MODERN EXPLORATION

To my daughter

MARTHA

By the same Author

THE ROMANCE OF GARDENING
PLANT HUNTER'S PARADISE
ASSAM ADVENTURE

MODERN EXPLORATION

by

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FOREWORD

IN a short book of this kind it is not possible to refer to the work of all modern explorers, of whom there are a large number in Britain alone. A few only have been mentioned to illustrate particular points; many who have done valuable work have been omitted, though I am conscious of their worth. But then this does not pretend to be a history of exploration.

If I have paid undue attention to south-east Asian geography in general, and to botanical exploration in particular, that may safely be put down to prejudice and to specialized knowledge. I wish to record my thanks to Dr. A. Brandt and to Miss D. Wilcox for valuable help.

F. K. W.

R.A.F., India
1944

PART ONE

KNOWING THE WORLD

CHAPTER I

EXPLORERS ALL

WE are all explorers nowadays, and the word has lost its savour. No longer is to be an explorer to be a demigod; although a demagogue is often a persistent explorer of every avenue.

At one end of the scale we explore the heavens, at the other end, the atom. In the middle we explore England. From our nursery days when we (quite justifiably) said to one another 'let's explore', and proceeded forthwith to explore the garden, or the new house, or the wood over the way, to a ripe middle age, life seems to have been one long session in the art of exploring the possibilities of the situation.

Let us therefore be quite clear what is meant in this book by exploration. Here it implies geographical exploration in the widest sense. There is such a thing as research, and research implies exploration through the microscope into the infinitely small — or through a telescope into the infinitely great; it also includes the precise handling of substances, as in chemical research, and refined measurement, as in physics. These, however, are static pursuits. As used here, the word exploration means active exploration and implies travel. We must, however, be on our guard against too rigid a definition. There are borderline cases. Research is ruled out. But there need not be much travel involved in, say, the pursuit of archaeology, which I nevertheless put in the very forefront of modern exploration.

This is not a treatise on how to earn one's living as an explorer. Travel may be quite a profitable business, when indulged in by business-minded people. However, the man who puts riches in the forefront of his ambitions will not turn to exploration to gratify them, since in the first place he will never make an explorer, and in the second will never become rich enough. The popular travellers of the day who monopolize the rationed limelight and make of travel a financial success will learn nothing here.

There is of course nothing ignoble in earning one's living as a traveller who interprets the world to the non-travelling public, or even as an explorer in whom the whole scientific world is interested. Rather is it a noble profession. It only becomes contemptible in the hands of the few who play down to the crowd, who exploit the popular ignorance of foreign lands by means of blatant advertisement and a colossal egotism. Such people neither add anything to knowledge nor spread true knowledge. Their talk is about themselves. They have astonishing adventures, through which they remain imperturbable, brightly conversational, and modishly dressed. They employ brazen publicity agents whose regard for truth is not of a high order. In this way they build up a reputation, founded on not too difficult travel which somehow has been made to look dangerous, interesting, and above all unique — pioneer exploration. Of these commercial travellers I need say no more.

In the nineteenth century the explorer, almost always an Englishman, cut a figure in London 'Society'. He was a lion for the season at least and roared to order. He was physically big, heroic even, bearded, silent, aloof; in short a type, and a fine type.

The nineteenth-century explorer did not soil his hands by making *money* out of his travels. He had plenty to say that was new, of course, and he wrote a book and no doubt his publisher paid him for it. But that was a bagatelle. There was not much travel literature in those days, and the reading public was much smaller. Now several hundred travel books are published annually in English alone.

In this twentieth century anyone can become an explorer. The strong silent Englishman of the nineteenth century has been replaced by a cosmopolitan of any race, or colour. In short the explorer is no longer a type. But the twentieth-century explorer, and the nineteenth-century too for that matter, should not forget that the foundations of geographical knowledge were laid, and much of the world's surface explored, when Europe was in the Dark Ages. With the great change in the explorer himself has come another change. To-day the explorer may earn his living by exploration and not lose caste.

Before the twentieth century, every explorer was a pioneer. He blazed the trail. There is not much blazing to do in the modern world; most trails have been blazed. But there is unlimited detailed work. The field has not, as some maintain, narrowed; it has enormously expanded. One can no longer be the first man to sail round the world; *that* became impossible after A.D. 1500. But one might be the first man to *fly* round the world. No longer can one be the first man, or even the 'first white man' (a foolish claim), to cross Australia, discover the source of the Nile, or reach the Poles or the 'Forbidden City'. But one can be the first to cross a Himalayan or Andine pass, to find the source of a lesser river, to climb a peak. It is surprising how much of the world was known by the end of the fifteenth century; it is even more surprising how much of it is unknown half-way through the twentieth.

There is, however, no merit in being the first to do anything unless the thing itself is worth doing. The merit is proportional to the usefulness of the deed, not to one's numerical order in a list of people who have done much the same thing. Besides, we all profit by the efforts of our predecessors, though few of us are foolproof against a secret elation at being publicly acclaimed as the first man to do anything, however trivial.

In 1923 John Buchan (afterwards Lord Tweedsmuir) wrote a book called *The Last Secrets*. It proclaimed the end of a chapter, if not of a volume. For the 'Last Secrets' were, it seemed, already solved. The world was explored and that was the end of it. Disconcerting! But of course it wasn't really as bad as that. For *every* generation has its last secrets. Every generation proclaims loudly that *it* has solved the last secrets, leaving nothing to its successors to discover. Yet the successors invariably pose new geographical problems for the explorer to solve. There is even room for a few pioneer journeys. It is not many years since man first entered the stratosphere. To fly an aircraft over Mount Everest, to descend half a mile below the sea's surface — *these* are the kind of pioneering deeds done to-day. So let us take heart, and continue the good work of exploration.

DIAGRAM OF THE EARTH'S SHELLS

(NOT DRAWN TO SCALE)

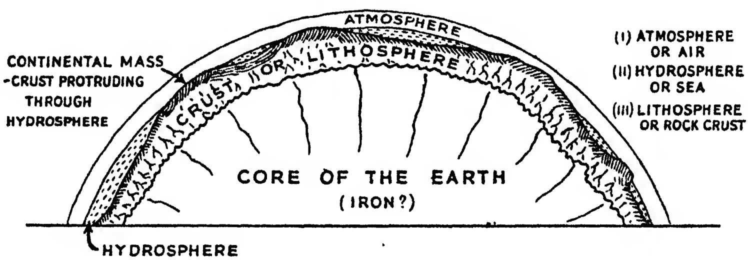


FIG 1

The crust of the earth is continuous over the entire surface of the globe. Only about a quarter of it is visible, however; the remaining three-quarters is hidden beneath the ocean, which fills several immense basins, connected with one another. Some or all of these basins appear to have existed from the beginning of the world.

Thus the earth may be regarded as consisting of three hollow spheres, the innermost enclosing a huge solid core; or looking at it another way, the earth consists of a solid core round which is shrunk a triple hollow sphere, consisting of the crust, supporting in turn another hollow sphere, the ocean or hydrosphere, which in turn supports a third hollow sphere, the atmosphere. The hydrosphere, though continuous, is not complete, being broken through in places by the crust, which thus comes into direct contact with the atmosphere. The core comes into direct contact, if at all, with the hydrosphere and the atmosphere only through volcanic vents. The crust rests directly on it, or passes gradually into it.

These three shells wrapped round the core are of different thicknesses, but all are very thin as compared with the huge core they surround. The atmosphere may be as much as 50 miles deep, but is probably much less. The hydrosphere, so far as we know, is not anywhere so much as 10 miles deep, and only occasionally plunges down to 7 miles, the deepest ocean sounding yet reached. Even that marks an unusual hole in the ocean floor. The highest mountains in the world rise nearly 6 miles above sea level; they are not quite so high as the deepest holes are low. Thus if there were no sea, we would observe surface irregularities of the crust amounting to about 12 miles — a picture which is obscured by taking sea level as datum line and measuring crust height upwards into the atmosphere and sea depths downwards into the hydrosphere. The two measurements are really one.

What proportion of the crust's thickness is 12 miles? Since we do not know the thickness of the crust it is impossible to say for certain; possibly a half, possibly a quarter or less. Neither physicists nor geologists are agreed on the thickness of the crust. If volcanoes are safety valves between the hot interior of the earth and the surface — safety valves which not infrequently blow up — how far down is the 'interior'? Does the volcanic pipe reach the core? If we assume that the crust is 30 to 50 miles thick, it seems very unlikely that the volcanic pipe could draw its supply of molten rock from so great a depth. The alternative would be to imagine lakes of molten rock enclosed within the crust much closer to the surface, or else thin spots in the crust itself. Suppose, however, for the sake of argument, that the crust is, on the average, 50 miles thick, shrunk loosely on to the rigid core. The diameter of the earth is about 8000 miles, so that the crust would be one-eightieth of a semi-diameter. Even so, volcanoes appear to be a mere skin eruption. Thus a section of the earth appears as in Fig. 1 on p. 10 (not drawn to scale). Actually the core is so immeasurably

FIG. 2

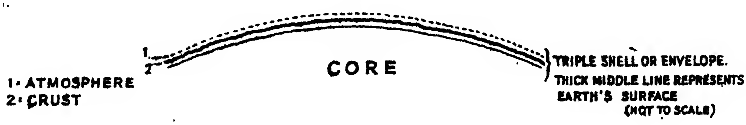
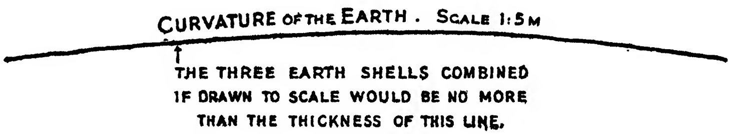


FIG. 3



thicker than the three shells which enclose it that the latter are more like skins, or coats of paint. Fig. 2 represents their relative importance more faithfully. Fig. 3 shows the surface of the earth on the scale 1:5,000,000.

This then is the bird's-eye picture of the earth which the modern explorer has to bear in mind, a world of three dimensions.

CHAPTER II

THE EVOLUTION OF EXPLORATION

THE history of exploration is in effect the history of the slow spread of civilization over the world. Always exploration has been carried out by the higher civilizations; the scene of their exploits has ever been less highly civilized lands. Backward peoples have always retreated before the advance of more highly civilized races, led on by explorers, and become, in the language of to-day, refugees. They abandoned the fertile lands which they had inhabited and moved off into more sterile lands, or up into the mountains, until they could go no further.

To-day, although two-dimensional exploration goes on merrily, our modern conception is rather of a three-dimensional world to be explored in depth. Exploration in fact is changing direction. It goes deep and high; it is less extensive, but more intensive.

Two Royal medals are presented annually by the Royal Geographical Society, on behalf of His Majesty the King, to the explorers of the world, without distinction of nationality.

If we compare the citations in the tables overleaf we shall notice the different slant which exploration is beginning to take. The first table cites the work of 20 explorers for the last decade of the nineteenth century. Compare this with the citations for the third decade of the twentieth century.

Exploration has in a sense been going on for the last 6000 years, but not more. Nor have all the peoples of the world contributed. For example, only three post-Christian civilizations have made any serious contribution to the exploration of the world — Christendom itself, during two periods, interrupted by the Dark Ages; Chinese civilization, in its zealous Buddhist days, about the beginning of the Christian era; and Islam, during the brief period of its rise, between the sixth and ninth centuries.

In this connection it is remarkable to note that civilization seems to have been developed entirely within a belt stretching diagonally across the southern half of the Eurasian continent (including the northern rim of Africa) in a north-west to south-east direction. This belt lies north of the equator, and is nowhere more than 2000 miles wide. In the north-west its limits are the parallels of 30° and 55°; in the south-east, 10° and 40°. From within this belt have sprung the cultures which for 60 centuries have dominated the world. It is within this belt that the archaeologist must look for the remains of early civilizations. The New World civilizations,

TABLE I

ROYAL GEOGRAPHICAL SOCIETY ROYAL MEDALS

	FOUNDERS' MEDAL	PATRONS' MEDAL
1891	Sir James Hector, M.D., for services to geology and allied sciences in his work as Naturalist to the Palliser Expedition to British North America, 1858.	Dr. Fridtjof Nansen, for having been the first to cross the inland ice of Greenland, a journey of 3 months 37 days; and for scientific results. b. 1861.
1892	Alfred Russel Wallace, in recognition of the high geological value of his works *The Geographical Distribution of Animals*, *Island Life*, and *The Malay Archipelago*. b. 1823.	Edward Whymper, for the results of his journey in 1879-80 as recorded in his work *Travels among the Great Andes of the Equator*, which includes a detailed survey of Chimborazo.
1893	Frederick Courteney Selous, in recognition of his 20 years' exploration and surveys in South Africa. b. 1851.	W. Woodville Rockhill, for travels and exploration in Western China and Tibet, and the results as published in his work *The Land of the Lamas*.
1894	Captain H. Bower, for his journey across Tibet, 1891-2.	M. Elisée Reclus, on completion of his work *La Nouvelle Geographie Universelle*.
1895	Dr. Murray, for services to physical geography and oceanography, especially as Editor of the results of the *Challenger* expedition.	Hon. G. N. Curzon, for his monograph on Persia, travels in Korea, French Indo-China and Pamirs, and determination of the course of the Oxus.
1896	Sir William McGregor, for his long services to geography when Lieut.-Governor of New Guinea.	St. George Littledale, for journey across the Pamirs, 1890, from Kothan to Peking, 1893, crossing Kuenlun and Tibet Plateau, north-south.
1897	M. P. Semenoff, Vice-President Imperial Russian Geographical Society, for promoting exploration of Central Asia and journeys in the Tian-Shan.	Dr. George Dawson, Director of Survey, Canada, for journeys and explorations, especially when in command of the Yukon Expedition.
1898	Sven Hedin, for journeys through Asia, crossing Taklamakan, discoveries in Tian-Shan and Lob Nor regions. b. 1865.	Lieut. Peary, especially for glacier exploration and journey with dogs 1200 miles over inland ice of Greenland. b. 1856.
1899	Captain Burger (French), for Niger exploration.	M. Foureau, for journeys in Sahara and scientific results.
1900	Captain H. H. P. Deasy, for exploration and mapping in Central Asia.	James McCarthy, for exploration and surveying in Siam.

TABLE II

ROYAL GEOGRAPHICAL SOCIETY ROYAL MEDALS

	Founders' Medal	Patrons' Medal
1921	V. Stefansson, for journeys in Canada and Alaska, 1908-12, and in command, Canadian Arctic Expedition, 1913. b. 1879.	General Bourgeois, Chief of the Geographical Service of the French Army, for various services in that post.
1922	Lieut.-Col. Howard Bury, for leading the Mount Everest Expedition, 1921.	E. de Koven Leffingwell, for survey and investigations, North Coast, Alaska.
1923	Knud Rasmussen, for his scientific exploration of Greenland and the American Archipelago. b. 1879.	Hon. M. S. Smith, for his journey to the interior of Papua, 1912.
1924	Ahmed Hassanein Bey, for explorations in the Libyan Desert.	Commander Frank Wild, for Antarctic exploration.
1925	Brig.-Gen. The Hon. C. Bruce, for explorations in Himalayas and Mount Everest Expeditions, 1922 and 1924.	A. F. R. Wollaston, for exploration and journeys in Dutch New Guinea.
1926	Lieut.-Col. E. F. Norton, for Everest Expeditions and highest ascent made up to that time.	Sir Edgeworth David, for services as geologist, first ascent of Mount Erebus and first to reach South Magnetic Pole.
1927	Major K. Mason, for surveys of India and Russian Turkestan and Pamirs, 1913; leadership of Shaksgam Expedition in 1926.	Dr. Lauge Koch, for 6 years' exploration of North Greenland. b. 1892.
1928	Dr. Longstaff, for discovery of Siachen glacier and geological work in the Himalayas.	Sir Hubert Wilkins, for exploration in the Arctic regions. b. 1888.
1929	F. Rennell Rodd, for journeys in Air and Sahara, and studies of the Tuareg.	C. H. Karius, for travels in Papua. b. 1888.
1930	F. Kingdon Ward, for geographical exploration and work on botanical distribution in South-West China and South-East Tibet.	C. E. Borchgrevink, for Antarctic explorations 1898-1900, and for being the first to winter in the Antarctic.

Inca, Aztec and others, which of course are not very ancient, were derived thence; so also were the South African civilizations. Geographers may profitably inquire what are the conditions which brought about human civilization within this restricted area, and denied it, as a spontaneous event, to the vaster areas beyond.

I have said that exploration has been going on for about 6000 years only. Why are the earlier wanderings of mankind not regarded as exploration? Before the invention of writing, however much people might move about the world — and during many thousands of years they moved about a lot — they recorded nothing, and so cannot be said to have explored anything. Only by speech could they report what they had seen, and no store of observation could be built up. Real exploration only began after the invention of writing. Very gradually, by long and patient exploration and research, we have learnt that there has been more than one species of man on this earth, and that even modern man is very old — much more than 6000 years old at any rate. Long before writing was invented he had wandered into every continent. The other species of men were exterminated or possibly absorbed. Yet there are many parts of the world which are thickly populated to-day but which 2000 or 3000 years ago were uninhabited. For example, the deltas of the great rivers in the monsoon countries must have been covered with impenetrable jungle. Such was the Irrawaddy delta, and the delta of the Mekong in further India. At that time these jungle-covered deltas were uninhabited or possibly a few pygmy tribes wandered stealthily over them. To-day the jungle is cleared and great numbers of villages stand amongst the endless paddy fields. Such tropical civilizations have sprung up within the last 3000 years, since it is certain that the great civilizations of that period were restricted to small and well-defined localities outside the tropics. They were situated close to the sea, generally to an inland sea, in the warmer temperate regions; nor was it possible in those days for their influence to spread far afield except up the rivers. It could not spread far inland, that is to say far from the coast, because at that time neither the equipment nor the technique necessary for difficult land travel existed. How could people armed with nothing more efficient than chipped stones conquer the jungle! Clearly the jungle was inviolate until the age of metal, that is until at least the Bronze Age, and more likely until the Iron Age; and the age of metal came to the tropical regions much later than it did to the Mediterranean regions. As will be pointed out in due course, these ages of stone and bronze and iron are not exact dates. They represent a sequence of cultures, any one of which may be missing in any particular place, as civilization spread outwards from its centres of origin. Any locality which made contacts with the world outside might obtain civilization almost ready made, or at least a new culture, just as the Japanese acquired the technique of a new culture in a generation. A people might pass from the Old Stone Age to the Iron Age — but it is probable that most of the Stone Age folk would themselves disappear in the process, replaced by the heralds of the new civilization. A large part of the world was still in the Stone Age when the higher civilizations were already in the Iron Age. Thus exploration like other human activities has evolved gradually; nor is it surprising that with the rapid changes which have taken place in the western world during the present century the direction of exploration has also changed.

Let us follow in brief outline the main changes in the history of exploration since civilized man became curious as to what lay beyond the next range of hills. And first we may observe that it is logical, and not mere chance, that the earliest explorers were mariners. Land exploration came later. The first parts of the earth's surface to be explored were inland seas, such as the Mediterranean, and the coastlines, especially broken coastlines offering abundant shelter — like the coast of Europe. These narrow seas offered the least resistance, mental and physical, to men poorly equipped. The art of shipbuilding came easily to people who lived by the sea and who used metal tools. Indeed it is quite possible that primitive man armed with stone implements only could make dugout canoes. Fire alone is almost sufficient for the purpose, given a log big enough! The only difficulty would be to fell the tree! But the dugout has its limitations; it cannot travel far from land. Under the conditions prevailing throughout the early days of civilization, land travel over the greater part of the globe was impossible, but oceanic travel was equally impossible. Where great open spaces existed, the conditions for living were otherwise adverse. It is obvious that early man was thwarted in every direction. He could travel only on foot. He could not cross the ocean. He had no means of combating extremes of heat, or cold, or drought. Thus he could neither cross the desert nor penetrate the jungle. Even a range of high mountains stopped him. Any rash attempt to make a long overland journey must have ended in disaster.

Thus early man, wherever located, was considerably immobilized. He occupied the coasts of inland seas, the open plains, steppes, wooded lands in temperate climates, the banks of rivers. And since he had not yet acquired dominion over the earth his movements were sharply restricted by those very physical barriers which to-day make it possible for him to travel swiftly from one part of the world to another — the sea and the air. Nor was it only the obvious physical barriers which baulked him. Climate also, which controls the type of vegetation, giving birth to desert, grassland or forest, influenced his movements and profoundly affected his settlements. If we knew what the world climates were when primitive man was battling with nature, we could make a pretty shrewd guess at what sort of vegetation covered any particular region, and might infer, if not where man lived, at any rate where he did *not* live. And these results could be checked in the field, for man has left traces of his occupation from the earliest times.

But as soon as man had acquired some of the arts of civilization he began to rise superior to his surroundings. Hitherto topography was man's master; now he realized for the first time that *he* was master. It was not that man did not speculate about what lay at the bottom of the ocean, or above the earth's surface; we may be sure he did. In the last five centuries before Christ, great stores of geographical knowledge had been accumulated, bold theories had been advanced by Herodotus, Strabo, Eratosthenes, Ptolemy, and other classical writers and philosophers. But until knowledge had progressed not in one direction only but in all directions, it was obviously impossible to reach the stratosphere or the ocean depths. In the later ages, when science had advanced so far that men knew exactly *why* they could not construct a heavier-than-air machine that would fly, or a submersible ship, they were already on the high road to success. It is obvious, too, that until civilization had reached a certain standard, it was impossible to attain the Poles, to climb Mount Everest, or to discover the source of the Nile. The progress of exploration keeps step with the evolution of civilization.

Thus, while the earlier maps of the world show the seas fairly accurately and the outlines of the continents, the interiors of the continents remain blank, or filled with pictures of imaginary terrors. Men were familiar with the outline of the land masses long before they knew anything of the interior; it was the mariners who, setting out from the coastal cities, crept along the coasts and at last, greatly daring, set forth boldly to cross the oceans themselves. Nor is it till we come right down to modern times that the interiors of the great land masses begin to be *explored*. Less than a century ago, Africa *was* the Dark Continent. What did we know of the interior of Australia, or of Tibet, a century ago? By the end of the eighteenth century North America, South America, Africa and Asia, even some of the large islands, looked pretty good on our charts, thanks to the navigators, Portuguese, Spanish, Dutch, French, and English, from Vasco da Gama and Cabot to Bougainville and Captain James Cook. But what would the 1/M. map of Asia, or even 1/5 M. map, have looked like? It was the shapes of the ocean basins with their gulfs and bays and inlets which had been mapped, not the interior lands. True, some remarkable land journeys of which accounts have come down to us had been made long before the Cape route to India was discovered. Fa Hien, Marco Polo and others performed astonishing feats of land travel. But they only serve to show how little men knew of the vast interior; the second millennium after Christ, like the two which preceded it, was still predominantly an age of sea exploration, whether by Arab, Chinese or European. By the time the steamship had begun to replace the sailing ship, five of the Seven Seas were, as to their surface and extent, comparatively well known. The Arctic and the Antarctic oceans alone had to await the age of steam, and a more specialized equipment.

