BEFORE THE NATIONAL GREEN TRIBUNAL

PRINCIPAL BENCH, NEW DELHI

ORIGINAL APPLICATION NO. 19/2014

IN THE MATTER OF:-

DR. KASHMIRA KAKATI & ORS. ...APPLICANT

VERSUS

UNION OF INDIA AND ORS. ...RESPONDENTS

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RESPONDENT NO.7

THROUGH

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IN THE MATTER OF:-

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RESPONSE ON BEHALF OF THE RESPONDENT NO.7, OIL INDIA LIMITED

MOST RESPECTFULLY SHOWETH –

1. It is submitted that the present response is being filed in view of and in pursuance to the Report dated 04.01.2023 filed by the Committee constituted by Ministry of Environment, Forest and Climate Change to conduct inquiry on the compliance of Hon'ble NGT, judgement dated 08.12.2017 in the OA No 19 of 2014 Dr. Kashmira Kakati vs UoI & ors.

2. The present response is being filed on behalf of the Respondent No. 8, Oil India Limited by Dr. Kumudani Sharma who is the Dy. General Manager (Legal) who is the Authorized Representative of the Respondent No. 7 company, duly authorized vide a General Power of Attorney dated 12.09.2021.

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3. It is most respectfully submitted that the geographical composition and the environmental factors of the area is intricately linked with the history of the region and therefore the same is important to be detailed herein.

A. Brief History & Topography of Digboi Oilfields

4. The tale of the history, geo-political factors surrounding the oil reserves has been captured at length by S.N Visvanath in his book 'A Hundred Years of Oil: A Narrative Account of the Search for Oil in India' published first in the year 1990. The second part of the book, i.e 'Pioneering in Assam' details the story of discovery of Oil in Assam by Lieut R. Wilcox of the 46th Regiment Native Infantry. It says, "*The report of Lieut Wilcox contains the earliest recorded reference to oil in Assam. He saw it 'rising to the surface at Supkhong with great bubbling of gas and green petroleum'.*" A copy of the relevant parts of the book 'A Hundred Years of Oil: A Narrative Account of the Search for Oil in India' by S.N Visvanath is attached herewith as **Document – 1.**

5. It merits the attention of this Hon'ble Tribunal that oil seepage was a common and historic phenomenon in the concerned region and the same is recounted in the abovementioned book as '*The Company had in the meantime also turned its attention to the north bank of the Dihing and particularly to the Borbhil area where railway engineers and workmen of a plate-layers camp had noticed oil seeps and had actually lived for months*

in an atmosphere laden with the odour of oil. The analogy with Makum-Namdang was too strong to be missed. To add color to geological reasoning, legends were created that an elephant with oil-soaked legs led the men to the salt lick where seepages were prolific. Other stories say that when the engineers were cooking a meal, the ground near the camp-fire suddenly burst into flames from a hidden oil seepage. '

6. It is humbly submitted that the author of the abovementioned book further informs that 'Assam Railways and Trading Company Limited (AR & T)' was responsible for drilling the Well No. 1 in the Digboi and took first steps towards the development of the Digboi. It was the AR & T that applied to the Government in March 1888 for a license to extract petroleum in the present Digboi field.

7. With the successful digging well yielding wells, the directors of the Board of AR & T Company recognised that Oil was a full time business and set up a separate organisation, namely the 'Assam Oil Company' (AOC) in 1899, which inherited 14 producing wells. AOC soon expanded the concessional area of the Field by purchasing the rights of Assam Oil Syndicate and built a new refinery in Digboi. However, by early 1900s, AOC was grappled with drilling and geographical concerns, when the Board of AR&T appointed Burma Oil Company as the Commercial and Technical Manager of Digboi.

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8. It was in January 1958, that the Burmah Oil Company signed a Promotion Agreement with the Government of India to form a Rupee Company to take over the management of the AOC-discovered field of Nahorkatiya and Moran. The new Company, Oil India Private Limited, i.e the Respondent No.7 herein was incorporated on 18th February 1959 with BOC holding two-third shares and Government of India the remaining one-third, which changed to a 50:50 partnership by July 1961. It is in the year 1981, the Burmah Oil Company exited the picture the Respondent No.7 became a Government of India enterprises and gained access to the Digboi fields.

9. It is humbly submitted that the renowned petroleum geologist W. Norman Kent has published two conference papers namely 'Structural Evolution of the Northern Assam Basin: A Case for a Dynamic Hydrocarbon System Model' presented at AAPG Annual Convention, Houston, Texas on 09.04.2006 to 12.04.2006 and 'Life and Death of Petroleum Systems and their included Oil Fields' dated January 2010 detailing about the geography of the region. The conference paper titled 'Structural Evolution of the Northern Assam Basin: A Case for a Dynamic Hydrocarbon System Model' along with the presentation is attached herewith as **Document – 2(Colly).** The conference paper titled 'Life and Death of Petroleum Systems and their included Oil Fields' is attached herewith as **Document -3.**

10. In the lecture notes prepared by AB Das Gupta for a Refresher Course for University and College teachers, organised by the Calcutta University in March, 2002, he remarks that '*The Digboi Oilfied in NE India was discovered at around this time by drilling close to an oil seepage, The party concerned, though eminently successful in other lines of endeavour, did not have any clue to the controlling mechanism of the field and could sustain a small production of less than 200 barrels a day, by drilling at random all around. It took another 30 years for the Burmah Oil Company (BOC) to come onto the scene, discover the anticlinal control and eventually to raise its production to the level of around 5000bis/day*'. A copy of the lecture notes prepared by AB Das Gupta is attached herewith as **Document - 4.**

11. It is submitted that Mr. Arupjyoti Saikia, a professor with the Department of Humanities and Social Sciences, Indian Institute of Technology, Guwahati in his article titled, 'Imperialism, Geology and Petroleum: History of Oil in Colonial Assam' published in Economic and Political Weekly Vol XLVI No. 12 on 19.03.2021, discussed about early sighting of natural oil seepage. It states, "*The possible existence of petroleum in eastern Assam was first noticed in the early 19th century. This actually preceded the significant finding of tea plants. While tea plants were noticed only in the 1830s, one of the first recorded notices of petroleum deposits was earlier, in April 1825, a year before the EIC concluded the Treaty of Yandaboo with the Burmese to occupy Assam. R Wilcox, an army*

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lieutenant and geologist, was the earliest observer of oil in an upper Assam village. Wilcox's survey of Assam showed the many possibilities of geological discoveries in the region. Wilcox's survey carefully noticed both the geological formations and mineral resources of the region. His chance notice of oil was no less dramatic. This occurred while he was surveying river Burhi Dihing at a place called Namchik. He noticed seepage of oil and bubbling gas at a place called Supkhong." A copy of the article titled, 'Imperialism, Geology and Petroleum: History of Oil in Colonial Assam' published in Economic and Political Weekly Vol XLVI No. 12 on 19.03.2021 is attached herewith and marked as **Document – 5.**

12. It is stated that Gokul K. Bayan, Principal scientist, CSIR-North East Institute of Science & Technology published his article namely 'Performance of Digboi Refinery Modernization Project from Geotechnical aspects- investigations and observations' with Missouri University of Science and Technology on 01.05.2023. The article states that the Digboi refinery is one of the world's oldest refinery. Elaborating on the history of the region, the articles states that '*When oil was discovered in Digboi there was no habitation in its immediate neighborhood. The jungle was dark and swampy. The forest was so thick and the undergrowth so dense that sunlight could never reach the ground. Once oil was found, the dense jungle made way for the growth of the oil industry in India. 'Dig-boy-dig', shouted the Canadian engineer, Mr W L Lake, at his men as they watched elephants emerging out of the dense forest with*

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oil stains on their feet.' The Articles further points to the instances of natural occurrence of oil from the banks of the river as the earliest record of existence of oil in India. As per the article, '*The Assam RAILWAYS & Trading Company while extending the Dibrugarh-Sadiya Railway line upto their coal fields in 1882 came across oil seepage near work sites around the present Digboi*', thereby indicating towards the existence of natural seepage in the Digboi oilfield from early times. A copy of the article namely Performance of Digboi Refinery Modernization Project from Geotechnical aspects-investigations and observations' published by Gokul K. Bayan with Missouri University of Science and Technology on 01.05.2023 is attached herewith as **Document - 6.**

13. It merits the attention of this Hon'ble Tribunal that the famous journal namely 'Digboi Batori:House Journal of the Assam Oil Company' had published various news pieces highlighting the exhaustive approach adopted by the Assam Oil Company and the numbers of wells digged in the region. The said news pieces are attached herewith as **Document – 7 'Colly'.**

B. STEPS TAKEN BY OIL FOR BIO-REMEDIATION

14. As can be seen from the history and topography of the said oilfields, oil seepage is a natural phenomenon in this area which has been documented for more than 100 years now. Therefore, the Respondent No. is trying to address the concerns raised due to such oil seepage which is a natural phenomenon by taking the following measures.

15. It is most humbly submitted that even though the geography of the region points towards the natural occurrence of the sludge, the answering Respondent has taken a pro-active approach and has adopted Bioremediation (both In-situ as well as Ex-situ) methods for treatment of oily sludge in Digboi field.

16. It is pertinent to mention that Bioremediation is a process that uses naturally occurring microorganisms to transform harmful substances to nontoxic compounds. Bioremediation exploits this natural process by promoting the growth of microbes that can effectively degrade specific contaminants. Hence Oil Zapper technology utilizes the bioremediation potential of specific microbes that degrades the toxic hydrocarbon compounds leaving behind non-hazardous end products or metabolites and hence no harmful effects.

17. It is most respectfully submitted that a joint venture was formed between ONGC and TERI named as 'ONGC TERI Biotech Limited' (**OTBL**) in 2007 for the commercial application of the bioremediation along with other technology for oil industries. It is pertinent to mention that Respondent no. 8 has engaged OTBL wherein a total of 3431 m^3 of oily sludge was treated In-situ and Ex-situ at Digboi oilfield using the Oil Zapper technology.

18. It merits the attention of this Hon'ble Tribunal that a work contract agreement of Contract No. 6104394/DCO and was executed between Respondent No.7 and M/s ONGC TERI

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Biotech Limited on 23.07.2010 for Ex-situ bio-remediation of 9180 cubic meter contaminated soil. The work contract agreement dated 23.07.2010 is attached herewith as **Document- 8.**

19.It is most humbly submitted that multiple bioremediation activities took place from April 2012 till June 2019. A record of the bioremediation activities that took place at Digboi Field is as following:

19.1. It is humbly submitted that in **April 2012** the construction of Ex-Situ bioremediation pit with concrete boundary wall and HDPE lines bottom surface near Well No. 139 in Digboi Oilfield. The work was executed by M/s OTBL and the same was completed in **February'2013.**

19.2. It is submitted that thereafter in **September 2013,** 970 m^3 of oily sludge were excavated and transported from Pit near Well No. 512 (120 m^3), Pit near Well No. 513 (800 m^3) and Pit near Well No. 19 (50 m^3) to Ex-Situ Bioremediation Pit near Well No. 139. Three applications of oil zapper was done by M/s OTBL in a phased manner from **November'2013 to March'2014** and completed the job.

19.3. It is most humbly submitted that from October 2015 to April 2016 another 810 m^3 of oil sludge was transported from pit near Well no. 513 to Ex-Situ bioremediation Pit

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near Well No. 139. The collected sludge was then bio-remediated through application of oil zapper by M/s OTBL in May 2016.

19.4. It is most humbly submitted that a General Condition of Contract (GCC) Part I- V, *vide* Contract No. 6110082 was executed between Dr. Banwari Lal CEO of ONGC TERI Biotech Ltd on 05.08.2016 for In-situ Bio-remediation of 14,700 cum and Ex-situ Bio-remediation of 15,300 cum contaminated soil/ oily sludge of various production pits in Assam Field for a period of 02(two) years. The General Condition of Contract (GCC) Part I-V along with the Integrity Pact dated 05.08.2016 is attached herewith as **Document- 9 (Colly)**.

19.5. It is most humbly submitted that at Site near well No. 513, Digboi oilfield, bioremediated In-situ the Total Petroleum Hydrocarbon (TPH) at Zero day, i.e., 08.11.2016 was 16.32% and after degradation on 13.02.2018 was 0.09%. The test report no. TERI/EIBD/2016/70 dated 22.11.2016 for the sample collected on 08.11.2016 for the oily sludge sampled from put near well no. 513, as prepared by TERI is attached herewith as **Document- 10.**

19.6. It is pertinent to mention that later in 2016 another oily sludge of volume 151 m^3 was In-situ bioremediated by M/s OTBL with three applications of oil zapper at Pit near Well No. 513 to remediate any remaining oily sludge and

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was completed in early 2018. The test report no. 14-130218-01 dated 19.02.2018 for the sample collected on 13.02.2018 from near the well no. 513 as prepared by TERI is attached herewith as **Document – 11**.

19.7. It merits the attention of this Hon'ble Tribunal that in June 2018 another Oily Sludge of 500 m^3 was identified and measured at Pit near Pumping Power No.11. The aforementioned oily sludge was then transferred to Ex-situ Bioremediation Pit near Well No. 139 during July 2018. This volume was bio-remediated by M/s OTBL through three nos. phased applications of oil zapper and was completed in April 2019.

19.8. It is most humbly submitted that oily sludge of 1000 m^3 was also identified in Pit near Well No. 512. This volume was In-situ bio-remediated by M/s OTBL through three nos. phased applications of oil zapper and was completed in June 2019.

20. It merits the attention of this Hon'ble Tribunal that all the sludge samples (Zero-time samples & post bioremediation samples) of various bioremediation sites had been analysed for Total Petroleum Hydrocarbons (TPH). Total Petroleum Hydrocarbon content in sludge is mentioned below:

20.1. It is submitted that at Site bioremediation pit- 139, Bioremediated Ex-situ (First batch), Digboi oilfield, the

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Total Petroleum Hydrocarbon (TPH) at Zero day, i.e., 08.11.2013 was 14.22% and after degradation on 27.04.2014 was 0.68%.

20.2. It is most respectfully submitted that at Site bioremediation pit- 139, Bioremediated Ex-situ (Second batch), Digboi oilfield, the Total Petroleum Hydrocarbon (TPH) at Zero day, i.e., 03.05.2016 was 8.52% and after degradation on 24.08.2016 was 0.73%.

20.3. It is most humbly submitted that at Site bioremediation pit- 139, Bioremediated Ex-situ (Third batch), Digboi oilfield, the Total Petroleum Hydrocarbon (TPH) at Zero day, i.e., 13.08.2018 was 13.83% and after degradation on 06.06.2019 was 0.73%. The test report no. TERI/EIBD/2018/35 dated 20.08.2018 for the sample collected on 13.08.2018 from Pit near Well no. 139 prepared by TERI is attached herewith as **Document- 12.** The test report no. TERI/EIBD/2019/94 dated 10.06.2019 for the sample collected on 08.06.2019 from Well No. 139 after third application of Oil Zapper, prepared by TERI is attached herewith as **Document- 13.**

20.4. It is most respectfully submitted that at Site near well No. 512, Digboi oilfield, bioremediated In-situ the Total Petroleum Hydrocarbon (TPH) at Zero day, i.e., 27.12.2018 was 22.49% and after degradation on 06.06.2019 was 0.64%. The test report no.

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TERI/EIBD/2018/24 dated 04.01.2019 for the sample collected on 27.12.2018 pit near Well no. 512 prepared by TERI is attached herewith as **Document- 14.** The test report no. TERI/EIBD/2019/93 dated 10.06.2019 for the sample collected on 08.06.2019 for the oil sample collected after third application of oilzapper prepared by TERI is attached herewith as **Document- 15.**

21. It is humbly submitted that the historical and geographical background of the Digboi Oil field merits attention of this Hon'ble Tribunal which has also been well accepted by the National Green Tribunal in the Impugned Order dated 08.12.2017 inasmuch as the Impugned Order *inter alia* specifically records that the *Committee noticed natural seepage in drain no. 1 of Digboi Oil Field* which has been accepted by the Tribunal and has not been challenged by any party till date. It merits the attention of this Hon'ble Tribunal that owing to the infamous story of elephant and their greasy paws, memoirs of the elephant were published as entertainment pieces to explain the discovery of oil and in the Digboi field. The Memoirs of an Elephant as referred to herein is attached herewith as **Document- 16.**

22. It is most respectfully submitted that even as per the compliance affidavit filed by the State of Assam in March 2023 before the Hon'ble Supreme Court, upon verification has been confirmed that the answering Respondent has complied with the directions of the Pollution Control Board Assam.

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C. **OBJECTIONS TO THE FINDINGS OF THE REPORT DATED 04.01.2023 OF THE COMMITTEE CONSTITUTED BY THE MOEF TO CONDUCT ENQUIRY PURSUANT TO JUDGEMENT DATED 08.12.2017 OF THIS HON'BLE TRIBUNAL**:

23. At the outset it is submitted that representatives of OIL were not present during the collection of samples. The samples are also not marked with reference to specific locations which can be identified for taking necessary remedial actions. The samples may have been collected from a natural seepage and seemed to have been assumed to be a leakage of an abandoned pipeline.

24. The report also does not factor-in the history and topography of the Digboi oilfields which are naturally prone to have such oil seepages as recorded in various publications referred hereinabove. The conclusions of leakage of pipes, etc. appear to be speculative as their exact location is not disclosed in the report either to validate or remedy the leakage, if any.

25. It is humbly submitted that notwithstanding the above and in addition thereof, the Answering Respondents *vide* the present response seeks to provide its responses qua the findings of the Ministry of Environment, Forest and Climate Change in respect of the directions passed by the National Green Tribunal vide its order dated 08.12.2017. The extract of the relevant direction of the National Green Tribunal concerning the answering

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Respondent is reproduced below for the sake of convenience of this Hon'ble Tribunal:

"Respondent No7 i.e. Oil India Limited to forthwith stop releasing of untreated oil effluent in open sludge pits and seepage areas around oil rigs in the Digboi Oil Field which falls within upper Dihing RF (East Block) and the Dihing – Patkai Elephant Reserve"

26. It is stated that the Ministry of Environment and Forest & Climate Change conducted an inquiry on the compliance of judgement of this Hon'ble Tribunal dated 08.12.2017 and presented its report dated 04.01.2023 in the Compliance Affidavit as filed before this Hon'ble Tribunal. It is most humbly submitted that the findings of the Ministry of Environment, Forest and Climate Change (MOEF) are erroneous and unsubstantiated and fail to bring before this Hon'ble Tribunal the correct representation of the conditions on ground. The findings of the Report of MOEF and the responses qua the same are as follows:

26.1. Finding *No. 1: <u>Oil is leaking from underground pipelines in the Reserve Forest</u>*

i. At the outset, it is stated that the Committee constituted by Ministry of Environment, Forest and Climate Change visited only 3 sites, namely Pit No. 512, 513 and 139 in the concerned Digboi region and have prepared the said Report on the basis of those findings alone. It is humbly

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submitted that there is no leakage or seepage of crude oil through any underground pipelines in the Reserve Forest area.

ii. It is brought to the notice of this Hon'ble Tribunal that most of the area is the Digboi reserve is covered with dense forest and therefore inaccessible or searchable by foot. The abandoned wells have been taken over by the dense forest in vicinity thereby making it extremely difficult to explore and verify the complete reserves to account for oily sludges spread across the region. The pictures and videos pertaining to the reserve forest and the oily sludges in the Digboi reserve as recently obtained in the month of September-October 2023 are attached herewith as '**Document – 17** 'Colly'.

iii. It merits the attention of this Hon'ble Tribunal that the concerned premises as inspected by the Committee does not have any crude oil pipeline. Further, it is submitted that the pipelines present are periodically supervised and monitored by the internal HSE (Health, Safety and Environment) department of the answering Respondent. However, in the absence of any specification provided by the Ld. Committee with respect to the block in which the pipeline has been allegedly found to be leaking, the answering Respondent has inspected all its pipelines which have found to be in good condition. Further, it is respectfully submitted that even otherwise the answering

Respondent regularly assures that there is no infiltration or leakage of pipeline as this is not only an environmental concern but also a hazard which can lead to an unfortunate incident. In addition, it is also humbly reiterated that Oil Industry Safety Directorate (OISD) also periodically audits the sites and therefore a sweeping statement of leakage of underground pipeline cannot be placed reliance upon.

26.2. Finding *No. 2: <u>At several places, oily sludge pits of abandoned wells have been found and natural drains pass through these pits.</u>*

i. It merits the attention of this Hon'ble Tribunal that the Digboi Oil field draws from a rich historical background, which plays a significant role in its present circumstances. The concerned Digboi Oil Fields have been in existing since last 100 years. The Crude Oil was discovered in the far east of India at Digboi in 1889 by the erstwhile Assam Railway & Trading Co (AR&T), which subsequently developed the Digboi Oil Field, located within the present day Dihing Patkai Reserve Forest.

ii. The Answering Respondent came into existence, much later in the year 1959 as a Joint Venture Company of Burmah Oil Company and Government of India, having minority share and was subsequently

fully nationalized only in the year 1981 through the Burmah Oil Company [Acquisition of Shares of OIL India Limited and of the Undertakings in India of Assam Oil Company Limited and the Burmah Oil Company (India Trading) Limited] Act, 1981. A copy of the Burmah Oil Company [Acquisition of Shares of OIL India Limited and of the Undertakings in India of Assam Oil Company Limited and the Burmah Oil Company (India Trading) Limited] Act, 1981 is attached herewith as '**Document -18**'. A news piece published in issue No. 5 Volume no. IV of the 'Digboi Batori: House Journal of the Assam Oil Company' dated May 1957 highlighting the General agreement entered between the parties as mentioned herein above is attached herewith as '**Document- 19**'.

iii. It merits the attention of this Hon'ble Tribunal that the answering Respondent has actively participated and undertaken proactive measures for bio-remediation of the natural phenomenon of oily seepage.

iv. It is humbly submitted and reiterated that the historical and geographical background of the Digboi Oil field merits attention of this Hon'ble Tribunal which has also been well accepted by the National Green Tribunal in the Impugned Order dated

08.12.2017 inasmuch as the Impugned Order *inter alia* specifically records that the *Committee noticed natural seepage in drain no. 1 of Digboi Oil Field* which has been accepted by the Tribunal and has not been challenged by any party till date.

v. It is submitted that even though the oily sludge pits have been noted and accepted as a natural phenomenon by this Hon'ble Tribunal, the answering Respondent has on its own accord undertaken bio-remediation activities in the Digboi Oil Field region. It is brought to the knowledge of this Hon'ble Tribunal that Bioremediation is a process that uses naturally occurring microorganisms to transform harmful substances to nontoxic compounds. Bioremediation exploits this natural process by promoting the growth of microbes that can effectively degrade specific contaminants. Thus, Oil Zapper technology utilizes the bioremediation potential of specific microbes that degrades the toxic hydrocarbon compounds leaving behind non-hazardous end products or metabolites and hence no harmful effects. Not only this is environment-friendly technique, but also is highly cost effective when compared to storage of oily waste/oily sludge in sludge pits.

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vi. It is humbly submitted that the answering Respondent had undertaken bio-remediation activities in the Digboi Oil Field region under the supervision of Research and Development, HSE and erstwhile Production (Oil) Department.

vii. It merits the attention of this Hon'ble Tribunal that on application of the Bio-remediation and Oil Zapper technology, the answering Respondent has been successful to reduce the Total Petroleum Hydrocarbons (TPH) at the Oily sludges to negligent levels.

viii. In furtherance, the Hon'ble Tribunal is humbly apprised that the Respondent No. 1 has planned Bio-remediation for 'Oil Contamination' in Pit No. 513 and 139 and has engaged M/s The Energy and Resource Institute (TERI) for the same *vide* LOA Ref. No. OIL/CONT/LOA/O/507/2021-22 dated 08.10.2021. TERI as a part of their project has visited the abovementioned sites on multiple occasions and have collected zero time samples for primary or zero-time TPH (Total Petroleum Hydrocarbon) concentration test.

ix. It is pertinent to state that as per the Case study of the Pit No. 513, TERI had concluded that the pit was filled with crude oil, however was dry at the time of

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digging and therefore the free oil was coming through unknown seepage. Even on re-examination of the whole site, the seepage source could not be identified. The Pit No. 139 was found suitable for bio-remediation and the zero time sample was collected.

26.3. Finding *No. 3: Oil spill have been found in several oil producing wells and Crude Gathering Stations. No fencing had been provided at these well sites.*

i. It is most humbly submitted that the findings of the Committee are unfortunately not supported by any pictures or on ground task reports. It is at the outset clarified that there do not exist any Oil Spills as alleged in the Report. However, it merits the attention of this Hon'ble Tribunal that in a circumstance that an oil spill occurs during operations or any other concern is found in the pipeline, the same is rectified immediately and the site is cleaned and restored, as per the internal SOPs of the answering Respondent.

ii. It is further humbly submitted that the answering Respondent in bona fide had also engaged in iron fencing of well sites, howsoever owing to local miscreants, a number of thefts of such iron fencing has been observed which results in severe inconvenience for the answering Respondent as well. Further the areas of operation are spread out in large extents hence physical monitoring of the entire fenced

area is practically unviable. However, the answering Respondent time and again addresses these concerns, even though the issue of theft is a recurring one.

26.4. *Finding No. 4: More than 800 wells have been drilled since the operation of Burma Oil Company Ltd. Oil India Ltd does not even have the inventories of these abandoned on wells, let alone treatment of these pits.*

i. It is humbly submitted that the oil fields are in operation since 1889 and have changed hands before the present Respondent No. 7, which was nationalized only in 1981. Post 1981 the present Respondent has been maintaining the records and the same have been subjected to various audits by independent and statutory agencies periodically. It is humbly submitted that there are a total of about 982 wells out of which about 651 are shut-in, about 293 are abandoned and 38 are producing wells. A colour coded map of the Digboi reserve marking out the Drilled wells, producing wells, abandoned wells, temporary abandoned wells is attached herewith and marked as **Document – 20.**

ii. It is further most humbly submitted that the Respondent No. 7 has been carrying out the task of Bio-remediation of these oily sludges way prior to the Judgment passed by this Hon'ble Tribunal and

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endeavors to undertake the same in the upcoming future as well. It merits the attention of this Hon'ble Tribunal that contrary to the findings of the Committee not every abandoned well has a pit and the origin of pits has not been document, however the same was not a result of any activities undertaken by the Respondent No. 7 in the concerned region.

iii. It is humbly submitted that Respondent No. 7, after periodically monitoring the pits have identified and steps are taken for rectification as and when oily sludge/seepage is found due to the natural phenomenon of the region. It however, also merits the attention of this Hon'ble Tribunal that despite the bio-remediation work being carried out in the area, the oil seepage has been observed which appears to be a natural seepage and not owing to any action or inaction of the answering Respondent and is recurring in nature.

iv. It is stated that the Office of Divisional Forest Officer, Digboi Division by Letter bearing no. B/NGT/2022/2743-45 dated 16.11.2022 had requested the present Respondent to provide details, including location, number of sites, geo-coordinates, area and map of dumping the waste with geographical location/ geo coordinates by the Digboi municipality, Indian Oil Corporation Limited and Oil India Limited along with details including location, number of pits,

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geo-coordinates, area and map of the open sludge pits, oil pits and contaminated water bodies in and around the Dihing Patkai Elephant Reserve. The answering Respondent accordingly in bona fide *vide* reply dated 28.11.2022 had shared the geo-coordinates of the Natural and artificial pits in the Digboi Oil Field along with the Map showing the location of the pits. A copy of the Letter bearing no. B/NGT/2022/2743-45 dated 16.11.2022 issued by the Office of Divisional Forest Officer, Digboi Division is attached herewith and marked as **Document - 21.** A copy of the letter dated 28.11.2022 issued by the answering Respondent replying to the communication from the Office of DFO is attached herewith and marked as **Document- 22.**

26.5. *Finding No. 5: <u>In the three oil sludge remediation sites visited, the remediation has not resulted in complete conversion of oily sludge into biodegradable matter. They do not even maintain the inventories of abandoned oil wells.</u>*

i. It is most humbly stated that as per the findings of the Committee, admittedly, despite the bio-remediation work being carried out in the area, oil seepage has been observed which appears to be a natural seepage and not owing to any action or inaction of the answering Respondent. It merits the attention of this

Hon'ble Tribunal that the Answering Respondent has been taking remedial measures from July 2010 itself and the entire oil debris have already been treated through Bio remedial measures. It is clarified that such oily debris could not be removed and dumped in some other places outside the forest area, as it would create environmental problem in such places. Hence, with the advent of scientific technique, the Answering Respondent had taken up the project for degrading the oily-debris through Bioremediation. It is respectfully submitted that Answering Respondent has bio-remediated all the oil-debris site, mostly inherited from erstwhile Assam Oil Company, and presently, however since the same is a natural phenomenon, the recurrence of the oily sludges has been observed in the Region.

ii. It is further humbly submitted that given the said circumstances, the answering Respondent is yet again undertaking bio-remediation work in the area and shall continue to address the issue, as and when observed.

iii. At the outset it is submitted that the oil fields are in operation since 1889 and have changed hands before the present Respondent No. 7 which was incorporated in 1959. Post 1981 the present Respondent has been maintaining the records and the same have been

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subjected to various audits by independent and statutory agencies periodically.

26.6. *Finding No. 6: Oil India limited has been unable to stop the release of untreated oil effluent in open sludge pits and seepage areas around oil rigs in the Digboi Oil field.*

i. It is humbly submitted that as against the finding of the Committee, the judgment passed by the Hon'ble Tribunal observes that no untreated oil effluent in open sludge pits is being released by Respondent No. 7 and that occurrence of oily sludges as witnessed is owing to natural seepage and not due to any action/ inaction of the answering Respondent.

ii. It is most humbly stated that a bare perusal of the test reports of the pits as visited by the Committee, conducted to examine the soil quality by taking a sample of Oily sludge in proximity of wells as prevalent before and after application of Oil Zapper shows remarkable deduction in presence of Total Petroleum Hydrocarbons (HE-TPH) in the same. It is most humbly stated that evidently the process of Bio-remediation and application of Oil Zapper technology has aided drastic reduction in the amount of Hydrocarbons to negligent levels in the areas adjoining the oil wells.

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iii. However, it is most humbly stated that the fresh seepage as observed is possibly due to the natural phenomenon and appropriate action has been taken for bio-remediation activity by the answering Respondent through TERI. As a matter of fact, the experts from TERI had visited the concerned site for analysis of the present circumstances and their proposal on bio-remediation is awaited by the Respondent No. 7.

27. It is therefore respectfully submitted that the present response is being filed in truth and bonafide.

PRAYER

In view of the aforementioned facts and circumstances, the answering Respondent No. 7 most graciously prays that this Hon'ble Tribunal may be pleased to:

a. Dismiss the captioned application wrongly preferred by the applicant in view of the directions passed by this Hon'ble Tribunal in judgement dated 18.12.2017 and their compliance thereof by the answering respondent.

Any other relief/ order/directions which this Hon'ble Court deems fit and proper in the circumstances of the case be allowed in favour of the Respondent No. 7 and against the Applicant.

RESPONDENT NO. 7

THROUGH

Dr. Kumudani Sharma
GM (Legal)
Oil India Limited
Authorised Signatory

For, **Trust Legal Advocates & Consultants**
Petal Chandhok, & Rupali Gupta
Advocates for Respondent No. 7
Off.: D-415, Defence Colony, New Delhi-110024
Ph.: (+91) 9654025754; (+9111) 40525619
Email: petalchandhok@trustlegal.in

Place: New Delhi

Date: 05.04.2024

VERIFICATION

Verified at New Delhi on this 5th day of April, 2024, that the contents of the above response are true and correct to the best of my knowledge and nothing material has been concealed therefrom and no part thereof is false. It is stated that the contents of paragraph 2 are based on personal knowledge, paragraph 1, 3-27 are on the basis of the documents maintained in the ordinary course of the business and paragraph Prayer is on the basis of the advice rendered to me.

RESPONDENT NO. 7

Dr. Kumudani Sharma
GM (Legal)
Oil India Limited
Authorised Signatory

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BEFORE THE NATIONAL GREEN TRIBUNAL

PRINCIPAL BENCH, NEW DELHI

ORIGINAL APPLICATION NO. 19/2014

IN THE MATTER OF:

DR. KASHMIRA KAKATI & ORS. ...APPLICANT

VERSUS

UNION OF INDIA & ORS. ...RESPONDENTS

AFFIDAVIT ON BEHALF OF THE RESPONDENT NO. 8

I, Dr. Kumudani Sharma, General Manager (Legal), the Authorized Representative of the Respondent No. 8 company, having its Corporate Office at Plot No. 19, Sector 16 A, Film City, Noida 201301, Uttar Pradesh, and duly authorized vide a General Power of Attorney dated 12.09.2021, today present at New Delhi, do hereby solemnly affirm and submit:

1. I state that I am the Respondent No. 8 in the present case and am well conversant with the facts and circumstances of the case and as such competent to swear this affidavit.

2. I state that the contents of the Response are true and correct to my knowledge and based on the records maintained and made available by the Respondent No. 8 Company, which may be read as a part and parcel of the present Affidavit.

3. I state that all the documents being filed along with the accompanying Response are true copies of their respective originals and annexures are attached herewith

NOTARY R.V. SINGH Advocate Regn.No.2282 Commission Expire on 24-10-2027 Area-Delhi GOVT. OF INDIA

DEPONENT

Dr. Kumudani Sharma
GM (Legal)
Oil India Limited
Authorised Signatory

VERIFICATION:

Verified at on this 5 APR 2024 day of , 2024 that the contents of the above Affidavit are true and correct to the best of my knowledge and derived from the records maintained by the Respondent No. 8 Company, no part of it is false and nothing material has been concealed therefrom.

I identified the deponent/executant who has signed in my presence.

DEPONENT

Dr. Kumudani Sharma
GM (Legal)
Oil India Limited
Authorised Signatory

NOTARY
R.V. SINGH
Advocate
Regn.No.2282
Commission
Expire on
24-10-2027
Area-Delhi
GOVT. OF INDIA

Solemnly affirmed before me read over & explained to the deponent.

Notary Public, Delhi

5 APR 2024

DOCUMENT 1

A Hundred Years of Oil

A narrative account of the search for oil in India

S N Visvanath

VIKAS PUBLISHING HOUSE PVT LTD

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Pioneering in Assam

(a) The Pathfinders

The story of oil exploration in India began in the dense jungles and swamps and river-valleys at the extreme north-eastern corner of Assam in the early years of the 19th century. One could also say that, like the tea industry so vividly described by Sir Percival Griffiths (The History of the Indian Tea Industry: *Weidenfield and Nicholson*, 1967), it began with Napoleon. A stimulating sense of danger and uneasiness pervaded the British spirit despite their victory at Waterloo, and kept them on their toes till Napoleon was safely buried in 1821.

The collective sigh of relief that marked this event was soon followed by the realization that something had to be done about the abundance of British energy and enterprise which suddenly became available. The answer was simple : flex the industrial muscle in the colonies across the seas, explore and exploit their natural resources, build up an infrastructure for further expansion and create a climate for investments in ventures hitherto considered foolhardy.

The hot and perspiring Lieut R. Wilcox of the 46th Regiment Native Infantry may not have been aware of this grand imperial design as he and his small survey party rowed up the Burhi Dihing River beyond Namchik on a September afternoon in 1825. He only knew that he was on a military reconnaissance mission in the land of the Singpho tribes to maintain law and order. His immediate concern was to ward off mosquitoes and depression as the rain forest pressed down increasingly on the winding river. And then he saw the oil[1].

The report of Lieut Wilcox[2] contains the earliest recorded reference to oil in Assam. He saw it "rising to the surface at Supkhong with great bubbling of gas and green petroleum". But the local inhabitants and hill tribes had no use for the oil or coal seen nearby and for outsiders it was, both historically and geographically, an awkward moment and place. The first Anglo Burmese War (1824- 26) was at its height with fierce battles raging in the Brahmaputra valley and further south against the Burmese invaders of Manipur and Assam. Geographically, few places could have been more forbidding. "No one unacquainted with the province " wrote

a distinguished civil servant, "can form any just conception of the obstacles to be contended with in making the most transitory survey. Footpaths are often obliterated by the inseparable jungle which in denseness can be matched by very few places in the world. Frequent rainstorms add to the unpleasantness of camping. Floods are common and the jungles are full of wild life. The member of the animal kingdom which makes its presence felt most is the leech –a scourge to man and beast".

This forbidding country did not discourage the tea planter who had been around since the beginning of the 19th century. While trying to locate the source of indigenous tea in Singpho country in 1828 (he ultimately found it near Bisa village after "parting with much opium and sweet words"), C.A. Bruce came across " many oil seepages upstream of Makum[3] for a distance of about 5 miles."

In 1837 W. Griffith went past Bisa village crossed the Noa-Dihing and headed towards Kamroop Putar, a cultivated rice-tract on the river Kamroop close to the Naga Hills. He reported that "petroleum wells are most numerous towards the summits of the range, and the place where they occur is free from shrubs. The petroleum is of all colours, from green to bluish-white; this last is the strongest, partaking of the character of naphtha."

There followed a rash of "military" discoveries of oil seepages: Major A. White (Nampong, 1837); Lt.W Bigge (Namrup, 1837); Capt. Francis Jenkins (Borhat and Makum, 1838); Capt. H. Vetch (Makum, 1842); and Capt P.S. Hannay (Namchik Pattar, 1845). Hannay's description is particularly colourful as he describes "muddy pools in a constant state of activity, throwing out with more or less force white mud mixed with petroleum. This is indeed a strange-looking place. At times there is an internal noise as that of distant thunder, when it bursts forth suddenly with a loud report and then subsides". In 1854 Capt. Dalton further described the Namchik and Makum finds.

Acting on these reports an Austrian speculator, Wagentreiber, applied for "leases and monopolistic rights over the tract of land between Bappapoong and Namchik". A ten-year lease was granted to him in 1854 by the Government of Bengal (Revenue Department) on the recommendation of the Chief Commissioner of Assam to "operate the petroleum springs at Makum". Apparently, the venture folded up swiftly.

In 1865, H.B.Medlicott of the Geological Survey of India chanced upon the Makum oil seepages while reporting on the coal-fields of Upper Assam and he recommended trial boring in the area[4]. This was an important first step in scientifically assessing the oil prospects of the northeastern region.

To the establishment in distant Bengal these curious manifestations up in the rivers and hills of the Brahmaputra Valley meant very little, but to a Mr Goodenough, a member of the Calcutta firm of Mckillop, Stewart & Co they conveyed a good deal. If there was oil in Assam as Medlicott had reported, perhaps there was a business to be made out of it.

In November 1866, having been granted certain rights over a large tract of land on both sides of the Dihing from Jaipur to beyond the Namchik confluence, Mr. Goodenough commenced drilling at Nahorpung near Jaipur. This well, bored by hand, was abandoned dry at 102 ft. Undismayed, he tried again with a steam engine acquired from Mather and

Platt, a renowned British enterprise which still exists today with branches in Bombay and Pune, to drive the machinery. Three wells drilled to 171, 162 and 99 ft. encountered some gas and very little oil.

While these borings were in progress at Jaipur others were begun at Makum-Namdang to fulfil the recommendations of Medlicott. The first well went down to 195 ft. but there was no success : only a few signs of gas. But on 26 March 1867 oil was struck in another well at a depth of 118 ft. and it immediately rose 74 ft. in the bore. About 300 gallons were drawn after which it was not found to flow continuously. *This second well at Makum was the first successful mechanically drilled well in Asia.* Between 1866-69 eight wells were drilled by the prospectors, with sporadic success. One well at Makum yielded about 400 gallons a day. Some flowed intermittently and other yielded "pure water which spouted for three or four hours, then almost pure oil for 15 to 30 minutes, after which all action ceased for an hour; and then activity set in again".

On the whole, Makum - Namdang drilling was distinctly more encouraging than at Jaipur.

Notwithstanding the generally promising results obtained, Goodenough never really tasted success. Transport difficulties in northeast India were the main cause of the failure of his enterprise; freight costs raised the price of oil in Calcutta to a figure at which it could not compete with oil from Burma. In recording this event, Hughes remarks that "the prospect of an abundance of mineral oil in Assam has been proved and if this splendid province should ever be opened up, fortunes will yet be made in this branch of mining". A cruel fate denied Mr. Goodenough both the fortune and the chance to become the father of the petroleum industry in India.

For the next 20 years it was all quiet on the oil front, save for a few shallow wells at Namdang, but considerable geological and mineral exploration work was carried out in northeast India by the Geological Survey of India[5]. The outstanding names are those of F.R. Mallet, T.H.D. La Touche, R.D. Oldham and H.H. Godwin-Austen. By 1880 the foundations for the understanding of Assam geology had been well and truly laid. A sketch map of Assam oilfields by Sir Boverton Redwood (1890) is reproduced in Fig. 2.

In an admirable pioneering venture S.E.Peal, a tea-planter, sailed up the Dihing River in early 1879 upto the Nongyang Lake on the Burmese frontier. He reported Jaipur as having "coal, and petroleum to be found in large quantities not far off" and mentioned petroleum springs near Margherita. Talking to village elders at Insa (or Bor Bhakial) just upstream from Makum he found evidence to believe that someone was extracting kerosine from local oil obtained from oil springs by 1879. When it started is not clearly known but quite conceivably it could be coeval with the famous 1865 distillation experiments of Dr. James Young which are generally regarded as the genesis of the petroleum refining industry.

These then were the pathfinders. They were brave and valiant spirits engaged in specific missions of a military nature, or civil servants with assignments in the frontier tracts, or geologists on a mapping spree or looking for coal, or intrepid men searching for the indigenous elusive tea-leaf and stumbling upon oil. They were all endowed with a keen sense of observation and detail, and in their diaries and memoirs they wrote themselves into immortality.

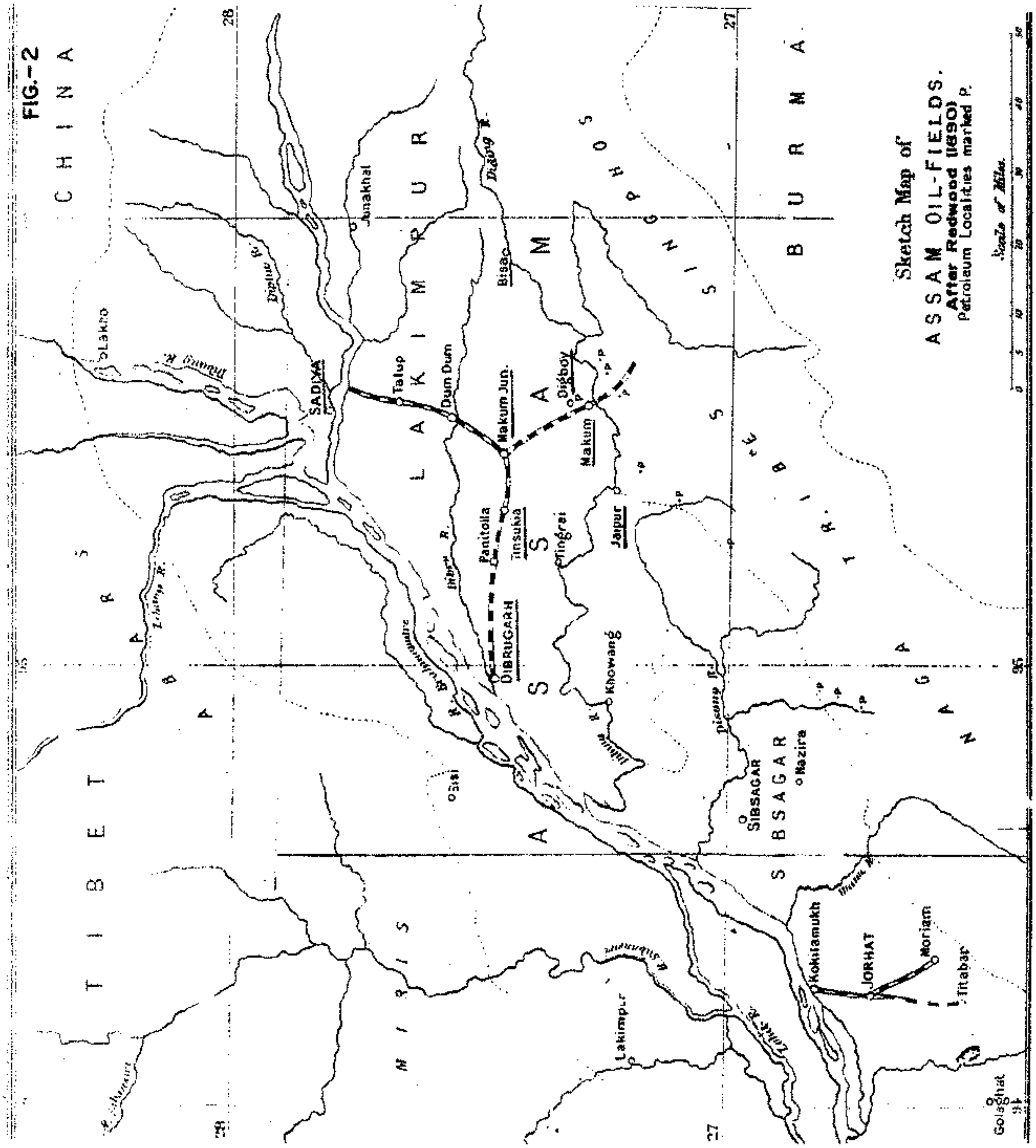
FIG.-2
CHINA
TIBET
LAKIMPUR
ASSAM
SIBSAGAR
BURMA
SINGPHOS
NAGA
MIRIS
SADIYA
Talup
Dum Dum
Makum Jun.
Digboy
Makum
Jaipur
Tinsukia
Panitolla
DIBRUGARH
Khowang
Nazira
JORHAT
Kokilamukh
Moriam
Titabar
Lakimpur
Golaghat
Junakhal
Lakho
Sketch Map of
ASSAM OIL-FIELDS.
After Redwood (1890)
Petroleum Localities marked P.
Scale of Miles.

(b) The Assam Railways and Trading Company Limited (AR & T Co.)

No account of the industrial growth of Assam, and least of all the present one, would be complete without a reference to the Assam Railways and Trading Company Limited (AR & T Co. Ltd.). It was this Company which, among other remarkable achievements, drilled Digboi Well No. 1 and took the first tentative steps towards the development of the Digboi discovery.

An excellent compilation of the AR & T Co. history by W.R. Gawthrop forms the basis for much that follows[6].

It was well known that Upper Assam was rich in natural resources. It was equally well-known that such resource could not be economically exploited for want of reasonable transport facilities. Thus, oil remained locked up in Makum-Namdang, coal-carrying boats from Safrai frequently capsized in their river journey, timber could not be rationally exploited and tea-planters wept as they sent their cargo along the most dreadful roads imaginable. Railways was the answer to this transport nightmare. They would provide the link and at the same time use the timber and coal for construction. Tea gardens could use the locally available coal, a mere 30 miles away rather than import coal from Raniganj, a 1000 miles away. The Railways however would require machinery, locomotives, rails etc. which could only be transported up the Brahmaputra starting from Calcutta.

In 1878-79, the Assam Railways Company tried to raise fund through public shares for a railway line between the steamer ghat at Dibrugarh and the 51st mile on the Sadiya Road, but the project failed. It was left to the AR & T Co. which was registered on July 30, 1881 in London to recognize that any railway system in Upper Assam which was unassociated with the development of natural resources was doomed to failure.

One of the founders of the AR & T Co. was Dr. John Berry White, a name engraved in the history of Assam as the founder and benefactor of the Berry White Medical School at Dibrugarh which evolved into the Assam Medical College after independence through the sustained efforts of the political and social leaders of Assam. What is perhaps less well known is that White was also directly involved in the early development of Assam's oil resources[7]. To quote Sir Boverton Redwood, "White's scientific and practical knowledge of the subject, coupled with his long experience, has been of the greatest service in connection with petroleum work". It was a great tribute from one who was himself a distinguished oilman[8]. It was undoubtedly at White's insistence that the prospectus clearly stipulated that the railway line should run as close as possible to the oil seepages of Borbhil and Makum.

Construction of the railways began in January 1882 under the overall supervision of Benjamin Piercy, a renowned engineer. On-site management was left to his brother Robert and three Italian engineers, all named Paganini. Work began at the Dibrugarh end, and the line to Makum Junction was opened for passenger traffic on July 16, 1883. Meanwhile, construction had progressed northwards from the Margherita end also. On Christmas day 1883 the two lines met at Borbhil in the middle of a dense forest. Borbhil was essentially the future Digboi.

We now jump back a couple of years in history. In 1882, a concession was acquired by the AR & T Co. covering the petroleum rights over 30 sq.mi. at Makum including the area on which Mr. Goodenough had laboured. Owing to pre-occupation with railway construction and collieries and general paucity of funds, it was however only in 1887-88 that the necessary drilling equipment was assembled. Three wells were drilled on the south bank of the Dihing to depths of 110, 216 and 310 ft respectively but no new resources were established.

