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The Deccan traps: an episode of the Tertiary era

General presidential address by Birbal Sahni at the twentyseventh Indian Science Congress, Madras, 1940

When a man of science accepts the position of honour in which I find myself this evening it is usually understood that he undertakes, among other things, to engage a large public audience, having the most varied pursuits in life, on some topic of general scientific interest. At the same time he is expected to have at least something to say that he can claim as his own and, what is more, to say it in plain language. Such a man, I assure you, is a man to be sympathized with, for he is shouldering a heavy task.

A world of fragments

The student of science lives in a world of fragments. Nothing in that vast array of visible things that we call nature appears to our restricted vision as a complete picture. True Artist that He is, the Creator never reveals the whole of His design at once. Like the child with a jigsaw puzzle we try to piece together the fragments of the picture.

We have our moods, too, like the child. Sometimes we gaze wistfully at fragments of the universe far beyond our reach. Sometimes we are bent upon a quest of the minute: a sort of splitting process that is awe-inspiring in its endlessness, for as we probe deeper and deeper it unfolds to our wondering eyes systems within systems, worlds within worlds. Sometimes, again, we are engaged in the reverse process: of building up fragments into what we like to think is a plausible whole. Not that we ever get at the real and complete whole; nor ever shall. For none of us has even a fraction of all the pieces, and each has his own way of putting together what little he has.

To the onlooker, who alone holds the key, the seriousness with which we go about our little attempts must seem pitiable. For after all there can be only one real solution, one truth. Some of us may boast that we have got at that one truth: we only delude ourselves. None the less, curiosity lures us on, for there are few pursuits so absorbing as this study of fragments that we call Science.

Yes, this is real science, the science of the original scientists, the seekers after truth.

At times, in our search for the truth, we come upon things we can make use of in a worldly way. And we know that some of these things we can use, as we like, for good or for evil. But if we are mere seekers after truth, we care no more about them but turn them over to others: and out of this comes much that is good and noble and beautiful. But sometimes, alas, as we see today, greed comes to conflict with truth, and the passion to rule harnesses science to ignoble ends. For all that science may have done to civilize him, man, it seems, can still be no less of a brute than he was. In the lurid light of happenings we see that civilization is not the same thing as culture.

But this is a sad digression which I had not intended for this occasion. My object this evening is to spend a brief hour with you in the contemplation of nature.

The Eocene age: A 'dawn of the new'

Less than six months ago the British Association for the Advancement of Science met under the presidentship of a renowned scientist. In his address at Dundee Sir Albert Seward gave a vivid account of the way in which, by a study of fragments, such as samples of rocks and of the remains of plants preserved in them as fossils, he was able to visualize a scene in the west of Scotland at the dawn of the Tertiary era. As a pupil I feel tempted to follow his example, and to attempt a reconstruction of an Indian scene at about the same period of the earth's history.

But I would ask you to bear with me if I seem at times to be telling a fairy tale. For at this distance of time we can only see a dim outline of the world as it was, and the exact language of science is ill-suited to the description of visions.

Competent authorities place the dawn of the Tertiary era between sixty and seventy million years ago. It is the birth of a new era in a very real sense. Stupendous forces, surging in the womb of the earth, had already caused gigantic rifts in the crust, and these rifts are gaping out into oceans. From smaller fissures in the crust molten rock is now pouring forth in repeated floods of lava which will cover millions of square miles of land and sea. Vast areas are being converted into desert by showers of volcanic ash. A new type of landscape develops, with high volcanic plateaus as a dominant feature. The face of the earth is rapidly changing. She puts on a more modern garb of vegetation; the land, lakes and rivers become peopled by creatures more familiar to us. Still there is no sign of man. But the stage is being set for his arrival. For this critical period foreshadows the birth, out of the sea, of the mightiest mountains of the world; and the heaving bosom of the earth, somewhere to the north of India, is to be the cradle of man.

Such was the Eocene age: it was literally a 'dawn of the new'.