In the nineteenth century the industrial revolution was completed, and an immense improvement took place in the means of transport. Populations increased rapidly. Material wealth increased by leaps and bounds. There was a frantic search for gold; the standard of living — for some — went up to dizzy heights; and with all this ferment of 'civilization' came an unsurpassed increase in land exploration. For the first time in history, men set themselves seriously to reveal the unknown interior lands, to fill in the great blank spaces on the navigators' maps — which were the land masses. Men attacked the continents one by one, crossed and recrossed them; the blank spaces were cut in half, sub-divided. The Americas, Central Asia, Australia, the dark heart of Africa, the interiors of great islands like Madagascar and New Guinea, the Arctic, were explored; the unknown world began to shrink rapidly. So the work of exploration went on, still in two dimensions over the earth's surface, until the end of the nineteenth century; and in the twentieth century a landing was made on the Antarctic Continent, the last large land mass. There were still great centres of civilization round the Mediterranean and the coasts of Europe where they had existed since the dawn of civilized life, but new centres had sprung up all over the world, some of them indigenous, but many of them transplanted from the north-western peninsula of the Eurasian continent. It may be that the steamship, by taking men more swiftly to their starting point, had an influence on land exploration. It speeded it up. Certain it is that the great advances in technique, in mechanical skill and in the control of power made land exploration possible. But before the land exploration was completed man, whose curiosity concerning the world in which he lived never waned, turned his attention to exploration in depth. With the turn of the century three-dimensional exploration had begun. Already the blank spaces on the land maps were fewer, smaller and more isolated from one another. Yet there were and are some left. It is mainly a matter of scale. Draw a large enough map, and the blank spaces would still show up, and even bulk large. Reduce the scale, and they sink into insignificance. But before the surface could be completely explored, and long before we knew everything of the earth's contents, early in the twentieth century, the new exploration which recognized the earth as a solid and not simply as a surface had begun. Strictly speaking, of course, the first hesitating explorations in depth of the sea and air, and of the land, had already been undertaken, but only in an experimental way. Now exploration in depth became the rule, and it is fair to regard the conception of a three-dimensional world made up of concentric spheres one within the other as a product of twentieth-century thought. For the twentieth century is the age of the submarine and the aircraft, two inventions peculiarly suited to exploration in depth. Coupled with skill in mechanical invention is a new awareness leading to a sharp curiosity as to the structure and contents of the world, indeed of the universe, the distribution of its contents in space and in time, and finally into the origin and history of man himself.

From our point of view, then, exploration may be said to have begun less than 3000 years ago with the Buddhist missionaries of whom Fa Hien (fifth century B.C.) was the most famous. His overland journey from China to India in search of the sacred Buddhist books is well known to scholars. He returned to China by sea, having been away for fifteen years. It is perhaps pertinent to ask whether anything but an all-consuming faith could have sustained these early travellers. At all events it was mainly religious enthusiasm, Buddhism in the East, Christianity in the West, which sent men to the ends of the known world and beyond during the first centuries of the Christian era.

Nevertheless, in pre-Christian times as to-day journeys were also undertaken for purposes of trade, especially by sea. There were certain famous marts in the ancient world, and to the neighbourhood of these marts, to the Persian Gulf and to Ceylon for example, traders came from Europe and from the Far East even in those early times. Thus Chinese junks came to Basrah. But it is probably correct to say that most of our knowledge of the world of 2000 years ago we owe to missionaries and pilgrims, Buddhist and Christian.

From the fourth to the ninth century the Nestorian Christians (an heretical offshoot of the True Church) made several remarkable overland journeys in Africa and Asia. Had the Nestorian missions survived they might have contributed greatly to our knowledge of the world, although a marked reluctance to record their experiences and observations distinguished them. But by the twelfth century their influence had waned, and thereafter we hear little of them.

The tale is now taken up by Islam, whose spectacular rise and astounding military success provided a new impetus to exploration. As soldiers and missionaries, the Saracens added much to the knowledge of Africa, while Christendom was sinking into the Dark Ages. Their triumph was short lived; for within three centuries the Saracens in turn had sunk into the slough from which indeed the Arab world has not yet extricated itself. Since its first meteoric ascent to power, Islam has never again made any serious contribution to geographical or scientific knowledge.

Passing over the period of the Crusades, which, if they did nothing else, broke down the barriers Islam had set between Europe and Asia and between Europe and Africa, and the Norse conquest based on sea power, let us turn to the glorious reawakening of Christendom when, in the fourteenth and fifteenth centuries, Europe became ocean-minded. This was the period of Henry the Navigator, and of the maritime exploration which culminated in the rounding of the Cape and the discovery of the sea route to India, the discovery of America and of the Pacific, and then, early in the sixteenth century, of the circumnavigation of the globe. With the death of Captain Cook in 1779 the later age of maritime exploration which had lasted for 300 years reached its zenith. The whole world was now known. No longer could man discover a new continent, or a new ocean. He had reached the limits and returned to his starting point. Maps had reached an exactness never before attained; the outlines of the continents had been drawn, and the ocean basins with their islands.

Yet much remained unknown; and in the nineteenth century, explorers, far better equipped than their predecessors, turned once more to the land.

Thus we perceive the natural evolution of exploration. It is clear that this evolution, by no means a steady progress, has taken place not merely within historical times, but chiefly within the last 2000 years, that is in a small fraction of the time man has been wandering over the earth. During the first 1000 years little progress was made, and much was lost or forgotten because Christendom would not be beholden to the heathen for knowledge. So Christendom went into eclipse for nigh 300 years, and men forgot even that the earth was round! After the passing of the Dark Ages in Europe, earth knowledge had to start all over again, and it was centuries before Christian knowledge had caught up with early heathen knowledge.

Modern exploration no doubt moves forward with a smoother motion, thanks to almost universal co-operation; but its progress is still halting. In particular it is likely to be checked by the vast amount of travel literature, and the difficulty of deciding what a traveller needs to know. Knowledge of so great and complex a subject as the earth and all its contents is bound to move forward slowly, and then only by unselfish co-operation. Travellers tell their various stories. After a period of years, perhaps, a geographer collates these accounts, builds up a picture of the region, comparing and contrasting it with other regions. Later travellers, armed with this knowledge, go forth with a more critical eye to make new discoveries. So the field narrows gradually and expands again more widely; the same light of intelligence is brought to bear on ever smaller areas. The age of the specialist dawns.

During the last 700 years the tempo gradually increased. By the time of Captain Cook, explorers were taking a lively interest in Natural History — in the *contents* of the world. The name of Sir Joseph Banks, the famous botanist, is well known in the world of science. Zoologists, botanists, geologists and many other scientific explorers were adding to our still meagre knowledge of the world and its infinite resources.

Thus we can recognize three ages of exploration, unequal in length — ancient, medieval, and modern.

Ancient exploration, from about 500 B.C. to the second or third century A.D., is memorable though it did not accomplish much. It was more an age of geographical theories than of journeys. Medieval exploration was mainly by land to begin with, but culminated in the great ocean voyages which gave us the shape of the earth, and of the continents and ocean basins.

Finally, Captain Cook's voyages may be said to have inaugurated modern exploration about the beginning of the nineteenth century. Exploration to-day, and the conception of a three-dimensional world to explore in depth, is simply the latest development of modern exploration.

Throughout the story, culture is being spread, and will continue to be spread as long as one part of the world is more highly cultured than another; just as water continues to flow until it finds its own level.

CHAPTER III

MODERN EXPLORATION

THE earth is of course three-dimensional, or solid, a fact we are apt to overlook since we normally move about only on its surface. Till the end of the nineteenth century, therefore, the explorer was exploring a two-dimensional world, the earth's surface. Exploration, considered as travel, was extensive rather than intensive, and so the earth's surface came to be regarded as a wide plain over which the explorer roamed in search of new lands to conquer.

Of course there are mountains and valleys as well as plains; even the earth's surface is not really two-dimensional. But the mountains after all are only surface features. Thus the explorer appeared to be working on a two-dimensional plain.

If we inspect the earth's surface from a short distance away, however, from the air or even from a hill-top, we can easily imagine it to consist of three separate and distinct, but close-fitting, spheres or shells, one inside the other, the last shell enclosing an enormously larger solid core. It is like a set of carved wooden balls, each opening to reveal another within, such as are made in India; or like the sculptured ivory balls of diminishing size, one within the other, carved by Chinese craftsmen.

On the outside and enclosing the whole in a continuous loose shell, many miles thick, is the *atmosphere*. It is invisible, but is well known to us by the sense of touch, or feel, as wind; visible in its effects too. The atmosphere is stratified, that is, it is composed of several distinct layers.

Next to the atmosphere is a more closely fitting, but incomplete fluid shell, the *hydrosphere* or ocean. This is in direct contact with the atmosphere above. It is not quite continuous, being interrupted in places by the land surface, which breaks through it. Thus the hydrosphere is divided by the up-thrust parts of the lithosphere into several more or less isolated basins, and becomes slightly discontinuous. The sea also is stratified, though even less obviously than the air.

Lastly the *lithosphere*, or rock shell, the crust of the earth, supports both hydrosphere and atmosphere, while itself resting directly on the core of the earth, round which it fits more or less loosely, like the skin of an elephant. Nearly three-quarters of the lithosphere is in contact with and hidden by the hydrosphere; only about 30 per cent of its surface breaks through to come into direct contact with the atmosphere. Like the outer and middle shells, the lithosphere also is stratified, and visibly so.

This conception of three-dimensional exploration is quite modern and is revolutionary. Never again can so great a revolution in geography be wrought. First, the seas were explored.

Then, when the necessary gear had been invented, the most stubborn lands, as deserts, jungles, and mountains. Lastly we come to modern exploration, when men became conscious that the habitable earth has a certain thickness.

It is really rather surprising that there should be *any* lithosphere showing through the hydrosphere, or in other words that there should be any land surface at all. The sea is quite large enough and deep enough to drown all the continents two miles deep without leaving a trace. If that happened the sea would be everywhere, the lithosphere nowhere, in contact with the atmosphere; and our three shells would each be complete, in perfect contact, and concentric; air, sea, and rock. The only land would be at the bottom of the sea.

The land above the sea level owes its existence to warping of the crust; but how the warping is brought about, geologists and physicists are not agreed. The first rock to appear above the surface of the ancient sea must have been naked crust. We may note that had there never been any dry land, there could never have been any stratified rocks save those composed of volcanic dust, or of the bones and skeletons of creatures great and small which live in the sea, and whose hard parts, calcareous or silicious, accumulate on the sea floor. At depths of two miles or more, there would form a layer of ooze or clay between the sea and the crust.

Let us call atmosphere, hydrosphere, and lithosphere by their shorter and more familiar names, air, sea, and crust; this is not likely to lead to misunderstanding. These three wrappings or shells then form a skin enclosing the immense core of the earth, of which perhaps we shall never know much more than that it exists.

If we assume a thickness of 25 miles for the effective air, a depth of 7 miles for the deepest sea, and a thickness of 33 miles for the crust beneath the sea floor, we have a total thickness of 65 miles for the triple shell enclosing the core. There exists, it is true, no sure means of measuring the thickness of the air, or of the crust. But at 25 miles the air must be so tenuous as to be almost impossible to detect; and 33 miles for the crust, taking the depth at which earthquakes originate into consideration, seems a fair allowance, although some geologists assume twice that thickness.

Since in some places the crust, with certain overlying strata, is pushed up above sea level to a height of over 5 miles, we are certainly justified in giving it a generous thickness below the sea.

The average depth of the sea is of course much less than 7 miles, though probably more than 2 miles.

Thus the explorer has not only the entire *surface* of the globe, land and sea to explore, but also a shell some 65 miles thick, made up of three distinct layers. His *surface* lies, not on the outside of the total sphere, but in the middle of the shell, rock (lithosphere) surface, and sea surface together forming the intermediate layer. From this surface he can explore both upwards and downwards, wherever he can penetrate either shell; upwards into the air, downwards into the sea. In other words, his field is no longer a surface, but a hollow sphere at least 65 miles thick,

That is why I say that the twentieth-century explorer is exploring a three-dimensional world, although, as we have seen, compared with the total thickness, this 65-mile deep shell is still only a surface skin.

To-day he travels high above the crust into the atmosphere, perhaps 10 miles above the earth and dives — but not so far — below the surface of the sea, towards the hidden crust at the bottom. He explores vertically as well as sideways. It may be remarked that until the twentieth century this was impossible for him, except to a very limited extent; the necessary knowledge, and hence the necessary apparatus and technique, did not exist.

Note however that, compared with the total area of the earth's surface, the total thickness of the complete shell is negligible; a mere skin. And of that thickness, less than half the crust is open to his direct observation — the greater part lies at the bottom of the sea. It must be remembered also that the relative proportions of apparent crust above and below sea level change slowly in the course of ages, if within narrow limits. I say *apparent* crust advisedly. The original crust which formed as the molten world cooled consisted of crystalline rocks only. Since then, many miles depth of stratified rocks has been laid down on top of the ancient crust.

If the thickness of the triple shell is negligible compared with the surface area, it is equally so compared with the thickness or diameter of the core. The entire outer shell has a thickness which is less than one-sixtieth of a semi-diameter; and since about half of that is made up of invisible air (the atmosphere), the visible part has a thickness only equal to about one two-hundred-and-fiftieth of the earth's diameter. That is to say, the earth's skin is very much thinner than the peel of a big orange. According to Professor Shand (*Geology Without Jargon*), it would be represented by the outermost half-inch of a 42-foot globe.

In the diagram, Fig. 1 (p. 10), the entire thickness of the shell, with its three layers, air, sea and crust, is included in the bounding line, the lower edge representing the lower limits of the crust where it rests on the surface of the core, more than 30 miles down. It is quite impossible on so small a scale to show the three shells separately. The hydrosphere, important as it is, forms a mere insulating layer between crust and atmosphere (lacking in places); its *average* thickness is not much more than 2 miles, or one-thirty-third of the total thickness of the shell. It is like the butter spread in a sandwich.

Thus the explorer's new world, even as here generously conceived, and in spite of recent advances in vertical exploration, is still *comparatively* flat!

Nor must we forget, when comparing the thickness of the skin with its area, that 70 per cent of the land surface is beyond our vision, covered by the sea. That is to say, the *surface* is composed of two contrasting elements, irregularly fitted together like pieces in a jigsaw puzzle, one solid, the other liquid.

If the exposed land surface were completely explored, the twentieth-century explorer might with a sigh of regret turn his undivided attention to vertical exploration in air, sea and crust. But he would quickly realize the need for extensive work here too. It is not enough to go up into the air, or down to the bottom of the sea. One needs to cruise along at a given height, or at a given depth, and explore an entire stratum extensively. In fact one needs to explore a number of strata extensively in order to gain a proper insight into the layers of matter round the core.

Thus the fact that thickness has been added to the explorer's world has not done away with the need for two-dimensional exploration; it has only added to the number of plains waiting to be explored.

But as a matter of fact the earth's surface is by no means fully explored, although it is the fashion for every generation of explorers to assure the next generation it has left it no worlds to conquer. Be that as it may, even in this twentieth century there are far more explorers exploring the earth's surface than there are engaged in exploring the atmosphere or the hydrosphere. One obvious reason for this is the enormous expense of stratosphere and deep-sea exploration.

Active exploration in the interior of the crust is of course virtually impossible, whether visible above the sea or invisible at the bottom of it. Only by indirect means can we gain any knowledge of its structure. The deepest mine is only 8500 feet — less than 2 miles — deep; and even supposing that it penetrated only the crust, with no superimposed stratified rocks anywhere, that is only one-seventeenth of the total thickness of the crust:

There are three chief sources of information about the crust.

(1) Direct observation below the surface, as in mines and volcanic craters. These tell us something of the composition, but not much of the structure. The same is true of borings.

(2) Direct observation at the surface, very useful except where sedimentary rocks conceal the crust. Even so, the dip and strike of the strata can be measured, and much which is invisible at the surface can be reconstructed. Where plutonic — that is to say, deep crustal — rock has come into contact with sedimentary rocks, after the latter were laid down, these have been *burnt* or even melted; which proves at least that the interior of the crust is *hot*. Volcanoes confirm this.

(3) Deflection of the plumb line.

The plumb line should point directly towards the earth's centre. But a solid mass of matter such as a mountain range will attract it a certain small amount, thereby deflecting it from the vertical; and this amount can be measured, and the attracting mass, and its distance away, can be calculated. Thus the plumb line reveals structure in a surprising way. For instance, the deflection of the plumb line on the plains of India several hundred miles south of the Himalayas was interpreted by Sir Sidney Burrard as due to a range of mountains hidden below the earth's surface, of which no trace is outwardly visible! The exact significance of this is not, however, quite clear.

The outermost shell, the atmosphere, is explored nowadays by aircraft, specially built to fly at stratosphere height. In the previous century it could be explored only by balloon, and the greatest height ever attained was 37,000 feet, although there is a doubt about this. Aircraft have reached heights of 47,572 feet (9 miles).

The sea is explored by the diver, either in a diving suit or in a bathysphere; but here again most of our knowledge of the interior of the sea is obtained indirectly. Divers have been down in shallow coastal waters in a few places — few, that is, compared with the vastness of the ocean. Beebe has been a half mile down — 500 fathoms — in his bathysphere. But these descents to the land surface under the sea, or vertical exploration of the sea itself, are as a few scattered parachute jumps over the whole land surface of the globe — with the parachutist remaining attached to his parachute when he reaches the bottom. For sea divers must remain on the spot where they go down.

Small wonder therefore that we know so little of the sea floor, and therefore of nearly three-quarters of the crustal surface which lies just beneath the sea floor; nothing at all about it, inside.

We must be careful not to confuse the explorer with the geographer. Geography has no meaning apart from man's relationship to the earth on which he lives. Even a world in which there is abundance of animal and plant life is no concern of the geographer until man appears on the scene. Previous to the Quaternary period geography is meaningless. There is no Palaeozoic geography, although land and sea had form. The Palaeozoic period refers to a geological age, and is exclusively the business of the geologist. Nor is there any geography of the moon — the moon is the concern of the astronomer, not the geographer. But since it is mainly responsible for the tides, which do affect man, the geographer must pay attention to the astronomer's conclusions.

It will be realized that geography casts its net widely, since man's relationship with the earth is many-sided. Yet wide as the scope of geography is, geographical exploration is not the only form of exploration. To-day exploration *is* more than skin deep. No longer does it confine itself to the surface of the earth; as we have just seen, it penetrates also upwards and downwards into the shells which form the roof and foundation of our world. We know, too, that the combined thickness of the three shells exceeds 60 miles. These shells are part of man's earth, of his environment even, although their outermost layers are not only uninhabited by man, but absolutely lifeless. No birds fly in the incredible cold of the stratosphere 12 miles above the earth, though that is but a fraction of the way to the surface of the outer shell. No fish survive in the eternal darkness and icy cold under the terrific pressure 6 miles below the sea's surface. It is doubtful whether there is even any microscopic life there. The ocean abyss may be, like the loftiest peaks, lifeless.

Nevertheless the air and, much more, the sea, supply food for man, besides affecting him directly or indirectly in many other ways; hence they are to that extent the business of the geographer who wants to know the results of any investigation of the air, whether carried out by the physicist, the chemist, or the meteorologist.

These experts are specialized explorers or research workers, not geographers. Nevertheless the geographer must pay attention to their results. These come within his radius of action because they affect man.

The ocean also is just as much the geographer's business. He is closely concerned with tides, currents, salinity, temperatures, and of course with marine life in general. The science of Oceanography, which is dealt with separately, offers an immense field to the explorer, the research worker, and finally the geographer. Not only must the sea be explored vertically from top to bottom, but also over wide horizontal levels, at various depths.

In only two ways does the earth's land surface seem to offer opportunity for exploration in depth; namely in mountain climbing and in caveing. But mountaineering in itself is not exploration. The explorer in the course of his journeys may have to climb peaks — he certainly has to cross mountains. Nevertheless mountaineering is a pastime apart, demanding its own technique and aiming at results of its own.

Caveing at first sight seems to imply a certain penetration of the crust, but actually this is not so. Though one descends apparently into the bowels of the earth, the rock out of which the largest and deepest caves are hollowed is always either limestone or sandstone, and therefore stratified. These rocks were laid down, *on* the crust of the earth, usually at the bottom of a shallow sea, which later disappeared as the land surface was raised. Caves in fact are quite superficial features. Stratified rocks, which form a large part of the earth's land surface, are not really part of the original crust though the material of which they are composed was derived from it. They are a later addition, and in a sense form a fourth very incomplete shell inserted between the hydrosphere and the crust. But it is convenient to regard them as part of the crust to which they are now welded. The floor of the sea is covered with these deposits which hide the older crust surface beneath. Actually the raw crust comes to the surface, breaking through sea and stratified rock, in comparatively few places.

With this brief sketch of the earth's surface, and the three shells which press closely on one another and on the central core, we may pass on to other aspects of modern exploration.

PART TWO

THE LAND SURFACE

CHAPTER I

UNEXPLORED

ALMOST every year, the land across which one can still write the magic word UNEXPLORED dwindles — at least it did down to 1940. Even on the comparatively large scale of 1:500,000 or half-millionth map (8 miles to an inch) there are not very many areas big enough to take the word in large letters. Two hundred square miles is not a vast area, although many experienced explorers would be glad to come upon a blank space of that size. On the half-millionth map it would be represented by a little square of 1¾ in. sides, hence it would scarcely be noticeable on a map-sheet which covered, say, the whole of Burma.[1]

Nevertheless the extent of unexplored land left in the world to-day is hardly realized even by the intelligent public. One reason for this is that the great majority of people never look at any but atlas maps. Children learn geography from wall maps, or, if they are lucky, from a globe. And all maps of this kind are small-scale maps. Even the international millionth map of the world — which is far from completed — approximately 16 miles to the inch, is a large-scale map compared with most of our atlas pages and wall maps, in which the scales run from 1/10 M. to 1/30 M. (Great Britain in an English atlas will of course be on much larger scales, up to 1/M. for parts of England.)

The millionth map is the first attempt to produce a large-scale map of the world on a uniform scale, in sheets of a uniform size,

[1] Thus: | U N E X P L O R E D |

with uniform colouring, printing, heights — everything. Thus for the first time large areas of the world can be faithfully compared. However, up to the outbreak of the war only a fraction of the total number of sheets had been published. Each sheet in the lower and middle latitudes covers 6° of longitude, 4° of latitude, so that the total number required to cover the whole world is over 5000. Of these about 4000 would be mostly sea.

The explorer who, without being an expert in any branch of natural science, wishes to 'explore' and map an unknown area can still find blanks on the map in countries like Colombia, Venezuela, Brazil, or in the Central American Republics, or in Arabia, Tibet, New Guinea, Borneo, and of course in the Arctic and Antarctic. One cannot be more precise in a short space, but a study of large-scale maps will convince the most sceptical that the day of the ordinary explorer is not yet over. There is ample work to be done. Unfortunately, in these days the explorer is suspect; the word has become almost synonymous with 'spy', which is insulting. Political obstacles make it almost impossible even to travel in countries like China, Tibet, Mongolia, Central Asia, Indonesia, Chile, Argentina, Central Africa, and many other places, let alone make maps there.

But the excellent sheets of the international millionth map, though inexpensive, are rarely met with in private houses or even in schools, although they measure only 17 in. by 25 in. (without the surround). Atlas maps even of regions so unexplored as Arabia and Tibet hardly suggest the unknown. There may be very few names, but that only conveys the idea that they are uninhabited. Rivers, lakes, and mountain ranges are put in with astonishing confidence.

Enlarge them to the 1/2 M. scale, however, and there is a certain amount of doubt coupled with a great deal of generalization. Each inch now represents only 32 miles instead of 64 or 160 miles, and if you are in doubt about the course of a river to the extent of a hundred miles or so, it is rather a tall order to draw it firmly across three inches of your map, not knowing whether it exists or not, or, if it does, whether it flows there or somewhere else!

Enlarge them further, to four times the size, that is to 1/M., and there is no longer any doubt about what is known and what isn't. Your map sheets must now inevitably show the great empty spaces which set the heart of the explorer tingling. Thus whether a map shows unexplored regions or not is mainly a matter of scale. There are in fact many unexplored parts of the world, although they are neither so large nor so numerous as they were at the beginning of the twentieth century. Every generation, as already pointed out, claims to have solved the last secrets. But every secret solved breeds new riddles. Only a small fraction of the world has been surveyed on the scale of an inch to a mile. It might surprise many people to learn how many sheets on this scale would show large blanks — very many indeed would be completely blank! They would be even more surprised to learn how many sheets would be required to cover Britain alone on such a large scale — and of course much bigger scale maps than that of Britain are available to the public.

