that they have been made ill by eating this preserved meat, but occasionally, at least, it is really perfectly edible. Thus Joseph Barnes, former correspondent of the New York *Herald Tribune*, remarked on the delicious flavor of some mammoth meat served to him at a dinner at the Academy of Sciences in Moscow in the 1930s (24).

What Birdseye proved was that meat to remain in edible condition must be kept very cold—not merely frozen, but at a temperature far below the freezing point. What the edible mammoth steaks proved was that meat had been so kept in at least a few cases for perhaps 10,000 to 15,000 years in the Siberian tundra. It is reasonable to suppose that the same cause that was responsible for the preservation of the meat also preserved the ivory and therefore that tens or hundreds of thousands of animals were killed in the same way.

How can such low temperatures for the original freeze be reconciled with the idea of individual accidents unless at least the animals died in the middle of the winter ? It is quite certain that such temperatures could never have prevailed at the surface or in mudholes during "spring freshets." Ripe seeds and buttercups found in the stomach of one of the mammoths, to be discussed later, showed that his death took place in the middle of the summer. It is obvious that during the summer the temperature at the top of the permafrost zone was and is 32° F. or 0° Centigrade, neither more nor less, since by definition that is where melting begins. And from that point down there would be only a relatively gradual fall in the prevailing temperature of the permafrost.

Even if mammoths died in the winter, it is difficult to see how very many of them could have become well enough buried to escape the warming effects of the thaws of thousands of springs and summers, which would have rotted both the meat and the ivory unless there was a change of climate.

The theory that mammoths may have been preserved by falls into pits or into rivers encounters further objections. Tolmachev, the Russian authority, pointed out that the remains are often found at high points—on the highest points of the tundra (412:51). He notes that the bodies are found in frozen ground, not in ice, and that they must have been buried in mud before freezing. This presents a serious problem because, he says,

... As a matter of fact, the swamps and bogs of a moderate climate with their treacherous pits, in northern Siberia, owing to the permanently frozen ground, could exist only in quite exceptional conditions (412:57).

Howorth remarked on this same problem :

While it is on the one hand clear that the ground in which the bodies are found has been hard frozen since the carcasses were entombed, it is no less inevitable that when these same carcasses were originally entombed, the ground must have been soft and unfrozen. You cannot thrust flesh into hard frozen earth without destroying it (225a:313).

Since Tolmachev can think of no other solution to this problem, he finds himself forced to conclude that the mammoths got trapped in mud when feeding on river terraces. We have seen that this conflicts seriously with the conditions of temperature required for the preservation of the meat, whether they were feeding on the terraces during the summer, when presumably the fresh-grass supply would be available there, or whether they were shoving aside the heavy snowdrifts during the winter to attempt to get at the dead grass below. For in either case they would fall into unfrozen water, the temperature of which could not be lower than 32° Fahrenheit. Furthermore, if this is the way it happened, why are the animals often found on the highest point of the tundra ?

Thus we see that the further we get into this question the thornier it becomes. We shall have, for one thing, to face the problem of the apparently sudden original freeze. How sudden, indeed, must it have been ? How can we account for it on the assumption of a comparatively slow displacement of the earth's crust ? So far as the first question is concerned, recent research has contributed interesting new data.

Research on the mechanics of the freezing process and its effects on animal tissues has been carried forward considerably since the experiments conducted by Birdseye's engineers. In an article in Science, Maryman summarizes the more recent findings. These are based on extremely thorough laboratory research, and they modify, to some extent, the Birdseye findings.

Meryman shows that initial freezing at deep temperatures is not required for the preservation of meat. On the contrary, such sudden deep freeze may destroy the cells. He remarks, "Lovelock considers -5° C. as the lowest temperature to which mammalian cells may be slowly frozen and still survive." Furthermore the tissues survive gradual freezing very well :

In most, if not all, soft tissue cells there is no gross membrane rupture by slow freezing. Even though it is frozen for long periods of time, upon thawing the water is reabsorbed by the cells, and their immediate histological appearance is often indistinguishable from the normal (304:518-19).

It appears that what damages the cells is dehydration, caused by the withdrawal of water from them to be incorporated in the ice. This process goes on after the initial freezing :

... The principal cause of injury from slow freezing is not the physical presence of extracellular ice crystals, but the denaturation incurred by the dehydration resulting from the incorporation of all free water into ice (ibid.).

There are only two known ways, according to Meryman, to prevent this damage. First, "... the temperature may be reduced immediately after freezing to very low, stabilizing temperatures." The other way is artificial; it consists of using glycerine to bind water in the liquid state, preventing freezing.

Meryman shows that once the temperature has fallen to a very low point, it must remain at that point if the frozen product is to escape serious damage. The reason for this is that except at these low temperatures, a recrystallization process may take place in ice, in which numerous small crystals are combined into large ones. The growth of the large crystals may disrupt cells and membranes. He remarks :

At very low temperatures, recrystallization is relatively slow, and equilibrium is approached while the crystals are quite small. At temperatures near the melting point, recrystallization is rapid, and the crystals may grow to nearly visible size in less than an hour (ibid.).

I am reminded, in writing these lines, of my experience in truck gardening. In trying to reduce damage from frost, I often resorted to a method that was effective but mysterious, for I could not understand why it worked. I learned that if the vegetables got frosted—even heavily frosted—they would not be seriously damaged if I could manage to get out before sunrise and thoroughly hose them off, washing away the frost. If, however, the sun should rise before I was finished, the unwashed vegetables would be damaged. It would seem, according to the explanation given by Meryman, that the frost damage was the result of recrystallization of the ice that had formed within the vegetable fibers. Small crystals, growing into large ones in the hour or so before the sun was up far enough to melt them may have caused the damage.

It follows, from this analysis of the mechanics of freezing, that the preservation of mammoth meat for thousands of years may be accounted for by normal initial freezing, followed by a sharp fall in temperature. Whenever the meat was preserved in an edible condition the deep freeze must have been uninterrupted; there must have been no thaws sufficient to bring the temperature near the freezing point.^[1]

Let us now take a closer look at one of these preserved mammoths and see what it may have to tell us.

5. The Beresovka Mammoth

Perhaps the most famous individual mammoth found preserved in the permafrost was the so-called Beresovka mammoth. This mammoth was discovered sticking out of the ground not far from the bank of the Beresovka River in Siberia about 1901. Word of it reached the capital, St. Petersburg. It so happened that, a long time before, word of another mammoth had come to the ears of Tsar Peter the Great. With his strong interest in natural science, the Tsar had issued a ukase ordering that whenever thereafter another mammoth was discovered, an expedition should be sent out by his Imperial Academy of Sciences to study it.

In accordance with this standing order, a group of distinguished academicians entrained at St. Petersburg and proceeded to the remote district of Siberia where the creature had been reported. When they arrived they found that the wolves had chewed off such parts of the mammoth as projected aboveground, but most of the carcass was still intact. They erected a structure over the body and built fires so as to thaw the ground and permit the removal of the remains. This process was hardly agreeable, since, the moment the meat began to thaw, the stench became terrific. However, several academicians remarked that after a little exposure to the stench, they became used to it. They ended by hardly noticing it.

