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The Emergence and Development of Geophysics in India: Contributions of Prof. Jagdeo Singh

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Abstract: **Geophysics as a science discipline has emerged through the application of Physics to Earth studies and kept on advancing with contributions from Newton, Gilbert, and later Wegener and Holmes, whose ideas on continental drift and mantle convection laid groundwork for plate tectonics. In India, early work focused mainly on geodetic and magnetic surveys, with systematic development beginning in the mid-19th century. Prof. K. S. Krishnan established theoretical foundations, while Prof. Jagdeo Singh, properly trained from Imperial College, London, pioneered geophysics education at Banaras Hindu University (BHU) and the Indian School of Mines (IIT-ISM), Dhanbad integrating teaching, research, and field training. Institutional growth through ONGC and NGRI further strengthened exploration geophysics, chiefly using gravity and magnetic methods, shaping modern geoscientific development in India.**

Index Terms: **Earth Science, Geophysics, India, BHU, ISM**

I. INTRODUCTION

Earth science encompasses interdisciplinary investigation of our dynamic earth which is 4.5 billion years old. It involves the study of geosphere, hydrosphere, atmosphere and biosphere. Proper understanding of natural processes such as geological evolution, plate tectonics and climate change becomes imperative in order to reveal its past, appreciate and comprehend its present and predict its future. The dynamic nature of our planet has made its understanding very challenging. It keeps on changing sometimes gradually and sometimes rapidly especially when severe storms, volcanic eruptions and landslides occur. Many earth scientists develop their understanding by taking field observations while others conduct focused experiments in the laboratory. Thus, observation and inference become important in science. This was realized earlier by Aristotle who believed in the analysis of 'deductive reasoning'. This works on generalized principles which is extended logically to new ideas (Neser, 2023). Nicolaus Steno (1638-1686) observed the sedimentary layers and initially proposed that surface of earth can change with time while James Hutton (1726-1797) studied the coast lines, rivers and the sedimentary rocks and subsequently proposed the principle of Uniformitarianism (Neser, 2023). This means that natural processes operate uniformly across space and time. Initially, the idea of uniformitarianism was not well received by others but ultimately it was widely accepted and the statement 'the present is the key to the past' became more popular among the geoscientists (Neser, 2013). Hutton believed more on field observations and presented correct method of understanding the earth's history and is also regarded as the founder of modern geology (Read, 1953). Hutton was first to demonstrate in the field that granite and basalts, the crystalline rocks form veins and dykes and intrude into the surrounding rocks and they have originated from the molten rock material by consolidation (Read, 1953).

II. EARLY HISTORY OF GEOPHYSICS

A. Global Scenario

Though the beginning of Geophysics as a subject in scientific discipline is closely related to the curiosity of early human beings to know about Earth, it grew with time through the application of physics to earth studies. Scholars in the ancient period tried to explain the natural phenomena such as volcanoes and earthquakes. During 17th century, Issac Newton came up with the law of gravitation which enabled us to understand gravitational field and mass of Earth. Subsequently, the work of William Gilbert made it possible to understand geomagnetism. John William Strutt made significant contributions in understanding Rayleigh scattering, Rayleigh-Jean's criterion and Rayleigh waves (Bercovici, 2007). Based on the field observations and by collecting the geographical evidences, Alfred Wegener, a German Meteorologist, conceptualized the idea of Continental Drift in 1912. He further believed that centrifugal force was driving this continent. Though, Arthur Holmes extended his support to the idea of Continental Drift but proposed a different theory. Along with Bull (1931) he believed that sub-solidus convection resulted into slow movement inside the mantle mainly due to heat generated from the radioactive elements inside the earth. Holmes

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further believed this mechanism to be responsible for continental break-up, formation of sea floor, continental drift and crustal accumulation at convergence zones (Holmes, 1931, 1933). He was of the opinion that mantle upwelling is responsible for the formation of sea floor but this was not accepted by others. Like Wegener's continental drift theory, Arthur Holmes convection theory could not get wide acceptance and was being ignored though he continued to teach his ideas for quite some time. Subsequently, Prof Harry Hess proposed the idea of sea floor spreading based on his observations and evidences collected by himself. He believed that oceanic crust diverges from linear ridges which was published in a paper (Hess, 1962). His paper was widely read and cited among the geoscience fraternity. Rapid progress continued in the field of Plate Tectonics and Mantle Convection Theory in 1960s and 1970s (Turcotte and Oxburgh, 1972; Oxburgh and Turcotte, 1978) and many fundamental problems on this issue were resolved thereafter.

