Nuclear Track Studies in India: A Historical Review

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Abstract

Nuclear Tracks originate from the spontaneous fission of Uranium in minerals and can be revealed by etching with suitable chemical reagents as tracks. The applications of Nuclear Tracks were developed by R.L. Fleischer, P.B. Price and R.M. Walker in USA in various fields, viz., Geology, Biology, Archaeology, Nuclear Physics, Reactor Physics, Earthquake Studies and Space Physics. A historical review of Nuclear Track Studies in India is presented in this paper along with contributions made by the author's group. Nuclear track shapes recorded in our laboratory are illustrated by microphotographs in different matrices. This technique became popular in developing countries as it involved minimal investments with maximum output of research publications in diverse fields.

Keywords: *Nuclear tracks, historical development, Nuclear Track Society, trackologist, fission track dating, ion track filters.*

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INTRODUCTION

Let us have a peep into the history of Nuclear Tracks in Solids and pay a tribute to our heroes both living and dead. The trio of Fleischer, Price and Walker of USA deserve a Nobel Prize for promoting one of the simplest experimental techniques with potential applications in almost all disciplines of science and technology. The maxim of 'Simple is Beautiful' is fully justified by this technique. It proved to be a boon for scientists of Third World countries who cannot afford expensive equipment and elaborate infrastructure to start some kind of research activity.

Let me quote some ground rules for achieving success in research enunciated by Professor R.M. Walker, one of the pioneers of nuclear track studies in meteorites, at the symposium on the History of Meteorites held at Kyoto, Japan in 1992:

1) One must be lucky.
2) A little bit of ignorance and a lot of naiveté can be very useful.

3) It is often better to do an experiment than to discuss why the experiment is not worth doing.
4) Where possible, quantitative estimates of probable results should be made. However, this rule should not interfere with rule three above.
5) Be acutely aware of the miserable fact that you tend to see only what you are looking for.
6) Choose your co-workers wisely.

HISTORICAL DEVELOPMENT

During fifties of the last century, nuclear tracks were discovered by Young in 1958 [1] and later confirmed by Silk and Barnes in 1959 [2] in mica using electron microscope. This neglected paper of Young in 'Nature' fortunately caught the sight of Price and Walker during sixties and a new era of nuclear track applications was opened up by the famous 'trio' working in General Electric Company (GEC), Schenectady (USA), after joining of Fleischer. The first application was fission track dating of rocks using chemical etching technique to make latent fossil fission tracks visible under an optical microscope [3-5]. This was a great breakthrough in the history of nuclear tracks in solids [6]. It was almost a romantic experience for most of us to see myriad geometrical shapes of tracks appear from crystal planes of dielectric materials. I was fortunate enough to develop and visualize cosmic ray tracks [7] in an olivine crystal from a meteorite recovered by Professor D. Lal and his associates at Physical Research Laboratory (PRL) in Ahmedabad. Sometimes during sixties, Professor P.B. Price visited India, viz. Tata Institute of Fundamental Research (TIFR), Bombay and Punjab University, Chandigarh. As a consequence of his visit, TIFR became the hub of nuclear track research in India. Professor S. Biswas continued his cosmic ray studies using this technique in TIFR. Professor D. Lal shifted to PRL, Ahmedabad and carried on his research activity in area of extra-terrestrial materials using track-etch technique. Two acronyms 'TINTS' and 'TINCLES' in nuclear track literature owe their origin to Professor Lal's geo-cosmo-physics laboratory.

Professor Rama, affectionately called Baba Rama by Professor Lal, is another TIFR don to promote nuclear track studies in geophysics. He was perhaps the first trackologist to observe annealing of fossil fission tracks in muscovite. The paper of 'Mehta and Rama' [8] is a classic one in fission track studies where annealing correction plays a predominant role in estimating the true ages of rocks. When Mehta returned to Kurukshetra University, the 'bug' of nuclear track studies entered Professor Nagpaul's laboratory [9]. The late Professor Nagpaul was instrumental in developing fission track dating technique in India and its exploitation in various domains, including tectonic uplift of Himalayas [10]. He deserves full credit for training most of Indian trackologists during the seventies of last century, including the author of this write up. If some one wants to name an Indian trio of nuclear tracks in solids, Professor K.K. Nagpaul and Professor D. Lal will always be there. Let the readers choose the third one from amongst the top brass of Indian trackologists by making an intelligent guess. Nuclear Track Society of India will offer a prize to any member of NTSI, who makes a correct prediction, at the 20th National Symposium to be held in Mysore University, Mysore in 2017.

