The decade of my association with research in India

Bernard Peters

To the study of cosmic-ray nuclei and the search for cosmic ray-produced radionuclides, Bernard Peters brought hard work and new ideas.

My first contact with India occurred soon after it was established that the primary cosmic radiation (CR) bombarding the earth consists of a variety of different nuclei. An obvious but very important question arose: Does this, the only material accessible to us from beyond the solar system, consist of matter only, or does it contain also antimatter (i.e. atomic nuclei of negative electric charge)? As far as it is known, both matter and antimatter are always created together and in equal amounts. Why only one kind (i.e. matter) can be found in the solar system and beyond is still an enigma.

At equatorial latitudes the geomagnetic field produces an asymmetry in the CR. It prevents positively charged particles in certain energy intervals from reaching the earth from the easterly direction, and, at the same time, it prevents negatively charged ones (i.e antinuclei) from reaching it from the westerly direction. Thus, a very basic problem in physics and cosmology could be investigated by measuring the arrival direction of complex CR nuclei in the equatorial stratosphere.

I met Dr H. J. Bhabha in New York in October 1949 to discuss this problem. He had then already initiated a CR research programme at the newly created Tata Institute of Fundamental Research (TIFR), Bombay, and the programme included balloon flights into the stratosphere. Obviously, a cooperation on this fundamental experiment between the TIFR and the University of Rochester at which I was then teaching was indicated.

I arrived in Bombay on 31 August 1950, with an apparatus designed to measure such an asymmetry. It would keep airborne packages of nuclear photographic emulsions oriented in space, independent of wind-induced rotation of the balloon clusters.

An early letter to my family describes my first impression of the people and the conditions available for this co-operative experiment:

> My first impression of the Tata Institute of Fundamental Research is very favourable, much more so than I had a right to expect. I have met a good many scientists, people with knowledge and interest, whom one likes at first sight. The institute, housed in a former royal officer club, has so much space, it would make everyone in Rochester green with envy. The library is large and adequate. The electronic labs and the machine shops look good. It is located at the Bay, from which it is separated by a small park with flowers. Mr Godbole, the secretary of the institute has reserved my room at the Taj Mahal Hotel ... looking out over the ocean with fishing boats and islands in the distance. It is hard to describe how beautiful it is.... I have not broached the subject yet, but who can pay for such royal quarters? I certainly can't....
>
> I have already talked to some of the physicists. I am very impressed and relieved that they have already made successful balloon flights to 95,000 feet for several hours with rubber balloons; so they know a great deal more about the subject of flying than I do. This was my greatest worry, so my hope for success is much increased. Their percentage of recovery, 60–90% return of equipment within two days, also sounds exceedingly good.... My first impression about facilities, competence of people, and their character is extremely favourable, but so far based on only four hours of contact.... Dr Taylor is the chief of the cosmic ray emulsion group, the division using photographic plates. He is half-time professor teaching at a college belonging to Bombay University and half time at the Tata Institute. An Englishman about 50 years old....

And:

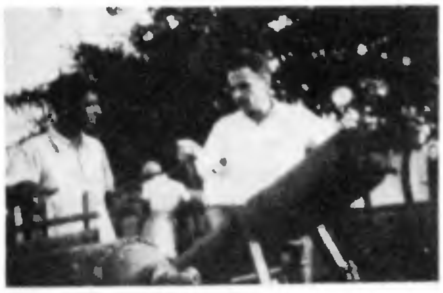
> Bombay, Sept. 29, 1950
>
> Taylor and I are flying to Madras on the 8 October, then drive to Bangalore, stopping at several places to pick out observation stations for theodolites. We will meet some of our crew in Bangalore, tranship equipment from there to Madras, and start flying on the 15.

A large number of rubber balloon flights were begun on 15 October from the cricket field of Madras Christian College in Tambaram. Another letter, of 22 October 1950:

> I was sitting in a moonlit night at a brick fireplace in the woods, cooking balloons from mid-night to 3 a m. Then I woke up our group, and, as planned, at 5.40 a.m, twenty minutes before sunrise, our 24-balloon flight went off. It was the most elegant launching operation with 25 people involved. Many college students volunteered. The flight stayed up for at least 10 hours and was observed by our theodolite stations in Madras, Vellore, Kolar and Bangalore. Wireless communication and weather perfect. Except for the fact that the old balloons did only go up to 75,000 feet instead of 95,000 feet, it was a perfect flight. Our score is now: first flight 15 October, a failure but recovered. Second flight, 70–80,000 feet. Weather permitted only four hours observation, but judging from the place at which it came down, it probably was an eight-hour flight. I am leaving tonight for Kuppam to recover it. Third flight today, probably 10–12 hours above 70,000 feet. I have no doubt that we will get excellent flights if we have better balloons and more rope.