In India and Burma the standard map sheet covers one degree each way (i.e. one degree of latitude and one degree of longitude) on a scale of 4 miles to an inch. This 'degree sheet', as it is called, measures about 22 by 27 in. No less than 78 sheets are needed to cover the whole of Burma on this scale, so that along the mountainous frontier it is hardly surprising that considerable areas are left blank, or are decorated with dotted rivers, hypothetical mountain ranges, questionable native tracks, non-existing villages and rumoured passes.

In order to discover what areas are unsurveyed, one must study large-scale maps. If there are ¼ and ½ in. maps in existence, then it is a surveyed region. If there is nothing larger than 1/2 M. or 1/M., no regular survey has been made; the maps have been compiled from the route reports of travellers and are unreliable, though better than nothing. But larger areas than can be clearly indicated on a 1/M. map sheet, though surveyed, are unexplored as regards their vegetation, animal life, and rock structure; that is to say, they are unexplored in the modern sense. North Burma in fact is an excellent example of a country which is surveyed, but not, as the word is understood here, explored. Great areas of Tibet are neither surveyed nor explored.

On the other hand it would be easy to describe the flora of any botanically unexplored region in general terms, whether in Australia, New Guinea, Brazil, Tibet, Arabia or anywhere else; the reason being, so much is already known that most of what remains can be guessed. The part is like the whole. We know just what plants, or at least what vegetation, to expect in any quarter of Tibet, for example. In Eastern Tibet a botanical explorer would be certain in advance of finding many new species of plants; but the majority would belong to genera we know already to be characteristic of Tibet.

If now we reverse the above process, making our large-scale map sheets shrink and shrink till one sheet covers the same area that was previously spread over 256 sheets (that is a reduction from one inch to a mile to one inch to 32 miles, or 1/2 M.), we can easily see why the whole area looks as though it were explored. On this scale, a thousand square miles is represented by a little square of 1-in. sides. Now reduce it still further to the size of an ordinary school atlas, say 9 by 12 in., and show the whole of Asia. The scale will need to be not larger than 1/40 M., that is 640 miles to an inch. The whole of Burma on this scale would cover about one square inch and would of course be rather insignificant. It would not be worth while to leave any part of it blank; rivers and mountain ranges outside it may as well be prolonged into it, even if their course is not known within 20, 30 or even 100 miles. If there are no names, what of it? There are plenty of places covering a much greater area than that — deserts, mountains, icy wastes, where names are scarce. Even Tibet on this scale looks well known and homey!

In short, the young explorer can console himself in the knowledge that there is plenty of unexplored country left, even under the old terms, when exploration meant something different from what it means to-day. Pioneer journeys can still be made in Central Africa, Central Asia, South and Central America, Australasia, Indonesia, the Polar regions — not on so grand a scale as at the beginning of the century, but on a quite adequate scale. The world to-day is relatively explored, yet it cannot be maintained that the great forested regions of the Amazon basin, and the Congo, the great desert regions of Australia and Tibet, or the mighty mountain ranges of the Andes and the Himalayas are fully explored. On the contrary, much still remains unexplored. According to Professor A. M. Low, less than half of the 55½ million square miles of the earth's land surface has been surveyed. It is impossible to say how much of it remains to be explored; but it is certain that its exploration is not yet completed.

The traveller who crosses an unexplored tract cannot see much of the country on either side of him, and what remains unvisited is unexplored. If he is provided with nothing better than a prismatic compass, an aneroid barometer, and a sketching board, the explorer must not expect to add much to our knowledge nowadays; but even so he can still do something to lighten our darkness. In 1935 I traced for a hundred miles, and crossed by three separate passes, an unknown snowy mountain range in Tibet, and with the help of the instruments mentioned and no other, put it on the map as accurately as anything else in that part of Asia; the new range is not grossly out of position even on the 1/M. map, for example, and is a considerable improvement on the blank which it has replaced.

Nevertheless it cannot be too strongly insisted that modern exploration is largely a matter of precision instruments recording regular series of observations. The days of the pioneer explorer, though not yet over, are rapidly drawing to an end; not because there are no lands left to pioneer, but because the standard has risen enormously and there is no excuse for the explorer to go forth ill equipped. The rough compass traverse which told us so much in the nineteenth century tells us comparatively little in the twentieth. If his ambition is to make a map, the explorer should aim to produce a better map than existed previously. It is worth while to carry the instruments and take the little extra trouble necessary to improve on any existing compilation, and to produce a map which will help future travellers.

As for the modern explorer who is primarily an archaeologist, botanist, geologist, ornithologist, or some other scientific expert, who works mainly with small-scale maps, the world is already sufficiently well mapped for his purpose. If he does any survey work at all he will be content with a less accurate map than the surveyor demands.

It is impossible to discuss here the many specific geographical problems which require to be solved. Moreover, unless one has closely studied the region with large-scale maps, read the travel literature, and kept abreast of what is being done — become, in fact, an authority — one cannot put one's finger on any spot and say confidently, 'No white man has ever been there before'! This indeed was the frantic boast of Victorian explorers, who fondly imagined that only white men explored! Nowdays only the crudest self-advertisers talk like that.

Nor must it be forgotten that many governments which in the last century did not maintain a survey department, and hence did not object to foreigners making maps, nowadays make their own — China, for example. And though there are still a few countries which produce no maps, or very poor ones, other than European explorers may be quite capable of doing it for them!

With regard to that small part of Asia which I myself know well, however, I can speak with confidence; and when I think of how much exploration remains to be done there, I am — well, pleasantly surprised! For many years I have travelled in South-East Asia, studied available maps, helped to make them with pioneer surveys much more accurate than anything previously in existence, followed closely the travels of others. So far as North Burma, the Assam Himalayas, Southern and South-Eastern Tibet and parts of Western China are concerned, I am, so to speak, on home ground. It might therefore be of interest to indicate a few of the problems which remain to be solved in this corner of Asia.

I must preface my remarks with the warning that in the realm of physical geography at least there are probably no big surprises in store.

In 1930 Lord Cranbrook and I explored the headwaters of the

Irrawaddy, crossing from the sources of the Nam Tamai to the sources of the Taron, these two rivers, especially the last-named, being the principal feeders of the Irrawaddy. We found that the Taron rises apparently in three or four nearly equal streams, at least two of which have never yet been followed to their sources. This, however, needs confirmation. If *one* of these is the source stream, which one? Or are all four equal? There are numerous glaciers here and the whole wild region is unsurveyed. It is not even certain which branch of the Adung river is the main stream of the Nam Tamai, that which we followed to the Namni Pass or the one which flows from the glaciers of Ka-Karpo-Razi, a snow peak rather over 19,000 feet high on the Burma-Tibet frontier. The latter valley has never been explored. In 1937 I reconnoitred the southern approach to Ka-Karpo-Razi. I concluded that it was unclimbable from the south, but it is possible it might be climbed from the north or east. The truth is, the whole mountain mass between the Lohit river and the sources of the Irrawaddy, covering 2000 square miles, is *terra incognita* — its peaks, passes, valleys, glaciers need to be rigorously explored; to the botanist it will prove a paradise of new and rare alpine flowers.

East of the Taron, in the north-west corner of Yunnan, the explorer can find a lot of work to do on the principal mountain ranges, all of which rise above the snow line, although we do not know the heights of the peaks. Between lat. 20° and lat. 30°, a distance of over 120 miles, the Mekong-Salween divide which comprises a string of glittering snow peaks — none of them have ever been climbed — is cut into by several passes of which nothing is known, although one or two of them have been crossed by European travellers. Of course the main framework of this 'land of deep corrosions', where for 150 miles the three great rivers, Yangtze, Mekong, and Salween flow parallel to and within 70 miles of one another, is known. But only the framework. Actually we know more about the flora of this terrific country than might be inferred from our ignorance of its topography, since the most indefatigable travellers here happen to have been first and foremost botanical explorers. In recent years some interesting anthropological and ethnographical work has been done in this region by Mr. C. P. Fitzgerald.

Along the Burma-China frontier between lats. 28°-29°, several routes lead from the Taron gorge over the Irrawaddy-Salween divide which have not been crossed; the divide itself from lat. 26° northwards is unknown ground.

Further west, in the Assam Himalayas, the southern approaches to the main range, dominated by the peak called Kangto, 23,400 feet high, are unexplored for 200 miles; the same applies to the gorges of the big rivers which rise on their flanks, including the Subansiri which rises in Tibet *behind* the Himalayas, the Bhareli, Kamla, Syom, and others.

Lastly we come to the south-eastern quadrant of Tibet itself, an enormous tract of country, so deeply slit by profound chasms and uplifted between them to the skies as to have lost all resemblance to a plateau. The whole region, though partly explored, is very little known, and contains many unexplored areas, bristling with geographical problems. For example, the Po-Yigrong (river) flows in a terrific gorge flanked on either side by towering snow peaks, about which we know nothing beyond the fact of their existence. Does the river cut diagonally *across* a single range, or does it flow between two separate parallel ranges? How high are the mountains? What passes are there over the northern range? Was the gorge ice-worn to begin with? These and many other questions require answers.

Yet these are all minor problems of topography, some of which can be cleared up by the simple process of making a survey, the foundation of all geographical knowledge. But topography is not graphy — it is just a tool with which the geographer works. en pioneer exploration, as I have said, is still possible, though iminishing scale. An outstanding pioneer journey was made as tly as the 'thirties by one of our youngest explorers, Ron Kaulback, who with John Hanbury-Tracy crossed South-ster Tibet in 1935-37. Kaulback, though he has certainly d to our scientific knowledge of a little-known part of the world, is more the fearless pioneer type of explorer and surveyor than most of his contemporaries. Another fine journey of this period was Martin Lindsay's crossing of Greenland. But the most notable pioneer explorer of the twentieth century is Lieut.-Col. F. M. Bailey, C.I.E., whose travels deserve to be far better known. Bailey's journey from the Yangtze to the Brahmapútra (1911) was an outstanding *tour de force*, and so also was his journey through Southern Tibet with Major Morshead two years later. Moreover, he had an important share in introducing to British gardens that incomparable 'blue poppy' commonly known as *Meconopsis Baileyi*, but more correctly equated with the longer-known *M. betonicifolia*.

Bailey's travels inspired a number of later explorers, including Ronald Kaulback and the writer (who is almost a contemporary!).

It is not always the most spectacular journeys which obtain the most valuable results. In fact, in the twentieth century, spectacular journeys, since they are generally across desert regions, hot or cold, are almost necessarily more barren of interesting geographical results than plainer journeys. Thus Bertram Thomas's journey across the Arabian desert, though a magnificent achievement, added little to our knowledge of Arabia. Not much could have escaped the keen and trained intelligence of the first man to cross the 'empty quarter'. Yet beyond confirming that it was indeed the 'empty quarter', Bertram Thomas did not, and could not, tell us much that was new. The same may be said of Philby's equally bold journey across the 'empty quarter' in another direction, which rounded off half a lifetime of Arabian travel. Martin Lindsay's journey referred to above, so well described in his book *Sledge*, actually tells us very little.

On the other hand, modern journeys in the Polar regions where a vast amount of work awaits a new generation — we do not even know the shape of the Antarctic Continent — often extend over years rather than months; and since they carry a large number of scientists, the sum total of knowledge gained is necessarily much greater than that acquired by a one-man specialist journey.

Dr. Sven Hedin, though his greatest journey took place i him.

early part of the present century, is really the last of the nineteenth-century pioneer explorers, rather than the first of the twentieth-century.

However, the nineteenth-century explorer meant only one thing by the word *unexplored*; he meant that to Europeans at least the physical features were unknown. For him, if the physical features were known, the country was explored, however ignorant he might be of its plant or animal life, its rocks, or prehistoric remains, or even its inhabitants. Large areas of the world of which we know little beyond the certainty that they contain much that is unknown, are written off as explored. The word unexplored is still restricted, in the popular mind at least, to *one* aspect of the geographer's work, and that perhaps no longer the most important. It is to the modern explorer that the modern geographer looks for his data, which must be drawn from every field.

To illustrate some of the major problems with which the geographer is faced in South-East Asia. How much of Burma was covered with ice during the Pleistocene glaciation, and was there the same sequence of glacial and interglacial periods that we find in Europe? Did any part of the preglacial flora survive? If so, where? What *was* the preglacial flora? That practically the whole of North Burma was covered by an ice sheet is clear enough, but the limits of the ice have not yet been accurately defined.

Until we know a great deal more about the glaciation of the Eastern Himalayas, Assam, North Burma, and Western China, we cannot really understand how plants reached Burma from Japan, Formosa, the China coast, Hong Kong, and elsewhere, or how it happens that rhododendrons reached Java and New Guinea but not peninsular India.[1]

These are the botanical problems of modern geography, problems of distribution, of extermination, of migration of plants; an explanation of the plant world as we find it. And before we can give that explanation we must complete a list of the world's contents.

We know that the movements of alpine and sub-tropical floras

[1] With one exception: *Rhododendron arboreum.*

in South-East Asia are closely bound up with the Pleistocene glaciation of Sino-Himalaya, and with the changes of climate which took place here in late Tertiary and early Quaternary times. But nothing definite is known about these movements, extensive though they must have been.

It so happens that this area of a quarter of a million square miles between the meridians of 92°-102°, and the parallels of 25°-31° is one of the richest botanical regions of its size in the world. It is a veritable treasure-house of plants. It contains not only an immense number of species, but a great variety of vegetation types, from tropical evergreen rain forest to sub-arctic tundra. It is the meeting place of several floras which have developed apart: Sino-Himalayan, Indo-Malaysian, Eastern Asiatic, Northern or Palaearctic, and Mediterranean.

To crown all, the flora is not only of scientific interest. It is not only dried specimens, the mummies of the living, breathing plants, which are desirable and which are the spoil of the collector. The living plants themselves, many of them, are of singular beauty and are worth bringing back alive, or as seed to be raised and grown in gardens and greenhouses throughout the civilized world.

In this lofty region grow many varieites of magnificent rhododendrons, besides alpine plants including the famous blue poppy of Tibet (*Meconopsis betonicifolia*), gentians, primulas, lilies, and other rock plants.

There are unexplored areas in other parts of the world, particularly in the Andes, New Guinea, Brazil, South-East Asia, Central Asia, and of course the Antarctic continent. Perhaps the greates journey of all time still remains to be made, namely the crossin of the Antarctic continent from sea to sea, via the South Pol Shackleton conceived and planned such a journey in 1914, but m with such misfortune that it was impossible to carry it out.

THE LAND SURFACE

CHAPTER II

MOUNTAINEERING

MOUNTAINEERING is not exploration, so there is no need to dwell on it unduly. On the other hand modern exploration often involves mountain climbing, so we must not entirely ignore it: nor would it be reasonable for the first explorers of the great African peaks, for example, to stop short of the summits. F. Spencer-Chapman, when he made his heroic ascent of Chumolari in 1935, added something to our geographical knowledge, and so did such fine explorers as A. F. R. Wollaston on Ruenzori, and Dr. Longstaff on Trissul, in the Karakoram.

Serious mountaineering is hardly a hundred years old. It began in the second half of the nineteenth century. The ascent of the Matterhorn by Whymper and his companions in 1865, and the disastrous descent, helped to inspire men to conquer the hills. But Hooker had crossed the Donkia La at the top of the Himalayas 20 years earlier and Hannibal had crossed the Alps some time before that. During the last decade of the nineteenth century climbing, in Europe at least, was in full swing; but we ar little about *exploration* in connection with great peaks.

ter the turn of the century, and particularly after the first world war, the position changed entirely. Men made deliberate ttempts to set foot on the highest places on earth. The Caucasus, e Andes, the New Zealand and Japanese Alps, Equatorial rica, and the Himalayas had already attracted both climbers d explorers. Now Mount Everest itself attracted climbers.

xploration was secondary; but so little was known of the ntains that it was impossible to avoid it entirely. Moreover, ut a first reconnaissance, it was impossible to plan a route to p. For mountaineers, as Sir Francis Younghusband insisted, ndard of achievement went up with each success. An en- w technique was evolved for high climbing; and not less was the special equipment now available. Half a century earlier it would have been *impossible* for man to have ascended a mountain to 28,000 feet.

It is important to realize that the difficulties of climbing a mountain are, apart from technical difficulties which may or may not be met with, precisely those which are due to an ascent into the atmosphere — cold and lack of oxygen. In ascending a mountain, one is moving not only in a third dimension but in the outermost shell of the earth; that is to say, vertically through the depth of the atmosphere. True, one is keeping entirely to the surface of the earth's crust, but it is an irregular surface; the only penetration of any of the three shells that is effected by climbing is penetration of the atmosphere.

Just as a deep sea fish suffers and dies if brought to the upper layers of the sea, so a mammal, living at the bottom of the atmosphere — that is at sea level — suffers and may die if brought to the upper layers. But some men live constantly at anything between 12,000 and 14,000 feet, and are scarcely affected at 20,000 feet.

Mountains, of course, are more difficult to explore than plains, and the greatest mountain ranges in the world are amongst the least known parts of the land surface. Mountains like those of Borneo, New Guinea, Western China and many other places are very little known, even when they are fairly well surveyed. Tropical mountains like Carstenz, Ruenzori, the eastern Assam ranges and the eastern slopes of the Andes are probably the most difficult in the world to explore, on account of the dense jungle which covers them and the complete lack of native paths. Mountains in a country like Tibet offer no difficulty, except the difficulty of inaccessibility.

From the explorer's point of view, mountains are important for several reasons. They may afford a view over the surrounding country. Isolated peaks are often rich in endemic species and may help to solve problems of distribution. And of course many parts of the world are mountainous, so that the explorer, without being a mountaineer, is forced to climb mountains anyhow.

So far as the naturalist is concerned, he does not need to climb above 18,000 or 19,000 feet, however high the peaks round him.

I can see no force in the argument that an explorer must set foot on every peak and therefore should be a mountaineer. A peak is only a point on the map. There are plenty of places on the plains where the foot of the explorer has never yet trod. If it is essential for him to tread everywhere before the region can be considered explored, let him at least begin with the plains.

A certain amount of pure exploration has been done by mountaineers whose main object has been mountain climbing. The first Mount Everest expedition was accompanied by trained surveyors, who did valuable pioneer work on the unknown approaches to the mountain and its topography; but subsequent expeditions added little to our geographical knowledge, being almost purely climbing parties.

Eric Shipton and H. Tilman, both first-rate climbers, have done splendid exploration work on the great Himalayan peaks apart from climbing. Here their prowess as mountaineers has been an asset to exploration.

The complete exploration of such mountains as Kilimanjaro, Kenya, Ruwenzori, and many others could not be accomplished without real climbing. The same is true of Ka-Karpo-Razi, in North Burma, still unclimbed and unexplored, and many other peaks.

Thus it becomes a little difficult to draw the line between pure mountaineering and pure exploration. The two overlap. The Tibetan explorer is habitually crossing passes much higher than Mont Blanc and is in a sense mountaineering; yet he need not climb to the top of a single mountain.

The Royal Geographical Society, on the other hand, has decided either that mountaineering *is* exploration, or that it is its business to further climbing expeditions. In the author's opinion, it is the Alpine Club, and not the Royal Geographical Society, which should take the lead in great climbing ventures. Unlike a succession of Mount Everest [illegible]s, the conquerors of Kamet, in spite of their success, received no special recognition from the R.G.S. But then Kamet, a mere 25,447 feet, is not the highest mountain in the world.

But perhaps this modern worship of climbing is merely an extreme example of the great change which has come over exploration since the close of last century. It marks a degree of specialization hitherto unattained and unattainable.

It is not of course necessary to climb a mountain in order to fix its position. The position of Mount Everest was fixed from several points in India in the latter half of last century. Climbers who are not exploring may be expected to make observations on glaciology, collect rock specimens, and note weather conditions at high altitudes. But even these modest contributions to geography must be a terrific strain at 25,000 feet. It is unreasonable to expect climbers, whose principal object is to climb higher and higher peaks, to do geographical work as well. From the geographical point of view, more valuable results are obtained nowadays by climbing mountains 12,000 to 18,000 feet high than by climbing the giants.

It would be interesting to draw up a list of peaks of modest altitude, which, owing to their peculiar position, it would be worth while for the geographer, as opposed to the climber, to tackle. Of late years, valuable geographical knowledge has been obtained by naturalists, especially by botanists on Ruenzori in Equatorial Africa, by ornithologists on Mount Victoria in Burma, and by geologists in the Himalayas.

There are literally hundreds of peaks in the Caucasus, the Andes, the Himalayas, and Tian Shan, in Tibet, Yunnan, Szechuan and other parts of Western China, possibly also in other much better known parts of the world, the climbing of which would add far more to our geographical knowledge than would the conquest of Mount Everest to-day. Prestige, that exacting goddess, may demand that we waste more lives and money over making certain that at least one man sets foot on the highest known point of earth; but not Geography. Even peaks of very modest altitude — and by modern *mountaineering* standards nothing under 19,000 feet is worth looking at — even peaks of ignominious altitude, whether the summit is reached or not, will, when systematically explored, add enormously to our geographical knowledge. Peaks of 12,000 feet and over, of which there are a great many anonymous examples in North Burma, Western China, and along the Assam frontier, to mention only a fraction of the world, are simply living museums to the naturalist. Unless, however, they are comparatively isolated, that is to say unless they rise one or two thousand feet higher than the average of the surrounding country, their fauna and flora are unlikely to differ in any marked degree from the fauna and flora of the neighbourhood. One can point to a few peaks, as yet unexplored, in North Burma and say with confidence 'There grow endemic[1] species of plants'. But it is the degree of endemism of the North Burma mountains as a whole, between about 5000 and 11,000 feet, which is so remarkable. The local endemism of a few isolated peaks such as Saramati[2], though interesting, is not a matter of great consequence, compared with the regional endemism of North Burma. There are to-day probably more unknown species of plants in North Burma than in any other area of the same size in the world. Nevertheless the naturalist might well pay attention to the isolated peaks of the Burma ranges. Given a clear 2000 feet of superior height, within the forest belt a high degree of local endemism is assured; whereas in the alpine region — above 12,000 feet, say — there is less chance of endemism, the North Burma alpine flora being markedly Sino-Himalayan in composition, i.e. very similar to that of the Himalayas generally.

But there are also plenty of high peaks left, the conquest of which would extend the best climbers. It will be many years before even half the mountains of the Assam Himalaya, Southern Tibet, and Yunnan are climbed. Our knowledge of Tibetan geography would be greatly increased by an ascent of Namcha Barwa, and of Gyala Peri, those twin peaks which stand on either side of the Tsangpo at the gateway to the gorges. Further east are the mighty peaks of the Po-Yigrong range, some of which probably exceed 25,000 feet. Ka-Karpo (Kargurpu), just south of Atuntzu in the north-west corner of Yunnan, from the summit of which a most comprehensive view of this difficult country would be obtained, is hardly less than 25,000 feet. Pai-ma-shan, not far to the east across the Mekong in the same region, is rather lower.

[1] i.e. species which grow there and nowhere else.
[2] Saramati was climbed by Pu Nyo, a young Karen officer.

It would be easy to multiply examples. From the Pai-ma pass one looks eastwards across the Yantgze to a tumbled sea of snow peaks whose very positions are unknown. On one occasion only I caught sight of a monarch in this direction, rising high above its neighbours; but I was unable to fix its position even approximately. It may have been 25,000 feet high, and it lies north of Chungtien.

From time to time vague rumours of a peak higher than Mount Everest are heard. They nearly always emanate from Tibet, a region sufficiently unknown to make the story at least plausible. But as they are invariably backed by guesses, estimates, and suppositions, and are never supported by anything so dull as measurements, geographers, although interested, do not take them very seriously. They listen, and reserve udgment.

Nevertheless in this field of high peaks is a fine chance for the young explorer — who need not climb to the top. There is no *a priori* reason why a mountain more than 29,000 feet high should not exist — only it has not yet been discovered. If such a peak does exist, we can say with absolute certainty that it is not in North or South America, or in Africa or Australia; it can only be in Asia and more particularly in Tibet or Western China.