Eventually the body of the entire mammoth was removed from the ground. The academicians, meantime, made careful observations of its original position. They saw evidence that, in their opinion, the mammoth had been mired in the mud. It looked as if its last struggles had been to get out of the mud, and as if it had frozen to death in a half-standing position. Strangely enough, the animal's penis was fully erect. Two major bones, a leg bone and the pelvic bone, had been broken as if by a fall. There was still some food on the animal's tongue and between his teeth, indicating an abrupt interruption of his last meal. The preliminary conclusion suggested by these facts was that the animal met his death by falling into the river.^[2]

Very special interest attached to the analysis of the contents of this animal's stomach. These consisted of about fifty pounds of material, largely undigested and remarkably well preserved. While the foregoing data were obtained from a translation of parts of the report of the academicians, published by the Smithsonian Institution, the section dealing with the stomach contents was specially translated for this work by my aunt, Mrs. Norman Hapgood. Since there are many interesting points essential to an understanding of the question, which can be noted only by a reading of the report itself and which do not figure in the published accounts, I reproduce the stomach analysis by V.N. Sukachev, with omission of technical botanical terms where possible, and with omission of bibliographical references to Russian, German, and Latin sources, and some shortening of the comment (400).

We can definitely establish the following types of plants in the food in the stomach and among the teeth of the Beresovka mammoth [Latin names are those of the Russian text]:

a. *Alopecurus alpinus* sin. The remains of this grass are numerous in the contents of the stomach. A significant portion of it consists of stems, with occasional remnants of leaves, usually mixed in with other vegetable remains. ... All these remains are so little destroyed that one is able to establish with exactitude to what species they belong. ...

Measurements of the individual parts of these plants, when compared with the varieties of the existing species, showed that the variety contained in the food was more closely related to that now found in the forest regions to the south of the tundra than to the varieties now found in the tundra. Nevertheless, this is an Arctic variety and is widely spread over the Arctic regions, in North America and Eurasia. However, in the forested regions it runs far to the south.

b. *Beckmannia eruciformis* (L.) Host. The florets of this plant are numerous in the contents of the stomach and usually are excellently preserved. [The detailed description of the remains (with precise measurements in millimeters) shows the species to be the same as that of the present day, although a little smaller, which may be the result of compaction in the stomach. At the present time the species is widely prevalent in Siberia and in the Arctic generally. It grows in flooded meadows or marshes. It is also found in North America, the south of Europe, and a major part of European Russia (although it has not been reported from northern Russia), almost all of Siberia, Japan, North China, and Mongolia.]

c. *Agropyrum cristatum* (L.) Bess. Remains of this plant are very numerous in the contents of the stomach. [They are so well preserved that there is no doubt as to the exact species. The individual specimens are slightly smaller than those of the typical more southern variety growing today, but this could be the result of some reduction of size because of pressure in the stomach, which is noted in other cases.]

The finding of these plants is of very great interest. Not only are they scarcely known anywhere in the Arctic regions, they are even, so far as I have been able to discover, very rare also in the Yakutsk district. ... Generally speaking the *Agropyrum cristatum* L. Bess is a plant of the plains (steppes) and is widespread in the plains of Dauria. ... The general range of this plant includes southern Europe (in European Russia it is adapted to the plains belt), southern Siberia, Turkestan, Djungaria, Tian-Shan, and Mongolia.

Nevertheless, the variety found in the stomach differs slightly from both the European and Oriental-Siberian varieties found today.

d. *Hordeum violaceum* Boiss. et Huet. [After a detailed anatomical description of the remains of this plant in the stomach contents, the writer continues.] Our specimens are in no particular different from the specimens of this species from the Yakutsk, Irkutsk, and Transbaikal districts. [The plant is, apparently, no longer found along the Lena River, except south of its junction with the Aldan River. It is found in dry, grassy areas. It is not found in the Arctic regions.] Its northernmost point is apparently Turochansk. ... Generally speaking, in Siberia this plant is a meadow plant and is also found in moister places in the plains.

e. *Agrostis sp.* ... it does not appear possible to identify the species positively. [Apparently, no plant precisely similar is known at the present day. Thus it may represent an extinct form.]

f. *Gramina gen. et sp.* A grass, but preservation is not good enough to allow any more precise identification.

g. *Carex lagopina Wahlenb.* The remains of this sedge are numerous in the contents of the stomach. [The specimens exactly resemble varieties growing today. The measurements show no reduction in size. Its range extends to the shores of the Arctic Ocean. It is found in mountainous regions, including the Carpathians, Alps, and Pyrenees. It is also found in the peat bogs of western Prussia, in Siberia as far south as Transbaikalia and Kamchatka, in eastern India, North America, and the southern island of New Zealand.]

h. [Omitted—apparently a numbering error in the text.]

i. *Ranunculus acris L.* [The specimens in the stomach did not permit identification of the precise variety of this buttercup, though pods equally large are occasionally found.] The general range of this plant is very great. It includes all Europe and Siberia, it stretches to the extreme north, spreads to China, Japan, Mongolia, and North America. However, over this area this species very much deteriorates into many varieties which are considered by some to be independent species. [This plant grows in rather dry places. It is not at present found growing together with the *Beckmannia Eruciformis*, although it is found with it in the stomach.]

j. *Oxytropis sordida (Willd) Trant.* In the contents of the stomach were found several fragments of these beans. ... In the fragments taken from the teeth there were found eight whole bean pods in a very good state of preservation; they even in places retained five beans. ... [The plant is now found in Arctic and sub-Arctic regions, but also in the northern forests. It grows in rather dry places.]

In addition to the nine species mentioned above, and described in the report, with numerous measurements, the author reports that two kinds of mosses were identified in the stomach contents by Professor Broterus, of Finland. There were five sprigs of *Hypnum fluitans (Dill.) L.* and one sprig of *Aulacomnium turgidum (Wahlenb.) Schwaegr.* The first is common in Siberia north of the 61st parallel of latitude and to the marshlands of northern Europe. Both of them "belong to species widely distributed over both the wooded and the tundra regions."

The report states, further, that another scientist, F.F. Herz, brought back several fragments of woody substances and bark from beneath the mammoth, and of the species of vegetation among which it was lying. Very surprisingly, these were found to differ in a marked degree from the contents of the stomach. A larch (*Larix sp.*) was finally identified, but the genus only, not the species.

Another tree identified in a general way was *Betula Alba L.s.I*, but the exact species could not be determined. The same was true of a third tree, *Alnus sp.* "All three of these kinds grow at present in the Kolyma River basin, and along the Beresovka, as they are widespread in general from the northern limits of the wooded belt to the southern plains."

