

## Manik Talwani (1933–2023)

Professor Manik Talwani, popularly known as the Pope of Marine Geophysics, passed away in the USA on 22 March 2023, aged 89. He was born in Patiala, India, on 22 August 1933. He was an internationally recognized marine geophysicist, having done exceptional research using gravity, magnetic and seismic methods. After obtaining Bachelor's Honors and Master's degrees in physics from Delhi University, India, Talwani joined Columbia University as a Doctoral student under the supervision of Maurice Ewing. In 1959, he earned a Ph.D. in geophysics. Talwani had a long association with Ewing, joining him on several research expeditions at sea and co-authoring a number of papers. Considering his adroitness in analysing the multi-parameter data and translating the results into models supported by Physics and Geology, Ewing described him as '*the best graduate student I ever had*'. Talwani was married to Anni Fittler and had three children: Rajeev, Indira, and Sanjay.

Talwani was a man with great talent, grit and determination. With the approach of analysing integrated marine geophysical data for understanding the Earth's internal structure and evolutionary processes, he became one of the most successful researchers in postulating new concepts and providing the most plausible tectonic models for various regions of the world's oceans. He thereby rose to the position of becoming the world's first and foremost integrated marine geophysicist.

Talwani held various positions at Columbia University, from research student to professor from 1959 to 1981 and also served as Director of the Lamont Doherty Earth Observatory, USA between 1972 and 1981. Thereafter, he joined Gulf Research and Development Company, USA, first as Director of the Center for Marine Crustal Studies and later as a Chief Scientist. He was offered the Schlumberger Chair in Advanced Studies and Research in 1985 by Chevron at Rice University, Houston, Texas. There he continued his research as a Professor of Geophysics until his retirement in 2006. Talwani also held the position of Founding Director of the Geotechnology Research Institute of the Houston Advanced Research Center during 1985–1998. Since 2006, he served as an Emeritus Professor, teaching and conducting research at Rice University till his demise. From 2004 to 2009, he also served as the President and

CEO of the Integrated Ocean Drilling Program Management International in Washington DC.

Talwani served on multiple national and international committees. These committees dealt with ocean affairs, scientific drilling, the Law of the Sea, Geodesy, etc. He served the Society of Exploration Geophysicists (SEG) in many ways. He was a member of the SEG Research Committee and its CO<sub>2</sub> sub-committee. He also served as a member of the board of Directors of SEG Advanced Modeling and was its Chairman in 2013.



Talwani authored over 150 peer-reviewed articles published in geophysical, geological and oceanographic journals, books, and atlases. He has guided a number of students from various nations for Doctoral degrees, and several of them are engaged in cutting-edge research in Earth Sciences and allied subjects at leading institutions around the world.

Talwani has received numerous honours, accolades, and scholarships from North America, Europe, and Asia. In 1981, he won the American Geophysical Union's Maurice Ewing Medal. He became the only person to get two Maurice Ewing Medals when SEG awarded him another highest accolade, the Maurice Ewing Medal, in 2015.

Hans-Jürgen Götze, Director of the Institute of Geosciences, Christian-Albrechts-Universität zu Kiel, said that Talwani's scientific leadership had contributed greatly to our understanding of how oceans and continents evolve. He is most recognized for his studies of the Earth's crust and dynamics of continental margins and ocean basins, using multi-scale observations in the fields of geophysics, geology, oceanography, and geodesy. Paul L. Stoffa, Professor Emeritus at the Institute for Geophysics, University of Texas at Austin, said that

Manik Talwani was the first scientist to successfully acquire marine gravity data, despite numerous challenges. He was a proponent for ocean bottom seismic measurements years before digital technology would advance to the point that made these measurements possible. He also worked with others at Lamont to develop multiple seismic ship shooting techniques long before the industry adopted the practice as a routine acquisition method, thereby encouraging partnerships between industry and university researchers. Albert W. Bally, Petroleum Geologist, described Talwani as a '*world citizen*' considering his contributions to diverse areas at the Baker Institute and political think tank at Rice, right from the hydrocarbon potential of Central Asia to Mexico's Petroleum Industry. Talwani's lasting involvement in various geophysical and oceanographic challenges and his curiosity about addressing those challenges prompted Albert to call him a modern '*man for all seasons*'.

During his early career, Talwani developed computer algorithms to determine the causative sources of anomalous gravity and magnetic signatures. These were the first of their kind introduced in geophysics for modelling the Earth's interior. Both approaches have truly dominated geophysical research around the globe to date. All the more so, these codes for modelling the potential field data have been used as a foundation for writing subsequent programs for modelling gravity and magnetic data.