The city of Bombay (now Mumbai) proved to be a cradle for nurturing the nuclear track baby of India. Both DAE & TIFR have played crucial roles in promotion of nuclear track studies in India. It was in Bombay during March 1979, the first meeting of Indian trackologists was held on the initiative and foresight shown by Dr. R.H. Iyer, one of the pioneers of this technique in Department of Atomic Energy (DAE). The present author was also invited to present the status report on nuclear track studies being carried out at Punjabi University, Patiala, where I was posted after my doctoral research in Marie Curie University of Paris, using nuclear emulsion technique. During seventies, nuclear emulsion technique came to a dead end, after its golden era of elementary particle discoveries and most of the nuclear emulsion trackologists were employing other sophisticated detection techniques or shifting to new fields of research, e.g., astrophysics or solid state nuclear track detectors (SSNTDs). Professors D. Lal, S. Biswas, Rama, V.S. Bhatia, T.D. Goswami, the present author and many others in India and abroad adopted nuclear track studies, popularly called SSNTD technique. The platform provided

by DAE in Bombay proved to be a milestone on the road of nuclear track studies in India. SSNTD groups were identified and a series of National Symposia/Conferences started in India under the auspices of Nuclear Track Society of India (NTSI) which was formally registered after the 5th National Symposium held in SINP, Calcutta.

NUCLEAR TRACK SOCIETY OF INDIA

The history of nuclear track studies in India is linked up with the history of Nuclear Track Society of India (NTSI) with a Life Membership of 430 at present. Perhaps, this is the only Track Society which brings out its Newsletter regularly and holds bi-annual conferences and regional workshops also. The track record of our society is far better than its counterpart 'International Nuclear Track Society (INTS)' which has many failures and a few success stories to its credit. I will not elaborate, being a respected member of INTS since its inception; the other Indian member is Dr. K.K. Dwivedi. Nuclear Track Society of India had the honour to organize 21st International Conference on Nuclear Tracks in Solids in India during October 2002. The event was organized with right earnest to present the best of Indian science and technology based on nuclear track studies before the international community. And here I come to illustrate some applications of nuclear track studies made by our research group in India, namely, Geochronology and Ion Tracks Technology.

OUR CONTRIBUTIONS

Our Geochronology laboratory became fully operational in 1974. Can you imagine it cost us just Rs. 5000 only? That is why I call nuclear track studies a boon for scientists of Third World countries. Our equipment included a simple optical microscope, a bottle of HF acid, an improvised etching bath, and some sheets of mica (muscovite & biotite). Irradiation facilities were provided by Bhabha Atomic Research Centre (BARC) using neutron beam of CIRUS reactor almost free of cost. Our first publications appeared in 1974 itself on detection of nuclear tracks in minerals [11] and fission track dating of biotites of Bihar mica belt [12]. In next 5 years, we published 2 dozen papers covering applications of nuclear tracks in fission track dating of pegmatites [13] and Himalayan rocks [14]; uranium estimation in minerals, plants and water [15-16]; origin and age of

tektites [17]; dating of iron and copper ore formations [18-19]; U inclusion dating and phase differentiation in minerals [20]; and annealing characteristics of nuclear tracks in minerals and glasses [21-22]. Figures [1-5] are added to show the aesthetic beauty of nuclear tracks in minerals, glasses and plastics.