The general conclusions reached in the report are as follows :

- a. The remains of plants in the mammoth's mouth, between its teeth, were the same as the stomach contents, and represented food the mammoth had not yet swallowed when it was killed.
- b. The food consisted preponderantly of grasses and sedge. "No remains at all of conifers were found." Therefore, "One may conclude that the Beresovka mammoth did not, as was previously thought, feed mainly on coniferous vegetation but mainly on meadow grasses." Evidently he wandered into low, moist places and also into higher, drier places such as are now found in the same region.
- c. "The finding of the wood remains under the mammoth, and even the cliff itself where the mammoth was lying, suggest that he was not feeding in the place where he died. The majority of the vegetation in his food did not grow along cliffs or in conjunction with species of trees."
- d. The discovery of the ripe fruits of sedges, grasses, and other plants suggests that "the mammoth died during the second half of July or the beginning of August."

6. The Interpretation of the Report

A vital prerequisite for any correct interpretation of the facts in this case is information on the age of the mammoth. This information was not available when the first edition of this work went to press, but is now at hand. It comes as a great surprise to those, like myself, who assumed that the mammoth must have died during the time that Siberia was moving northward in accordance with the crustdisplacement hypothesis; that is, between approximately 12,000 and 18,000 years ago. The age of the mammoth, however, turns out to be at least 39,000 years, and possibly as much as 47,500 years.

Where does this leave us ? Can we fit this into our scheme ? It appears from this timing (which there is no reason to doubt) that the Beresovka Mammoth died when the climate in Siberia was warming up—after the pole had left the Greenland Sea and migrated to

America. His death occurred at a time when we would assume that there was a high turbulence of climatic conditions, and when the level of earthquakes and volcanic eruptions would be at a peak. Since the warming of the climate had probably been going on for several thousand years herds of mammoths and other animals would have been moving northward into areas where the grasslands and forests had been reestablished.

And it was in the middle of this warming trend in Siberia, when the climate was warmer there than it is now, and right in the middle of the summer, that the mammoth died, and his body was immediately frozen ! And somehow or other it remained frozen all through the period of about 30,000 years when we have shown through much evidence that the Arctic Ocean was warm and luxuriant forests were growing along the Arctic coasts.

The evidence for the warm Arctic that we have presented in earlier chapters is overwhelming, and it tics in with the evidence we have produced for a warm Antarctic at the same time. It cannot be dismissed just because one mammoth (and a few other animals—see the table below) wanted to stay frozen for the whole period that the Arctic was warm. But it certainly is not easy to see how those bodies could have been kept in deep freeze for such a length of time when the climate of the region where they lay entombed was warm. Offhand one would be tempted to shout that the thing was impossible.

Of course there has to be a way out. Three or four bodies are not going to bulldoze us into giving up the assumption of the warm Arctic that is supported by so much evidence.

But if we are going to hold to our assumption of a warm Arctic, how are we going to explain the Beresovka Mammoth ? Perhaps we can do it this way :

The evidence shows that the animal suffered a very severe fall, severe enough to break his pelvis and leg. We learn also that the food in his stomach and mouth did not match the vegetation around him at the spot where he was found. He did not fall into water, because, as was ascertained by another investigator,^[3] large masses of his blood were found under him. The blood would, of course, have been washed away had he tumbled into a river. The fact that his penis was found to be erect indicates that he was not instantly killed by his fall, but that he froze to death. He was certainly plunged suddenly into extreme cold.

I think we can see how this might have happened. With a high level of earthquake activity large fissures could be opening in the crust in considerable numbers, as they commonly do in many earthquakes. Let us assume that the mammoth fell into one of these.

We must remember that according to our theory a long period of intense cold had gripped the Siberian coast until only a short while before. This would have been the time of the pole position in the Greenland Sea. The situation of the pole just north of Norway

would have logically involved an ice age in the region of the Beresovka River. The frozen ground, or permafrost, of this ice age might have extended down thousands of feet, as it does today in some places in the Arctic. When the pole moved to Hudson Bay the climate in the Beresovka region would have become about like that of Minnesota today, where the winters are severe enough to prevent, or greatly delay, the deep melting of a permafrost extending down thousands of feet.

We may suggest, then, that the Beresovka Mammoth fell into a deep crevasse or fracture in the earth's crust, perhaps several hundreds of feet deep. He might have tumbled down a sloping wall of the crevasse a long way without actually killing himself, but of course at the bottom loose earth dislodged by his fall could have cascaded down upon him and buried him alive. According to biologists I have consulted the erection of the penis could have resulted from the poor animal's emotions of terror and from his pain.

The mammoth might have frozen to death and afterwards been gradually frozen through in the manner I have suggested in the preceding pages. The fissure would very likely have been largely filled in as the result of continuing earth shocks, landslides and the like, and then gradually the temperature of the body would have been reduced to the low temperatures prevailing deep in the permafrost.

And what of that great fissure ? What is the existing evidence of it ? Why, the valley of the Beresovka River itself ! The valley, or channel, of the present river may have been created by the filling in of the fissure.

But how then, you may ask, did the mammoth come to the surface? The answer may be that erosion in the valley was rapid during the ensuing warm period because the river must have been much better fed by its tributaries then than it is now. Moreover it is generally thought that the coast stood higher then, than now, so that the New Siberian and Liakov Islands were connected with the mainland. The result of these factors would probably have been that the river was much larger and flowed much faster than now, and consequently in the 30,000 years or so of the warm period could have eroded the valley to a very considerable depth.

The Beresovka Mammoth, and the other bodies we have of about the same age, might thus have been brought nearer the surface but not actually uncovered until after the climate again grew cold with another poleward shift of Siberia.

The following table shows that warming periods after glaciations—that is, after crust displacements—have been just as fatal to species of animals as periods of increasing cold. I feel that this is because they succumbed to the turbulence of the climate, to the furious storms, to the abrupt changes of temperature caused by massive volcanism, to hurricanes, dust storms, torrential rains and unseasonable snows that probably decimated their food supplies. In America, after all, the horse, mastodon, mammoth and other ice-age animals died out as the climate was warming up. We shall see in the next chapter that cold climate had nothing whatever to do with the massive extinctions of animals in South America at the same time.

Of course, most of the animals found frozen in the Arctic do date, as Table 20 shows, from the end of the Wisconsin glaciation to the time when we assume Siberia was moving northward, and the refrigeration of the climate does account for the good preservation of the mammoth ivory. At the same time, the turbulence of the climatic conditions accounts for the fact that few entire bodies are found. The remains are for the most part just bones scattered about and piled in great heaps, together with heaps of frozen trees. These contribute an air of violence and tragedy to the endless reaches of the desolate tundra.

Table 20 -- not here

7. Storm !

I have referred to the possibility that the extinction of animals and preservation of their bodies may be accounted for in part by violent atmospheric disturbances, and I have offered some evidence that such disturbances did accompany the last displacement of the crust and therefore, presumably, earlier displacements.

It may be hard to distinguish between the effects on animal life of ice action (that is, of being melted out of glaciers and subjected to the action of glacial streams) and the effects of atmospheric factors. Nevertheless perhaps some evidence of the operation of the atmospheric factors is available.

The evidence is presented, in part, by Professor Frank C. Hibben in *The Lost Americans*, and since his description of the evidence is firsthand and is presented so clearly, I have asked his permission to reproduce the pertinent passages.