Early history of the Deccan

To arrive at our early Tertiary scene in India we can either work backwards from the present, or approach it from a still earlier past and try to appreciate the setting in which that scene was laid. I prefer the latter course, although for a few moments it will take us far behind the period with which we are specially concerned. For we shall have to go back to a time, at least three hundred million years ago, when neither the Atlantic nor the Indian Oceans were yet born.

Opinion is by no means agreed even upon the broad distribution of land and sea prior to the Tertiary era. But according to a theory now generally associated with the name of Professor Wegener, who died a hero's death in Greenland a few years ago in the pursuit of science, all the land areas of the globe were once directly united together into one world continent. The two Americas lay much further to the east, while Europe and Africa lay further west, than at present. Greenland, Iceland and the British Isles were all much closer together and were wedged in between Canada and Scandinavia. South America fitted into the great angle in the west coast of the African continent. Australia and Antarctica lay close up against the south-eastern coast of Africa, with the southern tip of India in contact wit Madagascar and wedged in between the African and Australian blocks. At this remote period the South Pole was somewhere in Cape Colony.

At intervals during a period of several hundred millions of years disruptive forces of unthinkable magnitude have caused ever widening fissures in the crust. The Great Rift Valley of Africa is believed to be one of the youngest of these fissures, still in the making. The Red Sea rift has now become two hundred miles wide; the Atlantic rift is already an ocean. And thus, like icebergs breaking off by the formation of crevasses from the snout of glacier, or from the edge of an ice-sheet that has spread out to sea, the continental blocks are supposed to have drifted away into their present positions. But these continental movements have not been all movements of separation. They have also brought into contact with each other land blocks formerly sundered by the ocean.

Here in Madras we stand at the eastern edge of one of these blocks which, according to Wegener, has drifted—and perhaps is still drifting—north-eastwards from its former position in the southern hemisphere. To the north of it formerly lay the great Tethys Sea which once separated it from the main Asiatic mass. The Asiatic block, in turn, has moved south-west, towards India. As the two great land masses approached each other, narrowing down the width of the intervening sea, parts of the ocean floor were caught up as between the jaws of a gigantic vice, and they have been squeezed, crumpled and uplifted into the chain of the Himalayas.

A primeval landscape

By far the greater part of the Indian peninsula is made up of rocks that have solidified from a molten state. But the igneous activity which these rocks indicate took place in distinct periods separated from each other by a span of time of which no adequate estimate is yet possible.

The eastern and southern portion of the peninsula (shown red in geological maps) forms one of the most ancient land surfaces of the globe. Parts of it are believed to belong to the primeval crust of our planet as it first cooled and condensed from a gaseous or liquid mass.

From time to time other molten rocks from the interior have burst through this crust and solidified in the cracks, forming thick sheets or walls cutting across the older rocks. The early convulsions of the earth, while she was young, are still recorded in the complex folds into which these archaic rocks have been thrown. Over large areas the original rocks have been fractured by earth movements or so badly crushed and altered that we can no longer tell their mode of origin.

This was the kind of primitive landscape on which, long afterwards, life first originated (in water) and on which the stratified crust of the earth was laid down.

With the passage of time the greater part of this crust has worn away, and the old surface has again been laid bare. But portions of the strata still remain protected in deep trough-like hollows in the old river basins, the Mahanadi, the Godavari and the Narbada (Narmada), and in a string of outlying patches along the east coast, from Trichinopoly (Tiruchirapalli) as far as Cuttack. These deposits were laid down chiefly in lakes and rivers, but partly also in shallow seas that flooded the land from the north and east. The wealth of evidence these strata contain tells of great changes of climate and of a long succession of floras and faunas that lived on the vast southern continent of which India once formed an integral part.

Except for these temporary incursions of the sea the plateau of the Deccan has remained a land area, so far as we know, ever since the original crust was formed.