The flights continued into November.

Subsequent examination of the emulsions at Rochester and Bombay gave a clear answer: The region of the galaxy where CR originates contains matter only; less than one in a thousand of the nuclei consists of antimatter. This answer stands today. The upper limit for antimatter has since been lowered from 10^{-3} to about 10^{-5}. This result is quite surprising and disturbing, if one accepts big bang models of cosmology. Various attempts to explain the asymmetry are still quite tentative.



Peters (*right*) and assistant, producing hydrogen gas for balloons in high-pressure autoclaves, Tambaram, 1950

The enthusiastic work of the TIFR emulsion group led by H. J. Taylor* of Wilson College in Bombay and the

*See *Curr. Sci.*, 1990, **59**, p. 1267 for article by H J Taylor excellent help and cooperation we got from the Madras Christian College staff and students in carrying out this very arduous balloon campaign in Tambaram motivated me to accept Bhabha's offer to return to India for a longer stay. And so, having returned to Rochester at the end of 1950, I returned to India at the end of 1951 and brought my family.

The 1950 experiment was an auspicious beginning for my work in India, which should last throughout the decade. I realized then that the geographical position of India, combined with the facilities built up at the TIFR, presented a unique combination for research on many other basic problems related to CR, a fact which Bhabha had realized already when he founded the institute. The geomagnetic field at low latitude prevents the bulk of low-energy CR from reaching the earth's atmosphere, so that the very rare high-energy processes could be studied here without being swamped by background, a great advantage over the situation in the USA and Europe. It remained to identify feasible experiments, which could be expected to yield new and relevant results in high-energy physics. We chose to investigate the following problems:

1. The chemical composition of high-energy CR, especially a search for evidence that it may reveal traces of its prehistory, its acceleration by as yet unknown processes at unknown sources, and its passage through interstellar space. Are all atoms completely or only partially ionized before acceleration? In other words, what is the temperature in the source region? How many, if any, long-lived radioactive nuclei which may be present in the source have survived the transit to the solar system? How long have the particles been on the way, how much interstellar matter (mostly hydrogen gas) have they traversed?, etc.

2. What happens when CR nuclei of energy far greater than could then be produced in laboratories collide with other nuclei? How do complex nuclei then disintegrate? What are the collision cross-sections for the various disintegration products?

3. What unstable particles are created as the result of the prodigious energies released in these collisions? (Some of them were known to be pions which had been discovered a few years earlier by C. F. Powell in Bristol.) How many subatomic particles are created? What is their angular and energy distribution when they emerge from the collision centre and what can this tell us about the interaction of subatomic particles

Stimulating discussions

B. V. Sreekantan

The Tata Institute of Fundamental Research was founded by Homi Bhabha in June 1945, and immediately after that experimental cosmic-ray research was organized under three different groups—the high-altitude studies group under A. S. Rao, the nuclear emulsion group under H. J. Taylor and the cloud chamber group under A. B. Sahiar. I joined the cloud chamber group of the institute in August 1948, and as suggested by Bhabha I started to build fast-pulse electronics circuits and detector systems for a systematic investigation of μ-meson decay. In 1949 we moved from the Peddar Road premises, which was Bhabha's own house, to the spacious Yacht Club building next to the Gateway of India, and by the time Peters came in August 1950, the activities in all the three groups were in full swing and the institute had also started work in other areas like nuclear spectroscopy, under B. V. Thosar, and nuclear reactions, under R. Ramanna. Towards the end of 1950, Bhabha organized the first international conference on elementary particles, which was attended by many leading cosmic-ray physicists and theoretical physicists. Peters was already there in connection with his heavy-primary experiment carried out in Madras in collaboration with TIFR. Just around this time Bhabha suggested to me that I should take a Geiger telescope down the Kolar Gold Mines and measure the intensity of the penetrating component, and then using the μ-decay set-up check whether all underground penetrating particles are indeed muons. By the time Peters returned in December 1951 from the US to join TIFR on a more permanent basis, Naranan and myself had completed the intensity measurement up to a depth of 1000 ft below ground and were busy building the detector system for measuring the angular distribution of particles at various depths. Our very first paper entitled 'Cosmic rays underground', published in the *Proceedings of the Indian Academy of Sciences* in 1952, was based on extensive discussions with Peters. The second paper entitled 'On the angular distribution of penetrating cosmic-ray particles at a depth of 103 MWE below ground' (which had a bearing on the proportion at production and lifetime of the just then discovered K-mesons), which also appeared in the *Proceedings of the Indian Academy of Sciences*, was communicated by Peters himself.