Some dozen years ago it was being freely stated in certain quarters that Minya Gonkar, a snow mountain a few miles south of Tatsienlu in Far Western China, was higher than Mount Everest. I had myself camped on the lower slopes of Minya Gonkar, at about 16,000 feet altitude, in 1911, and for the first time had seen the great Tibetan yellow poppies growing there. I had also, of course, had good views of the peak and of its glaciers, and was impressed. But Western China seemed to bristle with snow peaks equally high. In 1934 the Secretary of the Royal Geographical Society asked me my considered opinion of its height, and I gave reasons for believing that there was no mountain in Western China more than 25,000 feet high.

Two years later Minya Gonkar was climbed by a party of Americans. It proved to be just under 25,000 feet.

That mountaineering and exploration are indeed different is emphasized by no less an authority than Hugh Ruttledge, who writes in his book *Everest 1933*: 'All members of the party with the exception of the leader had so far been selected with the definite idea that they were potentially capable of taking part in the final assaults on the mountain. Scientific or other attainments were secondary considerations and everything had to give way to *mountaineering proper*' (My italics). We may, I think, leave it at that.

CHAPTER III

THE WORLD OF THE TREE-TOPS

It cannot be too strongly insisted that modern exploration demands two qualities, namely (1) expert knowledge, and (2) concentration. The happy-go-lucky days of exploration are virtually over, at least as a means of adding anything substantial to our knowledge of the earth. It is true that whole new worlds have lately been opened up for exploration — the depths of the ocean, the earth's crust, the stratosphere — and that we are only at the beginnings of these; whereas we are nearing the end of the exploration of the earth's surface. Yet we cannot approach the exploration of these new worlds in the same haphazard way in which we approached the older two-dimensional exploration. For the new exploration is a highly technical and also a very expensive business. It is just here that expert knowledge and specialization are absolutely essential. So also is team work. Before dealing with these advanced fields, however, I will say something about modern methods in the older field of two-dimensional, or surface, exploration. One interesting line, which has been especially developed by that distinguished Himalayan naturalist Major R. W. G. Hingston, M.C., I.M.S., and later by Dr. Sanderson of Oxford, is the exploration of the equatorial forest canopy.

This demands some explanation. All round the equatorial belt, in South America, in Central Africa, in Malaysia, over a breadth which varies from 1000 to 1500 miles, spreads the tropical evergreen rain forest at its best. The height of the trees varies from about 150 to over 250 feet, with occasional specimens reaching to greater heights. The canopy is closed; that is to say the trees grow close together and their crowns meet overhead, forming a continuous roof. There is not room for another tree to break through the canopy until one of the existing ones dies, unless it is content to live in the darkness *under* the canopy. There are smaller trees, shrubs, and of course herbs, usually with big leaves, forming lower tiers of vegetation under the main canopy; these are secondary to the high jungle, though part of it.

In passing we may note that the tallest trees in the world, the blue gums (Eucalyptus) of Australia, and the redwoods (Sequoia) of California and British Columbia, do not occur in the equatorial forest belt. These trees, which reach the immense height of 400 feet and the great age of over 2000 years, do not make a closed canopy, neither do they grow in regions of prolific life. It is unlikely, therefore, that they conceal any tree-top life, 300-400 feet above ground, of which we know nothing, since in those open forests life is difficult to conceal.

In the dense dark equatorial forests, however, it is a very different matter. Here the canopy is a self-contained world, solid, continuous, connected with the world on the ground, but not of it. It is a three-dimensional world, difficult of access, suspended 100-300 feet above the ground, between the ground, in fact, and the free air above. It affords cover, sunshine or shadow, food and water, and produces fragrant scents, bright colours. Here life is hidden, as well from the man on the ground as from the man skimming over the tree-tops.

Does that life differ in any way from life on the ground a couple of hundred feet below? If so, in what way? And why? Hingston says it does, and he is worth listening to.

Life in the tree-tops is purely arboreal — it keeps to the tree-tops, or much of it does. Birds and insects, of course, being free to rove at will, might be expected to be the same as birds and insects met with down below in the forest. Apparently they are not.

(Incidentally, one meets with few birds in the depths of the forest.) Arboreal mammals and reptiles, on the other hand, are another matter. There is no reason why, if there are any mammals and reptiles in the tree-tops, they should be the same as those lower down.

In the South American tree-top roof live monkeys with prehensile tails; also sloths, which are skilful tree climbers.

In the eastern jungles, on the other hand, arboreal mammals have developed means of gliding or planing through the air. They can only plane downhill, of course, but they cover considerable gaps by this means. Thus there are 'flying' squirrels and 'flying' lemurs. There are, strange to relate, also 'flying' frogs with enormously expanded feet which act like sails when the frog leaps from tree to tree. None of these creatures ever descends to ground level.

There are plenty of small mammals also, non-flying, which rarely or never come down to earth, for example the small panda. I once isolated a panda in a small tree on a steep mountain-side, and forced it slowly out on to a thin branch, along which it could not return. It moved slowly and with immense deliberation, till the branch bent far down under its weight. Finally the panda had to drop and run for it, or stay where it was and be caught. It dropped; and anything more awkward than that panda running away on steep and stony ground I have rarely seen. Nevertheless it moved surprisingly fast, taking little leaps. Gibbons, too, rarely leave the trees.

Many birds in the eastern tropics, such as hornbills, green pigeons and woodpeckers, are practically confined to the tree-tops and consequently are difficult to watch, if not to see. Whole groups of birds, one suspects, are rarely or never seen by the naturalist in the jungle when he is confined to the ground. My own explorations have been chiefly in the hill jungle where one can often look down into the canopy from a steep ridge. Here in North Burma and Assam the trees are smaller, the canopy not so close knit, the jungle less luxuriant. Even so, in the evergreen rain forests of Burma far north of the equator, one gets the impression of a world of the tree-tops, a life apart. Looking down on to it, one sees strange birds flitting from tree-top to tree-top, gorgeous butterflies rocketing across the landscape, clouds of insects gathered round some flowering tree; all pointing to a stratum of life very different from any which lives in the perpetual blackout down below.

But it is in the insect world that most discoveries are likely to be made, at least as regards the finding of new species. Even new species of butterfly might be discovered amongst the tree-tops of the equatorial forest, or of the dense hill forests. And new plants also; epiphytes, small orchids and others. Epiphytes are not usually shade-loving plants. A few are, but more are sun-worshippers. It is to get light and air that they have left the ground and perched themselves up on the branches of big trees. For there is only a very subdued light down below, the canopy is too thick. But plants also want water, and unless they take precautions they may find themselves cut off from it aloft. The epiphytic fig trees, from their perch on the branch of the host, drop roots to earth, and eventually these become strong enough to support the fig tree, which shows its gratitude to its host by strangling it. It has stolen a march on all its competitors. They started at the bottom and climbed up. The fig tree started at the top and thence reached the bottom.

But orchids and rhododendrons cannot emulate the fig. They have to compromise between the need for light and the need for water. Many of them develop water-storing tissue of some kind, and are able, like the camel, to go for long periods without drinking.

Epiphytes are more varied and abundant in the hill jungle than on the great plains and estuarine flats of the tropical zone, and for a good reason; the hill jungle, in the monsoon region especially, is more constantly moist than the plains jungle. When it is fine, hot, and dry on the plains, it is often fine, cool, and cloudy in the hills. More rain falls on the hills than on the plains. The hill jungle, however, is not so tall as the plains jungle. In North Burma it rarely exceeds 120 feet; nor is the canopy so dense as it is on the plains. In fact there are extensive holes in the roof, through which the light streams as through the ruins of some enormous cathedral. In botanical parlance, the association (here called hill jungle) is not closed; there is room for more trees. However, though many are called, few are chosen; there are far more competitors than places.

Finally, as a result of the more open canopy, and more illumination, there is a denser undergrowth.

Earlier generations of naturalist explorers were largely concerned with discovering new species, that is to say, with making an inventory of the contents of the world. They also described examples of animal camouflage, mimicry and the like, particularly in the insect world. While taxonomists and others will always be interested in new species, modern explorers are less concerned about them than were their predecessors. Animal and plant associations and their environments are more important than individuals to-day. It is the society as a unit that the modern naturalist studies.

In this connection the world of the tree-tops opens up a fascinating field which is worth inquiring into more fully, by means of collections made at different heights above the ground, and also by means of continuous observation. Special tackle, of course, is essential. Plenty of stout rope, climbing irons, perhaps a small rocket apparatus to throw the first line over a high branch — for tropical tree trunks rise smooth and branchless for a hundred feet, and, being of considerable girth, require a special technique. Hingston hauled observers up the trees in a sort of bos'n's chair; he also hauled insect traps up to various levels to catch the life of different strata, just as trawl nets are pulled through the sea at various levels. The methods used by Hingston, who was a pioneer in this field, are capable of improvement. Personally I should enjoy a lonely vigil in the bos'n's chair, suspended 150 feet above the ground directly under the rich canopy of the evergreen rain forest of North Burma. But — 'ware ants!

PART THREE

THE LITHOSPHERE

CHAPTER I

EXPLORATION OF THE EARTH'S CRUST

Both atmosphere and hydrosphere are fluid, the former gaseous, the latter liquid. They are easily penetrated. Lack of oxygen and intense cold make it impossible for man or any other form of life to reach the outer limits of the atmosphere, which may extend anything from 30 to 50 miles above the earth's surface. Unbearable pressure, and perhaps also lack of oxygen — certainly of food — make it equally impossible to sustain life at the lower limits of the hydrosphere, more than 6 miles below the surface. But within limits, given the instruments, man can penetrate both atmosphere and hydrosphere.

The crust itself, which supports the two fluid shells, is however solid. The weight of both atmosphere and hydrosphere presses on it heavily. Even more heavily does it press on itself. It cannot be penetrated, hence we know very little about its structure and composition. Because it is solid, we can bore holes in it, holes large enough for us to descend — mine shafts. But the deepest mine is only a little over 8000 feet deep — less than 2 miles — an invisible scratch on the surface. Another source of information is by means of borings, as when drilling for oil. Yet neither mines (coal mines at any rate) nor borings for oil are made in the original crust of the earth. They are confined chiefly to stratified or sedimentary rocks, which are not part of the first crust, though since derived from it.

If we suppose that in the beginning the hydrosphere formed a complete shell covering the crust, with the atmosphere above it, then there would have been no rivers pouring silt into the sea, and the only accumulations on the sea floor would have been those derived from the skeletons of creatures living in the sea, falling to the bottom and accumulating as beds of lime or silica; or from submarine volcanic eruptions; or from outside sources, that is to say, cosmic dust. There may have been clouds, producing heavy rain, but the rain carried nothing with it from the atmosphere except gases in solution, back to the sea. Over the whole world, therefore, the sea would rest directly on the crust, the atmosphere directly on the sea.

As soon as crust, that is to say land, appeared above sea level, however, owing to warping, and came into direct contact with the atmosphere it began to disintegrate or 'weather' under the influence of wind, rain, snow, changes of temperature and so on; and rivers began to transport the small loose fragments broken off back to the sea, where they were laid down in layers or strata and sorted, the largest fragments dropping nearer the coast, the smallest further out. In this way the stratified rocks were, and are still being, formed. The action of waves along the coast also destroys the land. In the course of time further warping of the crust would lift up the shallow sea bottom where such sediments had accumulated, and this might happen several times over, the land rising and sinking again — there is ample evidence that it has happened over and over again in many parts of the world.

Thus the continental land is not all pure crust unless it can be shown that it has never again been depressed beneath the sea's surface since it was first warped up, but will be at least in part made up of sedimentary rocks and granite — the latter probably original crust. Whether any of the land is so ancient that it has *never* been under the sea is not certain; but there are several land surfaces older than the oldest (pre-Cambrian) stratified rocks which might claim that distinction. These are called by Suess the pre-Cambrian shields, and represent the oldest known parts of the earth's land surface. For example, the Indian peninsula is one of the oldest pieces of land in the world. It has not been under the sea since before Cambrian times. Moreover, much of it has been flooded with lava welling out of the earth along extensive cracks, so that it has a further claim to be considered as pure crust, though the lava is not so very ancient. On the other hand, the mighty Himalayas are composed largely of sedimentary rocks which were beneath the sea in Mesozoic times, and are by no means of purely original crust. The hard crystalline core of the Himalayas may, however, be original crust. Of course crust, once it has reached the surface, is attacked by the weather, vegetation, and other agencies just like any other exposed surface, so that a film of soil is rapidly formed over it; and wind may blow dust or sand into the hollows. But it is none the less crust for that.

However, it is at the bottom of the ocean, say from 4 to 6 miles down, that the largest area of crust is found, with only a thin layer of ooze or clay slowly accumulated during countless millenniums to cover it. Difficult as it is to explore this terrific depth of water, how much more difficult must it be to find out the least thing about the interior of the crust over more than half the world's surface! The ordinary sounding tube brings up only an inch or two of the surface deposit. It tells us what lies *on* the crust, but nothing about what is *in* it. Recently a 'gun' has been invented which will bring up cores several feet long, from a depth of over a mile; but it is doubtful whether these include more than surface deposits. We do not know how thick the deep-sea deposits of clay, ooze, and so on are. However there is this to be said for the crust, where you find it forming part of the dry land; you can make a hole in it, and it stays a hole, whereas you cannot make a hole in the sea or in the air and climb down or up it.

There are strict limits to making holes in the crust and climbing down them. Many of us as children have started to dig a hole to Australia, usually in the garden. We never got to Australia that way. Nature can and does make bigger and better holes than man can, and they really are made through the crust, and not just through the surface sediments which in many places hide the crust like a coat of paint. These holes, called volcanic craters, which occur along fairly well defined lines, show up and emphasize the difficulties. A volcanic crater is a hole in the crust — or rather the vent at the bottom of it is a hole in the crust: it may go down for several miles for all we know to the contrary. But obviously one cannot climb down the vent of an active volcano. If it is really active, and large enough to climb down, one cannot even approach it closely. One has to wait for the 'cease fire'. But the vent of an extinct volcano is plugged by a cork, a cork of hard stone. If the crater is big enough, and the active vent small enough, one can climb into the crater of a not too active volcano and wander about the hard lava floor. I once spent several hours in the enormous crater of the Gedeh, an active volcano in Java. The floor of most volcanic craters consists of lava and of rocks hurled out by the explosions. But the crater is really only a cup-shaped mountain of debris, thrown up round the vent. It is not itself a hole in the crust. Still one must not expect too much. If it is not a hole in the crust, it is at least composed of crustal material, and that is something. Lava, pumice, and other volcanic rocks are all derived from the crust, and throw some light on its composition.

Earthquakes are another possible source of information concerning the earth's crust. Great differences of level, both of land and sea floor, may be brought about, as in the great Japanese 'quake of 1923. But unless the crust actually splits open, the two edges remaining apart, not much of the structure is visible. One learns more of what the crust does than of what it is. Of course, as already suggested, where the crust itself has always been a land surface, without any coat of varnish in the shape of stratified rocks, direct observation does tell us something. There is one locality on earth, and perhaps only one, where an *illusion* of vertical exploration into the earth's crust is well-nigh perfect. I refer to the great gorge of the Tsangpo, in Tibet, where that river, after a terrific assault, batters its way through the Himalayas. There indeed one may truly feel that the crust has been split open to reveal the turmoil raging beneath. With the wooded cliffs towering up for 15,000 feet to the snows on either side, with a twisted ribbon of sky for roof, with the hard-pressed river thundering and echoing between the walls, one might be in the very bowels of the earth.

However it is obvious that we know much less about the composition and structure of the lithosphere than we do of the two overlying spheres; though that has only stimulated geologists and physicists to speculate the more.

One reason why modern scientists are interested in the exploration of the earth's crust is on account of the light it may throw on the age of the earth. Many attempts have been made to estimate this. The latest method is based on the rate of disintegration of radio-active substances. Geologists believe that five hundred million years have passed since Cambrian times — nor is that the beginning of the story. Again, if Wegener's theory of drifting slabs of lighter crusts floating in a heavier fluid magma is true, this also may be bound up with radio-activity.

Thus there is ample scope for the scientific explorer to discover more about the 30- to 50-mile thick crust. Volcanoes perhaps offer the best possible chance, and certainly one should lose no opportunity of exploring them intensively from every point of view. New methods are likely to be developed, perhaps even a new approach in the light of a novel theory of the earth's origin. But from the nature of the problem it seems unlikely that we shall ever be able to explore the thickness of the earth's crust very fully.

CHAPTER II

EXPLORING CAVES

FROM the earliest times caves must have attracted man. From the earliest times, and particularly *in* the earliest times, they afforded him shelter both from the frightfulness of the weather and from the attacks of wild animals. No doubt wild animals made use of caves long before man appeared on the scene. In

Europe, bears, tigers, bison and many other animals lived in them. In parts of India leopards and baboons live in caves to-day. I used to know a sea cave on the lonely south coast of Java inhabited by a family of monitors — giant carnivorous lizards — innumerable bats, and hundreds of sea swifts.

Man took over the caves when and where he could. He lived in them, buried his dead in them, and left behind the bones of the animals he had slain. On the walls he drew or cut pictures. Remarkable rock drawings are found on cave walls in the Pyrenees and other mountains. Even in those remote times man yearned to express himself — or perhaps he was only amusing himself.

Although the unknown caves of the world no doubt far outnumber the known ones, the majority of men even in very early times must have had to get along without them. There simply weren't enough to go round. Caves in fact are not very common. Great areas of otherwise desirable residential property possess no caves. They may have many other attractions — a fertile soil, a mild climate, water laid on, and, more important still, abundant game; but no ready-made caves fit for immediate occupation. In some parts of the world, notably in North-Western China, primitive man could dig his own caves in the soft yielding loess which is nothing more than compact dust. But many had to get along without roofs over their heads. Thus cave men may have been somewhat exceptional. On the other hand, it is possible that only where caves existed did man exist.

The former alternation of cold and warm climates in Europe has been conclusively proved by the exploration of caves, more especially those of the Somme Valley. These caves high up on the slopes above where the river flows to-day were inhabited by animals for tens of thousands of years, and their bones lie buried in the cave earth, layer on layer. There are two different faunas, an Arctic fauna where reindeer, Arctic fox and other northern animals are associated, and a sub-tropical fauna with the remains of animals such as lion, hyena, elephant, which lived and still live in a warm climate. One fauna supplanted the other as a glacial climate succeeded an interglacial, and was again succeeded by intense cold. When the ice advanced, the warm-climate animals migrated southwards, and when the ice retreated they came north again. This proves a former land connection between Europe and Africa, across the Mediterranean basin. The story of the Glacial Age in Europe has been worked out in great detail, largely on the evidence afforded by caves. Many explorers and scientists, geologists, archaeologists, anthropologists and zoologists have contributed to this knowledge. Yet a great deal remains to be done.

Of the Glacial Age in the Himalayas and in China, however, we know practically nothing. An extensive field lies open to the explorer and student in Asia, and also in Africa. Caves will no doubt give us many clues, and we may perhaps anticipate discoveries which will modify many of our present theories.

The explorer who discovers a cave should examine it closely. He may not be able to carry out a full investigation; but at least he should be able to give some account of it, for the benefit of specialists who follow him. It seems pretty certain that there were interglacial periods during the long glacial history of the Himalayas, North-Eastern Assam, Northern Burma, Western China, and South-Eastern Tibet. But of early man in this region we know nothing. Nor do we know anything of the animals and plants which throve here during glacial and interglacial times, or of their migrations.

There are plenty of caves in other parts of the world. In South America man is such a recent intruder that caves are not likely to give us much information about early man. But South Africa is another story. Rhodesian caves have thrown light on the story of the Bushmen; and here too we are only at the beginning of the discoveries which await the modern explorer. It is to caves we must look for further evidence of other species of man, the predecessors and contemporaries of *Homo sapiens* in Africa, Asia and Europe.

Caves occur both along sea coasts and far inland. They may be due to wave action working on soft rock, such as sandstone, or to water action, dissolving the rock, and carrying it away in solution. This latter work in limestone districts often goes on underground and unsuspected. Most of the really important caves in the world are in limestone rock, and were made by running water. It has been shown lately that as regards limestone caves, what is visible at the surface usually forms only a fraction of the hollowness concealed underground. Water works underground as patiently and as efficiently as it does above ground. But subterranean caves betray their presence scarcely at all. Like a hollow tooth, a vast cavern may exist, unsuspected save for a tiny spot on the clean exterior visible only to the expert. One may walk over a mountain which is a mere shell. The ways of underground streams in excavating these vast chambers are mysterious. A small stream — 'where Alph the sacred river ran' — disappearing into the earth may be all the outward evidence for 'caverns measureless to man'. The wide-awake explorer, noticing Alph's disappearance, may halt for a moment to ponder on the curious ways of nature, and pass on, little suspecting what lies right under his feet. At the other end of the story is the point where the stream issues into the light of day once more. Now it is a spring, which comes to the surface perhaps many miles from where it went to ground, and many hundred feet lower. What lies between its entrance into and its exit from the earth is a secret. Cave punchers, or if you like, spelaeologists, in Europe, including Great Britain, and America have been revealing these secrets during recent years.

But though searching for, and exploring, the passages of caves is an important activity of a Spelaeological Society (of which we have several in Britain) it is not the only one. There is no more fascinating story than the early history of man, and, as we have already seen, some of the earliest chapters of this story are bound up with caves. It is the antiquarian and the ethnologist who unravel for us the story of cave men. Other scientists whose co-operation is needed if we are to read the whole story are geologists, zoologists, and sometimes botanists. In caves, as opposed to subterranean caverns, there is often abundant and varied animal life. The famous Kentucky caves in North America have a fauna of their own which has long been isolated. But no trace of man more than about 3000 years old has been discovered in the New World. Cave animals are usually blind, since having eyes they would not see. In the Mammoth Cave and in Jacob's Cavern, Colossal Cavern, and other caves have been found blind — and wingless — grasshoppers, blind crayfish, fish, spiders, flies, and beetles. To the zoologist also falls the task of interpreting the bones of extinct animals found in the cave earth. Sea caves, especially tropical sea caves, are the abode of special creatures of which more anon.

Plant life, or at all events flowering plant life, is generally absent, owing to the eternal darkness, because green plants need light; but plant remains are sometimes found in the cave floor, as in the Somme caves already mentioned.

In Great Britain the Mendips are the hunting-ground of our most expert cave punchers. There are also caves and swallow holes in the Peak District of Derbyshire, and in Yorkshire, and no doubt elsewhere. The Mendip caves are believed to be amongst the earliest inhabited parts of Britain, though whether their first inhabitants were human or sub-human is a moot point. At some period, however, they were undoubtedly inhabited by undoubted man, though not necessarily by *Homo sapiens*. However, modern cavers have reached vast subterranean chambers which neither Cro-Magnon nor any other race of man ever knew, if only because he lacked the technique necessary to reach them. The twentieth-century expert caver is a skilled climber who has evolved a technique of his own. As in other specialized fields, such as crossing the Antarctic continent and climbing high mountains, primitive man could not compete. He could not strap a power lamp round his head, nor had he the other necessary equipment, apart from the pocket survey instruments, special flashlight apparatus, and cameras, carried nowadays. The Mendip cavern revealed by Messrs. Goddard and Pearce in 1941, dissolved from within by the ceaseless action of water and plastered with stalactites as water charged with lime in solution dripped for unnumbered centuries, may be half a million years old; but it remained for twentieth-century man to discover it.

So far as such subterranean caverns are concerned there is little to be done beyond routine exploration, including measurements and a pictorial record of their fantastic beauty, too long concealed. Only the geologist can estimate their probable age. Clearly there is no place here for the zoologist, botanist or archaeologist, over 400 feet down in the bowels of the earth in everlasting darkness. On the other hand, there are questions to be put to the chemist and the physicist.

