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# The oil exploration in India and the discovery of the Anklesvar oil field

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Oil seepages were known to be present in India already in the nineteenth century. They led to the very early discovery of oil in Assam (Digboy) and in what is now known as the Potwar oil fields located in Western Pakistan. Although geologically the subsoil of India appears suitable for finding oil, the exploration of this sub-continent was rather neglected up to the independence. The reason of this neglect may be traced perhaps to the relative vicinity of the prolific Iranian oil-fields as well as to the proximity of the oil-fields of Burmah and Indonesia.

As a developing country, India needs as much as possible its foreign exchange for acquiring capital goods manufactured in the industrialized nations. Importing oil or oil products is a drain on foreign exchange which is estimated to attain 5000 million rupees for the year 1975. Consequently, the Government of India has undertaken to search for oil and, chronologically the following steps were taken:

In 1945, a post of Petroleum Geologist was created in the Geological Survey of India and sometime later, the Ministry of Natural Resources and Scientific Research realized that a separate Petroleum Exploration Division should be established. As a consequence of these measures, gravity surveys were performed in Rajasthan (ancient Rajputana) and in the Cambay area already since 1949. The Petroleum Geologist of the Geological Survey of India executed detailed mapping and reconnaissance surveys from 1947 to 1955 in the foot-hills of Punjab and Himachal Pradesh as well as in other parts of the country. In 1955, the Government of India established an organization for oil exploration (Oil and Natural Gas Commission) under the leadership of Mr. A. M. N. Ghosh [2]), former Superintending Geologist of the Geological Survey of India and under the chairmanship of Mr. K. D. Malaviya, now Minister for Mines

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[2]) In Calcutta, on the 2nd of January 1961, Mr. A. M. N. Ghosh, to whose energy and organizational ability the Oil and Natural Gas Commission owes its existence as a large and successful body, suddenly left for his heavenly abode.

and Oils. This Commission sought for the advice of American, German, Swiss and Russian oil exploration specialists. The reports submitted were all favouring the exploration of the Indian sub-continent and more or less for the same areas. However, the Russian experts report furnished also a plan phasing and linking various exploration operations as well as targets.

These reports were available for establishing the Second Five Year Plan (ending 31st March, 1961). In 1956, the Oil and Natural Gas Commission started recruiting a large number of personnel and from August 1956 to February 1957 practical and theoretical training was imparted at Dehradun and in the mountains surrounding Dehradun. During the same period the Palynological, Palaeontological, Chemical and Petrological Laboratories as well as a Geophysical Workshop were established. In October 1959, the Oil and Natural Gas Commission was accorded the status of a Statutory Body by an act of the Indian Parliament. This measure is intended to provide greater flexibility for the complex operations of an oil exploration organization. The strength of the Oil and Natural Gas Commission at the end of 1960 is of 2500 employees (technical and non-technical) with the result that in October 1960, 18 geological parties, 10 gravity-cum-magnetic parties, 12 seismic parties were sent in the field, and presently 3 deep rigs (15,000 feet) one 10,000 feet rig, 6 medium rigs and 4 slim hole rigs are under operation. The wildcat activity is located in the foot-hills of Punjab and in Assam whereas wildcat, step out and development activities are recorded in the Cambay basin.

Proceeding anti-clockwise and starting from southern India, we can quote the following exploration activities:

On the south-western coast, gravity-cum-magnetic survey as well as the surface geology of the *Malabar Coastal Basin,* on the eastern coast the *Coromandel coastal basin* is being investigated by surface geology. The gravity-cum-magnetic survey has already been performed and the seismic exploration has started. As the Cretaceous and Eocene sequences are marine, hydro-carbon accumulations are possible.

The western part of the *Bengal basin* located between the Arakan chain on the east and the north-eastern corner of the Deccan shield on the west, has been the object on Indian territory of an extensive exploration by Stanvac. Eight wells were drilled unfortunately without results. In the Andaman islands, where mud volcanoes are recorded, the geological exploration is on its way.

In *Assam,* the exploration is intended to test structures in a trend south-west of the developed fields of Moran and Nahorkatiya and the objective is the producing Barrail formation, as in Moran and Nahorkatiya, with an eye open to the possibilities of the Eocene.

During tests performed during the first days of January 1961, the second wildcat in Assam (Rudrasagar No. 1) of the Oil and Natural Gas Commission was likely to be completed as a producer from a depth of 3100 metres.

The exploration of the *Indo-Gangetic plains,* which extends over 1500 kilometers length and a varying width of around 150 kilometers, is of course, an important affair to tackle with. In 1956, an air-borne magnetometer survey was performed and in 1960 about half of the basin had been surveyed by ground gravity-cum-magnetic parties. In addition several seismic profiles were executed. The exploration of such a basin is not an easy undertaking and will require a lot of time. It appears natural first to concentrate in the north-western segments and in the eastern segments of this basin, as the first segment is near to the Potwar basin and the second segment being near the Bengal basin a gulf filled with suitable sediments could be present as an appendix of this basin.