Peters stayed on at TIFR till 1959 and during the eight years that he spent there played a major role in not only leading the activities of the nuclear emulsion group, but also in influencing the activities in other areas of cosmic-ray research. In 1955 he started, along with Lal and Rama, investigations on cosmic-ray-induced radioactive isotopes in the atmosphere.

Though in the beginning Peters was not very enthusiastic about my starting extensive air-shower work at TIFR since India did not have any special advantage over other groups, he did change his opinion and supported me later. In starting this work I had taken the stand that the opportunity for developing frontline electronics and detector systems was equally important and challenging and an air-shower investigation did provide this wonderful opportunity. The nanosecond timing system that we developed in this spirit, and also the total absorption spectrometer, became extremely important assets to much of the later investigations on the time structure of particles in extensive air showers. Interestingly, Peters, after moving to Copenhagen, started studies on time structure of muons in air showers in search of 'heavy-mass particles' which he called plutons, and at Ooty we started time-structure studies on hadrons using a total absorption spectrometer. These studies led to one of the most important results from Ooty in high-energy-interaction studies, namely the dramatic increase in the cross-section for nucleon–antinucleon production at tens of GeV energies much before the advent of the CERN accelerators. Peters spent almost a month with us at Ooty when we were doing this exciting experiment in the summer of 1965. Discussions with him were stimulating and always made us feel more confident.

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Marking emulsion sheets with radioactive nylon fibres for assembly into emulsion blocks, TIFR, Bombay, 1953.

with nuclei and with each other? What are the rest masses of these particles, their decay times and other properties?

Thus an enormous research programme lay before us, in which the advantages deriving from India's geographical position could be exploited.

4. There is, however, at least one more subject of great interest in high-energy CR research which we did not take up, namely the study of the so-called extensive air showers. These are produced in the atmosphere by extremely rare CR primaries of extraordinarily high energies. Here India has no geographic advantage over other regions since the measurements on extensive air showers have to be carried out on the ground, where the thick overlying atmosphere excludes low-energy background at all latitudes. A vigorous programme on extensive air showers was, nevertheless, also initiated at the institute at that time, and produced under the leadership of B. V. Sreekantan many useful results. The success of his work can in part be ascribed to the fact that India possesses in the Kolar Gold Mines one of the deepest underground installations suitable for CR research.

Enduring influence

R. R. Daniel

When Bernard Peters first came to India in 1950 to conduct a well-planned high-altitude rubber balloon experiment to study primary cosmic rays, the group at TIFR consisted of fresh M Sc's in their twenties with just one to three years of introduction to research. H. J. Taylor, professor of physics at Wilson College, was our research guide while Homi Bhabha used to take part in scientific discussions and planning. And Bernard, fresh from the success of the discovery of heavy nuclei in cosmic radiation, was in a hurry to achieve more. To accomplish this he came prepared to drive himself to the limit and to sweep the rest of us with his excitement and success. He worked with us literally day and night, shoulder to shoulder, sharing every bit of work, manual or intellectual, in the launch ground or in the laboratory. His subsequent stint at TIFR from 1951 was a turning point in the lives and careers of many young men who went on to achieve great things in their own lives. Bernard's association with TIFR was only for about seven years, but its effect was lasting and immense.

It is not just the very good science that was done during his tenure in TIFR that I consider to be his great contribution. It was the objective method of approaching problems and the importance of honesty in thought and action that he inculcated in the minds and lives of his young colleagues by his example and emphasis that left an enduring impact. We were very impressionable in those days, and the open discussions he encouraged, his respect for individual opinions, and the close relations he established with each one of us contributed to our acceptance of the value system he stood for and promoted. In my own experience I recall that in spite of his intense interest and activity then on the study of heavy nuclei in cosmic radiation, he allowed me to start a programme on my own to study nuclear disintegrations caused by energetic helium nuclei in photographic emulsions.

