



Patilka

July 1990 No. 21 Newsletter of the Indian Academy of Sciences

56th Annual Meeting

At the invitation of the Utkal University and the Institute of Physics, the 56th Annual Meeting of the Academy will be held at Bhubaneswar from 8 to 11 November 1990.

The scientific programme will consist of two symposia, evening lectures and lectures by new Fellows and Associates.

The symposia will be on 'Physics with Accelerators' and 'Food and Hunger in India'.

The following is a provisional list of lectures by Fellows and Associates:

Towards an understanding of the origin of social life in insects – R Gadagkar

Advantages and limitations of amorphous silicon alloy materials for large area electronic devices – G Ganguly

X-ray and optical studies of magnetized white dwarf binaries – P C Agrawal

Insect genetics: basic and applied – R P Sharma

Potential use of biological material such as monoclonal antibodies and tumor cell lines in management of cancer, with reference to cancer of the oral cavity – Sudha G Gangal

Pressure-induced amorphization – S K Sikka

Biological membrane structure and dynamics – V Sitaramam

CD2 and leprosy – V R Muthukkaruppan
Self organized criticality in nature – Deepak Dhar

Protein structure: analysis and modelling – C Ramakrishnan

Thyroid hormone and brain development – P K Sarkar

Intracellular applications of cholera phage – Rukhsana Chowdhury.

Visits to Puri and Konarak will be organized on 10 November.

All Fellows and Associates attending the Annual Meeting will be paid first class railway fare from their place of residence to Bhubaneswar and back, in case they are unable to obtain travel support from other sources. Arrangements for the stay of the Fellows and Associates and other delegates will be taken care of by the organisers.

During the period of the Annual Meeting, the Editorial Boards of the Academy journals and Sectional Committees will also meet at Bhubaneswar.

Associates – 1990

P K Chattaraj, Indian Institute of Technology, Kharagpur – Quantum chemistry

B J Cherayil, Indian Institute of Science, Bangalore – Polymer science

N Krishnan, Tata Institute of Fundamental Research, Bombay – Gravitation experiments

A D Patel, Indian Institute of Science, Bangalore – Particle theory

T P Radhakrishnan, University of Hyderabad, Hyderabad – Organic solids

Debashis Ray, Indian Association for the Cultivation of Science, Calcutta – Bioinorganic chemistry

Daman Saluja, University of Delhi, Delhi – Plant molecular biology

Ravi Subrahmanyam, Radio Astronomy Centre, Ooty – Observational cosmology

Usha Vijayaraghavan, Indian Institute of Science, Bangalore – Molecular genetics

Mid-Year Meeting

In order to provide an opportunity to more Fellows and Associates to present their work at meetings organized by the Academy, the Council decided that an additional meeting should be held during the middle of every year and a beginning should be made this year. Accordingly the first Mid-year Meeting was held on Friday, 27 July 1990 at the Indian Institute of Science, Bangalore.

There were thirteen lectures by Fellows and Associates and an evening lecture by Dr V K Gaur, Department of Ocean Development, on "Oceans, flywheel of the earth system".

The morning session started with brief introductory remarks by Prof. C N R Rao, President of the Academy.

The first session under the chairmanship of Prof. A Chakravorty was on chemical sciences and the first talk was by Uday Maitra, Indian Institute of Science, Bangalore, on "Unnatural Products". He spoke of the synthesis of organic compounds which can complex small organic molecules in solution and of the potential applications of such artificial receptors in chromatography, molecular sensors, slow release of bioactive compounds, detoxification and as artificial catalysts. He ended by describing work done by his group towards the synthesis and evaluation of their first-generation receptors.

K M Madyastha, Indian Institute of Science, Bangalore, next spoke on the "Effect of plant xenobiotics on drug-metabolising enzymes and the chemical basis for pulegone-mediated toxicity".

The last talk in the first session was by T Ramasami, Central Leather Research Institute, Madras, on "Chromium: an intriguing reaction centre". He spoke of how a series of related investigations on the aqueous chemistry of chromium has led to the role of chromium as a pollutant, as a micronutrient, as a forerunner in transitional metal chemistry and as an experimental probe.