The reasons for the exploration in the *Himalayan foot-hills* were that some weak gas seepages were known, one of them, howewer, was big enough to have permitted the erection of the small Jawalamukhi (flame's mouth) temple over it and the proximity of the Potwar oil-fields as well as the theoretical considerations that oil can be found in foot-hills between a mountain range and a shelf. The foot-hills extend from the Nepalese frontier to the eastern boundary of West Pakistan in Jammu. The surface formations exposed are the famous Siwaliks which are divided into three groups: Lower, Middle and Upper. The structure of the foot-hills appear to be simple when examined superficially. Howewer,detailed mapping has revealed major strike faults as well as over-thrusts. It appears that these thrusts are usually epiglyptic thrusts, that means that the thrusts masses have been travelling over a previously folded and eroded topography. This particular type of tectonic renders the drawing of the structure at depth quite difficult and therefore, since 1959, seismic is being applied to the structural deciphering of the foot-hills. However, still a great amount of work and thinking will be necessary before a correct understanding of these structures at depths is gained. A well (Hoshiarpur No. 1) intended as a stratigraphic test to gather information regarding the thickness and facies of the sediments on the shelf area could, unfortunately for mechanical reasons, not be drilled to the objective depth.

A well is now being drilled right on the first fold of the foot-hills of Punjab on the Janauri anticline with a 4500 metres capacity rig. Janauri is a structure of tremendous size (80 km length). Howewer, the exposed formation on the surface is Upper Siwalik and, therefore, the depths of the objective is situated very deep, around 4,000 metres, and it will be a good luck if the oil possibilities of that structure were proven by the first well. Further mountainwards, the exploration which had been carried on by the Petroleum Section of the Geological Survey of India from 1947 to 1955 had chosen and recommended the drilling of the Jawalamukhi «strukture». This recommendation was based on an entirely justifiable tectonic view of the area at that time. Howewer, the basic assumptions for the choice of this area were neglected or misunderstood at the time of selecting the first location and the well was drilled near the edge of a thrustsheet. However, being drilled in the neighbourhood of the gas show of the Jawalamukhi temple, this wildcat met some gas at shallow depth.

Abandoning the Punjab plains and going southwards towards Rajasthan (ancient Rajputana) one crosses the axis of a, for a long time supposed, basement ridge called Delhi-Lahore ridge. The geophysical exploration performed during these last years have proven the existence of that ridge which will be better, from now on, called an arch separating the north-western plains of India into two basins, the Punjab basin on the north and the Rajasthan basin on the south.

The exploration of *western Rajasthan* was started already by geophysical parties of the Geological Survey of India prior to the creation of the Oil and Natural Gas Commission and was continued by the Oil and Natural Gas Commission during these last years. Western Rajasthan is obviously located on the shelf bordering on the east the basin in which flows the Indus and which extends from Waziristan to Karachi, east of the folded chains of Baluchistan (Kirthar and Sulaiman ranges). Since the discovery of the gas field at Sui in West Pakistan, the attention was further attracted to the western part of Rajasthan. However, it is only after the completion of gravity-cum-magnetic surveys in 1960, that all the results of the work performed before, became understandable and the area can now safely be integrated within the hydrocarbon bearing basin of Central West Pakistan.

Proceeding further south-wards one reaches the area of *Cutch,* famous since a long time for its well preserved Jurassic ammonite fauna. Well marked anticlines are

known to cross east-west the Cutch peninsula and on its southern edge progressively younger formations, dipping southwards under the sea are met with. The lithology of the Tertiary deposits there, have attracted the attention of experienced petroleum geologists and since the stratigraphy of the oil-bearing Cambay basin is now better known, the Oil an Natural Gas Commission has started additional geophysical exploration in the plains of Cutch bordering the Indian Ocean after the gravity-cum-magnetic surveys were performed. Geological parties are sent in this peninsula since 1957.

Proceeding south-eastwards one reaches the *Cambay basin* where the Oil and Natural Gas Commission has experienced its most interesting achievements. The two first wildcats in the area, located 70 kilometers apart, have revealed the presence of two oil-fields one at Cambay in autumn 1958, and one in Anklesvar in May 1960.

The oil exploration history of the Cambay basin is, howewer, already 11 years old: In 1949, BANERJEE made a regional magnetic survey. In 1952 and 1954, B. S. NEGI, after a gravity-cum-magnetic detailed survey, revealed the presence of a gravity high in the area of Cambay and seismic surveys were recommended over that gravity high. KAILASAM, in 1956, performed two small seismic regional profiles over the gravity high and they showed a small reversal. In 1957, KAILASAM and CHELLAM performed detailed seismic survey over the reversal and the work done at that occasion was the basis for choosing the location of Cambay No. 1, which discovered oil at two separate depths. It can be seen from the above short history, that discovery must go to the Indian geophysicists and geologists who have surveyed the outcropping formations around the margins of the basin.