Yet another quality in him is worth mentioning. It is a common practice among scientists to continue research for a lifetime on the same problem in which they made interesting contributions in their youth. This is one of the major reasons why the quality of research carried out by even good scientists becomes pedestrian with time; and this practice is quite widespread in not only India but the world over. Bernard was different. He was always looking for new openings and opportunities. Even within the seven years he was with us he changed his field of prime interest from primary cosmic rays to the search for radioisotopes produced by cosmic rays and their applications in various fields. He was always open to change. This example stood many of us in good stead in our later careers.

Of course he was an aggressive, high-pressure worker. And he expected his younger colleagues to be always hardworking and sincere. In summary, the abiding benefits that Bernard Peters left behind to TIFR and the band of young researchers were scientific temper for the individual and an enabling atmosphere in which free and objective human thoughts can thrive.

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But the attention of the group which I had joined concentrated on high-altitude measurement and on the first three listed subjects. We employed nuclear emulsions and balloon technology and were able, in the course of time, to improve both these technologies significantly.

Intensive scientific work at the institute engulfed me almost immediately after returning from the US. Among the large number of CR interactions which had been found in the emulsions exposed in the 1950 flights there was one very rare and huge one with nearly four hundred created subatomic particles, initiated by a primary CR nucleus of magnesium. This interaction remained for years the largest nuclear disintegration observed anywhere in the world. It became the subject of much theoretical investigations on meson production, and it yielded a great deal of new information.

For one thing, it answered a question which was still under discussion at that time, namely whether pions are produced individually in successive encounters with nucleons of the target, or whether they are produced *en masse* in nucleon-nucleon collisions like a cloud whose size increases with energy. The several hundred particles created in our event were incompatible with single-production models.

The event also permitted a new technique for determining the very high energy of the primary. Postulating symmetry in the forward and backward emission of secondary particles in the

New ideas

Gaurang B. Yodh

At one end of a panelled library at the Yacht Club there were two offices—one of the professor of mathematics, D. D. Kosambi, and the other of the professor of experimental physics, Bernard Peters. It was January of 1957, I had just joined TIFR and was on my way to see Professor Peters. As I entered his office I saw a strong face with deep-set, intense eyes and a broad smile welcoming me. I wanted to start research in cosmic rays. I had come to Bernard in search of a good problem to make myself familiar with the frontiers in cosmic rays. He immediately suggested that I work with him on the problem of composition of cosmic rays near the 'knee' of the energy spectrum at 10^{15} eV. I welcomed the offer.

This was the start of the rigidity cut-off model of Bernard Peters. We were trying to understand the variation of the content of nuclear-active particles in air showers through the 'knee'. In typical Peters style we developed an equilibrium model for shower propagation which made it possible to do calculations without the use of computers! Many different aspects of shower development were studied. We had many vigorous discussions, comparing results and discussing limitations of the particle-physics models. The model predicted that cosmic rays should have different elemental composition above the 'knee' compared with that at lower energies, composition becoming dominated by heavy nuclei above 10^{15} eV.

This prediction was a radical departure from known composition at low energies, which was dominated by protons and helium nuclei; the year was 1958! Only 30 years later are experiments pointing towards the validity of this prediction. Peters worked on phenomenological improvements and extension of this basic approach for the next five years. This work culminated in the comprehensive paper of Yash Pal and Bernard Peters on cosmic-ray propagation in the atmosphere.

Bernard always encouraged pursuit of new ideas, while at the same time examining them with a critical eye. He was the dominant figure in cosmic rays in India for over ten years. He established an outstanding school of cosmic ray physics at TIFR. Much of my work during the last fifteen years in cosmic rays reflects the deep interest that was generated while working with Bernard in the fifties. I extend my felicitation to Bernard Peters on his entering the ninth decade of his life.

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centre-of-mass system of the collision, one easily obtains from their angular distribution, if a large number of secondaries is involved, a precise determination of the velocity of this centre-of-mass system, and thereby the energy of the incident primary particle. Energies could here be measured which were several thousand times higher than those which could previously be deduced from particle trajectories in the earth's magnetic field. In our case, the incident magnesium nucleus had 7.8×10^{12} electron volts (eV) per nucleon or a total incident energy of 1.9×10^{14} eV. Most of the shower particles had energies of the order of 10^{11} eV.

