Introduction to this special section: India

This special section about India is of special relevance because providing affordable energy is a key requirement for economic development in our nation. Rapid urbanization and industrialization after India's independence led to a multifold increase in petroleum consumption and the demand for petroleum products continues to grow with no sign of abatement. Presently, India produces about 820 000 barrels of crude oil per day but consumes about 2 560 000 barrels per day. This means that India can produce only 30% of the petroleum products that it consumes. Similarly, gas production is about 29.4 billion m^3 per day and we consume about 32.1 billion m^3 per day, a total which is expected to increase many times. This indicates that there is a huge gap between the indigenous production and demand which is likely to increase in the years to come.

Figure 1. *Sedimentary basins of India.*

To reduce dependence on imports, India must adopt and develop energy-efficient technologies and enhance oil and gas production from its 26 sedimentary basins which cover an area of about 3.14 million km^2. This includes 1.34 million km^2 on land and 1.8 million km^2 offshore (Figure 1). Only seven basins have been extensively explored. The others are either unexplored or lightly explored due to logistics and/or geologic complexity. To intensify E&P activity, the government of India has proposed a program to stimulate exploration in frontier and already-producing basins and for unconventional hydrocarbon resources. Recent discoveries of giant deepwater oil and gas fields around the world have shifted the focus toward the vast unexplored deepwater sediments of the Arabian Sea and Bay of Bengal, proximal to the Indian coasts. India has made a strong commitment to deepwater exploration with the New Exploration Licensing Policy (NELP), which should stimulate geophysical investigations of the 1.3 million km^2 of unexplored sedimentary areas on both coasts beneath water depths of 400 m.

These E&P aspects prompted the timely decision of the *TLE* Editorial Board to publish this special section on India in close association with the Society of Petroleum Geophysicists, India. The nine papers cover a wide array of topics which include geologic perspectives of the basins (evolution and petroleum potential), specific case studies pertaining to thrust belt and sub-basalt imaging with emphasis on high-quality seismic data acquisition and processing, structural and stratigraphic interpretation, and reservoir characterization using advanced state-of-the-art tools in an integrated way.

Bastia ("An overview of Indian sedimentary basins with special focus on emerging east coast deepwater frontiers") presents a comprehensive review of the current Indian petroleum exploration scenario, with a focus on deepwater basins along the east coast. Making use of 2D as well as 3D seismic imaging information, the author discusses the different hydrocarbon systems and play types for both rift-related and structural styles and talks about geophysical challenges that they present. Seismic signatures reveal younger clastic depositional environments ranging from sinuous channels, overbank, levee, basin floor fan to turbidite fan complexes overlying the older rift-related fluvial-to-near-shore environment below.

Gupta ("Basin architecture and petroleum system of Krishna Godavari Basin, east coast of India") discusses the basin's evolution from Permian to the present. Clastic reservoirs are from the Permian, Cretaceous, Eocene, Miocene, and Pliestocene. Both structural and stratigraphic traps are common in these systems.

Bastia and Nayak ("Tectonostratigraphy and depositional patterns in Krishna Offshore Basin, Bay of Bengal") describe the basinal sedimentation in the southwest offshore part of Krishna Delta. Using log data and stratal amplitudes, the authors discern depositional patterns in the present stratigraphic sequence.

Kumar et al. ("Growth of 3D seismic technology in India") discuss advances in seismic acquisition, processing, and interpretation from an ONGC perspective. The authors believe that the coming years will see greater application of 3D seismic technology in India, together with a focus on seismic imaging, reservoir characterization, and integration of different disciplines.

Avadhani et al. ("Acoustic impedance as lithological and hydrocarbon indicator—a case study from Cauvery Basin, India") use plots of acoustic impedance and appropriate reservoir parameters to identify zones associated with different clusters of indicators. After obtaining a good correlation between the derived average impedance corresponding to stratigraphic/sand units and their log-derived impedance, an effective sand thickness map is prepared. Also, making use of the relationship between porosity and acoustic impedance, porosity maps are prepared for the formations of interest. These maps and impedance data are then used to predict sand/shale-prone areas and the possibility of hydrocarbon occurrence.

Habeebuddin and Pandey ("Advanced static solution for relating outcrop and subcrop geology: A key to exploration in Himalayan thrust belt") discuss the application of wave-equation datuming in statics correction for a seismic profile from a structurally complex area. This enhanced image quality and facilitated interpretation via a better correlation with surface geology and mapping of prospective subthrust structures.

Recently, a team of young geoscientists took a field trip to study the subsurface outcrops in mines in the southern-most tectonic block of Cambay Basin. "Outcrop study in south Cambay Basin, India—an overview" by Mahanti et al. summarizes the characteristic depositional environment of the formations.

The paper by Negi et al. ("Fusing geologic knowledge and seismic in searching for subtle hydrocarbon traps in India's Cambay Basin") lists some success stories of hydrocarbon finds/discoveries in the structural lows due to integration of geologic knowledge and seismic technology. This approach identified a prospective area in the Ahmedabad block of Cambay Basin, which is hoped will open up exploration opportunities in a new unconventional gas system.

The Mesozoic sediments in the western onshore part of India are prospective but offer challenges for exploration. Satpal et al. ("Integrated interpretation for sub-basalt imaging in Saurashtra Basin, India") present the results of an integrated approach to modeling and interpretation of data from diverse geophysical imaging methods to come up with reliable estimates of Mesozoic sediment thickness, trap thickness, and the mapping of the basement.