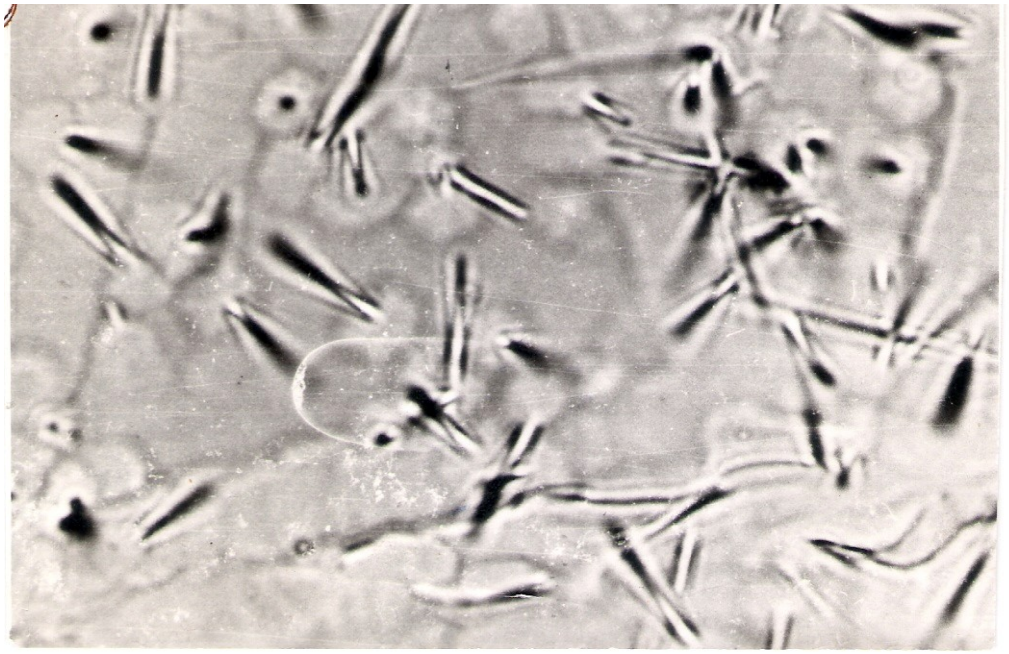

Fig. 1: Nuclear tracks recorded in apatite crystal of Borra mine, Andhra Pradesh.