The Company had in the meantime also turned its attention to the north bank of the Dihing and particularly to the Borbhil area where railway engineers and workmen of a plate-layers camp had noticed oil seeps and had actually lived for months in an atmosphere laden with the odour of oil. The analogy with Makum-Namdang was too strong to be missed. To add colour to geological reasoning, legends were created that an elephant with oil-soaked legs led the men to the salt lick where seepages were prolific. Other stories say that when the engineers were cooking a meal, the ground near the camp-fire suddenly burst into flames from a hidden oil seepage.

Whether influenced by geology or myth, the Company applied to the Government in March 1888 for a licence to extract petroleum in the area now known as the Digboi field. At a time when ecology and environment were unknown words, the Chief Commissioner rejected the application saying that "a proposal that involves the destruction of so much timber of a reserve forest area cannot be lightly entertained". He, however, agreed that if the borings south of the Dihing proved fruitless the application may be reconsidered incorporating suitable safeguards for preserving the forest.

Ignoring this reply, the Company went ahead in 1888-89 with arrangements to drill at Digboi, merely submitting a memorandum to the Viceroy, asking that "all the terms and conditions of the lease or deed concession to be granted by Government may be forthwith considered and definitely decided upon".

The birth-pangs of Digboi Well No 1 had begun.

NOTES AND REFERENCES

1. From ancient writings in the *tai* dialect it would appear that an invading Burmese army saw it earlier in the third week of March 1817 when they camped at Yenankyang (river of kerosine). The descriptions of river systems in *Waisali,* as the frontier regions of Upper Assam were then called, suggest that Yenankyang could be the Namchik River. Familiar with oil in their own country, and more anxious to capture Sibsagar, the army moved on unmindful of what they had seen. The official credit, therefore, still goes to Wilcox.
2. The earlier non-geological writing of the pioneers, mainly military officers on reconnaissance duties or punitive expeditions, are clubbed together below for ease of reference.
   (i) Wilcox, R. Lieut (1832): 'Memoir of a Survey of Assam and the Neighbouring Countries executed in 1825-6-7-8.' *Asiatic Researches Vol. XVII, pp 314-469.*
   (ii) Bruce, C.A. (1836): Report to Government dt. 1st October.
   (iii) White, A. Major (1837): 'Notes' : *Journ. Asiatic Soc. Bengal Vol. VI.*
   (iv) Bigge, W. Lieut (1837): 'Notice of the discovery of coal and petroleum on the Namrup River'. *Journ. Asiatic Soc. Bengal Vol. VI, p.243.*

(v) Griffith, W (1837) : Journey from Upper Assam towards Hookhoom, Ava and Rangoon. *Extract from selection of papers regarding the hill tracts between Assam and Burmah, Bengal Secretariat Press.*

(vi) Jenkins, F.Capt. (1838): Political Consultations, India 28 March Nos.44-45.

(vii) Hannay, P.S.Capt.(1845): 'The Assam Petroleum Beds' *Journ. Asiatic Soc. Bengal Vol. XIV, p.817.*

(viii) Dalton, E.T.Capt.(1854): Revenue *Proceedings* Bengal : 27 July No.204.

(ix) Miscellaneous: *Revenue Proceedings Bengal*: 27 July No.18 of 1854 deals with the application for lease by Wagentreiber and disposal thereof.

3. Makum (originally Makoom), which means meeting place in a Singpho dialect, is basically today's Margherita plus an area to the southeast upto the Namdang River. It is not to be confused with the much better known Makum 5 miles east of Tinsukia, which is a railway junction where the Dibrugarh-Sadiya line and the Dibrugarh-Digboi-Lekhapani line part company.

4. Medlicott, H.B. (1865): 'The Coal of Assam; results of a brief visit to the Coalfields of that Province; with Geological Notes on Assam and the hills to the south of it' *Mem. Geol. Surv. India, Vol.IV, pt.3, pp.387-442.*

5. (i) Godwin-Austen, H.H. (1874): 'Geology of parts of the Naga Hills and Manipur' *Rep. Surv. Gen. Ind.pp.79-84.*

(ii) Hughes, T.W.H. (1874): 'Petroleum in Assam' *Rec. Geol. Surv. India, Vol.VII, pt.2.*

(iii) Mallet, F.R. (1876): 'The Coalfields of the Naga Hills bordering the Lakhimpur and Sibsagar Districts, Assam' *Mem. Geol. Surv. India, Vol. XII pt.2, pp.269-363.*

(iv) Oldham, R.D. (1883): 'Report on the geology of parts of Manipur and Naga Hills'. *Mem. Geol. Surv. India, Vol.XIX, pt.4, pp.217-242.*

(v) La Touche, T.H.D. (1886): 'Geology of the upper Dehing Basin in the Singpho Hills' *Rec. Geol. Surv. India, Vol. XIX, pt.2, pp.111-115.*

6. Gawthrop W.R. (1951): 'The Story of the Assam Railways and Trading Company Limited, 1881-1951' *Harley Publishing Co. Ltd., London.*

7. Berry White was not the first medical man to venture into and gain expertise in the realms of geology and geomorphology. J. M'Cosh who wrote the first authentic topography of Assam in 1837 was an Assistant Surgeon. His superior officer, James Ranken, had a spell in the Naga Hills and wrote 'natural resources' notes before becoming Secretary of the Medical Board in Calcutta. Science and the scientific temper certainly had a more generous, and less compartmentalized, meaning in those days; however, there is no record of a geologist having performed an appendectomy.

8. Sir Boverton Redwood (1846-1919) was a leading oil consultant in the U.K. to several public bodies and was intimately associated with oilfield and refinery practices in Burma, Assam, Punjab and Baluchistan. A summary of his early work in these areas is contained in *The Journal of the Society of the Chemical Industry,* April 30, 1890, pp.359-370. He was part-time Consultant to The Burmah Oil Company Ltd. from 1893 to 1919.

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Uphill and Downhill (1890–1920)

The successful completion of Digboi Well No. 1 was yet another feather in the already overloaded cap of the AR & T Co. To commemorate the event, or perhaps coincidentally, a railway station was built at Digboi preparatory to dismantling the old station at Borbhil nearby. Digboi Well No. 2 in the same area began in February 1891 and was abandoned as dry at a depth of 720 ft.

In 1892 providence, which has frequently played a decisive role in the oil industry, converted Well No. 3 from despair to hope. Arrangements were in hand to abandon this well and Mr. Slack, Senior Engineer, had gone to Margherita to make equipment and other arrangements for Well No. 4. His brother, not having anything else to do and presumably fed up with the mosquitoes and croaking of frogs, decided to drill a few feet deeper in Well No. 3. He had scarcely been at work for half-an hour when he struck a reservoir and the oil gushed up 40 ft. and nearly engulfed him and his men. Well No. 4 drilled to a depth of 910 ft. also proved to be successful and by 1893 there were ten wells yielding oil.

The year 1893 was marked by three significant events. Negotiations with Government were finally concluded with the grant of the Digboi concession to the AR & T Co. Also, an adjoining concession to the north was granted to the Assam Oil Syndicate and they drilled several wells from which modest but short-lived production was obtained. Finally, a small refinery was built at Margherita and for 6 years, Digboi oil was sent there by rail in tank wagons.

The drilling activities of the AR & T Co. progressed satisfactorily with 11 wells yielding oil in 1894. It would appear that the siting of these wells was more instinctive than on any scientific basis, but since they produced oil no inconvenient questions were asked. The Chief Commissioner of Assam Sir Henry Cotton visiting Digboi in 1898 observed : "The sight of 4 jets spouting black oil to a height of not less than 70 ft. was a striking spectacle".

The Directors of the Board of AR & T Co., however, had the vision to recognize that the oil business was a full-time business which could not be mixed up with timber, coal, railways etc. and that a separate organization was essential to manage the Digboi and Makum

fields. Accordingly, a new Company, the Assam Oil Company (AOC) was promoted in 1899 with a capital of £310,000 to take over "the petroleum interests of the AR & T Co. including the Digboi and Makum concessions". There was a common Chairman, Lord Ribblesdale. The General Manager and the Agent were also common, but the Boards were separate.

The new Company inherited 14 producing wells with a total production of 2000 gallons per day (50 barrels of oil per day, bopd). Confident of its destiny, a prospectus issued by the AOC in 1899 says "As evidence of the remarkably prolific character of the Digboi Field it should be mentioned that out of the 15 wells drilled only one has been unproductive, and that one would almost certainly have yielded oil if it had been carried deeper. It will be seen that the Field is a most valuable one".

Almost immediately after coming into being, the AOC expanded the concessional area of the Field by purchasing the rights of the Assam Oil Syndicate. A new refinery was built at Digboi and the romantic, if creaky, journey of Digboi oil to the Margherita refinery declined and finally ended with the dismantling of the latter in 1902. In 1904 the Civil Surgeon of Lakhimpur was appointed as "the Officer by whom the sample of petroleum refined at Digboi Oil Works shall be tested each month".

The integration goal of the A.R. & T Co. was rapidly attaining fulfilment. The railway line was completed and the collieries opened by 1884-85. At the same time river transport was stream-lined (no pun is intended) by commissioning 5 steamers and 16 flats. Oil was struck at Digboi, saw-mills were established at Margherita and a brick-works set up at Ledo. The Makum (Assam) Tea Company came into being in 1892. Small wonder, therefore, that in a lengthy note dated Sept. 24 1898 to the Government of India the Chief Commissioner of Assam wrote that "without the great work of the A.R. & T Co. there would have been no Borjuli tea, no Margherita settlement, no Digboi oil and no Makum coal".

Thus at the turn of the century, AR & T/AOC were on top of the world. While visiting the area on March 7 1900 the Viceroy, Lord Curzon, observed "I find here a most interesting and enterprising corner of Her Majesty's Dominions". Pride of accomplishment was further inflated when the first batch of kerosine oil made in the new refinery was symbolically released to the market in December 1901. There was now genuine native oil for the lamps of India.

In 1903/1904, A.B. Hawkins took over as General Manager of the AOC and shifted his headquarters decisively (as against the off-on procedure of previous years) to Digboi. This signalled a somewhat distinct severance from the AR & T Co. though the latter still had substantial shares. Hawkins started his job with energy and enthusiasm despite a wind-storm which badly damaged the Refinery in 1903, and endless trouble in obtaining and retaining labour[1].

The early wells of the Digboi Field were drilled by the percussion system using pole tools. This was subsequently modified by the substitution of wire-line for poles in the lower portion of the deeper wells. Shortly afterwards, poles were entirely discarded and cable drilling adopted as standard.

In 1912 the rotary system was introduced, Well 47 being the first well to be drilled by this method. It was an immediate success.

Several wells in northeastern Digboi were commenced by rotary and finished by cable tool.

Well records were faithfully kept though English was not always a strong point. A requisition for 6 pairs of men must have driven the then Labour Superintendent, or whatever he was called, crazy. In his delirium he would have had the companionship of the rig engineer who had to deal with such profound remarks as "all night had to quarrel with the water-swivel".

On the production front, the figure almost trebled from 43 bopd in 1901 to 120 bopd in 1902. Thereafter there was a steady rise to 247 bopd in 1911 reaching a maximum of 435 bopd in 1917.

The First World War (1914-1918) was just a distant thunder for the AOC. There was no involvement in any manner. Great Britain, France and Italy obtained their oil from the U.S and Mexico. Germany got her oil from Romania (Galicia) till such time as the Romanians destroyed their oilfields and thus dealt a mortal blow to hopes of German victory. The war underlined the importance of petroleum with Lord Curzon stating that "the allies floated to victory on waves of oil" and Clemenceau emotionally declaring that every drop of oil was worth as much to France as a drop of blood.

For the AOC, however, this message was apparently lost. The downhill journey had long since begun though it was masked by temporary production gains. After paying due obeisance to the hard work, pioneering spirit and integrity of the AOC one must record with the hindsight of history the inborn lapses that accompanied their growth.

The Company was not entirely devoid of geological knowledge of the field. The west south west-east north east trend of the rocks ("strike") was appreciated and there was a belt of good producers that could have been followed up. Instead, an enormous amount was spent in obtaining worthless ground from the Assam Oil Syndicate.

Sensing that things could go wrong, the Board called for an increase in crude oil supply keeping the capital expenditure down to a minimum. A letter dated May 6 1904 from London warned that "until we treble our present supply there must be no rest to your feet nor slumber to your eyelids". Cold-shouldering geology, the local management opted for a drilling orgy. The circular went forth : " I do not think it matters much to my Board where you drill so long as you drill, but only drill drill and drill anywhere you like and get us oil". The same letter also insisted upon an adequate labour force, irrespective of cost.

In conformity with this policy, there was what may best be described as promiscuous wild-catting with obviously no oil. This wildcat mania was an important contributory factor in the decline of the Company.

It was with a sense of reluctance that drilling in the proved areas was undertaken. Well 19 was spudded in early 1902 and it was almost 7 years later that the next well was started in the proved area. That the Company survived these 7 years wandering in the wilderness is a tribute to the earlier randomly established resources of the Digboi Field. The orginally stated objective was to drill 6 to 7 wells a year in the proved area "and swamp the refinery with oil". It took 10 years to reach the objective of 6 wells per year.

Many drilling problems such as fishing and crooked holes arose due to inexperience. Non-observance of elementary safety rules regarding lighting, dumping of waste oil, open fires and handling of gassy wells led to fires and massive destruction in Wells 5, 20, 21, 25, 27. The Well 5 fire was a particularly warm welcome for a Lieutenant Governor who was on a visit to Digboi field.

About 20 drillers were employed in Digboi and it must be conceded that they were trained well. However, they could not achieve good footage. Later, other drillers came to the Field, all of them Canadians. They laughed at the performance but fared no better.

While the failure to utilize geological reasoning was in a sense understandable[2], what defied comprehension was the nonchalance with which the Board dished out dividends unmindful of dwindling profits.

The same lack of direction and destination underlined the Company's approach to refining. Potential should first have been established in the Fields before giving up the Margherita Refinery and embarking on a new one at Digboi. Records show that even as early as 1904 almost £100,000 had been spent on the Refinery and only a quarter of this sum on the Fields.

Compounding the errors of the Home Board was the near total lack of technical support to a non-technical General Manager in the Fields. The bewildered man viewed every accident as "a piece of bad luck" with apparently no further thought to remedial measures. Regarding casing troubles in Wells 20 and 22 he wrote "everything that can go wrong has done so... and I can give no idea as to what has caused this terrible trouble". And again "it is a terrible climax to a horrible season and I am feeling utterly impotent".

By 1920, by which time the Company had completed 80 wells with a total average production of 350 bopd, the impotence had become all pervasive in both technical and financial aspects. From Burma across the blue Patkai hills, The Burmah Oil Company Limited which had already established a toe-hold in the Surma Valley[3], thought it the right moment to move in.

NOTES AND REFERENCES

1. A.B. Hawkins (1872-1920) demonstrated in his rather brief life a remarkable sense of loyalty and perseverance. Forced out of England due to ill-health at the age of 17, he sailed out to his elder brother who was working in the Railways in Assam and joined the AR & T Co. a few years later. He married in 1902 and continued in Assam despite dangerous bouts of illness. He retired prematurely in 1920 and died at sea while en route to an elder brother in New Zealand (personal communication from his daughter, Mrs. Bruno, to whom I am indebted for the life-sketch).
2. Geologists apparently played no part in the oil exploration activities of the 19th century. Surface seepages were still the prime guide. The Burmah Oil Company was perhaps the first in the industry to have a geological staff of its own as early as 1905/06 and to make consistent use of them for both exploration and development. Across the Atlantic, the attitude was a mixture of mild respect and mild amusement. Charles J. Hares, first geologist of the Ohio Oil Company lamented "I do not remember drawing or seeing a contour map of any field while I worked for the Company ... soon after the Rock River Oilfield came in 1918, I said to Jack McFadyn the Vice-President 'May be we should finally make some contour maps'. His curt reply was 'I'll take care of this field; you go and find another.'"
3. The Surma Valley is a broad belt of low ground about 125 miles long and 60 miles wide, south of the Shillong Plateau and the North Cachar Hills. It is occupied by the Barak River and its tributaries, including the Surma River.

9

Aftermath of Success (1953-1959)

The success at Nahorkatiya was the culmination of a long story of failure, frustration and despair in the oil exploration activities of Upper Assam. It was also the prelude (and, quite conceivably, the trigger) to a string of oil exploration programmes elsewhere in the country.

Shortly after the Nahorkatiya discovery, the Union Deputy Minister for Natural Resources and Scientific Research, Shri K.D.Malaviya, visited the Upper Assam Oilfield areas. The competence, dedication and team- spirit which he saw in the operations must have convinced him that India and Indians could manage the oil business. *To this conviction we owe the beginnings of the national oil industry.* Back in Delhi, he noted with a sense of pride that "the latest oil-wells in Assam were struck under the guidance of an Indian, Shri W.B.Metre" (*Assam Tribune*: 19 June 1955). That this was not a transitory emotion is borne out by the fact that 21 years later, while presiding over the 9th Debenture draw ceremony of OIL on 23 Sept. 1976, Shri Malaviya who was then Union Minister of Petroleum and Chemicals, observed: "We have many things to learn from OIL: their standard of working in the fields, their appreciation of the economics of oil exploration, operating in a situation of optimism.... in its totality, I must congratulate the OIL leadership for carrying on its tasks in the face of difficulties of several types."

Perhaps the most salutary fall-out of the Nahorkatiya discovery was the hastening of the decision to create what was ultimately to become the Oil and Natural Gas Commission (ONGC). As early as 1948 an Industrial Policy Statement had clearly indicated increasing State participation in the commanding heights of economy. Within the next few years, the socialistic pattern of society was adopted and the 5- year planning system switched on. The Industrial Policy Statement of 1956 endorsed and tightened the 1948 resolution and squarely placed oil as a priority Schedule 'A' Commodity[1].

In order to carry out this directive, the Oil and Natural Gas Division of the Ministry of Natural Resources was established in 1955, incorporating a petroleum exploration group which for some time had been working in the Geological Survey. The Division became a Directorate

and subsequently a Commission, working as a department of Government. In 1959 the Commission attained the status of an autonomous statutory body. The coming into being of the ONGC was a particularly significant milestone in the continuing story of the oil industry in India. Between 1956 and 1959 the ONGC had completed a well at Jawalamukhi in the Punjab foothills, established the Cambay and Anklesvar fields (the Anklesvar completion was actually in 1960) and was poised for exploration in other parts of the country; further reference to this activity will be made in a later chapter.

In West Bengal[2], another development was taking place. In 1949 the Standard Vacuum Oil Company, a joint venture of Socony Vacuum Oil Company of New York and the Standard Oil Company of New Jersey was formed for oil exploration in West Bengal. For the first five years the Company ran the show alone, spending Rs. 640 million in the process, and carried out an aeromagnetic survey of approximately 15000 line miles between October 1951 and March 1952. *This was the first survey of its kind in Asia.*

On 24 December 1953 an agreement was signed between the Government of India and Standard Vacuum Oil Company for a joint exploration programme over 10,000 sq miles in West Bengal with Government participation of 25% to a ceiling of Rs 25 million. This was the Indo-Stanvac Project under which extensive geophysical surveys, seismic and gravity, were carried out in 1954-1956 followed by the drilling of 10 wells in 1957- 60. All the wells proved to be dry and the Project was terminated in 1960 (Appendix F).

Reverting back to Nahorkatiya and Upper Assam, the successful outcome of NHK-1 was a triumphant vindication of the geophysical methods of exploration for possible oil-bearing rocks hidden beneath the plains. The discovery signified the possibility, even probability, of the existence of other oil pools elsewhere beneath the Upper Assam alluvium. An immediate resumption of the geophysical work which was suspended in 1939 on account of the war was, therefore, fully justified.

Arrangements were made soon after the completion of NHK-1 for a detailed gravity survey of the whole alluvial area using the improved methods that had then become available, for an aeromagnetic survey and for seismic work in selected areas.

The magnetic survey provided a general picture of the distribution of sediments throughout the whole of the Assam Valley. The gravity survey proved to be disappointing and failed to produce a satisfactory guide to the areas which were worthy of serious investigation by seismic survey. In consequence, the seismic survey had to be far more extensive than expected, but the reconnaissance survey and much detailed work had been completed by 1954 when the geophysical licence expired.

In accordance with the terms of the guarantee given by the Assam Government in 1937, the Assam Oil Company, before the expiry date, applied for prospecting licences over 2516 sq. miles within the alluvial area. Meantime, drilling continued at Nahorkatiya and several producers were satisfactorily completed. A prospecting licence had already been issued for the Nahorkatiya Extension Area in 1953. In 1955 licences were issued for the Hugrijan area

and for Moran, about 30 miles southwest of Nahorkatiya. A well was drilled at Moran and completed as a producer in October 1956. By 1957, the seismic survey of the areas for which prospecting licences had been granted was complete.

At this stage it would be pertinent to point out that the forties and fifties were witness to a great intellectual adventure in several spheres of the oil industry in Assam. Some of the work on strata correlation, mud engineering, handling of produced fluids, etc. were of pioneering nature and set world standards in excellence. Many Indians were associated with these achievements (see Appendix E) and the expertise they had gained contributed to the Nahorkatiya discovery. And after the discovery it contributed to the development[3].

The latter contribution was truly impressive. Nahorkatiya was discovered in 1953 when the science of reservoir engineering was entering into adolescence. By 1956 only 16 wells had been drilled and the evidence suggested a subsurface broken into blocks by a criss-cross of faults which could have acted either as barriers or conduits to oil movement. Despite this meagre and disquieting evidence, the geoscientific team headed by W.B. Metre and A.B. Das Gupta could announce in September 1956 that 'the proved and probable reserves in the Nahorkatiya area ... are sufficient to plan a production target of nearly 2.5 million tons of oil per year with 45 million cubic feet of gas per day'. This forecast was a courageous declaration at the end of a strenuous geoscientific exercise to which, of course, was added the inevitable hunch factor. And all this within 3-4 years of the discovery. On the basis of this assurance, which was fortified later in the year by new discoveries at Hugrijan and Moran, the erection of a public sector refinery with help from Romania began at Guwahati in 1959. The refinery was commissioned in 1962.

To ensure that the tradition of excellence would be maintained in the development of the Nahorkatiya discovery, several qualified young men from foreign and Indian Universities were recruited in the 1953-59 period. Amongst others, these included R. Mitra, K.P. Gupta, S. Chaliha, C. Ratnam, B.D. Datta in the geosciences; B.K. Bhattacharyya and C.G. Banerjee in chemical; H.L. Khushalani, A. Chandwani, D.K. Chanda in drilling; and, A.K. Sarma, R.K. Barooah, S. Palit, K.N. Ramchandani, P.D. Kataria in engineering departments. In a marked departure from the managerial practice of that era, these young men were given responsible assignments from the start of their career and they invariably proved worthy of the confidence thus reposed in them.

All of the heavy workload of exploration and drilling following the Nahorkatiya discovery obviously meant the building and/or upgrading of roads, bridges, culverts, embankments etc. for the safe movement of heavy oilfield traffic. It was, however, still too early to think of building a township, so Digboi continued to be the main base. A South Bank camp near Nahorkatiya town housed the personnel immediately concerned with drilling of the first few wells.

In 1954 Barua Camp was built at the Field on the north bank of the Burhi Dihing River as a temporary local headquarters to cut down on commuting from Digboi. Land for the camp

was acquired from Tankeswar Baruah who had started his career with the AOC and then migrated to the greener pastures of contracting. The camp consisted of a few houses and two-roomed residential bungalows built in the Assam-style with rush walls and grass thatch. Despite their flimsy appearance, these buildings have withstood over 40 years of beating by heavy monsoons. Some of them were destroyed to make way for a new oil-collecting station but many are still inhabited after minor repairs.

The Barua Camp had the usual cheerful retinue of snakes, cockroaches and assorted insects. At nightfall, the only prominent sounds were those of the jackal and the owl. At times, the music of Mohammed Rafi and Lata Mangeshkar filtered through the traffic noises from Basanta Cinema House as if to invite the inhabitants of the Camp to the next show. The Camp was on low-lying grassy terrain and the water-table was never far from the dining table. Virtually every monsoon it was a question of wading or rowing into one's house.

Around this time it was also decided to construct a 24-mile long road through the thick Dihing Reserve Forest to link Digboi with the Nahorkatiya Field. The new road would replace the twice-as-long poor quality road via Tinsukia. Work began in August 1953. At the Digboi end was a 7.5 mile jungle track which originally accommodated a light railway serving the oil-drilling operations many years earlier. Following this, was 2.5 miles of an ancient 'ali' (highway of the Ahom Kings). These 10 miles were cleared, widened to 16 ft and strengthened. Much of the remaining 14 miles lay in thick uncharted jungle and assorted bush country. With a massive effort from the Digboi and Nahorkatiya ends as also from the centre of the spread, the road was carved out in 8 months time. On June 16, 1954 Peter Williams an assistant engineer of the AOC had the distinction of being the first person to drive down the entire length of the road. A vital link had been established in the industrial life of Upper Assam. This was fortified by the opening of the telephone link on July 1, 1954.

The success of Nahorkatiya Well No.1 set in motion a series of field activities, one of the most important of which was the release of new locations for follow-up drilling. The geologist and civil engineer of today would be surprised to learn that within a year of the Nahorkatiya discovery, locations had already started posing problems. A technical writing of April 1954 laments : 'Upto the present we have had scope to move locations to get on to good ground; shortly, this will have to stop and the number of unavoidable bad locations will increase. Though we shall try to do much in the cold weather as possible, this will not always be practicable.....'. The writing concludes with the advice that 'sand and silt from the river makes an admirable fill; the contrast between No 2 plinth (clay) and No.3 (river sand and silt) in the recent heavy rains was remarkable'.

The acquisition of land was in most instances a sensitive and emotionally wrenching experience. In overcoming the difficulty, patient negotiations with land-owners, village elders and the local civil officials conducted well in advance, paid off making it unnecessary in most cases to resort to the lengthy and unpopular process of compulsory acquisition. This was an important aspect of the early development programme, for the goodwill of a population drawing its livelihood from the land was an essential pre-requisite to the launching of the large-scale works that were to follow.

The same methodology of tact and tolerance paid rich dividends in the Moran Field where, as mentioned earlier, oil was struck in 1956.

While these oilfield activities continued in the heat and dust and swamps of the Valley, the winds of change were blowing at the higher echelon. Bowing to these winds, the Burmah Oil Company Ltd. signed a Promotion Agreement with the Government of India (GOI) in January 1958 to form a Rupee Company to take over the management of the AOC-discovered fields of Nahorkatiya and Moran. The new Company, known as Oil India Private Limited (OIL), was incorporated on 18 February 1959 with the BOC holding two-third of the shares and GOI one-third. The agreement contained the assurance that Burmah would get a guaranteed dividend of 10% and OIL would supply 1.3 million barrels of oil per year to Digboi Refinery. Mr. W.P.G. Maclachlan, who played a decisive role in the negotiations, became the first Chairman of OIL.

On the day of incorporation, which was celebrated with much pomp and ceremony at Duliajan, the underground assets of the Company consisted approximately of 260 million barrels (40 million tonnes) of gross ultimate recovery of which about 193 million barrels (30 million tonnes) under the category of proved oil reserves.

On 27 July 1961, the Government of India share holding in the Company increased from one-third to one-half and a 50:50 partnership, destined to endure for 20 years and to become an example and an inspiration to the joint sector concept, came into being. At the beginning of 1962 J.C. Finlay, grandson of Kirkman Finlay, became the Chief Representative of the Burmah Group in India as also the Managing Director of OIL. As deputies he had men of exceptional calibre, G.N.S. Robertson and V.W. Good, who helped him keep the BOC culture alive and well in Delhi. Under the Finlay regime, the process of Indianization was accelerated; it climaxed with the appointment of A.B. Das Gupta a renowned geologist and administrator with 28 years of service in BOC/AOC/OIL as Managing Director on 5 November 1969.

It was also fortunate that in the formative years, the Chairmanship of OIL was held by distinguished personalities drawn from the political and social life of the country. These included Sarvashree Khandubhai K. Desai (1961-68), Dev Kanta Barooah (1968-71), Sarat Chandra Sinha (1971-72), Sriman Prafulla Goswami (1972-74) and Raja Ajit Narayan Deb (1974-76). Their presence at the helm provided the stability and that atmosphere of tolerance and adjustment between the two partners that led Mrs. Indira Gandhi to remark that "OIL is a fine example of the co-operation between the public and private sectors".

The new Company quite understandably sought to establish its own identity away and apart from Digboi. The search was started for an area near to or in the heart of oilfield activity where a township and industrial complex could be set up. The search proved to be unexpectedly easy. A large tract of land, with satisfactory natural features and close to the railway station of Duliajan, was available. The land belonged almost entirely to the Zaloni Tea Estate and its acquisition was effortless since only one owner was involved.

After obtaining the land, clearance work started. Records show that in the process, 4 leopards and 2 tigers laid down their lives. It was bush country and Duliajan had to grow out

of nothing. Provision had to be made for schools, hospital, recreation and all the other needs of community life. There was more than ample space; what was required was that special blend of aesthetics and engineering.

Abandoning architectural sophistication, the planners settled for 5 basic types of bungalow design. They then set out to make wide roads, parks, flowering trees in the 590 acres set aside for housing (this figure presently stands at 743 acres). In this "pleasantness" process they were aided by the counsel and guidance of Enid Hawkins who had a life-long love affair with flowers and plants and Dr. N.K.A. Iyer, G.M. of AR & T Co. who helped make the general layout plans. Building material was obtained by the railway which was running through Duliajan since 1905 although the actual siding was built only in 1912. The Company encouraged private businessmen to manufacture bricks from local clay by making natural gas available to the kilns. Brickworks were thus established and as work for the new township tailed off, other markets were found.

The first priority in the building programme was, of course, on the operational and administrative side. This included, besides the office buildings, an industrial complex spread over 131 acres (exclusive of the 35 acres since occupied by the LPG plant) and a water-treatment plant for both industrial and domestic purposes. At the same time, streets and sites were prepared in the "Settlement Area" where employees could build their houses to a standard design with liberal assistance in cash and kind from the Company. All the houses have good gardens in which vegetables thrive in Assam's fertile soil to supplement household food supplies and reduce dependence on the market.

The OIL market came up in 1961, the Duliajan Club in 1962, the Zaloni Club in 1968 and the general office in 1968-69.

The township which was so painfully carved out of the jungle had to have a name. Zaloni was lovely but it could have led to serious postal and communication complications vis-a-vis the tea-estate. And so the name of the railway station, Duliajan, was selected. Various stories exist regarding the origin of this name; the most plausible one is that it was the camp or settling place of the Dhulias, the palanquin bearers of the Ahom Kings. And since a stream or *jan* flows nearby, the explanation is complete. Actually, there exists the village of Duliagaon on the western side of the railway line opposite the industrial area.

Today, the new Duliajan has a population of about 75,000 from all over India. There are adequate educational, medical and recreational facilities and a fine scope for social and cultural expression.

The transformation of Duliajan from forest to metropolis was accomplished without creating any major trauma to the population of the adjoining and neighbouring areas. This is a tribute to the patience, tact and compassionate understanding of those who guided the destinies of OIL at that point of time.

NOTES AND REFERENCES

1. Like all winds, it started as a breeze with the Industrial Policy Resolution of 1948 which divided industries into three categories:

(i) exclusive monopoly of the State like atomic energy, defence;

(ii) six industries in which the State took the responsibility for the establishment of new undertakings without disturbing the old such as coal, iron and steel, telephones, petroleum etc.; and,

(iii) broadly controlled private enterprise in respect of 18 industries such as textiles, rubber, sugar, cement etc. Foreign investment was still welcome in the field of oil exploration and refining, and assurances were given that such investment would be accorded rational treatment. This was reiterated in an official policy statement by the Prime Minister on 6 April 1949. Two years later, the Industrial Development and Regulation Act, 1951 laid down specific guidelines for controlling private sector enterprises.

At the 60th session of the Indian National Congress held at Avadi on January 21-23 1955, the Socialistic pattern of society was adopted as India's natural destiny. The Industrial Policy Resolution of 1956 correspondingly reflected a hardened attitude. Increasing state intervention was envisaged in all sensitive industries and restrictions were placed on foreign investments, collaborations and pricing policies. It was the historically inevitable and logical assault on "the commanding heights of economy".

2. For the sake of geographic and geological continuity, West Bengal is included in northeast India.

3. In this context, one is strongly tempted to quote Buckminister Fuller (1893-1983) : 'Development is programmable; discovery is not. Discovery.. is a flash of transcendental light comprehensible to exquisitely prescient minds. It requires a little bit of creative insanity'.

Structural Evolution of the Northern Assam Basin: A Case for a Dynamic Hydrocarbon System Model*

By

W. Norman Kent[1]

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Click to view presentation in PDF format (~2.7mb).

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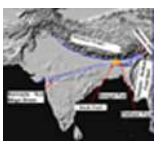
Abstract

The upper Assam basin is an intermountain basin surrounded on three sides by fold and thrust belts. The area is known as one of the most seismic active areas of the world. It has experienced two of the largest earthquakes in recorded history. Upper Assam basin is also the home to two of the world's largest oil and gas fields. These two superlative characteristics of the basin suggest the temporal nature of oil and gas accumulations and underline the significance of viewing petroleum systems as dynamic processes as opposed to static entities.

An integrated regional study was conducted part of a petroleum exploration program of the Jaipur anticline area. In this study, structural modeling and sequence stratigraphy techniques were used to define the stratigraphic and structural evolution of the basin and to relate that geologic history to timing of maturation and migration of hydrocarbons.

During the study, regional unconformities, recognizable on geologic maps, seismic profiles and well logs, were identified. Mapping truncation of formations at each of the unconformities and construction of isopach maps provided insight into the development of regional structural features. Maturity data for the source rocks in the basin indicate that hydrocarbon generation began as early as mid-Oligocene, with a major pulse occurring in late Miocene. These data also show that the source rocks are now at peak maturity for oil generation in parts of the basin. This interval of hydrocarbon generation includes nearly the entire time in which the region evolved from an extensional plate margin to an intermountain basin between two orogenic belts. Sustained hydrocarbon generation throughout a complex structural history implies a complex history for migration and accumulation of hydrocarbons in the basin.

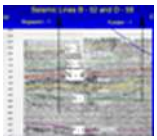
Selected Figures



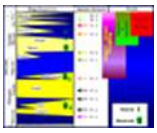
Tectonic setting, upper Assam basin between Assam-Arakan fold belt and Himalayan orogen.

Assam-Bengal basin.

Upper Assam Valley oil fields.

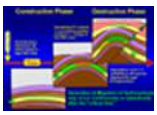


Seismic markers and relative dating.



Stratigraphic-structural event chart.

Oil field characteristics.



Dynamic hydrocarbon system.

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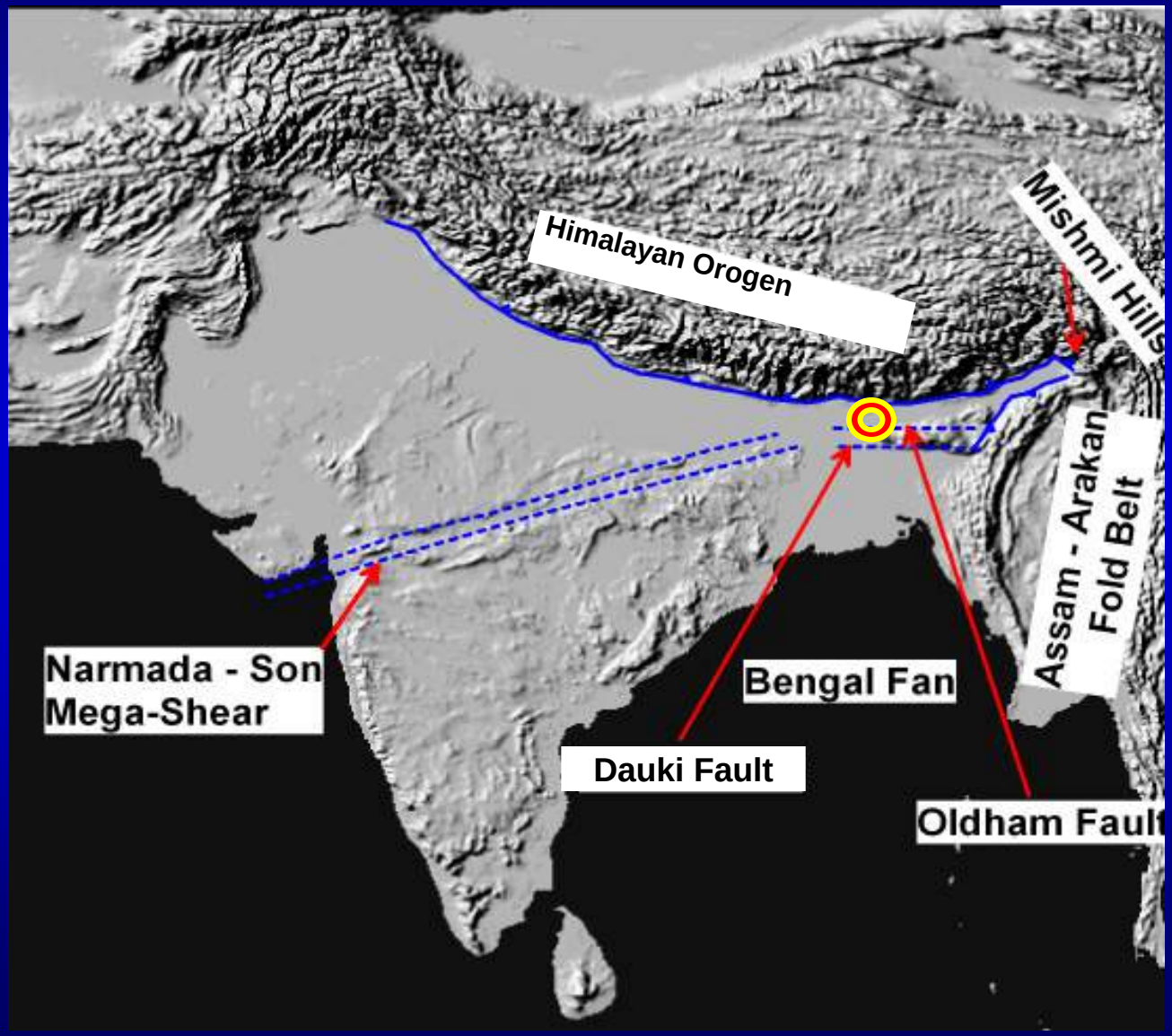
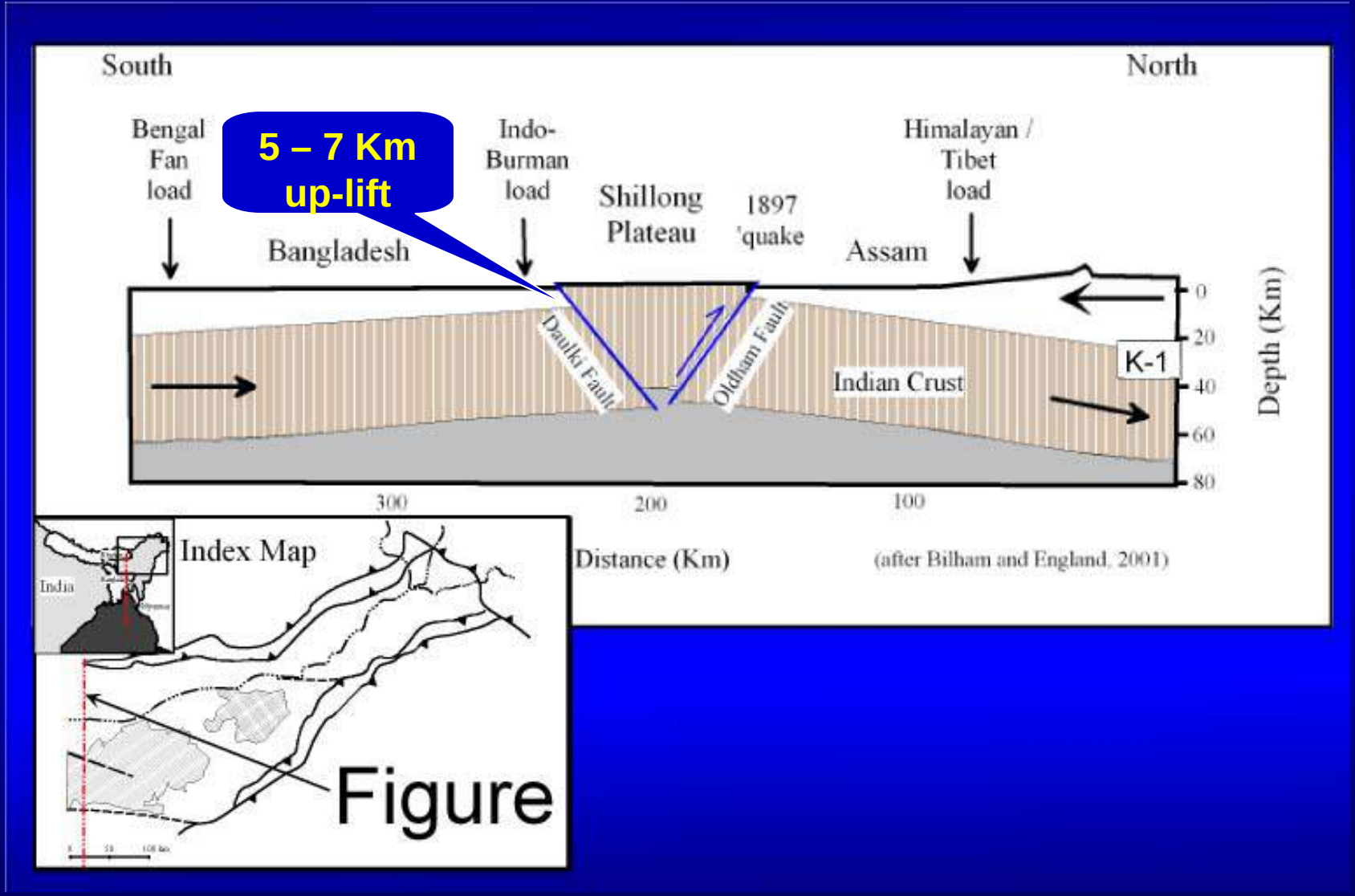
Outline

- Basin Tectonics & Regional Geology
- Questions
- Basin Structure and Stratigraphy
- Geologic History
- Oil Field Characteristics
- Hydrocarbon System Model

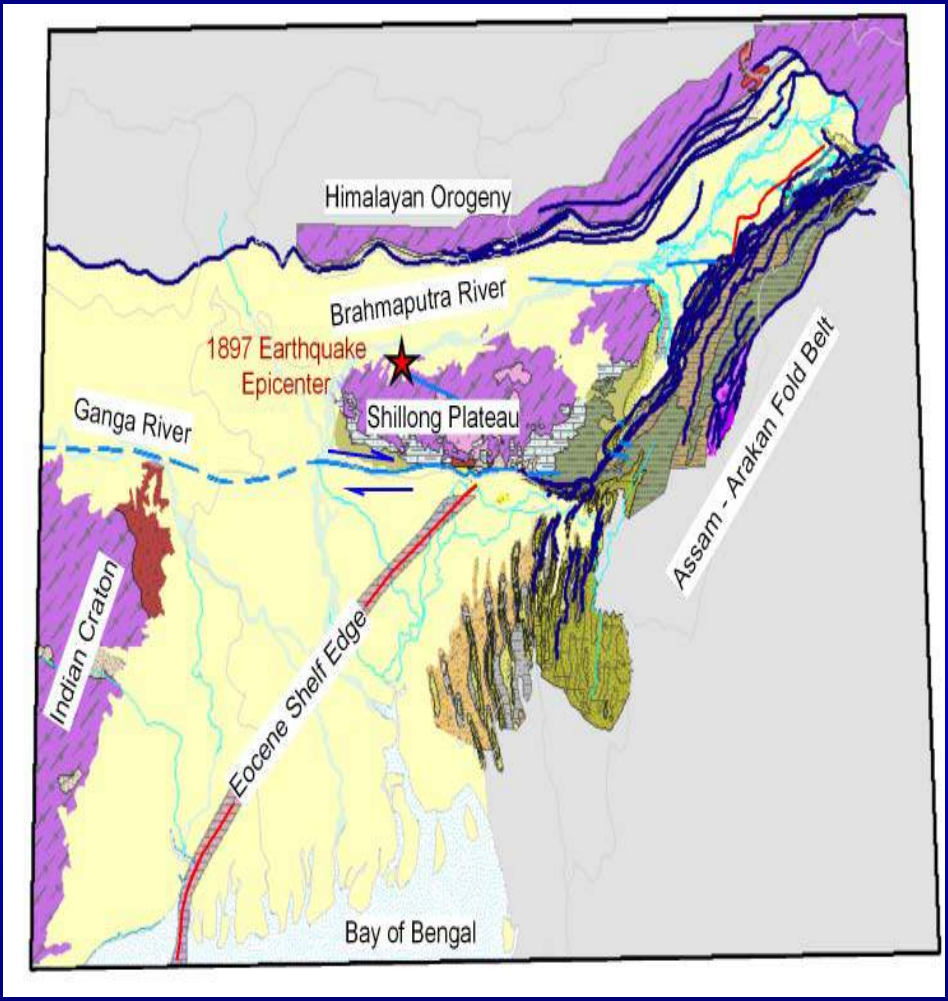
Tectonic Setting

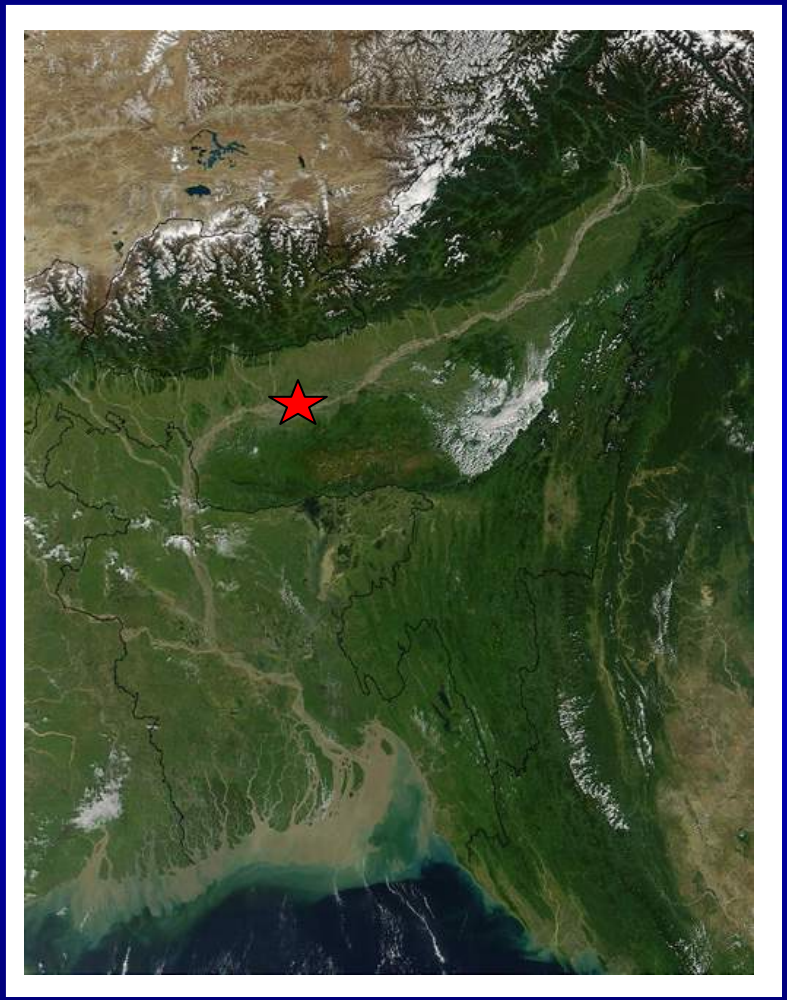


Regional Cross Section



Assam – Bengal Basin





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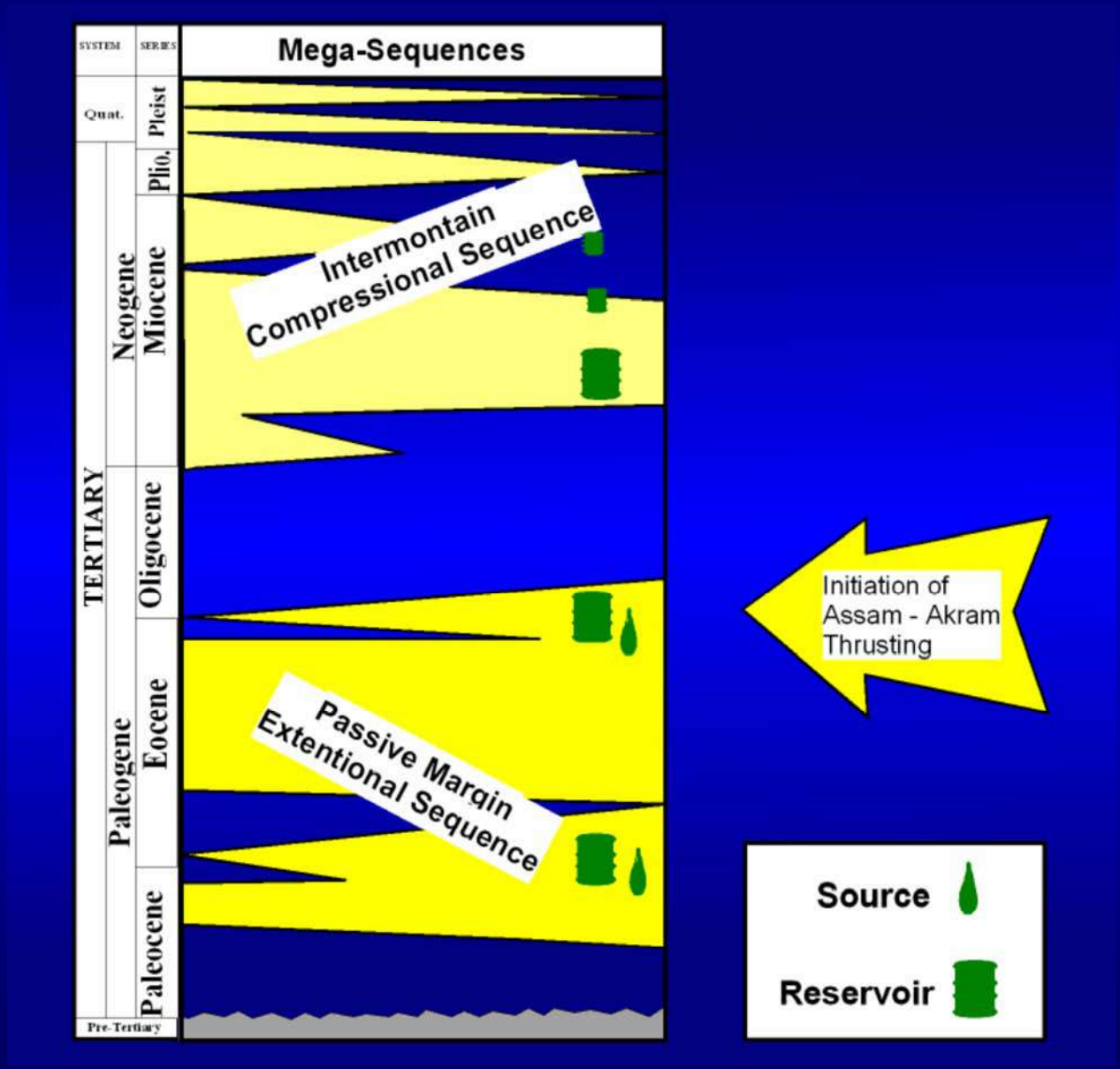