We have seen that the eastern and southern parts of the peninsula are composed mostly of rocks of great antiquity. Similar rocks, in fact, form the foundations of all the continental blocks, the eroded tops of the ancient mountains often projecting through rocks of more recent date. The Nilgiris, and the Palni and Annamalai Hills, are composed of large dome-like masses of semi-molten rock which have heaved up the overlying crust and have later been exposed by the denuding action of rain and rivers. These primeval hills usually have rounded, undulating outlines. Occasionally an isolated dome rises suddenly out of the alluvial plain. There it stands, like a petrified sentinel of the hoary past, with his face obliterated and his feet buried in the dust of ages.

Through untold aeons of time nature has carved this ancient surface into fantastic shapes. Great masses of rock sometimes lie uneasily perched one on top of another in threatening piles, like dilapidated towers. Vast areas are strewn with enormous weathered blocks lying in utter confusion, as if a great city, where only giants must have lived, had been laid in ruins. Occasionally a huge sphere of granite lies precariously poised on the rounded back of a hill as if one could, with a mere push, send it hurtling down the hill-side. A later day has seen the handiwork of man superimposed upon nature's in sculptured epics like those at Mahabalipuram—unsurpassed in the grandeur of their conception or in the depth of devotion that inspired them.

The Deccan trap country

Very different is the landscape in the central and western parts of the Deccan, coloured green, by convention, in all geological maps. This is much younger ground, for as we step over from the red part of the map to the green we traverse, at a single bound, a vast span of geological time: in most places the newer rocks rest directly upon the eroded surface of the old foundations. Abruptly we are transported into a new era of the earth's history. In fact we have arrived at the dawn of the Tertiary. After a long period of quiescence the volcanic energy pent up in the interior of the earth is now bursting forth in floods of lava on a scale never witnessed before or since.

Delegates to this Congress who have travelled here from the north by way of Bombay or Nagpur must have noticed the long, low, flat-topped hills which dominate the scenery over the greater part of the country drained by the Narbada and Tapti and by the upper reaches of the Godavari and Krishna rivers. The same type of scenery extends into Kathiawar and Cutch, and for at least two hundred miles north of the Narbada. Crossing the Western Ghats from Bombay to Poona the railway climbs up through gorges cut through a series of terraces at different levels, like the remnants of a gigantic staircase. These terraces are the exposed surfaces of successive sheets of lava which were poured out at intervals, during a period that must have extended through many thounsands of years, and which on the west coast were piled up to a thickness of six to ten thousand feet.

The Deccan before the eruptive period

With the fragmentary data at hand let us try to picture the geography of the Deccan during the Cretaceous epoch which preceded this era of fire and devastation. The south-east coast is flooded by a shallow sea, teeming with life, from Trichinopoly as far as Pondicherry. The same sea stretches north-eastwards into what is now the province of Assam, for similar types of fossil shells have been found in the two regions. Near Utatur we may pick up fossil timber, riddled with holes made by extinct types of wood-boring molluscs. The shells of the creatures still lie in their burrows, petrified within the wood: the logs must have drifted down an east-flowing river into an estuary or lagoon a hundred and fifty miles south of Madras.

The northern sea has also overflowed the land, in the region of the lower Narbada. But the fauna here is very different, because the barrier of the plateau cuts it off from the southern sea. The northern fauna is more allied to the European—in fact, the same ocean stretches on one side into Europe and on the other as far as Tibet and China.

But of our western coast at this period there is no evidence; either India has not yet split away from Africa; or, what seems more likely it has brought away with it a large tract of land which lies to the west. By the sinking of this tract the gulf between India and Africa will widen out into the Arabian Sea, isolating our triangular island of the Deccan which, like a gigantic raft that has been cut adrift, will continue on its long journey to the north-east.

Amongst the denizens of the land, dinosaurs abound in the forests of the Central Provinces. Many of them belong to types peculiar to India but, strangely enough, they have their nearest relatives among the dinosaurs of Madagascar and south America: there must still be some land connection left that allowed these reptiles to intermigrate. But they are rapidly running out their race. The last of the Indian dinosaurs lie buried in the Lameta beds near Jabalpur and at the village of Pisdura near Warora, to the south-east of Wardha.

