that ONGC was admirably positioned for a transition to geothermal resource exploration.

Balakrishnan loved being part of field explorations and enjoyed living in tents and leading his team consisting of large number of geophysicists, technicians and other support staff. He always remained a part of the team, which is what made him a huge success as a leader. Talking to me about the early days of her life with Balakrishnan, his wife once recounted how she had to pack her baggage and accompany him to the field camp at Cuddalore (Tamil Nadu), soon after her marriage. That was their first trip after the marriage, she recalled. That was the nature of Balakrishnan. He was so passionate about his work, that other issues seemed quite peripheral.

As Balakrishnan devoted much of his time in the field searching for potential sites of oil deposits, he had very little time to work on publications. The ONGC's restriction on the publication of the data he collected was possibly another reason why he could not publish much of his work. He was busy building the foundations for oil exploration in India and remained focused on that mission. As a man who never sought name and fame, I think, he joins the ranks of an expanding company of unsung heroes of the Indian geoscientific community.

Working with maps was of course his ultimate passion and he carried that all along, until his death. We are told that during the months of October to December of 2017, he had travelled to Florida to live with Meera and the one thing he insisted on carrying with him was his set of maps. He continued working on them, marking boundaries of tectonic blocks and other features expressed by geophysical data. Two days after his demise we had visited Rohini's home where he spent his last days. The room where he sat and worked until about two weeks ago, when he was bedridden, remains the way he had left it. Maps showing gravity anomalies, tectonic features and locations of potential geothermal fields, marked by various shades and patterns, remain spread out on his work table. It looked as if he had run out of colour pencils to shade the newly found structures and had just stepped out to get more of them. Opening a large cabinet full of maps, his daughters recounted how they have grown up in houses with maps rolled and stacked up all around and how they have also developed a great love for maps. The maps he made would continue to illuminate structures of interest in future efforts of exploration. The geothermal spots mapped by him might brighten up as future sources of energy. He truly laid strong foundations for meeting India's energy requirements. Indeed, the country has lost a very talented geophysicist whose potential was not tapped to its fullest benefit.

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Cadatur Badrinathan (1930–2018)

It was with much sadness that friends, colleagues and admirers of Cadatur Badrinathan, known to all as Badri, received the news of his passing away on 11 April 2018 in Navi Mumbai. Badri, who was born in Salem, Tamil Nadu, on 20 September 1930, did his Master's in Physics from the University of Rajasthan in Jaipur before joining Tata Institute of Fundamental Research (TIFR), Mumbai on 23 November 1955. His early work was with E. Kondiah and was based largely around the 1 MV Cockroft–Walton cascade generator accelerator at the Institute. It was during this time that Badri completed his doctoral degree that involved extensive experimental studies of transfer reactions using deuterons and 14 MeV neutrons. He also utilized neutrons that were made available from the Apsara and Cirus reactors at Bhabha Atomic Research Centre (BARC), Mumbai. His level of enthusiasm and acumen for high-quality experimental work was evident right from the beginning of his research career. Within a short time of joining TIFR, he was publishing well-noticed papers, with colleagues like K. V. K. Iyengar and N. Lingappa, on various topics like the interaction with fluorine of fast neutrons arising from D (d, n), Be (d, n) and T (d, n) reactions using deuterons accelerated in the cascade generator, and on the width of excited states of isotopes of tin by studying nuclear resonance scattering of de-excitation gamma rays. His skills as a top-notch experimenter were exemplified in the large number and variety of instruments that he developed, including the building of many of the early detector systems that were used by him and his colleagues at TIFR and, subsequently, at BARC and further afield.

In the period from the mid to late 1960s, Badri spent two fruitful years at the University of California, Davis, USA and a year at the Max-Planck Institute for Nuclear Physics at Heidelberg, Germany. Not only was this time well spent in updating and further sharpening his skills in state-of-the-art experimental techniques, but he also contributed to cutting-edge basic research in nuclear physics, with studies that included what were amongst the earliest experiments on neutron–proton bremsstrahlung at 208 MeV – pioneering work that appeared in *Physical Review Letters*[1] in 1968. Upon his return to TIFR, Badri played a leading role in the 1970s in attempts to build, in-house, a tandem van de Graaff accelerator and, along with his colleagues, he succeeded in constructing a pellet-chain charging system and was able to demonstrate its ability to generate high voltages. Such a charging system lies at the heart of contemporary pelletron accelerators.