There is also an economic side to caves which may be mentioned. The guano caves of Chile were formerly more important than they are to-day; while in the sea caves of the eastern tropics are found those edible birds'-nests which for a thousand years have been a Chinese delicacy appreciated by no one else. Large sums are paid for the monopoly of collecting them. I once entered such a sea cave by boat off the coast of Siam, and found lop-sided bamboo ladders, their bases resting on slippery ledges, jammed against the damp walls at alarming angles. They disappeared into the darkness above. The nests, made of seaweed plastered over with saliva, are the work of a small swift.

Nor should we neglect the aesthetic side of cave exploration. Photography is of course a necessary part of modern exploration, and there is no reason why an illustration meant for scientific purposes should not be beautiful. As a matter of fact the quaint beauty of underground caverns, lined with stalactites and more stalactites, pales beside the wonder of many a sea cave.

Whereas the Mendip caverns are famed for internal decoration — the delicate tracery of their walls where liquid limestone has run down like frozen wax and candelabra hang rigidly from the vaulted roof or spring upright in clusters from the stony floor like petrified bamboos — the sea limestone caves are decorated mainly without. Some years ago when steaming in a launch along the outer edge of a continental shelf from which projected an archipelago of peaks whose bases were sunk beneath the waves, I spied the Marble Rocks off the Tenasserim coast. These comprised a small constellation of snowy-white limestone turrets and towers, sculptured by the waves. The windward rock rose like Aphrodite out of the violet sea, sheer and smooth as the Eddystone light-house, its fluted cliffs drawn up into airy points with knife edges, till the whole summit glittered with Gothic spires. It might have been a castle in Spain, or a fairy tale. No beach broke the grim front that bare rock opposed to the sea; it shone with an incandescent white heat beneath the tropic sun. If, as I thought possible, this solid looking bastion was hollow with a sea cave inside, how had it been hollowed out? Anyhow there was no climbing up those sharp and naked walls, where only the limpet and the whelk could cling. One dared not take the little launch too close in, for fear the swell rolled her on to a spike of rock. On circling the isle for the second time, however, my eye was caught by what I can only describe as a jade-green pool in the midst of the violet sea, near the foot of the cliff; and even as I stared at it wondering, it grew brighter, greener. It was as though sunlight were streaming upwards from the bottom of the ocean! On reaching the green pool I found that the illumination actually came from under the cliff itself and flush now with the falling water — for the tide was ebbing fast, the dark entrance to a tunnel appeared!

Then everything became suddenly clear. The tower *was* hollow! Also there was a hole in the roof, which let in not rain only, but sunlight. And there was a hole in the solid wall too, a submarine hole, a tunnel into the cave, through which shot out the beam of light which had illuminated the green pool. The invisible maggot of chemistry had been at work silently, ruthlessly, through the centuries and had gnawed out the guts of the sea fortress, leaving only the husk to beat back the tide!

Even so — and the explanation was as certain now as though it had been written across the aquamarine sky — I was not prepared for what followed. When the tide had ebbed far enough to permit the launch's gig to enter the tunnel, we pushed our way in, crouching to avoid the dripping roof, and met a river of sea water flowing swiftly from the cave. Our keel scraped over the sharp rocks. At the far end, thirty yards off, we saw the hard glare of tropic sunshine, then white cliffs, and — blue sky! It was fantastic! Were we sliding off the everyday world into a fourth dimension? Here indeed was the kind of exploration children dream of!

Next minute we were through the tunnel, the gig afloat in the placid lagoon, beneath the burnished sky, shut in by towering cliffs. You could neither see nor hear the ocean; a heavy silence reigned. Look which way we would across forty yards of silken blue water, we saw only a circle of fretted white cliffs — only on this side they were climbable cliffs. We lay at the bottom of a crater, and it needed all our faith to believe that, if we scrambled up the inside we could gaze down on to the ocean we had just left! For our sea fortress had no roof! There *had* been a roof; but now the whole interior of the Marble Rock had dissolved, as decay hollows out a tooth, leaving only the enamel. Then the roof had fallen in.

But, as already suggested, it is as the home of primitive man, and of extinct animals — or of animals which, if not extinct, no longer inhabit that region — that caves are of abiding interest. In almost any cave there is the chance of finding evidence of man's occupation. His pictures, his tools, his ornaments, the bones of the animals he trained, or whose flesh he ate, or whose skins he wore, have been found in many parts of Europe, and also in Africa. Skeletons of man himself, the greatest discovery of all, have been found; the explorer who discovers a cave in which are the authentic remains of man's ancestors, tens of thousands of years old, has done something big, for he has added greatly to our knowledge and opened up new avenues of research. The zoologist also, working over the bones of Pleistocene or Pliocene animals, teaches us that bears, rhinoceros, the terrible sabre-toothed tiger, even the mammoth, lived in England long ago. There are few more fascinating branches of study than the past distribution of animal and plant life, and the reasons for the changes we observe. In the modern world caves are inhabited by crepuscular animals — twilight assassins such as owls, bats, and shrews; also by leopards, bears, monitors. One imagines that many small creatures gladly take up their abode in these natural bomb-proof shelters! In the Java sea cave I visited, which penetrated no great distance into the cliff, I found the low roof so thickly coated with bats that I could thrust my hand wrist deep into the quivering fur and feel nothing but its delicious softness. At dusk the bats flitted out in endless procession. Underfoot the ground was ankle deep in a mealy unctuous guano, the droppings of thousands of bats, and of the swifts which occupied another section of the roof, already paved with edible nests. This cave soil was crawling with insects, and was certainly very rich in nitrogen. The larger fauna of this cave, the fierce-looking, ugly, but harmless monitors, I have already mentioned. Coming out on to the beach to hunt food, they would raise their crocodile heads, lash their tails, and then, if alarmed, scuttle. They lived in holes at the back of the cave. This cave fauna, as a biological unit, would be an interesting field study.

In Burma, Siam, and Malaya are enormous ranges of limestone mountains, derelict fragments of which litter the coastal plain. There are caves here in plenty, hidden and exposed, awaiting the coming of explorers. Hollow or not, the inland towers, which once rose from a shallow sea now silted up, are still 'islands' in the sense of being scattered over the mud plain. Mr. M. W. F. Tweedie of Raffles Museum, Singapore, for example, recently made the interesting discovery that while several such isolated stacks near the Malayan coast shared a few widely distributed species of Gasteropod shells, each also possessed its own peculiar species. I examined those he had collected under a magnifying glass. No larger than a pin's head, each of these minute shells revealed the most exquisite ornamentation, and in every case those from different stacks had a slightly different pattern. That these rocks almost within sight of one another should have evolved so many different species is remarkable. I have heard it said in Malaya that one can enter the caves at Kota Bharu on the north-east coast, and travel right across the peninsula to Malacca on the west coast, a distance of 250 miles, without ever appearing above ground! But this may be an exaggeration! — or a travellers' tale!

What of the future? We know that in the warm Carboniferous sea enough lime was deposited from solution to build new worlds. Limestone was also laid down in Mesozoic seas, and chalk too. Ages later, these deposits were uplifted above the surface of the sea, forming great ranges of mountains. Immense areas of Tibet are built of almost pure mountain limestone. Much of Western China, and especially Yunnan, riven by abysmal gorges which are flanked by terrific ranges of snow mountains, is made of limestone. In South-East Asia limestone ranges traverse Burma, Malaya, Siam, Indo-China, and many of the big islands. The animals which inhabited caves on what are now islands in the Mediterranean prove a former land connection between Europe and Africa. An immense amount of exploration along similar lines remains to be done in the East as well as in other parts of the world.

Whence was all this lime derived? Calcium is an abundant ingredient of the earth's crust, and from the earliest times marine life has been using it in the construction of homes for the million — corals and shells, whether of Crustacea or the more humble molluscs. The calcium got into the sea in the form of salts in solution, marine life extracted it as lime, and when the animals died they returned it to the sea beds, afterwards to be upraised as mountains. So the wheel revolved full circle.

When all these limestone ranges of Asia, with those of Africa and the Americas, have been explored with the same thoroughness as have the limestone districts of England, we may be certain that hundreds of caves will be revealed, many discoveries will be made, and a wealth of knowledge be gained. If caverns hundreds of yards long can be discovered in England in the year 1941, what of the rest of this hollow world? Let those who pine for new worlds to conquer take heart; it is certain that there is an immense field awaiting the explorer, and few activities are more fraught with possibilities than cave exploration.

The world explorer of international reputation may smile at the sometimes extravagant claims of the cave punchers, who go underground. Cave punching, like mountaineering during the twentieth century, has perhaps stolen more of the limelight than its scientific results entitle it to. On the whole, it is a student's vacation sport, at least in Great Britain—one must not expect too much of it. But there can be no doubt that skill and courage of no mean order are required of the explorer who descends in total darkness a subterranean shaft, inside which a stream of cold water plunges with him into the fathomless pit; or who swims under water through a tunnel of unknown length in the hope of reaching an open cavern before his lungs are ready to burst, as has been done by a French explorer in certain underground caves!

The best cave work will be done by explorers who are specialists in some branch of natural science, whether it be geology, anthropology or zoology. But the important thing is to find the caves, and thus blaze the trail.

CHAPTER III

VOLCANOES

A VOLCANO is a hole in the crust of the earth, a passage between the surface and the interior of the crust. It does not, so far as we know, reach down to the core; though it may do so. How can a mountain, thousands of feet high, be a hole in the crust? I hear someone ask. True the word volcano has come to be applied to the mountain of debris and lava which has been built up gradually round the *vent*, which is at the bottom of the cup shaped depression known as the crater. But the essential part of the volcano is the vent; or rather the pipe opening at the vent. The mountain and crater are secondary. A volcano always begins as a hole, or sometimes as a long crack or fissure in the earth's crust; only by repeated eruptions does it build up a mountain (or a series of plateaux if the eruptions take place along cracks). When looking at a volcano such as Fujiyama thousands of feet high, its cone white with snow, one must in imagination strip it of non-essentials, and remember that it began as, and still consists essentially of, a hole piercing the earth's crust to an unknown depth.

Many books have been written about volcanoes in general, or about particular volcanoes. A few, like Etna, the volcanoes of Hawaii, and some others, have been scientifically explored. But although their dramatic appearance, at least when active, and disastrous effects have riveted the attention of mankind from the earliest times, we still know very little about them. No sooner had men acquired the art of writing than some of the great catastrophes which have afflicted them acquired significance, not least volcanic explosions. Happily the Mediterranean region, which nourished some of the earliest civilizations known to us, is in part volcanic, and we have written records of disastrous eruptions which took place more than 2000 years ago. But we may be sure that ages before men wrote about them they were *talking* about them, and that cave man himself looked upon these terrifying and destructive mountains with awe.

A volcano and its offspring, a geyser, are the only direct links with the interior of the earth's crust known to us; they afford the only direct evidence as to the structure and condition of the crust below the surface. Unfortunately from their very nature volcanoes utterly defy the explorer just when they are most interesting, that is when they are not merely active, but at the very moment when they are in eruption.

Apart from written records, the only clue we have to the history of volcanoes is that enshrined in the rocks. These prove conclusively that volcanic activity is as old as the world; in fact it was much more violent and took place on a much larger scale when the earth was young than it does to-day.

From the explorer's point of view, then, a volcano may be regarded as (1) a topographical feature, a mountain; (2) a passage leading to the interior of the crust, which is its primary function.

So far as the first interest is concerned, a volcanic mountain is outwardly explored much like any other mountain; and so far as the second interest is concerned, the explorer is very nearly helpless until the volcano has ceased to be itself — for the vent is closed by a plug of rock when the volcano ceases work. If one is lucky enough to be present at the birth of a volcano, of course, the trained observer can make valuable observations. If he is present at the eruption of an old one — preferably at a safe distance — he may add something to our stock of knowledge, or confirm an earlier observation, or contradict one. Exploring the crater of a dormant or of an extinct volcano — and there are many volcanoes whose craters are unexplored — is a job for the geologist, chemist, and physicist; there may also be work for the biologist. With patience these may add much to our knowledge. As is now well known, volcanoes do not occur haphazard over the earth's surface, but along comparatively well-defined lines of weakness. What determines these lines is not known, but they fringe for the most part the margins of the great oceanic basins. Thus fringing the western side of the Pacific is the Andine chain of active volcanoes, while on the eastern side the line of weakness runs through the Netherlands Indies and Japan to the Aleutian Islands. Volcanoes also occur along the Mediterranean basin — the remnant of a Mesozoic ocean, and the line is continued southwards along the African rift valley on the fringes of the Indian Ocean. On the eastern side of the same ocean, a line of weakness runs through Burma to Sumatra, where it links up with the eastern Pacific arc.

In course of time these lines of weakness change their position (although the great oceanic basins apparently do not). Millions of years ago Scotland was a volcanic region; so, too, was India.

There is plenty of scope for the explorer to study volcanoes, active, dormant, and extinct *as* volcanoes; but there is perhaps even more opportunity for the naturalist explorer to study them as mountains.

There is, however, one important biological side even to an active volcano, which may conveniently be considered first. An active volcano may completely sterilize the soil all round it over a considerable area. When after some lapse of time it again becomes capable of nourishing vegetation what will be the first plants to appear, and in what order? What type of vegetation will spring up, and what will succeed it? What animals, birds, insects, will appear first? When the sterile land happens to be an island separated from all other land, the problem has a special interest.

Many years ago the volcanic island of Krakatoa, between Java and Sumatra, blew up after a series of terrific eruptions, and what remained of it was completely sterilized for months. The first plants to reappear on it were ferns, whose tiny spores must have been wafted thither by the wind. They were closely followed by plants whose seeds had been carried by ocean currents, which appeared on the shores, for example coconut palms. Studies in the sequence of plants which appear on devastated volcanic areas, whether inland or not, are valuable to the geographical botanist. Our knowledge in this field is very limited. A few general observations may not be out of place. Firstly, only those plants which grow within reasonable distance of a vacancy are likely to appear. Other things being equal, they have first chance; the further away a plant grows, the further its seeds have to travel, and the less likely it is to crop up. The first plants to arrive would naturally be those in the vicinity which possessed a good seed-dispersal technique. It would not avail that a plant grew within a mile of the vacant lot if its seeds could not reach it; whereas a plant with wind-borne seeds or long-lived spores might quickly cover the bare area. It is not enough for the seed to arrive. It must germinate, and the seedling live, before the particular plant can establish itself.

However, in time the area is covered with a type of vegetation which gradually alters as more and more seeds arrive, germinate, and grow up into plants. Suppose, for example, that the first plants to arrive are Compositae, a vast family whose members probably have the best seed-dispersal technique in the world. After a time saplings begin to appear, shrubs and bushes grow up, casting shade, killing off plants which live only in sunshine. Climbing plants arrive, and, now finding solid supports to climb up, survive. Eventually forest replaces scrub. This succession of vegetative types is a subject of which botanists know little outside a few limited areas, and one on which explorers can enlighten them. It requires, however, patient and careful observation over long periods of time to get any useful results.

I mention this particular line of research because it is specially applicable to volcanic regions, where complete sterilization of an area is a commonplace event. But any agency which destroys vegetation—fire, flood, above all man himself—sets the machinery of succession in motion. None of the last-mentioned, however, not even fire, destroy the vegetation so completely as does a stream of hot lava. If fire or flood sweep away all visible vegetation, there will be plenty of seeds left alive in the soil, and also bacteria.

The explorer then, though he may not be able to discover anything new about the crust of the earth, can nevertheless do good work in volcanic regions, or on isolated volcanic peaks. Ancient lava beds, which often retain their clinker-like properties, support a peculiar vegetation about which we know little, although it has long been recognized that soils derived from the disintegration of lava are amongst the richest in the world. It would be well worth while to compare the volcanic floras from all parts of the world. Of course climate has a greater influence on the type of vegetation than soil.

A volcano which has been extinct for many millions of years begins to lose its characteristic shape. Its crater, for example, sags and may disappear, wholly or in part; even its outline may be modified, yet there are many ancient volcanic cones, unmistakable as such, which have not been active since Tertiary times, for example Popa in Burma, the Tengchung (Teng-yueh) volcano in Yunnan, several in East Africa, and elsewhere.

Even the ancient and withered stumps of volcanoes which have not been active since Mesozoic or Palaeozoic times may still be recognized. They afford the geological explorer an opportunity to trace former lines of weakness in the earth's crust. These fissures are now sealed up, the crust hardened. We know very little about these ancient rifts, and there is a fine field of research here for the modern explorer properly equipped for the task.

But no doubt it is to the active volcano that the modern explorer will be most strongly drawn, whether he be geologist eager to learn more about the interior of the earth, or biologist eager to learn about the fauna and flora which thrive on volcanic soil, and the changes brought about by volcanic outpourings. Only once have I been inside the crater of an active volcano — the Gedeh in Java, a mountain 10,000 feet high. From the point of view of a botanist, the vegetation on the outer slopes was the most interesting feature; but I well recollect how the vast empty sulphur-coated crater itself, with its smoking holes, gave me the feeling of being down in the very bowels of the earth, or on the surface of the moon. The complete absence of life after the luxuriant tanglewood forest on the outer slope was striking.

The great snow-covered volcanoes of the Andes and of Central Africa inevitably attract the modern explorer. We still await studies of these high mountains comparable with that which Sir Charles Lyell made of Mount Etna, more than a century ago.

Many volcanic explosions take place under the sea floor; submarine volcanoes are probably far more numerous than land volcanoes. In shallow seas the debris thrown out may appear temporarily above the surface. Even on land, the hole connecting the surface with the interior of the crust may have to pierce hundreds or thousands of feet of stratified rocks before reaching the original crustal surface. But if exploration of land volcanoes is difficult, that of submarine volcanoes is obviously far more so.

PART FOUR

THE HYDROSPHERE

CHAPTER I

EXPLORING THE OCEAN FLOOR

MANY of us, when we were children, have sat on the sea shore, gazing out at the hard line where sea and sky meet, and thought passionately of all the wonderful sights hidden beneath the waves and how marvellous it would be if only the sea would dry up! What treasures seem to be for ever concealed! What sights! And what terrors! But our curiosity has ever conquered our fears. We have racked our brains trying to imagine what it would look like, with its splendours and strange submarine scenes; we have pictured fascinating water landscapes, at least on tropic shores. Sea-green grottoes floored with tinted corals, gorges fringed with feathery forests of weed, delicate as lace, shells, larger, brighter, more cunningly twisted than any ever known, mermaids perhaps...

Imaginative writers, striking a more sombre note, have emphasized the horrors of the deep. Giant sharks and monstrous cuttlefish with baleful eyes are promising subjects, and the ingenious novelist can let himself go on sea serpents and saurians to his heart's content and still be plausible. In the coral seas there is, it must be confessed, a certain amount of evidence to support the fairy landscape theory; the coral reef at its best is often beautiful. Rainbow-hued fish pass to and fro amongst the waving weed, dark-coloured sea anemones, their soft tentacles vibrating in the current, blossom on the rocks, now and then columns of silver bubbles gurgle up from the depths looking like the beaded stems of exotic plants, starfish creep over the sand, bluish jelly-fish drift by. Everything tells of a region teeming with life, quick with beauty. There are thousands of atolls and coral islands in the Pacific and Indian Oceans.

During the present century much has been added to our knowledge concerning the sea. Yet our knowledge is almost negligible compared with what remains unknown. However, the science of Oceanography only dates from the famous *Challenger* expedition (1869-73); it is barely three-quarters of a century old.

H.M.S. *Challenger* was the first vessel specially fitted out to discover everything possible about the ocean, and carrying a team of experts to explore it in three dimensions. Here fantasy recedes into the background, facts are prominent, romance gives way to sober truth; and perhaps the seas are in a measure debunked. But as usual truth is stranger than fiction, and while some of the more turgid imaginings have not come up to expectations, others have been surpassed by reality.

The truth is, however, that if the seas dried up so as to expose the rocky surface of the earth's crust, most of which it now covers, it would reveal an intolerably dull landscape; a landscape infinitely less varied than that which is normally familiar to us. Only rarely, and then always in shallow seas within sight of land, would the world under the sea compare favourably with the world under the air — the clash of peak and gorge, the roll of hill and dale, the sweep of crumpled moor, the hard, brilliant desert, above all the violent beauty of great mountain ranges. In place of this rich variety, interminable plains with hardly a furrow to wrinkle their monotony, uniform in texture as in substance, sober in colour for unnumbered miles. Hardly a plant would be seen; so that the ground would be bare as well as dull, a dried mud plain, bluish grey, or chocolate red, a very desert, stretching away to endless horizons. (Of course vegetation would soon spring up — land vegetation.)

This we suspect, and with reason. And who would wish to exchange our green and pleasant land with its many-hued mantle of vegetation for so drab a prospect! True, some geomorphologists claim that the sea floor is by no means everywhere a succession of plains. Detailed surveys off the Alaskan coast, for example, show a rugged submarine landscape. But this is probably an exception.

There is perhaps no living creature whatever at the bottom of the ocean abyss, just as there is no life, bird or insect, in the high thin layers of the stratosphere ten miles up, or in the crust of the earth itself. That is to say, life as we know it is practically confined to a fluid film composed of the upper layers of the hydrosphere[1] and the lower layers of the atmosphere, enclosing between them the crustal surface where it breaks through the hydrosphere to meet the atmosphere. Assuming that there is abundant life in the sea to a depth of 3 miles, and in the air to a height of 5 miles, we see that the life containing fluid film is less than 10 miles thick, equal to about 0.0246 of the thickness of the earth, from the outer layers of the atmosphere to the centre of the core. Life's hold on our earth in terms of three-dimensional space is therefore somewhat superficial!

That there should be no life 6 miles above the earth's surface does not surprise us, since we are used to the idea of intense cold and the difficulty of breathing at great heights; many of us have had experience of these adverse conditions, which rapidly increase as we ascend. But that the ocean depths should be almost lifeless is perhaps less widely known.

On the surface, land and sea, everything is pressed on by the weight of the atmosphere only, amounting to 14 lbs to the square inch, or rather less than 1 ton per square foot at sea level. At only 1 mile below the sea's surface utter darkness and icy cold reign in an iron silence. At 6 miles down, the weight of the sea presses in everything less rigid than steel. It is obvious that the crust itself must be very strong to support such an immense load.

Just as the outer surface of the land had to be explored first, so the surface of the sea, which is continuous with it, had to be explored before the interior. This sea surface, limiting land exploration, inspired some of the greatest voyages of all times.

But it is only within the last hundred years that man has begun

[1] The hydrosphere includes not only the seas, but the waters of the land surface, lakes and rivers also.

to penetrate below the surface and explore the depths, and only during the present century that he has descended any distance; even so, he has himself descended no more than one-twelfth of the way to the bottom.

Nearly three-quarters of the earth's crust is hidden beneath the sea. If the visible familiar land surface is difficult to explore fully — and after 6000 years of civilization its exploration by modern standards is far from complete — how much more difficult must it be to explore the thrice larger invisible *surface*! The shape of the ocean is known, the outlines of the several great basins composing it have been nearly completed; and since the sea is fluid we should be able to penetrate the surface and discover the submarine crust relief either indirectly by soundings, or directly, in shallow water, by observation. Our charts do indeed show a vast number of soundings of the sea bottom. But the sea bottom is measured in millions of square miles, and though the figures on our charts are often spread as thick as leaves in autumn, particularly along the coasts, even in congested areas they may be a mile or two apart. Enormous areas are completely blank, while other great areas are crossed by a few slim lines of figures only, so that over wide spaces the relief of the bottom is mainly guesswork. That is to say, we lack even small-scale maps of the submarine landscape, while large-scale maps exist only for coastal waters. Nevertheless small-scale sections based on hundreds of soundings have been drawn across the great oceans and broadly reveal many interesting facts, such as the elevated ridge which runs like an S-shaped spine down the middle of the Atlantic, and the great plains of the Pacific floor with its hundreds of needle isles, each ringed with coral, rising from profound depths. The shape of the ocean floor so far as we know it lends no support to the attractive theory of 'lost' continents. This does not mean that the outlines of the continents have remained unchanged throughout the ages. On the contrary, there has been a good deal of change. The warping which first pushed up the crust above the surface of the sea, and thus brought it into direct contact with the air, still continues, although it is confined to shallow seas, and visibly affects mainly sedimentary rocks. The deep-sea crust so far as we know is affected only by submarine volcanoes. The warping of the crust which has heaved up the shallow sea bottom into new land, or depressed land beneath the sea, took place very slowly; such movements may still be going on. Submarine explosions in the crust may create visible land where formerly the sea was 1000 to 2000 fathoms deep, in a few days; but land so formed rarely lasts more than a few weeks or months.