The dawn of the Tertiary era

We are now approaching the end of the Mesozoic era. The old southern continent is breaking up. The gulfs widen. The same sea that washes the northern shores of the Deccan receives the rivers that drain parts of Egypt, France, Belgium and England. It also laps the shores of Mexico in the far west. In the far east, it sweeps southwards, past Borneo. This is the equatorial ocean of the time, the birth place of the great mountain ranges of the world in the era that is to come.

It is over such a scene as this that the Tertiary era dawns, with the lurid light of volcanic outbursts. There are, indeed, no volcanoes in the familiar, Vesuvian, sense. The lava wells up quietly through fissures in the earth. But these fissures are hundreds of yards wide and stretch for miles across the country, with crooked cracks branching off to right and left, all brimming with the fiery liquid. In the Rajpipla hills near Broach, in Kutch, Kathiawar and other parts of Western India, some of these old fissures can still be recognized, with the lava solidified inside them in the form of walls or dykes.

The Deccan lavas, being rich in iron, are of a specially fluid kind that takes long to set. They flow almost like water, filling up hollows in the land and spreading rapidly in horizontal sheets, covering miles of country before they harden into the basalt or 'trap' rock that is familiar to us. In its devastating march the 'fiery deluge' bakes up the soil and consumes all surface vegetation. The very earth is on fire.

Pools and tarns begin to seethe as the lava flows over them. Here and there a stream is dammed up and collects its waters in a temporary lake till it finds or makes a new channel, or the lake itself is covered up by another eruption. The bigger rivers, not so easily blocked manage to keep their old course, gradually cutting their way through any lava flows that might cross their path. But the eruptions continue from time to time, and from place to place over an enormous area, originally perhaps half a million square miles, from Rajahmundry to Cutch and from near Dharwar almost as far as Jhansi; piling sheet upon sheet of molten rock and loading the old foundations under a plateau thousands of feet thick. Even after the continuous erosion of millions of years the Deccan traps still cover an area of 200,000 square miles, and you can travel all the way from Nagpur to Bombay, a distance of five hundred miles, without ever stepping off the volcanic rocks. Their abrupt ending along the west coast, where they are thickest and form the great scarp of the Western Ghats, leaves us no real measure of their original extension into the tract of land that foundered into the Arabian Sea.

It is difficult to tell where, in the enormous area of the Deccan traps, this igneous activity first began. The traps of the Nagpur-Chhindwara region were certainly among the earliest to be poured out and, so far as we know at present, the highest flow of the series is to be seen on Malabar Hill and at Worli in Bombay. It appears the vulcanicity began in the eastern parts of the Deccan and gradually spread to the west.

The lava flows vary in thickness from a few feet to as much as a hundred. As one flow overlaps another, it seals up the old fissures, and any later eruptions have to force their way up through the entire pile. There is a tremendous outburst. A fresh crack has been rent open, or an old one has split wider. The yawning mouth of Hell roars with thunder, and hurls fire and smoke and ashes miles up into the sky, as if spitting curses on Heaven itself.

The ash comes down again, raining upon the lava still hot round the fissures, perhaps raising a mound here and there; or it extends the desolate waste by burying under its weight any fresh vegetation farther a field. Beds of vocanic ash abound in many parts of western India, specially round Poona and Mahabaleshwar. There must be an eruptive centre in the vicinity.

If a lake or river happens to be near by, the ash settles down on the water, forming a sort of volcanic sediment in which the creatures living there find a speedy grave.

But it is an immortal grave. For, through a process that is still largely a mystery to us, the bodies of these plants and animals become imperishably preserved. Particle for particle, cell for cell, the plant tissues are replaced by silica dervied from the ash, or from a lava flow that may have overwhelmed the lake; and in the end we are left with an exact replica of the original in hard, indestructible silica.

This is not a mere cast or an impression of the external features of the plant, but a petrification in the strict sense, which you may cut into thin sections and of which you may examine under the microscope the minutest details of the anatomy. The preservation of the tissues of sometimes so perfect, and the resemblance with the tissues of modern plants is so complete, that while engrossed in their investigation in the laboratory we are apt to forget that we are dealing with forms of plant life that existed fifty or sixty million years ago.