He begins with a general description of the Alaskan muck, in which enormous quantities of bones (and even parts of bodies) are found :

In many places the Alaskan muck is packed with animal bones and debris in trainload lots. Bones of mammoth, mastodon, several kinds of bison, horses, wolves, bears, and lions tell a story of a faunal population. ...

The Alaskan muck is like a fine, dark gray sand. ... Within this mass, frozen solid, lie the twisted parts of animals and trees intermingled with lenses of ice and layers of peat and mosses. It looks as though in the midst of some cataclysmic catastrophe of ten thousand years ago the whole Alaskan world of living animals and plants was suddenly frozen in midmotion in a grim charade. ...

Throughout the Yukon and its tributaries, the gnawing currents of the river had eaten into many a frozen bank of muck to reveal bones and tusks of these animals protruding at all levels. Whole gravel bars in the muddy river were formed of the jumbled fragments of animal remains. ... (212:90-92).

In a later chapter Hibben writes :

The Pleistocene period ended in death. This is no ordinary extinction of a vague geological period which fizzled to an uncertain end. This death was catastrophic and all-inclusive. ... The large animals that had given their name to the period became extinct. Their death marked the end of an era.

But how did they die ? What caused the extinction of forty million animals ? This mystery forms one of the oldest detective stories in the world. A good detective story involves humans and death. These conditions are met at the end of the Pleistocene. In this particular case, the death was of such colossal proportions as to be staggering to contemplate. ...

The 'corpus delicti' of the deceased in this mystery may be found almost everywhere ... the animals of the period wandered into every corner of the New World not actually covered by the ice sheets. Their bones lie bleaching on the sands of Florida and in the gravels of New Jersey. They weather out of the dry terraces of Texas and protrude from the sticky ooze of the tar pits of Wilshire Boulevard in Los Angeles. Thousands of these remains have been encountered in Mexico and even in South America. The bodies lie as articulated skeletons revealed by dust storms, or as isolated bones and fragments in ditches or canals. The bodies of the victims are everywhere in evidence.

It might at first appear that many of these great animals died natural deaths; that is, that the remains that we find in the Pleistocene strata over the continent represent the normal death that ends the ordinary life cycle. However, where we can study these animals in some detail, such as in the great bone pits of Nebraska, we find literally thousands of these remains together. The young lie with the old, foal with dam and calf with cow. Whole herds of animals were apparently killed together, overcome by some common power.

We have already seen that the muck pits of Alaska are filled with the evidences of universal death. Mingled in these frozen masses are the remains of many thousands of animals killed in their prime. The best evidence we could have that this Pleistocene death was not simply a case of the bison and the mammoth dying after their normal span of years is found in the Alaskan muck. In this dark gray frozen stuff is preserved, quite commonly, fragments of ligaments, skin, hair, and even flesh. We have gained from the muck pits of the Yukon Valley a picture of quick extinction. The evidences of violence there are as obvious as in the horror camps of Germany. Such piles of bodies of animals or men simply do not occur by any ordinary natural means. ... (212:168-70).

It is evident that the animals that were killed far to the south, in Florida, Texas, Mexico, and South America, cannot have been contained in any ice cap, whether thin or thick. Hibben suggests that other factors were at work :

One of the most interesting of the theories of the Pleistocene end is that which explains this ancient tragedy by world-wide, earthshaking volcanic eruptions of catastrophic violence. This bizarre idea, queerly enough, has considerable support, especially in the Alaskan and Siberian regions. Interspersed in the muck depths and sometimes through the very piles of bones and tusks themselves are layers of volcanic ash. There is no doubt that coincidental with the end of the Pleistocene animals, at least in Alaska, there were volcanic eruptions of tremendous proportions. It stands to reason that animals whose flesh is still preserved must have been killed and buried quickly to be preserved at all. Bodies that die and lie on the surface soon disintegrate and the bones are scattered. A volcanic eruption would explain the end of the Alaskan animals all at one time, and in a manner that would satisfy the evidences there as we know them. The herds would be killed in their tracks either by the blanket of volcanic ash covering them and causing death by heat or suffocation, or, indirectly, by volcanic gases. Toxic clouds of gas from volcanic upheavals could well cause death on a gigantic scale. ...

Throughout the Alaskan mucks, too, there is evidence of atmospheric disturbances of unparalleled violence. Mammoth and bison alike were torn and twisted as though by a cosmic hand in Godly rage. In one place, we can find the foreleg and shoulder of a mammoth with portions of the flesh and the toenails and the hair still clinging to the blackened bones. Close by is the neck and skull of a bison with the vertebrae clinging together with tendons and ligaments and the chitinous covering of the horns intact. There is no mark of a knife or cutting instrument. The animals were simply torn apart and scattered over the landscape like things of straw and string, even though some of them weighed several tons. Mixed with the piles of bones are trees, also twisted and torn and piled in tangled groups; and the whole is covered with fine sifting muck, then frozen solid.

Storms, too, accompany volcanic disturbances of the proportions indicated here. Differences in temperature and the influence of the cubic miles of ash and pumice thrown into the air by eruptions of this sort might well produce winds and blasts of inconceivable violence. If this is the explanation of the end of all this animal life, the Pleistocene period was terminated by a very exciting time indeed (212:176-78).

In Chapter IX we saw that volcanic eruptions, possibly on a great scale, are a corollary of any displacement of the crust; therefore our theory strongly supports and reinforces the suggestions advanced by Hibben, and at the same time his evidence strongly supports our theory. But Hibben points out certain consequences that would flow from our theory, which I have not stressed. Wherever volcanism is very intensive, toxic gases could locally be very effective in destroying life. This is also true of violent local windstorms. Massive volcanic eruptions might, of course, occur anywhere on earth during a movement of the crust, and we saw, in Chapter IX, that they apparently occurred in a good many places, some of them far removed from the ice sheets themselves.

Despite the unquestionable importance of these locally acting factors, it seems that we must give much greater importance to the meteorological results of the universally acting volcanic dust. As we have noted, this dust has a powerful effect in reducing the average temperatures of the earth's surface. A sufficient fall in temperature could easily wipe out large numbers of animals, either directly or by killing their food or even by favoring the spread of epizootic diseases. Then the dust could greatly increase rainfall, which, in certain circumstances would produce extensive floods, thus drowning numbers of animals and perhaps piling their bodies in certain spots. As already mentioned, the dust would also act to increase the temperature differences between the climatic zones (the temperature gradient), thereby increasing, perhaps very noticeably, the average wind velocities everywhere. Violent gales, lasting for days at a time and recurring frequently throughout the year, might raise great dust storms in which animals might be caught and killed by thirst or suffocation. It must not be forgotten that, at the same time, changes in land elevations would be in progress, and these also would be affecting the climate and the availability of food supplies. The gradual character of these changes would be punctuated at times by the abrupt release of accumulating tensions in the crust, accompanied by terrific earthquakes and by sudden changes of elevation locally amounting perhaps to a good many feet, which also could be the cause of floods either inland (by the sudden damming of rivers) or along the coasts. There is, as a matter of fact, as already mentioned, much evidence of turbulence throughout the world during the last North American ice age, not only in the air but in the sea.