These energy determinations indicated that complex primary CR nuclei exist at least up to those energies at which extensive air showers become observable on the ground. Their contribution to the extensive air shower phenomenon is probably significant if not dominant.

The microscopic investigation of the 24 emulsion-covered glass plates, which were traversed by the hundreds of shower particles, took us several months of very intensive effort, usually lasting late into the night. By scanning along the tracks of the created particles through successive emulsion layers, one found numerous interactions in this as yet unexplored energy regime, and could study their characteristics, in particular how they differed from the interaction of protons at comparable energies. One found numerous examples of electron–positron pairs produced by the decay gamma rays of neutral pions, and thereby obtained limits on π^0 abundance and lifetime. One also found not previously observed examples of electron–positron pairs produced by charged particles, i.e fast electrons and protons.

The entire field of particle physics and high energy remained the exclusive domain of CR research for almost another two years, i.e until 1954. Then the particle accelerators began to operate at Brookhaven and Berkeley. The tantalizing results obtained in CR were instrumental in stimulating the construction of those and even more powerful accelerators.

In these detailed studies of high-energy collisions there were indications that particles, other than pions, were created. However, a detector composed of glass-backed thin emulsion sheets did not lend itself easily to the identification of such particles and to the study of their properties. What was needed were solid blocks of pure emulsions, sensitive throughout their volume and yet capable of being studied microscopically with high magnification.

Our group experimented with various ways to process free-floating, large thin sheets of emulsion, which, although they swell up during processing, could then be dried to return them to almost their original dimensions, and to mark them precisely, so they could be brought back into the relative positions which they occupied when exposed as a solid block during flight, with precision of the order of a few hundredths of a millimetre. After some false starts we were successful almost beyond expectation. Now the decays and interactions of numerous charged and neutral particles could be observed. By tracing tracks backwards and forwards into the emulsion block, particle decay modes could be identified and the nuclear events could be identified in which the particles had been created. The particles observed in these detectors are now known as pions, K-mesons and hyperons. Their masses could be determined with good precision, their decay modes were clarified, and the association of K-mesons and hyperons in production and in nuclear capture was observed. The number of unstable subatomic particles in these preaccelerator years rose to about 14; it has increased only slightly since the accelerators entered this field more than 35 years ago.

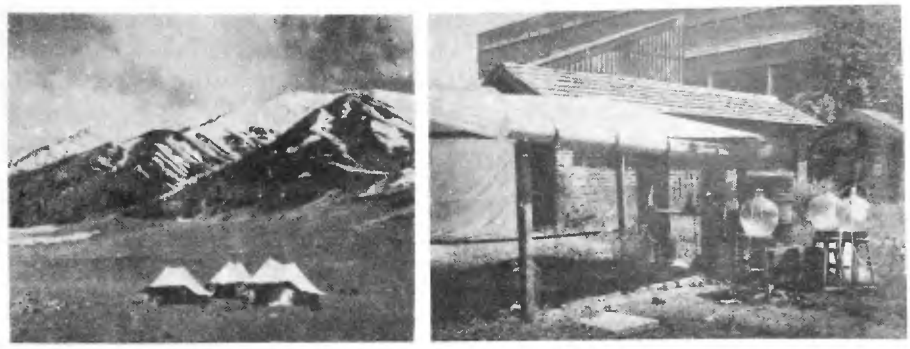
At the 1953 CR conference at Bagnères de Bigorre, sponsored by the International Union of Pure and Applied Physics, the new results obtained by means of our emulsion block detectors played a significant role in clarifying the then confusing situation in particle physics. Yet, within a year, it became apparent that when high-energy accelerators would enter the field, the unique role of CR in this research area must come to an end. A change of direction in our CR research became necessary.

We decided to study the production of radioactive isotopes produced by CR in collision with atmospheric nuclei and their subsequent fate. How many and what type of isotopes are being produced? How do they reach the earth? By what pathways and how fast are they distributed among the principal geophysical reservoirs, such as atmosphere, hydrosphere, lithosphere, biosphere and the polar ice cap? The concentration of these isotopes of different life-times should make it possible to study the turnover of matter in these various reservoirs, and the rate at which matter is transferred among them. One might study the exchange of air masses between stratosphere and troposphere, the ablation rate of rock surfaces, the sedimentation rate in lakes and on the ocean floor, the mixing of water between deep sea and surface layers, the ablation of polar ice by evaporation and by winds and ice flow. All these and many other phenomena should give rise to characteristic concentrations of the radioactive nuclei produced by CR.