Partly with the heat of the lava, but largely through the action of percolating minerals, the entire bed of the lake becomes hardened into a rock that rings under the hammer like a piece of steel. Embedded in the mud and silt are also the remains of any land plants, or the bones of animals living on the banks, that may have been carried down by a stream. Thus we may have a whole flora and fauna sealed up in a bed of volcanic ash, or in lake and river deposits interbedded between sheets of lava.

Life in the Deccan trap period

After what I have said it will be easy for you to picture the conditions in the Deccan trap period, and to realize how valuable for the historian of plant and animal life must be the documents preserved in these intertrappean beds. They have their value, too, in the study of rocks, for the state of evolution of a flora or a fauna gives a measure of geological age more trustworthy than any yet discovered.

The age of the Deccan traps has now been a matter of discussion among geologists for over seventy years. The main point at issue was whether the volcanic period began during the decline of the Mesozoic era or at the dawn of the Tertiary. To most of you, the wranglings of geologists over the age of a stratum may seem rather futile and meaningless. But apart from its scientific interest, a precise knowledge of the positions of strata in the geological time scale is of value in the exploitation of the mineral wealth of the earth.

We shall revert a little later to the question of the age of the Deccan lavas, for on this question the flora of the intertrappean beds gives evidence which, I venture to believe, is decisive. First let us examine a few selected specimens from this remarkable museum of plant antiquities.

By far the greater part of our knowledge of this flora is based upon collections made in the Nagpur and Chhindwara districts. This is a fortunate fact because here, as we have seen, some of the lowest beds of the series are exposed. According to Sir L. Leigh Fermor these are the oldest beds in the whole series, so that if we could fix the age of the fossils preserved in them we should know when the volcanic activity began. From here we have a great variety of spores, seeds and fruits; abundant remains of water ferns and other aquatic weeds; different species of the lowly fungus order, sometimes found within the tissues of other plants which they have reduced to decay, as well as numerous kinds of petrified timbers, including palm stems in bewildering variety and number. Associated with these plant remains are the relics of animals that lived at the same time: the shells of many types of freshwater snails, the scales and bones of different kinds of fish, the wings of insects, and the skeletons of many other creatures of land and water. All these relics lie buried in a common grave.

Some of the earliest plant collections were made about ninety to a hundred years ago, chiefly by Christian missionaries, medical men and military officers in the service of the East India Company. Among these men the name of Stephen Hislop will always stand out prominently. It is a pity that this valuable material was not described in Hislop's day, for some of his most interesting specimens, mentioned in his published letters, can no longer be traced. I owe to the kindness of Mr W. N. Edwards of the British Museum the loan of what remains in London of the Hislop collection. The rapid sketch I am about to attempt is based partly on this material, but mostly on specimens collected in recent years by members of the Geological Survey of India, by Professors K. P. Rode, S. P. Agharkar and P. Parija, by Mr V. N. Shukla and myself. In the investigation of this material several workers have taken part and it is a pleasure to acknowledge the assistance I have received from the late Professor B. P. Srivastava, Mr H. S. Rao and Mr K. N. Kaul.

The intertrappean plants of the important area near Rajahmundry, which must have lived in the brackish waters of an estuary, are being investigated by Professor L. Rama Rao and his associates at Bangalore. These Rajahmundry beds are also low down in the series, and the plants probably lived at about the same time as those of Nagpur–Chhindwara.

Among the commonest of fossils in the Deccan beds are some extinct species of stoneworts known under the expressive name *Gyrogonites*, derived from their tiny spirally twisted fruits. The great majority of speices of this genus, described from France, England and other countries, are of early Tertiary age, and it is interesting that some of these are identical with our Deccan forms.