B. Geophysics In India

Early geophysical investigations were confined to geodetic and magnetic surveys, with a prime focus on Earth's ellipticity and magnetism. Systematic documentation, however, began in 1856 by the Geological Survey of India though, the first geomagnetic laboratory was established earlier, in 1847, in Mumbai. Mineral exploration began in the 1920s, with the first geophysical survey for hydrocarbons starting in 1923 in the Indus Valley, utilizing torsion balance techniques. Burmah Oil Company conducted similar surveys, along with magnetic surveys, in the 1930s for mineral exploration. Thus, the systematic development of Geophysics in India involved several stages. Theoretical foundation was laid by Prof. K. S. Krishnan, a renowned Physicist, during 1920s- 1940s through his work in magnetism. He carried out experimentations to systematically measure magnetic anisotropy of dia- and paramagnetic crystals and correlated them with the anisotropy of individual molecules or ionic groups. Subsequently after independence, Prof, Jagdeo Singh (Fig 1) established geophysics education in Banaras Hindu University (BHU), Varanasi during late 1940s and in Indian School of Mines (now IIT-ISM), Dhanbad during 1950s focusing holistic growth and created trained personnel. Further developments were made when Oil & Natural Gas Corporation (ONGC) and National Geophysical Research Institute (NGRI) were established. Dr. Hari Narain joined ONGC in 1956 and was appointed as Director of Research and Training Institute of ONGC and was instrumental in creating Keshav Dev Malaviya Institute for Petroleum Exploration (KDMIPE) at Dehradun. He made further advancement in 1960s using gravity and magnetic methods for exploration of geo-resources. He initiated the preparation of gravity map of India, which helped to identify potential oil and mineral-bearing sub-surface structures. During 1960s he also promoted the use of proton precision magnetometers in aeromagnetic surveys which helped in understanding regional geology.

1. Beginning of Geophysics at Banaras Hindu University

The beginning of Geophysics at Banaras Hindu University can best be understood by examining the academic journey of **Jagdeo Singh** from Physics to Geophysics. Jagdeo Singh passed out his BSc in 1940 securing highest number of marks in Physics. In addition, he took an extra paper namely on 'Electricity' and passed in it obtaining more than 60% of marks and this, according to University regulations entitled him to write Honors after his BSc. He was also recipient of the University's 'Devasthale' prize for obtaining the highest percentage of marks in Physics. Subsequently, he passed out MSc in Physics in 1942 and obtained first class and topped the list of successful candidates. For his MSc thesis he worked on 'emission spectra in discharge tube' under the direction of Prof. R. K. Asundi. He published two notes on his work, one in **'Nature'** and another in **'Current Science'** (Asundi et al., 1942; Singh, 1945).

Prof. B. Dasannacharya, the then Head of the department of Physics had all praise for Jagdeo Singh and he considered him as a very diligent and hard-working student of the department. In a testimonial, Prof. S. S. Joshi, University Professor of Chemistry and Principal of College of Science, wrote that "particularly during the period of Jagdeo Singh's work in MSc, I had numerous occasions to come into contact with him and can therefore, bear testimony from personal knowledge to his great devotion to his subject and capacity for sustained hard work. I share fully the high opinion of his Professors about Jagdeo Singh both as a man and as a brilliant student of Physics. He is certainly one of the very best products of this university". In a personal discussion, once he revealed that as a student of Physics, he was highly curious and eager to understand everything in depth and frequently used to ask numerous questions in class. While the teachers answered his queries, his persistent questioning occasionally caused annoyance to some teachers.