For this new direction of research we had to acquire new unfamiliar techniques. Instead of emulsions and microscopes we now used:

- Ion exchange columns to extract certain nuclei from rain water
- Microchemistry to concentrate the extraordinarily small samples (one is always dealing with quantities far below the limits of visibility)
- Low level particle and gamma-ray counters to detect disintegration rates (sometimes as low as one or less per hour)

These then became our new research tools. More important still, we had to familiarize ourselves with many branches in geophysics and learn what was known at the time about the transport of air masses, global precipitation patterns, and, in particular, the build-up sediments on the ocean floor, where some of the long-lived isotopes, which could survive the transport, would finally come to rest. We began to collect samples in the stratosphere, troposphere, biosphere, in rivers, lakes and oceans, in deep-sea sediments and polar ice caps.



Search for ^{10}Be in melt water of fresh snow fields, Khilanmarg (13,000 feet), 1955 (*left*), and rain water analysis for cosmogenic radionuclides in the first isotope laboratory in Colaba, TIFR, 1956.

Through our emulsion work we had already accumulated a considerable body of knowledge on the number and kind of nuclear interactions which CR produce in the atmosphere at different heights and latitudes. This permitted us to make rather reliable estimates of the rates at which suitable radioactive isotopes were continually being introduced into the atmosphere. These rates are rather small. Typical values are: three nuclei of ^{10}Be per minute per kilogram of air, 0.1 nucleus of ^{32}Si per minute, and one nucleus of ^{26}Al every two hours. All these and many other isotopes are brought down to the earth in rain water and slowly diffuse into the various geophysical reservoirs while at the same time disappearing by decay at their characteristic rates.

We began the work by collecting enormous quantities of rain water. Large plastic sheets were spread over the roofs of the huts which served as temporary chemical laboratories at Colaba where later the modern laboratories of TIFR should arise. We even collected water on the large terrace of our apartment on Peddar Road. From there we channelled the monsoon waters through ion-exchange columns to extract the very small number of interesting atoms.

At that time the only radioactive nuclei on earth were those of the heavy elements of the natural radioactive series (whose life exceeds the age of the earth) and their decay products. All other radioactive isotopes on earth were cosmic-ray produced. This had been true through the ages until atomic-bomb testing began to disturb this peaceful state. From then on appropriate corrections became necessary.

Instead of launching balloons we now went on mountain expeditions. In one of our first experiments in search of the long-lived isotope ^{10}Be ($\tau \approx 1.6$ m.y.), we set up ion-exchange columns above Gulmarg in Kashmir, high up in the melt water of snow fields, to get hold of these rare atoms before they could make contact with the soil and adhere to it. Only two of the horses that carried our apparatus and equipment up to Khilanmarg were capable of going high enough. We extracted nuclei from thousands of litres of water. But soon, after verifying our theoretical calculations about production rates, we learned to extract most of the isotopes from much more modest samples of a few litres and began to analyse individual rain samples.

The CR-produced isotopes which can now be identified are shown in the table, many of them were first obtained in Bombay.

Element	Half-life
^{3}He	Stable
^{10}Be	1.6 m.y.
^{26}Al	710 k.y.
^{36}Cl	300 k.y.
^{81}Kr	210 k.y.
^{14}C	5730 y
^{32}Si	130 y
^{39}Ar	270 y
^{3}H	12.3 y
^{22}Na	2.6 y
^{35}S	87 d
^{7}Be	53 d
^{37}Ar	35 d
^{33}P	25 d
^{32}P	14.3 d

The detection of the isotopes with very long half-lives was difficult. We finally succeeded in measuring the ^{10}Be concentration in deep-sea sediments using one of the very earliest deep-sea ocean cores, which had been obtained by Petterssen and B. Kullenberg in Göteborg, Sweden. Another important long-lived CR isotope, ^{26}Al, was not isolated in ocean sediments until many years later. The tiny concentration of ^{32}Si in ocean water was not measured until Lal extracted this isotope by a novel technique from hundreds of tons of water *in situ* and identified it through its short-lived radioactive decay product ^{32}P.