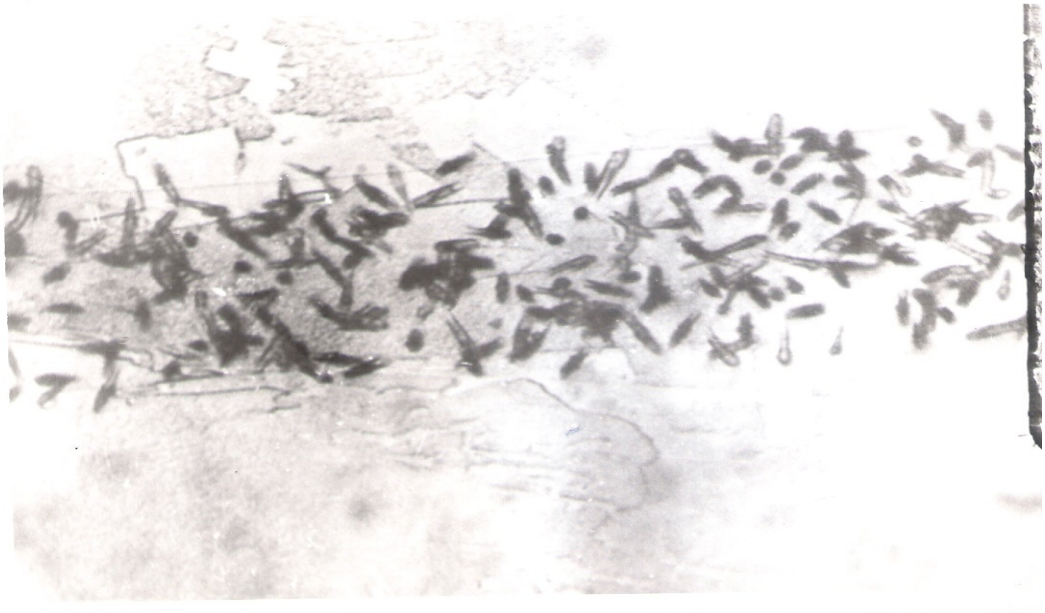

Fig. 2: Nuclear tracks recorded due to fission of U inclusion in Bihar biotite

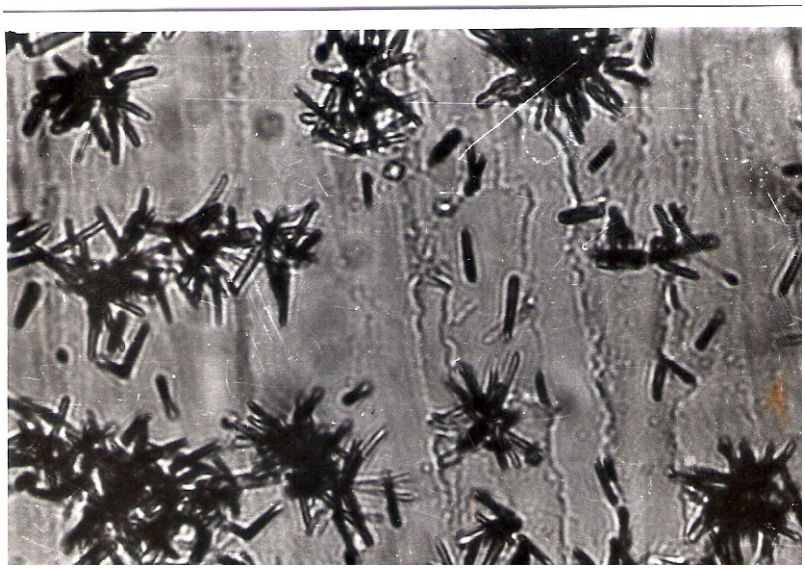

Fig. 3: Nuclear track clusters recorded in Himalayan Muscovite of Kathmandu (Nepal)

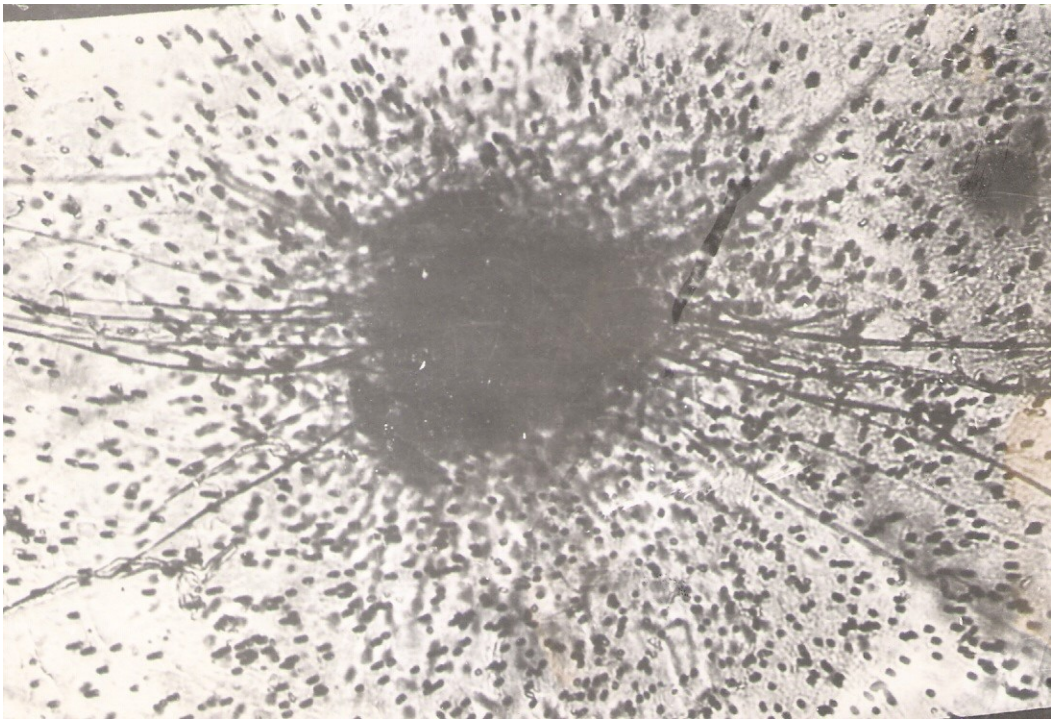

Fig. 4: A solar burst of nuclear tracks recorded in muscovite pegmatite of Bhilwara (Rajasthan State) after nuclear fission events.