It is little wonder that, faced by all these unpleasant conditions, a good many species in all parts of the world, even very far from the ice caps, gave up the struggle for existence.

In conclusion, it appears to me that the whole mass of the evidence relative to the animal and plant remains in the Siberian tundra, interpreted in the light of the evidence from North America, sufficiently confirms the conclusion that there was a northward displacement of Siberia coincident with the southward displacement of North America at the end of the last North American ice age.

chapter 11

THE EVIDENCE OF VIOLENT EXTINCTION IN SOUTH AMERICA

by J.B. Delair and E.F. Oppé

In the foregoing chapters the whole of North America and Siberia have testified to violent physical changes and to the destructive effects of unidentified forces upon a widespread animal population at the end of the Pleistocene Epoch. The evidence from South

America will be found as strong or even stronger. In this chapter we shall present a number of aspects of this evidence. They include evidence of a geological revolution having to do not so much with ice caps and ice ages as with the upheaval of half a continent in which the deaths of millions of animals resulted from extensive volcanic eruptions and vast floods. To begin with, we consider the evidence for great changes in the elevation of the high plateau of Peru and Bolivia in very recent time.

1. The Lost Sea of the Andes

Outstanding among the unsolved problems of the recent geological history of South America are those connected with that part of the Cordillera where Bolivia and Peru meet. There, in the heart of the Andes at an average elevation of 12,300 feet, extends the highest lacustrine basin in the world, the Meseta or Altiplano, on the floor of which occurs a succession of remarkable lakes.

The largest of these, Lake Titicaca, is navigable, being some 110 miles long, 35 miles wide and 890 feet deep at the maximum. Its waters are only slightly brackish and support the only species of seahorse (*Hippocampus*) known to live in a land-locked body of water. *Hippocampus* is a typically marine creature and, with *Allorchestes* and a few other oceanic forms inhabiting this lake, strongly suggests that the present fauna of Lake Titicaca has survived from a time when the lake communicated directly with the ocean.

Lake Poöπό, some 180 miles southeast of Titicaca and 12,051 feet above sea level, receives its water from Lake Titicaca via the sluggish Desaguadero River; despite the fact that it is about 50 miles long and 20 miles wide, its greatest depth is a mere 9 feet and its water so salt that fishes reaching it from Titicaca seem unable to propagate in it.

The waters of Poöπό seep seasonally southward through the Lacadahaira River into the shallow, marshy, and very briny Lake Coipasa—12,031 feet above sea level—which has no outlet. It is of very uncertain extent, much of its southern portion forming a vast salt desert some 50 miles by 35 miles in area. Still farther south is the immense salt plain of Uyuni, which, at slightly over 12,000 feet above sea level, is about 80 by 10 miles in area. It is joined in the southwest by a long chain of small salt, saltpeter, and borax lakes and marshes lying on the floor of a winding valley nearly 100 miles in length but only 5 to 8 miles wide (6:15).

The sequence is further defined and its strangeness enhanced by continuing south over the Bolivian border to northwestern Argentina. There another series of salt deserts and large saline marshes reaches southward as far as the southern extremity of Atacama province while in the valley between the eastern slopes of the Cordillera and the Sierra de Cordoba is another succession of enormous salt lakes, the largest of which are Salinas Grandes, Sal de la Rioja, and Pampa de la Salina.

Discussing the salinity of the lakes of the high plateau, Professor Arthur Posnansky of La Paz observed :

Titicaca and Poöπό, lake and salt-bed of Coipasa, salt beds of Uyuni—several of these lakes and salt-beds have chemical compositions similar to those of the ocean (16:23). He pointed out that Lake Titicaca is ... full of characteristic [saltwater] molluscs, such as *Paludestrina* and *Ancylus*, which shows that it is, geologically speaking, of relatively modern origin (*ibid.*).

Hans S. Bellamy, who gave the problem of the salinity of this region very considerable thought, had the following to say :

The region in which the feeders of Lake Titicaca rise consist almost exclusively of old crystalline, and younger volcanic rocks; Triassic formations, from which salt is usually derived through extraction, are markedly absent.

Hence the presence of so much salt in the Bolivian Tableland can only be accounted for by postulating a former connection of the great lacustrine basin with the Ocean, and by assuming the eventual evaporation of this body of water when the connection with the Ocean was at last severed (6:16).

The modern oceanic character of the faunas of these lakes^[1] and the chemical composition of the salt deserts support this conclusion. Additional confirmation is to be found in the *recent age* of the strand-lines left by this ancient sea on the slopes of the mountains enclosing the Altiplano. Bellamy called this body of water the Inter-Andean Sea. Indeed, when H.P. Moon wrote his account of the geology of the region he put great stress on the "... freshness of many of the strand-lines and the modern character of such fossils as occur (41:32)."

A few miles south of Lake Titicaca lies the celebrated ruin site of Tiahuanaco, a collection of shattered edifices of some ancient civilization, itself outside the present inquiry but bearing very definitely upon the radical changes which have occurred throughout the Altiplano within geologically very recent times. Of these ruins A. Hyatt Verrill wrote :

Although the ruins are now over thirteen miles from Lake Titicaca there are reasons to think that in the days when the city was occupied it stood on the shores of the Lake itself or on an arm, or bay, for traces of what was apparently a dock or mole are to be seen just north of the principal ruins. If so the lake has receded ... (52:260).

Bellamy refers to a "canal" which appears to have surrounded the principal group of ruins at Tiahuanaco, including the structure referred to hereafter as the "fortress" (6:51) and adds :

Some explorers of the site of Tiahuanaco are of the opinion that the "canal" was, at most, only a "dry-moat," and hence will not concede that the peculiar rectangular depressions near the ruins were once actual docks or harbour basins.

But the proofs in favour of our assertion that Tiahuanaco was once a harbour-town are stronger than any of the objections put forward by more superficial observers.

Firstly : there is a rapid fall in level from the edge of the territory which bears culture-remains to the floor of the territory which we say was covered by the waters of the Inter-Andean Sea. ... The difference in level is about 35 feet north of Tiahuanaco proper. ...

Secondly : while the soil of the territory which we say was above the water-level contains numerous ceramic fragments and other remains, the former sea-bottom yields practically nothing but the stone-rings with which the fishermen of that time used to weight their nets.

Thirdly : the "dumps" of roughly squared stone blocks [with which the edifices at Tiahuanaco were built] are found only on territory which formerly was sea-bottom (*op. cit.*, 177).

Bellamy concluded from this last fact that the builders of Tiahuanaco, who obtained their material from quarries many miles distant—for structures which in their skilled and accurate masonry alone remain a mystery—floated their stone blocks in a roughly squared condition on large rafts and that the foundering of these occasionally would leave "dumps" of, in effect, raw material where now found. He made another observation of like force :

Moreover, the "dry-moat" must have been a water-bearing canal because the great sewer, which drained the overflow of the pond on the platform of the "fortress" of Akapana discharged into it (*ibid.*).