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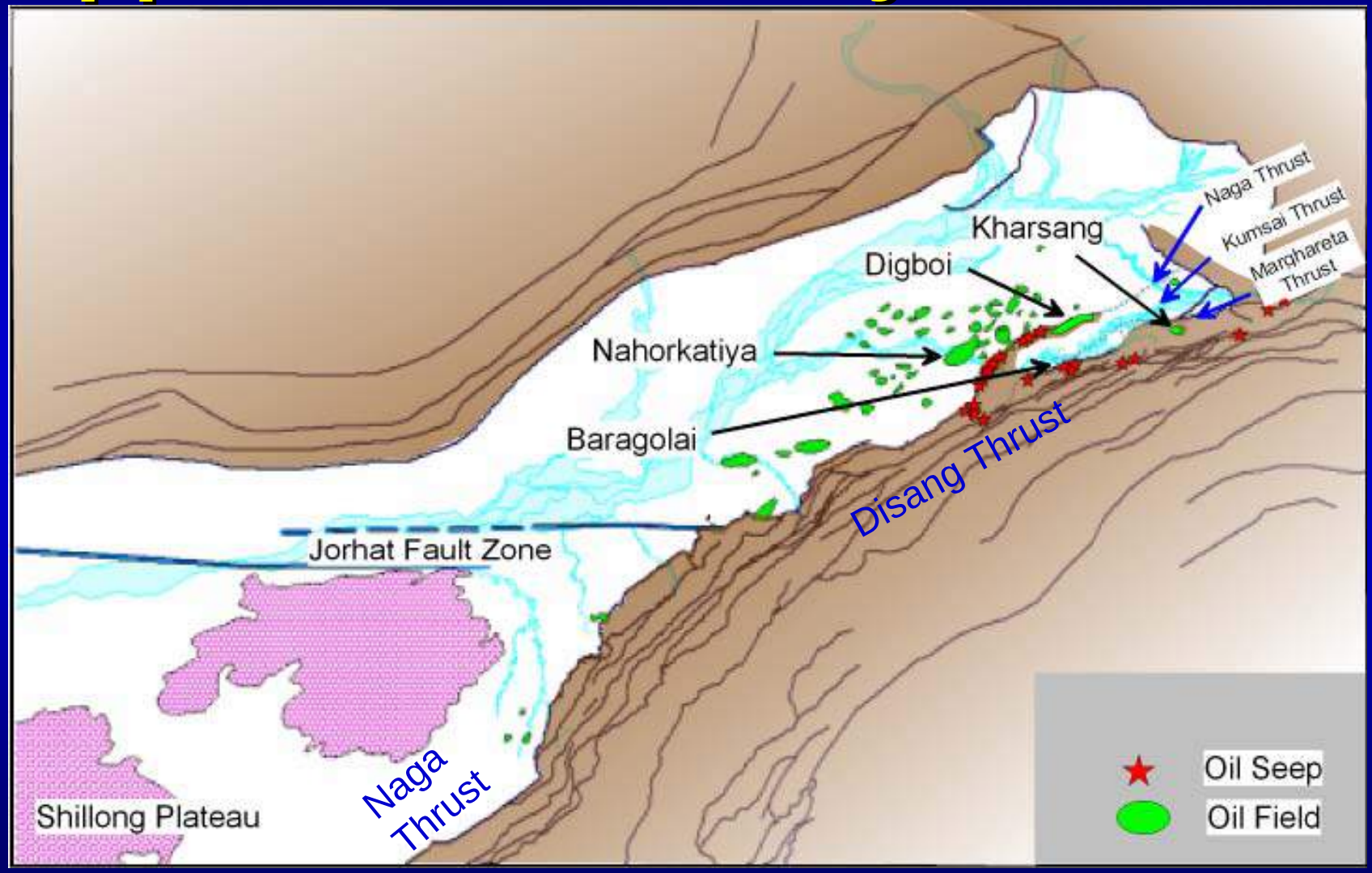

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Basin Stratigraphy
&
Structure

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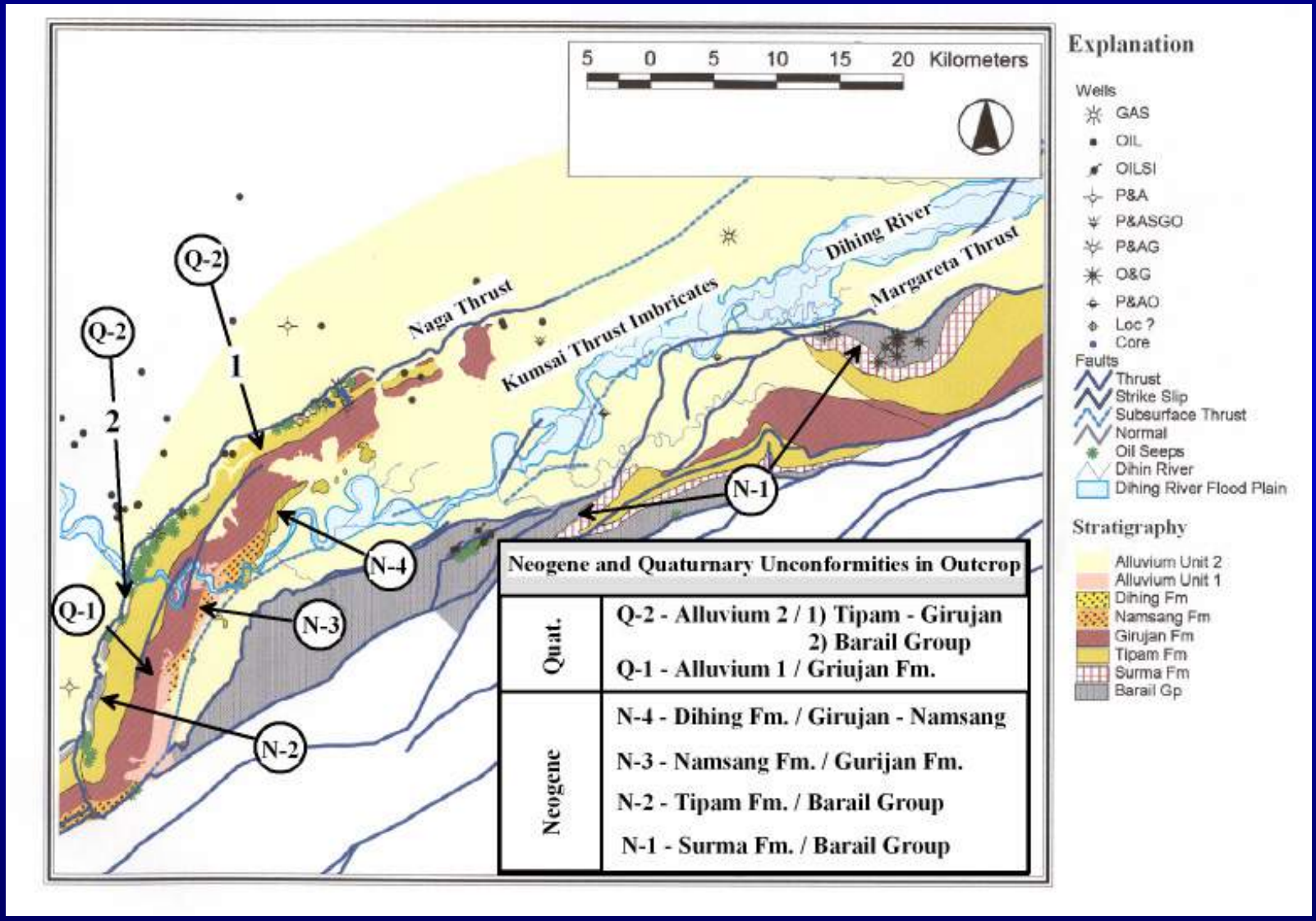

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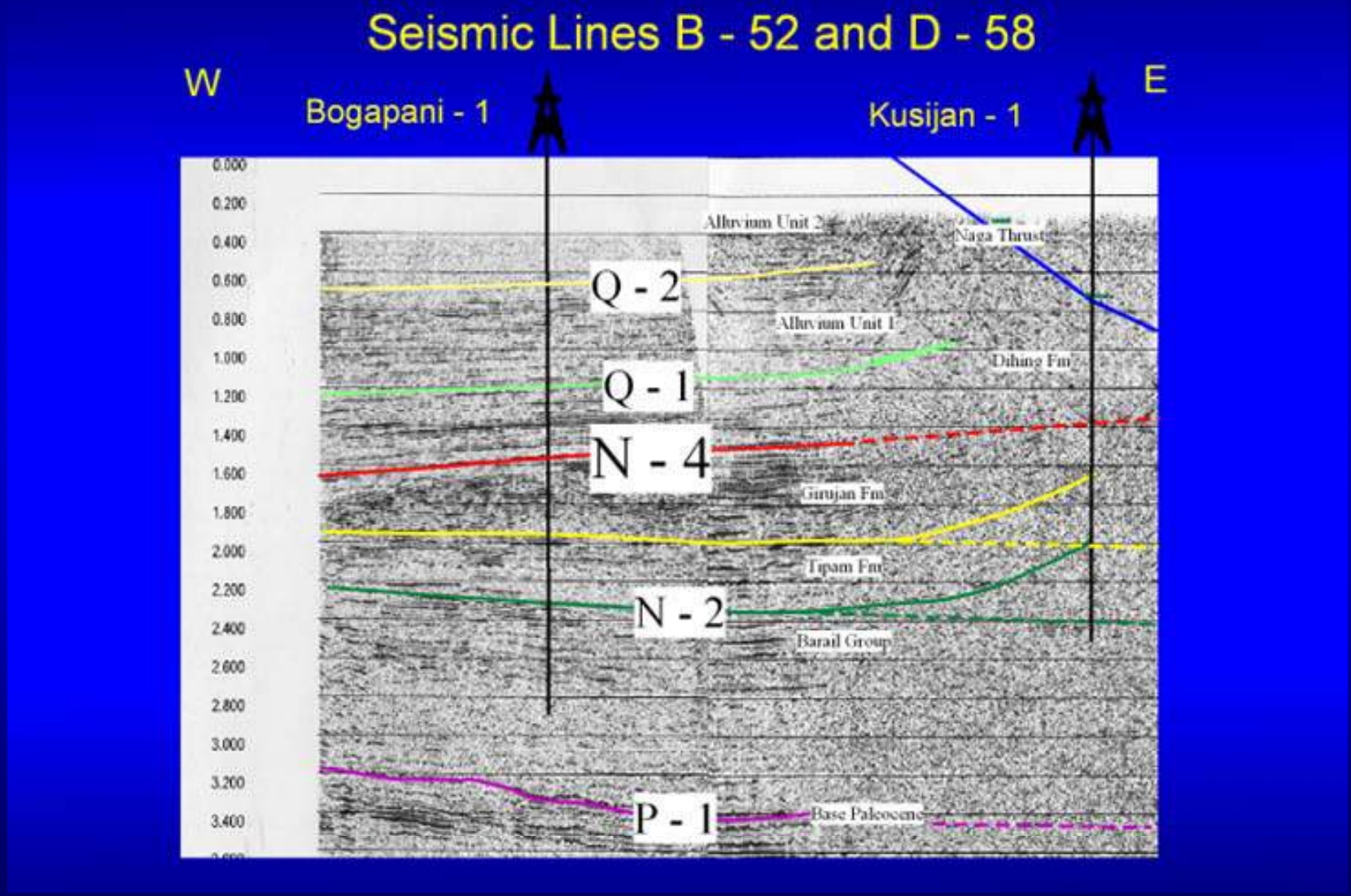
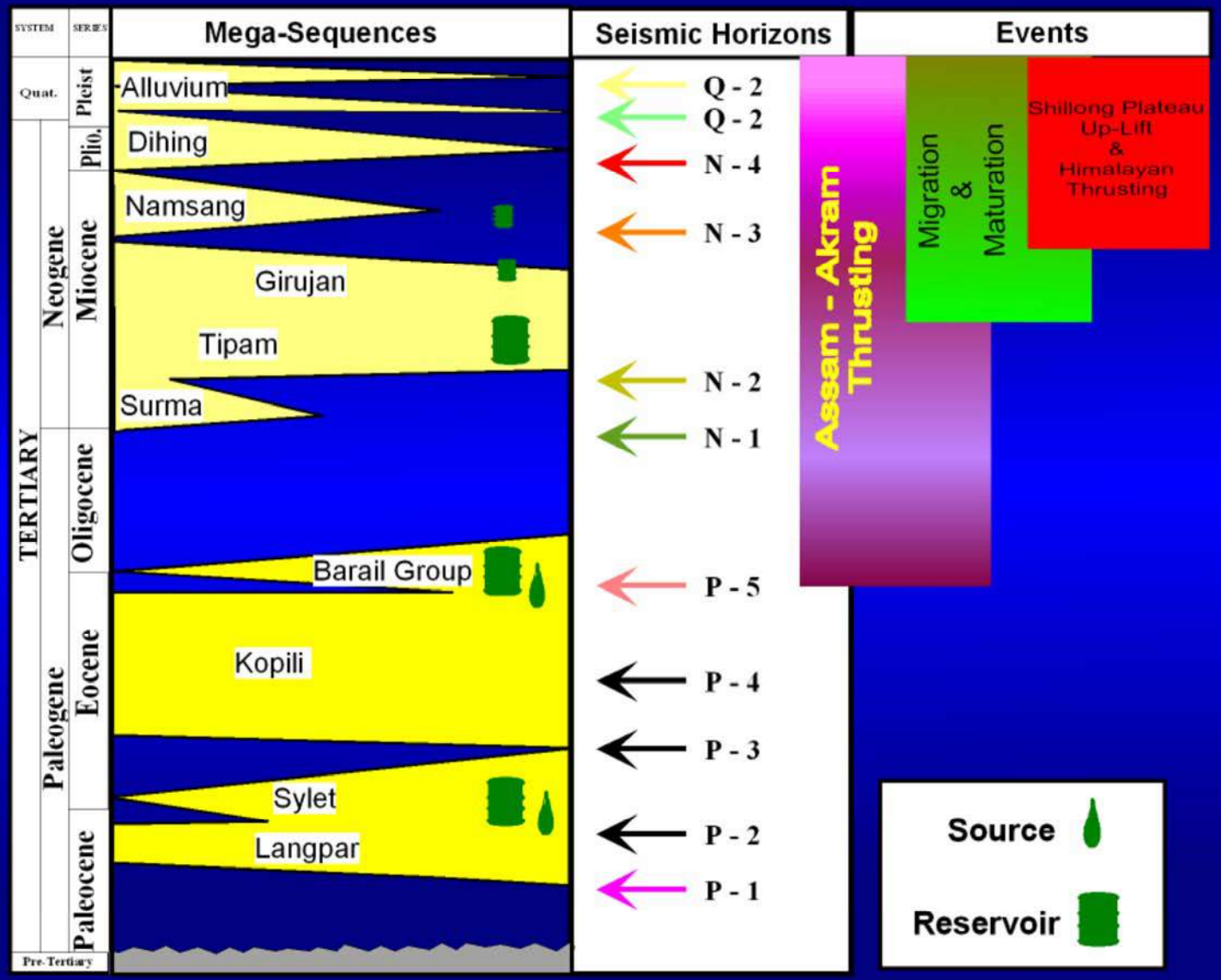


Strat - Structure Event Chart



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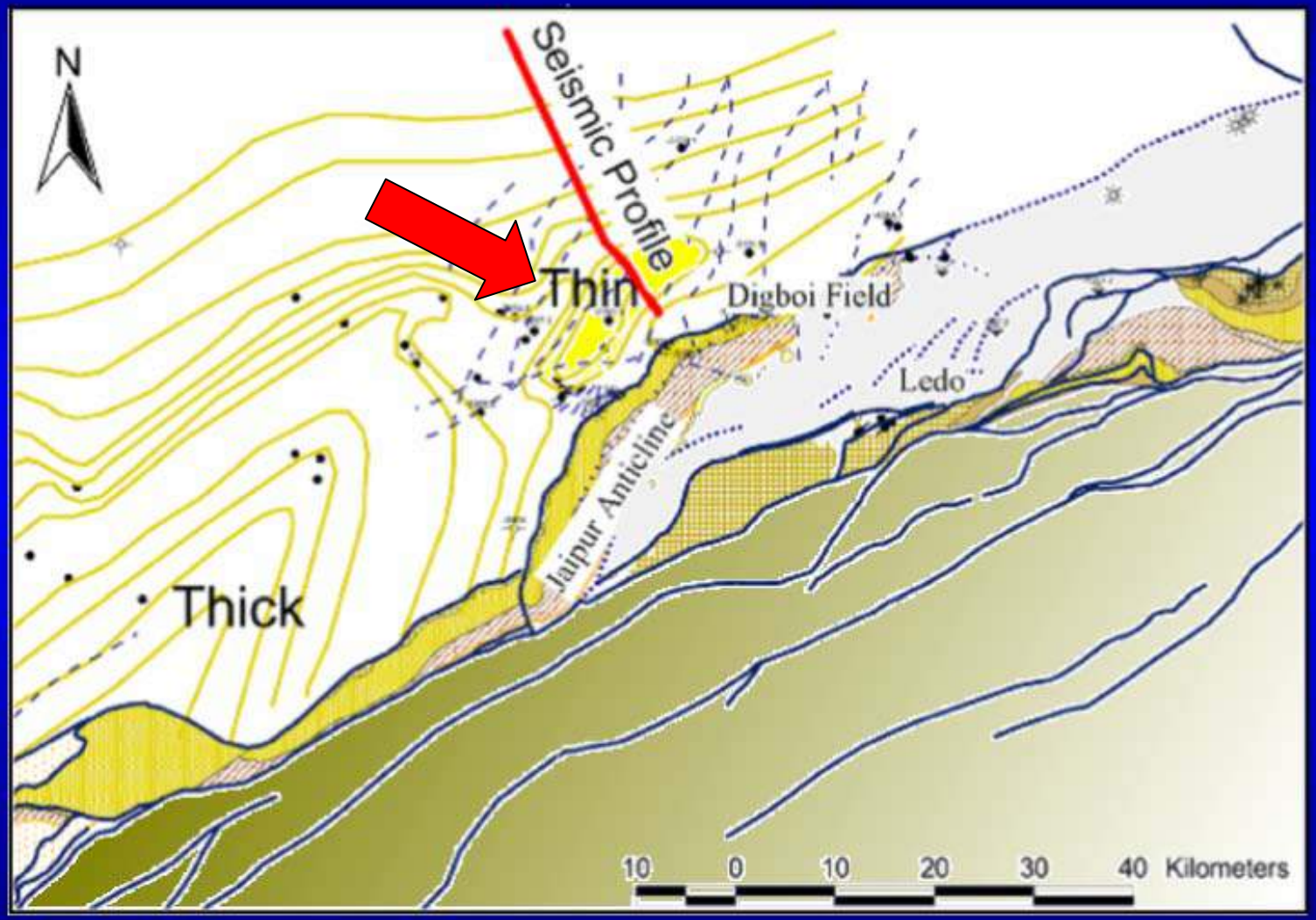
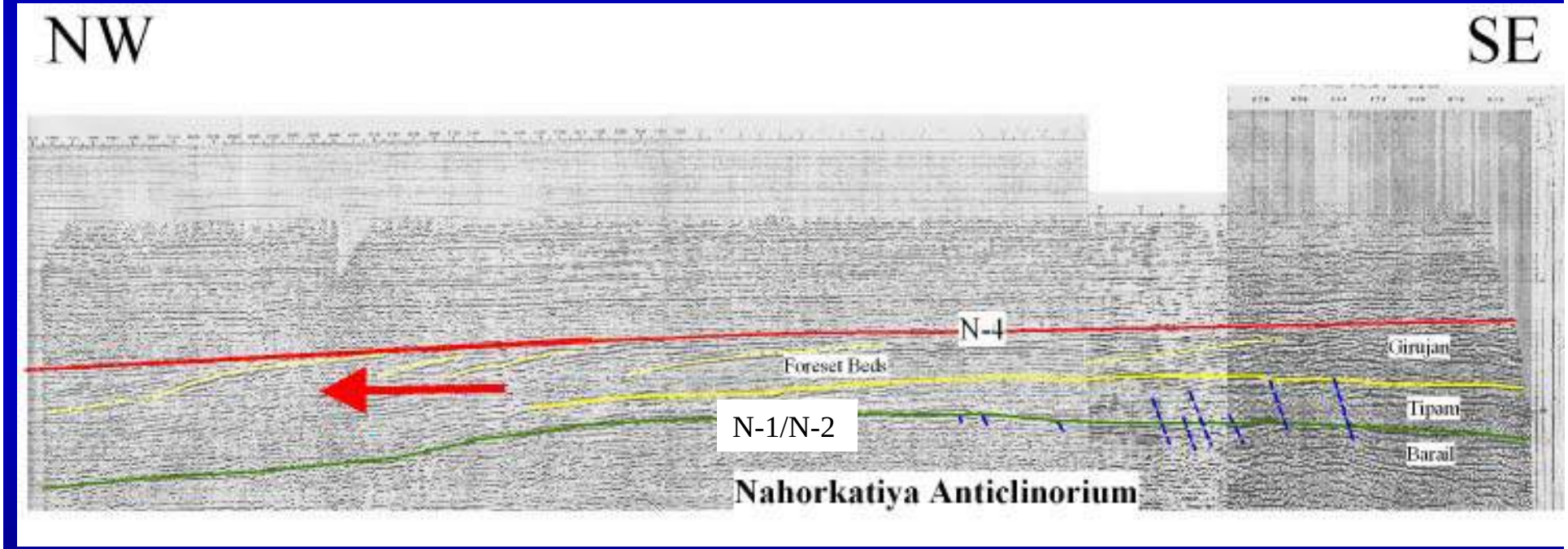
Early Structure

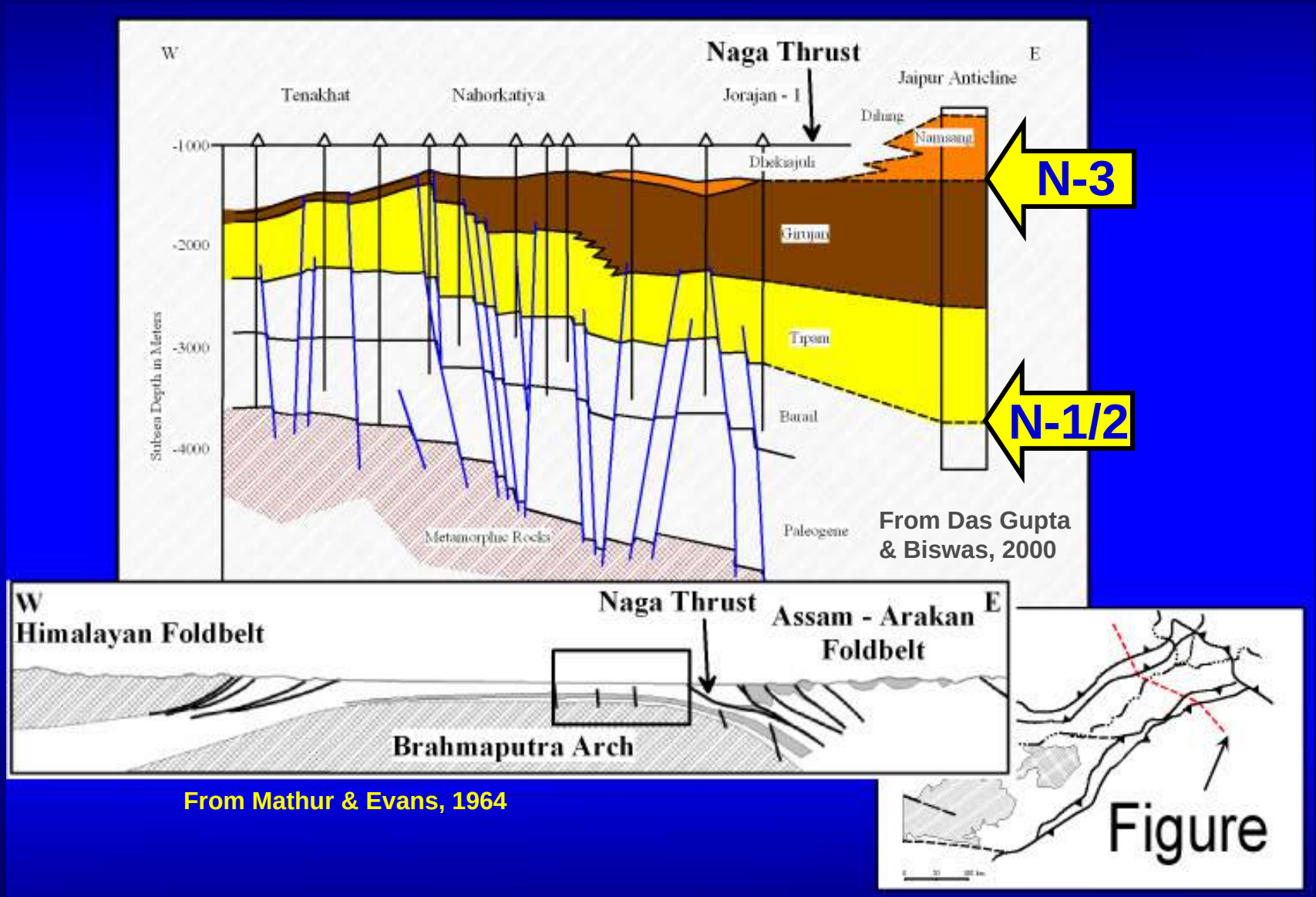
Lower Miocene, Tipam Isopach



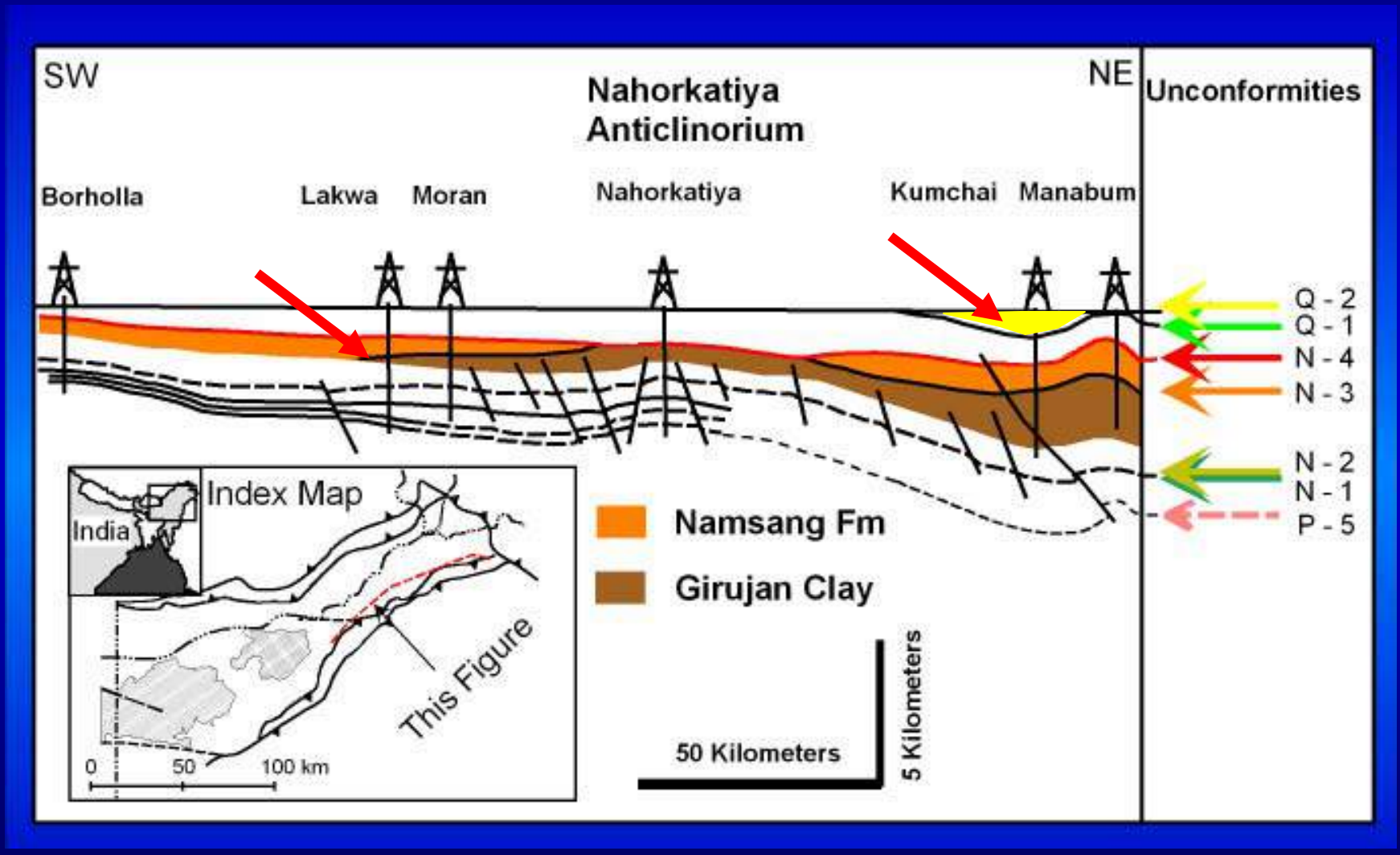
Regional Foreland Seismic Profile



Basin Dip Section

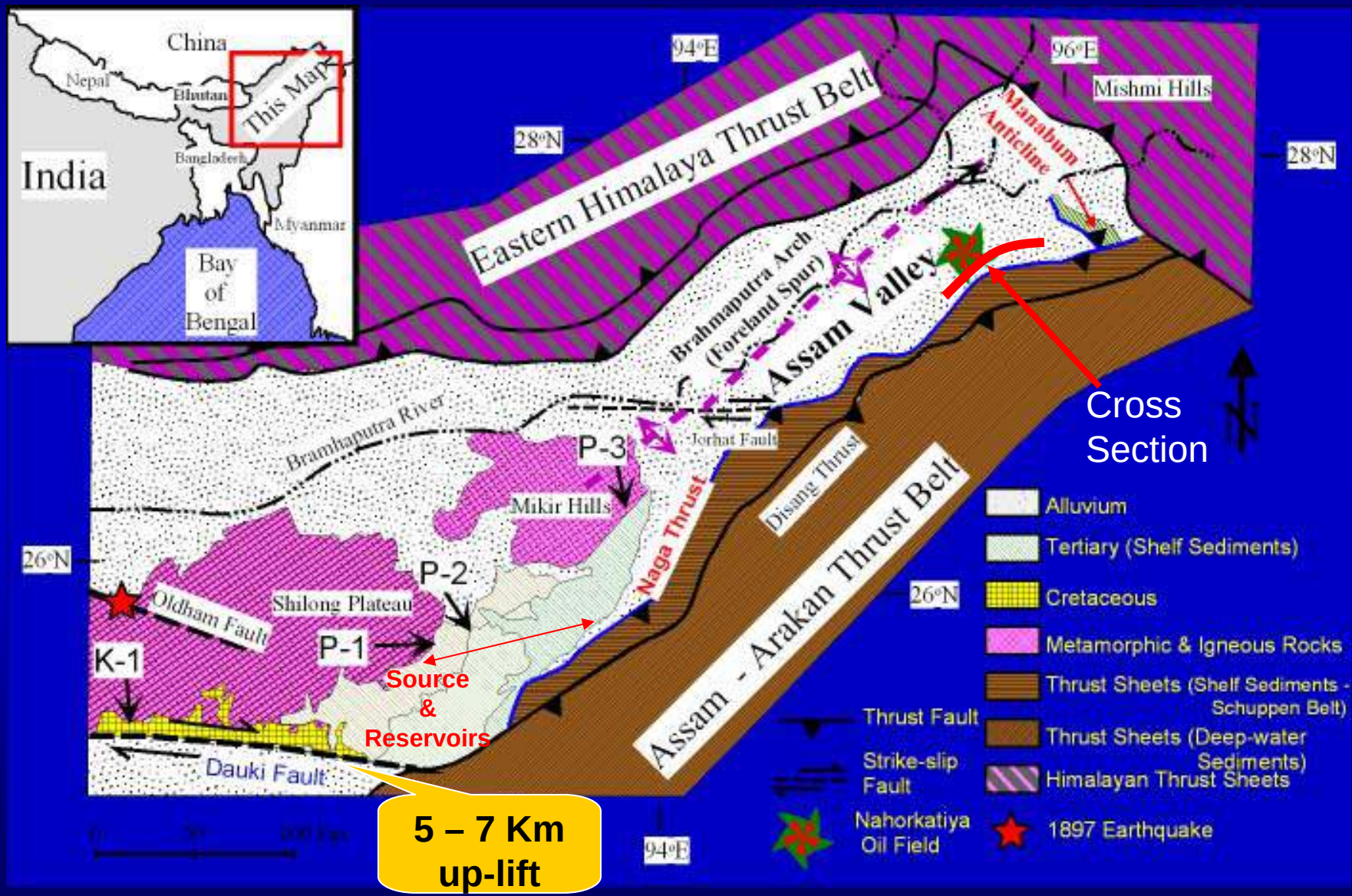


Basin Plunge Section

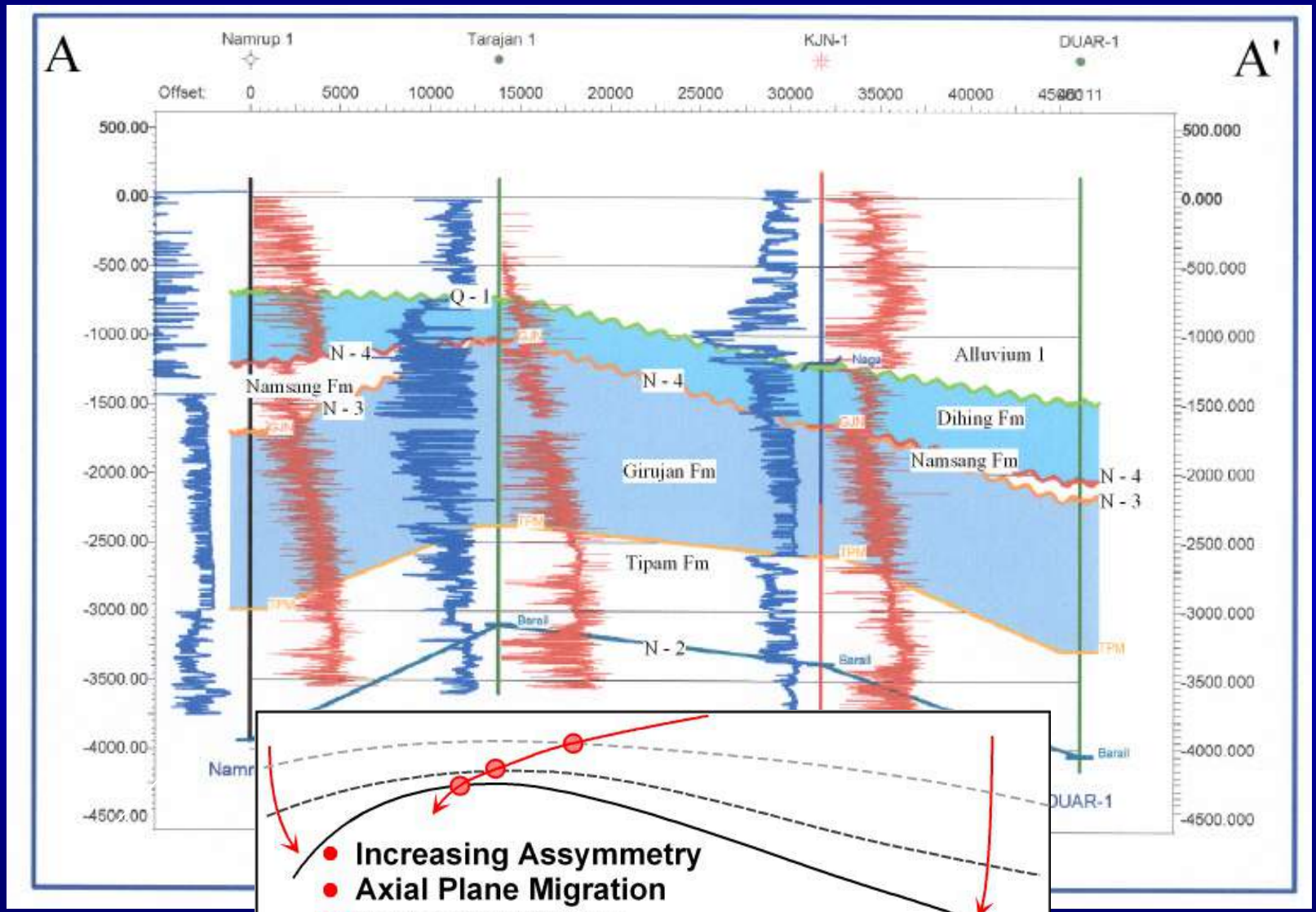


From Handique & Mallick, 1989

Structure Map

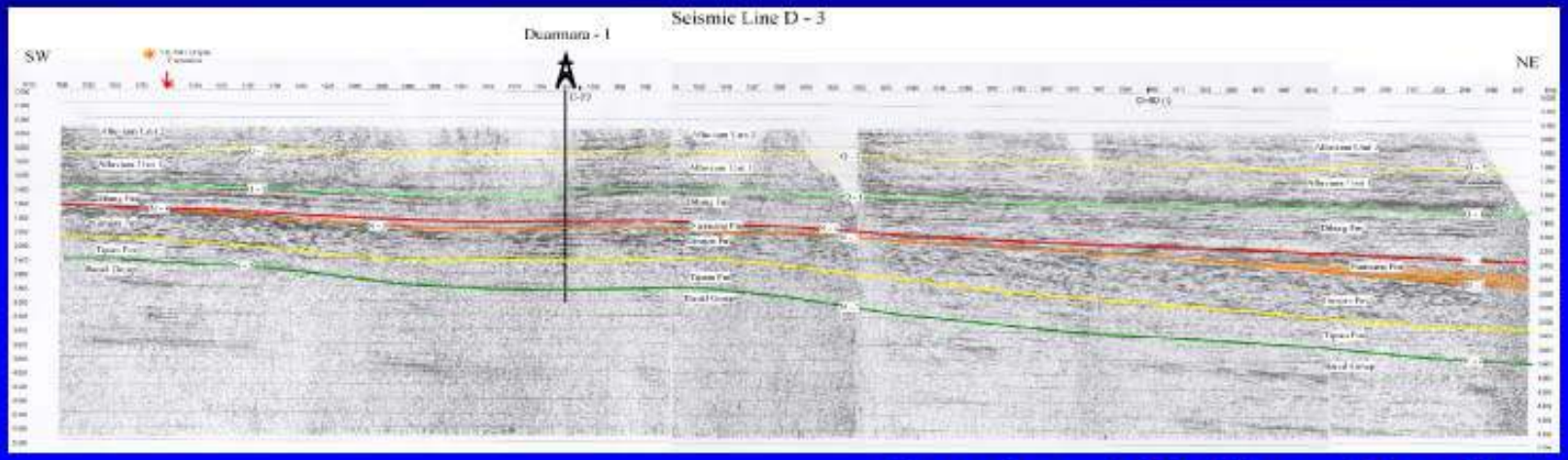


Structural Evolution

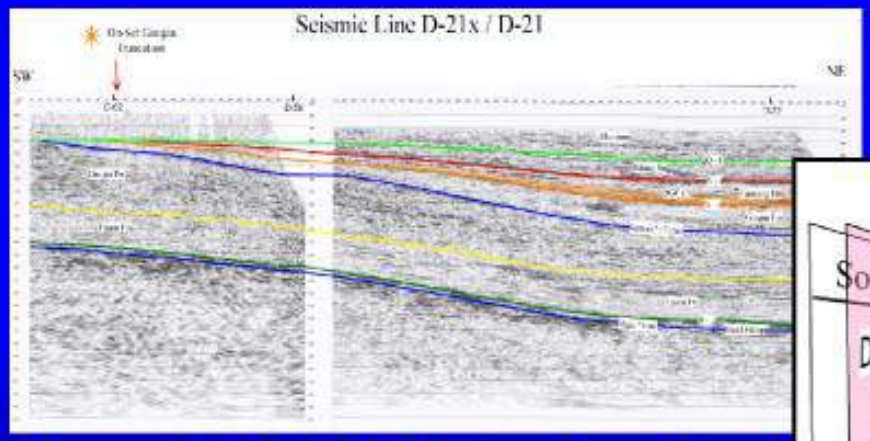


Foreland - Thrust Belt Co-Evolution

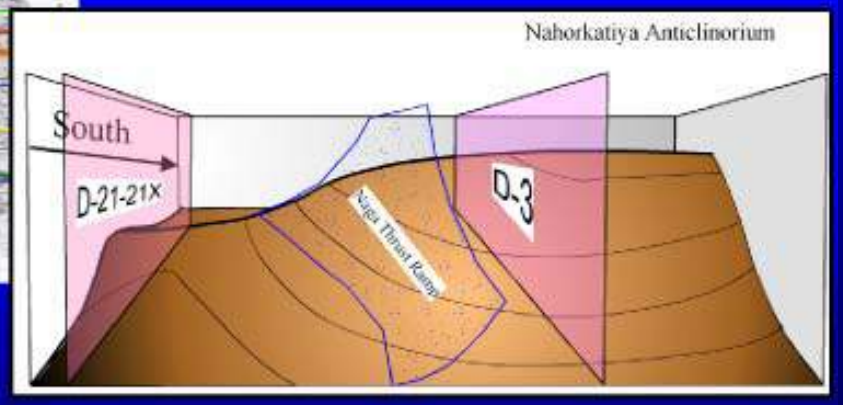
Fault Strike Lines



Foreland Strike - Section



Thrust Belt Strike - Section



Foreland - Thrust Belt Co-Evolution

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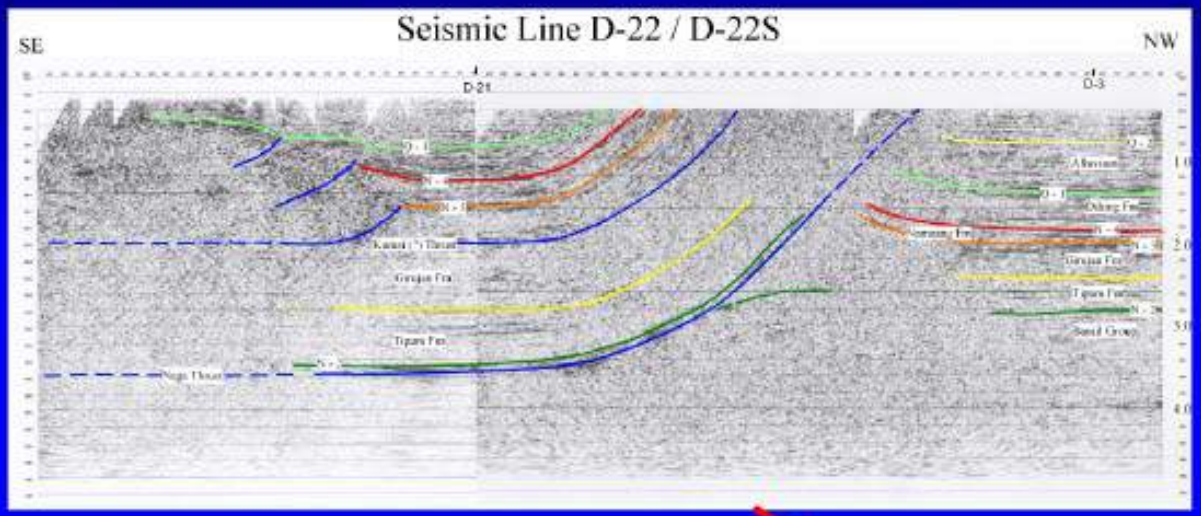
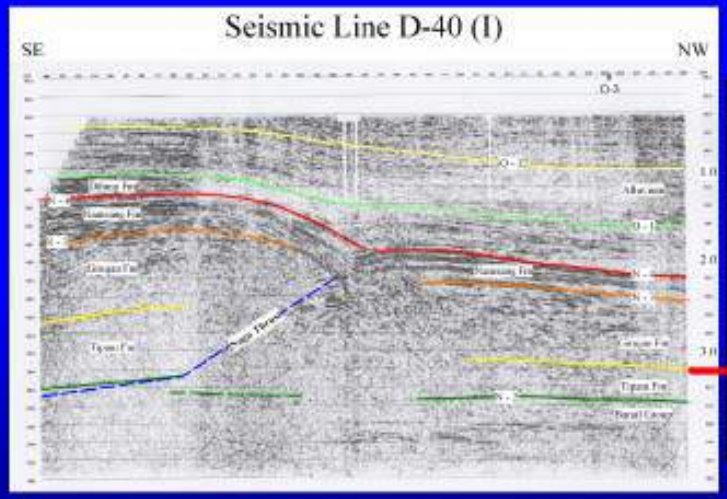
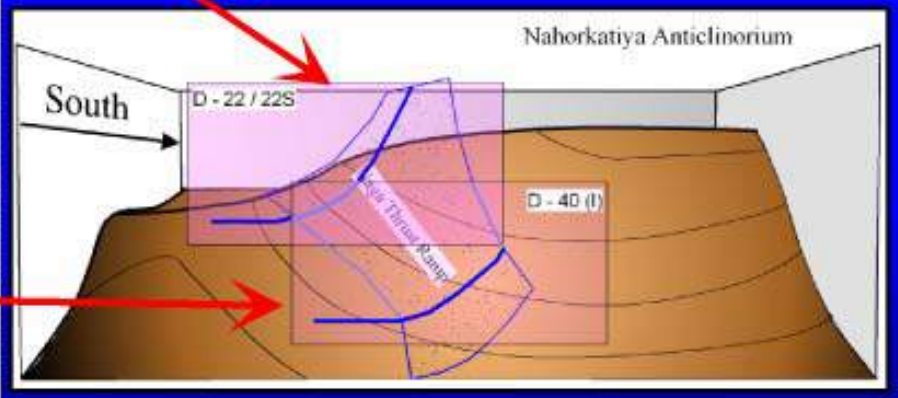
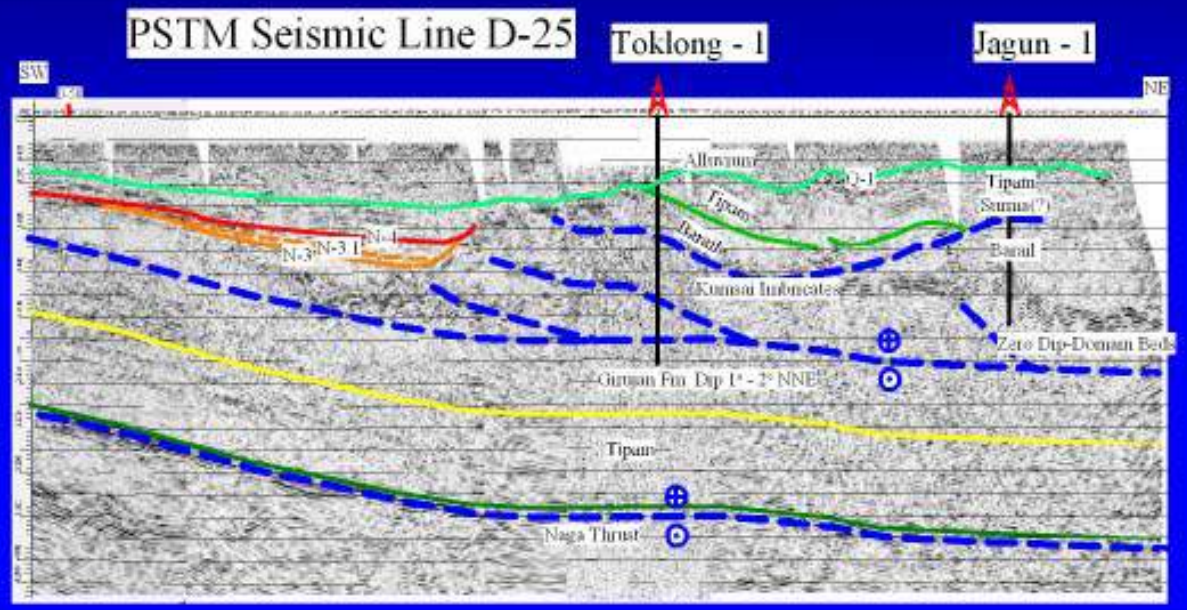
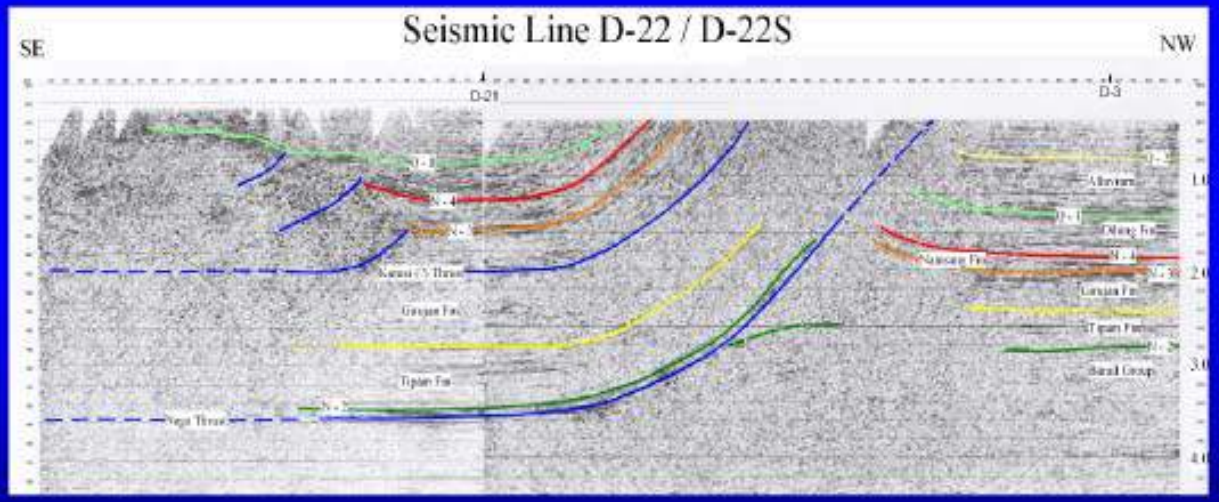