The second session under the chairmanship of Dr R A Mashelkar started with a talk by V B Kartha, Bhabha Atomic Research Centre, Bombay, on "Applied laser spectroscopy — techniques and trends". He spoke of the applications of lasers as spectroscopic sources in a variety of fields like atomic and molecular physics, chemical dynamics, plasma physics, biophysics etc., and described current techniques

and future trends in laser-enhanced ionisation spectroscopy, resonance multiphoton ionisation, spectroscopy of discharges and flames, supersonic beams and laser ablated metal vapour spectroscopy.

The next talk was by N Sathyamurthy, Department of Chemistry, Indian Institute of Technology, Kanpur, on "Fractals in atomic and molecular collisions" and he demonstrated their occurrence using examples chosen predominantly from his own research, and showed that there is a connection between fractal behaviour and scattering resonances.

K S Gandhi, Indian Institute of Science, Bangalore next spoke on "Turbulent stirred dispersions".

The last talk in the morning was by Anurag Mehra, University of Bombay, Bombay, on "Diffusion accompanied by reaction in water-in-oil media". He presented a theory of mass transfer (accompanied by chemical reaction) incorporating transient effects in microheterogeneous media such as water-in-oil emulsions.

In the first afternoon session under the chairmanship of Prof. S C Dutta Roy, R N Iyengar, Indian Institute of Science, Bangalore, spoke on "Stochastic characterization of the onset of chaos in nonlinear oscillators". He was followed by G Athithan, ANURAG, Hyderabad, who spoke on "Neural network modelling", primarily an activity to understand the functioning of the network of neurons, which forms the brain and its significant implications in the fields of pattern recognition and robotics and hence to artificial intelligence.

The last speaker in this session was B Basu, Tata Research Development and Design Centre, Pune, on "Heat and fluid flow during melting and solidification". He described the various aspects of heat and fluid flow during melting and solidification of pure metals as well as alloys, using numerical models.

The fourth and last session, under the chairmanship of Prof. J C Bhattacharyya was on geological topics. V Rajamani, Jawaharlal Nehru University, New Delhi, in his talk on "A chemical approach to geological problems" spoke of the tremendous progress made in certain areas of geology by the application of chemical methods such as the formation of the continental crust and its associated mineral deposits — by quantitative treatment of high quality chemical data on minerals and rocks, using as an example his geological studies of the area around the Kolar Schist Belt.

The second talk was by N Bhandari, Physical Research Laboratory, Ahmedabad, on "Collision with the earth over geological times".

The last talk was by A Mookherjee, Indian Institute of Technology, Kharagpur, on "Metallogeny: the rationale behind space-time selectivity of mineral deposit formation". He described the attempts to explain the non-uniform distribution patterns that seem to be region-specific, time-specific and/or even element-specific.

Each talk was followed by a lively session of questions and answers.

The evening lecture was by V K Gaur, who spoke of how the oceans act as the fly wheel of the atmosphere-hydrosphere-lithosphere system and how the oceans help to tone down the large scale changes forecast for the atmosphere due to the burning of fossil fuels and the injection of large amounts of pollutants into the atmosphere.

The Mid-year Meeting was characterized by the high quality of the lectures, the excellence of their presentation and the large attendance at all the sessions — an unqualified success by any standard.

Von Neumann Algebras

A two-day discussion meeting on "Von Neumann Algebras and their applications in Quantum Mechanics", was organised by the Academy and was held on 19 and 20 April 1990 at the Indian Institute of Science, Bangalore.

The theme lectures were given by Prof. K.B. Sinha and Prof. V.S. Sunder of the Delhi and Bangalore centres of the Indian Statistical Institute. Prof. Sunder's talk on "Introduction to Von Neumann algebras and the Tomita-Takesaki theory" began with the fundamentals of such algebras and of the theory of their representations, and went on to describe the beautiful Tomita-Takesaki theorem, giving a map between a standard Von Neumann algebra and its commutant, via an antiunitary operator. Prof. Sinha's talk on "Applications of Von Neumann algebras in Quantum Mechanics" dealt with an explicit construction of the aforementioned antiunitary operator and the associated modular operator in the Araki-Woods representation (reducible by a factor) of the canonical commutation relations of quantum mechanics, with infinite degrees of freedom. Another application of the Tomita-Takesaki theory in statistical mechanics of quantum lattice gas was also described. There were short talks by Prof. K.R. Parthasarathy of the Indian Statistical Institute, Delhi on the "Matrix phase in irreversible dynamics", by Prof. S.G. Dani of the Tata Institute of Fundamental Research, Bombay on "Infinitely divisible distributions on Lie groups", by Prof. M.G. Nadkarni of the University of Bombay, Bombay on "The existence of finite invariant measure" and by Prof. R. Bhatia of the Indian Statistical Institute, Delhi on "Non-commutative versions of some elementary classical inequalities". The talks were followed by a lively discussion. The meeting, the first of its kind aiming to bring together mathematicians and theoretical physicists for discussions at an advanced level, was attended by 25 scientists from various universities and research institutions in the country.