These are matters with which the modern explorer of the ocean is greatly concerned, and there is plenty of scope for oceanographic exploration along these lines. Many a scientist longs to explore, but few probably are chosen.

During the late tertiary and early quaternary times, much movement of the land and sea floor took place, particularly in Western Europe and in the East Indies. But there is no evidence to show that the great oceans were not always where they are to-day, although the continents may be the result of crustal warping since the time of a universal ocean.

Round every continent is a shallow band of sea, wider or narrower, resting on what is known as the continental shelf, the edge of a platform rising from the deep. Beyond the platform and the shallow belt of sea which covers it, the crust plunges down more or less abruptly to extreme depths. Then the slope eases off and the sea bottom stretches away as a vast level or gently undulating plain to distant horizons. It is mainly this submarine shelf within the 100-fathom line which has been affected by upward and downward movements of the crust; and since this is the area within which rock removed from the land by rivers is deposited, it is mainly stratified rocks which are brought to the surface or depressed beneath it by earth movements.

These earth movements on the fringes of the continents are important and much work needs to be done by geological explorers before we are in a position to fully understand them. Island-studded coasts offer a great opportunity. Little if anything has been written about the Mergui Archipelago off the coast of southernmost Burma, where hundreds of islands, coral-lined or fringed with mangrove swamp, stud the violet sea with deep green jungle. The island-strewn coast of Chile and the immense region of Indonesia are other places where the trained explorer can hope to find evidence of subsidence or elevation, and of when it happened. A comparison between the fauna and flora of the nearest mainland, and of the island, affords indirect evidence of the age of the island, and is a fascinating line of inquiry. Another interesting fact which has been brought to light by sounding is the existence of submarine gorges and valleys cut out by rivers; proof, perhaps, that what is now at the bottom of the sea must formerly have been dry land. The submarine gorge of the Hudson off the coast of North America is a well-known example. It stretches many miles out to sea and remains more or less as it was, sculptured in the rock, tens of thousands of years ago, though no doubt the gaunt cliffs, stripped of their green forest, are not so picturesque a feature of the sea bottom as they were formerly of the air bottom. Not all geomorphologists, however, accept this explanation everywhere. Sometimes this would imply a rise of 10,000 feet in the sea level, and that is a big order.

In short, then, our maps of the sea floor are very crude and small-scale affairs compared with those of the visible crust, and a huge amount of work will have to be done, both by sounding and where possible by direct observation, to make them equally good. At present we have almost no detailed knowledge of well over half the crustal surface of the earth!

From the commercial and therefore more obviously human point of view, the continental shelf, within the 100-fathom line, is the most important part of the sea. All the principal food fishes live within this narrow shallow zone, and in order to keep up the supply of fish we need to know all about them — their food, the conditions under which they thrive best, where and when they breed, their life histories complete. The sea is also a source of raw materials, and others not so raw, from pearls and cod liver oil to edible birds'-nests and whalebone. Certain creatures, mammals especially, such as whales and seals, have been exploited almost out of existence, greedily and foolishly. Rubber sponges may have checked the natural sponge industry; but now that rubber is in short supply, it will no doubt revive. There is gold in sea water, and the total amount in the sea must be considerable; but it is doubtful if it will ever be worth-while to extract it!

However this is a problem for the technician rather than the oceanographer, though the latter in the course of his explorations may at any time discover a new marine product, or a new source for an old one. The chemistry of sea water is indeed very important, not less to the biologist than to the chemist. Differences of salinity occur in different places, at different depths, and at different seasons. These cause small currents, and help to keep the ocean in constant movement below the surface. The polar ice-caps and rivers pour in streams of fresh water which cause further differences of concentration. But it is the constant winds which, blowing over the surface, cause the main oceanic currents; and the whole surface layer, to a depth of 100 fathoms or so, is in slow motion under the influence of these winds and minor causes, a fact of great significance in that by far the greater part of the sea's food supply is microscopic and floats at the mercy of the currents on or near the surface. From the commercial point of view it is obviously important to know where are the principal feeding grounds of the food fishes, what they feed on, and what factors govern the food supply. We know that the salinity affects the distribution of life in the sea, hence its importance no less from an economic than from a scientific point of view.

A great deal of research has been devoted to the chemistry of the sea, but vastly more work remains to be done. Like all modern exploration, that of the sea has reached the stage where worth-while work is intensive rather than extensive and often requires years of observation and reflection to get results. Only occasionally does it become spectacular. An enormous amount of routine work, of which the layman hears scarcely an echo, is carried on by experts at the various marine biological stations of the world, and in ships of all kinds. The layman may have to thank these patient research workers, of whom he has never heard, for his regular breakfast kipper, his unfailing cheap parcel of fish (and chips), or for the fact that cod liver oil or its equivalent is in ample supply.

Not less important than the chemistry of the sea is the physics of the sea — since nearly three-quarters of the earth's surface is covered by the sea, it must be, together with the even more fluid air, the chief regulator of climate; and, owing to its physical properties, it acts always as a moderator. How violent world climates would be if the position of land and sea were reversed! If on the other hand the sea were continuous over the globe, severe storms at least would probably be unknown. Unfortunately the presence of comparatively large land masses throws a spanner in the gentle works, and fierce storms arise owing largely to the differential heating of the air over land and sea, their cooling by unequal radiation. Another cause of unequal heating is the zoning of the earth with the formation of ice at the Poles and warm water round the equatorial belt.

However, were it not for the fact that the earth's crust in places breaks through the hydrosphere to come into direct contact with the air, milder climates would prevail everywhere, including the Poles, and furious storms be altogether absent.

Thus we see that both fluids, atmosphere and hydrosphere, are in a constant state of flux.

While general laws which control climate have been stated, there is plenty of detailed work, including routine observations, to be done. The number of meterological stations in the world is small. The study of what the meterologist calls 'fronts' is in its infancy. Explorers can throw light on this problem.

Moreover there is reason to believe that the plastic rock beneath the crust, and in places even within the crust, is, like the sea and the air, also in slow motion. It is certainly in a state of potential motion, and on the slightest release of pressure will move. But what external effect — if any — this has is not known.

The study of the various deposits which cover the sea floor, from the mud on the continental shelf laid down by rivers to the grey ooze on the floor of the Atlantic 3000 fathoms deep or the red volcanic clay on the floor of the Pacific 5 miles down, is the province of the geologist. Each type of deposit is generally more or less uniform over vast areas, the ooze or mud being derived from the skeletons of countless myriads of microscopic unicellular organisms. These skeletons are made of lime or silica.

Thus the science of the sea is an immense subject, and touches the geographer at every point. The seas in fact have a controlling influence on climate, migrations, food supply, communications, and many other human interests. They have played their part in nation building, no less than in race isolation.

But no part of the oceanographer's work is so fascinating to the layman as the sea's contents — the fish, molluscs, sponges, Crustacea, mammals, worms, star-fish, jelly-fish, corals, microscopic animals and plants, seaweeds, and other creatures which spend most of their lives in the sea. We will therefore devote the next chapter to a consideration of marine life. It is especially of the 'wonders of the deep' that the beginner is thinking when he speaks of the romance of the sea; and it is the life of the sea, rather than its physics, chemistry, or geology, which chiefly attracts the explorer.

CHAPTER II

EXPLORING THE OCEAN DEPTHS

Most of us collect something. What begins as a hobby in our spare time often ends as a passion consuming most of our life. As children we acquire the habit and never afterwards do we unlearn it. A first visit to the seaside inevitably arouses the latent imp in us when we see shells scattered along the beach in all their fanciful shapes and colours. Immediately we begin to collect, and we cannot but distinguish different species such as cockles, fans, tops and spirals. Later on in the course of our researches we note also many varieties of seaweeds, crabs, other Crustacea, fishes, and, if our enthusiasm is aroused, perhaps more exotic classes of creatures.

Not unnaturally we argue that if there are so many different beautiful and curious objects along the sea-shore, how many more must there be out of sight beyond the furthest point to which the tide goes out, and beyond that again in the vast expanses of the ocean painted blue in our atlases! Our imagination then gets to work. . . .

But it is not only children who love to collect things; even more do grown-ups. And like children they, too, go into ecstasies. Modern exploration involves much careful collecting; and undoubtedly the layman's idea of deep sea exploration is of someone who goes to sea with a fishing net and dredges up countless numbers of new fishes and shells from the bottom of the ocean.

It is true that the oceanographer, or more particularly the marine biologist, wants to know everything that lives in the seas, and all about each—its life history, its distribution in space, depth and time, its food, habits and associates. Men have caught fish from the dawn of time, but it is only very recently that they have learnt anything about their life history. That there are as good fish in the sea as ever came out of it is probably not true, or at least it will soon no longer be true, unless we learn more about them and take steps to act upon our knowledge. Some species at least may become, not extinct, but so rare in comparison with the volume of the sea that their supply as food will be seriously threatened.

Nowadays it is mainly from the point of view of fish as human food, or as a source of raw material, that urgent marine problems arise. But it is the exploration of the sea, often with no other motive than the desire to know, that supplies a clue.

Oceanographic expeditions, unlike land expeditions, must be organized on a big scale to get results. Hence, on account of the great expense, they are usually undertaken by governments which have been convinced by scientists, not without difficulty, of their national importance. On a more modest scale, such expeditions are also sponsored by museums and scientific societies, especially in America. Expeditions such as the recent Great Barrier Reef Expedition are also largely oceanographic, though more static than most. The number of scientists necessary to carry out a deep sea oceanographic expedition varies, but would hardly be fewer than six, allowing for only two zoologists, one botanist, one chemist, one physicist, and one bacteriologist. There would also need to be technicians, besides the crew. The *Challenger* scientific staff in 1869-73 numbered over a dozen. Beebe in his last bathysphere expedition had a staff of ten, including several artists.

The common belief that there must be a far greater variety of living creatures in the deep sea than there is round the coast is not altogether true. It is in fact, in shallow coastal waters, on the continental shelf and on the banks, as shallows are called, that marine life is most prolific. Anyone who has been on a sea voyage and has been sufficiently interested to stand on the fo'c'sle head and look down into the clear water must have noticed what a variety of life is visible close to the shore compared with far out in the open sea. In tropical waters particularly one sees innumerable jelly-fish, sea weeds, and patches of coloured scum floating by. Flying fish leap and flit on either side of the vessel, sea snakes wriggle swiftly across the bows, occasionally a shark or other large fish is seen. It seems as though marine life must cling as closely as possible to the crust beneath the sea, leaving the huge deep basins almost empty. However it is not really quite like that, for down to depths of 1000 to 1500 fathoms there is plenty of life.

Whether life is more abundant in torrid or in temperate seas is questionable. We have no exact figures; but there is certainly a greater *variety* of life in the warmer seas. Yet even in Arctic waters life is still abundant. Most of the marine mammals inhabit the colder seas.

In order to get a picture of life within the sea we must imagine it stratified into zones of varying thickness, just as animal and plant life is stratified on a great mountain range. As we ascend a high mountain both temperature and pressure fall — it gets colder, slowly at first, then more rapidly, and there is less oxygen. We are of course penetrating the atmosphere. Nevertheless until we have ascended some 6000 to 8000 feet on the equator (very much less in the latitude of London), the change in the vegetation is not particularly noticeable, at least by the layman. Even in the Himalayas there are still great stretches of forest at 10,000 or

12,000 feet, although not of course in the more northerly European Alps, or in higher latitudes generally. But above that height wind and diminishing pressure together with falling temperature take effect, and *trees* cease altogether. The vegetation in fact becomes more highly specialized, being adapted to conditions deeply submerged in the atmosphere, so to speak; yet it is as varied as ever. Wind and lack of pressure increase transpiration (the loss of water through the leaves by plants) but has little effect on animal life except in so far as it is dependent on vegetation. Between 16,000 and 19,000 feet on the equator, or in the Himalayas, all plant life ceases.

Meanwhile animal life, particularly bird life, has changed completely with increased altitude just as plant life has changed.

Animal and vegetable life teems in the hot moist valleys of the Himalayan foothills, at the base of the mountains. As we ascend the variety seems to increase, reaches in North Burma and Assam a maximum variation between 5000 and 7000 feet, then begins to fall off as the zone of standardized conifer forest is approached. At 12,000 feet there is a second increase with a maximum, at least for plants, at about 14,000 feet, as the forest type changes to alpine. This is probably not true for all mountain ranges, even in the tropical belt; but it is noticeable in the wet mountains of Eastern Assam, North Burma, and South-Eastern Tibet.

Now let us compare this sequence as we plunge into the atmosphere with what we find in the sea. The two sets of conditions are not strictly comparable, but the resemblance is sufficiently striking!

As we descend into the sea, temperature falls but pressure increases. At 2510 feet, the pressure is 1129 lbs per square inch — 80 times the atmospheric pressure at the sea's surface. At 3028 feet, more than half a mile, the pressure is 1360 lbs per square inch. The temperature is only a few degrees above freezing point, and the darkness is absolute. The temperature indeed does not fall either so fast or so far as it does when ascending a mountain. Even at the bottom of the sea, 5 miles down, it is still a couple of degrees above the freezing point of salt water. But light disappears completely long before we reach the bottom; there is absolute darkness at less than 1000 fathoms. On mountains, the intensity of light increases as we ascend.

Hence it is not surprising that life should gradually diminish below depths of a mile or so, although very little is known of the zoning of life in the sea. This is a point on which future marine biologists are likely to concentrate. Just as there is plenty of life at the foot of the hills, so is there a concentration of undersea life on the continental shelf, at the foot of the land, so to speak. It does not appear that life increases below the 100-fathom line.

We can distinguish three layers of marine life:

(1) Surface life, consisting mainly of microscopic animals and plants, which float with the currents. This is known as *Plankton*.

(2) Medium depth fish and other forms of life, such as sponges, and jelly-fish: they occur between 100 and 500 fathoms.

(3) Deep sea fish found below 500 fathoms.

To these three groups may be added those animals and plants — seaweeds — which live between tide marks, literally lining the edge of the atmosphere and many of them spending several hours of each day bathed in it. Thus in a sense they are both submarine and subaerial, though this is exceptional. Most forms of life are adapted either to the atmosphere or to the hydrosphere, but not to both. Adaptation to the atmosphere, however, is possibly more apparent than real, because a film of sea water may be considered to spread itself over most of the intertidal zone, or over the living forms which inhabit it while the tide is down.

From the modern explorer's point of view deep sea fishing is the most fascinating pastime, and the one which comes nearest to the popular idea of oceanographic exploration.

Well over a thousand species of deep sea fish are known, but there must be many more undiscovered. The oceanographer whose chief interest lies in collecting specimens can with luck and patience, and of course the right technique, always discover new species of deep sea fish, which are certainly amongst the strangest and indeed most grotesque creatures alive. Many of them are luminous, and hence visible even in the midnight darkness which obtains at 500 fathoms.

But the oceanographer spends far more time on research than on exploration. That is inevitable. The *Challenger* spent a little over 3 years on her voyage which laid the foundations of modern oceanography; but 19 years elapsed before all the reports were published, although a small army of experts was at work — not all the time, of course.

The commercial aspect of fishing is obviously of very great importance to-day, when we want to know how much food the world can produce and *distribute*. Food fish like herrings, sardines, eels, salmon, and many more are the subject of long and careful inquiry. To obtain the best results in the great fishing industry and to conserve the stocks, one must know the life histories of the various fish. The man who collects the facts is the explorer. But the man who correlates and interprets them is more often than not the man who stays at home, the research worker who has never been to sea in his life. Such knowledge is only obtained by patient work and observation in the laboratory, with precision instruments and methods. The explorer is the man in the news; the laboratory worker is the man *behind* the news. This is as true of sea exploration as of land and air exploration.

Thus there is no lack of scope for the modern explorer of the ocean, though he must not expect to leap at once into the limelight like a new Columbus or Captain Cook. If he pushes back the dark frontier of ignorance a little way here or there he has deserved well of mankind.

It is only a few years since the spawning ground of eels was discovered far away in the South Atlantic — a discovery of far-reaching significance, which solved an old mystery and gave birth to another — what instinct enables the European eels to go northwards from the same breeding ground with never a mistake; while the American eel goes from the same place to America, and never makes a mistake either!

Few fish are more familiar than the salmon, yet its breeding ground remains unknown. Many food fishes, such as the herring, occur in such astronomical numbers that no amount of fishing or death from natural causes seems to have any appreciable effect on them. On the other hand larger and perhaps less important marine creatures, notably seals and certain whales, had been almost exterminated before 'enlightened' governments were persuaded to take action. All such action must be preceded by exact knowledge, slowly and often painfully acquired, in order that an unassailable case may be put before a government of hesitating and sceptical laymen.

Probably we in Great Britain could do without seal-skin jackets before kippers, leaving seal skins to the people who really do need them!

But in a really well conducted world we ought to be able to say, not only that next year the herring catch will be adequate; we should be able to say that given so many fishing boats, with so much gear, the catch will be so many thousand tons, providing a kipper a day for so many persons!

Perhaps the experts could solve that particular equation. But its complexity is formidable, according to B. Webster Smith, who states in *The World Under the Sea* that one reason why herrings migrate is the instinct to spawn in shallow water. But the principal food of herrings are the helpless young of Crustacea known as copepods, whose numbers vary enormously from month to month, and which can only exist within a very restricted range of saltness and temperature. The herrings must go whither the copepods lead, and the copepods must go whither the diatoms, which are their principal food supply, lead. But the diatoms are even more sensitive to external conditions than are the copepods, and since they are incapable of independent motion and live on or close to the surface of the sea, they drift with the currents. Hence it would seem that the herrings must also follow the currents!

Fish eat fish wholesale, and the ocean shows nature at its most merciless. Some, however, are more voracious than others, though only a few feed on diatoms and other microscopic plankton, or on seaweeds. There are also bacteria in the sea — still more minute plants, about which very little is known.

How does one become an oceanographer? The answer is — one doesn't; at least, not just like that. Clearly there are certain qualifications before one can even begin, though the greatest oceanographers had to begin somewhere.

It may be assumed then that a young man starts in the ordinary way as chemist, physicist, or better still as marine biologist, with perhaps a sceptical attitude towards the great sea serpent, an open mind about Jonah and the whale, and an ultramarine outlook. If he can get a post at one of the various marine biological stations, such as that at Plymouth, or in the Department of Zoology (marine section) at the Natural History Museum in London, his footsteps are set upon the right path. As a research worker he now has the opportunity to show what sort of a scientist he will turn out.

It is certain that the sea will attract more interest in the future. It offers a far wider field than the visible lithosphere, and we know much less about it. Moreover the stratified rocks which overlie otherwise visible crust, though thousands of feet thick, are as it were a mere coat of paint, laid on under the sea, compressed, and heaved up by underground forces into their present place. The process is still going on to-day, so that we are able to see, not indeed the first crust but the later additions to the lithosphere in the making.

There is no royal road, no short cut, to becoming an oceanographer. Even millionaires who fit out their own private yachts for oceanographic research are not thereby promoted to that exalted status, except vicariously. Oceanographers are drawn from the ranks of those who study the seas and all that is in them. The great majority are not really oceanographers at all, but specialists and experts in particular departments. Only a few lucky ones and those exceptional men of broad vision and comprehensive mind can take in the whole vast subject.

Amongst the huge mass of marine biological problems which await solution is the interesting one of what fish are associated together at various depths, as certain plants are associated together at various altitudes; the fish communities, in fact, comparable with plant communities.

Of recent years special problems connected with the sea and marine life generally have become immensely important. The destruction of sea birds due to oil, the preservation of whales, especially the almost extinct Greenland whale, the problem of lean years amongst certain common food fish, are familiar examples. Only team work can solve such intricate problems.

Not less interesting to the biologist than deep sea fish are the mud fish of Australia and elsewhere which can bury themselves in the mud, and, when the water dries up, remain embalmed as it were for weeks, to come alive once more when the water returns; and the tree climbing fish of the eastern tropical mangrove swamps, which can live out of water for hours, move across country, and hop about in the mangrove trees. Another interesting problem not yet satisfactorily explained by geologists is why the Irrawaddy porpoise should be utterly different from the Brahmaputra porpoise, although both rivers flow into the Bay of Bengal, their mouths being barely 500 miles apart.

Land exploration has this advantage over deep sea exploration: the lone explorer can still do good work on land, but very little at sea. The exploration of the sea in depth, as of the air, is not a one-man job — although one man in the stratosphere is a practical proposition, just as one man in a diving suit is a practical proposition, and both can make valuable observations. Nevertheless team work, which is merely useful on land, is essential to the advancement of oceanography by reason both of the expense and the expanse. Yet small expeditions comprising a few trained scientists which, like the Great Barrier Reef Expedition, stay put more or less on land, can amass a lot of new knowledge.

The aeroplane has almost revolutionized archaeology, making the invisible visible, and it is possible that in clear shallow seas it will do the same for oceanography. Apparently it has not yet been put to such use.

Our sources of information about the sea are many. All big ships nowadays are fitted with echo sounding apparatus, by means of which soundings are taken with great rapidity at frequent intervals. Thus the submarine relief along the ship's course can be plotted accurately in section. But of course ships normally follow beaten tracks, and there are vast areas of lonely ocean and thousands of miles of rock-bound coast about which we know almost nothing.

The bathysphere may give us valuable knowledge down to depths of half a mile. But how many bathyspheres would be required and how long would it take to explore the ocean completely to a depth of even half a mile! Obviously it will be a long time before we have even a rough picture of life at a mile down. So far we have only the story given by Dr. Beebe in *Half Mile Down* of the first bathysphere descents off the coast of Bermuda, a mere star point in the great ocean spaces.

The diver in shallow seas can still bring back new knowledge. But nowadays the most fruitful source of marine knowledge is the specially fitted ship with its complement of trained scientists working in conjunction with shore staffs in marine biological laboratories.

However that may be, the ocean offers a wide field to the modern explorer, with deep sea exploration ranking almost as high as archaeological and botanical exploration. These three fields I consider likely to produce the most valuable results for the next century. The student determined to be an explorer can take his choice.

PART FIVE

THE ATMOSPHERE

CHAPTER I

HIGH FLYING

EXPLORATION upwards into the air is almost as difficult for men as exploration downwards into the sea. It is not however impossible, as exploration *below* the sea into the earth's crust is impossible. To-day it is carried out by men flying in specially constructed aircraft, and by small balloons carrying self-registering instruments. Some aircraft, not specially constructed, have flown, and perhaps regularly fly, as high as the highest balloon ascent of pre-aeroplane days.

Stratosphere flying has in fact become possible. Scientists collect samples of air from high up for analysis just as they collect samples of sea water from far down; instruments sent up into the air register temperatures and pressures at a given height. As already pointed out, the atmosphere or air ocean is much deeper than the water ocean — and man lives at the bottom of it. The depth may be 40 or 50 miles, though it is certain that the tension of the gas (air) is imperceptible by any instrument we possess considerably below that level. While both air and sea are fluid, the former is much more so than the latter. Moreover the weight or pressure of the air is very little compared with its depth, while that of the sea is enormous. The weight of the atmosphere rests for the most part directly on the sea, which is itself incompressible.

Active explorers of the atmosphere must be few for some time to come, though many may fly at stratosphere height. A single ascent into the stratosphere is a full-scale job; moreover a machine capable of penetrating ten miles towards the surface of the air ocean is a costly item. But there are other ways of exploring the atmosphere, and the majority of those whose inclination and curiosity lie in that direction may have to stick to simpler methods for the present.