In the 1980s, Badri shifted his interests towards the emerging field of experimental atomic and molecular physics. He developed low-energy ion sources and various types of mass spectrometers for experiments conducted at low energies – over the range 1 eV to 5 keV – and helped incorporate them into a new generation of laboratory-made instruments designed to explore in adiabatic fashion, the dynamics of electron–molecule and ion–molecule collisions, especially those

that had relevance to processes and situations in plasma physics, atmospheric and ionospheric sciences, and in astrophysics. It was one such apparatus that he helped develop – a crossed atomic beam – ion beam apparatus that resulted in what was the first atomic physics paper, in 1980, to emerge from experiments conducted with the newly set up pelletron accelerator at TIFR (the second paper published from the pelletron)[2]. Here, ultra-slow, multiply-charged recoil ions were shown to be produced in high-energy collisions of hydrogenic and helium-like fluorine ions from the pelletron accelerator with neutral rare-gas atomic beams at impact energies in the range 60–99 MeV. The highly charged rare gas ions, like Xe^{10+}, possessed only a few electron volts of kinetic energy. These became precursors for future ion–molecule experiments conducted at low enough energies to permit studies to be made of how electronic charge clouds on projectile ions and target molecules interacted with each other, and adjusted to each others' presence in the course of the collision.

Badri became an enthusiastic participant in the new instrumentation-intensive, low-energy atomic and molecular sciences programme that was being developed in TIFR from the early 1980s. His contributions to the design, fabrication and use of many novel forms of ion sources, molecular beams, ultrahigh vacuum systems, mass spectrometers and computerized data-handing systems laid a firm foundation for the successful and globally visible programme that continued well beyond his retirement from TIFR in 1990.

Over and above his formal work at TIFR, Badri was also an accomplished and internationally renowned photographer. He was amongst the first photographers in India to be honoured with membership of the Royal Society of Photography for his expertise gained in the ancient photographic technique of developing prints using natural sunlight. He was one of the few photographers to make use of carbon printing which is based on the fact that gelatin, upon sensitization to light by a dichromate, becomes hard and is made insoluble in water when exposed to the ultraviolet components of sunlight. He printed on dichromate-sensitized sheets of gelatin-coated carbon tissue which, upon developing in warm water, dissolves the unhardened gelatin, leaving a relief image that is thickest where it received the strongest exposure. The finished print resulting from such a process is usually of outstanding visual quality and proven archival permanence. He published detailed information, including relevant formulae, for all to freely utilize in a seminal article in *Royal Photographic Society Journal*[3]; it continues to draw attention to this day.

Badri was known to all as dynamic, knowledgeable and extremely cheerful. Over and above the wisdom in physics and photography that he readily shared with colleagues and friends, in the course of long periods during experimental runs, he would regale colleagues with tales of travels he had undertaken on little-used railway lines, visiting obscure railway stations, and of long hikes in the hills around Mumbai, and further afield. He was, most certainly, a fun person to be with. He will surely be greatly missed by his wife, two sons, a daughter, and six grandchildren, and also by all those who knew him.

1. Brady, F. P., Young, J. C. and Badrinathan, C., *Phys. Rev. Lett*., 1968, **20**, 750.
2. Mathur, D., Krishnakumar, E., Rajgara, F. A., Raheja, U. T. and Badrinathan, C., *Int. J. Mass. Spectrom. Ion. Process*., 1990, **99**, 237.
3. Badrinathan, C. and Rajagopal, C., *R. Photograph. Soc. J*., 1978, **118**, 68.

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Edited by S. K. Satheesh, and printed & published by G. Madhavan for Current Science Association, Bengaluru 560 080.
Typeset by WINTECS Typesetters (Ph: 2332 7311), Bengaluru and Printed at Printek Printers, Bengaluru (Ph: 2328 7763)