Special Issues of Journals

Journal of Genetics, Vol. 69, No. 1, April 1990, pages 1–66.

This special issue is devoted to the publication of papers presented at a conference organized by the "A Buzzati – Traverso" Department of Genetics and Microbiology of the University of Pavia and the Institute of Biochemistry and Evolutionary Genetics of the National Research Council of Italy, to honour the memory of Suresh D Jayakar, a leading population biologist. In addition to his distinguished work in population biology and evolutionary theory, he was editor/co-editor with J B S Haldane of the *Journal of Genetics* from 1963 to 1977 and a member of the Editorial Board from 1985 till his tragic death at an early age in 1988.

The Pavia Conference was held on 30 September 1989 and this special issue contains in addition to 4 papers on topics Jayakar worked on, a list of Jayakar's scientific publications and three obituaries on Jayakar which appeared in other journals.

Bulletin of Materials Science, Vol. 13, Numbers 1 and 2, March 1990, pages 1–159.

This issue of the *Bulletin of Materials Science* consists of 18 papers presented at the First National Seminar on "GaAs and III-V Compound Semiconductors" held at the Indian Institute of Technology, Kharagpur on 29 and 30 April 1988. It discusses new devices and new growth technologies involving fundamental science, materials processing technology and application, such as the bulk growth of polycrystalline crystals, the growth of III-V compounds by liquid phase epitaxy, electrodeposition of GaAs from aqueous electrolytes etc. Among newer processing technologies laser ion beam processing is shown to have interesting possibilities while ion implantation is already well established.

The other topics dealt with include defect characterization, electrical techniques such as deep level transient analysis and positron annihilation spectroscopy, transport in high mobility ternary layers and the unique optoelectronic materials GaAs and InP. The guest editors hope that the contents of the issue on work being carried out in this technologically exciting area will stimulate further research.

Proceedings — Animal Sciences, Vol. 99, No. 3, May 1990.

The ten papers presented in this issue are based on a series of specialist lectures delivered at the DST National Workshop for young scientists held at the Entomology Research Institute, Loyola College, Madras, from 22 July 1989 to 7 February 1990, on insect-plant interactions. The papers relate to resistance mechanisms of plants to insects, the role of insects in wheat control, the impact of natural products and bioenergetics and biosystematics in relation to insect-plant interactions.

Proceedings — Earth and Planetary Sciences, Vol. 99, No. 1, March 1990 — Special Issue on Experimental Petrology.

This special issue is devoted to modern developments and implications of the new, exciting results in experimental petrology. There are 12 papers by acknowledged leaders in the field, beginning with the overview by Peter Wyllie on the illuminating power of experimental petrology in tracing the progression of earth processes. The papers are individually dedicated, as well as the volume as a whole, to Prof. C.V. Raman on the occasion of his birth centenary, "when applications of his celebrated discovery are revolutionizing the study of mineral science".

Special Publications

From Mantle to Meteorites — A Garland of Perspectives. A Festschrift for Devendra Lal, edited by K Gopalan, V K Gaur, B L K Somayajulu and J D Macdougall, 1990, 325+4 pages.



This volume was prepared as a tribute to Professor Devendra Lal on the occasion of his sixtieth birthday. There are 21 papers contributed by his distinguished colleagues and admirers on a wide range of topics, from the earth's mantle to meteorites and beyond, many of which Professor Lal himself has done so much to enrich, varying from life on early earth to geophysical searches for new forces in nature. The papers generally outline the authors' futuristic perceptions and visualizations of uncharted areas. The editors felt that "restrained speculation on conceptual and technical advances coupled with a vision of new directions would inspire the younger generation to leave the trodden path for the venturesome and the unknown".