There is at any rate one obvious way for the explorer of the outermost shell to discover some of its properties a few miles above the surface of the hydrosphere. He can do that indeed without ever quitting the earth's surface — by climbing a mountain. And here it may be remarked that since the floor of the air ocean is the sea or land surface, the most important and the most difficult exploration of the air is that of the middle and upper layers, which obviously do not contain much that is solid to impede progress. The contents of the air ocean are in fact mostly microscopic particles — water vapour, visible as clouds, and dust. On a larger scale are birds, insects, and plants or their parts. It thus appears that exploration of the atmosphere is mainly static, that is to say in the nature of research, which finds no place here. But since active exploration into the atmosphere *is* in point of fact carried out, it is right to say a few words on the subject.

Every mountaineer can make observations on the behaviour of the atmosphere. For ages men feared the high places of the earth, where, they supposed, resided the gods or spirits. To disturb these was impious and invited the wrath of the gods. Hence they knew little of the great ocean of air which bathed them. Even its effects as wind, though seen, were not understood. But as soon as their early fears were overcome, and they climbed a few thousand feet, they must gradually have acquired *some* knowledge of the atmosphere.

The vast majority of men live at or very near sea level, that is on the plains; or we might say, in the deepest abysses of the air ocean; just as certain organisms live at the bottom of the water ocean. They live here, not because they cannot live in a shallower air ocean, but for two obvious reasons. (1) It requires less effort to cultivate the plains than the hills, and (2) it is easier to trade across the seas than overland. However, in the modern world many men live in the hills, and the number is likely to increase in the future. To most of us at least it appears natural to live at about sea level — and perhaps it *is* natural. At any rate not man only but an enormous variety of animal and vegetable life lives close to sea level, whether on the land or sea surface; that is to say at the bottom of the air ocean and at the top of the water ocean. The highest inhabited places on the earth's surface, in Tibet and in the Andes, are not more than 14,000 or 15,000 feet above sea level, a mere three to three-and-a-half miles. It would be impossible for man to live four miles above the earth's surface (sea level) without special apparatus. To live even three miles up needs a high degree of adaptation, economic and social, as well as physiological.

As soon as we leave the sea surface and begin to climb crust mountains which project through the hydrosphere, we are ascending towards the vague but certainly distant surface of the atmosphere. The deeper we descend into the sea, the more the pressure, or weight of water above, increases. But the water itself remains the same — it is incompressible. As we ascend into shallower air, however, not only does the weight or pressure of the air above us become less, but the air becomes thinner — there is actually less of it, and notably less oxygen.

It may be as well to point out at once that there is *no* life at or indeed anywhere near the surface of the atmosphere, whether it is 15 or 50 miles above the surface of the sea. In the air ocean, all life is concentrated at or near the bottom — just the reverse ot the water ocean in which most life is at or close to the surface.

The first knowledge of the air men acquired without leaving the earth's surface must have been that as they ascended it grew colder; they may also have noticed that it became more difficult to breathe — that they more easily grew 'out of breath', and that the air grew clearer — the stars shone more brightly at night, they could see greater distances by day. Perhaps they noticed the more frequent and stronger wind. In the monsoon countries they could not fail to remark how in the rainy season they climbed up into the mist. They would not of course connect these various phenomena, nor could they account for them. By the time technical skill had advanced so far that men could leave the earth's crust and *float* in the atmosphere, they knew about the blood stream and oxygen, and atmospheric pressure and air currents.

But it was not until the twentieth century that the importance of the atmosphere in transmitting electro-magnetic waves was fully realized, and the real exploration of the upper layers began. This is the main reason for stratosphere ascents to-day — in connection with broadcasting, wireless, radiolocation and so on.

The lower and middle strata of the atmosphere are concerned chiefly with the weather, and are the province of the meteorologist; the upper strata are the province of the physicist — and particularly of the physicist who is a wireless expert. The chemist is also interested in the atmosphere.

Much knowledge of the atmosphere, particularly as it affects human beings, was acquired by mountaineers during the 20 years following the first great war. Men actually climbed to a height of 28,000 feet, more than five miles above sea level — yet not very far towards the surface of the atmosphere! It must be stressed, however, that the atmosphere at say 15,000 feet in contact with a mountain 20,000 feet high does not behave quite the same as the free atmosphere; it is to some extent conditioned by the land close beneath — and above — it.

To the meteorologist the air is of paramount importance. I have referred to 'fronts', which are formed in the atmosphere when great masses of air at different temperatures and of different degrees of humidity meet. In the monsoon region terrific turbulence occurs during the south-west monsoons which requires investigation. The meteorological explorer could find no more fruitful field.

I have referred to tree-top exploration. Compared with the total depth (or height) of the air, tree-top level might be regarded as ground level, although as we have seen there is plenty of tree-top life which as a fact never does descend to earth. Many birds, however, habitually fly far above the tops of the tallest trees. Seeds such as those of the thistle, dandelion, and many more, are wafted about by the lower air currents at various levels, as are the spores of ferns and other Cryptogams. But, except when they are blown across an alpine valley, they are not found very high above where they habitually grow.

Insects fly at many different heights, mostly low or very low down. True, one finds insects in mountainous regions normally living at 16,000 feet or more, though it does not necessarily follow that one would find them freely flying at that altitude, divorced from the mountains on which they live.

What kinds of life are found at various altitudes, and in what form — fruits, seeds, spores, bacteria, birds, insects? At what height is there *no* life? This is an interesting line of inquiry, and no systematic work has yet been done on it by the biologist. Yet the importance of the atmosphere and of air currents as affecting the distribution of plants, diseases, dusts, and so forth, can hardly be over-estimated. Everybody has seen thistledown, silk-cotton, willow and other seed floating away on the breeze. Hundreds, probably thousands, of species of plants are distributed in this manner. The above are familiar examples, but clematis, maple, rhododendrons and a great many other trees, shrubs and herbs depend only in lesser measure on the air to spread their fruits or seeds far and wide. The subject is a big one and has received little attention from botanists. The biologist whose interest in the atmosphere is aroused must be content to work at low levels, and to make a continuous series of observations. In many parts of the world winds blow steadily in one direction for months on end. What do these air currents carry? For example, it would be instructive to sample the freight borne up the river gorges of Eastern Tibet by the daily wind. This might be done by hanging out sheets of stiff card smeared with sticky subtance; or by means of kites similarly prepared; or even by means of large butterfly nets.

The loess deposits of the Eurasian continent were wind-borne; some of these deposits are thousands of feet thick.

However, the biologist is concerned only with the deepest layers of the air ocean.

It is the middle and higher (that is shallower) strata, concerned with weather, and with electro-magnetic waves, which offer the widest scope to the explorer. Here it is only necessary to point the way — for the biologist, with any technique he can devise; for the meteorologist, with his observation balloons and instruments; for the chemist and the physicist, armed with delicate precision instruments. Probably not one explorer in a million will actually explore the stratosphere in an aircraft; but there is abundant opportunity for explorers to tell us more about the properties, composition, and behaviour of the atmosphere in different parts of the vast air ocean, and at different seasons.

Nor are the light spores of Cryptogams the only minute solid particles found in the atmosphere. Volcanic explosions shoot 'smoke' (really steam darkened by dust) to a terrific height. Air currents carry the dust away. It is believed that dust from the explosion of Krakatoa in 1883 was shot 50 miles into the air and carried right round the globe, causing a series of remarkably brilliant sunsets which continued for months. There is much more to be learnt about these things.

The aurora is an atmospheric display of which we still know little, though it is a common enough sight. We say that the aurora is an electro-magnetic storm in the region of the earth's magnetic pole. But what does that explain? No one has ever made an artificial aurora — unless 'neon' lights may be regarded as such.

Recent research has shown that the atmosphere though fluid is stratified; more markedly so than the ocean. Several layers have been recognized and their positions charted. We are only at the beginning of air exploration.

Finally, we have already seen that mountaineers have reached points on the earth's crust more than 5 miles above sea level; though it is impossible for them to stay there by reason of the intense cold and lack of oxygen. The factors which limit permanent human settlement upwards are those which limit the growth of plants, especially pasture and crops; low temperature and wind. The limiting altitude — climate, of course, having the last word — is well below the altitude at which the oxygen supply is inadequate to support human life. There are summer grazing camps dotted all over the Tibetan plateau at 16,000 feet, but no permanent settlements above 14,000 feet. Thus there is no reason why, given a well-built house, properly warmed and stocked with food, an observer should not spend some time at a height of 18,000 or 20,000 feet. But again we are encroaching on the preserves of the research worker who is not, in our sense of the word, an explorer.

Of course aircraft can be used in survey work with good results, and for surveying difficult or featureless country rapidly the aeroplane is invaluable. It is equally useful in mountainous country. But this has nothing to do with exploring the atmosphere. In this connection the aeroplane is merely an instrument to assist the land explorer.

No geographer has yet given us a complete picture of the vertical distribution of man in the modern world, and no doubt a great deal of work in the mountains remains to be done by explorers before such a complete picture is possible. But this at least needs to be emphasized — that the upper and lower limits of life on this earth, 5 miles upwards into the atmosphere, and 5 miles downwards into the hydrosphere, are very close together as compared with the whole vertical distance of some 4000 miles from the surface of the atmosphere to the centre of the earth's core. The world's life belt is a narrow one — a film dependent on the presence of one gas, oxygen.

PART SIX

THE WORLD'S CONTENTS

CHAPTER I

COLLECTING

In order to arrive at broad generalizations, the geographer requires to know not only the shape of the earth and the thickness and shape of the several shells which envelop the core; he also needs a complete list of their contents. Hence the importance in modern exploration of collecting. The modern explorer is essentially a collector. He is in fact or should be much more a collector than a surveyor.

The young man setting out on his first journey, and already seeing himself in the romantic role of explorer, not unnaturally wants to discover new rivers, new mountains, new lakes; he does not want to be bothered to collect things, and too often does not know what to collect, or where to begin. If he is persuaded to collect anything, he naturally collects the conspicuous, that is the common things, and too often preserves them badly, and omits essential information.

Now this is all wrong. The explorer ought to know what to collect and how to collect. In modern exploration, collecting is of more importance than map making. It is true there are many unsurveyed areas; but after all the main features of the continents are known, and for a long time to come the naturalist will not need maps on a larger scale than those he already possesses, because he has not the named collections to match such a scale.

Modern exploration, so far as the naturalist is concerned, is influenced by the great current generalizations. The naturalist works under the stimulus of hypotheses which are on trial.

Unconsciously, or more often consciously, he is collecting evidence for the defence; or it may be for the prosecution. For the past 75 years at least, field naturalists have been under the influence of Darwin and *The Origin of Species*. For the last 25 years they have received an additional stimulus from Wegener's theory of Continental Drift. Another stimulating generalization, which however is not a theory but a fact, is that of the Pleistocene glaciation which so greatly altered the distribution of animals and plants over the world and especially over the northern hemisphere. The glacial age ushered in man himself.

An immense amount of work has been done investigating the results of a million years of the Ice Age in Europe and North America; a little, a very little, has been done in the Himalayas. But Burma, Assam and China, where also the ice brought about the most profound changes, are virgin ground to the glaciologist.

Collecting looks easy enough. Anybody can collect, you say. What normal boy, brought up in the country, does not collect birds' eggs, butterflies, or flowers! But it is not so easy. That anybody can *learn* to collect is probably true. Nevertheless it is necessary to learn in order to collect intelligently.

Unintelligent collecting is at worst just a waste of time, or at best of opportunity. In the first place, unless one has studied the subject, one will see, or rather one will *notice*, very little. By 'notice' I mean pick out the important items from the mass seen, so that they register, while the less important majority remain in the background. Thus the trained ornithologist in the jungle sees, out of the corner of his eye, a flicker in the trees which the layman would miss altogether. He knows almost by instinct whether it is a rare or a common bird, and whether or not to collect it. And it is important to get one's eye in for the particular locality, or the particular type of country, whatever one happens to be collecting. To know *where* to look is almost as important as to know *what* to look for. Colonel J. K. Stanford, M.C., is the ideal type of modern field ornithologist, and his bird explorations in Burma are classical.

Every subject-matter — botany, entomology, ornithology — has its own technique which the collector must study. There is no need to go into details here; instructions for collectors are published in pamphlet form by the national museums and learned societies, and are to be found in many books. Here it is proposed to offer a few general observations only. As I have already remarked, intelligent collecting is not easy, and has to be learnt, partly by bitter experience in the field. The mere amassing of specimens is not enough. The scientific collector will always collect with a definite object, and that implies a knowledge of what to compare and what to contrast, of what is significant and what is trivial. He must also provide the necessary data for the laboratory worker.

Co-operation between collectors, if there is more than one on an expedition, may produce valuable results. For example, the botanist and the entomologist can enlighten the ornithologist as to what is the food of the birds he collects; both seeds and the recognizable remains of insects will be found inside the crop or other part of the bird's interior. Further, the botanist can describe the type of vegetation which the birds prefer, or name the trees to which they most frequently resort. Useful work of this nature was done by Colonel J. K. Stanford and the author on the Vernay-Cutting expedition to North Burma in 1938-39, on behalf of the American Museum of Natural History. A zoological expedition should for this reason always include a botanist, who, besides collecting specimens of the flora, and seeds, will study environment.

During the twentieth century, there has been a pronounced eagerness to broaden the basis of horticulture all over the world by collecting seeds of beautiful hardy plants, especially rock garden plants and alpines; and plant explorers have seized the opportunity to collect at the same time herbarium specimens of plants which have no garden value, but are of botanical interest and may indeed turn out to be of economic value. A series of distinguished plant collectors from Douglas, Lobb, and Robert Fortune to E. H. Wilson and George Forrest were British. These men roamed the whole world, and especially Eastern Asia. Indeed Great Britain has always been in the forefront of botanical exploration. Many parts of Asia are explored in the conventional sense of the word, though we know little about the flora except that it is of a certain type—forest, alpine and so on. What is certain is that the high mountains of Burma, Assam, and still more of Western China are peculiarly rich in alpine and sub-alpine plants of horticultural value, many of them new to science. Many hundreds of them have found their way into cultivation.

Within the glaciated regions, isolated high peaks in particular are interesting because they are as it were islands on which alpines became stranded in the general shipwreck of floras brought about by the Ice Age. Two high peaks on the Burma-Assam frontier deserve special mention. They have never been climbed by any naturalist, and it is quite certain that the first botanical explorer who ascends into the alpine zone on either Saramati (12,622 ft.) or on Dapha Bum (15,020 ft.) will not only reap a rich harvest, but will throw a flood of light on the intricate problems of distribution in this part of Asia. These peaks, close to the plains of Assam and nearly 200 miles apart on the same range, both stand head and shoulders above the surrounding country. They are of no particular interest *except to the naturalist*, and *especially to the botanist*. The ornithologist, too, might enjoy himself here. They are not high enough to attract the climber, and the fact that their position is fixed, that they have names, and that there is therefore no mystery about them, causes them to be passed by. The young explorer, searching the maps for a likely-looking spot on which to win his spurs, observes that the area is surveyed. He concludes that it is 'explored' and ignores it; what he wants is a blank space. Few blank spaces are likely to yield such valuable results!

Saramati was climbed by Po Nyu, a young Karen officer of the Burma Frontier Service, in 1935. Po Nyu spent a few hours on the summit, and perhaps two or three days on the mountain itself, but unfortunately he was no naturalist. Nevertheless his name will be remembered gratefully by geographers for showing the way to the top.

There is no record of anybody ever reaching even 10,000 feet on Dapha Bum, though it has frequently been seen, and was known at least 50 years ago. Prince Henry of Orleans passed close by its base in 1895, and mentions its snowy cone (*From Tonkin to India*). Cooper, a courageous traveller, saw it from the Lohit Valley even earlier, and remarks on it in his book *The Mishmee Hills*.

Both peaks are certain to be covered with forest and scrub, almost to their summits, and amongst the trees and shrubs are certain to be new species of rhododendron. What alpine flowers are there on Dapha Bum, isolated for ages from their relations? Those of us who are interested in the flora of this part of Asia would dearly like to spend a couple of months on either peak!

Over 200 miles south-west again from Saramati and on the same range is Mount Victoria, more than 10,000 feet high, and standing well above the surrounding mountains. We do know something — not very much — of the flora of this peak, more still of its birds. But here again we need a much fuller exploration, and any naturalist who is content to explore one area thoroughly might do much worse than spend a year on Mount Victoria, observing and collecting. Even more promising districts in the same general region are the lofty areas east and west of the Mali Hka in North Burma, just south of Fort Hertz. Both include peaks of over 11,000 feet, these being the highest points on their respective ranges where they begin to tail off southwards to the plains of Burma. The eastern peaks here referred to are situated on the range between the two branches of the Irrawaddy, in the parallelogram known as the 'triangle'. They form part of the Mali-'Nmai divide, an unexplored range of mountains, snow-covered in winter.

Both areas will yield valuable information about the flora of North Burma and the Pleistocene glaciation. Any naturalist who could devote say 10 years to the intensive study of these four mountains and the surrounding country would be certain of making highly interesting discoveries including many new species of plants at any rate. But there is no lack of such isolated peaks in the world to attract the botanist, ornithologist, mammalogist, or entomologist of the future.

As showing how little is really known of such regions, I may mention the Htawgaw Hills on the Burma-China frontier, north-east of Myitkyina. This district became easily accessible after 1914, and no part of North Burma is better known to botanists, several of whom, including the author, have collected there.

In 1938-39 I accompanied the Verny-Cutting expedition to Htawgaw and beyond, and in the five winter and spring months collected some 500 species of plants. About 12 per cent of these proved to be new to science, and a number of others were new to Burma. The expedition discovered species of mammals, and several birds new to Burma. Dr. Harold Anthony of the American Museum of Natural History, and that fine field ornithologist J. K. Stanford did splendid work. Another expedition which avoided our exact routes might do as much.

Two tendencies of modern scientific exploration as regards natural history are: to collect live animals and birds rather than dead ones, and to photograph rather than shoot them. Of course it is necessary to shoot animals and birds for museum study, and to press plants for the herbarium; but more can always be learnt from the living than from the dead. Dead men tell no tales!

The photographing of flowers, especially in their natural colours, has also come into great favour, and is a very valuable help to the field collector and explorer as well as to botanists at home. Major George Sherriff has done some first-rate work photographing the unique Tibetan flora. Colour photography is also applicable to butterflies, native dress, especially the picturesque women's dress of the Burmese hill tribes, and of course to archaeological discovery. In fact, anyone who aspires to do good work as an explorer *must* become an expert photographer — or employ one.

As we have not yet learnt how to grow many of the most brilliant alpine flowers from the Himalayas in England, this is a good way of putting these living jewels on record, accompanied by dried and pressed specimens with complete notes for the benefit of science.

I am myself only too well aware of how little we yet know of the mountain flora of Burma, not to mention Assam, Tibet and, to a lesser extent, of Western China. Many of the most promising mountain ranges are very inaccessible, and practically uninhabited. That only makes them more alluring, and urges on the explorer. Here indeed is a unique opportunity for the trained botanist!

In the light of what has been said of the thickness of the triple shell which surrounds the earth's core, it is interesting to consider just how much of it can support life. What is the thickness of the biosphere? Life has in fact a vertical distribution of less than ten miles. Five miles above the sea level, that is at over 26,000 feet, there is no life, though the condor soars above the Andes at about that altitude; and five miles below the sea's surface life ceases, or very nearly so; the deepest of deep sea fish have been hauled to the surface from 2000 fathoms. As for man himself, he extends from sea level to about 15,000 feet, though very few men live above 12,000 feet. That is, man extends into the atmosphere for about 2½ miles, equal to 0.04 of the total thickness of the three shells! A mere film! We may also reflect that, though plant life exists in all three shells, it is permanent in only two, namely: hydrosphere and lithosphere. There is no permanent plant life entirely confined to the atmosphere. Such life as occurs — spores, bacteria, wind-borne fruits and seeds—must come to earth some time or perish, just as the animals, birds, bats, insects and others, must come to earth or perish. With very few exceptions, all plant life is dependent on two of the three shells for its existence; of which the most important is the lithosphere. To animal life, on the other hand, the hydrosphere is more important.

Thus land plants are rooted in the lithosphere and spread up into the atmosphere which bathes them; while water plants are also generally rooted in the lithosphere and bathed by the hydrosphere. A few plants, mostly microscopic or very small, spend their entire lives in the hydrosphere and atmosphere only, e.g. the common duckweed; or submerged in the hydrosphere like Algae.

Explorers, as previously remarked, have found that in the jungle life is stratified. That is to say, some insects and birds live near ground level, another set of insects live half way up the giant forest trees, a third set live at tree-top level; and so on. This opens up a new field for investigation, as it is often of practical importance to know at what average level certain creatures live, e.g. mosquitoes, on land, and at what level food fishes live in the sea.

Perhaps the most valuable and interesting specimens to collect nowadays are antiquarian remains, plants, small mammals, and birds. Too many people collect butterflies. Of course *all* natural history specimens from a *terra incognita* like Saramati, including rocks, snakes and lizards, insects and everything else are valuable. But the greatest prize of all is the skull of primitive man.

PART SEVEN

EXPLORING IN TIME

CHAPTER I

PEERING INTO THE PAST

THERE is probably no field of modern exploration where the beginner may achieve more interesting and valuable results than in the field of archaeology, and none in which the results are likely to be less spectacular to the general public. Once in a generation world-wide interest is quickened by the discovery of a Tutankhamen's tomb, a mysterious temple buried in the jungle, or a skull belonging to another race of man. But the bulk of the work is slow and laborious, and requires much patient research on the part of experts. Let us consider some of the problems which confront the archaeologist.

The world has always known contemporary peoples living at very different levels of culture. Such a state of affairs is as obvious to-day as it was 4000 years ago. If a uniform standard of civilization prevailed everywhere, it would be a duller world. But it is not likely to come about. Difference of climate alone, as between frigid and torrid zones, the irregular distribution of raw materials, and other factors ensure the maintenance of different standards of living and provoke different cultures.

Even within the same community social distinctions, however achieved, inevitably compel different strata of the population to live at different standards in so far as culture and comfort can be bought for cash. So the standard of living in any community is measured by that of the upper classes. If all the people in a self-governing state do not achieve the same standard of living, much less do the peoples of different states.

When we speak of the Bronze Age, we are speaking of a type of culture. The Bronze Age in Egypt can be dated, with some accuracy, in the second millennium before Christ. But it must not be imagined that the whole world, or even the whole civilized world, experienced a Bronze Age. It would depend a good deal upon how far away copper and tin occurred, and what facilities existed for trade, whether any particular civilization passed through a particular cultural stage or not. To many parts of the world man very early penetrated, to other places he did not go till much later. Already he might have been highly civilized when he went there; indeed to some places, like the Antarctic Continent, he could not possibly go until he *was* highly civilized.

What, then, was the rest of the world doing in the second millennium before Christ? The use of bronze of course spread slowly over the civilized world; it reached India, Indonesia, China. But when? At any rate there was a Bronze Age culture, more or less contemporary with those of Egypt and the Middle East, in the Persian Gulf, as the recent excavations on Bahrein Island have shown. When we consider the size of the world, the wide spaces over which man could wander, and over which we must search for any little clue he has left concerning his mode of life, and above all the great length of time, amounting to thousands of years, during which he wandered, some inkling of the gigantic nature of the task begins to dawn.

The explorer as much as anybody may discover the caves, the lake sites, the river banks, and similar places where early man lived. He may even discover evidence that he *did* live there, though the interpretation of that evidence is not his job. Only a tiny fraction of the world has been systematically explored for prehistoric remains. Moreover those remains are not for the most part on the surface. They may be anything up to 50 feet below the surface, occasionally even more; they may be covered with jungle, or with grass, or sand. Nor are there likely to be many clues as to where he should look; nothing to tell him during his search whether he is 'hot' or 'cold'.