Some microscopic branched filaments, no doubt belonging to fungi, are seen attached to reproductive organs of two different kinds. One form, with more or less spherical closed bodies of a dark colour, recalling the fruit bodies of modern mildews of the family Perisporiaceae, has been described as a new species, *Perisporiacites varians*. The other has flask-shaped bodies, and for this the genus *Palaeosordaria* has been created. Very little is known of the fossil history of the Perisporiaceae and Sordariaceae, but the few previous records, whatever their worth, are all from rocks of Tertiary age. The Deccan fungi were discovered in certain lake-muds at Sausar, midway between Nagpur and Chhindwara.

In the same lake deposits were found, in great abundance, the remains of *Azolla*, a familiar genus of small floating water ferns which even today cover stagnant pools in many parts of the world. The extinct species from Sausar, which has been named *A. intertrappea*, is geologically the oldest known form of the genus: a striking example of the tenacity with which even highly specialized forms of life can persist through the ages. The preservation is so perfect that most of the details of the anatomy, specially of the reproductive bodies which are highly characteristic of the genus, have been studied. Some hollow spherical bodies, associated with the *Azolla* no doubt belong to an unknown genus of water ferns, probably related to the modern *Salvinia*; the provisional name *Massulites* has been given to them. The spongy mass of which the body is composed contains small spores embedded in it much in the same manner as in *Salvinia*. Among many types of free-lying spores seen in the same rocks are two which deserve special mention. They are of two very different sizes, but they resemble each other so much in certain peculiar features that they appear to be the megaspores and microspores of one and the same species, most probably another water fern. The interesting point about them is the close resemblance they show, both in their structure and in their mode of germination, to the two kinds of spores, large and small, of the rare genus *Regnellidium*, which today is confined to South America. So far as I know, the water ferns are unknown from rocks older than the Tertiaries.

In the Hislop collection at the British Museum there are a number of seed-bearing cones; some of them were found embedded in volcanic ash. The new name *Takliostrobus* has been given to one of them after Takli, a suburb of Nagpur, where it was discovered. Another has been named *Indostrobus*; a third was referred to the old genus *Pityostrobus*. All these cones have peculiar features of their own but the fact that in all of them the scales bear a pair of elongated seeds on the upper surface indicates that they were distantly related to our modern pines and deodars.

Of the several kinds of seeds found at Sausar, there is one intriguing type, *Sausarospermum*, remarkable for its several antique features. It recalls the seeds of certain fern-like plants from the coal measures of Europe, but it is hardly conceivable that there is any real affinity between them; at present it is best to reserve opinion on this matter. The name *Viracarpon* has been given to a cylindrical fruit, derived from a number of small flowers densely crowded on a thick axis. This is from the Hislop collection and it may be the very specimen which he mentions in his writings as a mulberry-like fruit, though unfortunately he never described it. The resemblance to a mulberry is purely superficial, for each flower produced a group of six seeds. It is impossible to say anything yet about the affinities, except that the nearest resemblance that I have so far been able to trace is with the fruits of certain palm-like plants of the family Cyclanthaceae now confined to tropical America.

A very interesting fruit, *Enigmocarpon*, was first discovered by Professor Rode near his home at Mohgaon Kalan, east of Chhindwara. The name is eloquent of our ignorance concerning its affinities, but the structure is perfectly preserved. It is an elliptical eight-chambered fruit about the size of a large pistachionut, with numerous dicotyledonous seeds in each chamber, attached on a central column from which the eight partitions radiate. The wall of the fruit is thick and spongy; the fruit was no doubt dispersed by water. To let out the ripe seeds the fruit wall bursts lengthwise, neatly, down the middle of each chamber.

Among Hislop's specimens are two species of cardamoms, both very like the small green kind that we commonly offer, with other spices, to guests in our homes. One of the specimens was so deceptive that a friend actually tried to peel it, till he discovered that it was petrified. In one broken specimen the seeds are exposed, showing their characteristic wrinkled surface.