Before joining BHU in 1947, Jagdeo Singh held several brief positions. At the Indian Meteorological Department (1942–1943), he gained extensive training in meteorology. Subsequently, shifted to an academic career, with lectureships at U.P. College, Varanasi, and Balwant Rajput College, Agra. In 1947 Jagdeo Singh got appointed as Lecturer in 'College of Agriculture', BHU where he was teaching Physics and Mathematics. During the same period, he also started research in Spectroscopy in the Department of Physics, BHU under Prof. R. K. Asundi (Singh, 1947, 1950a-b). Prof. S. N. Thakur (Ex Prof of Experimental Spectroscopy, BHU) on occasion of 75 years of Spectroscopy in the Conference Proceeding writes that "by the late 1940s, the Intermediate Science classes were shifted to Central Hindu College at Kamachha and the then Vice-chancellor Pt. Govind Malviya, impressed by the research atmosphere of spectroscopy laboratory, permitted the vacant space to be occupied by Prof. R. K. Asundi and his group. The students of spectroscopy laboratory by this time included some of the very bright ones like Jagdeo Singh, D. D. Pant, D. P. Misra, Lalji Lal, P. Venkateswarlu, R. M. Singh, M. R. Padhye, K. S. Adiga and N. A. Narasimham, who brought much glory in the later years. The brilliant spectroscopy students from BHU joined several major universities and laboratories across the country and excelled in their teaching and research. Prof. Jagdeo Singh and Prof. Devi Dutt Pant were from the first batch of spectroscopy at BHU" (Thakur, 2015).

Pandit Govind Malviya, son of BHU founder Mahamana Pandit Madan Mohan Malviya, served the university as Vice-Chancellor during 1948-51. He was instrumental in starting Geophysics as a

science subject in BHU at a time when geophysics was still emerging as a distinct discipline in the West especially in United Kingdom and Germany. At his initiative in 1949, Department of Geophysics was started and Jagdeo Singh was invited to teach different branches of geophysics. The venue of Geophysics department was provided in the department of Geology. Prof Rajnath, who was Head of the department of Geology, was also given the charge of Geophysics. Thus, Jagdeo Singh became the first teacher of Geophysics and he initially handled all Geophysics courses. In 1950, Jagdeo Singh was shifted from 'College of Agriculture' to 'College of Science' as

In 1951 at the initiative of Pandit Govind Malviya, 'Holkar Fellowship' was awarded to Jagdeo Singh that enabled him to pursue advanced research in Geophysics at Imperial College, London. At Imperial College, Jagdeo Singh commenced his research under the guidance of Prof. J. McG Bruckshaw, an eminent figure in the field of Geophysics. Before commencing his PhD research, he was required to complete the Diploma of Imperial College of Science and Technology (DIC) which he successfully obtained in 1952. During his PhD at Imperial College, he worked on the topic *'An investigation into the Process of Magnetization of some rocks'* which he completed in 1954. His experimental results proved valuable in differentiating between