In addition to a subject index and an author index, the volume also includes a list of publications of Professor Lal.

Obituaries

Trupapur Antony Davis was born on 9 February 1923 in Tamil Nadu. After completing his school education, he took his BA degree in Botany from St. Joseph's College, Tiruchirapalli, a post-graduate diploma from the Agricultural Research Institute, Coimbatore, a diploma in "Radio-Tracer Techniques" from the Indian Agricultural Research Institute, New Delhi and a Ph D in Biostatistics from the Indian Statistical Institute, Calcutta. Starting his career in sugarcane research at the Sugarcane Breeding Institute, Coimbatore around 1947, he joined the Central Coconut Research Station, Kayamkulam as Plant Physiologist in 1952.

Working on coconut palms, he made the staggering discovery that trees whose leaves were arranged in a left-handed spiral, gave a higher yield, without the use of extra fertilizer or any special breeding programme. This brought him to the notice of Prof. J B S Haldane, who was so impressed with his work that he encouraged him to join the Indian Statistical Institute, Calcutta so that he could continue his work on the genetics of the coconut palm, along lines which had proved successful in other plants. He was Professor and Head of the Crop Science Unit at the Indian Statistical Institute from 1960 till 1972, when he was appointed Head of the Biology Division of the Institute, a position he held till his retirement. He then established the J B S Haldane Research Centre in Nagercoil, Tamil Nadu and served as its Director till his death.

His main interests were in the biology of asymmetry and in coconut and other palms; his most outstanding contributions relate to symmetry and asymmetry and right and left-handedness in plants and animals, but specially in the coconut palm. His discovery that levo- and dextro-rotatory asymmetry in plants is non-genetic came from the unique application of statistics and mathematics to aspects to plant and animal life, neither common nor fashionable at the time. His construction of the sunflower (capitulum) and the demonstration of the existence of Divine Proportion (Golden Ratio) in Man, were the result of the application of his favourite Fibonacci concept to plants and animals. He had such a lively interest in things around him that there was no difficulty for him to find problems to work on. He had a flair for recording and analysing quantitative data on biological specimens or materials, which contributed to

precision in understanding form and function in plant and animal systems.

Examples of the extraordinary range of his interests may be seen in his publications which range from problems such as the role of pressure in xylem transport in palms, the biology and mathematics of the chambered nautilus, the golden mean of the human body and the selection of nesting trees and the frequency of nest visits by the Baya weaverbird.

His invention of an electronic detector to detect insects within plant organs, wooden structures or storage casks, and of a vertical bicycle to climb palms and forest trees, reflect his many and varied interests. Besides these, he had a passion for photography and he built a superb collection of photographs of palms, plants, birds and animals from many parts of the world.

He was a member of many national and international Societies and Associations. He was elected a Fellow of the Academy in 1979. His geniality and generosity, dignity and modesty, his flair for languages and for culture won him many friends and admirers in many countries.

He passed away on 10 November 1989 following a heart attack. In his death the Academy has lost a distinguished Fellow and his admirers and colleagues a valued and greatly respected friend.

Coimbatore Ramadorai Krishna Murti was born on 3 March 1923 at Trichur, in the erstwhile Cochin State, where his maternal grandfather was the Dewan at the time. He lost his father when he was only two years old and so grew up in his maternal grandfather's house. His early schooling was at Vivekodayam High School and at St. Thomas College, Trichur. He took his B.Sc (honours) degree in Chemical Technology from the Andhra University, Waltair where he studied under Prof. T.R. Seshadri.

After a short spell of apprenticeship at Calcutta, he joined the Indian Institute of Science, Bangalore for research, working under Prof. V Subramanyam on several schemes, including the patented process for the production of cheese using fig barks.

He joined the Central Drug Research Institute, Lucknow in early 1950 and worked there for the next 25 years, retiring as its Deputy Director. He built up an active school of biochemistry, oriented towards the problems of drug research, biochemical toxicology and utilization of biological resources for development. His researches were transferred to the Industrial Toxicology Research Centre, Lucknow in August 1975.