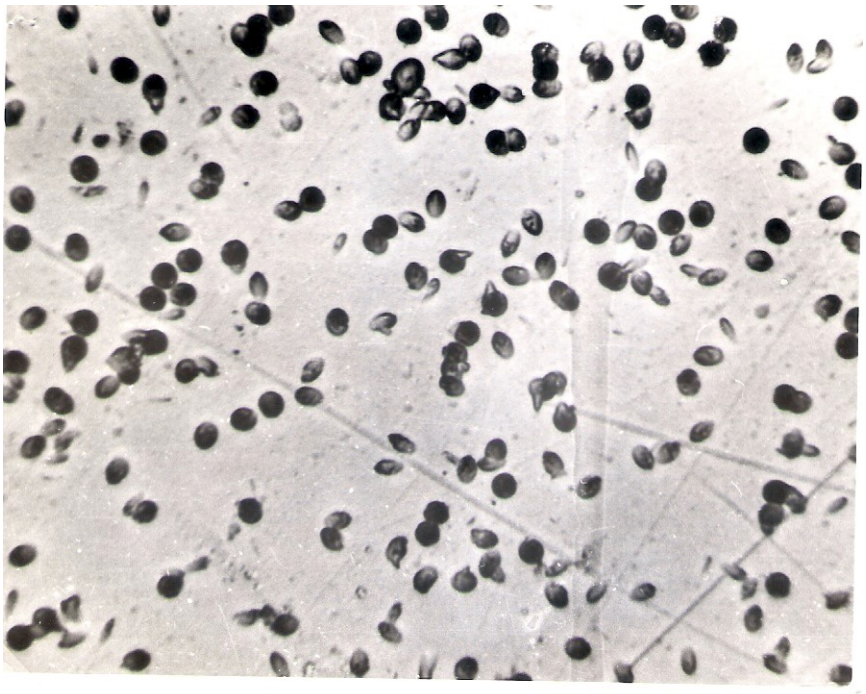

Fig. 5: Nuclear tracks recorded in a glass dosimeter (circles & ellipses).

Radiation damage annealing studies were carried out in our laboratory for almost two decades resulting in the culmination of an empirical model, popularly known as "Single Activation Energy Model of Annealing". Its formulation and applications are highlighted in my Review Paper: "Modgil-Virk Formulation of Single Activation Energy Model of Radiation Damage Annealing in SSNTDs: A Critical Appraisal" [23].

The simple technique of ion track filters (ITFs) was developed along with fission track dating in the early years of nuclear track applications. No one could guess that nuclear track pores in mica and plastics [Figs. 6-8] will lead to micro/nanotechnology [24], a technology of the new millennium. There is a lot of potential in creating new materials and devices with exotic properties using ion tracks, a new tool in micromechanics [25]. The author's laboratory prepared microstructures of Cu and Cu-Se for use in diode arrays [26-27]. Ion track membranes, as smart materials, find applications in drug delivery and pollution control [28-29]. Nanopore membranes of anodic alumina and polymers have been used by us for fabrication of nanowires and nanoflowers [30-31]. To sum up, Ion Track Technology can be developed in India since we are lucky to have heavy ion beams

available in India at Inter-University Accelerator Centre (IUAC), New Delhi and use of AFM/STM/SEM is also picking up in most of nuclear track laboratories.