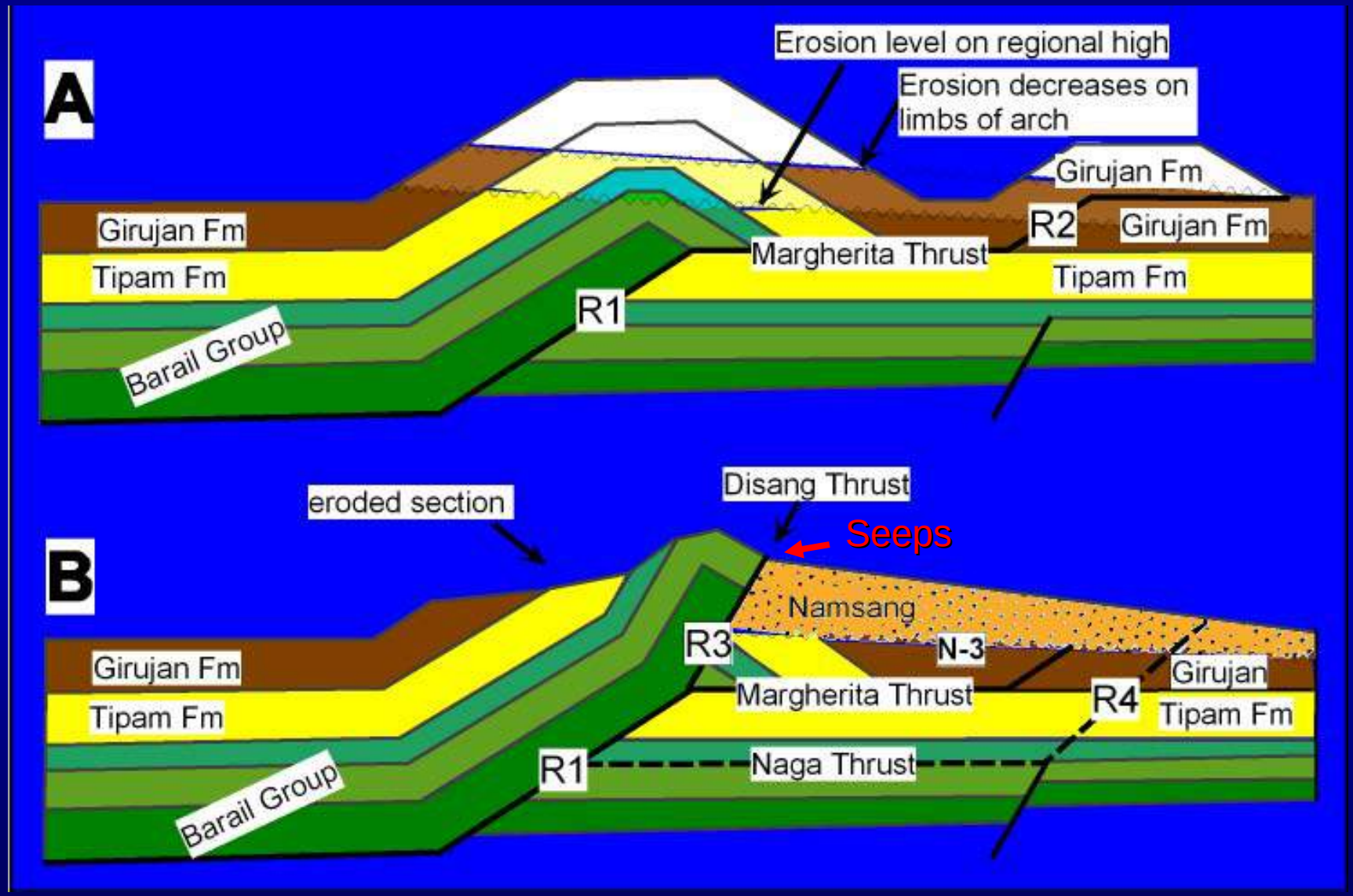


Kumsai Thrust Imbricates





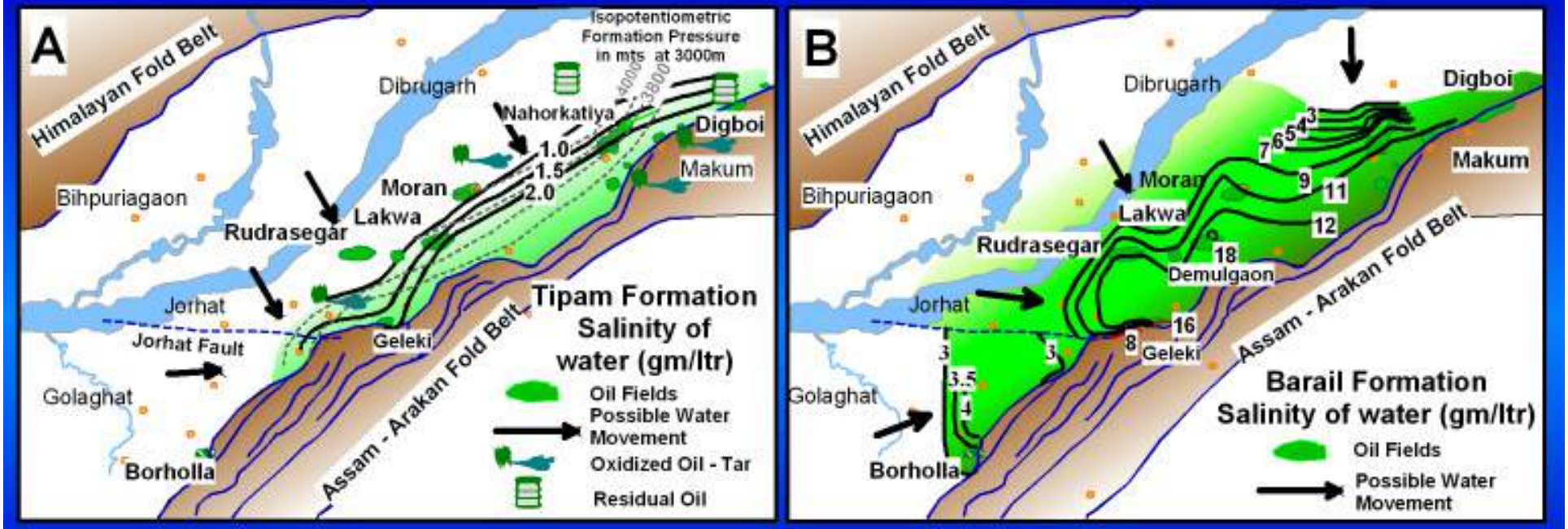
Thrust Sequence



Structural Summary

- Early Structures = Horsts and Grabens
- Mild Inversion of Normal Faults
- Multiple episodes of thrusting and erosion
- Several Generations of up-lift on the Dauki Fault System

Oil Field Characteristics

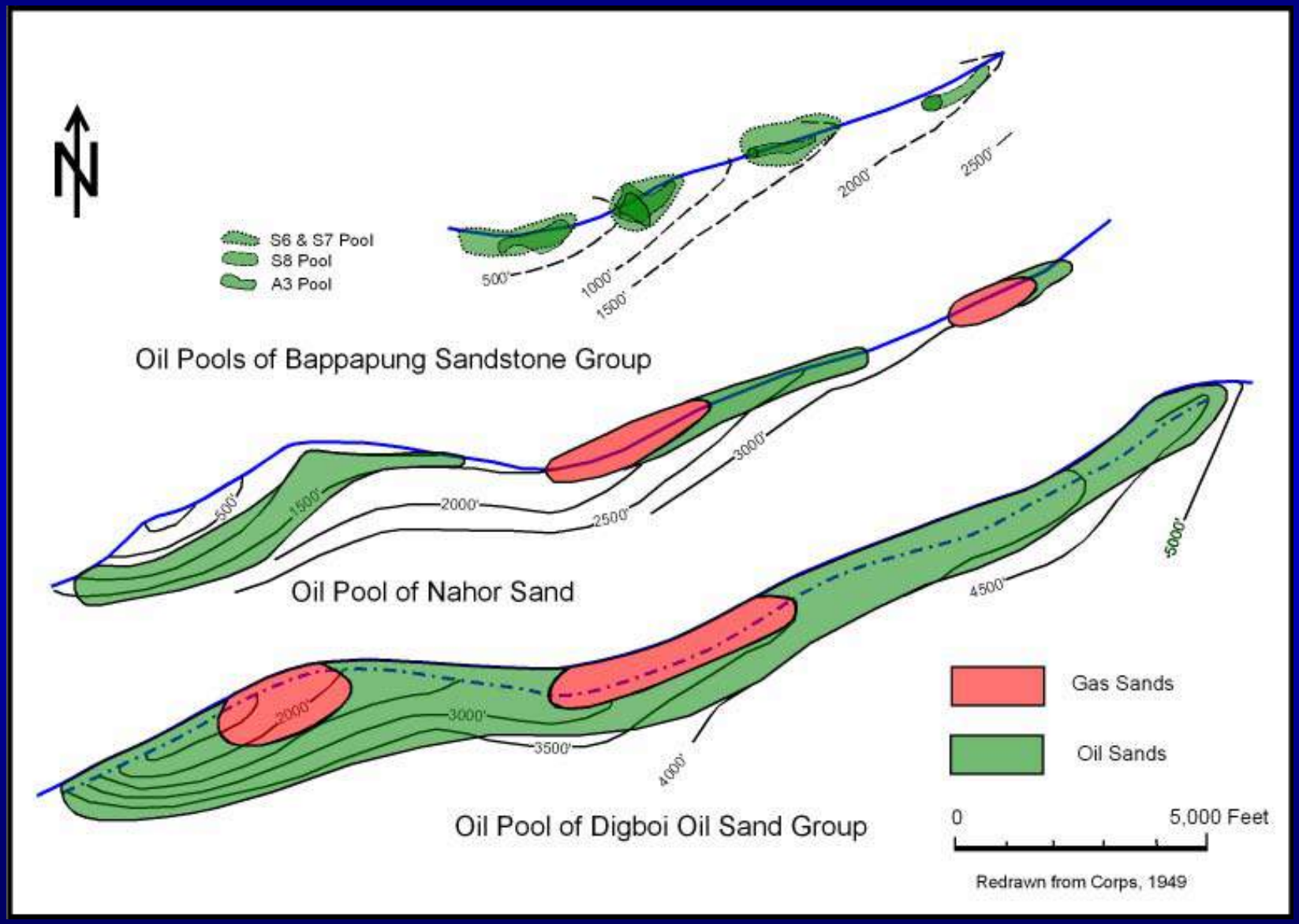


Shallow Reservoir

Deeper Reservoir

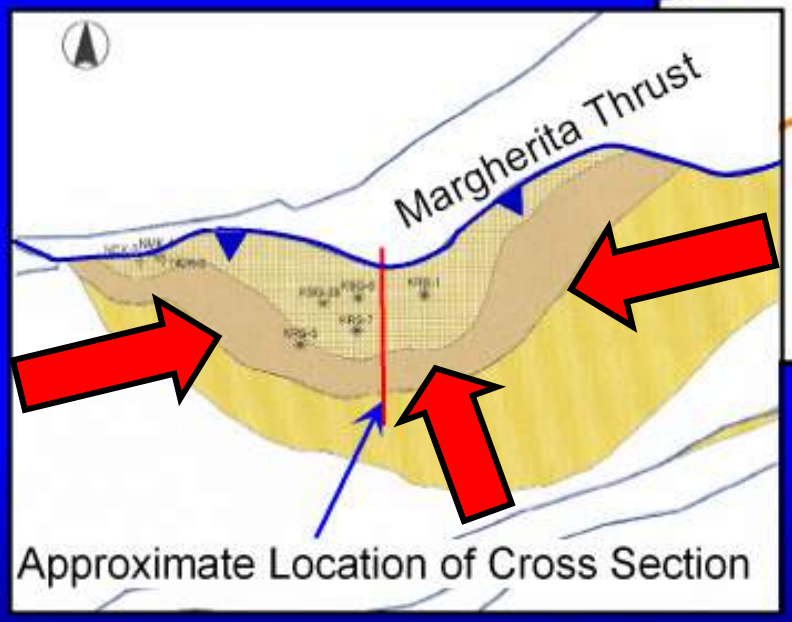
Figures from Seshavataram, et al., 1980

Digboi Field



Kharsang Field

- Oil generally 19° - 29° API but one well has 35° oil
- Oil is Aromatic in the East Napthanic in the West
- Residual oil shows below 1000m



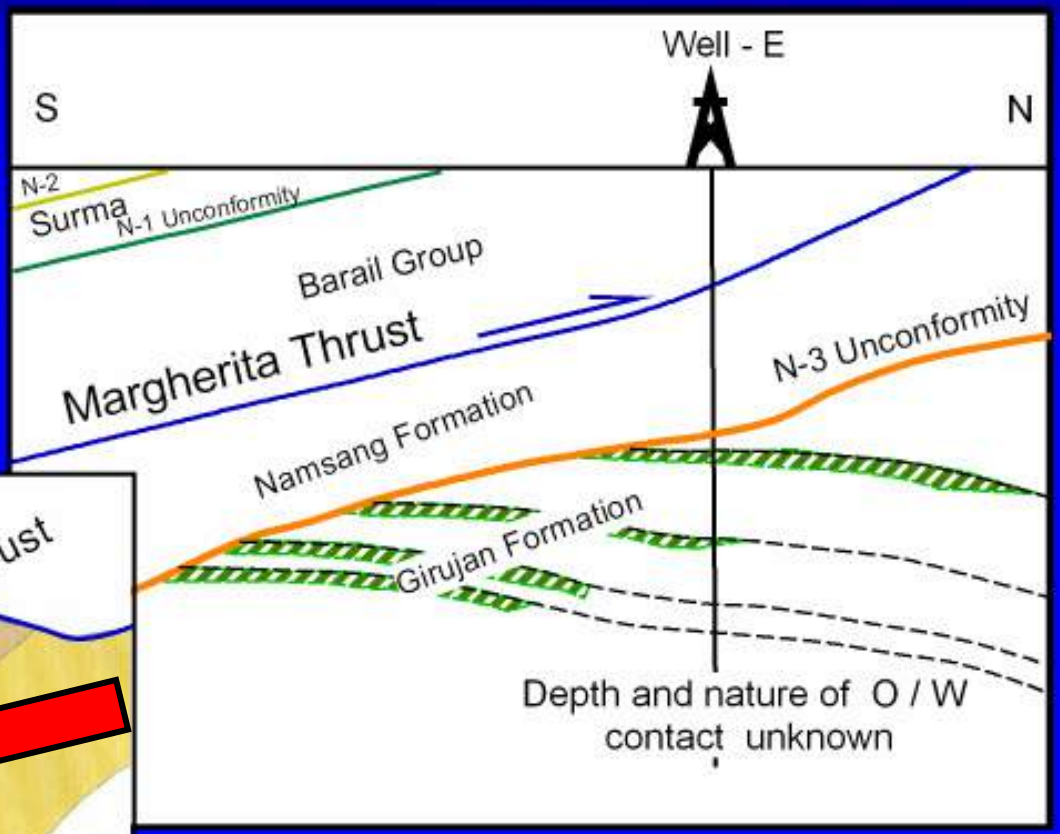
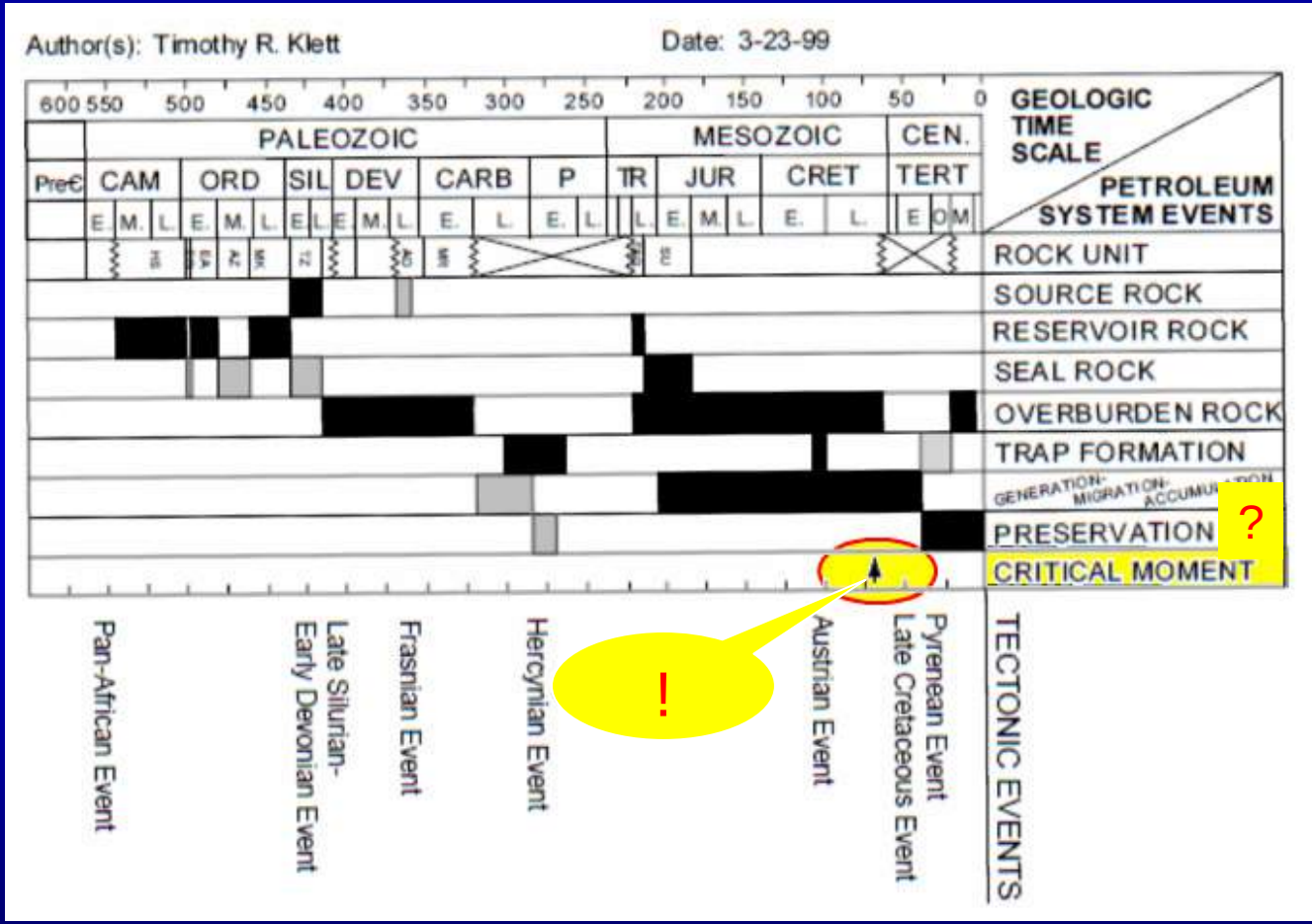


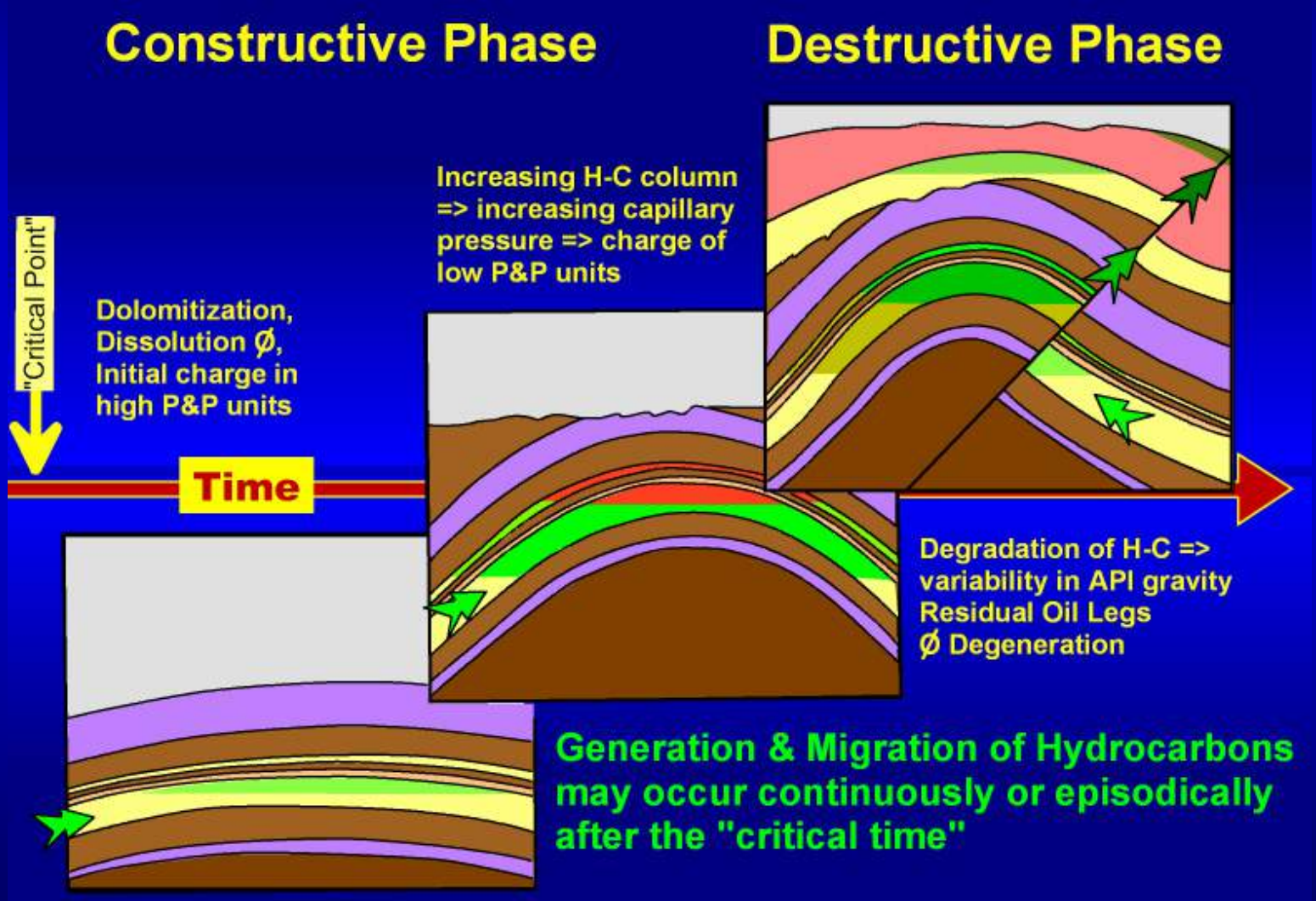
Figure from Handique & Bharali, 1984

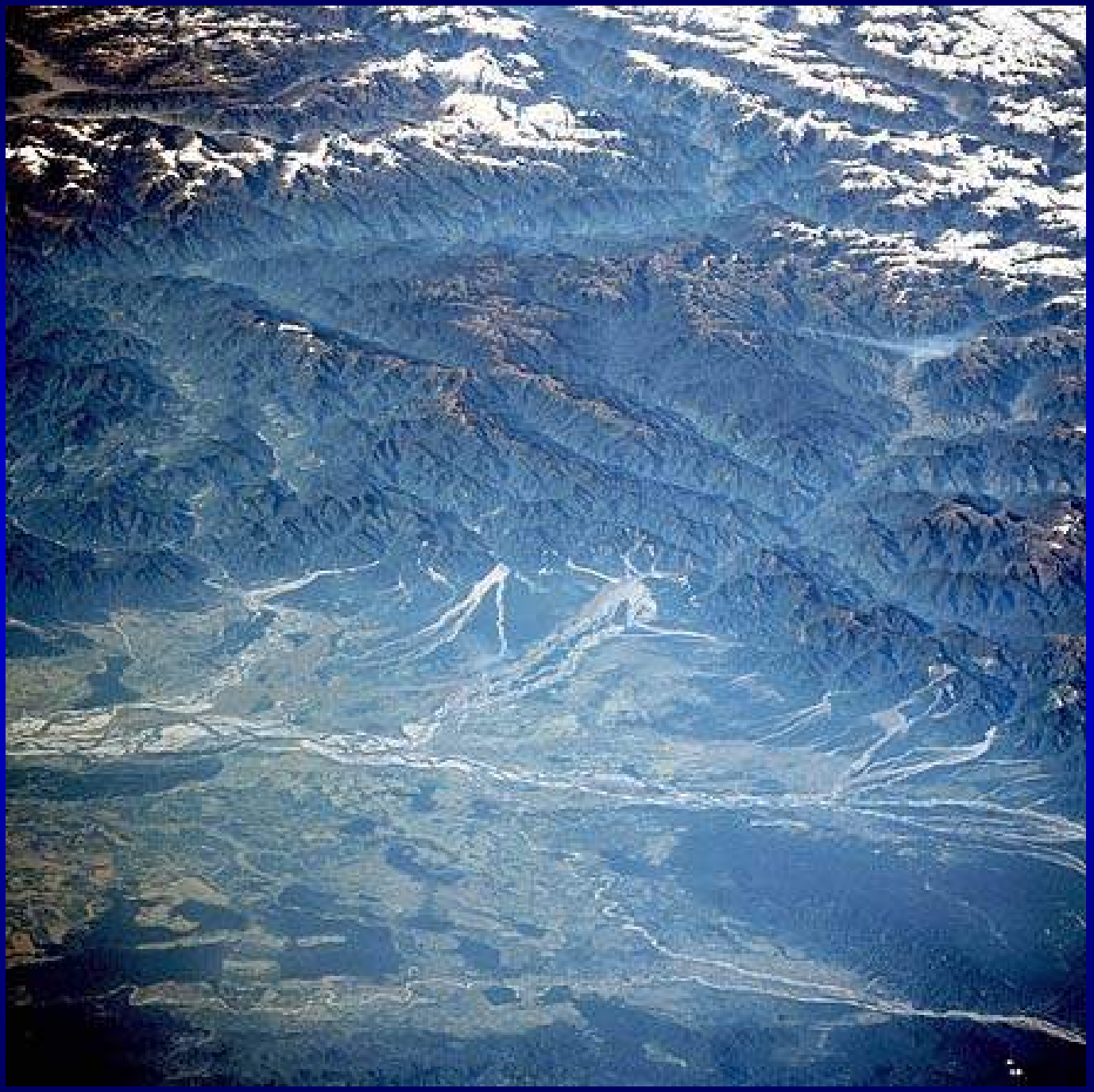
Petroleum System Model

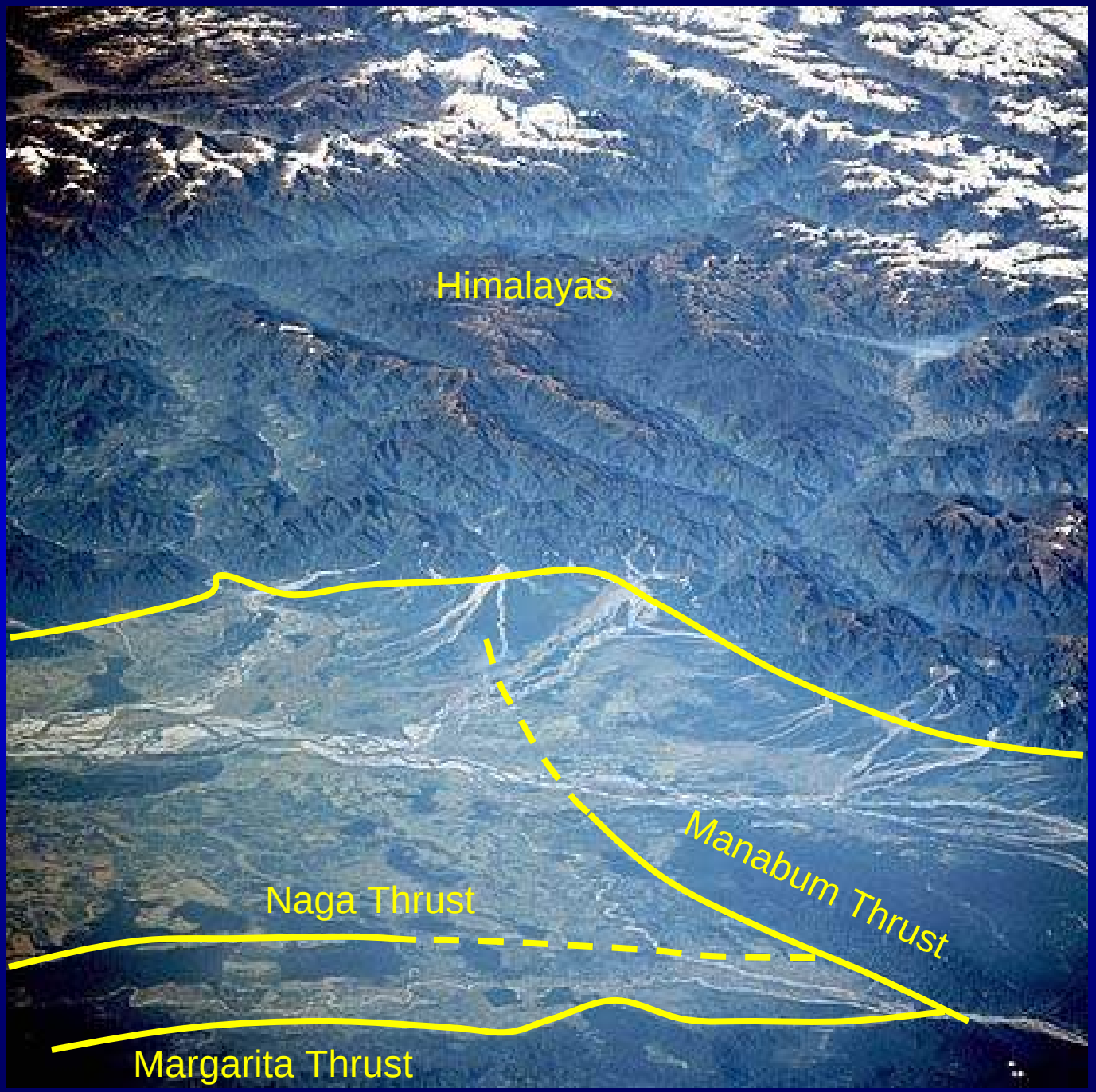


From USGS Bull 2202-C

Dynamic Hydrocarbon System






Himalayas
Manabum Thrust
Naga Thrust
Margarita Thrust

END

Structural Evolution of the Northern Assam Basin: a case for a dynamic hydrocarbon system model

W. Norman Kent

Kent GeoScience Associates

Acknowledgements

Udayan Das Gupta – Hindustan Oil Exploration Company

Outline

- Basin Tectonics & Regional Geology
- ➢ Questions
- Basin Structure and Stratigraphy
- Geologic History
- Oil Field Characteristics
- ➢ Hydrocarbon System Model

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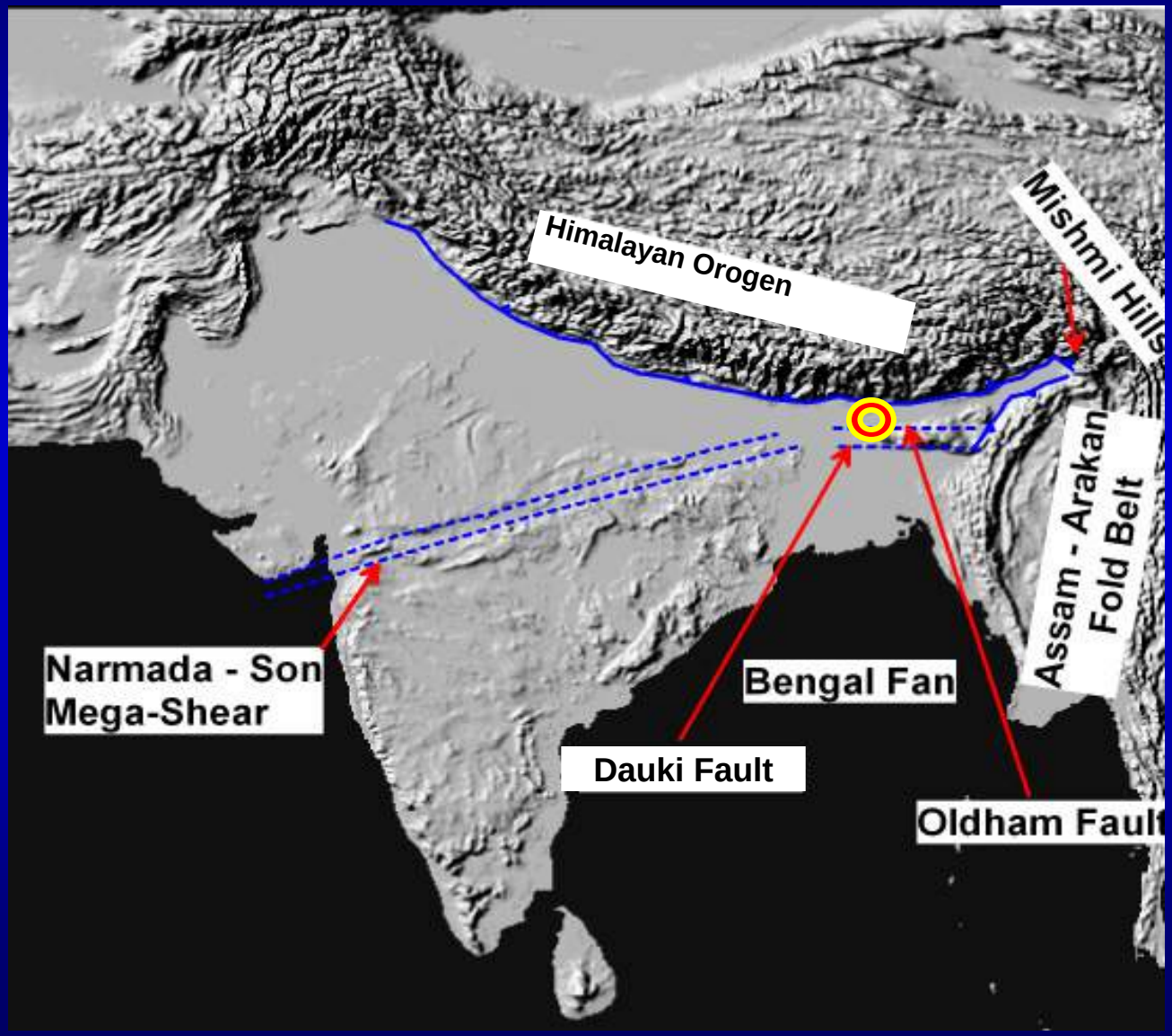

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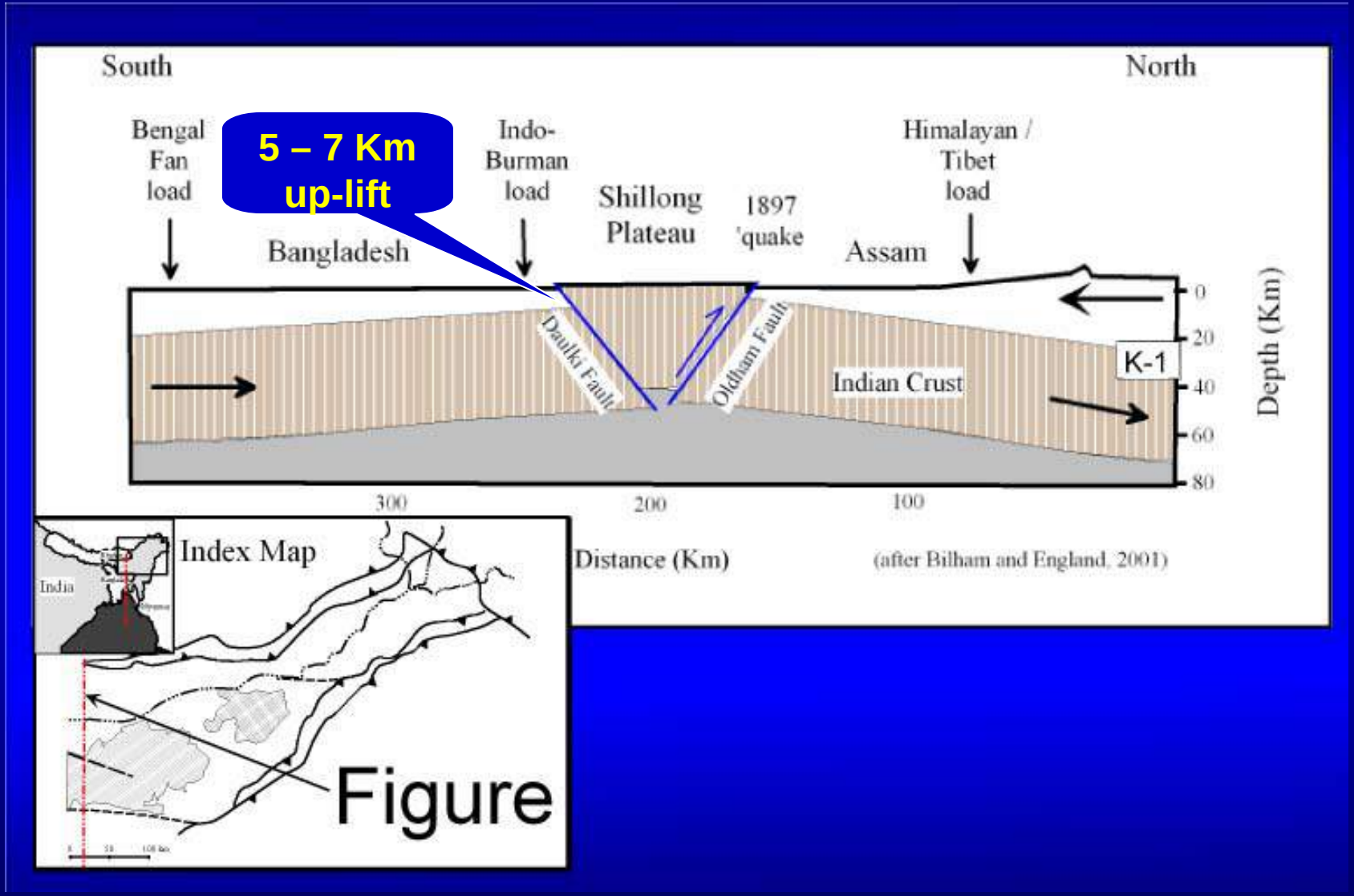

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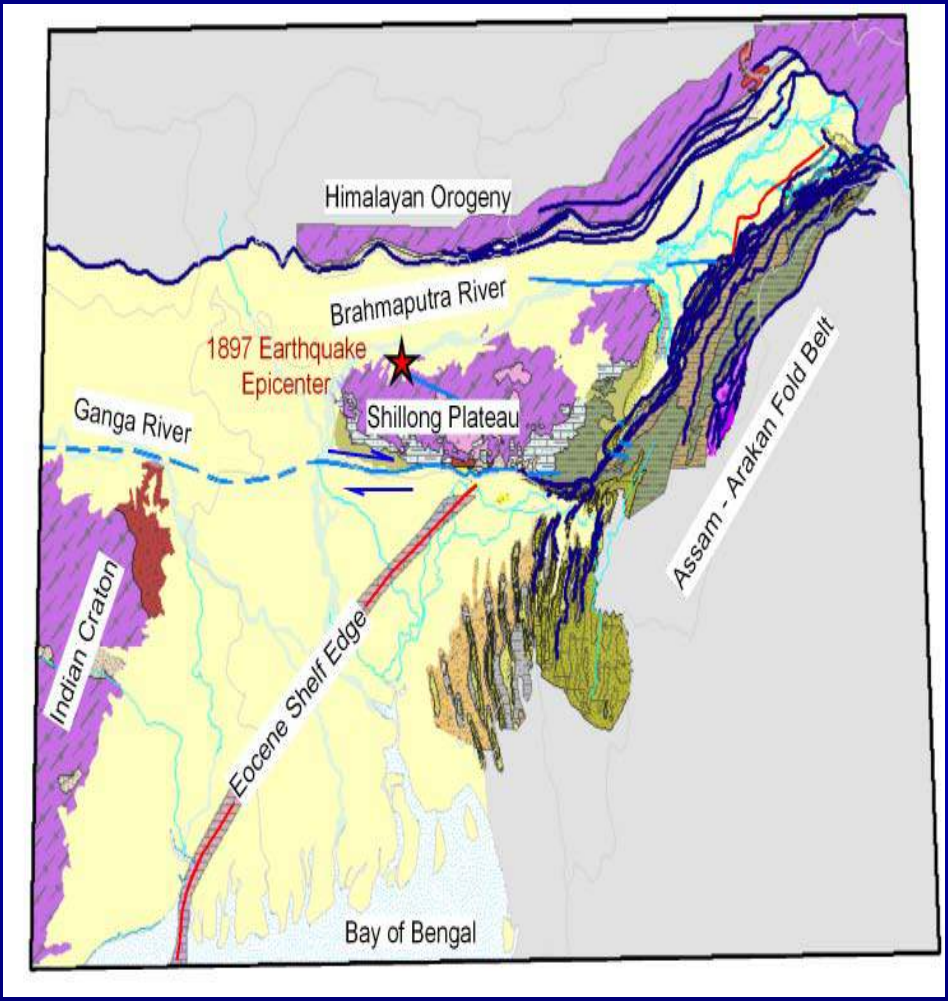

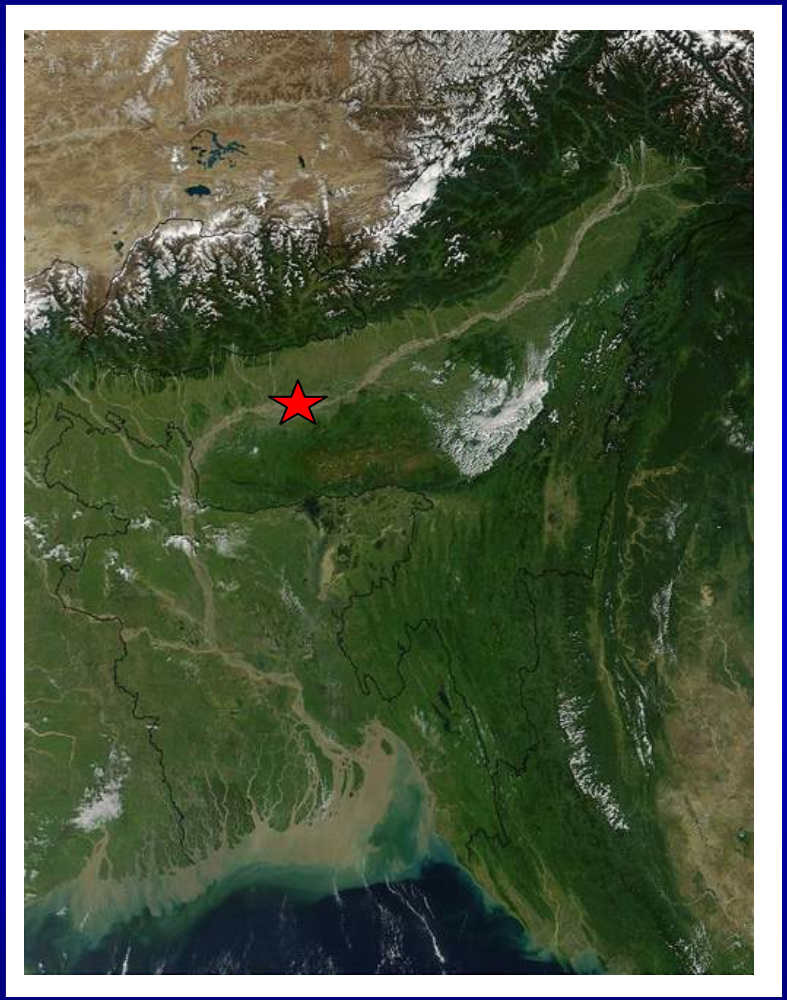

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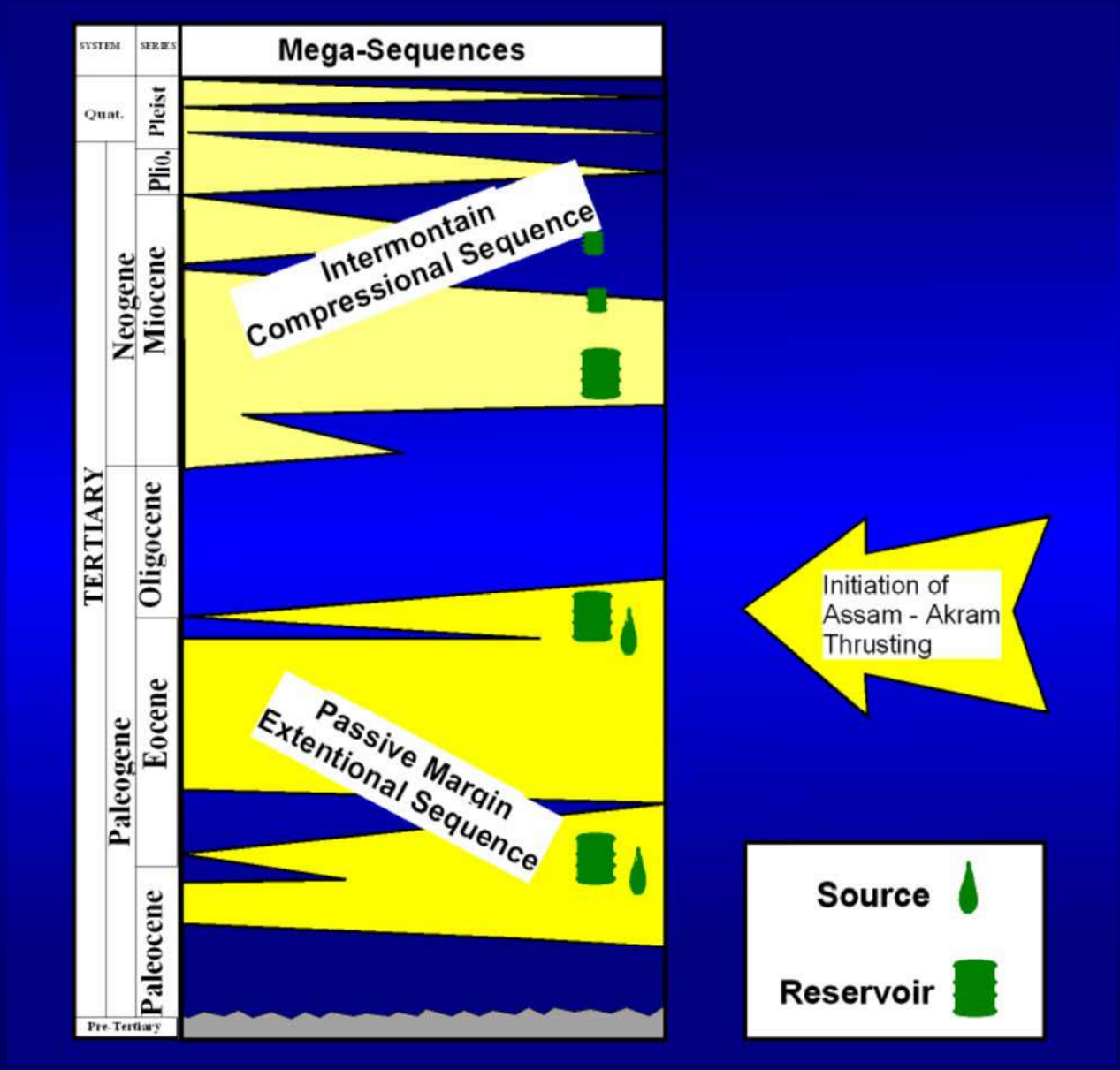