The large number of technical papers covering a wide variety of technical interests submitted to this special section strongly reflects the extensive E&P activities carried out using advanced geophysical technologies in different sedimentary basins of India. We hope that the papers will be educational, interesting, and useful to those geoscientists who want to understand Indian sedimentary basins and their hydrocarbon potential. We encourage you to increase your knowledge of this promising region by writing to the authors directly. TLE

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This month *TLE* features a special section that focuses on India—a land both enchanting and vibrant. India has a huge reservoir of skilled technical manpower, research capabilities, extensive infrastructure, and experience in the oil sector. This has helped the country produce more than half a billion tons of crude oil to date. India has more than 1.79 million km^2 of sedimentary basins onland and offshore up to 200-m bathymetry, and 1.35 million km^2 beyond the 200-m bathymetry in deep waters. This offers a vast scope for higher production of hydrocarbons. The oil and gas industry, estimated to be worth US$90 billion, is among the largest contributors to the central and state exchequers in India with a share of about 15%.

Although India is the home of a little more than 15% of the world's population, it is responsible for only 3% of world oil consumption (in contrast to China with 7.6%), but that still ranks among the top 10 oil-consuming countries in the world. However, India's energy consumption is rapidly increasing. Oil and gas represent more than 40% of the total energy consumption in India, and demand far exceeds domestic supply. India imports 70% of its oil, mostly from the Middle East, and with an economy that has recently grown at 8% per year, this figure should rise beyond the $21 billion a year that India spends on oil imports, unless domestic production is enhanced.

India's oil reserves are relatively low, 5.9 billion barrels which is just 0.5% of global reserves. Most reserves are in fields offshore Bombay and onshore in the provinces of Gujarat and Assam. When India gained independence (1947), domestic oil production was around 250 000 tons, and all came from only one province, Assam. There was not much expectation for domestic oil production as the foreign experts of the time had written off the country, as far as the discovery of hydrocarbons was concerned. By the middle of the 1950s, the two national oil companies, Oil and Natural Gas Commission (ONGC) and Oil India Ltd. (OIL), began exploring for oil and gas in the country. The modern oil saga in India started in 1957 with the first well drilled at Jwalamukhi which discovered noncommercial quantities of hydrocarbons. Oil was discovered in Cambay later that year. The 1960s discoveries of Rudrasagar Field in Assam (1960–61) and Ankleshwar and Sanand in Gujarat (1960 and 1962, respectively) provided the initial thrust for more active exploration in the 1970s in the country's six producing sedimentary basins and in potential basins (e.g., Bengal, Ganges valley, Mahanadi, Kerala-Konkan, Kutch, and Andaman). Production peaked in the 1980s when the supply reached more than 70% of the domestic requirement, and a number of fields were discovered. Examples are Heera, Panna, Mukta, Tapti in the western offshore, Gandhar onland west India, and Geleki and Lakwa fields in the northeast. However, since the late 1980s, domestic production has declined, the main setbacks being reduced yields from the two big fields (Bombay High and Neelam) off the country's west coast.

Since then, the Indian government has attempted to enlarge the risk capital available for exploration and development of the existing and newly discovered fields via private and multinational companies. This was a necessary step to help stem the decline and bridge the increasing gap between demand and supply for energy resources. This was done by making different exploration blocks in the country available under the so-called New Exploration Licensing Policy (NELP), which ended the monopoly held by the two national oil companies for decades. To date, six rounds of NELP and three rounds of coal-bed methane (CBM) have been announced. Under these bidding rounds many exploration and development contracts have been signed with different companies.

Reliance Industries, the country's largest private sector energy group, announced a gas discovery in Krishna-Godavari Basin, offshore the east coast, in 2002, which was the largest in the world in that year. Such Indian companies as HOEC, GSPCL, Hardy, Essar, Phoenix, Jubilant Enpro, BPCL, HPCL, IOC, and overseas companies such as Cairn Energy, British Gas, Premier Oil, and Tullow Oil (United Kingdom), Niko Resources, Canoro, and Geoglobal Resources (Canada), OAO Gazprom (Russia), and Mosabacher and Oakland (USA) are operating in India, and some have made significant finds.

Within ONGC, steps have been taken to upgrade technology for seismic exploration, exploration in deepwater, Mesozoic prospects in Kutch, and frontier basins, and for unconventional sources of energy such as coal-bed methane and gas hydrates. The government is also encouraging renewable energy sources (e.g., ethanol from sugar cane, as is being done in Brazil, and biodiesel extracted from trees commonly found in many parts of the country). In addition, India is gradually emerging as a growing market for solar, wind, nuclear, and hydroelectric power.

ONGC, through its overseas arm, ONGC Videsh Ltd. (OVL), has acquired stakes in existing oilfields and secured future rights in other countries. India has invested $750 million in Sudan, reached a deal with Nigeria to purchase 44 million barrels of crude oil per year on a long-term basis, and finalized a contract in Syria for exploration, development, and production of petroleum. Similar investments have been made in Sakhalin (Russia), Vietnam, Iran, Iraq, and Myanmar, which are/could be suppliers to the Indian market. Efforts are now under way to become active in the Caspian Basin.

I hope *TLE*'s readers will find this section informative and that it will arouse interest among companies considering India as a petroleum target. TLE

—*Satinder Chopra*
TLE *Editorial Board member*

A final note: Although not a part of this special section, the GAC Spotlight in this issue of *TLE* also contains several items which confirm the statement at the beginning of this introduction about the skilled personnel and superlative geophysical educational institutions in India.