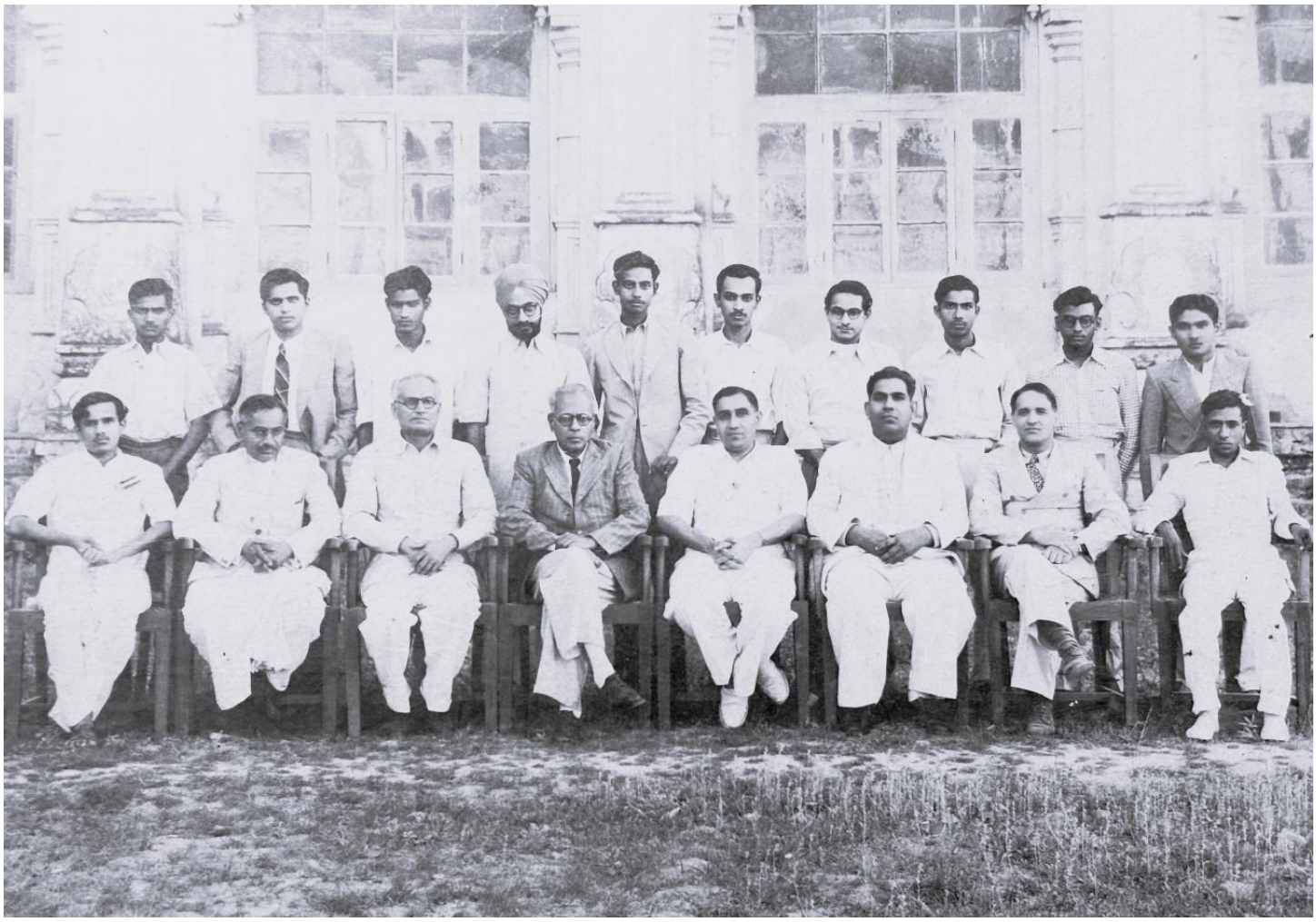

Fig. 1. M. Sc. first batch students (Standing) of Department of Geophysics, Banaras Hindu University (1949-1951). Chairs (L-R): Prof. V. L. N. Sharma, Prof. V. C. Ghosh, Dr. S. S. Joshi (Principal), Dr. P. Parija (Pro VC), Dr. S. Mull (Director I. M. D. Cal), Dr. Raj Nath (Head, Department of Geology & Geophysics), Prof. S. S. Gairola, **Dr. Jagdeo Singh.**

Lecturer in Geophysics. He was the first faculty member of Geophysics department. Fig 1 shows the first batch students (1949-1951) of Geophysics in Banaras Hindu University.

two theories proposed to account for the inverse magnetization of rocks. Through personal interactions with him, I learned that he had a strong inclination towards designing instruments and keen interest in understanding their underlying mechanisms. His supervisor at the Imperial college, Prof. J. McG Bruckshaw encouraged this and gave him considerable freedom and appreciated his experimental capabilities. As a result, he designed much of his experimental apparatus and even constructed some of it himself for his PhD research work. He not only enjoyed this freedom and the work culture at Imperial College but by making some instrument himself and seeing it work gave him complete satisfaction.

Fig. 2. Jagdeo Singh captured on a stroll: (a) at Trafalgar Square (extreme left) along with his colleagues, and (b) south toward Whitehall from Trafalgar Square, London during his PhD (1951-1954)

A candid glimpse into his life beyond the PhD at Imperial College is seen in Fig 2 a-b**.** This period really served as foundation for his future career. This is reflected in some of his research publications (Singh and Rao, 1958, 1964, 1970; Singh, 1958a, 1962,1970a-b). In 1954 he returned back to BHU and resumed his service in Geophysics department. During one of our discussions, he mentioned that he had been involved in the fundamental design of a gravimeter. Elements of some of his ideas were reflected in his earlier studies (Singh and Gaur, 1955-56; Singh, 1958b).

Fig. 3. Indian School of Mines, Dhanbad, 1957-58 (Teachers Association). This year Geophysics was established in ISM. Chairs (L-R): N.V.R. Subramanyam, J.N. Chakravorty, N. Srinivasan, Dr. S. Mitra, K.S. Singh, Prof. H. N. Dasgupta, Prof. N.L. Sharma, P.L. Ballaney, Dr. M.S. Krishnan (Director), Prof. R.S. Batni, R. Naganathan, Prof. D.N. Prasad, Prof. M.S. Pai, Dr. J. Dhar, Dr. K.K. Mazumdar, **Dr. Jagdeo Singh,** S.N. Mitra, G.B. Misra, K.S. Vijayalakshmi.