The other monocotyledonous fruits all belong to palms: some have been described under the general name *Palmocarpon* which may include fruits belonging to widely different kinds of palms. One was named *Tricoccites* because of its supposed resemblance (which has proved deceptive) with the fruits of the Euphorbia family. It has three large chambers, each occupied by an equally large oblong seed. The fibrous fruit wall is thick and adapted for dispersal by water. It seems to have been divided up into a number of longitudinal chambers separated by partitions to hard tissue. The 'chambers' may have been quite empty, or filled with a loose spongy tissue which acted as float. The surface was covered by a thin, smooth, watertight rind. The whole fruit was about the size of a walnut, which it superficially resembled also in having a curious beak-like point.

But the most interesting of the Deccan palm fruits is one which Hislop writes he had found, but of which we have not been able to trace the original specimen. It is the fossil genus *Nipadites*, so-called because of its resemblance with the fruit of the modern stemless palm *Nipa fruticans*, which forms dense clumps today in many tropical estuaries, and is common in the Sundarbans. Eighty years after Hislop's discovery was announced, Professor Rode found another specimen at Mohgaon Kalan. This specimen shows all the characters of the modern genus, so we need have no hesitation in calling it a *Nipa*, although the species is different. The fruits of *Nipa* are by far the commonest fossils in the London Clay, which everybody agrees was deposited in the Eocene period; they have also been found in the Eocene of Belgium, and of the Paris basin, in fact, in the very grounds of the old Trocadero, now dismantled; also in the Mississippi basin, in southern

Russia, in Egypt and in far-off Borneo. These fossil records of a brackish-water plant help us to draw at least roughly the coastline of the old Tethys sea, which must have swept the northern shores of the Deccan not far from where Chhindwara now stands. This important genus is scarcely known from rocks older than the Eocene.

It is interesting to see this evidence of brackish water conditions in the Deccan supported by the fossil remains of aquatic animals. Dr Hora describes several kinds of fossil scales belonging to types of fish which ordinarily inhabit fresh waters near the sea-shore but are capable of descending to the mouths of rivers. It is interesting, too, that on the whole the evidence of the fish-remains from the Deccan beds, first emphasized by Sir Arthur Smith Woodward over thirty years ago, and now confirmed by Dr Hora, is in favour of an Eocene age; and Professor Bonnema wrote to me that the same is the case with the remains of some small crustaceans which show a treacherous resemblance to the seeds of plants.

But we must return to the palms, for these are by far the most important constituent of the intertrappean flora, and no doubt must have dominated the vegetation of those days. As a rule we only find bits of petrified stems which, for lack of a proper system of classification, we lump together under the artificial genus *Palmoxylon*; although among them there must certainly be many distinct genera that we could easily recognize, if we only knew the flowers or fruits. Sometimes we come across entire trunks, or large portions of them, with the thick mantle of roots still attached round the base. At the Nagpur museum there is a fine specimen, probably discovered at Saugor in Central India well over a hundred years ago; and in 1934 I was able to unearth from the dust and oblivion of the vaults of a Bombay museum a heap of petrified palm stems, some of which were certainly collected at Saugor before the year 1857. It is this very collection that H. J. Carter mentions in a paper of that date, but which had apparently been lost. Luckily, silicified plants do not deteriorate with age; they are immortal as I have explained already; but alas, most of the labels are gone, except those that were painted on the specimens.

By their sheer number and amazing variety these palms of the volcanic period compel the attention of geologists, because from all accounts its appears that this family of plants, although it first arose in the Cretaceous period, did not rise to any prominence till after the Mesozoic era had begun.

The age of the Deccan lavas

I have tried to put before you, as briefly as I can, what we know today of the fossil flora of the north-eastern part of the Deccan. For deciding the question of the age of the Deccan traps it is perhaps unfortunate that so many of the plants are new to science and confined to this country; but, of course, they have an interest of their own. For the rest, you will have noticed that from what we know of the geological history of the stoneworts, the fungi, the water ferns and particularly of the palms, which formed such a vast proportion of the flora, everything seems to point to a Tertiary age. What is more, the fishes and the crustaceans, too, seem to fall into line with the plants.