If so very little is known of uncivilized man during the long period of time he was wandering about the earth, or of the routes he followed, not much more is known of the sequence of civilization in any particular locality. I have mentioned the Bronze Age, which succeeded the Stone Age in the Mediterranean. But in other parts of the world, men carrying an Iron Age culture came into direct contact with a Stone Age culture. This must indeed have happened over and over again as we recede from the chief centres of culture. While it lasted, the Bronze Age was the highest type of civilization ever known in that place, and whoever developed it, somewhere in the Middle East, was the most highly cultured people in the world. Only a few places could have known the use of bronze up to the end of the second millennium before Christ. There must at that time have been thousands of settlements in Europe, Asia and America, and tens of thousands of nomadic people, who knew nothing of bronze, who lived at a much lower level of culture, who were in fact still in the Stone Age.

Nor is this surprising. Nowadays we see higher and lower cultures side by side. We know of many peoples who have never used steel and concrete for building, people whose cultures could not possibly include or produce such things, living cheek by jowl with Western people who habitually use these materials.

Civilizations—perhaps cultures is the better word—overlap. In the Middle East, Palaeolithic is followed by Neolithic, and this in turn by the age of bronze, and the age of iron. But the whole world is not immediately converted from the use of stone to the use of bronze, or from bronze to iron. There is a great deal of overlapping while the new idea and the new technique spread. How much of the world had been converted to the use of iron by the time Christ was born? No very large part we may be sure, though iron had been in use in a few places for a thousand years.

Going further back, in the third millennium before Christ, Egypt was in the Neolithic Age, although metals were being worked in Mesopotamia. But the civilizations of India and China had hardly begun, and what the greater part of Asia and the

Americas were like we can only guess. The civilizations of the New World, in Mexico, Central America, and on the Pacific slope of the Peruvian Andes came much later. There are no written records for South America, so that the archaeology of the continent is particularly difficult to unravel. The Maya culture of Yucatan possessed a sort of picture writing; but the whole story of man in the New World is very dim. An immense field of exploration and of research is open. Much of the story is perhaps irretrievably lost owing to the greed of ignorant treasure hunters who have destroyed many monuments — and, in the absence of written records, monuments are the only evidence.

Going back yet further, to the sixth or seventh millennium before Christ, we reach a time when the Glacial Age which had persisted over Europe for tens of thousands of years was just coming to an end, and with its passing the long-drawn-out older Palaeolithic Age was also ending. The dawn of a higher culture and a more settled population was at hand.

But while we know something of the highest cultures of every age we know almost nothing of the lowest. These do not necessarily partake of the advantages offered by a high degree of culture, except by reflection. For example, our own age might be called the Age of Steel and Concrete, but it can hardly be maintained that every section of the community enjoys the benefits of such a culture — except by proxy!

When we inquire into the means by which culture is spread, we can easily understand how it comes about that there is overlapping. For culture is contagious. It is spread not by books, or by broadcasting, or even by the cinema, but by direct contact. People copy one another as children copy their parents. Mimicry is a very potent force. Few creatures are born more helpless than humans. They do not instinctively walk, or swim, or climb. They *learn* by copying others, their parents first of all.

Amongst people at the same level of culture, custom is a powerful force making for uniformity. Nevertheless bold spirits react to new ideas. You see a new gadget and your reaction is probably: 'By jove! That's rather neat! I must try it!' Of course you don't have to *make* it. *You* buy it ready-made, whether it is a new lipstick or a new camera. But primitive man had to *make* it — if he could. With metal so rare, articles are made for family or tribal use, not for sale. It is often very difficult or impossible to buy family possessions from tribesmen to-day.

Because of the drag of custom culture spreads slowly, and not less slowly amongst peoples at different levels of culture than amongst the different social ranks included under one general culture. We find a higher type of culture on, say, the plains of Burma than in the adjacent hills. Throughout the tropics at any rate it is always the weaker tribes or the later comers who occupy the hills, where living is harder than on the plains. One might suppose that hill tribes, like the Chingpaw of North Burma, would be quick to recognize the advantages of a higher culture such as the Burmese possess, and copy them in everything. Nothing of the sort. Burmese and Chingpaw come into contact often enough for the exchange of goods and ideas, yet very little interchange of culture actually takes place. In dress, speech, manners, customs, belief, outlook, the Burman remains a Burman, the Chingpaw a Chingpaw. Why? Because every tribe and nation is powerfully inoculated against catching a foreign culture by its own culture. Culture is contagious, yes; but *custom* is a very powerful antidote. We all hate change. We are blind to any possible advantage in the new order. Even the most advanced, the most liberal-minded people move but a tiny step forward — or backward — at a time. Thus only very gradually does a strange culture prevail against the tide of an established culture, though small elements in it may be snapped up.

One can imagine the time it took for a new culture to diffuse itself outwards over Europe and Asia from a centre in the Middle East several thousands of years ago! Even the physical obstacles must then have been formidable. But we can picture a very slow diffusion going on, because we can see the same thing going on to-day; for example between the Chingpaw already referred to and the more highly cultured Burmese and Chinese. But no far-reaching change takes place in a lifetime, or even in a century.

The modern Chingpaw may buy matches in the bazaar, as an amusing toy, but he does not discard his flint and steel; nor does he cease to weave his cloth on a hand loom because he can buy ready made clothes cheaply in the bazaar.

While it may not be so difficult to correlate a cultural stage in one part of the world with its equivalent stage in another part, the corresponding dates are far harder to fix. When we remember that there have been no Stone Age men in Europe for several thousand years, and that at the beginning of the twentieth century there were Stone Age men in Australia, the significance of this overlap becomes clear. A great deal of work and research remains to be done before the story of man's struggle with Nature in every part of the world can be told.

What part can the explorer play in revealing the past?

It is at least probable that all the big discoveries have been made, that there are no more cities like Pagan in Burma, temples like Angkor in Cambodia, monoliths like those of Sumatra, Java, Celebes, or rock dwellings like those of India and Western China to be revealed. Nor need this discourage the explorer; at any rate there is a vast amount of research in connection with past discoveries waiting to be done.

For the explorer, some of the most interesting fields are Indo-China, Burma, Assam and Malaysia. Unfortunately these are the very countries where the climate is most destructive to archaeological remains. However, traces of ancient man certainly exist there, though he did not leave very much behind him. The dry zones where monuments are far more likely to be preserved — the North African coast, including even Egypt, not yet completely explored, Arabia, Iraq, Iran, Central Asia, North-Western India, Scind, Central Burma, North China, and the New World semi-desert regions, still conceal an immense wealth of evidence. Even Tibet may hold secrets of man's early occupation.

What is required now is an Explorers' Guide. As an example, I might refer to an excellent article by Major the Hon. R. A. B. Hamilton which appeared in a recent number of the *Geographical Journal*, entitled 'Archaeological Sites in the Western Aden

Protectorate'. This gives details not only of how little we know about this area, but of how much evidence there is lying around waiting to be explored and recorded. Articles on the same lines by other specialists would be equally useful to the young explorer.

CHAPTER II

THE DAWN OF CIVILIZATION

WHILE the conclusions of archaeologists are part of the material of the geographer, the archaeologist himself is not usually regarded as an explorer. Perhaps only exceptionally does he become one. The explorer may now and then stumble on buried cities or other signs of human occupation — he has done so before now — which the archaeologist will later reveal fully and correlate with known history. But the explorer need not be an archaeologist in order to discover lost cities, and the archaeologist need not explore anything beyond the already discovered site. Yet the combination of explorer and archaeologist is a good one, and holds out fascinating possibilities. However that may be, the results obtained by the archaeologist are of such profound significance to the geographer, and are so often obtained from remote parts of the world, that it is impossible to ignore the subject in a book devoted to modern exploration. Nor must we overlook the claims of so great an archaeologist, scholar, and traveller as the late Sir Aurel Stein to a foremost place in the history of exploration.

By the end of the nineteenth century, the antiquity of man in Europe had been firmly established. Man was not 5000 years old; he was nearer 500,000 years old. There had been more than one species of *Homo*, at least in the Old World. Stone Age, Bronze Age, and Iron Age cultures had been recognized, and the history of pre-civilization, in outline at least, had been traced back for thousands of years into the glacial epoch.

Yet exploration of the past, in the twenty years between 1918 and 1939, made greater strides so far as the public was concerned than at any time during the last hundred years. In the language of to-day, archaeology was put on the map.

The immediate cause of this was undoubtedly the discovery of Tutankhamen's tomb. But who knew who Tutankhamen was? Not the public at any rate. It was just a first class sensation. The illustrated papers published pages of pictures. The daily press headlined it. Without detracting from the undoubted importance and interest of archaeological discovery, it seemed during this period to get more attention from the man in the street than it deserved. In fact no other serious human activity, let alone any rival form of exploration, held the public interest for anything like so long, or in so deep a measure.

Had Mount Everest been climbed, or Antarctica itself been crossed from sea to sea during this period, it would not have received more publicity.

Why?

Possibly the rage for antique furniture after the first world war had something to do with it! This was just another fashion, as short-lived as most fashions. While it lasted, however, antique shops sprang up in London and elsewhere like mushrooms in an attempt to satisfy an insatiable demand from a great many people who had plenty of money and not much background. Nor must it be overlooked that the material objects taken from the tomb were most of them homely pieces of furniture such as everyone is familiar with: chairs, tables, bedsteads and suchlike. Though regal beyond the dreams of princes, anyone could understand them; and to the great British public it seemed somehow democratic that the mysterious and mighty Pharaohs should have sat on chairs which were recognizably chairs, and lain on bedsteads not unlike their own bedsteads, a thousand years before the birth of Christ! Moreover there was a dramatic quality in the thought that this majestic suite of bedroom furniture should have been buried in the desert for more than 3000 years!

Finally we must remember that during more than four years the people of Great Britain had become accustomed to every kind of shock. Peace, though yearned for, when it did come seemed tame after the resounding events of a life and death struggle. No sooner had they recovered their breath than they needed something more stimulating than their daily toil to inspire them. The discovery of the great Egyptian king's tomb did that, and it was exploited by the boosters for all it was worth, with some art and much skill. Besides Egypt was, for the rich at least, within easy reach; and if the Valley of the Kings turned out to be rather remote and fatiguing to visit, Cairo supplied the authentic atmosphere without any unnecessary fuss.

A minor reason was possibly the great technical advances in colour photography and colour printing which came after the war. As a result, some exquisite pictures of the richly coloured objects and the crude but dynamic Egyptian landscape were published. Take it all round, Tutankhamen's tomb, aided by the newly invented broadcasting, received a publicity never previously vouchsafed to such a theme.

Whatever the reason of this sudden and widespread interest in a science which normally the man in the street might consider was concerned only with musty old relics, the fact remains he began to take a deep interest in civilizations long past, and the more spectacular results of digging; this though it is certain the vast majority knew little or nothing of the history of civilization, which is the background of archaeology.

As to the highly specialized technique employed, the scholarship involved, and the laborious process of building up the story and fitting it into the framework of known history, these things were just tedious to the general public. But they enjoyed the fruits of scholarship.

As a result of innumerable small discoveries and some big ones, archaeologists have been able to put together, roughly as yet, the story of early man and the slow evolution of civilization. This is why we are enabled to read the fascinating accounts, by both experts and laymen, of the peoples who lived widely scattered about the world, civilized and barbarous, and who loved and hunted and died thousands of years ago. Yet in spite of the great amount of work done, we still know very little about the evolution of agriculture and of the domestication of animals, the origin of cultivated plants, the discovery of fire, the invention of writing, and so on.

The slow, painful steps which led up to such discoveries, the years of exploration of caves, river gravels, glacial drifts, the correlation of the remains revealed in hundreds of places, often far apart, testify to man's co-operation in science.

Yet a vast amount of work remains to be done in tracing in greater detail the history of man in Europe alone, let alone in Africa and in Asia. There may be no caves undiscovered in Britain; but there are plenty still unexplored in Europe, and many sites where the remains of early man — Stone Age or later — together with skeletons, will yet be found. It is here that the genuine explorer has his chance as an archaeologist.

Find the caves!

It was during the Pleistocene glaciation of Europe — a period quite remarkable for the oscillations of land and sea level as well as for its changes of climate — that the caves of Great Britain, France, Germany, Spain, Italy, Austria and other places, were occupied by Palaeolithic man. These caves tell an absorbing story, which archaeologists, geologists, botanists, zoologists and anthropologists working together have interpreted.

Turning now to the tropics, one of the most sensational discoveries ever made was that of Angkor Vat, a great temple (with a city to match not far distant) buried in the jungles of Cambodia. Stumbled upon by chance, it was lost for nearly a century. Then M. Henri Mouhot rediscovered it in 1859. Rarely are such complete and magnificent remains of so great age found in tropical regions; the jungle shroud which wraps the dead is itself the destroyer. Yet the ancient temples of Cambodia, Java, Ceylon, Assam, Burma and other tropical regions, though of venerable age by ordinary standards, are young compared with the immense age of cities preserved in the sands of North Africa, Iraq, India, Arabia, and Egypt.

If the explorer in tropical countries is unlikely to discover lost cities and temples off the record, he has an excellent chance of finding still older traces of man — provided he knows where to look. Here no written clue can help him — we are dealing with a prehistoric age. The trained mind of the geologist with an eye for country, or of the archaeologist, can alone avail. At the time when civilization first reached a high level in the Mediterranean basin, say in the Bronze Age 6000 years ago, man was already old. If we imagine him to become extinct in A.D. 2000 he had, by B.C. 4000, already lived three-quarters of his life-span. In fact he was approaching 60 — an old man by the human scale of three score years and ten.

Many desirable sites in tropical Asia must have been occupied long before the Bronze Age, but they were occupied by wandering tribes who were still in the Palaeolithic Age. In other words, settled civilization came to the tropics much later than to more favoured lands with a drier climate. It is doubtful whether civilization could ever have developed in the tropics, where the violence of vegetation, though favourable to modern man, must have been hostile to him in a ruder age.

There is no question of exploring the whole land surface of the earth for human remains. The most profitable areas have again and again been overrun by successive waves of immigrants, each succeeding wave driving out or absorbing its predecessor, until the population became so strong that it could meet the next invader on equal terms and hold its own. War and peaceful penetration, or infiltration, alternated. Each conqueror imposed his own culture as far as he could. It is surprising how, right down to the twentieth century, the same lands have been coveted by a succession of peoples. Just as Palaeolithic man retreated from the low grounds of Europe with the slowly retiring Arctic and steppe floras, while Neolithic man came in with the advancing forest climate, so the defeated peoples everywhere had to move on — or up, if there were mountains at hand — or be absorbed by more powerful newcomers, or be exterminated; probably something of each.

Asia is hollow. The population to-day is arranged round its coastal fringe, and especially in the southern peninsulas and islands. Trans-Asian highways, marked in the Stone Age by gold mines, at a later date by temples and road houses, led from one coveted region to another.

So far as tropical lands are concerned, little detailed work has been done even on those ruins which have been uncovered. The few which, like Angkor and the Borobadoer in Java, have reached the very pinnacle of fame and become 'sights' ('sights you must on no account miss') may have yielded their last secrets; but Pagan, ancient capital of Burma, now completely deserted, certainly has not. Its hundreds of temples, great and small, no doubt conceal a wealth of records some of which the patient archaeological explorer might unearth. Their interpretation, of course, would be work for the specialist rather than the explorer. A lot of good work on that line has been done by Professor G. H. Luce and the Burma Research Society.

Pagan itself has long been known to scholars; standing in the heart of the dry zone it never was buried in the jungle. Nor is it likely that a second Pagan will ever be discovered on the banks of the Irrawaddy. In short, it is more likely that written records and cultural objects will be found in known sites than that new sites will be found in Central Burma.

Assam is different. It is well known that there were powerful dynasties in the valley of the Brahmaputra a thousand years ago. Written records, besides the ruins themselves, testify to this. That there may be cities and temples still buried in the jungles of Assam is possible. But it must be remembered that they are built of brick and that in the hot moist ever-rain climate of Assam, where the surging vegetation grows up overnight, brick walls are rapidly destroyed.

Nevertheless, the explorer in such outlying frontier tracts as Sadiya, Balipara, even Cachar, might discover a second Angkor. Any ruins, if they exist, would be Kachari, possibly a thousand years old. It is almost certain, for example, that there was a Kachari city at the foot of the hills north-west of modern Sadiya; yet it has never been located.

It would be rash to predict that no more discoveries of thousand-year-old cities will ever be made in South-East Asia, for much of it is virgin territory. In casting doubt on the probability, I do not imply disbelief in their former existence, still less do I suggest that they have all been discovered, but simply that the climate is such that only under exceptional circumstances are they likely to be preserved. At the same time, it is only over limited areas, now fairly well defined, that it is worth searching.

Of early man in the tropics we know almost nothing except by inference. A chance find of worked flints, such as any explorer might come across, or of a cave with traces of human occupation, might be as valuable as the discovery of a 'lost city' to which one had been led by a written clue. The cave might have been occupied less than 2000 years ago, and still have been occupied by prehistoric man. There have been no Stone Age men in Europe for 4000 years; but there are Stone Age men living in Australia to-day and there certainly were Stone Age men living in Burma 1000 years ago.

Thus it is not that Burmese or Singhalese temples 5000 years old have mouldered away and fallen to dust. They never existed. Bronze Age men may have come into Stone Age Europe from the Middle East. But no great civilization flourished east of the Indus while the Mediterranean region was sunk in total darkness. On the contrary, night lasted longer in the tropics than it did in the temperate zone. The great civilizations of Elam, Egypt, and elsewhere in the Middle East must have diffused themselves across Asia as well as across Europe; for no earlier civilization is known anywhere in the world. Even Chinese civilization only goes back to about 2500 B.C., and that of India, with the exception of the Indus delta, is no older. Five thousand years ago, when great cultures already flourished in Egypt, Iraq, Crete, and elsewhere, the peoples of Eastern Asia still lived in the Stone Age, and over a large part of Asia they continued to do so for another three thousand years.

Nor is Asia the only field for the archaeological explorer outside Europe. Remembering that Central Africa has been tipped for the cradle of the human race, might one not expect to find traces of very early man there? But here again the climate is hostile. It is hardly possible for anything in the perpetual damp heat of the mid-African jungle to last a thousand years. Angkor is about a thousand years old. If man first emerged from the African jungle — where he could have left little more than his bones — it must have been a very long time ago, to enable him to spread over Europe and Asia thousands of years before written history begins, even if a more direct route via Gondwanaland — the 'lost continent' of the Indian Ocean — had been available to him. Moreover, as we know, man had certainly appeared in Europe by the first interglacial period, which could not have been less than 50,000 years ago, and may have been a lot more.

On the other hand, if man appeared first in Central Asia, and spread thence outwards to the ends of the earth, as Griffith Taylor ingeniously suggests, he had just as far to go, if just as long to get there. But there is no *direct* proof that man originated in either of these cradles, or even that he originated in one cradle only, like Moses. It is at least possible that the ape-men from which modern man descended were themselves widely distributed over the Afro-Eurasian land mass a million years ago; though, if so, it is singular that their remains have never been found, in spite of the fact that more than one type of man was evolved! It is significant that the remains of an ancient civilization have been found in Africa south of the equator, as well as north. The Rhodesian temples are indeed medieval, no more. But the gold mines are far more ancient, and the Bushmen caves may take us back thousands of years and still not see the beginnings of man in South-Central Africa. Here is further scope for the explorer trained in the methods of archaeology; very little is known about early African civilizations.

Turning to the New World, the three most important civilizations seem to have been those of Mexico, Peru, and Yucatan in Central America. None of them can compare in age with those of the Mediterranean region, and perhaps the last word has been said about them. On the other hand, there is a wide field for research on prehistoric man, from Palaeolithic onwards. Man seems to have entered the New World in late Palaeolithic or early Neolithic times via the land bridge across Behring Straits, and his remains have been found in the caves of North America as in Europe. But of his journey into South America, where no written records exist, we are very much in the dark.

The study of those rare and much-to-be-desired skulls of early man, belonging to several well marked species, which at fairly long intervals in widely separated localities have been unearthed — those of Neanderthal man, Peking man, Rhodesian man, Piltdown man, and others — can only be undertaken by the anthropologist. Rarely, one imagines, is the anthropologist who pronounces judgment on them himself the discoverer of the skull. That might be anyone's luck; but generally speaking the finder is seeking, not blindly but according to plan, something to which a clue has led him, be he archaeologist or geologist.

Aerial survey has already revealed much that was invisible on the ground, especially in Britain. It was only applied to archaeology after the first world war, with good results in Iraq and elsewhere.

The work of the archaeologist passes below into that of the geologist, who explores the evidence for changes of sea level in the northern hemisphere brought about by the last glacial age. The geologist deals with fossils, animal and vegetable, many of which date, of course, from after the time of man's appearance on the earth. The discovery of dinosaur's eggs in the Mongolian desert was another spectacular event of the Tutenkhamen era, equally well publicized. This, however, takes us back a hundred million years or more to Mesozoic times and the age of reptiles, far beyond the archaeologist's horizon. In the same category are the many finds of fossil seeds and plants in various parts of the world, going right back to the coal measures. Most interesting to the archaeologist in this connection are the plant remains found in European caves dating from the end of the Pleistocene age, and affording, like the animal skeletons, unmistakable evidence of the changes of climate witnessed by early man himself. The explorer should never miss an opportunity to collect such material; hence a basic knowledge of geology is invaluable to him. But the most far-reaching discoveries of this kind have been made by geologists, rather than by explorers. The late Professor J. W. Gregory was the ideal geologist-explorer, though he was concerned more with pre-human than with post-human geology.

All that the explorer who is not himself an expert can hope to do is to provide material for the several kinds of experts seeking to reveal a past world — archaeologists, anthropologists, and geologists. The areas in which archaeological finds are likely to be made are fairly well known by now, and they compose only a small part of the world. Much work remains to be done even in the best known fields like Egypt, Crete, and Iraq; still more in Tunis, Iran, India and elsewhere. Exploration in South-East Arabia and in the Indus delta has hardly begun. Central Asia is an almost virgin field; but a clue would be a necessary precursor to success. In fact, the modern archaeologist largely relies on following up clues for his sites. He does not go out into the desert at hazard, on the chance of finding something.

Yet clues turn up in unlikely places, and may be picked up by anybody. In Calcutta in 1943, the army turned up some interesting Buddhist remains which will stimulate archaeological work in India, where there is an endless field for research.

Knowledge derived from many sources has made it clear that 5000 years ago there were few centres of civilization in the world and that they occupied restricted areas. It is therefore useless to dig outside those areas in the expectation of uncovering cities and temples. Going further back to still earlier times, however, primitive man must have been widely distributed over much greater areas (though only in small numbers), and the explorer may come across traces of his occupation in unknown sites.

How does the modern explorer, whose tastes lie in the direction of archaeology, set about his work? Where in the world, literally, does he begin? What are his prospects — the keen student without money, who desires to explore, and to dig, and at the same time to earn a living?

In the first place it is to be noted that the archaeologist has had what is usually called a classical education, although his approach to his subject must be scientific. To get the habit of proceeding in orderly fashion is to tackle the subject scientifically.

Up to 1939 the young man who was ambitious to explore the past usually studied at the British School in Rome, or in Athens. A British School had also been established in Jerusalem. An appointment at the British Museum or similar place might follow. Many distinguished archaeologists studied at Oxford. The young man with an original turn of mind can always get a hearing.

A great fund of knowledge now exists in Europe and America. Digging, as already remarked, is no haphazard affair. To begin with it is a fairly expensive business, and unless the archaeologist has private means he must dig under the auspices of some society which will pay the piper, and call the tune. He will be sent to a definite spot to look for something which can be more or less defined. Even the private archaeologist with means is not permitted to dig just anywhere his whim dictates; he must help the common cause which is the advancement of knowledge. The ultimate aim of the geographer is of course to tell the story of civilization, and so of mankind. For geography deals with man's relationship to the earth on which he lives, in all its aspects.

There geography stops, and there also archaeology and geography part company.