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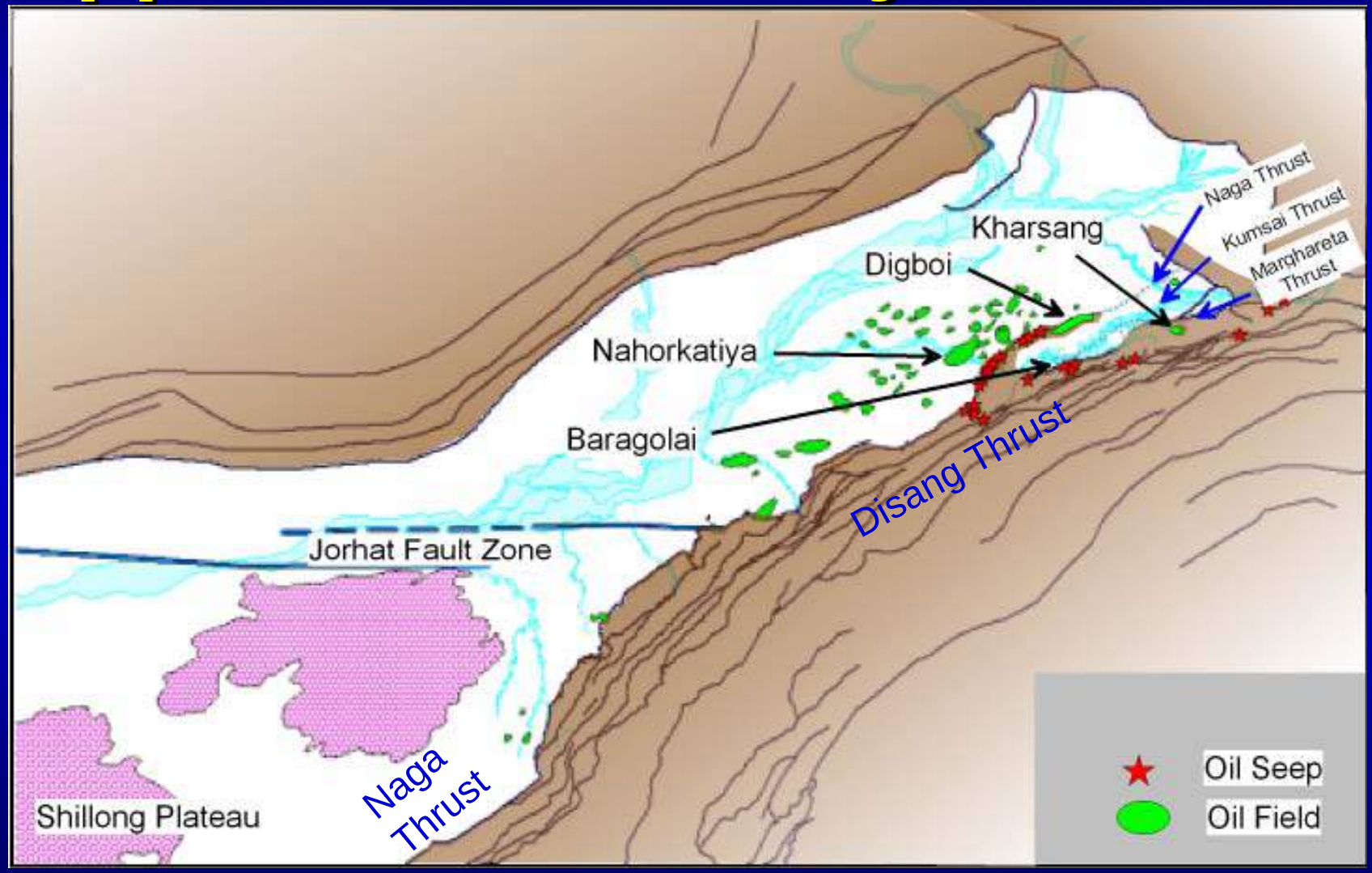

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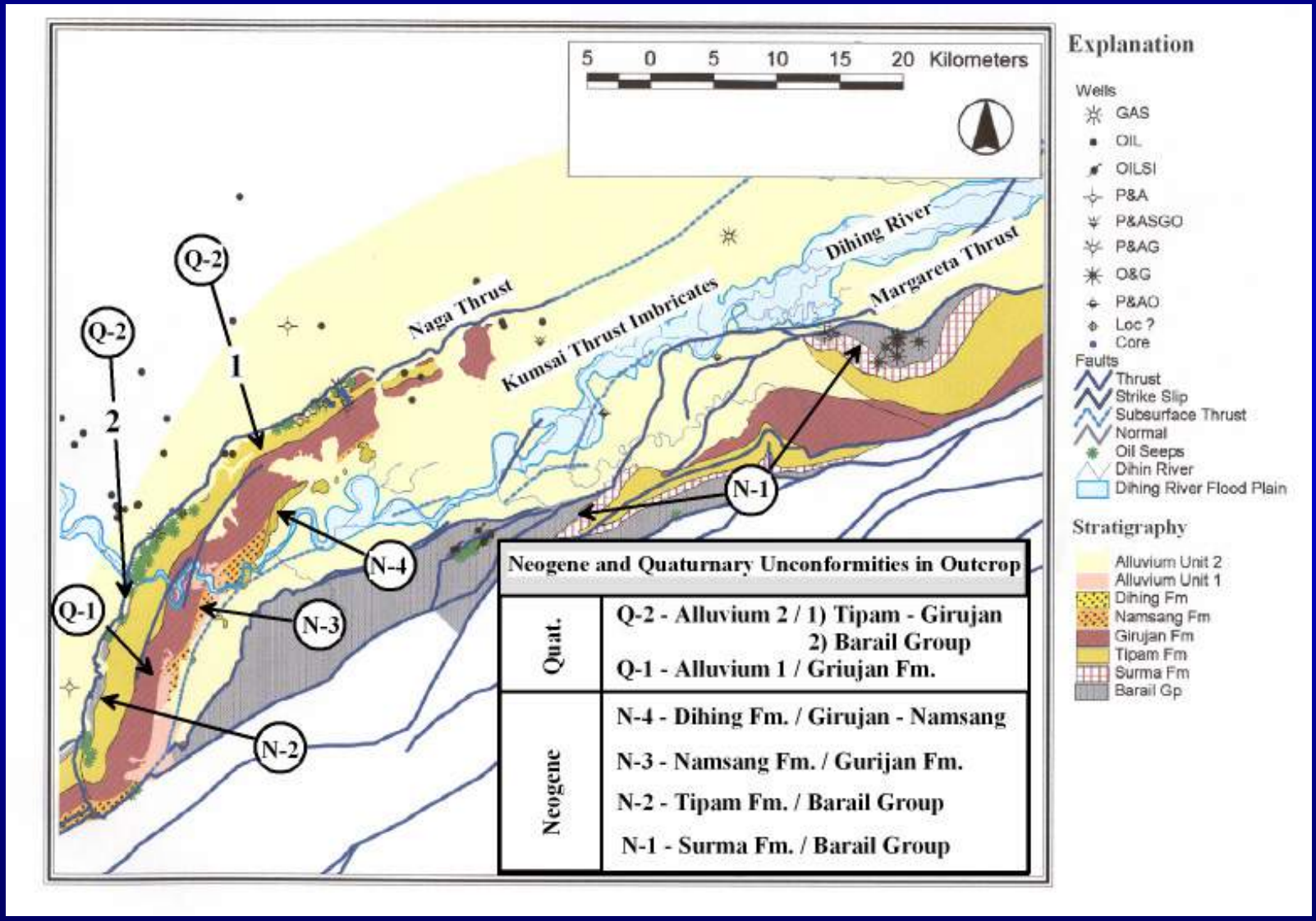

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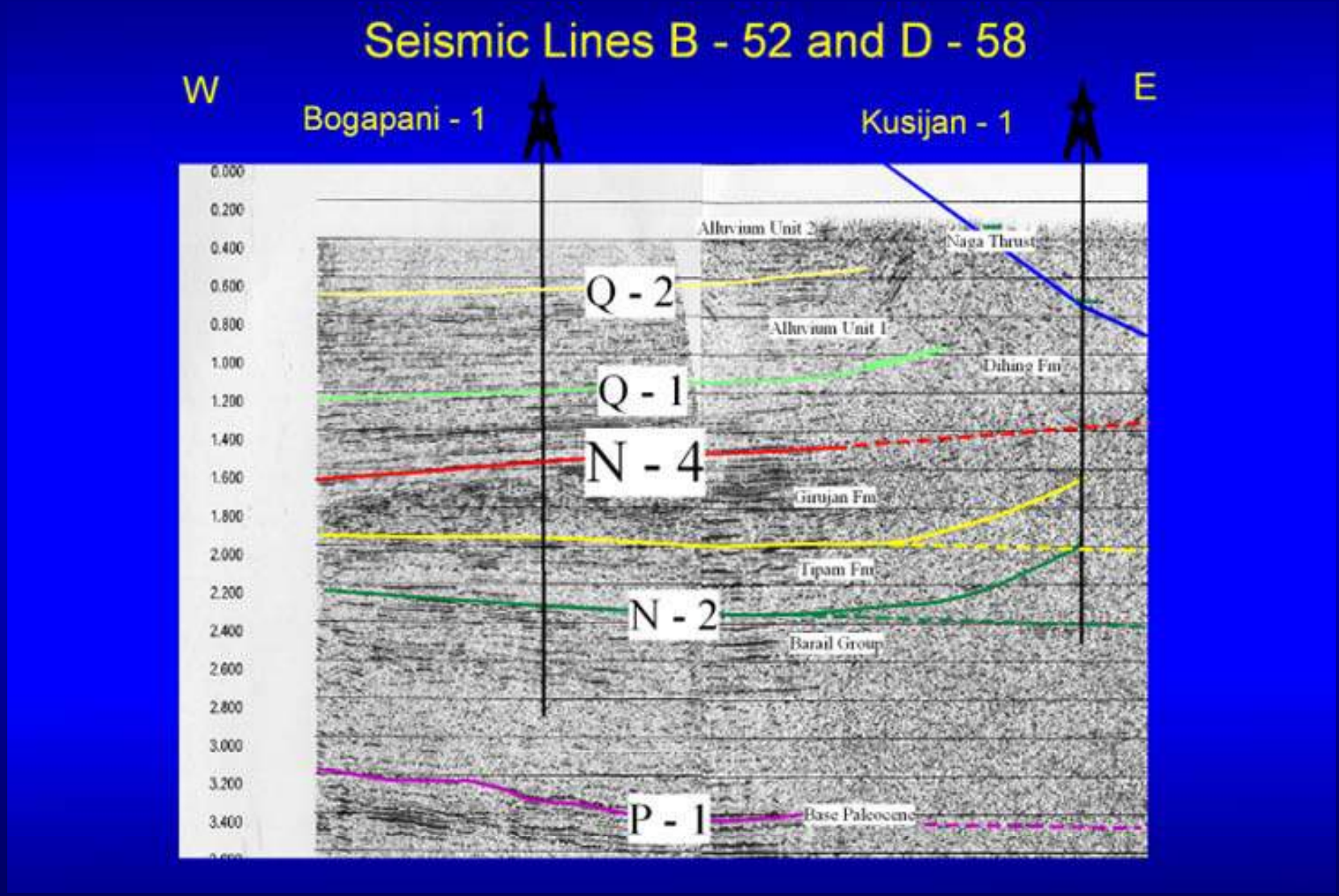

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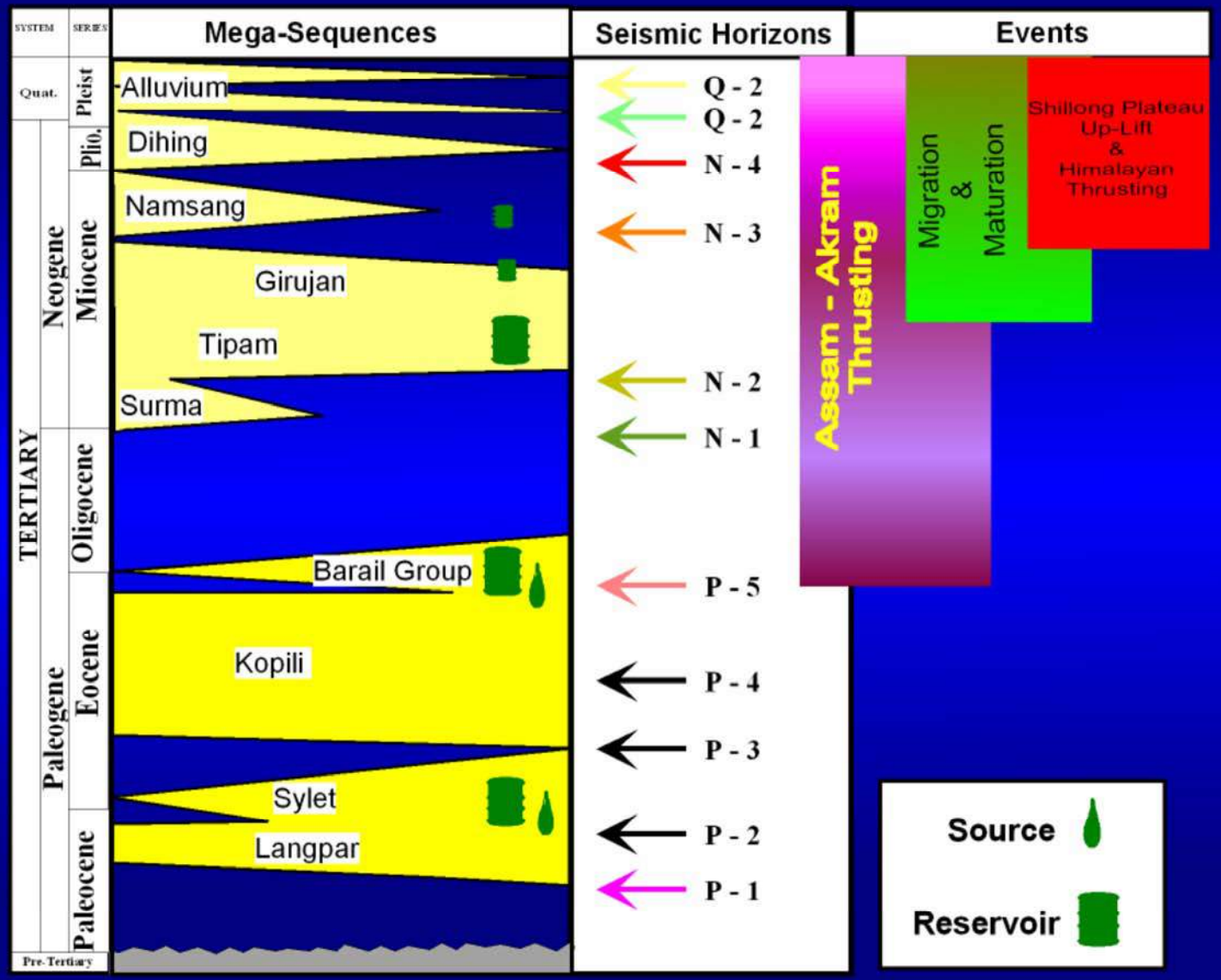

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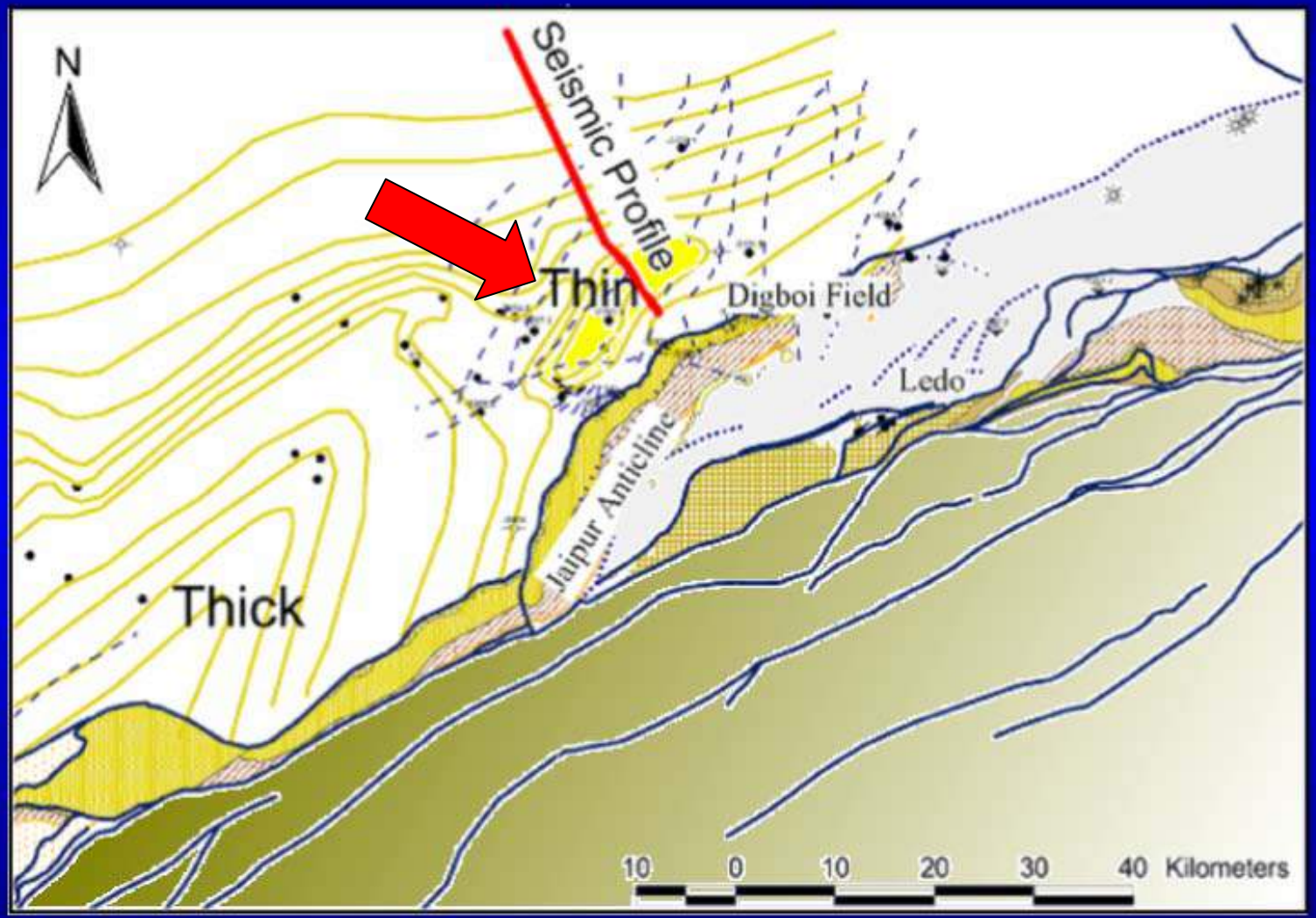

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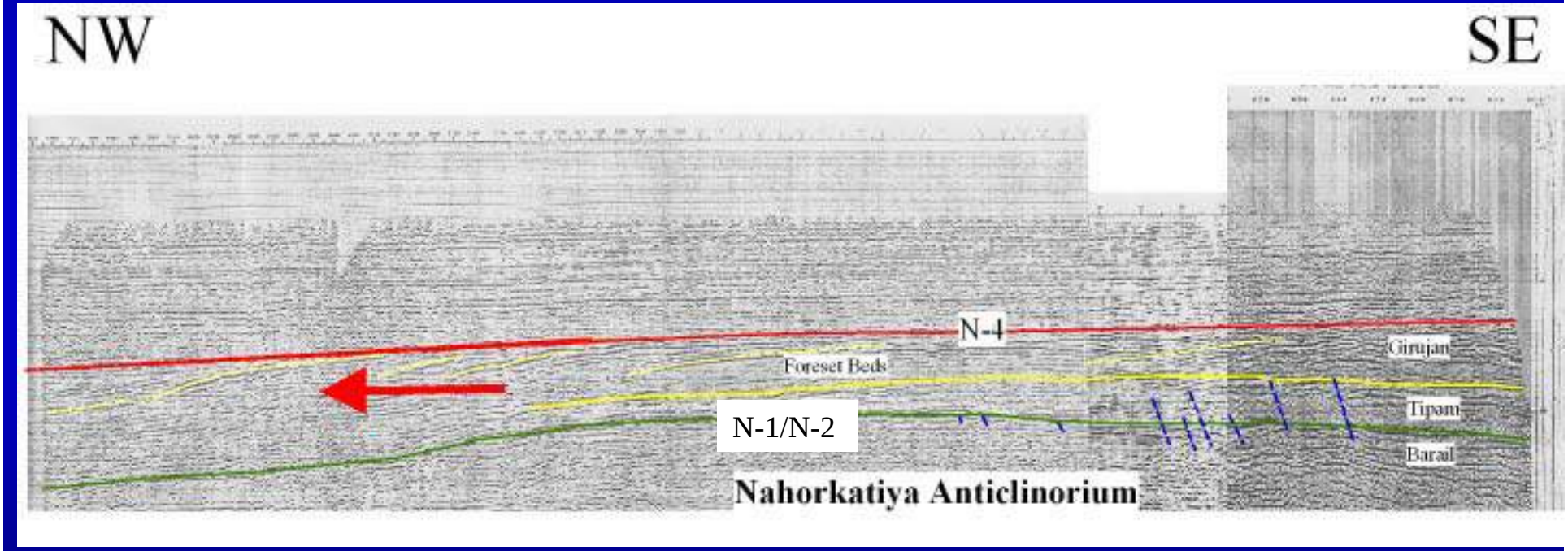

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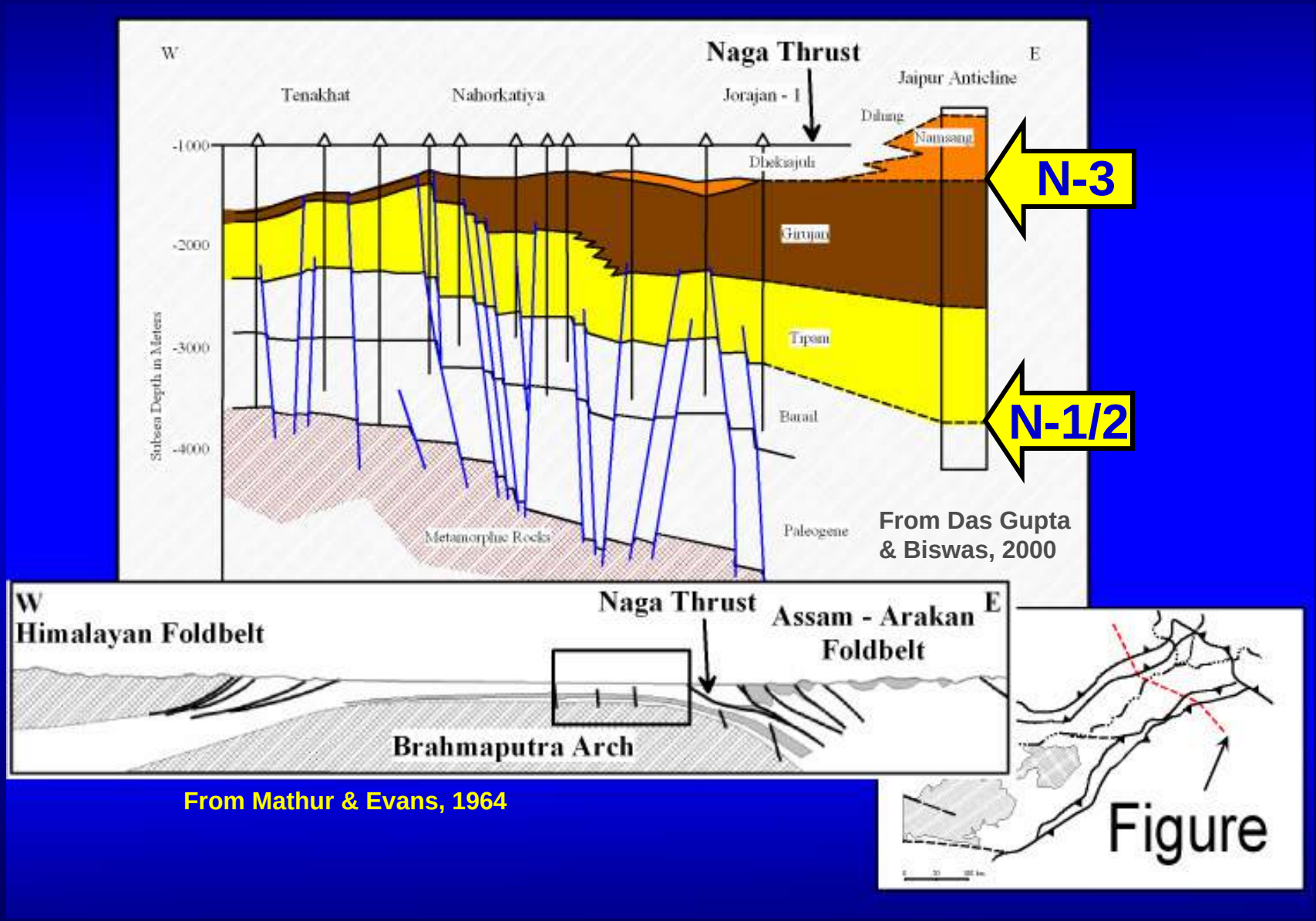
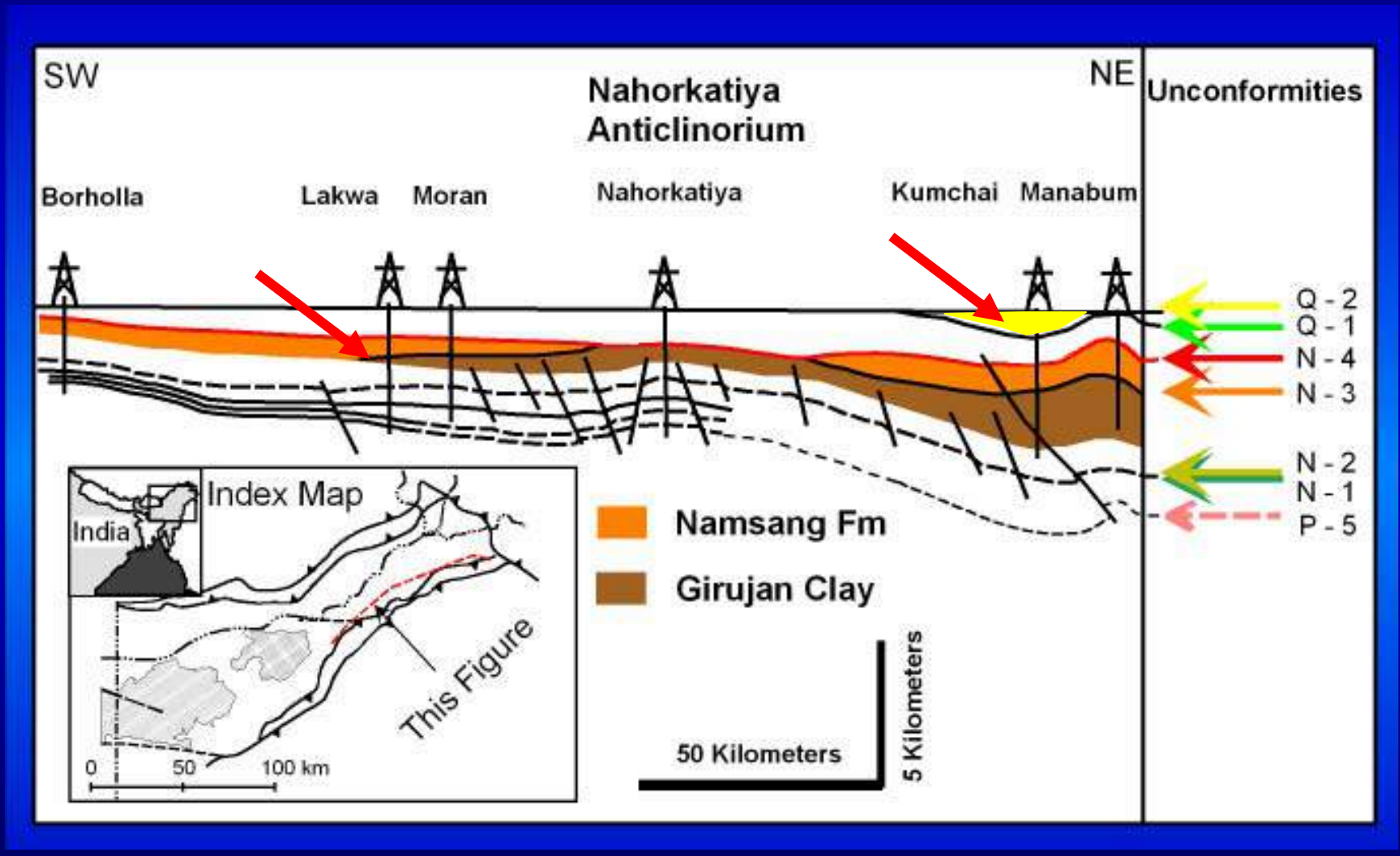


Basin Plunge Section



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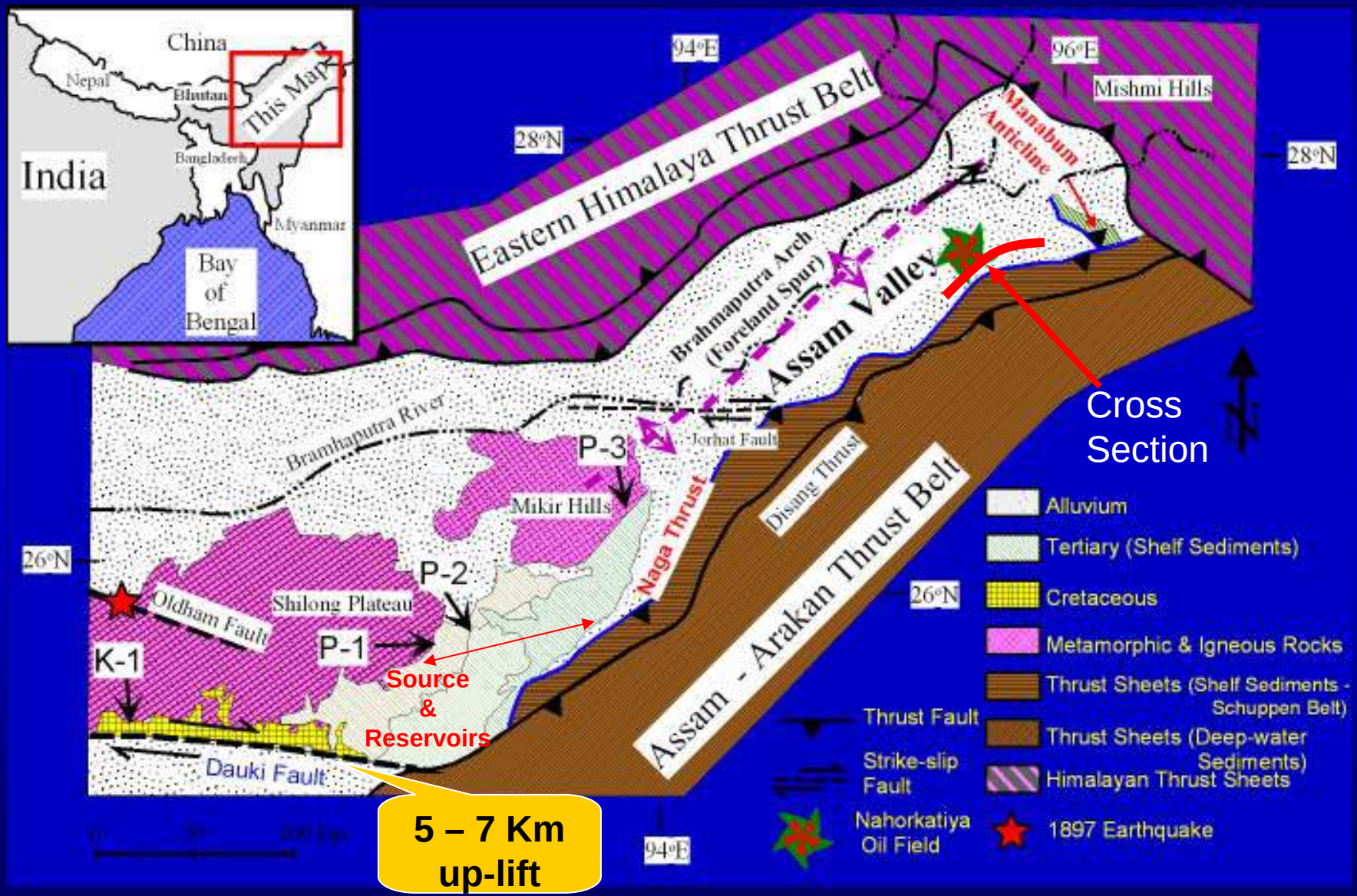

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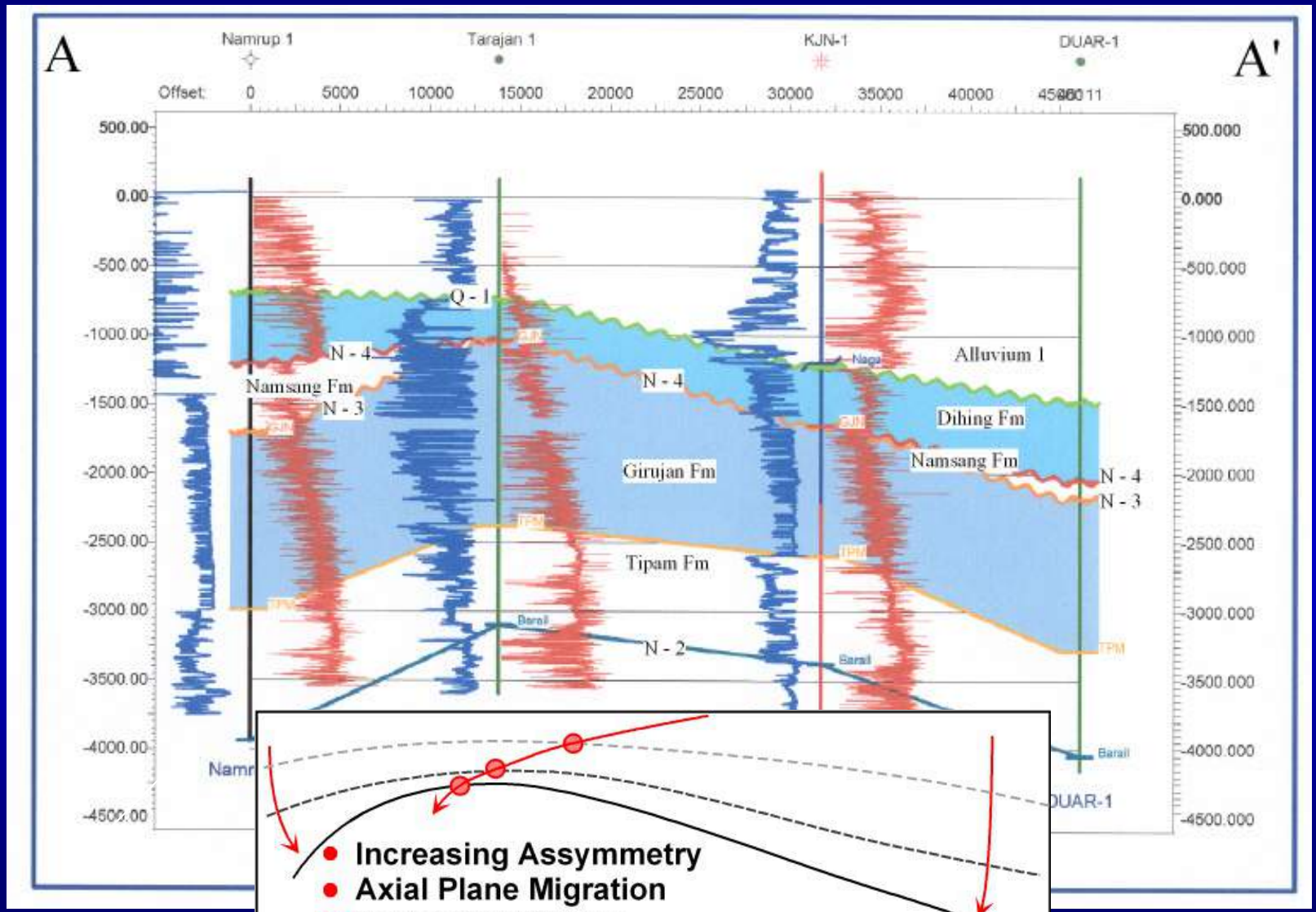

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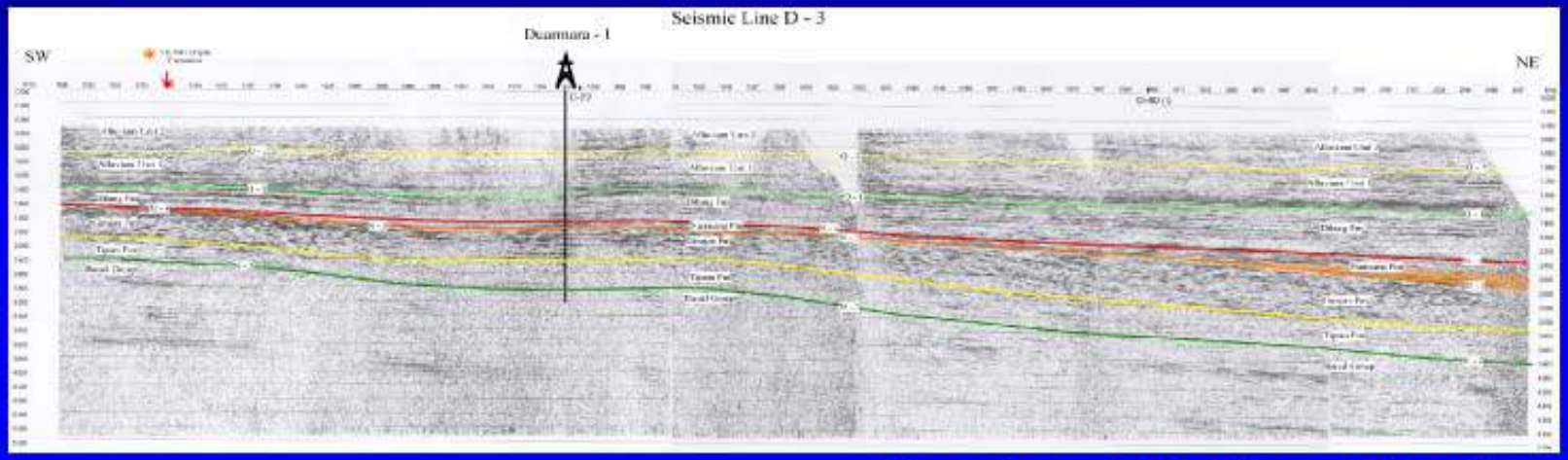
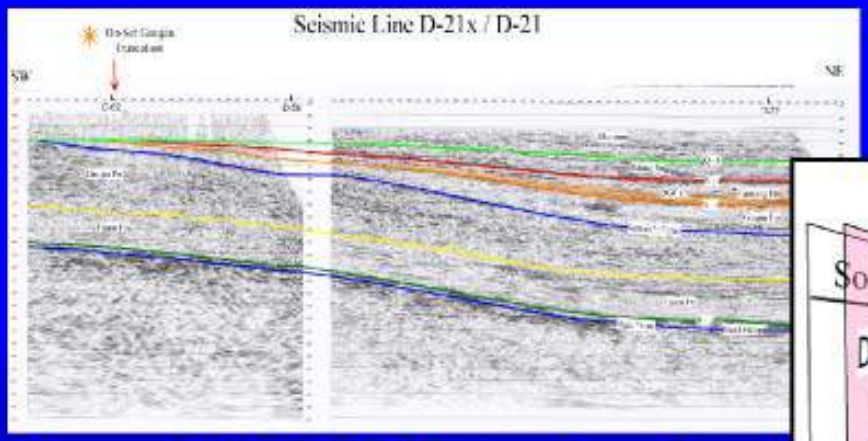
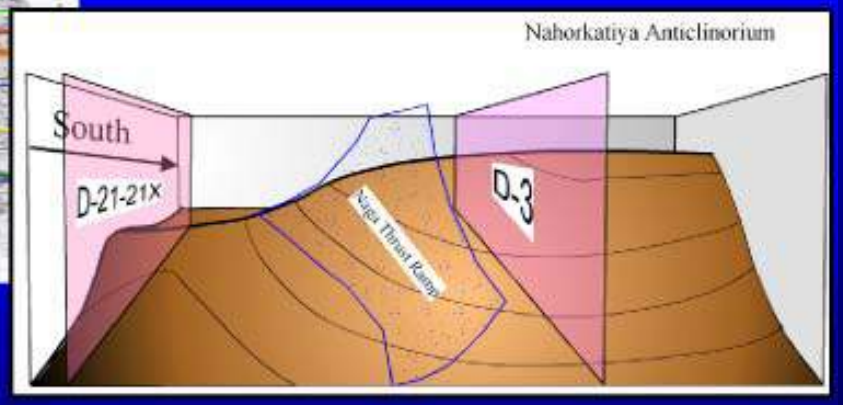
Fault Strike Lines