His specialization was in nutrition, biochemical toxicology and applied biochemistry and his

contributions to the biochemistry of pathogenic bacteria and the encystation of pathogenic protozoa are outstanding. He was elected a Fellow of the Indian Academy of Sciences, the Indian National Science Academy, the National Academy of Sciences Allahabad and the National Academy of Medical Sciences. He was President of the Society of Biological Chemists, India and of the Indian Association of Biomedical Scientists. He was given the Basanki Devi Amarchand Award by the Indian Council of Medical Research and he was nominated the National Professor in Biochemistry in 1976 by the University Grants Commission. He also received the Pitambar Pant National Fellowship in Environmental Sciences in 1983.

Throughout his life he took an active interest in understanding environmental changes caused by developmental activities, specifically with pollution by heavy metals and non-biodegradable organic chemicals, as a result of industrial growth and modernization of agriculture. He synthesized toxicological information on industrial and agro-chemicals and evolved multi-disciplinary approaches for their safety evaluation.

He initiated studies on consumer safety involving non-soap detergents, their ecotoxicological effects and the misuse and abuse of pesticides. He prepared a status report in 1984 on residue levels of pesticides in food and biological tissues. Among his major publications are "Man, Environment and Chemicals" and "Toxic Metals in the Indian Environment".

He was also involved in organising R&D programmes on the ecodevelopment of the Ganga Basin and the Kaveri Basin, in the various universities near the rivers, leading to a complete documentation on the water quality of the rivers and published two books on "Ganga — A Scientific Study" and "Ganga — A Cultural Heritage".

As Chairman of the Scientific Commission on Bhopal Gas Leakage, appointed by the Government of India, he activated an integrated programme on evaluating the continuing and long-term effects of the Bhopal gas leakage on life systems. He also co-ordinated an inter-ministerial group on the prevention and control of chemical accidents and a study on the current practices of industrial waste disposal in India. He was a keen musician and writer. Soft-spoken and gentle by temperament, he always had an encouraging word for the young. He set high ethical standards for himself and those around him and all through life "tirelessly stretched his arms towards perfection." He passed away at Madras on 30 June 1990, leaving his family and his many friends and admirers to mourn his loss.

Amurtur Narayna Aiyar Radhakrishnan was born on 17 May 1927 in Amurtur, Karnataka and had his early education in Central College, Bangalore. Soon after his M.Sc., he obtained a diploma in chemical engineering, and later his Ph.D. degree working at the Indian Institute of Science, Bangalore, with the late Prof. K.V. Giri. He did pioneering work in paper chromatography and developed a procedure for the quantitative determination of amino acids. He also discovered *cis*-4-hydroxy-L-proline as a free amino acid in the sandalwood tree, the first new amino acid reported from India.

He joined the National Institute of Health, Bethesda, USA in 1955 and later the Tufts University School of Medicine, Boston. Working with Prof. Alton Meister he showed the enzymatic and non-enzymatic conversion of hydroxy proline to pyrrole-2-carboxylic acid, a reaction which provided a breakthrough for further work in this field. He also worked on the synthesis of proline and pipercolic acid, and subsequently demonstrated for the first time the synthesis of amino acids by a reversal of the amino acid oxidase reaction.

In 1957 he joined Prof. Esmond E. Snell at the University of California at Berkeley and was able to delineate the crucial reactions involved in the biosynthesis of branched chain amino acids, valine and isoleucine. This work facilitated further studies on the control mechanisms in the biosynthesis of branched chain amino acids.

On his return to India in 1960, he worked in the Department of Biochemistry, Indian Institute of Science, Bangalore and extended his work on the branched chain amino acids. In 1962, he joined the Wellcome Research Unit at the Christian Medical College Hospital, Vellore and for 15 years was involved in the study of the biochemistry of the small intestine in normal and pathological conditions. He established a very active centre of research at Vellore and his Unit attracted a number of motivated young students from India and visitors from abroad.

In May 1977, he joined the University of Hyderabad, as Professor and later Dean of the School of Life Sciences. One of the main features of the School was the interdisciplinary and integrated approach to teaching and research, maintaining at the same time high standards in areas of specialization. Since his retirement in 1987, he has been associated with the Department of Biochemistry, Indian Institute of Science as Emeritus Scientist.

In the biomedical area, he made extensive contributions, mainly on various enzymes of the

small intestine and on transport mechanisms of amino acids, vitamins and peptides. He discovered a general transport system for dipeptidase. His other contributions were in the area of amino acid nutrition and metabolism in Kwashiorkor, malabsorption syndrome and in collagen metabolism in leprosy.