2. Beginning of Geophysics at Indian School of Mines (IIT-ISM), Dhanbad

The history of Geophysics in ISM began in the middle of 20th century with the establishment of department of Geophysics in 1957 (Fig 3). It so happened that in 1956 Jagdeo Singh left Banaras Hindu University and joined ONGC as Senior Geophysicist. But after eight months, he decided to leave his geophysicist role, as it did not meet his expectations and joined Indian School of Mines in 1957. This year was globally celebrated as 'International Geophysical Year (IGY). Prof. Jagdeo Singh is credited as the founder of this department who served as the first Head of the Department of Applied Geophysics in ISM. The inception of this department was in response to explore the vast mineral resources of the country especially hydrocarbons as there was growing need for expertise in geophysics. He built the geophysics department into a powerhouse and established it as the first and premier department of its kind in the country. He is therefore regarded as the principal architect of Applied Geophysics in India **(Fig 4)**. He merged the classical Geology with Physics and Mathematics and designed the academic framework of the department. Under his leadership pioneering research work in gravity, seismic, magnetic and other geophysical methods started in the department in lines with the national requirement. He did not believe in 'armchair geophysics' but his 'Field-First Approach' made him more popular as he believed that a geophysicist cannot be made in a classroom but through field experience in the rugged terrain.

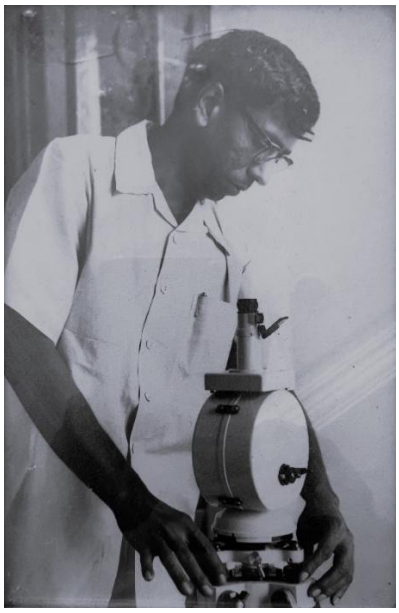

Fig. 4. Jagdeo Singh while at work

Prof Jagdeo Singh once shared in a personal discussion that he used to take all the 29 theory classes in a week. Moreover, he had developed a habit of conducting 180 mts of theory sessions at a time, a practice that continued for decades. While most of the students were fully consumed by the class and none complained ever. In turn, he earned high respect from his students. He had excellent command in all the branches of Geophysics be it a part of General Geophysics or one in Exploration Geophysics and even in Meteorology. His student and former Director, NGRI, Prof. V. P. Dimri, while delivering a lecture on 'Monsoon course changed Uttarakhand' in June 2024 once said "I learnt about cloudburst when I was a student doing masters' degree in Geophysics. Our teacher late Professor Jagdeo Singh, Ph. D. from United Kingdom, taught us basics of Meteorology, different types of clouds, cloudburst, Indian Monsoon etc". Although many of his students subsequently attained high-ranking positions, he frequently spoke of a select few. I would like to highlight two of them here: one from BHU, Varanasi, and the other from ISM, Dhanbad. When Dr Jagdeo Singh was returning from Imperial College, London, after completing his PhD, his supervisor, Prof. J. McG. Bruckshaw, impressed by his work, sought his recommendation for a candidate of comparable caliber to join his research group. He subsequently recommended one of his most brilliant students, Shri Vinod Kumar Gaur from BHU (Fig 5), who passed out his M.Sc in 1955 and went to Imperial College and completed his PhD under Prof. Bruckshaw. Later, Prof. V.K. Gaur joined the University of Roorkee (now IIT Roorkee) in 1961, before moving to NGRI, Hyderabad, as Director in 1983. After serving NGRI for six years, he was appointed by the Government of India as the Secretary to the Department of Ocean Development (MoES, Ministry of Earth Sciences). He held this position until 1992, then moved to the CSIR-Centre for Mathematical Modelling and Computer Simulation (CMMACS) as a Distinguished Professor, where he served until 1996. Following his superannuation in 1996, he has continued his work as a CSIR Honorary Emeritus Scientist. His career is distinguished by numerous honors, most notably the Shanti Swarup Bhatnagar Award.