The salient proof, and one wholly relevant in present review, that Tiahuanaco possessed a waterfront rests upon discernible traces of alkaline incrustations on the sides of the huge stone blocks forming a part of the above-described mole, harbor-basin, or canal wall.

The line of these incrustations corresponds closely with that of the strand-line on the slopes of the surrounding mountains, about which Bellamy wrote :

It was carefully surveyed for a length of about 375 miles.

And then it was established that it is not "straight." It was found that the Inter-Andean Sea ... was not merely a Lake Titicaca of higher level extending far to the south, but that its level showed a slant of a most peculiar character in relation to the present ocean-level, or, which amounts to the same, relative to the present level of Lake Titicaca.

The level of the Inter-Andean Sea revealed by the ancient ... strandline was higher to the north of Tiahuanaco and lower to the south. The actuality of this peculiarity cannot be doubted, for it was established independently by different persons at different times, using different methods of surveying.

The northernmost point at which the former strand-line of the Inter-Andean Sea ... has been surveyed is on the mountain-slopes near Sillustani and to the west of Lake Umayo in the Peruvian department of Puno.

There the former littoral is about 295 feet above the present level of Lake Titicaca, whose surface is 12,506 feet above sea-level.

At Tiahuanaco, at the southern end of Lake Titicaca, the same strandline is 90 feet above the level of that great sheet of water, and 4 feet below the coping stones of the parapets of the long-dry harbours and docks and canals of that mysterious metropolis. The ancient strand-line and the ruined prehistoric city are linked beyond any doubt.

The height of the strand-line relative to the ocean-level decreases the further south we go. At the northern end of Lake Poöπό on the mountain slopes south of Oruro it is 12,232 feet above sea-level, or 181 feet above the level of Lake Poöπό, or 274 feet below the level of Lake Titicaca, or 364 feet below the level of the same ancient strand-line in the latitude of Tiahuanaco.

Still further south, it is discernible just a few feet above the level of Lake Coipasa. It becomes lost in the Salt Desert of Uyuni some 12,300 feet above sea-level.

From Sillustani to beyond Lake Coipasa, a distance of about 375 miles, the strand-line dips about 800 feet.

A peculiarity of the dip is that it seems to be progressive. In the first quarter of the distance it is only about a foot and a quarter per mile, while in the last fourth it increases to more than two feet per mile. ...

The strand-line ... is very distinct. It consists not only of notches cut into the rock by the prolonged action of shore waves, and of fanlike delta deposits of mud and gravel which former streams dropped on meeting the ancient water's edge, but chiefly of conspicuous deposits of white lime, of a thickness of many feet, upon the red sandstone, or brown porphyry and amorphous slate, or grey granite and andesite.

This white streak, which is drawn along the slopes of the mountain chains surrounding the Altiplano, and visible on the islands of Lake Titicaca like a chalk-line, is the residue of certain calcareous algae, chiefly of *alga characea*.

This lowly organized plant, which contains about 80 per cent of lime, is still found growing in certain shallow shore parts of Lake Titicaca. It only thrives in slightly muddy water down to a depth not exceeding three feet (*op. cit.*, 58-60).

The phenomenon of this slanting strand-line is generally thought to be due to an "imbalanced rise" of South America out of the waters of the ocean. These forces, it has been argued, lifted the continent to a greater height in the north than in the south, thus explaining why the level of the former Inter-Andean Sea is not parallel with that of either Lake Titicaca or the present ocean.

On the basis of paleontological and hydrological evidence, Bellamy believed that in geologically recent time the whole Cordillera was violently upheaved, and the Inter-Andean Sea thereby caused to vanish, the remnants of which have, over long periods of time, shrunk to their present vestigial condition.

Remarkable confirmation of the immensity of this uplift is represented by the ancient agricultural stone terraces surrounding the Titicaca basin. These structures, belonging to some bygone civilization, occur at altitudes far too high to support the growth of crops for which they were originally built. Some rise to 15,000 feet above sea level, or about 2,500 feet above the ruins of Tiahuanaco, and on Mt. Illimani they occur up to 18,400 feet above sea level; that is, above the line of eternal snow (46:39).

Posnansky, who described these terraces as *practically endless*, concluded that the entire Altiplano region was formerly at a much lower level than at present (46:39).^[2] It is clear, however that other areas of the Cordillera underwent profound changes also; Dr. E. Huntington noted from aerial survey photographs of arid and desert regions in Peru : ... an unexpected number of old ruins, and an almost incredible number of terraces for cultivation (30:578), showing how some ancient race had cultivated formerly fertile tracts, now absolutely desiccated.

2. The Pleistocene Graveyards of South America

The discoveries of vast quantities of animal remains in almost every part of South America have invariably been made in recent formations. As long ago as 1887 Sir Henry H. Howorth in his monumental work, *The Mammoth and the Flood*, an enlarged version of an earlier paper dated 1881 (225a), summarized our knowledge of these beds as follows :

In South America the Pleistocene beds are developed on a very large scale. They cover plains of the Argentine Republic, in the form of modified loess or loess, to which the name Pampas mud was given by Darwin and "formation Pampeana" by D'Orbigny.

In other places they exist in the form of beds of gravel and clay, and occasionally as beds of tuff. As in Europe and North America, we also meet with caverns of Pleistocene age, many of which have been explored in Brazil by Land, Claussen, Bravard and Liais. The distribution of these beds is exceedingly widespread over South America.

According to Burmeister, they are richest in organic remains in the province of Buenos Aires, becoming less rich as we travel westward and northward. Rich deposits of this age have also been found in the Banda Oriental, at various points on the river Parana, and at Berrero in Patagonia.

Burmeister says, "the diluvial deposit containing bones of animals of this age extends over the whole Brazilian plain, from the flanks of the Cordilleras to the borders of the Atlantic." They have also been found abundantly in Bolivia on the great plateau; and also west of the mountains both in Peru and Chile.

From Caracas in the north, to the sierra of Tandiel in Patagonia in the south, they have, in fact, occurred in more or less abundance over the whole continent.

In the great Argentine plain they are found close to the sea-level, while in Bolivia they occur, according to D'Orbigny, at a height of 4000 metres, and they are found with a singular similarity if not uniformity of contents in all latitudes.

That the surface beds of the Pampas and the deposits in the caves were synchronous; is admitted by all explorers. The same creatures are found in both, of course in different proportions, as is the case elsewhere.

Nor is there any doubt that both sets of beds date from the same horizon as the Mammoth beds of other countries.

The fauna of the Pleistocene beds of the Southern States of North America is, in fact, largely identical with that from the beds we are now discussing; the megatherium and mylodon, the tapir and capybara, the mastodon and horse, &c., &c.; being found in both, and every observer, from Darwin to Burmeister, is agreed in assigning them to the same horizon (29:325-6).

Historically the bones of Pleistocene mammals, especially those of the larger genera, were noticed in South America soon after the Spanish Conquest. Curious theories were advanced by the early discoverers to explain the presence of these bones, usually by

reference to a race of giants who were supposed to have anciently inhabited various parts of the New World. Among the earliest reports is that of Pedro de Cieza de Leon, who wrote :

.... when the most illustrious Don Antonio de Mendoza was viceroy and governor of New Spain, he found certain bones of men who must have been even larger than these giants (11:191).