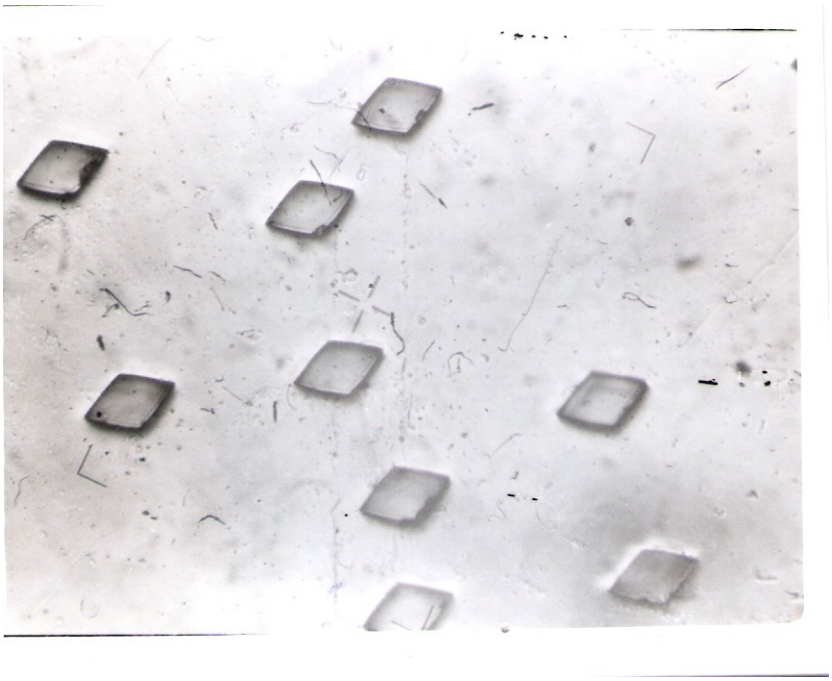

Fig. 6: Nuclear track pores of Xe in Muscovite mica matrix

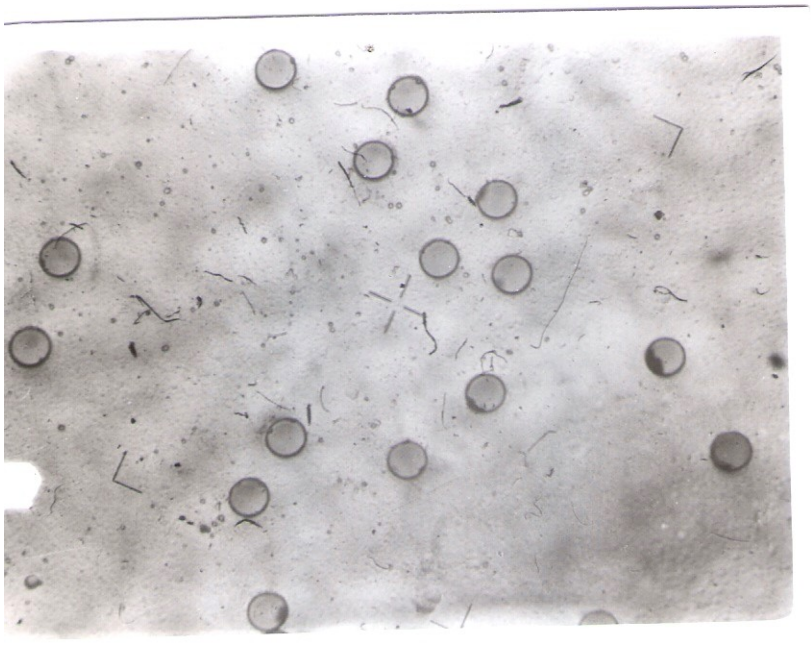

Fig. 7: Nuclear track pores of U in PVDF polymer matrix

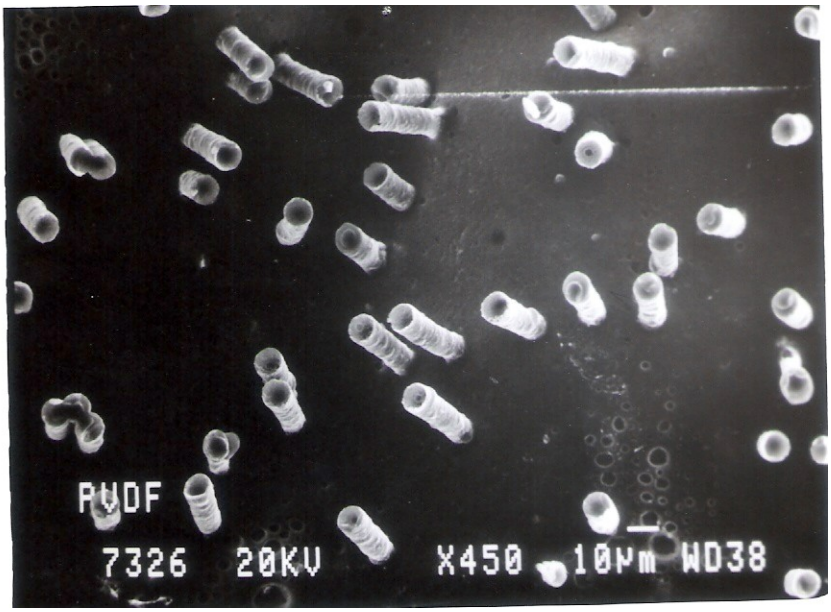

Fig. 8: Microtubules grown in Ion Track Filter of PVDF polymer

CONCLUSIONS

Nuclear track studies started in India during sixties of last century. It is unfortunate that within fifty years, fission track dating (Geochronology) is already a dead field in India while it is still flourishing in Europe and some other countries. Most of Indian researchers have shifted to Radon Studies in environment, which is of course a branch of nuclear track applications. Some of our scientists have found an escape route to other areas, for example, heavy ion interactions in polymers and nanotechnology. It is advisable that NTSI prepare a directory of Indian researchers engaged in nuclear track studies.

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