Foreland Strike - Section

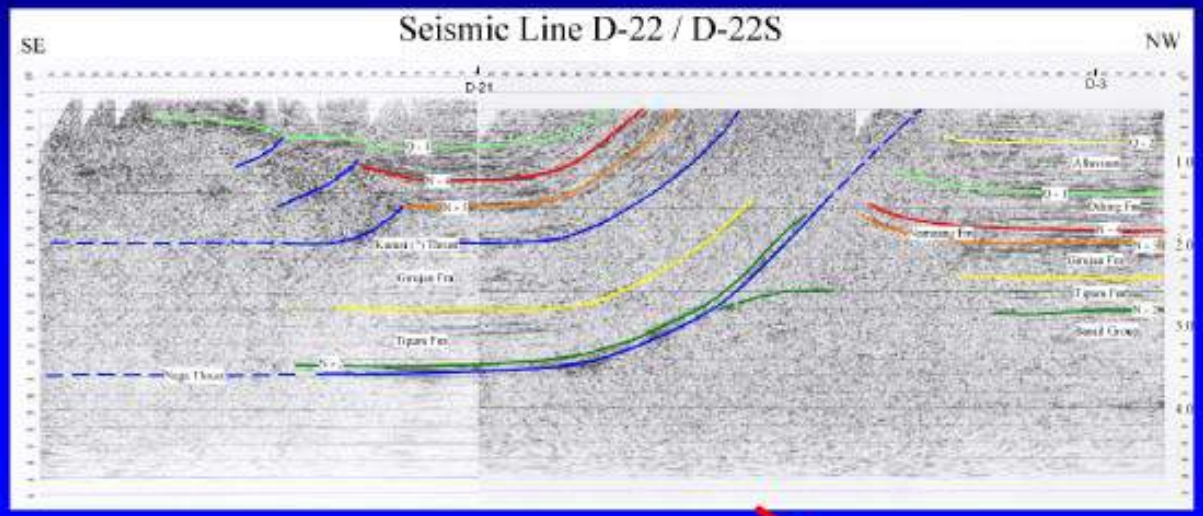


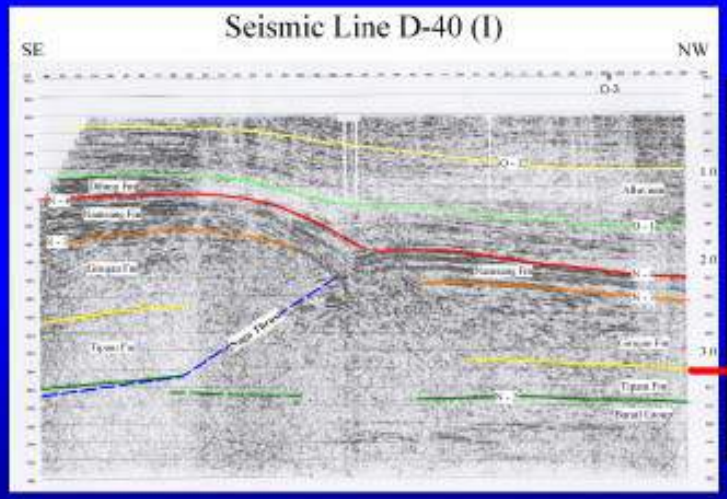
Thrust Belt Strike - Section

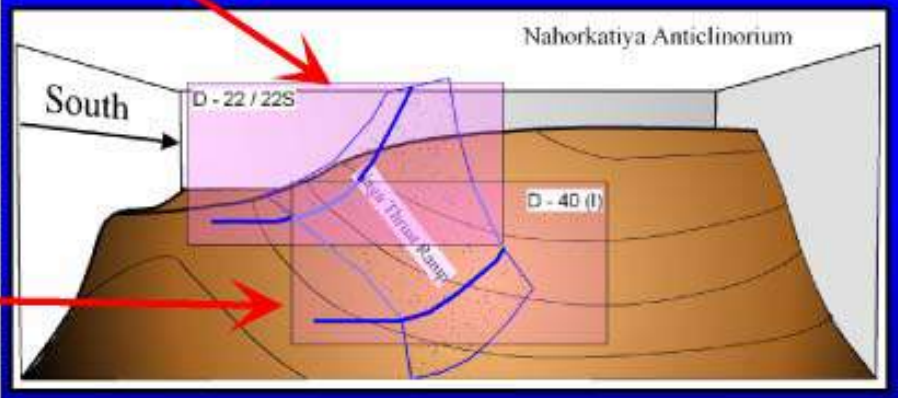


Foreland - Thrust Belt Co-Evolution

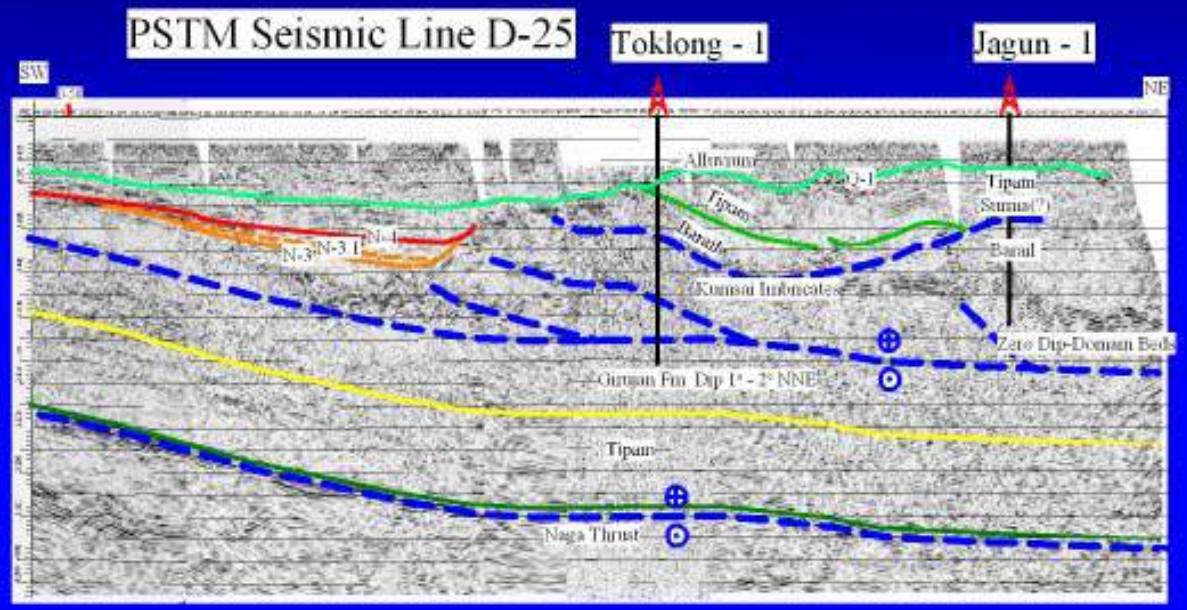
Fault Dip Lines

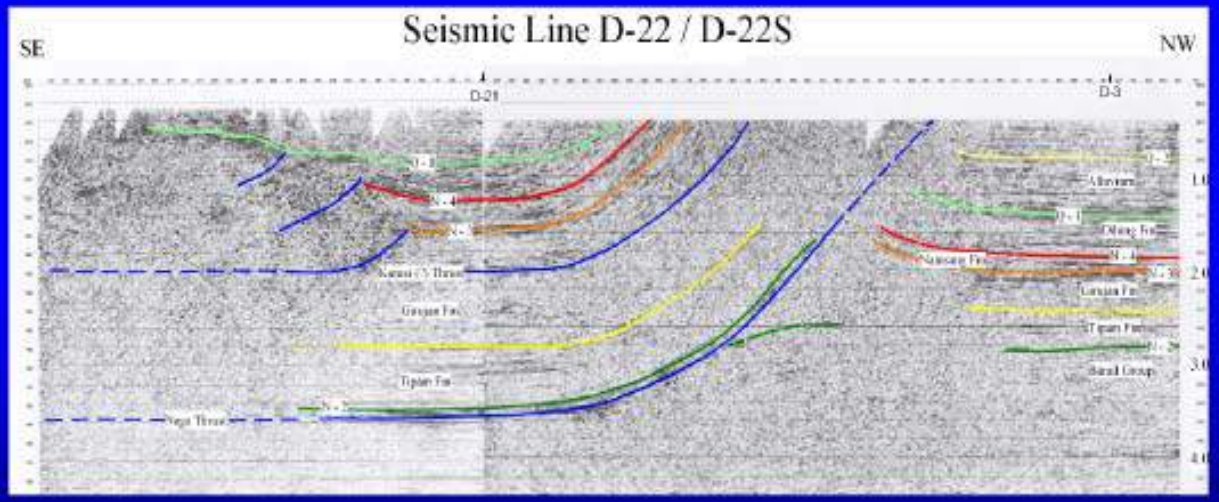




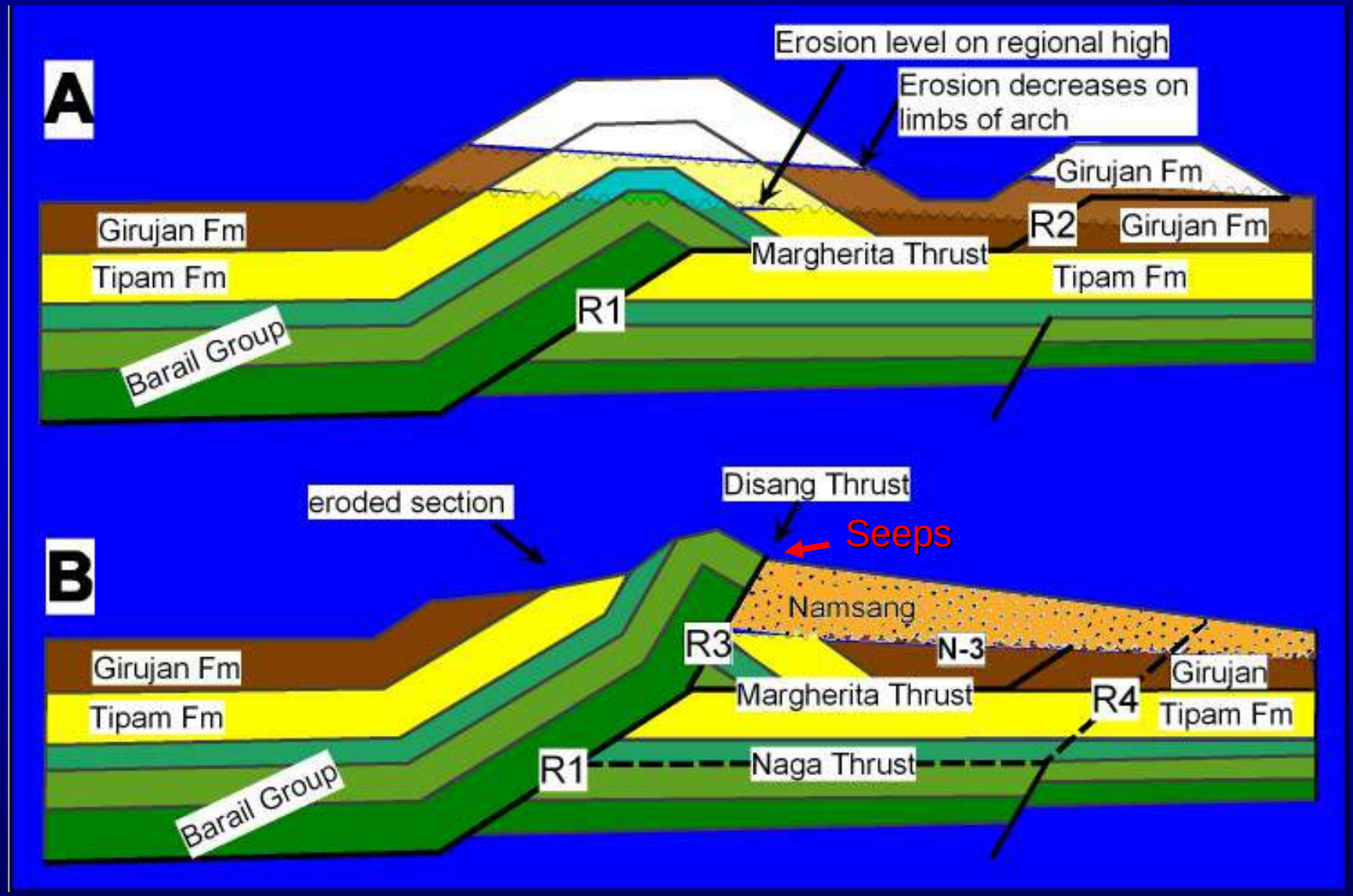


Kumsai Thrust Imbricates





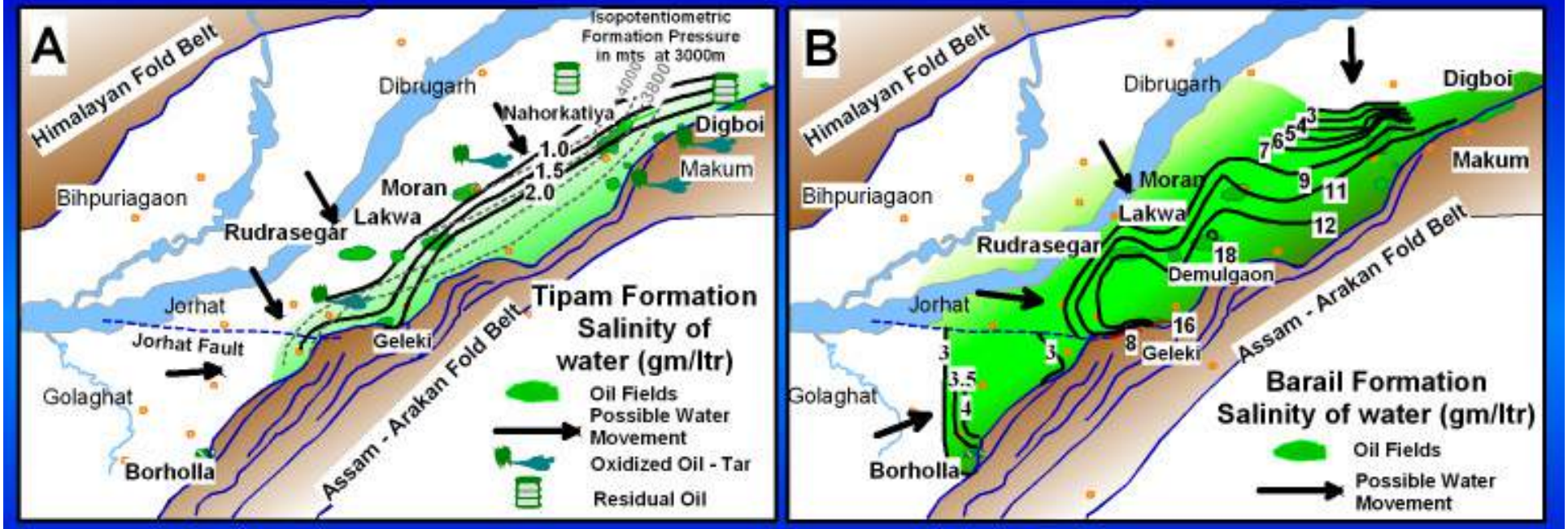
Thrust Sequence



Structural Summary

- Early Structures = Horsts and Grabens
- Mild Inversion of Normal Faults
- Multiple episodes of thrusting and erosion
- Several Generations of up-lift on the Dauki Fault System

Oil Field Characteristics

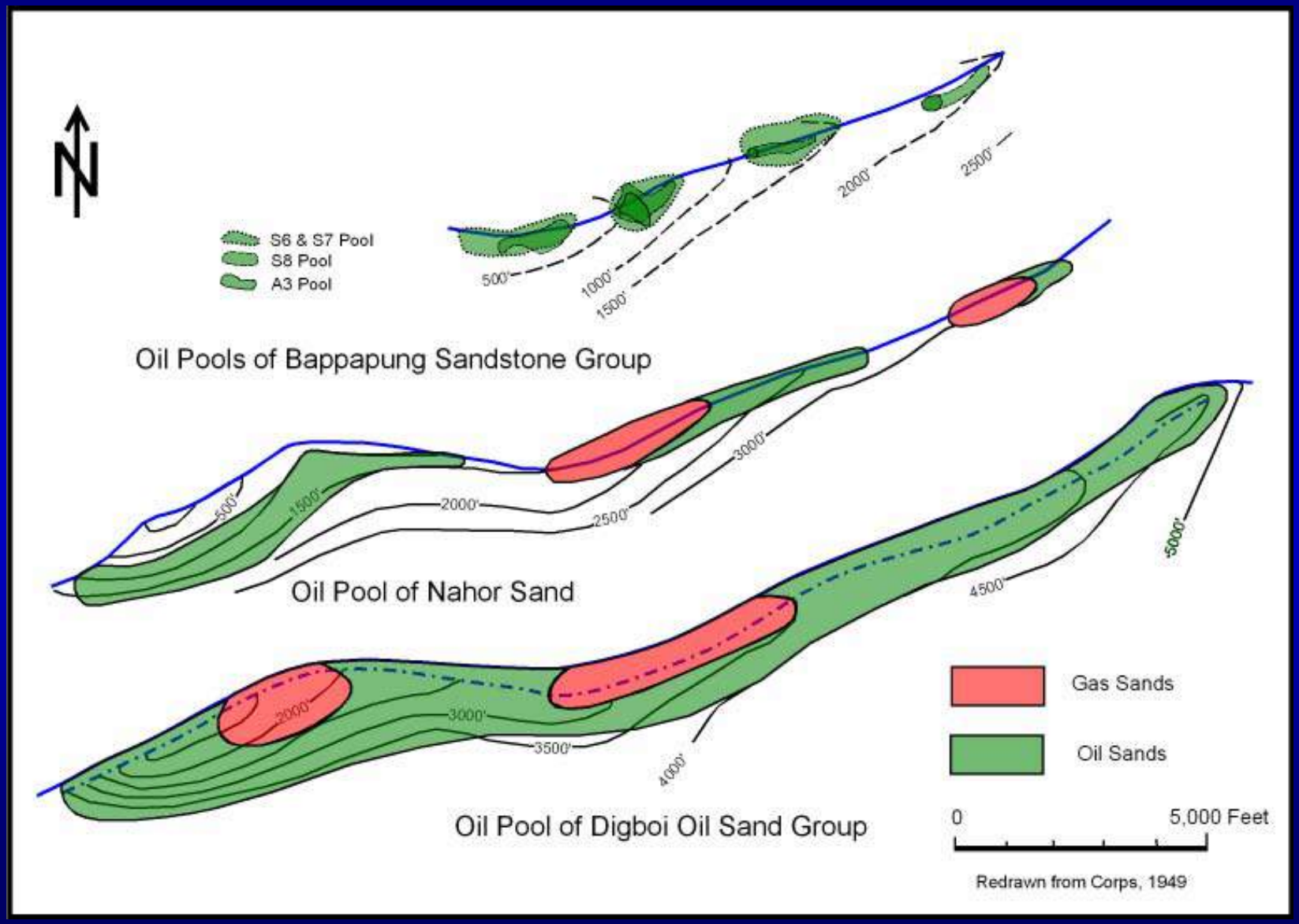


Shallow Reservoir

Deeper Reservoir

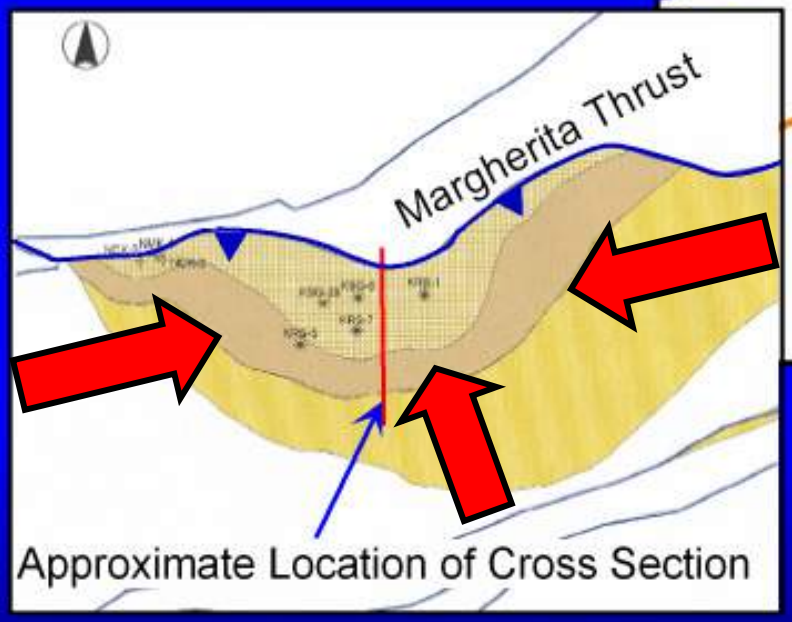
Figures from Seshavataram, et al., 1980

Digboi Field



Kharsang Field

- Oil generally 19° - 29° API but one well has 35° oil
- Oil is Aromatic in the East Napthanic in the West
- Residual oil shows below 1000m



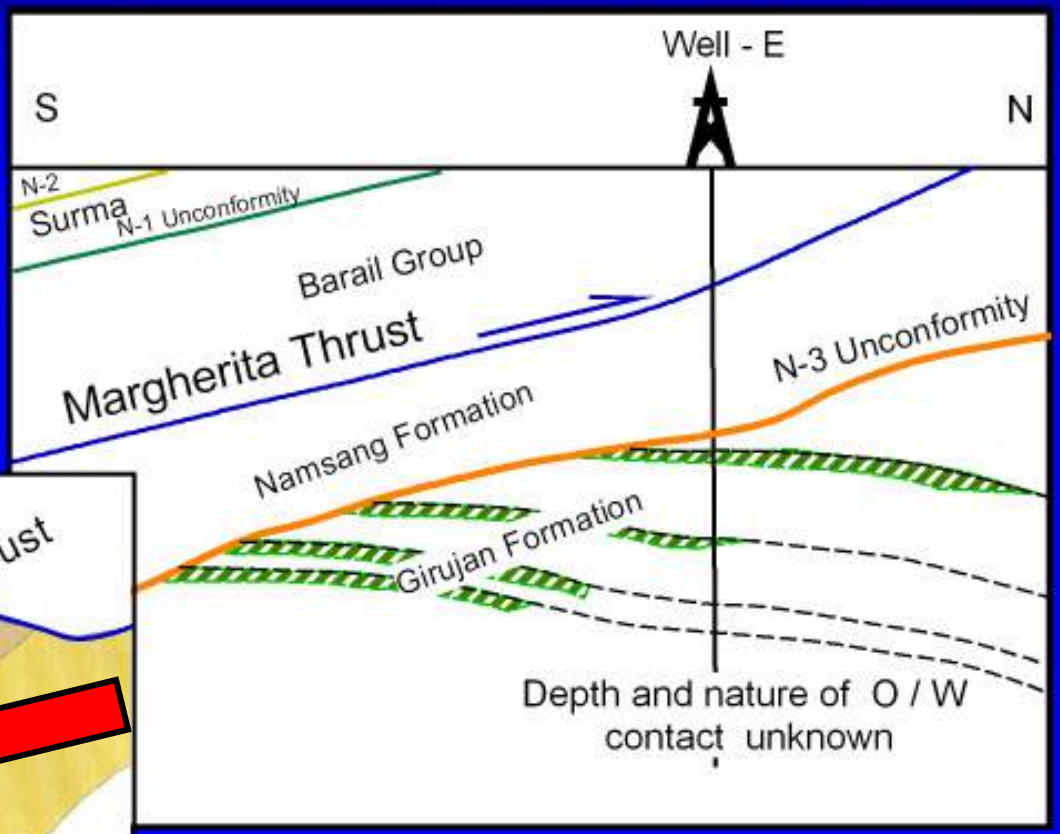
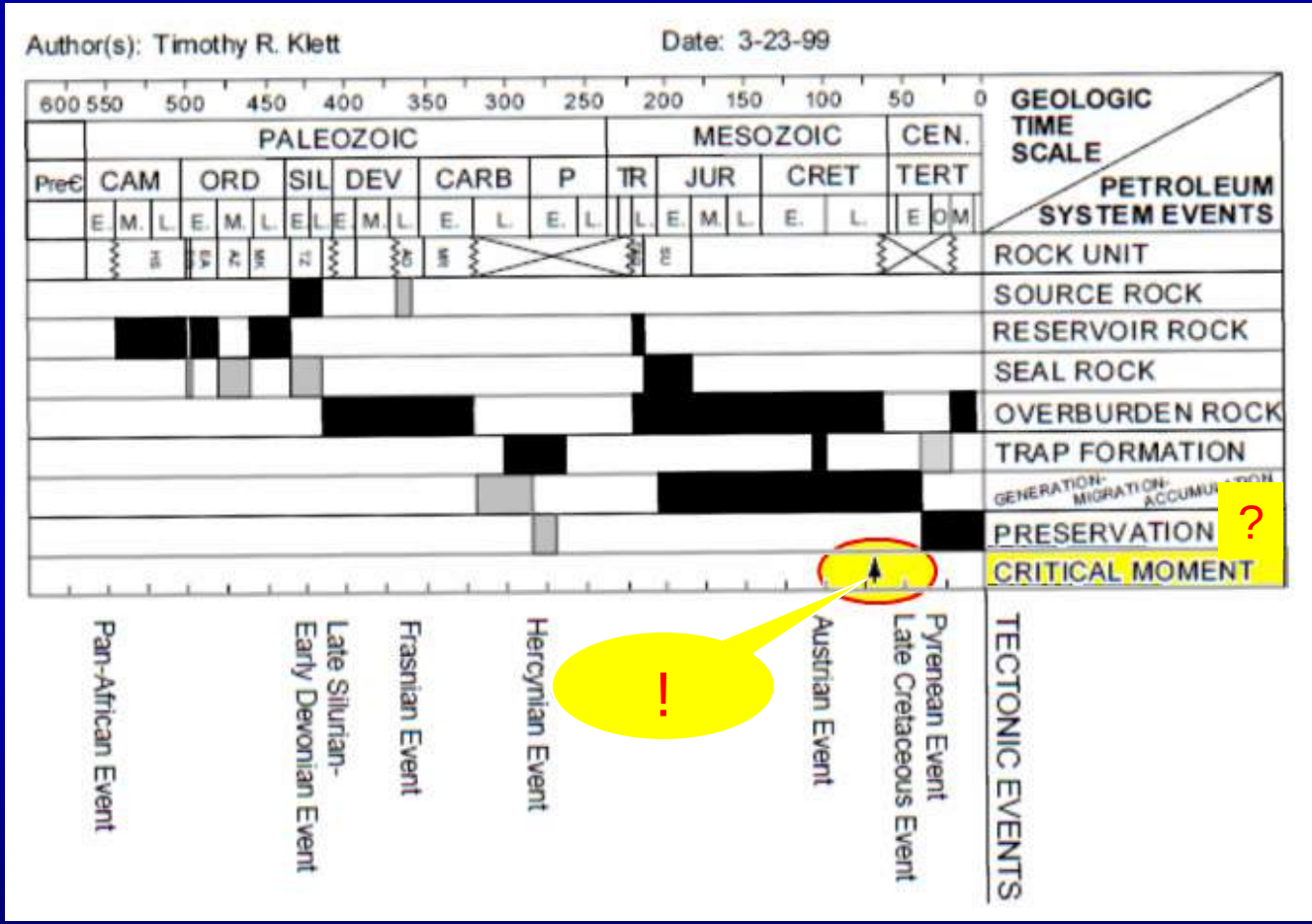


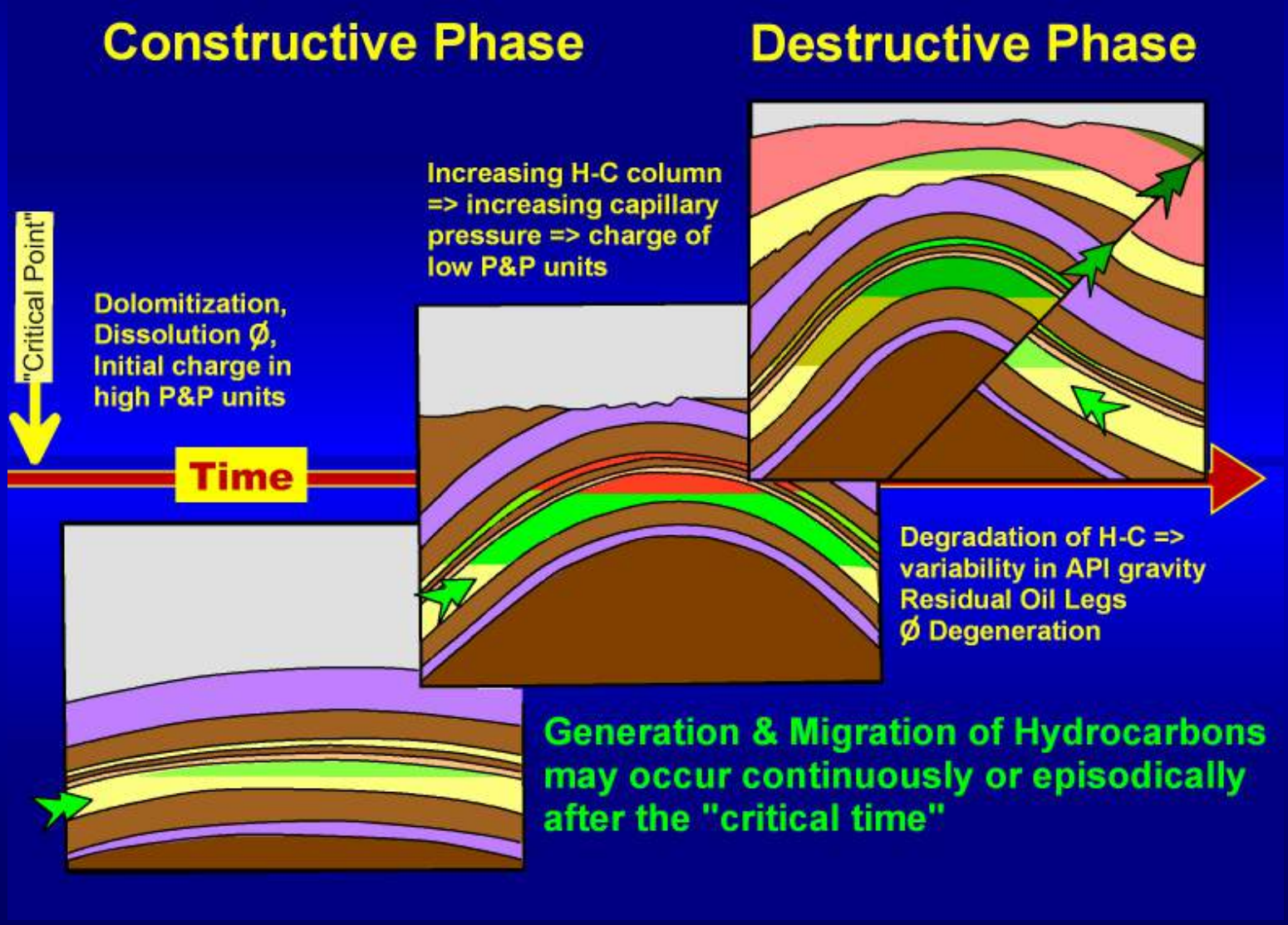
Figure from Handique & Bharali, 1984

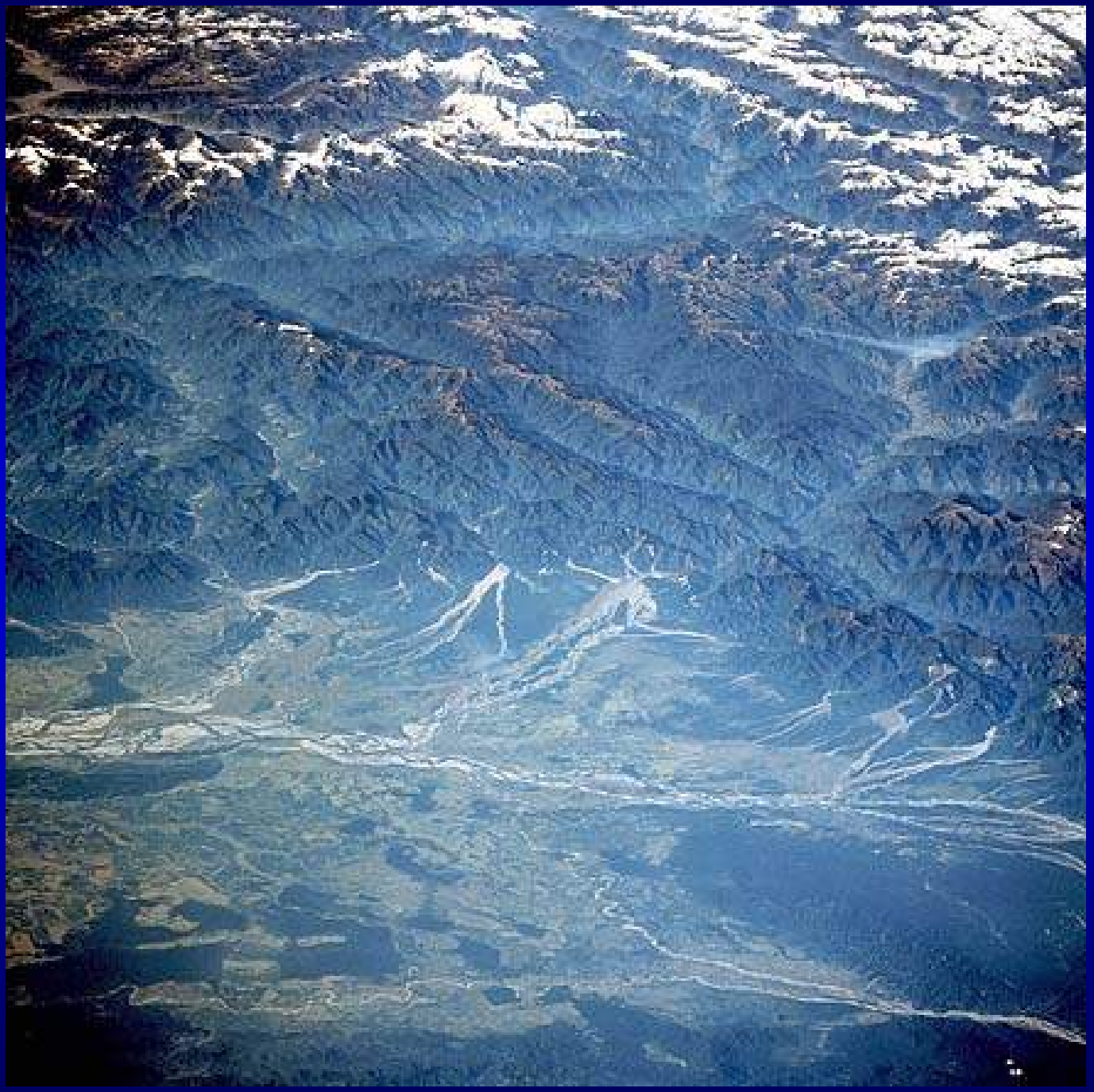
Petroleum System Model

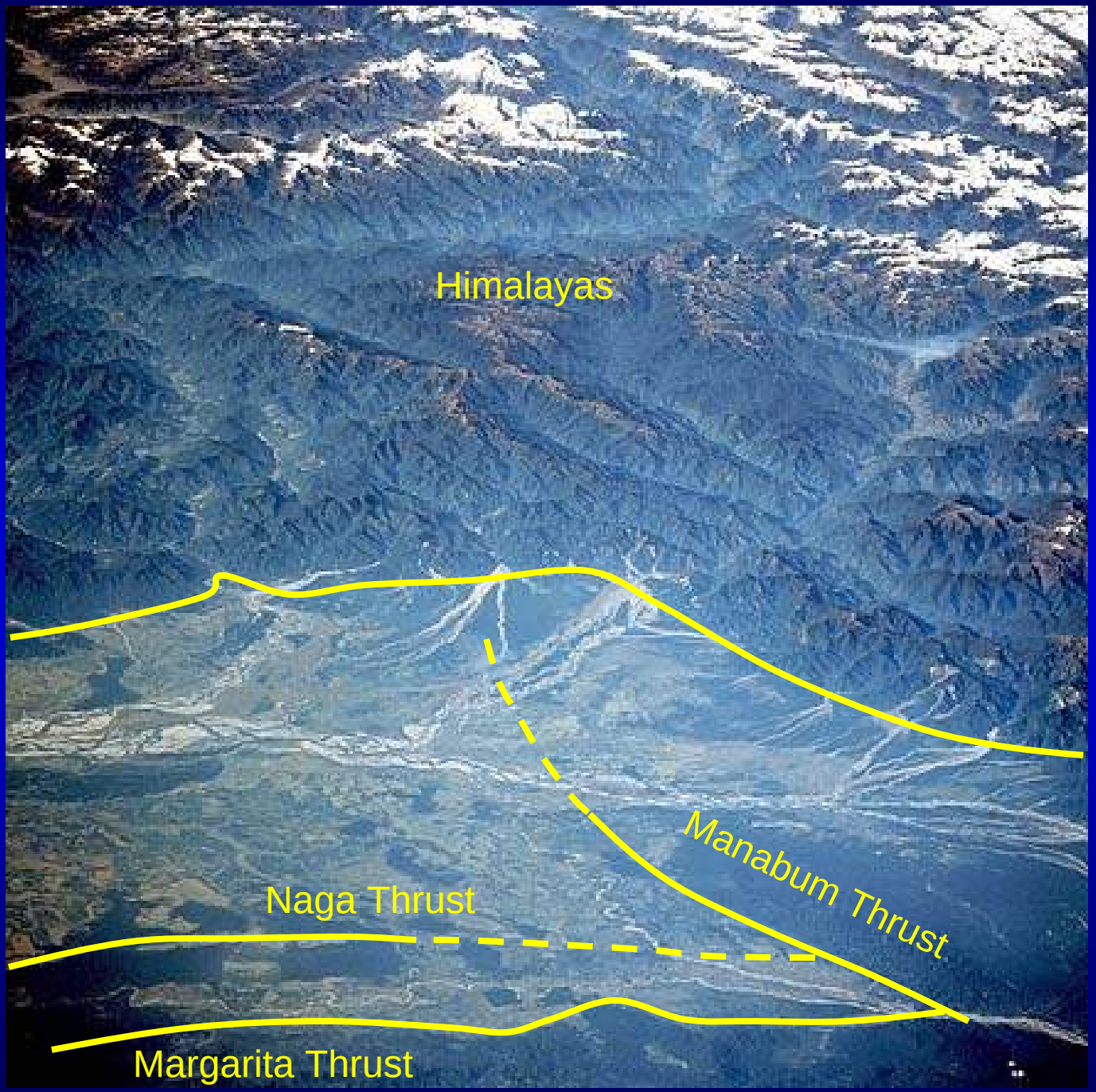


From USGS Bull 2202-C

Dynamic Hydrocarbon System






Himalayas
Manabum Thrust
Naga Thrust
Margarita Thrust

END

Life & Death of Petroleum Systems and their included Oil Fields

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Life & Death of Petroleum Systems and their included Oil Fields

W. Norman Kent

Hunting the Tiger

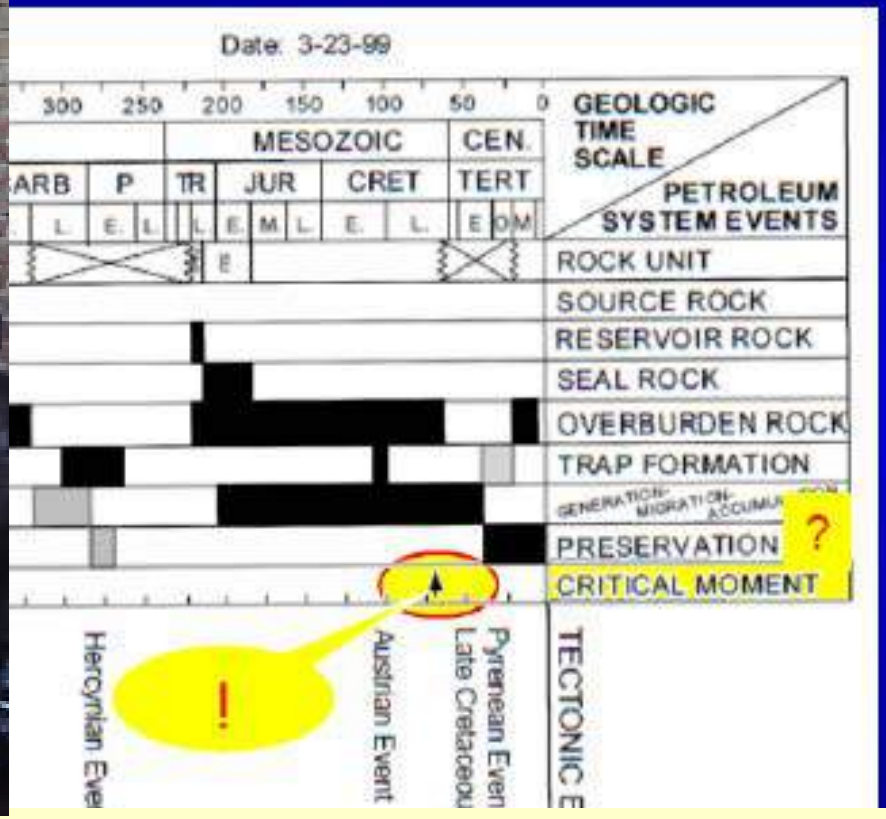
What we need to know about Tiger

- What is a Tiger
- **Tiger is alive**
- Where does Tiger **live**
- How does Tiger **move**
- Tiger leaves **tracks**
- What does tiger's tracks look like
- Who are Tiger's enemies and friends

If we are hunting Oil, we need to answer the same questions

Static

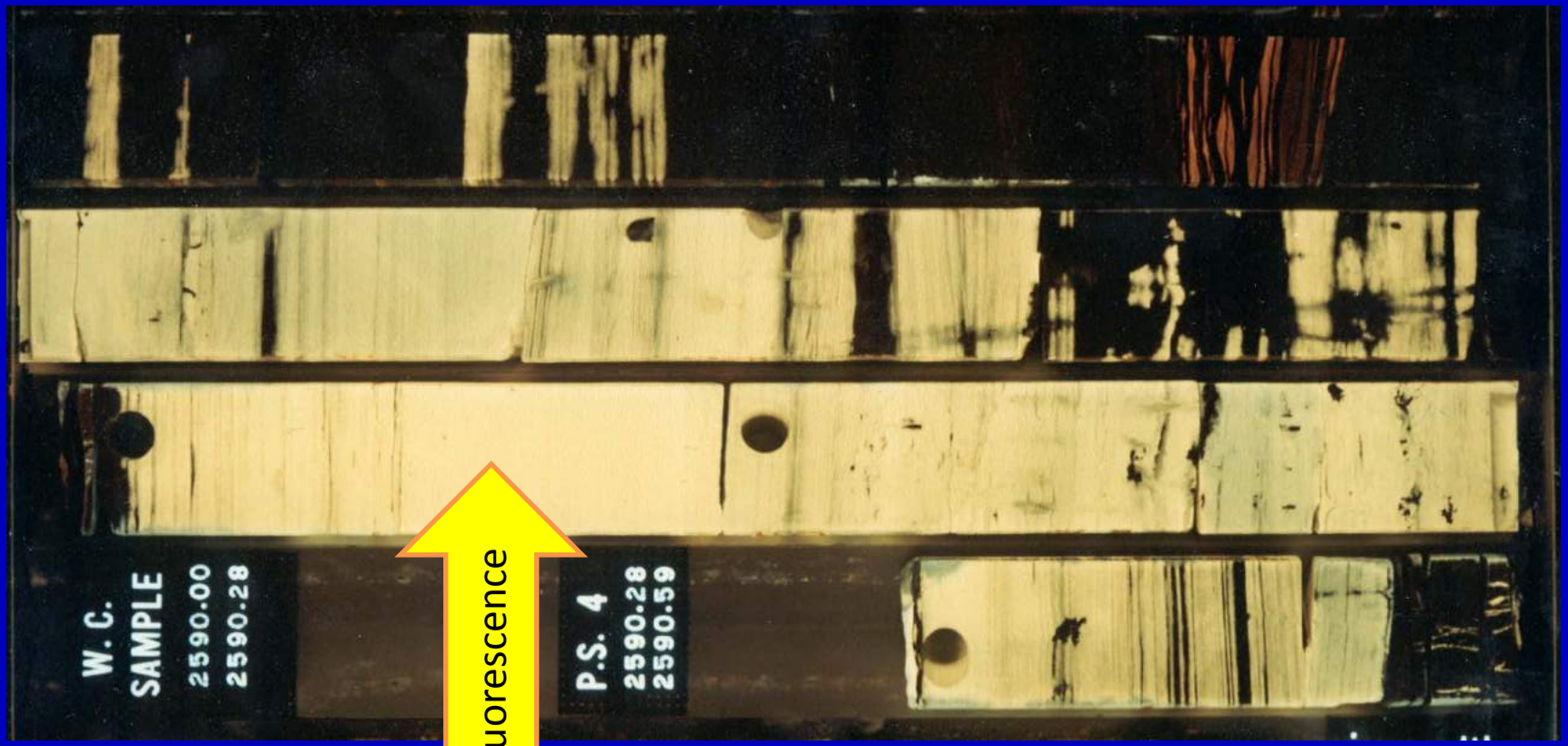
Petroleum System Model



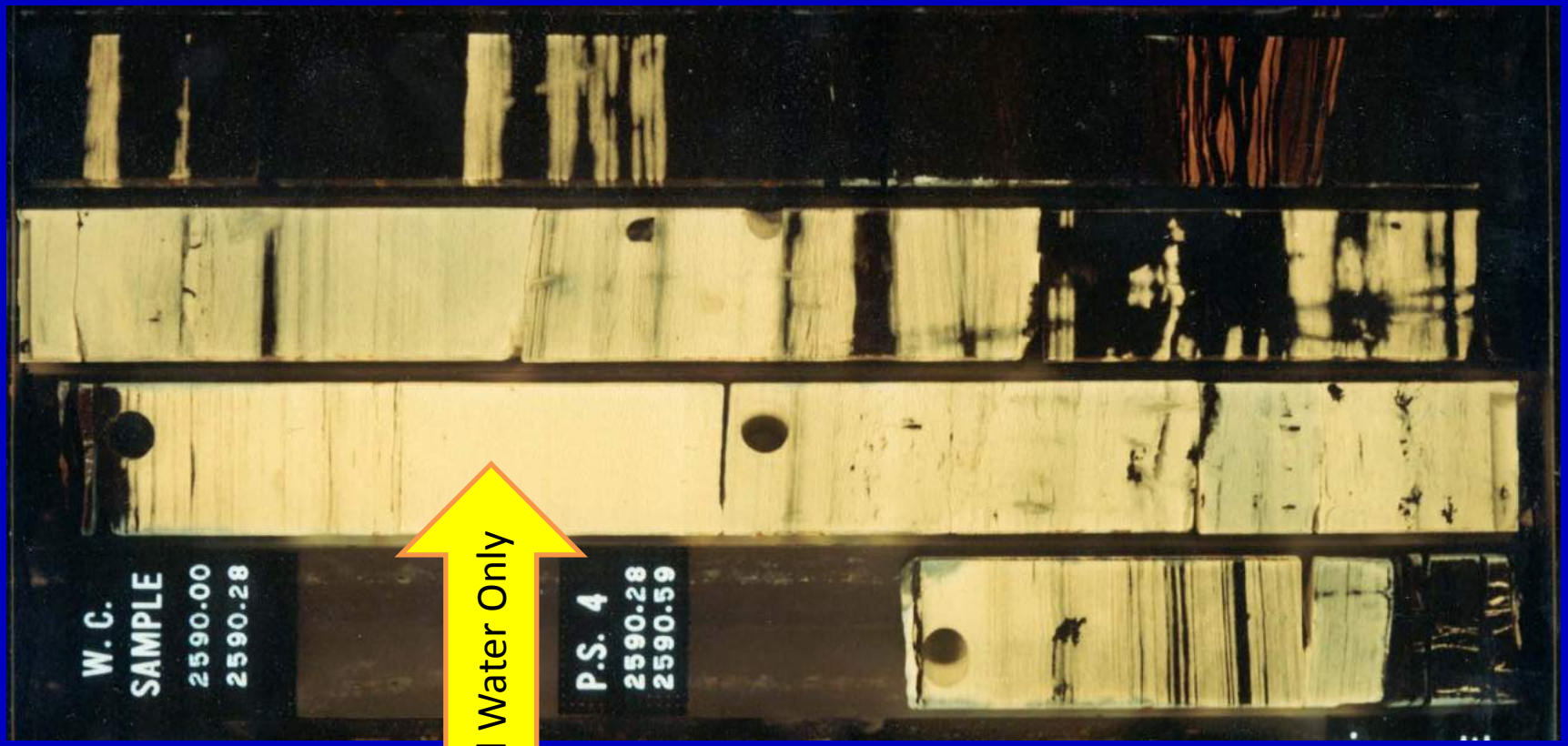
A Single Event – a thing – not "alive"

From USGS Bull 2202-C

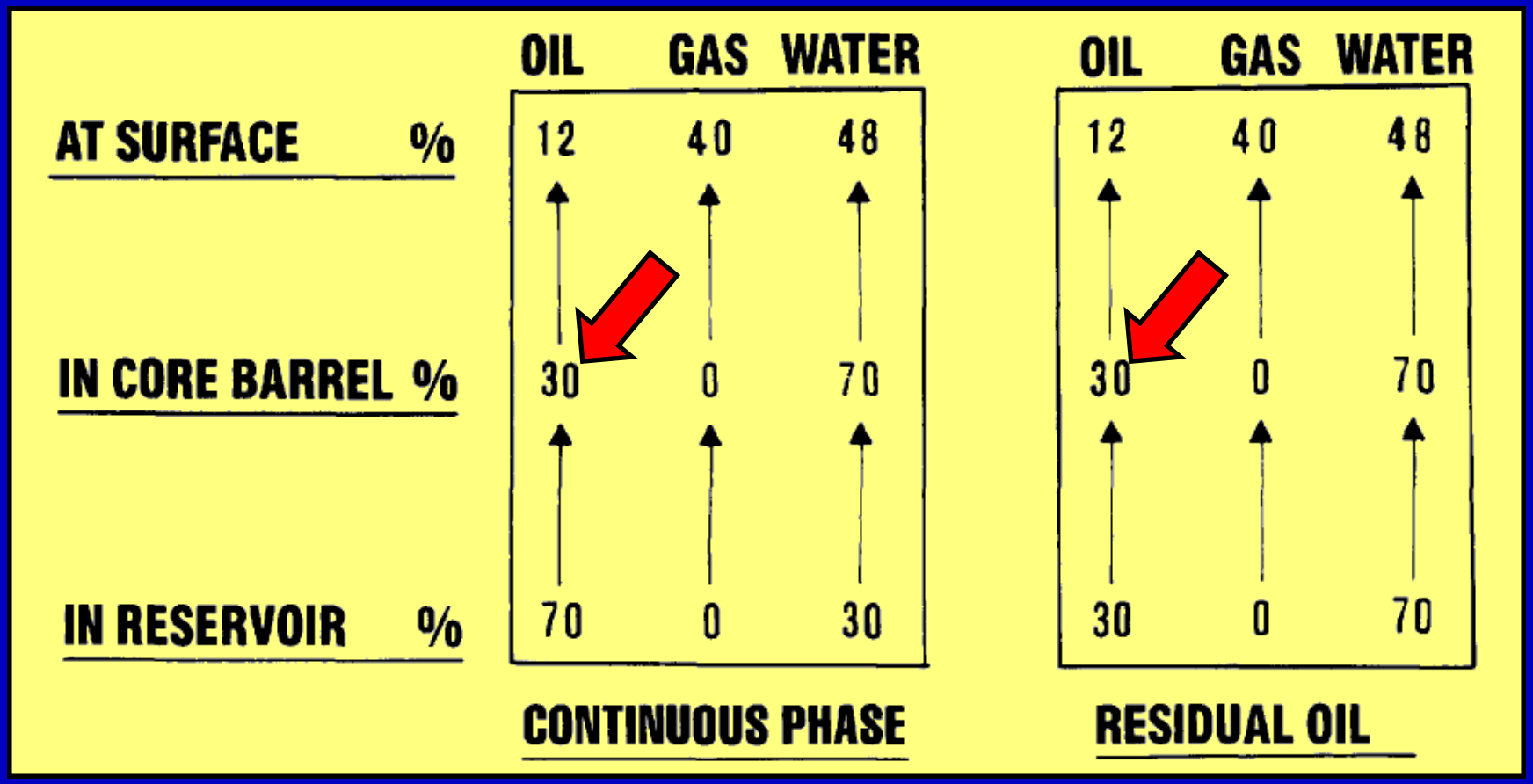
Core Photo in UV Light



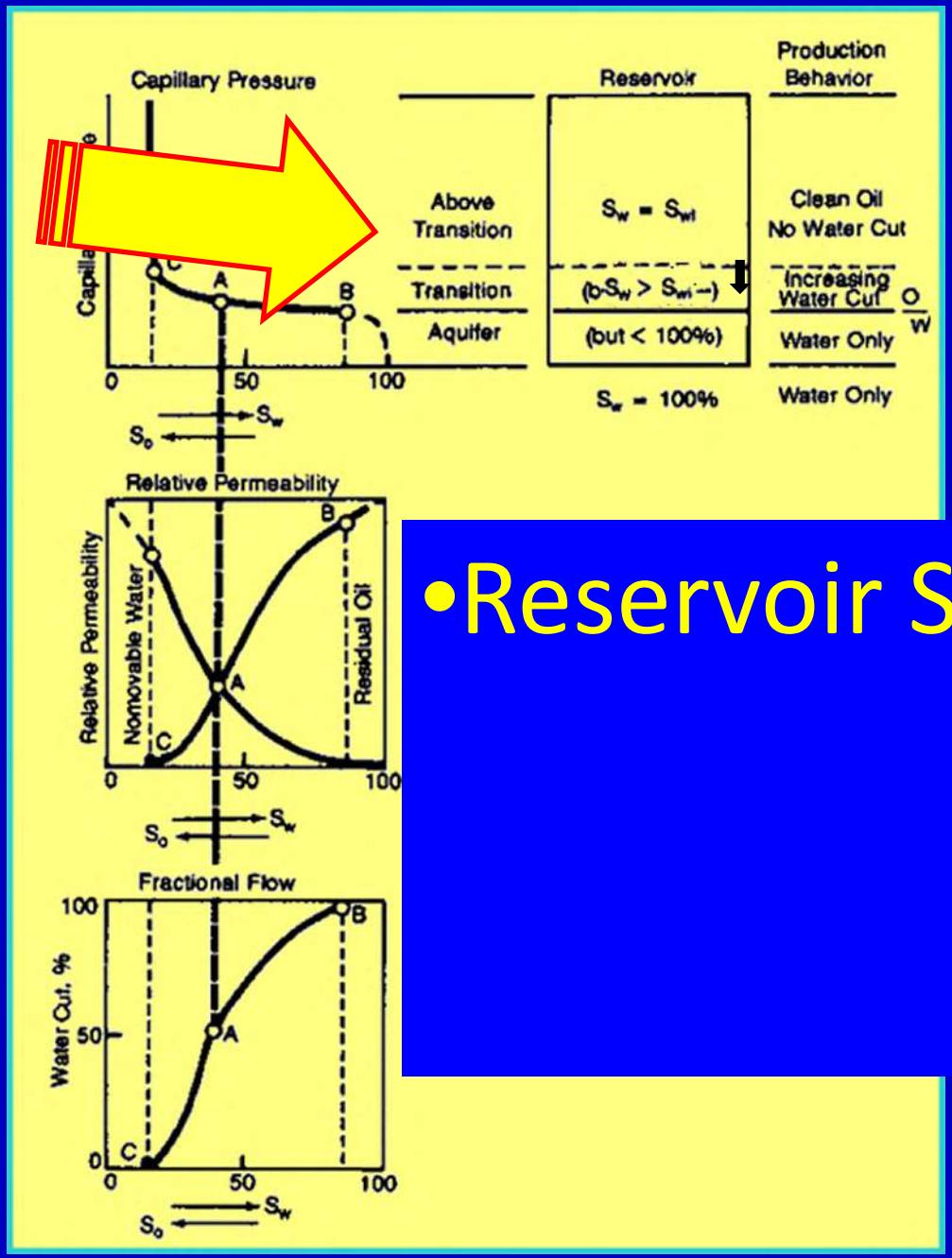
Core Photo in UV Light



Core Saturation



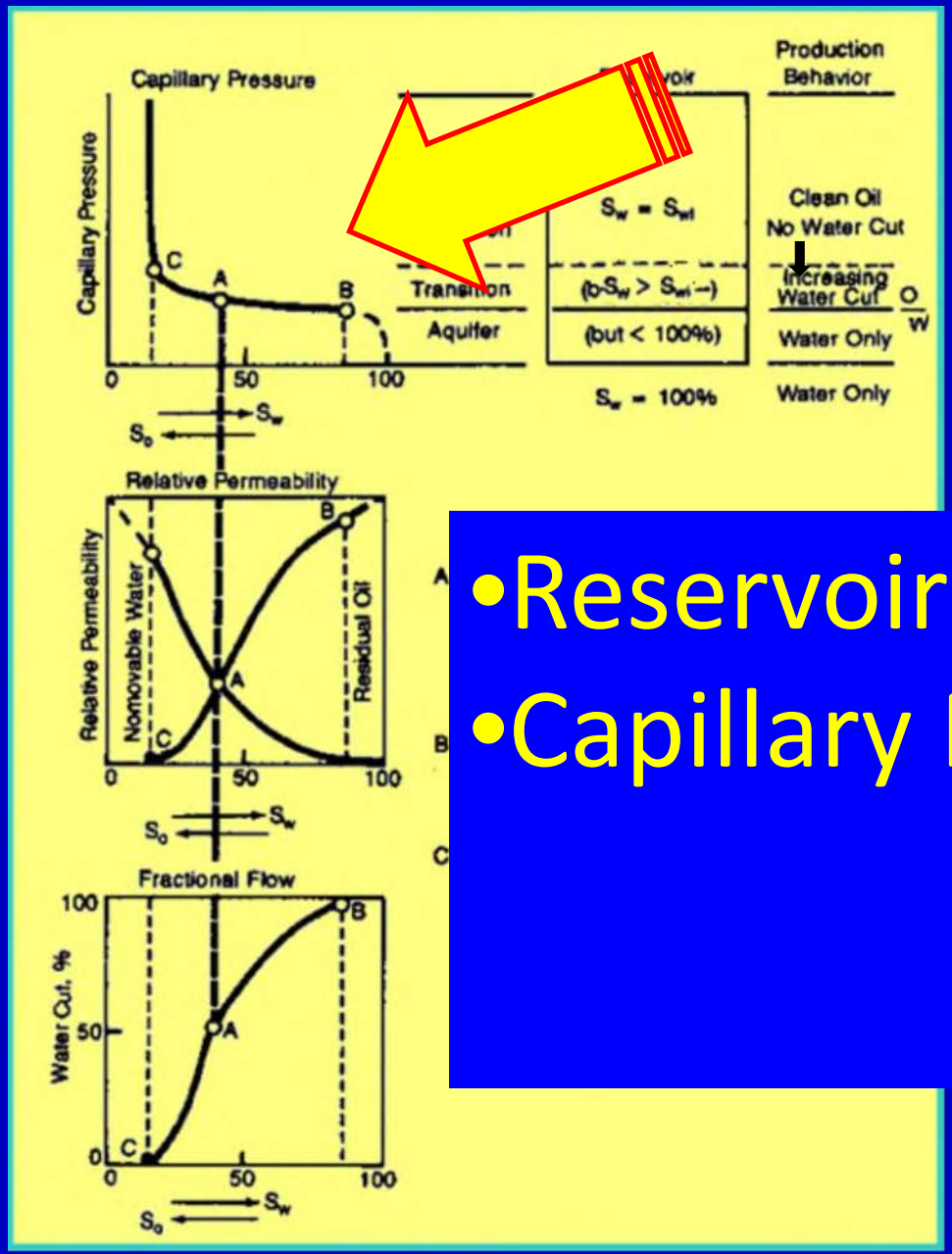
This chart is for an oil reservoir badly flushed by water based mud. Other scenarios exist for gas reservoirs and oil mud. From the Fundamentals of Core Analysis, Core Lab