Fig. 5. Prof. Vinod K Gaur

Prof. Jagdeo Singh frequently spoke of another brilliant student, Shri. Harsh Kumar Gupta (Fig 6), whom he taught at ISM, Dhanbad. He passed out his MSc in 1963 from ISM. After earning his doctorate from IIT Roorkee, he received a UNESCO fellowship to study at the Institute of Seismology and Earthquake Engineering in Tokyo, subsequently moving to the University of Texas at Dallas until 1977. Dr Gupta then served as Director of the Centre for Earth Science Studies in Thiruvananthapuram until 1987. Following his tenure as Vice-Chancellor of Cochin University of Science and Technology (CUSAT) until 1990, he was appointed Advisor to the Department of Science and Technology for two years. He later led NGRI, Hyderabad, as Director for nine years before being appointed Secretary of the Department of Ocean Development by the Government of India. Since his superannuation in 2005, he has continued to serve in various prestigious capacities, including as a member of the National Disaster Management Authority (NDMA) from 2011 to 2014, and as President of several scientific bodies such as the International Union of Geodesy and Geophysics (IUGG), the Asia Oceania Geosciences Society, and the Geological Society of India. Globally he is known for his scientific insight in the field of reservoir triggered seismicity. A recipient of the prestigious Padma Shri and Shanti Swarup Bhatnagar Award, Prof. Gupta has earned high honours and has enjoyed a remarkably decorated career.

Fig. 6. Prof. Harsh K Gupta

Through his teaching, research, and institutional efforts, Jagdeo Singh played a key role in establishing and advancing Geophysics during its formative years in India. He believed in developing a strong foundation in experimental and theoretical methods. To honor him, the department of Applied Geophysics, Indian School of Mines, Dhanbad has started 'Prof. Jagdeo Singh Memorial Lecture Series' which is held annually. The department has also dedicated one 'prof. Jagdeo Singh Memorial Hall' in his name which is meant for significant academic and memorial events. The Indian Geophysical Union (IGU) which is an apex body of geoscientists in the country maintains 'Prof. Jagdeo Singh Memorial Grant'. This grant is annually awarded to the university toppers in Geophysics across India. The Geological Society of India offers 'Jagdeo Singh Award', which was instituted by his student, Prof. B. N. P. Agrawal. Fig 7 shows the Photograph of Prof. Jagdeo Singh taken at the time of his retirement.

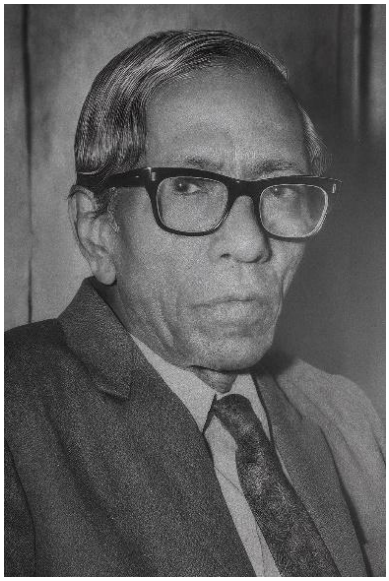

Fig. 7. Professor Jagdeo Singh

3. Other institution of Geophysics in the country

Andhra University, Visakhapatnam: The Department of Geophysics at Andhra University, Visakhapatnam (Waltair), as per the website, was established in 1949 with the idea of imparting training in Meteorology, Oceanography, and Physics of the Earth. Successive Vice-Chancellors aimed to introduce new courses to train manpower for national requirements. The website notes that Banaras Hindu University holds the distinction of starting the first full-fledged MSc course in Geophysics in the country. The department in Visakhapatnam was initially established by retired India Meteorological Department Directors Dr. N. K. Sur and Dr. S. R. Savier. In 1962, the department was bifurcated into the Department of Geophysics and the Department of Meteorology and Oceanography. Subsequently, Prof. B.S. Rao, trained at Imperial College, London, was appointed Head of the Department of Geophysics in 1962.

IIT Kharagpur: The Department of Geology and Geophysics in IIT Kharagpur began in 1952. It grew to include practical geology and geophysical exploration. The department achieved major successes by teaming up with groups such as ONGC, GSI, OIL, UCIL, and DAE.