He was deeply interested in genetic disorders in man. His early work on phenylketonuria and later the critical report on the chemical, biochemical and pathological evidence for the first such case of neonatal arginosuccinic aciduria are substantial contributions in this area. He was the first to report in 1970 by critical experiments using biopsy material, the existence of lactase deficiency (leading to lactose intolerance) in Indian population.

One of his finest contributions was his work on the size, shape and subunit structure of rabbit intestinal glucoamylase, using its hydrodynamic and physicochemical properties. The supraquaternary structure of this enzyme was theoretically derived as a 'string of beads', and later supported by electron microscope observations. His contributions in vital areas in biochemistry and clinical nutrition and to the development of biochemical education and research in India are outstanding.

He was the recipient of several honours and awards. He received the J C Bose Award of the University Grants Commission in 1977 and the B C Guha Memorial Lecture Award of the Indian National Science Academy in 1981. He was elected a Fellow of the Academy in 1973.

Those who had privilege of knowing him will remember him with lasting affection and admiration. He died of lung cancer on 17 June 1990, exactly one month after his 63rd birthday. He leaves behind his wife and two daughters and many friends and colleagues to mourn his loss.

Shantilal Chhaganlal Sheth, was born on 29 October 1912. After obtaining his MBBS degree from Grant Medical College, Bombay in 1937, he worked for some years in the JJ Group of Hospitals, Bombay. Opting for a career in paediatrics, he left for England, where he took his Diploma in Child Health (DCH) from the Royal College of Physicians and Surgeons of London in 1947. He also passed the examination for the membership of the Royal College of Physicians of London (MRCP) in 1948, obtaining considerable clinical experience during his stay in England. He returned home soon after and obtained the degree of Doctorate of Medicine (MD) of the Bombay University in the same year.

He established the Department of Paediatrics in TN Medical College, Bombay which grew to be an important centre for training and research in paediatrics. He also took an active part in the work of the Bombay University, the SNDT University for Women, the College of Physicians and Surgeons, Bombay, the Indian Medical Association, the Medical Council of India as well as various paediatric institutions. He was instrumental in establishing the Indian Academy of Paediatrics. He represented the University of Bombay in the Medical Council of India, of which he became the President (1969-75).

The main subjects of his studies were childhood cirrhosis, diarrhoeal diseases in children, malnutrition, infantile and neonatal tetanus and epidemiological studies in diphtheria and childhood tuberculosis. Basic topics like nutrition, liver diseases and tropical and communicable diseases, conceptual themes on preventive and social paediatrics, under-graduate and post-graduate education, continuing medical education, the role of family physicians and organisations like the Indian Medical Association, clinical evaluation of drugs, epidemiological studies in childhood disorders and general topics like the part to be played by the profession in maternal and child health (MCH), are some of the areas in which he has made substantial contributions.

He received several awards of distinction during his long and successful career as a paediatrician, teacher, medical educationist, active social worker and pioneer in several fields of activities in the clinical and social aspects of medicine.

He was elected a Fellow of the Royal College of Physicians (London) in 1956, a Honorary Fellow of the American Academy of Paediatrics and a Fellow of the Academy in 1965. He was appointed Hon. Surgeon Commodore (Indian Army) and Hon. Physician to the President of India and was awarded the Padma Bhushan in 1972.

He remained in active practice and public work almost to the end. He passed away on 25 January 1990 at Bombay. He leaves behind his wife, a son and a daughter and innumerable friends and admirers to mourn his loss.

The Deccan Traps

We reproduce below the Presidential Address given by Professor Birbal Sahni at the Indian Science Congress held at Madras in 1940. His birth centenary is being celebrated in 1991.

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 with 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 a 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 Nerbada, and in a string of outlying patches along the east coast, from Trichinopoly 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 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 thousands of years, and which on the west coast were piled up to a thickness of 6–10 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 connexion 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 Cutch, 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 afield. Beds of volcanic 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 derived 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 is 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 Professor 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 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 species 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 8-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 of hard tissue. The 'chambers' may have been quite empty, or filled with a loose spongy tissue which acted as a float. The surface was covered by a thin, smooth, water-tight 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 constituents 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 *Palmoxyton*; 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 it 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. Professor Rama Rao and his colleagues, Messrs 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 there 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 deposition 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 wide-spread 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, as 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.