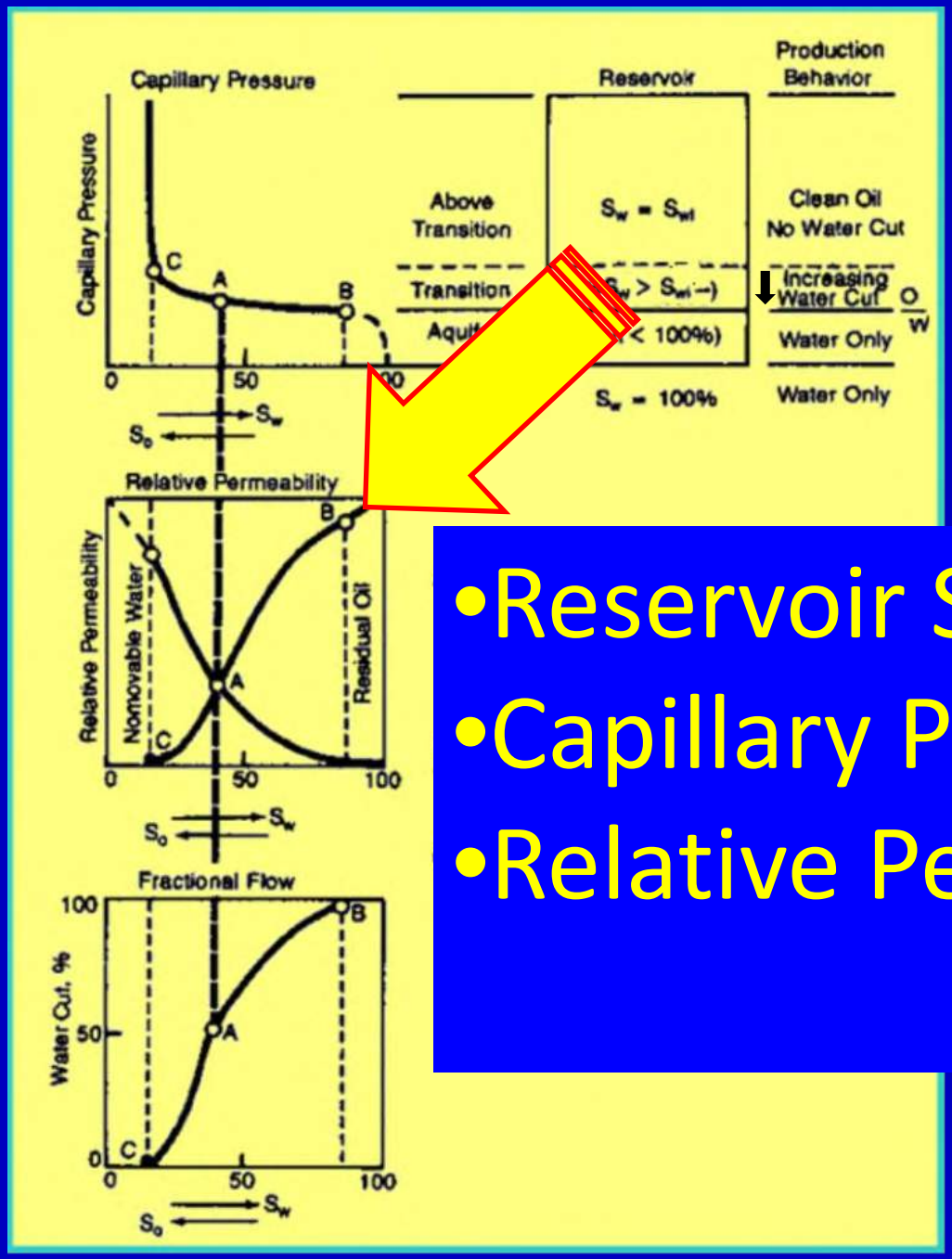
Oil & Water in a Reservoir Rock

- Reservoir Saturations

Oil & Water in a Reservoir Rock

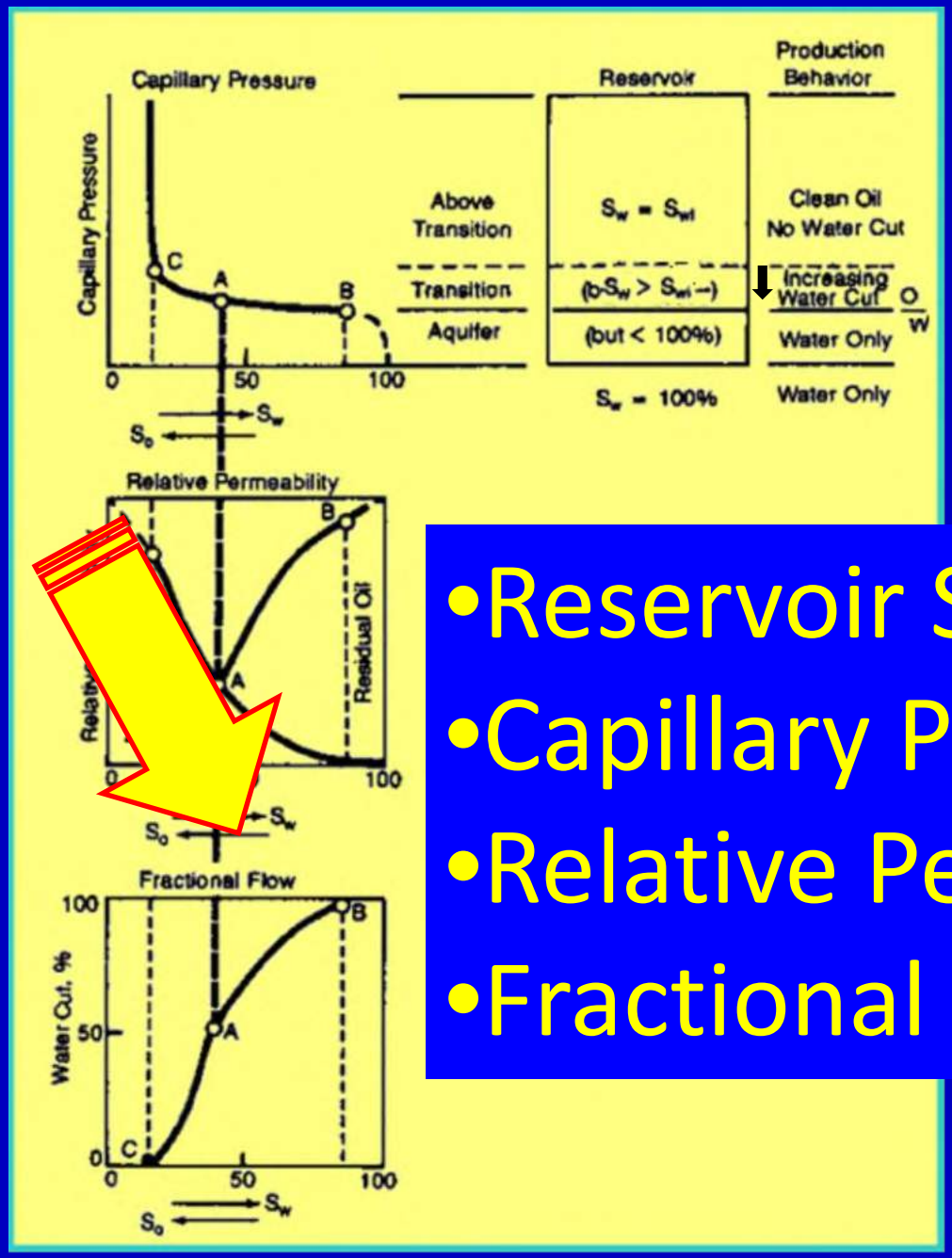


- Reservoir Saturations
- Capillary Pressure



Oil & Water in a Reservoir Rock

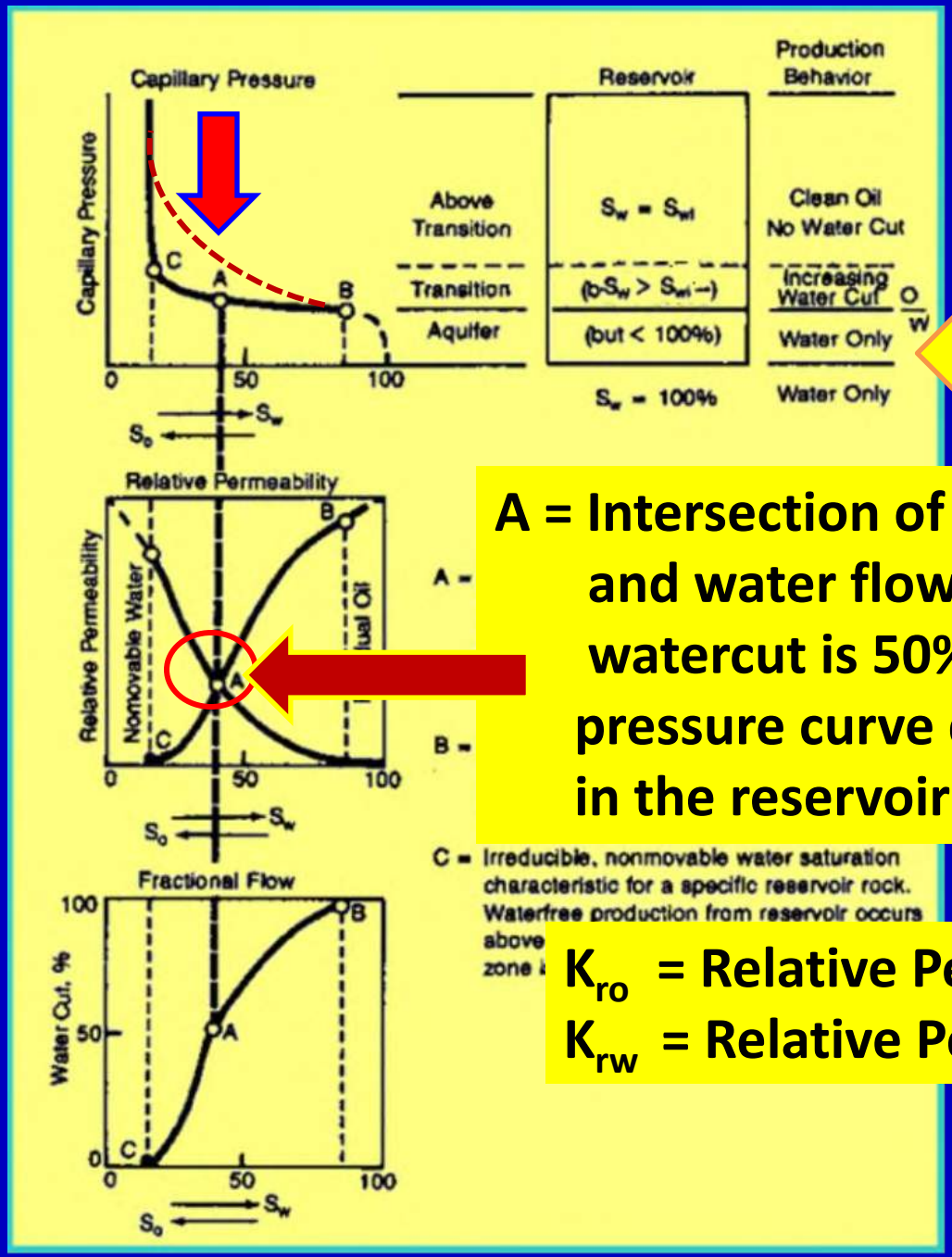
- Reservoir Saturations
- Capillary Pressure
- Relative Permeability



Oil & Water in a Reservoir Rock

- Reservoir Saturations
- Capillary Pressure
- Relative Permeability
- Fractional Flow

Relative Permeability

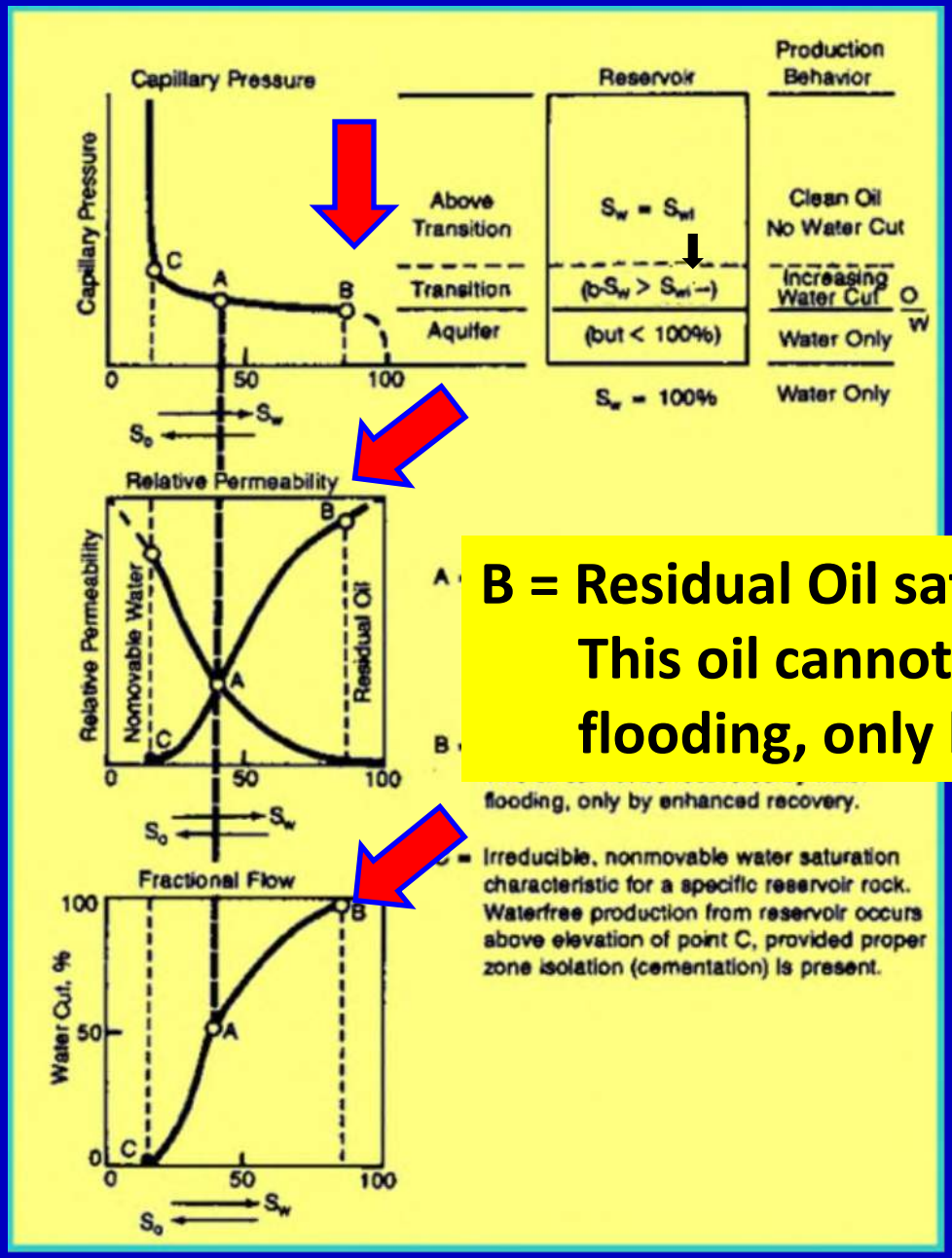


Free water table

A = Intersection of K_{ro} with K_{rw} curves. Oil and water flow at equal ease. Hence, watercut is 50%. Position of capillary pressure curve defines elevation (height) in the reservoir above free water table

K_{ro} = Relative Permeability to oil

K_{rw} = Relative Permeability to water



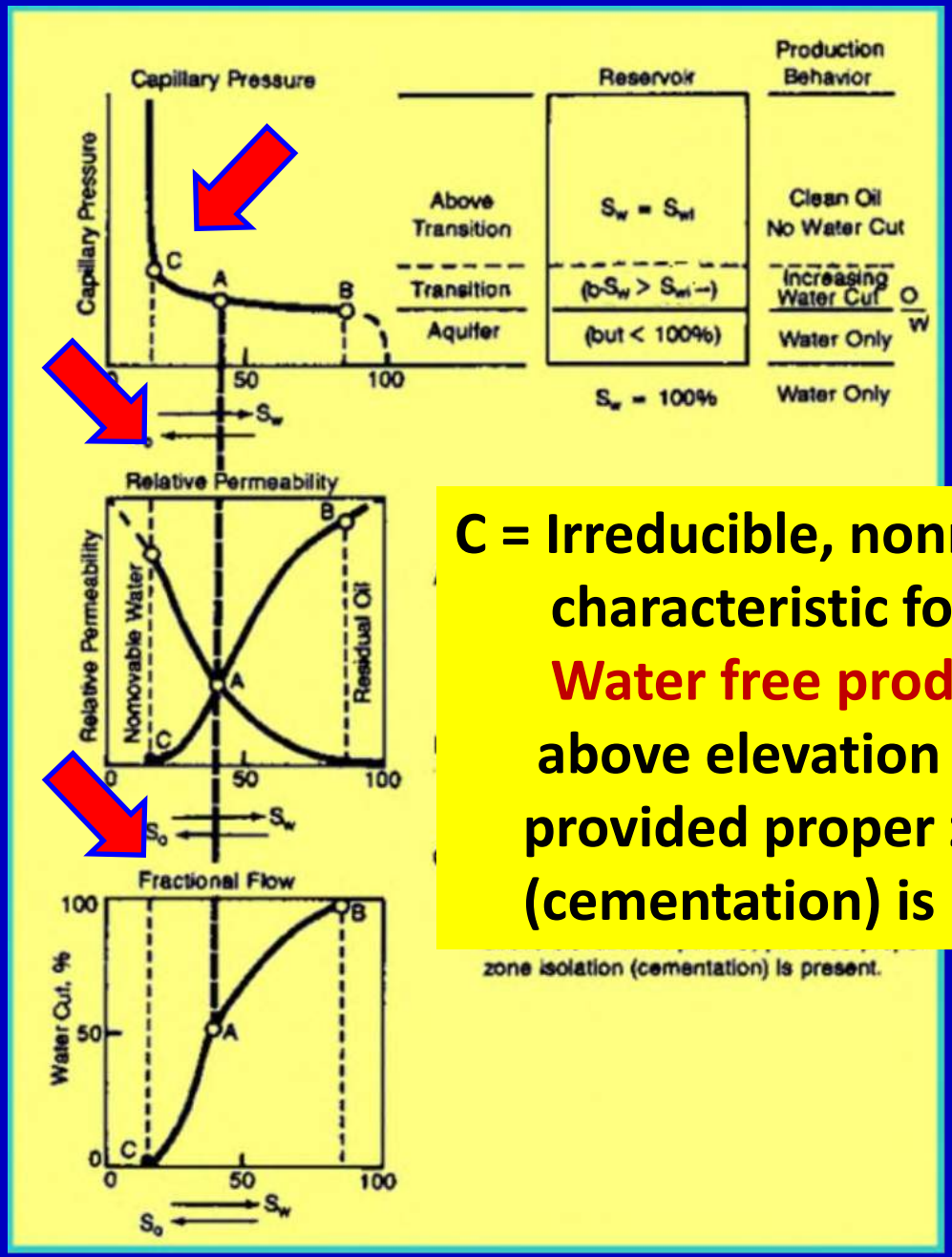
Irreducible Oil Saturation

B = Residual Oil saturation (nonmovable Oil)
This oil cannot be recovered by water flooding, only by enhanced recovery

flooding, only by enhanced recovery.

Irreducible, nonmovable water saturation characteristic for a specific reservoir rock. Waterfree production from reservoir occurs above elevation of point C, provided proper zone isolation (cementation) is present.

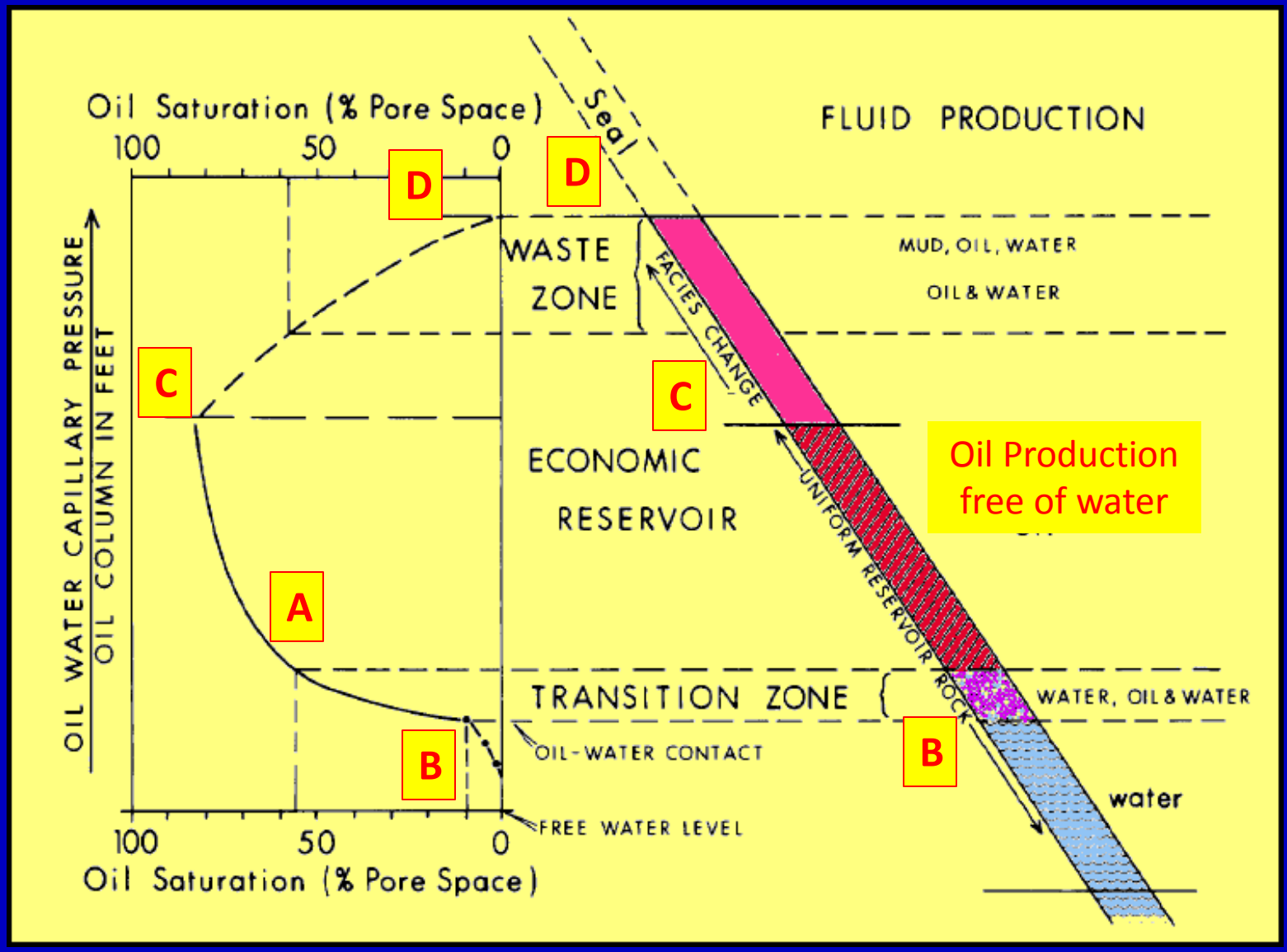
Irreducible Water Saturation



C = Irreducible, nonmovable water saturation characteristic for a specific reservoir rock.

Water free production from reservoir above elevation of point C – provided proper zone isolation (cementation) is present

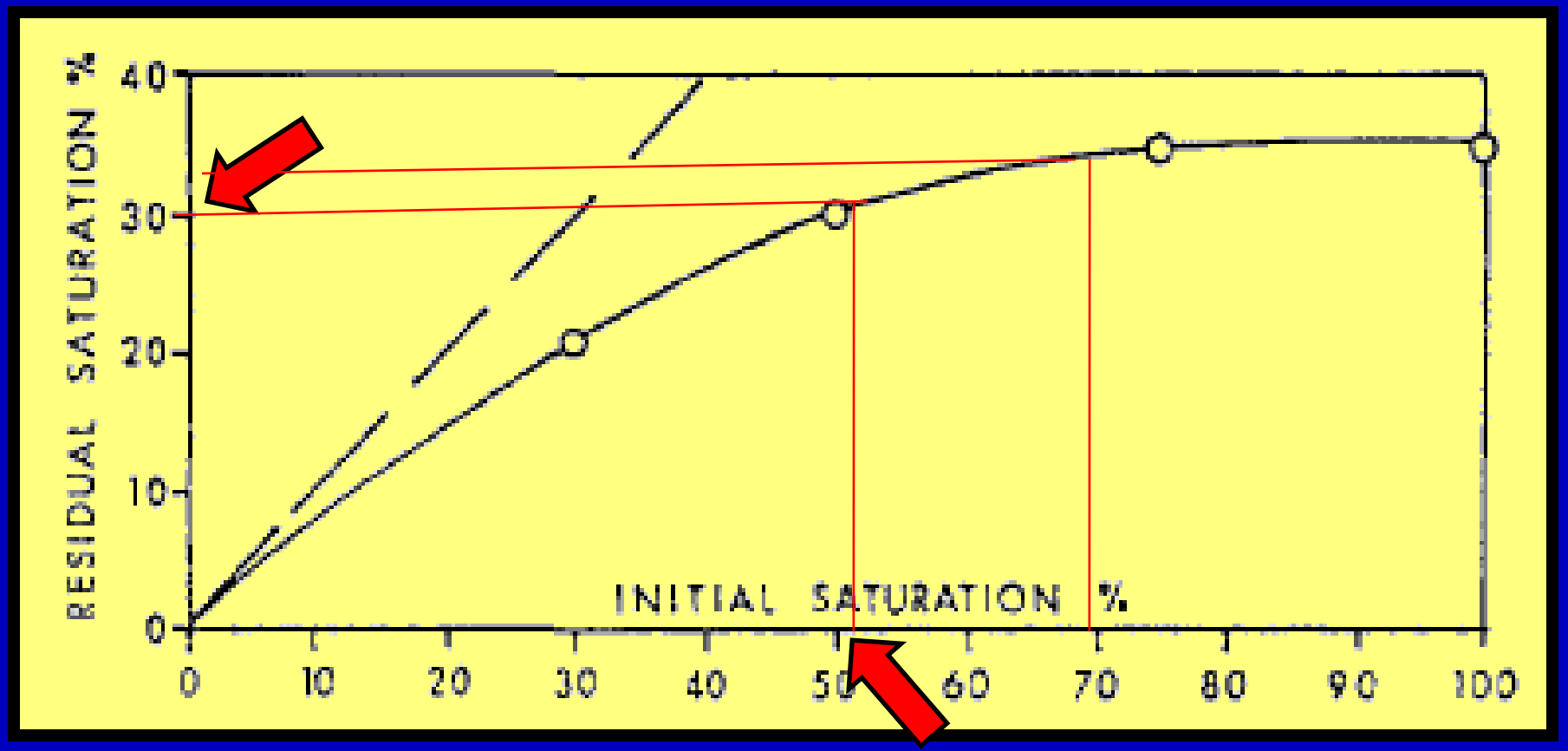
zone isolation (cementation) is present.



Modified From Schowalter & Hess, 1982

Residual Oil / Initial Saturation

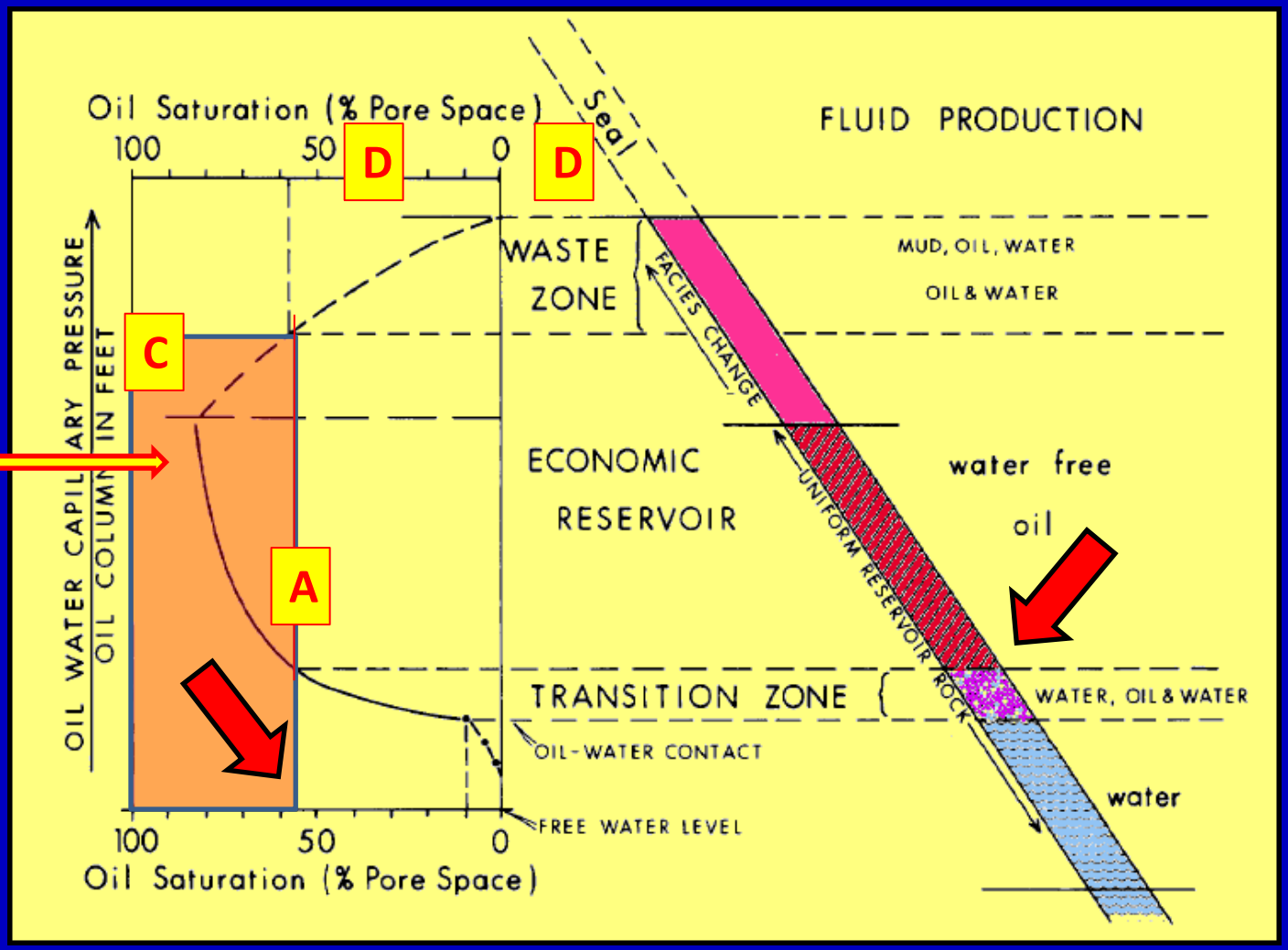
Results are a function of Porosity and Permeability



Modified From Schowalter & Hess 1982

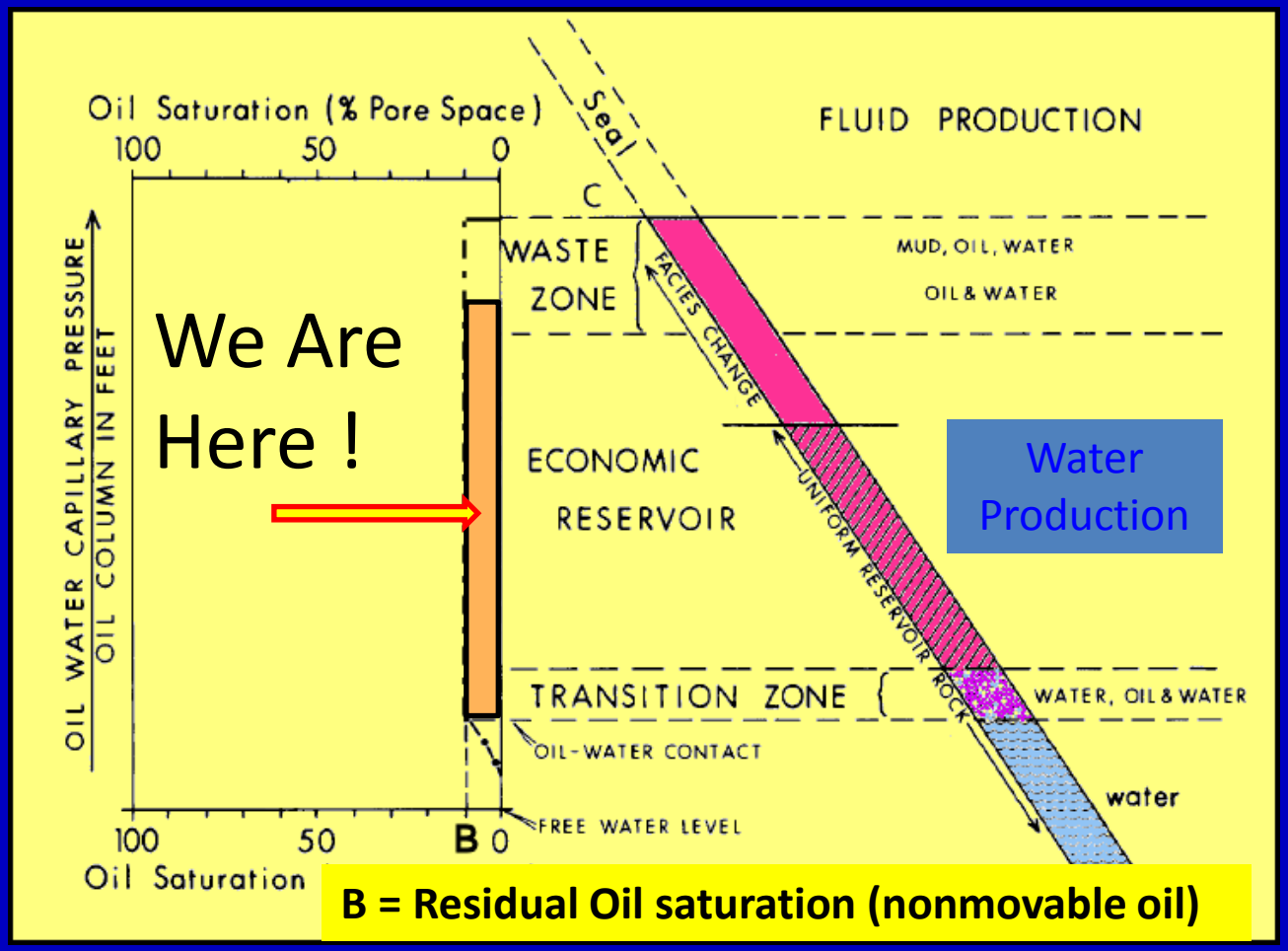
Productive Reservoir

We Are Here?



Modified From Schowalter & Hess 1982

Residual Reservoir
Dead Oil Field



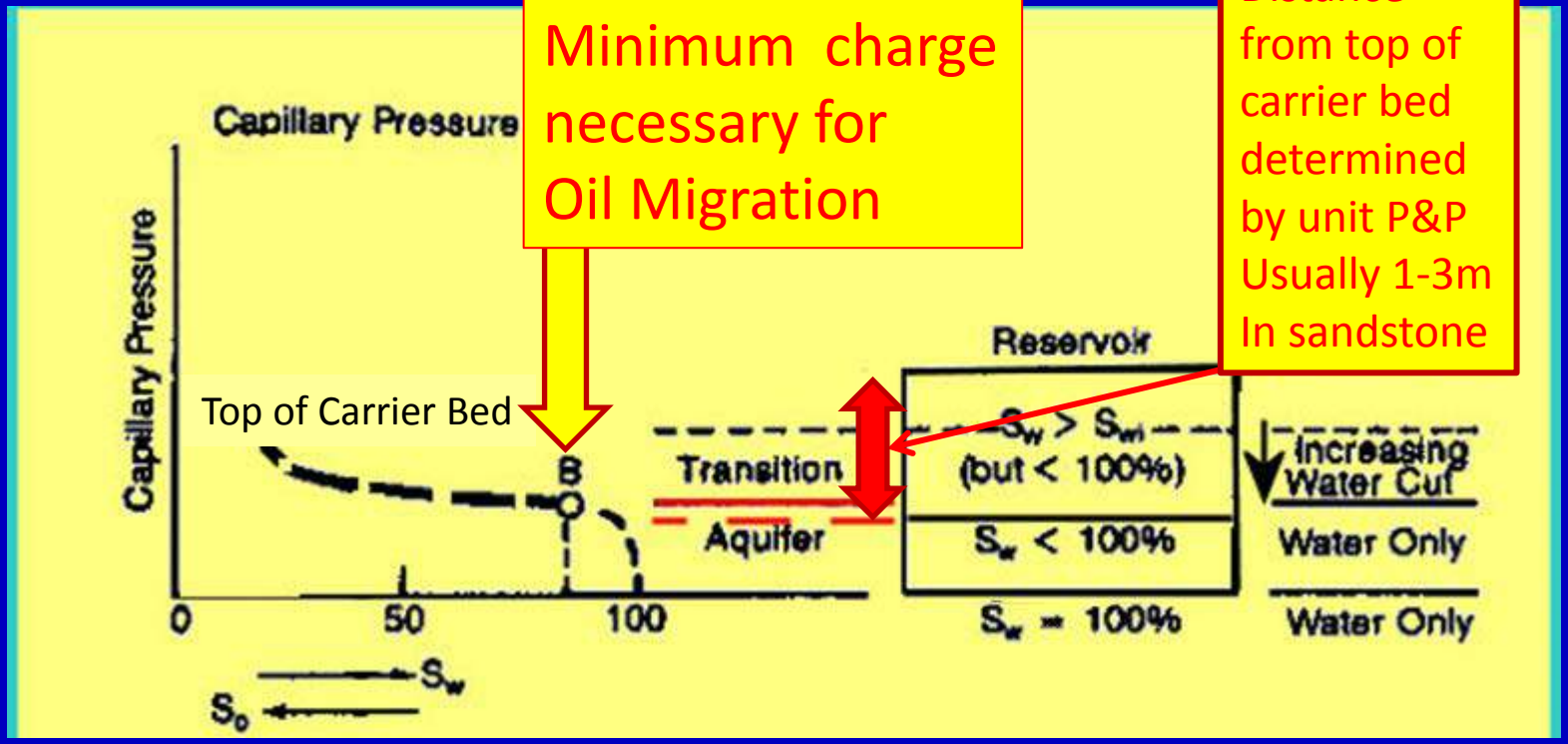
Modified From Schowalter & Hess 1982

Hydrocarbon Shows (Oil Tracks)

Mode of Occurance	Show Type	Significance	
		Production	Exploration
Continuous Phase	I	Productive (?)	Traped Oil
Residual 1	IIa	Non-Productive	Depleted Trap
Residual 2	IIb		Migratory Oil
Residual 3	IIc		Dead Oil
Detrital Oil	III		Moved Dead Oil
Disolved Oil	IV		H-C in System
In Kerogen	V		Source Rock

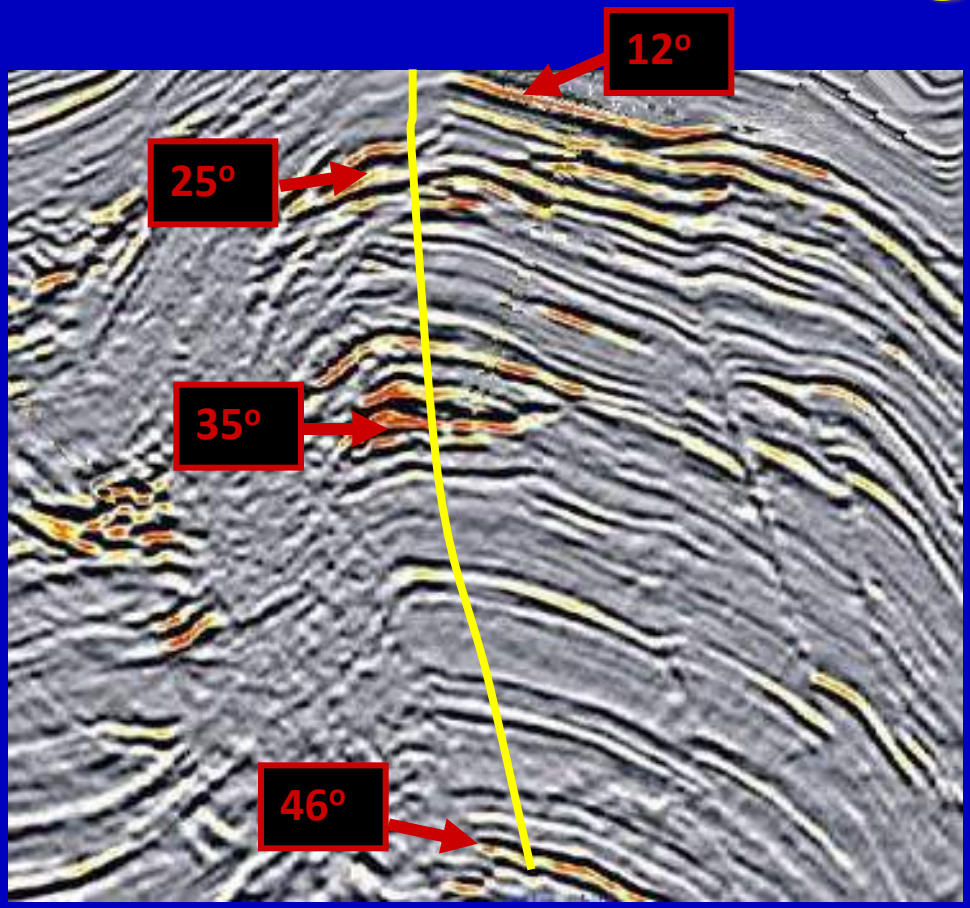
Modified From Schowalter & Hess 1982

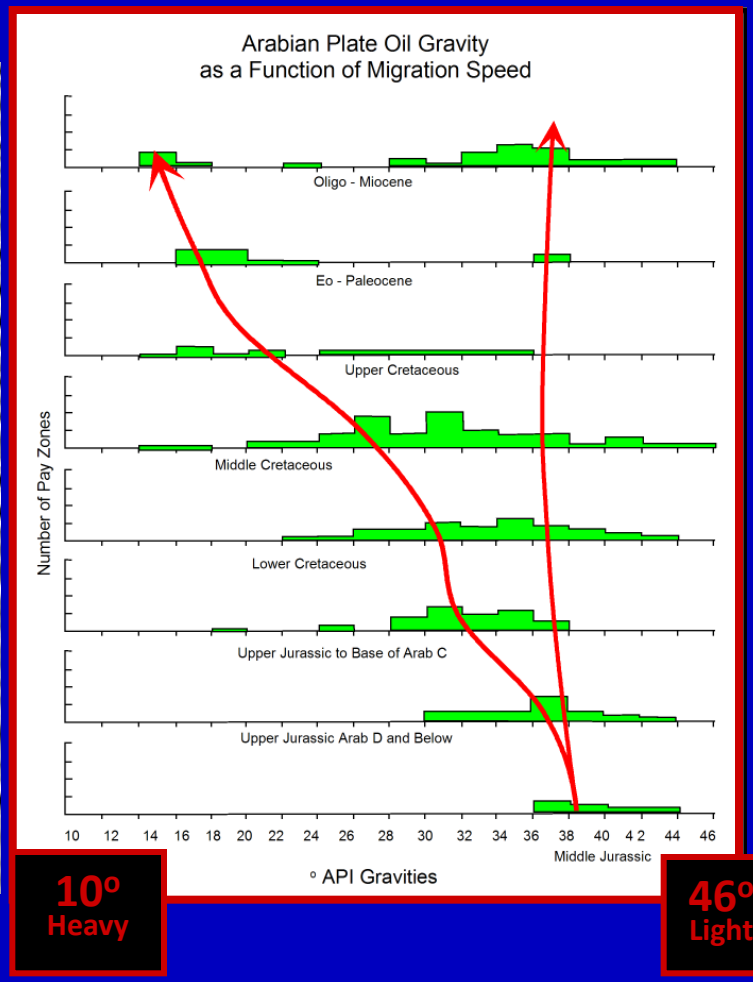
Migration Shows



Must have greater than Irreducible Oil Saturation (S_o) for migration

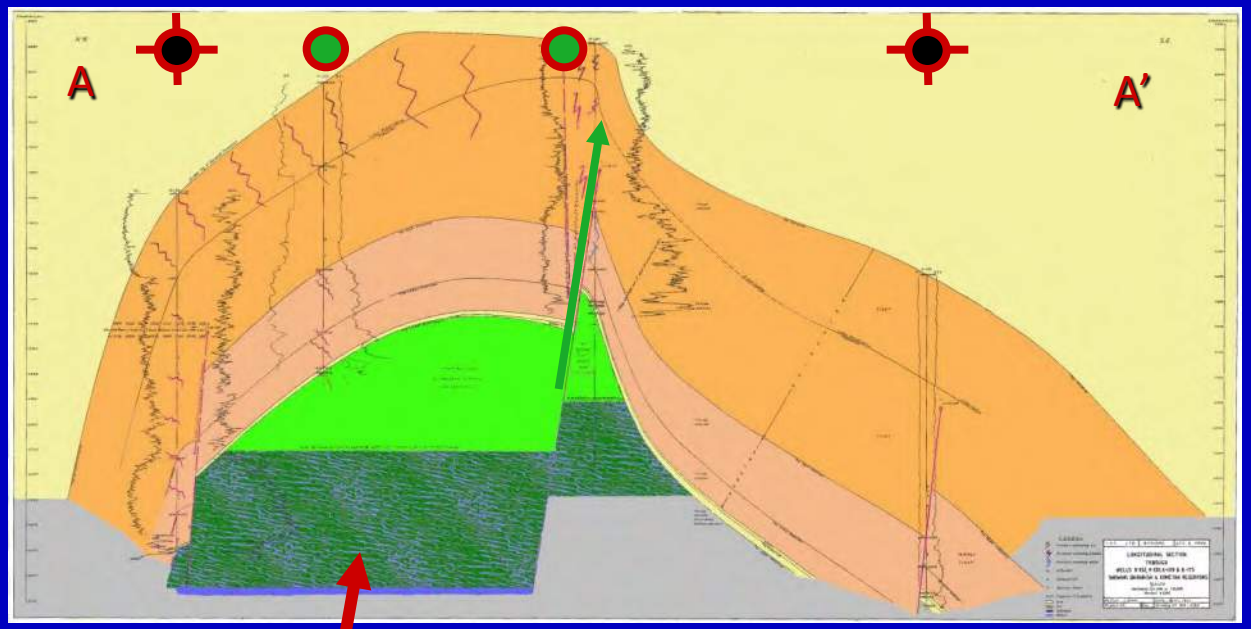
Oil Quality v/s Depth
Vertical Migration