Cieza traveled through Peru and the adjacent lands from 1532 to 1550. A contemporary, Augustin de Zarate, probably referred to the same discovery when he mentioned that Juan de Holmos, a native of Truxillo, excavating near that place, exhumed enormous teeth, a huge rib, and other bones, all of which were, of course, assigned to the legendary giants (56:ch.iv). Joseph de Acosta recorded, only a little later, the discovery of similarly large bones at Puerto Viego and Manta in Ecuador (1:56).

Some very large mammalian bones, among other finds recorded throughout the seventeenth and eighteenth centuries, were described by Father Guevarra in 1770 (24:8) as occurring in the Paraguayan districts of Argentina and in Paraguay itself. Four years later the Jesuit Father Thomas Falkner referred to the discovery on the banks of the Carcaranan or Tercero River of numerous large bones, some of which evidently belonged to a gigantic species of fossil armadillo. Falkner's description is the earliest we have of this creature's existence.

About 1789 the greater part of the skeleton of an enormous unknown animal, which science was later to identify as the *Megatherium*, was found near Lujan, some 9 miles west of Buenos Aires, Argentina. This skeleton was sent to Madrid—where incidentally it still is; the Danish scholar, M. Abildgaard, published the first scientific notice of it in 1793. In 1795 M. Roume published a longer account (48), greatly amplified in 1796 as part of the text of the first memoir on the skeleton by Garriga and Bru. This memoir was translated from the Spanish original in 1804 by the French comparative anatomist, Baron Georges Cuvier (14), who, although he never personally examined the Madrid skeleton, later wrote a detailed account of its osteology from copies of the engravings illustrating Garriga and Bru's monograph (15:vol.iv).

During the years around the dawn of the nineteenth century when the great Alexander von Humboldt was exploring the Orinoco valley, he found elephant bones embedded in gravel near Cumanacoa in Venezuela (36:547). A little later the same traveler found numerous fossil bones of mastodons near Santa Fe de Bogota, in Colombia, these being especially abundant at a locality known as *Camp des Geants* ("Field of the Giants"). Humboldt also found elephant teeth near Concepción, in Chile, and other fossil bones in the Cordillera de Chiquitos near Santa Cruz de la Sierra (19:13). Some of these remains and an elephant molar found by the same traveler on the volcano of Ibambura, at an elevation of 7,200 feet above sea level, were described by Cuvier in 1812 (15).

With these notices and the discovery during 1795 of another *Megatherium* skeleton in Argentina, the world of natural science was introduced to a hitherto entirely unsuspected mammalian fauna which had flourished in South America during geologically very recent times. Later discoveries were to show that man had been contemporaneous with it.

Not long after the appearance of Cuvier's great work, Professor Charles Lyell was shown in the Museum of the American Philosophical Society at Philadelphia a block of limestone from Santos in Brazil, obtained by Captain Elliot of the U.S. Navy about 1827.

The block contained a human skull, teeth, and other bones, together with fragments of shells, some of which *still retained traces of their original colors*. Remains of several hundred other human skeletons were dug out of similar calcareous tufa at the same place, where the presence of serpulæ in the rock suggested that all the remains were deposited through marine action, for as Lyell observed (38:ii, 200-1), the shell would not have been brought so far inland by natives for food. Dr. C.D. Meigs, who wrote an account of this discovery, said :

Captain Elliot, while riding along the banks of the river Santos on his way from the port of Santos to the town of St. Paul, found a mound three acres in extent and 14 feet high, about 10 miles from the sea and 4 from Santos.

The bones he took with him to America ... were dug from the face of the hill, where it was cut by the wash of the stream, and are parts of one skeleton out of many hundreds that are still lying in their bed of tufa.

They were lying on the rock in an oblique direction, the heads uppermost, and the lower extremities dipping at an angle of from 20° to 25° below the horizon.

Portions of the bones were invested externally with a stalactitic deposit of carbonate of lime, looking very much like a mummified skin. Close to one of the teeth was a serpula and a piece of oyster-shell. The rock in which the skeleton was embedded consisted of fragments of shells united by a stalactitic matter, and contained nodules of carbonaceous matter. ...

A question naturally arises as to the date of that catastrophe which enclosed several hundred individuals in that tufa of the Rio Santos. ...

It seems unlikely that these remains were formally buried by sorrowing friends. It is unlikely that so solid a stone should have been formed at so great a distance from the sea. ... No doubt they are co-existent with the emerged land; they are not to be considered as the results of human industry.

The shore of the Atlantic must have formerly swept nearly in a line with these remarkable deposits. ... Within this bed, or nearer than it to the sea, are found fossil bones of elephants, &c., which cannot be so old as the unfossilized oyster-shells, since they could not have been fossilized anterior to the existence of the soil out of which they are dug, unless you consider them as boulders, which is inadmissible. ... (29:355-6).

In a limestone cavern on the borders of the Lagoa do Sumidouro, some three leagues from Santa Lucia, Dr. P.W. Lund excavated the bones of more than thirty individuals (human) of both sexes and various ages. The skeletons lay buried in hard clay overlying the original red soil forming the floor of the cave and were found mixed together in such great confusion—not only with one another but with the remains of the *Megatherium* and other Pleistocene mammals—as to preclude the idea that they had been entombed by the hand of man. All the bones, whether human or animal, showed evidence of having been contemporary with one another.

In other caves investigated by Lund, bones of ancient men were found alongside those of the formidable *Smilodon*, a giant feline which became extinct during the last Pleistocene times. Referring to the evidence from these and other Brazilian fossiliferous caves, the Marquis de Nadaillac wrote :

... Doubtless these men and animals lived together and perished together, common victims of catastrophes, the time and cause of which are alike unknown (42:25).

Two further cases are of particular interest. The first of these concerns the discovery, by Savage-Landor, of the remains of primitive humanoid mammals, associated with the bones of creatures regarded by him as gigantic saurians, in volcanic ash and lava deposits encountered in Matto Grosso State (34:vol.i, 371-4).

The second case relates to the occurrence of the remains of *mastodons*, *camels*, and an extinct species of horse in beds of volcanic ash high in the Andes near Punin in Ecuador. Associated with these mammalian bones was the fossilized skull of a woman of Australoid type (33:311-2). This cranium, which is dolichocephalous (9:145), was scientifically described in 1925 by Drs. Louis R. Sullivan and Milo Hellman (51) and has since become generally known as the "Punin" skull.

The presence of an Australoid type in Ecuadorian South America during geologically recent times poses questions about prehistoric human populations in the continent, to the solution or partial solution of which the different configuration of South America before, or up to, late Pleistocene times, although conjectural in many respects, may well contribute. The critical importance of the Punin and Matto Grosso discoveries in the present context, however, lies in their stark demonstration that in South America human and animal denizens of the late Pleistocene world were exposed to, and perished by, geological upheavals of inconceivable violence and extent.