Osmania University, Hyderabad: Geophysics education at Osmania University, Hyderabad began in 1963. This led to the launch of the MSc (Tech) course in 1965 and creation of an independent department in 1967. In 1969, the Centre of Exploration Geophysics was established as an advanced research centre under an Indo-Soviet agreement.

IIT, Roorkee: The Department of Earth Sciences, formerly the Department of Geology and Geophysics, at IIT, Roorkee was established in 1960. This renowned center offers a top-tier M.Tech. in Geophysical Technology backed by six decades of expertise in research and consultancy.

IIT Bombay: Established in 1982 from a 1964 geology section, the Department of Earth Sciences at IIT Bombay offers postgraduate and doctoral programmes. It specializes mainly in Applied Geology, Applied Geophysics, Geo-exploration, and Petroleum Geoscience.

Kurukshetra University: Department of Geophysics at Kurukshetra University offers a 3-year Master's in Applied Geophysics since 1985. This specialized program trains students in geophysical techniques, supported by experienced faculty and research projects.

University of Kerala: The Department of Geology at the University of Kerala (Thiruvananthapuram) was started in 1963**.** In the early 1980s, attempts were made to add an Applied Geophysics course to the Geology Department but it did not immediately result in a separate department. Unlike institutions with general geophysics departments, it focuses mainly on Geology and Environmental Science, though also specializes in geochemistry, paleomagnetism, and environmental magnetism.

Cochin University of Science and Technology: The Department of Marine Geology and Geophysics at Cochin University of Science and Technology (CUSAT), was established as a division in 1976 and as a full-fledged department in 1996. It is one of the premier Indian institutions for ocean research. It excels by combining geology and geophysics studies. By the launch of the Marine Geophysics course in 1992, it got more strengthened offering specialized education and research.

Besides, a number of key research laboratories exist in India where advanced geophysical research is carried out. Some of these include, CSIR-National Geophysical Research Institute (NGRI), Hyderabad; Borehole Geophysics Research Laboratory (BGRL), Karad (Maharashtra); Indian Institute of Geomagnetism (IIG), Navi Mumbai; North-East Geophysical Research Laboratory (NEGRL), Shillong; Equatorial Geophysical Research Laboratory (EGRL), Tirunelveli; Dr. K.S. Krishnan Geomagnetic Research Laboratory (KSKGRL), Prayagraj; National Centre for Earth Science Studies (NCESS), Thiruvananthapuram; Wadia Institute of Himalayan Geology (WIHG), Dehradun; CSIR-National Institute of Oceanography (NIO), Goa; CSIR-Fourth Paradigm Institute (CSIR-4PI), Bengaluru and many others.

III. CONCLUSIONS

The scientific understanding of Earth Science evolved through early deductive reasoning, proposed by Aristotle. The contributions made by Nicolaus Steno and James Hutton laid down early foundation and established key principles such as stratigraphy and uniformitarianism, emphasizing that present processes provide insights into the past. Geophysics emerged as a science discipline through the application of physics to Earth studies. Significant contributions were made by Isaac Newton in gravitation and William Gilbert in geomagnetism. Subsequent developments came from Alfred Wegener, Arthur Holmes, and Harry Hess leading to the formulation of continental drift, mantle convection, and seafloor spreading. Eventually came the theory of plate tectonics.

In India, geophysics developed as a result of systematic surveys and institutional efforts. Early work focused on geodetic and magnetic studies, with major progress beginning in the 20th century. Dr. K. S. Krishnan laid the early theoretical foundation through his work in geomagnetism, while Prof. Jagdeo Singh pioneered geophysics education initially at Banaras Hindu University and then at Indian School of Mines. He integrated physics, mathematics, and geology and laid a strong impetus on field-based learning. He played a crucial role in training skilled geophysicists. The establishment of institutions such as Oil and Natural Gas Corporation and National Geophysical Research Institute further strengthened Applied Geophysics, particularly in resource exploration using gravity and magnetic methods. Overall, the development of geophysics in India reflects a combination of strong theoretical foundations, visionary leadership, and institutional growth. It has evolved in response to national needs for resource exploration and scientific advancement, and continues to progress with advancements in technology and interdisciplinary research.

ACKNOWLEDGEMENT

The author would like to thank his daughter, Anjali, for her enduring curiosity to know more and more about her grandfather, Prof. Jagdeo Singh. Her deep interest in his legacy and her desire to understand his scientific temperament, his approach to experimentation, and his style of education, has been the inspiration behind this article.

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