The Cambay basin extends from the lower course of the Tapti river in the south, and towards north is recognized for the moment upto the parallel of Palampur (N of Ahmedabad). On the surface it has an apparent width of about 130 kilometers and a length of about 400 kilometers. It has a very rough rectangular shape: On the eastern side the crystalline archaean basement is outcropping covered in some places on its edge by a sedimentary cover of Cretaceous sandstones. On the southern and western sides, the basin is limited by extensive outcrops of the mainly basaltic flows called Deccan traps of uppermost Cretaceous age. The Cambay gulf is now a submerged portion of this basin. Considerable speculations as to the tectonic character were made prior to the gravity-cum-magnetic surveys which have covered now the basin as described above. In the north of Ahmedabad there are indications in the gravity-cum-magnetic maps of some north-north-west trending faults limiting the basin on the eastern and western side. However, the remaining part of the basin does not seem to be a graben and it is probable that only warping of the surface of trap allowed for the deposition of the Tertiary sediments which are found within that basin. North of the Narbada river the geophysical surveys are revealing north-north-west to north-south alignement, whereas south of the Narbada river, the tectonic is controlled by a north-east south-west trend. We believe, that this last trend is due to a major tear fault of continental size cutting the Indian sub-continent into two segments and following approximately the course of the Narbada and of the Son rivers. (Vindhyan sediments are found only north of that line, whereas the various Gondwana basins of Central Eastern India are found only south of that line. It is probable that the re-entrant formed by the Kathiawar peninsula from Diu to Piram Island is also due to this major tear fault.)

At the surface, on the western (Gogha) and eastern (Baroda) margins, Miocene sediments are seen resting unconformably over the trap. South of the Narbada Eocene sediments are seen resting unconformably over the trap and they are in their turn unconformably overlain by the Miocene.

The Cambay basin area is not devoid of hydrocarbon indications: On the eastern margin at Baroda, waterwells had previously struck gas. Similarly, at Gogha, one waterwell had also struck gas. A gas show is also known in the area of Jagadhia on the south-western side of the Kathiawar peninsula (Saurashtra). But the most important natural surface manifestation of hydrocarbon is found in a large artificial square pond some 5 kilometers south-west of the locality of Anklesvar and about 6 kilometers south of the Narbada river; there, a fairly large gas show can be admired. The systematic gravity survey of the Oil and Natural Gas Commission having revealed the presence of a gravity high in this last area, a seismic survey performed over this gravity high revealed the presence of an anticlinal structure aligned north-east south-west with a steeper south-eastern flank and with the gas show near the apex of the structure. A medium depth rig located in the neighbourhood of the top of this structure discovered, in May 1960, at a depth of about 1200 metres an appreciable cumulative thickness of oilsands. The extent and thickness of the oilsands so far recognized (at the time of writing, a total of 5 wells had been drilled and 3 more are being drilled) allow the optimistic view that the reserves may be of the order of $100.10^6$ barrels.

In Cambay area, the general stratigraphic succession is found to be the following:

| | | |
|---|---|---|
| Pleistocene | = | 100— 300 m. |
| Pliocene | = | 300— 800 m. |
| Miocene | = | 800—1450 m. |
| Lower Oligocene and Uppermost Eocene | = | 1450—1550 m. |
| Kirthar | = | 1550—1900 m. |
| Laki | = | 1900—2000 m. |
| Trap | = | 2000 m. |

A considerable amount of work has been done trying to zone this sequence with the aid of palynology, heavy minerals and micropalaeontology. Now, only palaeontological control is used although some zones and the limit Eocene/Miocene are consistently detected by palynology. Micropalaeontology gives a fair amount of precise zones with *Ostracods, Assilina, Hantkenina, Bulimina, reticulate Nummulites* and a certain species of *Rotalia.*

Black shales characterize the sequence from 1400 metres downwards and it is most likely that they constitute the source rock.

At Anklesvar the following sequence is met:

| | | |
|---|---|---|
| Recent and Miocene | = | 0— 680 m. |
| Oligocene | = | 680— 730 m. |
| Upper Eocene | = | 730— 880 m. |
| Kirthar | = | 880—1450 m. |
| Laki | = | 1450—1690 m. |
| Deccan Trap | = | 1690 m. |

The oil at Anklesvar is very light (around 35 ° API) whereas in Cambay the oil is rather heavy with a great amount of paraffin and, on account of the presence of this paraffin, production tests were so far not carried out very easily.

As in Cambay the sequence is characterized by black shales during the whole Eocene, again here these black shales most likely constitute the source rock.

As during the deposition of the Eocene, the emerged lands were made up of crystalline basement, of Cretaceous and Upper Gondwana sondstone-formations as well as of trap, the sandstones derived from the first two groups are contaminated by the addition of clays derived from the decay of the traps. The problem is, therefore, to find clean sands and a considerable amount of thinking, of sedimentological and stratigraphic studies will have to be done in order to choose the next favourable place for a new wildcat. From the available geological informations, it seems now logical that due to the proximity of the crystalline basement and of the Cretaceous sandstones, the eastern and northern part of the Cambay basin are more likely to contain clean sands than the south-western part where only trap was exposed during the deposition of Eocene strata.

The possibility of finding, within Laki, a limestone intercalation which would be productive, is not ruled out.