3. "Freshness" of Fossil Remains

In abundance of Pleistocene animal fossils South America compares very well with Siberia and North America. Authorities are as one in stressing the freshness of a high proportion of the skeletal remains and associated substances found on a continent mostly within the tropical zone.

Darwin observed, in *Voyage of the Beagle* (1876 edition), that some remains of a large unknown mammal exhumed from Pleistocene deposits in the Banda Oriental district of Uruguay appeared so fresh that :

... it is difficult to believe that they have lain buried for ages underground. The bone contains so much animal matter, that when heated in the flame of a spirit-lamp it not only exhales a very strong animal odour, but likewise burns with a slight flame (*op. cit.*, iii, 181).

Fossil bones when subjected to heat or fire do not ordinarily burn with a flame. Elsewhere Darwin referred to the perfect preservation of even the minutest details of fossil bones dug up at Bahia Blanca. In his description of the skeleton of the giant sloth *Myloodon*, Professor Richard Owen noted a similarly perfect state of preservation as regards the individual bones and concluded that the individual represented must have been buried *almost immediately* upon death. Dr. P.W. Lund also recorded how he found, in a Brazilian cavern, a skeleton of *Scelidotherium oweni*, in which not only did all the bones lie in correct relative position, but they were covered with a cellulose tissue of calcareous matter evidently derived from the petrification of the soft parts of the animal (35:377-383).

From the extensive literature on the subject it is impracticable here either to acknowledge further sources or to extract the many additional examples known of similar burials. Special reference, however, should be made to the undermentioned specimens derived from the Pampas areas, which suggest flood action :

- a. Mammalian skeletons in natural, or *upright*, positions. These are embedded respectively in undisturbed and largely unstratified beds of gravel, loam, or mud.
- b. A skeleton of an adult female *Myloodon* found in a natural posture alongside that of its young one embedded in gravel.

In addition, a markedly high percentage of Megatherium skeletons apparently had lost only their left extremities, suggesting human agency.

In these and other cases it is generally agreed that the individuals perished *before* their carcasses were subjected to the eventful last stages of entombment. Included in this category are the discoveries in the La Pumilla Valley of the carapaces of giant armadillos standing *upright on their edges* in the Pampas mud (8:ii,85). Burmeister, who noted these occurrences, also mentioned that the cuirasses of the great glyptodonts are generally found *reversed*, and that many instances are known of large, though usually incomplete, mammalian skeletons being found upside down, or with their bones manifestly disjointed and scattered within a small space (*ibid.*).

These extraordinary modes of burial are further exemplified by the groups or caches of animal fossils unearthed at widely separated South American localities, in which incongruous animal types (carnivores and herbivores) are mixed promiscuously with human bones. These are found not only in the Pampas formation but also in Brazilian caves and in volcanic ash at Punin and elsewhere. No less significant is the association—over truly widespread areas—of fossilized land and sea creatures mingled in no order and yet entombed in the same geological horizon, and also the occurrence of mastodon remains in the Cordilleras at altitudes impossibly high for their ordinary existence. Clearly these varied, but apparently contemporaneous, burials all over the South American continent are the results of different and relatively localized effects of a single tremendous upheaval, the numerous ramifications of which operated synchronously. In seeking to explain one of these effects, one must explain them all.

4. Theories and Considerations

The aforecited facts, in their full accumulative presentation, are inconsistent with nature's normal disposal of bodies. This has long been recognized, and the mysterious character of the problem has been admitted by the highest authorities. But no comprehensive explanation has been advanced to date which accounts for all the phenomena. Theories ascribing mass animal extermination variously to glacial cold (29:343), colossal sand and wind storms (Bravard), immense floods (Lund and others), volcanic gas (27:47), local river flooding (Burmeister), pestilence and parasitical poisoning (*ibid.*) are not lacking, but none of these has been able to win general acceptance.

Now, however, that it is possible, with the aid of the theory developed in this book, to evaluate the position, who will doubt that South America exhibits part and counterpart of the global convulsion which terminated the Pleistocene world? The reader will not fail to be impressed by the conclusions reached by Alcide d'Orbigny, to whose standing and accuracy tribute must still be paid; he wrote :

It would seem that one cause destroyed the terrestrial animals of South America, and that this cause is to be found in great dislocations of the ground caused by the upheaval of the Cordilleras.

If not, it is difficult to conceive on the one hand the sudden and fortuitous destruction of the great animals which inhabited the American continents, and on the other the vast deposit of Pampan mud.

I argue that this destruction was caused by an invasion of the continent by water, a view which is completely en rapport with the facts presented by the great Pampan deposit, which was clearly laid down by water.

How otherwise can we account for this complete destruction and the homogeneity of the Pampas deposits containing bones ? I find an evident proof of this in the immense number of bones and of entire animals whose numbers are greatest at the outlets of the valleys, as Mr. Darwin shows.

He found the greatest number of the remains at Bahia Blanca, at Bajada, also on the coast, and on affluents of the Rio Negro, also at the outlet of the valley. This proves that the animals were floated, and hence were chiefly carried to the coast.

This hypothesis necessitates that the Pampas mud was deposited suddenly as the result of violent floods of water, which carried off the soil and other superfluous debris, and mingled them together. This homogeneity of the soil in all parts of the Pampas, even in places 200 leagues apart, is very remarkable.

These are not different strata differently coloured, but a homogeneous mass, which is more or less porous, and shows no signs of distinct stratification. The deposit is also of one uniform colour, as if it had been mixed in one muddy flood slightly tinted by oxide of iron.

The bones, again, are only found isolated in the lower strata, while entire animals occur on the circumference or the upper part of the basin. Thus they are very rare at Buenos Aires, while they abound in the Banda Oriental and in the White Bay. Mr. Darwin says they are heaped up in the latter place, which again supports the contention.

Another argument may be drawn from the fact that the Pampas mud is identical in colour and appearance with the earth in which the fossil remains occur in the caverns and fissures of Minas Geraes in Brazil, and the fragments brought by M. Claussen are completely like the others in colour and texture.

My final conclusion from the geological facts I have observed in America is, that there was a perfect coincidence between the upheaval of the Cordilleras, the destruction of the great race of animals, and the great deposit of Pampas mud (21:iii, 3, 82, 85, 86).

Nor will a researcher today withhold agreement with Professor Thomas Henry Huxley, quoted by Howorth, who said in 1869 :

To my mind there appears to be no sort of theoretical antagonism between Catastrophism and Uniformitarianism; on the contrary, it is very conceivable that catastrophes may be part and parcel of uniformity.

Let me illustrate my case by analogy. The working of a clock is a model of uniform action. Good timekeeping means uniformity of action. But the striking of a clock is essentially a catastrophe.

The hammer might be made to blow up a barrel of gunpowder, or turn on a deluge of water, and by proper arrangement the clock, instead of marking the hours, might strike all sorts of irregular intervals, never twice alike in the intervals, force or numbers of its blows.

Nevertheless, all these irregular and apparently lawless catastrophes would be the result of an absolutely Uniformitarian action, and we might have two schools of clock theorists, one studying the hammer and the other the pendulum. (Address to the Geological Society, 1869)





CHARLES HAPGOOD
Social Studies