This branch of CR research has been prospering since its beginning in 1955; CR-produced isotopes continue to play a role in oceanography and other branches of geophysics.

It was primarily for family reasons that I decided to leave India in 1958. I then accepted a position at the Niels Bohr Institute in Copenhagen but my connection with India did not ce visited India and the TIFR repe over the years. Scientists from the have been guests in Copenhage worked with me both at the Niels Institute and later at the Danish Research Institute. This connectic remained intact even after my ment.

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The discovery of cosmogenic ^{10}Be in India

D. Lal

The search for beryllium-10 was an exciting mix of brilliant ideas, ingenious and heroic metho thousands of gallons of Bombay rain water and Himalayan snow melt—and tenacity.

The story of the discovery of cosmogenic ^{10}Be produced in the earth's atmosphere is the story of independent evolution of scientific ideas in two groups in distant continents. This often happens in important scientific discoveries—and the discovery of ^{10}Be was indeed an important milestone in nuclear geophysics/geochemistry. More than a dozen groups all over the world are now measuring the concentrations of ^{10}Be in a wide variety of samples to learn about various parameters; past cosmic ray and geomagnetic field intensities, subduction of marine sediments along the plate margins and rates of erosion of natural surfaces, and many other leading questions in geosciences. I relate here the story of discovery of ^{10}Be by B. Peters in India.

If the title of 'king' had to be given to a terrestrial cosmogenic nuclide (a nuclide produced by nuclear interactions of cosmic-ray particles (with matter), it would no doubt go to ^{14}C (half-life = 5730 yr), the very first to be discovered[1-3]. By any standards, its detection was a brilliant accomplishment. The ratio $^{14}C/^{12}C$ in modern carbon is $\sim 10^{-12}$. The detection[4] of ^{3}H (half-life = 12.3 yr) with electrolytic enrichment was later accomplished by Libby and his colleagues for rain-water samples having $^{3}H/^{1}H$ ratios of $\geq 10^{-18}$. This was another significant milestone in the field of cosmogenic nuclides. The third long-lived terrestrial cosmonucleus to be detected was ^{10}Be (half-life = 1.5 m.y.). Peters[5] discussed the potential applications of this nuclide in 1955. The nuclide was detected unambiguously and independently in 1956 in marine sediments by J. R. Arnold[6] in Chicago*, and by B. Peters[7] and his colleagues in Bombay. Amongst the terrestrial atmospheric cosmogenic nuclides (henceforth called cosmonuclei; cosmonucleus for singular), ^{10}Be occupies a high rank as a radiotracer because of its long half-life, 1.5 m.y. It is the longest lived of the terrestrial atmospheric radioactive cosmonuclei and is useful for the study of processes and time-scales back to the Late Miocene. The detection of ^{10}Be in the late fifties was therefore another milestone in the field of cosmogenic nuclides, but its studies, although the only means for determining accumulation rates of marine sediments and manganese nodules back to 10 m.y. in the past, remained confined to a few scientific groups in the world. This was a direct consequence of the fact that the measurement of ^{10}Be activity involved very sophisticated radiochemical and low-level beta-counting methods. With the development of the AMS meth 1977, leading to substantial im ments in the detection sensitiv ^{10}Be (and other long-lived nu there was an almost immediate application explosion. This nucl being currently studied[8,9] in c samples of air, rain water, snow rocks, ocean water, marine sedi etc. to answer a wide range of que in palaeoclimatology, glaciology chronology, subduction of the sphere, geomagnetism and cosm physics. Studies of ^{10}Be have bec sort of industry. This nuclide rank to the 'king', of cosmonuclei, ^{14}C.

The first detection of cosmo (terrestrial or extraterrestrial) was rally accomplished by chemist instance, of ^{14}C by Libby. For Arr chemist, it would probably be natural and a relatively simple t go after this nuclide! Peters was, ever, a physicist. He launched a fledged attack to discover this n after he had convinced himself th was an important nuclide in view chemical behaviour and long half-l the first paper[4] on ^{10}Be in 'Radioactive beryllium in the sphere and on the earth', he said:

It is estimated that about 1000 nu radioactive ^{10}Be (2.7 m.y. half-lif

*See article by Arnold, page 727 this issue.