So much for the Nagpur–Chhindwara traps which, according to the geologists of the Indian Survey, are the oldest in the whole series. For all we know, the Chhindwara traps may have flowed out into an arm of the northern sea which was not far off. The lavas of the east coast, too, seem to be equally old. Rama Rao and his colleagues Narayan Rao and Sripada Rao have quite recently found stoneworts and other algae of early Tertiary age in the estuarine beds of Rajahmundry, at the head of the Godavari delta.

It is curious that no intertrappean beds at all have been discovered in the middle part of the series, which we cross as we travel towards the west coast. Not until we actually reach Bombay Island, where the highest members of the series are exposed, do we again come upon any sedimentary beds. It may be that during the middle part of the volcanic period the lavas were poured out in such rapid succession that no time was allowed for any plants or animals to colonize the desolate surface. Still, I think, a search ought to be made for traces of fossils along the planes between the lava flows, e.g. at Matheran, Poona and elsewhere.

In the highest intertrappean beds, namely those at Malabar Hill and Worli, plenty of organic remains have been collected, including a multitude of skeletons of a pigmy species of frogs. I have not seen any plants from here and cannot say whether these beds are much younger (geologically speaking) than those of the Central Provinces. But this seems to me unlikely, because we are told that near Surat and Broach the highest traps are covered by marine beds of definitely known Eocene age. If this is true, then here, at least, the volcanic activity must have already come to a stop before the sea began to encroach upon the land in early Tertiary times. According to Professor V. S. Dubey the radioactive content of some of the traps in western India also indicates an early Tertiary age.

Thus the chances are that the whole of this imposing thickness of thousands of feet of igneous rock was poured out within the relatively short interval of the Eocene period. Quite probably this terrible drama of fire and thunder was only a brief episode of the very earliest part of the Eocene. The thickness of a stratum is by itself no measure of time. For after all it would not take long for a lava flow a hundred feet thick to be poured out like a flood from a fissure volcano, once it came to business. It is the depostion of the relatively thin sedimentary beds during the quiet intervals that must have taken up most of the time of the Deccan Trap period.

The conclusion that the Deccan traps were poured out at the dawn of the Tertiary era and not at the close of the Mesozoic, brings them into line with other vast outpourings of Eocene lavas: for example, those that now cover at least 200,000 square miles of the north-western United States and the equally widespread lavas of the old Thulean continent that once united the western Isles of Scotland with Iceland, Greenland and other arctic lands.

Before I close I ought to say that this idea of the Tertiary age of the Deccan traps is by no means a new one. Indeed, it is over a hundred years old, for it was first put forward, so far as I know, by Malcolmson in 1837; and it was repeatedly expressed by Hislop and others in the middle of last century. In later years the question has been discussed and rediscussed by so many, and from so many different angles, that we could hardly see the wood for the trees. But the pioneers were right, as they so often are. They saw things more clearly because they worked with a clean slate and, so we all know, a clean slate is a very useful thing.

But the pioneer geologists were right also for another reason. They did not despise the mute but eloquent testimony of the plants that suffered the fiery ordeals of the dawn of the Tertiary era. For, as the first flashes from the fissure volcanoes flared up on the eastern horizon, the stalwart Palm said to the little *Azolla*:

> This lurid light is not a sunset glow—
> It is the herald of a morn.

And the fact is that this was the dawn of a new era: for, look at the number of Eocene genera of plants and animals that survive to this day.

Conclusion

We have now seen the contrast between the red part of the map and the green. Between the two lies a vista of time stretching back through well-nigh two thousand millions of years. But man, a recent creature of the earth, has united them in one poem of duty to his Creator: If the foundation rocks of the south have given us Mahabalipuram and the Seven Pagodas, the Deccan traps have given us Ajanta and Ellora[1].

1. In this popular presentation of the subject of the Deccan traps references to original sources have been purposely omitted. Those interested will find most of these works cited in an address delivered before the botany section of this Congress in January, 1938, at the Jubilee Session held jointly with the British Association for the Advancement of Science (see *Proc. 25th Indian Science Congress*, 1938, Part II, pp. 133–176; reprinted as Lucknow University Studies No. II, pp. 1–100, 1938).