His most challenging mission was leading the Apollo 17 Traverse Gravity Team to take the first gravity readings on the Moon. In addition, he studied the topography and gravity field of the terrestrial planet Venus. Besides, he analysed satellite altimeter observations to describe the gravity field of the world's oceans and, in particular, discovered the presence of geoidal low in the northern Indian Ocean. His long career in studying the world's oceans and celestial bodies of the solar system shows his mammoth interest in carrying out frontier research of the 21st century.

Following the development of plate tectonics theory with the consideration of seafloor spreading, Earth's ancient magnetic fields of the rocks, differential motions of the Earth's top two physical layers, etc. Talwani added a new understanding to support the idea even more. He discovered a contributing source in a thin (~500 m) and

highly magnetized layer of the uppermost oceanic crust for the formation of seafloor spreading anomalies in the oceans. This concept has been well-received by the global earth science community and has been put into practice for calculating the synthetic magnetic model identifying seafloor spreading anomalies, thereby dating the ocean floor.

Talwani studied the magnetic and gravity signatures of rifted continental margins, particularly the Norwegian and South African margins, to delineate the boundary for the termination of attenuated continental rocks against the incipient ocean crustal rocks. The concept has been well received and put forth in an application for the demarcation of the boundary along the global passive margins. Finally, the boundary has developed into a useful tectonic constraint for lithospheric plate reconstructions, particularly the assembly of the continental masses. The studies on the Norwegian rifted continental margin led by Talwani and his team brought out another remarkable feature, 'Seaward Dipping Reflectors', consisting of a layered acoustic stratification in the upper oceanic crust adjacent to the margin. The identified feature has been used globally as a character for classifying the volcanically rifted continental margins.

It is commendable that Talwani has made significant contributions to our understanding of the evolution of important regions of the Indian Ocean. Lamont's field expedition to the Arabian Sea, led by him, brought out the comprehensive structural and tectonic framework of the region, besides mapping a sunken continental sliver called the Laxmi Ridge. The discovery of this continental sliver has far-reaching consequences for determining the limits of the continental shelf on India's western offshore region.

In order to offer the most plausible explanation for the tectonic origin of the Bay of Bengal and Bangladesh, Talwani followed a revolutionary approach of integrating diverse geophysical information from the regions of the East Antarctica margin, Bay of Bengal, and Bangladesh. Together with the Indian scholars, he delineated the rare presence of the Continent-Ocean Boundary underneath the landmass, which led to the reveal of the presence of oceanic crust beneath most of the Bangladesh landmass.

Talwani was an Indian at heart and loved to visit CSIR-National Institute of Oceanography (NIO), Goa, and other Indian institutions. During his numerous visits over the past few decades, he guided the marine geophysicists at NIO in data acquisition, analysis and interpretation. He was invited as an Adjunct Scientist to work with the Marine Geophysics team at CSIR-NIO for three years (2012–2015). His guidance and encouragement to scientists of the NIO during his tenure have advanced their scientific research beyond doubt. His publication 'The Tectonic origin of the Bay of Bengal and Bangladesh', co-authored with the scientists from NIO, has received overwhelming appreciation from people all around the world.

Talwani has significantly promoted and supported geophysical research in India. He is the Patron of the Indian Geophysical Union and has instituted the Anni Talwani Memorial Prize for the deserving scientist who has significantly contributed to geoscience research in India. Additionally, he has provided an Anni Talwani memorial travel grant for women researchers to attend the annual IGU conference. Coincidentally he was the first recipient of the IGU-Krishnan Medal in 1964 and was awarded the IGU-Hari Narain Lifetime Achievement

Award in geosciences in 2018. He was also designated a Foreign Fellow of the Geological Society of India in 2000.

Talwani, a pioneer in geosciences, contributed immensely towards the advancement of geosciences both in India and overseas. His innumerable accolades and publications attest to his outstanding work on everything from the deep oceans to celestial bodies. It is challenging to surpass his phenomenal achievements.

Talwani has left a huge void in the field of marine geophysics. We have lost an outstanding mentor, excellent guide and wise advisor to whom we could turn and talk about everything. The times we have spent together with him at the NIO and at other institutions in India, and at the AGU Fall Meetings will always be cherished. He will always be a source of inspiration not only to us but also to future generations of geoscientists.

On behalf of the Earth Science community of India, we wish to send our deepest condolences to the entire family of Talwani.

MARIA A. DESA<sup>1</sup>  
M. ISMAIEL<sup>2</sup>  
K. S. KRISHNA<sup>3,\*</sup>

<sup>1</sup>*CSIR-National Institute of Oceanography,  
Dona Paula,*

*Goa 403 004, India*

<sup>2</sup>*Department of Earth Sciences,  
Khalifa University of Science and Technology,*

*Abu Dhabi, 127788, UAE*

<sup>3</sup>*School of Sciences,  
GITAM (Deemed to be University),  
Rushikonda,*

*Visakhapatnam 530 045, India*

*\*e-mail: nio.krishna@gmail.com*