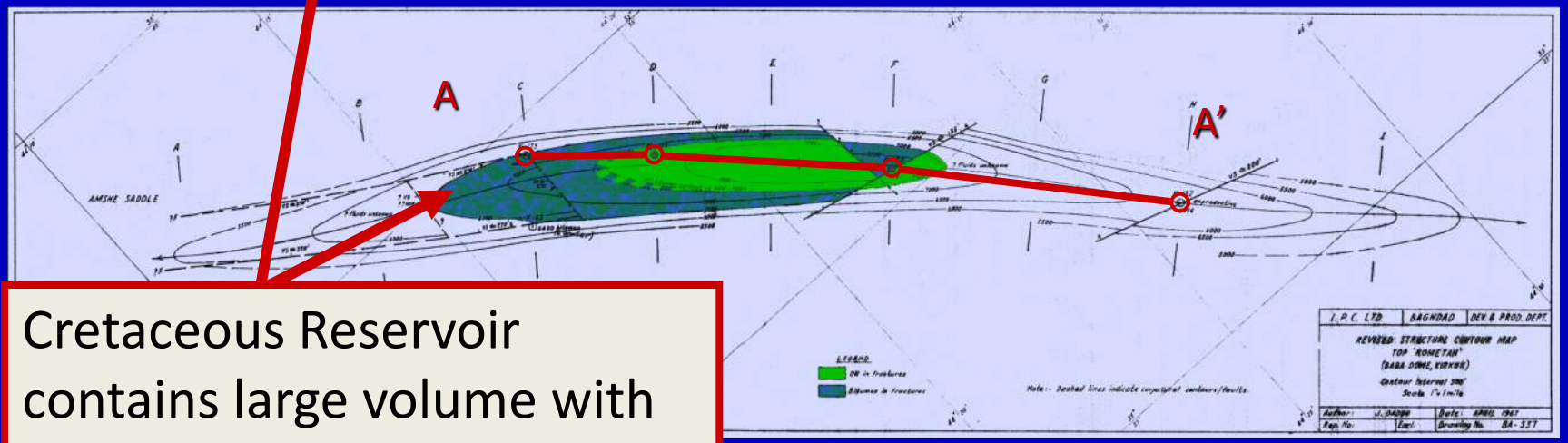




Low Gravity Oil generally has a Low Gas to Oil Ratio (GOR)

Kirkuk Anticline Baba Dome





Cretaceous Reservoir contains large volume with residual oil (bitumen)

From Gaddo, 1967

Berat Dagh & Pir-i-Mugrum (breached) Anticlines

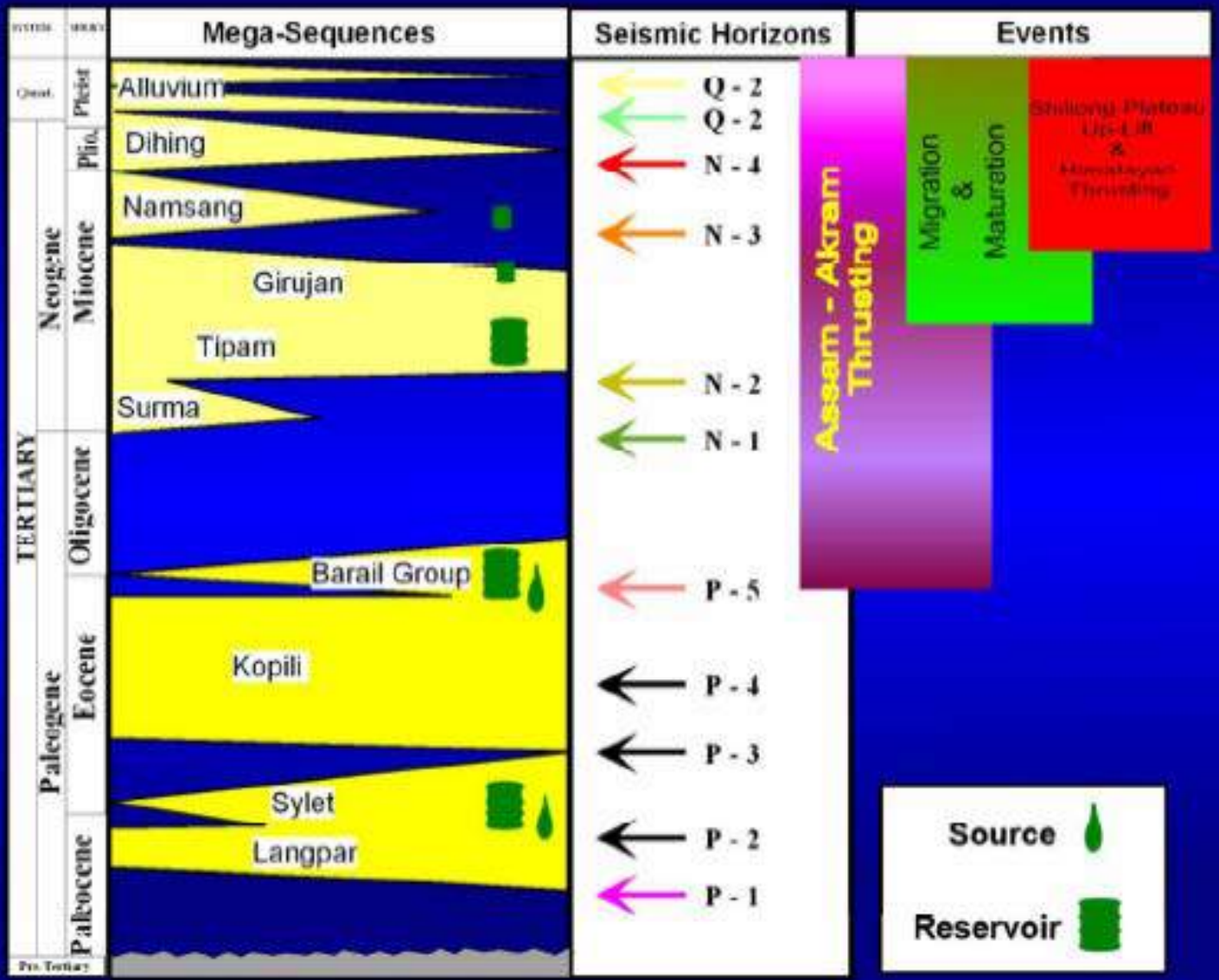
The rivers carry away bits of asphalt, limestone, and clay

"The reef and fore-reef limestones are saturated with bitumen …"

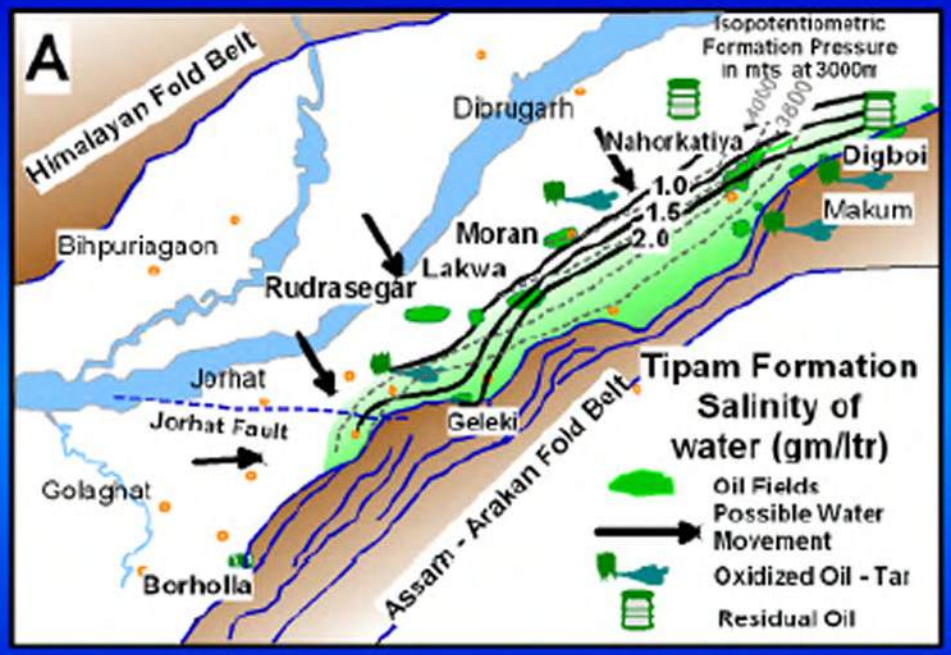
Oil Seeps

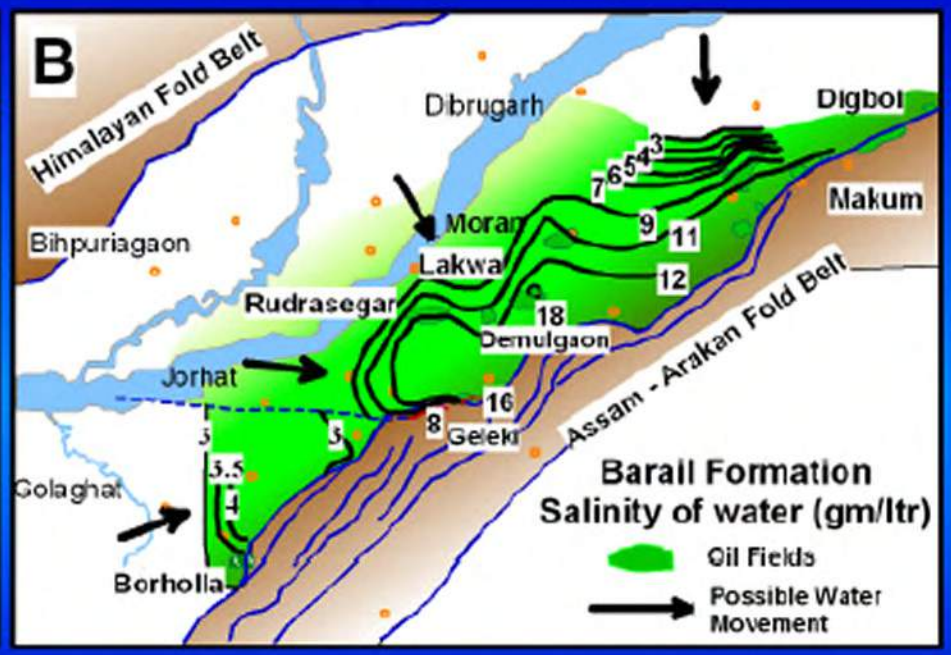
Digboi Field, Assam India

Strat - Structure Event Chart



Oil Field Characteristics





Shallow Reservoir

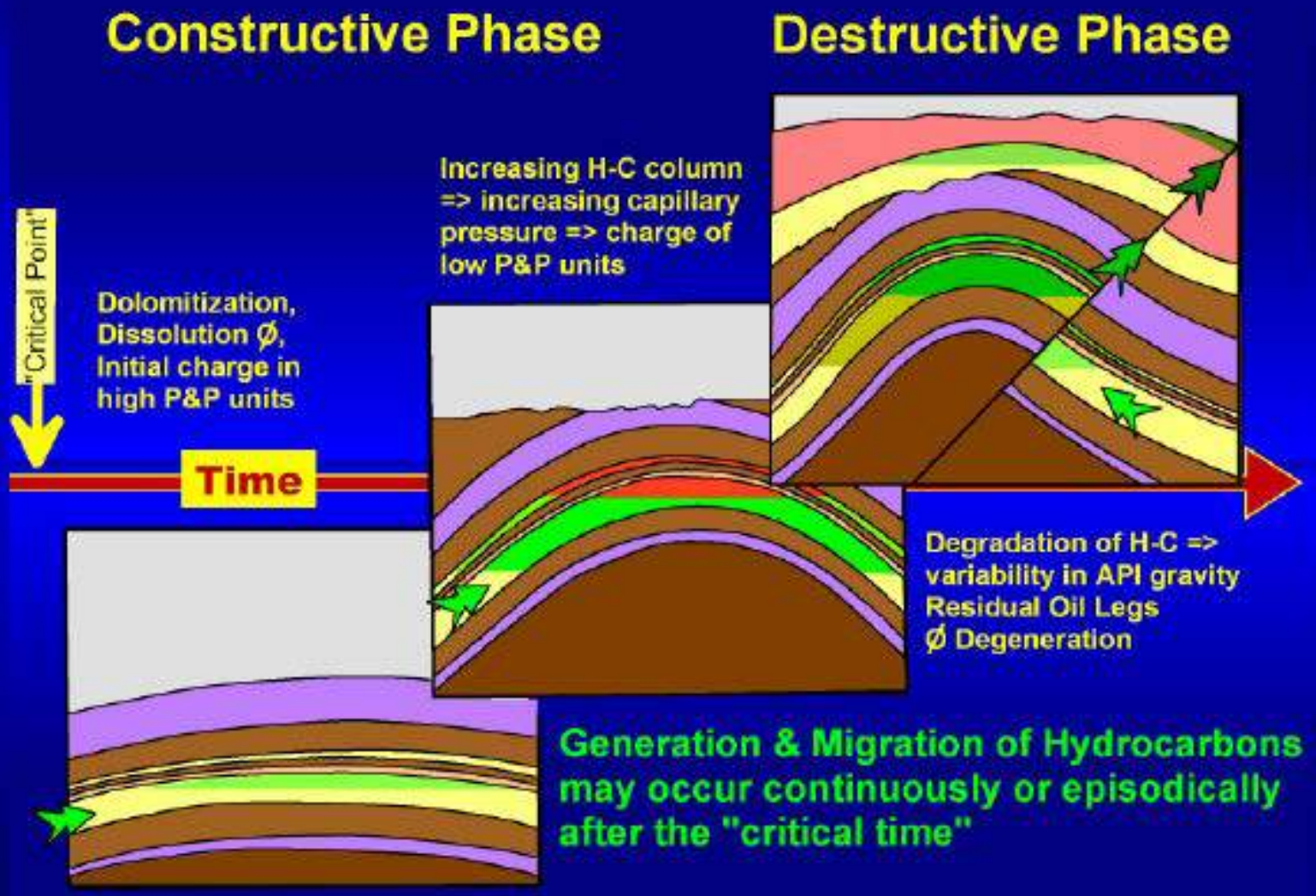
Deeper Reservoir

Fresh water is not a friend of Oil

It brings Microbes & oxygen

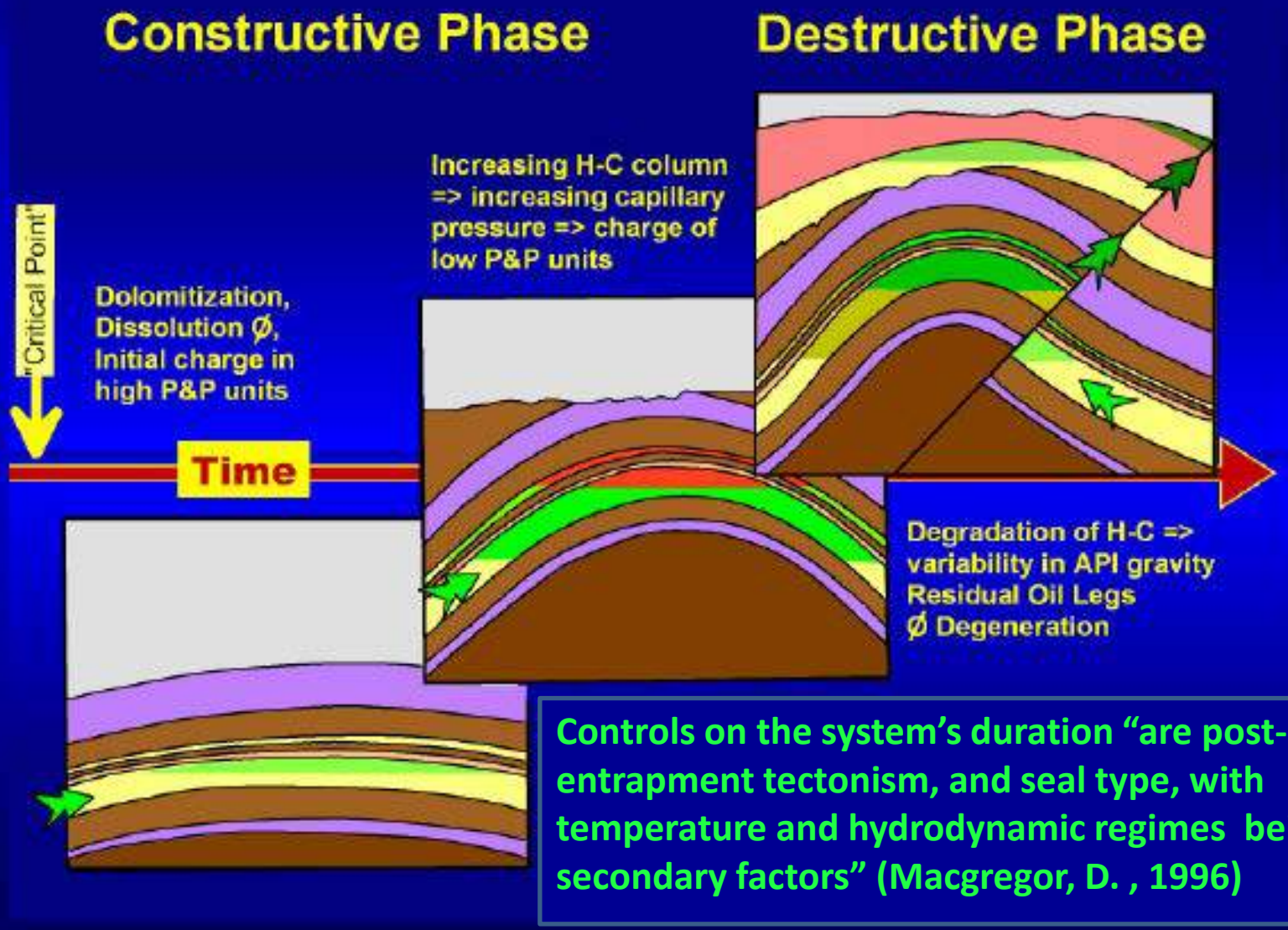
Figures from Seshavataram, et al., 1980

Dynamic Hydrocarbon System



Kent, W. N., 2006

Dynamic Hydrocarbon System



Controls on the system's duration "are post-entrapment tectonism, and seal type, with temperature and hydrodynamic regimes being secondary factors" (Macgregor, D. , 1996)

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Dunnington, H. V., 1958, Generation, Migration, Accumulation, and Dissipation of Oil in Northern Iraq, *in* L. G. Weeks, ed., Habitat of Oil: Tulsa, OK American Association of Petroleum Geologists, p. 1194-1251.

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DOCUMENT 4

NOTES

GEOLOGY OF PETROLEUM: A SIMPLIFIED ACCOUNT*

Petroleum **and** its Generation Process:

Petroleum or Rock-oil is a naturally occurring admixture of various hydrocarbons. These are compounds made primarily of carbon and hydrogen, and range from straight-chain paraffins to ring type cyclo-paraffins (i.e. napthenes) and aromatics. defines are usually not present in the naturally occurring substance. The components present can occur either in simple admixtures or in complex combinations. In molecular size, the individual hydrocarbon constituents can range from the simple methane (CH_4) to highly complex and heavy semi-solids like asphalt and bitumen.

Individually, the lightest hydrocarbons are gases at the surface temperature and pressure, but, in their admixed state, the individual molecules get shared between the liquid and the vapour phase (i.e. gas) according to the equilibrium constant appropriate to the pressure-temperature regime of their occurrence. If the regime undergoes any change, the system tries to stabilise to the new conditions.

Although inorganic reactions, like that of metallic carbides with water, can produce some hydrocarbons, and the earth itself is supposed by some to have had a hydrogen-methane - ammonia atmosphere long before it had its first life forms. The general belief is that most of the commercially produced petroleum was generated by the decay of organic matter from both plant and animal life forms in sedimentary basins under an oxygen deficient environment. The organic matter can be both marine and non-marine. Oxygen deficiency can be produced by basin configuration (e.g. stagnant bottom-water in silled basins), rapid subsidence of the basin floor, flushing out of the pores in the newly laid sediments by the upward moving water (which has been rendered oxygen deficient) from the compacting sediments below, and by a variety of other factors.

The organic materials which produce petroleum can come from many sources, but these tend to accumulate primarily with fine grained sediments. Any material which comes with coarse-grained sediments tend to get winnowed out and destroyed. Some limestone formations can have their own source for the generation of petroleum.

The organic matter thus accumulated, initially forms a dark coloured substance called kerogen. It is highly variable in composition and consists of stacked sheets of aromatic rings in which atoms of nitrogen, sulphur and oxygen also occur. Based on their source materials, 3-types of kerogen are currently recognised (Fig.l). Kerogens are the precursors to petroleum, and their presence in appreciable quantities in fine grained elastics (and limestones) helps to recognise potential petroleum mother - or source rocks. Although, highly variable, each type has a somewhat different originating matter and results in a somewhat different category of the produced petroleum. The Type I kerogen, for example, forms mainly from

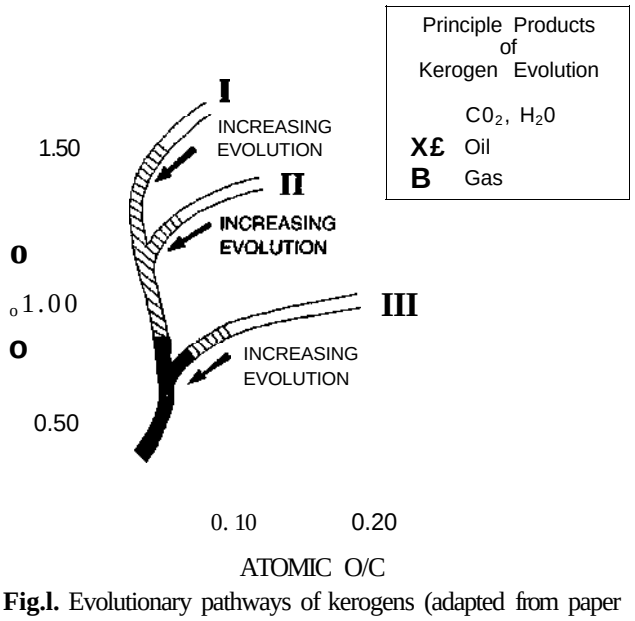

Fig.l. Evolutionary pathways of kerogens (adapted from paper by Tissot et al. in SAAPG, 1974).

lacustrine planktonic debris, intensively reworked by bacteria. Type II forms from marine planktonic debris, sedimented under anoxic conditions. Type III forms from land plant debris sedimented in near-shore marine, lacustrine, deltaic, parallic and flysch-type environments. At the same maturation stage, the capacity to generate more

** This write-up is based on the lecture notes prepared by A.B. Das Gupta for a Refresher Course for University and College teachers, organized by the Calcutta Universit in March, 2002.*

hydrocarbons per unit weight of kerogen, decreases from Type I to II to III.

In the petroleum generation process, not all the organic matter is broken down or reconstituted. Some of the compounds pass through without any major change. These help to trace back the basic type of source material. There are also other aspects of the composition which can be used to fingerprint the oil and thus help to distinguish one crude from the other, even in mixed environments. For example, terrestrial material like land plants and insects generate paraffin waxes with a predominance of such odd numbered hydrocarbons as C_{27}, C_{2g}, $C_{3]}$. Marine plants also produce odd numbered hydrocarbons, but in a lower molecular weight range of $C_{)5}$, C_{17}, $C_{]9}$. High wax crudes with paraffins in the C_{27}, C_{29}, $C_{3]}$ range would thus be expected to have a terrestrial source. Then there are the carbon isotopes. Lipids from marine planktons tend to have a higher proportion of ^{13}C than those from the terrestrial organic matter.

All these help in tracking down the source rock of the petroleum that has been discovered. Conversely, once a petroleum mother-rock has been found, it also helps assess what type of accumulation can be expected.

In addition, to its conversion to kerogen, the organic matter trapped in sediments initially generates some biogenic methane. With increasing burial, as it reaches an adequate temperature-pressure regime, the kerogen starts to form oil. With further burial and further increase in temperature (and pressure), the hydrocarbons start breaking down into smaller molecules, and the organic matter begins to generate increasing volumes of pyrogenetic gas (primarily methane). The change over from one regime to another is gradual but the major temperature zone within which the main oil formation takes place is around 60° to 165°C. This is popularly known as the *oil window* (Fig.2). Similarly, the geotectonic parts of the basin where any organic accumulations are likely to be so 'cooked' into oil and gas is referred to as the *kitchen.* The pyrolitic gas (methane) generation increases to a maximum rate at around 200°C. With further burial (and consequent rise in temperature), the gas generation slows down abruptly at around 300°C. The residue ultimately left behind can be graphite.The precise depths of burial at which these will happen depends on the geothermal gradient which can vary from basin to basin and from one part of the basin to another.

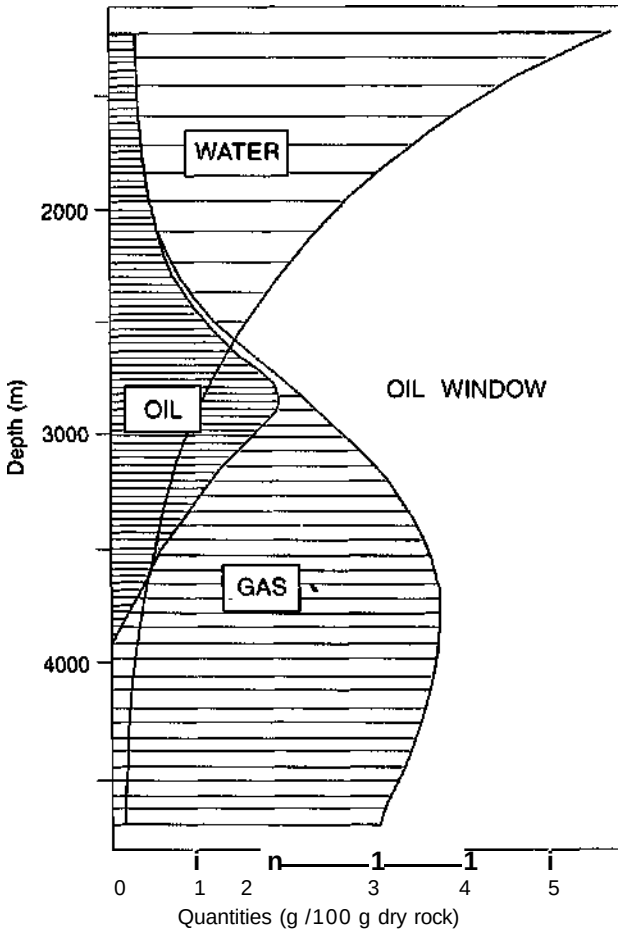

Fig.2. Oil window: compared quantities of water and hydrocarbons in source rocks as a function of burial *(afterTissol,* 1987).

Expulsion, Migration and Accumulation

Petroleum, thus formed, has to be expelled from the mother-rock, transported and trapped at the dead-end of its migrating path to give an accumulation. This calls for availability of expulsion mechanism, migrateable paths and reservoirs in which it can accumulate.Petro-physical properties of the stratigraphical elements involved, differential pressure and gravity play an important role in this process.

Ultimately, in any sedimentary belt, there can be myriads of possible traps and reservoirs, but only a small proportion of these contain commercially exploitable petroleum resources. Very large accumulations of the giant or super-giant class would be fewer still.

It is the task of petroleum exploration groups to sift the "grains from the chaff from whatever observations they can make and locate those that contain these buried exploitable resources. This is naturally a very complex task, and the exploration for petroleum today involves many facets that go far beyond the limits of conventional geology.

At the time of their deposition, fine grained sediments like clays can have upto 90% or more of water. With

increasing depth of burial,and its attendant compaction, these sediments begin to lose the absorbed and the adsorbed water. This is the initial stage. Eventually the clays begin to turn into hydro-micas and release large volumes of chemically bound (and now resurgent) water. Compaction of the entire sedimentary column below (and conversion of its clays into hydro-micas) releases additional water- a part of which can also flow through the hydrocarbon mother-rock. The water thus squeezed out carries with it initially the lipids or oily matter of the original organic load, together with biogenetically produced methane and carbon-dioxide. Later, further increase in the depth of burial, leads to the increasing formation of petroleum liquids and gases. By this time, much of the absorbed water has also been squeezed out. Some chemically bound water starts getting released, but its magnitude is variable, as it depends upon the composition of the clays present. The total amount of water still coming out aided by whatever squeezed out additional water is filtering up from the sedimentary succession below, can carry away a part of the generated oil and gas, either in solution or, in micellar and colloidal suspension. Some other mechanism is required to expel the remaining oil and gas. It is believed that the conversion of soild kerogen into liquids (oil) and gases leads to an internal overpressuring and micro-fracturing of the reservoir from time to time. This helps direct release of the major part of the generated oil and gas into the more permeable migration pathways, without necessarily having to go through the solution/micro-emulsion route in water.

After expulsion from the mother-rock, the water carrying the solution/suspended load, as well as the free blobs of oil and gas coming out through the fractures, move along higher porosity and permeability layers of the sediments (and sometimes open fractures and faults) into lower temperature - pressure environments. There the water tends to release its hydrocarbon load which, in its turn, tends to join the free oil/gas stream. At this stage the physico-chemical laws which control the flow of mixed fluids through porous media take over.

Sediments laid under water are primarily water-wet, and water can pass through at rates that the permeability will permit. Oil and gas would however be stopped where the pore sizes in their path are too small to allow their entry under the available pressure differential. An accumulation will then form, in which the gas,oil and water will eventually be gravitationally segregated. The pressure differential is related to the buoyancy of the accumulating oil/gas column. This is usually not of a very high magnitude. If the pressure differential is later increased (either through natural causes or through human intervention) the gas and oil may leak away.

When a clay rock is squeezed, the expressed fluids can move in any direction (up, down, or sideways). Otherwise the primary driving mechanism is gravity. In a stratified system, most of the fluid flow will be updip, and its rate will be proportional to the sine of the angle of dip. Otherwise, it will take the shortest available path, which can be vertical.

If the strata, through which oil and gas is moving, develops an anticlinal form, and the layer concerned has a less permeable cover, we would have the classical anticlinal trap. Many other types of traps are possible, and one can even have a transient accumulation, through the queueing effect, if the slope of the beds decreases appreciably in the up-dip direction, Digboi has similar accumulations in some of its sands at every arrestment of pitch.

How far the oil can travel in this fashion, before it is trapped into an accumulation, has been debated from time to time. There are oil-fields which seem to have formed not far from their oil source. Equally, there are others which have been involved in fairly long distance migration. Apart from the criterion of their distance from the nearest available *kitchen*, there are some subtle indicators which are claimed to be able to give an order of magnitude indication of the distance the oil has travelled.

Non-alkylated benzocarbazoles, which are present in trace quantities in oils (and are not affected by the oil-window level of maturation process), have been suggested as one such indicator. Amongst these, the rod-shaped benzo(a) carbazole molecules seem to get adsorbed on the clay minerals and solid organic matter in their migration path to a greater extent than the sub-spherical benzo(c) carbazoles, with increasing distance of migration. The benzocarbazole ratio (a/a+c) may therefore provide a quasi-quantitative idea of the migration distance. However, at low concentrations, the requirements of analytical precision would be high, and one would need either samples from multiple points or well established parallels to come to any reliable conclusions.

On the whole, the feeling seems to be that both long and short distance migrations are possible. Out of the many oil-fields where various indicators seem to have established a reasonably reliable link with their sources, those containing long distance migrated oil seems to account for over 50% (AAPG Mem. 60, pp. 82-86). Migration distances in excess of 160 Km and possibly upto 500 km are reported to have been observed.The most natural migration path is up-dip from the *kitchen.* An

extensive regional cover rock over the migration pathway prevents the oil from getting dissipated Lack of a regional cover permits many points of vertical movement into the nearby reservoirs Petroleum thus needs not only a local cover rock, permeability barrier, or change in the path gradient, to help it to accumulate, but it also needs a regional cover to sweep large areas in its pathway

Geotectonic Framework of Petroliferous Basins

Most sedimentary basins have a Shelf Zone, where the sediments are relatively thin This would be followed by a Hinge Zone, a Slope, and a Basin Deep In compressional basins, the latter would be followed by a faulted and folded Mobile Rim (Figs 3 1, 3 2 and 3 3)

In the Basin Deeps, where the floor subsides *pari pasu* with sedimentation, the sediments have their thickest development The Slope is the zone in which the most rapid change in sediment thickness (including many wedge-outs) takes place Regionally, it is also the zone of the most pronounced upward gradient This flattens rapidly across the hinge zone, into the Shelf There are also wide differences in the lithological facies developed in each of these zones

The Shelves tend to develop cleaner (and more permeable) sands, back lagoon organic rich sediments and limestone reefs The bottoms of the slopes can have turbidites suitable for hosting petroleum The basinal sediments are usually dirty, but these can be rich in organic matter - particularly closer to the shelf and the mobile rim Parts of these are also likely to reach the temperature-pressure regime required for the petroleum kitchens Shelves are seldom absolutely flat These too tend to have their own relatively thick sediment filled depressions, which can also take organic rich sediments down to the oil-window level and generate oil and gas for some of the shelf reservoirs

Interestingly, when Knebel and Rodngues-Eraso were looking into the habitat of oil in 1956, they found that 71% of the oil discovered till then was from the shelf environment, 23% was from the Hinge Zone, 2% from the basin centres and 4% from the mobile rim These possibly relate primarily to basins developed in the zone of compressional tectonics In intra-cratonic basins developed by sagging down of the basement, structures near the basin centre can also have important accumulations Parts of the basin regimes conducive to the generation of petroleum are also those that can develop salt deposits and evapontes Under gravitional pressure, the salt can move up like a plug and carry a lot of oil and gas for filling up the reservoirs in the vicinity

Early History of Petroleum Development

All the factors concerning the generation, migration and accumulation of petroleum were naturally not known at the outset Petroleum residues left behind at the surface by ancient seepages have of course been known and used locally for a variety of purposes in a number of countries tor many centuries but without the people trying to find out much about it From around 200 BC, the Chinese have been producing natural gas in some of their inland provinces like Szechuan for local consumption Their object however was primarily salt They found it much cheaper to produce salt from salt-water springs in their area rather than bring it all the way from the coast Eventually, they developed methods to drill wells for salt-water In the process, they found that they were also producing a combustible gas (methane) Their entire operations from drilling to transportation of gas were conducted with bamboo pipes

In Myanmar, some surface oil seepages in Yenaung-yaung were tracked down to shallow oil sands They developed their own technology for digging deep wells by hand They lifted the oil in buckets and used it as a bullock cart wheel grease and for lighting lamps These were however all small-scale local activities and made no major global impact This came with the Industrial Revolution in the West and the successful drilling of a well close to an oil seepage in USA by Col Drake in 1859 Initially, the Industrial Revolution was fuelled by wood and coal but petroleum took over in time, particularly in the transportation and mobile power sectors The development of internal combustion engines which could operate on a very low weight to generated power ratio revolutionised these sectors and made activities like flying possible The result was a tremendous burst of activity to discover and develop petroleum resources

The Early Modern Era and the Subsequent Evolution of Concepts

In the early stages, the main exploration tool foi finding commercially producible petroleum was to drill oi dig wells close to seepages or residues of petroleum Away from the clogged near-surface zone, the oil tended to be more fluid and could give much larger rates of flow Oil finding was an adventure and a gamble, and many followed their hunch with diverse tools like the Doodle-bug and the Divining Rod Some found commercial fields, many did not Out of these, grew the first concepts that oil accumulations formed at the top of anticlinal (and other) structures m porous reservoir rocks, sealed above by impervious shales or other cover rocks

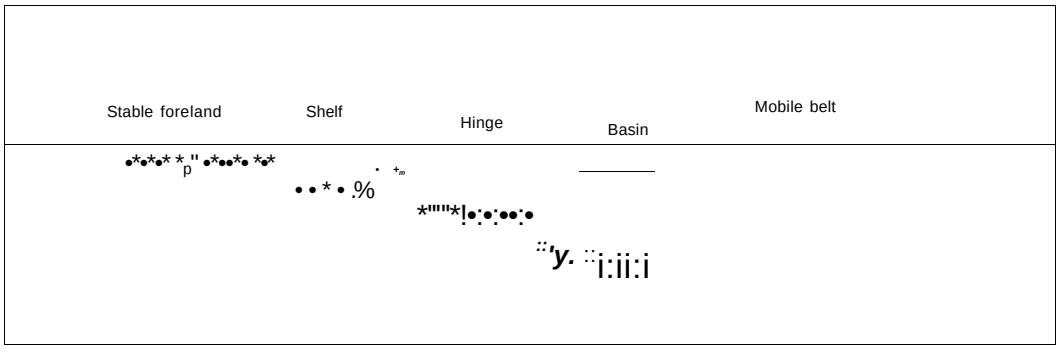

Fig.3.1. Generalised geometry of an asymmetnc sedimentary basin *(after* Tlratsoo, 1973)

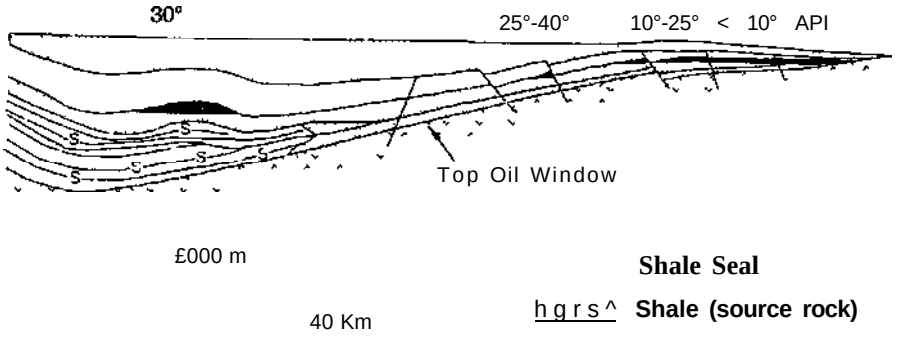

Fig.3.2. Example of a petroleum system, after the eastern Venezuela foreland basin, *(after* Petroleum Systems, 1994)

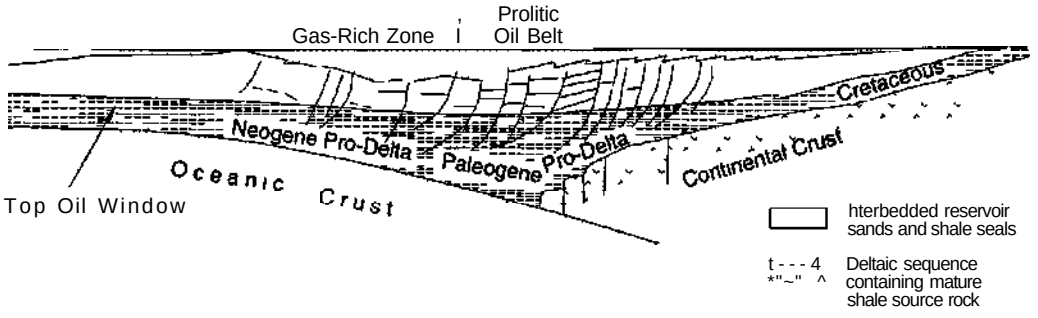

Fig.3.3. Example of a petroleum system, patterned after Niger delta, Nigeria *(after* Petroleum Systems, 1994)

Although the beginnings of this theory were propounded in 1861, by Andrews and enlarged in 1863 by Sterry Hunt, it dtd not get any industry-wise acceptance for many years It had eventually to be revived by IC White in 1896 and to lead to the discovery of Manmngton field before it found acceptance The Digboi Oilfield in NE India was discovered at around this time by drilling close to an oil seepage The party concerned, though eminently successful in other lines of endeavour, did not have any clue to the controlling mechanism of the field and could sustain a small production of less than 200 barrels a day, by drilling at random all around It took another 30 years for the Burmah Oil Company (BOC) to come onto the scene, discover its anticlinal control and eventually to raise its production to the level of around 5000 bis/day In the process they found that not only the anticlinal summit but every arrestment of pitch in the crestal area could also hold accumulations Many could be transient in terms of geological time A clay

barrier was not essential to stop the upward movement of oil or gas and even a minor compressional fault in the same sand body could be adequate to hold back the oil or gas and form an accumulation Conversely, the same fault could permit leakage if the pressure difference across was increased They also found that the fold had a pronounced asymmetry in its summit area, and that the culmination of the deeper sand layers there did not he directly below those of the layers above The asymmetry caused a southerly down flank staggering of the deeper culminations, and they had to devise section construction methods which would be able to reasonably predict their positions This helped them to bring in major production from the sands below

Whilst these lessons were being learnt in Digboi, many other important developments were taking place elsewhere in the world During the 1930s, Krumbein, Pettijohn, Sloss and others observed that the sedimentary htho facies were not random in their distribution, they had a distinct relation with the geotectonic regime of the basin in which they were deposited Subsequent investigations on the habitat of oil carried out by Knebel and others showed a parallel association of organic-rich sediments, reservoir rocks, and petroleum accumulations with the geotectonic set up of the sedimentary basins The position of the petroleum *kitchens*, the development of petroleum migration pathways and of the strati graphic cum tectonic associations that trap the oil and gas and form oil/gas fields are all ultimately controlled by the geotectonic fiamework of the basin In fact, even the basin formation itself is a reflection of the overall geotectonic situation

On the micro-scale, of course, there are many local factors which contribute to the development and attributes of all petroleum accumulations The same physicochemical laws which prevent the oil from entering the less permeable strata may also make it bypass the less permeable zones of a heterogeneous but otherwise oil-filled reservoir The oil-water margin normally tends to be horizontal, but if there is any hydro-dynamic movement of the water below, it can develop a tilt in the direction of the flow (Figs 4 and 5) The development of the reservoir, its geometric form, and porosity-permeability pattern, can all be controlled by the immediate mechanism of its sediment transport and deposition. A channel sand can have a long meandering body, cleaner and more permeable below, but more dirty and less permeable towards the top A bar sand can also be linear but, porosity-permeability-wise, just the reverse These are only some stray examples The petroleum accumulation and its geological setting can have a wide diversity based on the local factors

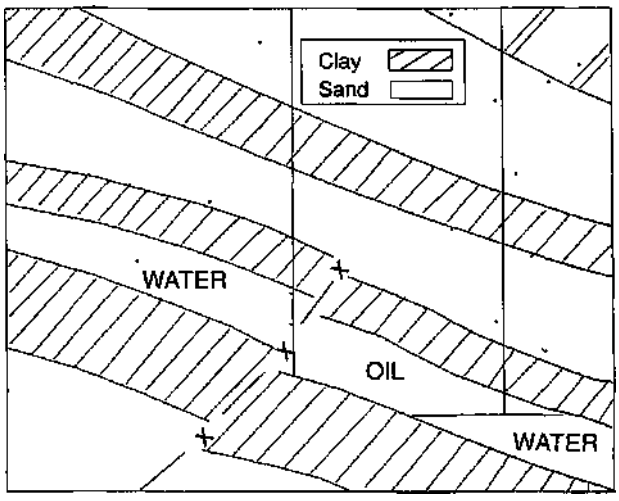

Fig.4. Water overlying oil in the same sand body across a mnoi reverse fault *(after* Das Gupta, 1969)

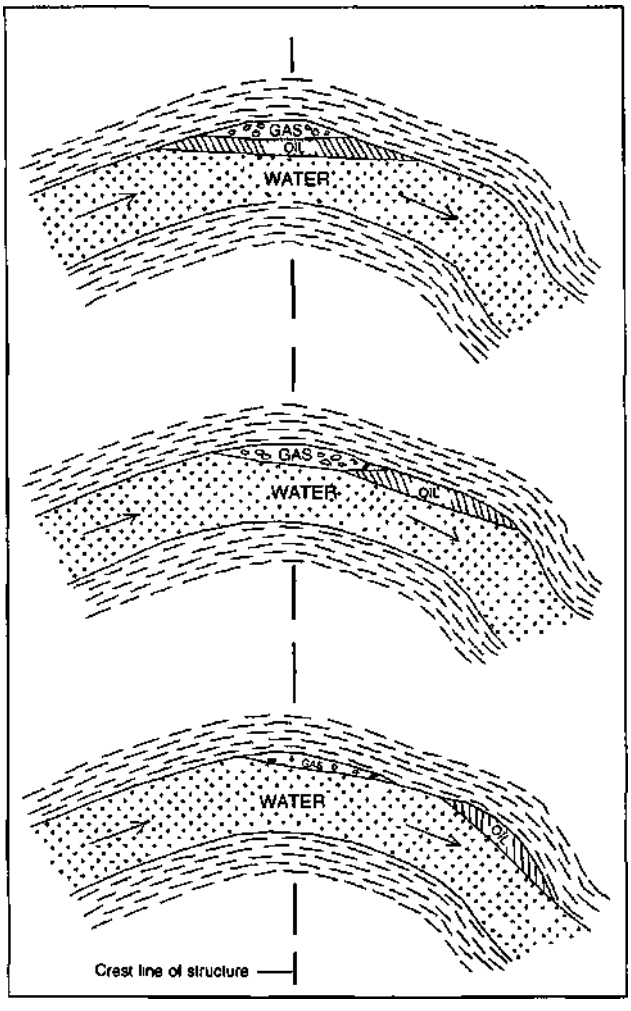

Fig.5. Off centre accumulation of petroleum as a result of formation - water movement *[after* Hubert and ONGC Bull v 6, no 2, Dec 1969)

Exploration Modality, Tools and Philosophy

The problem is how to recognise these in a new area This involves total geology using all possible scientific knowledge and tools that human ingenuity has been able to develop Some of these have grown into highly specialised branches of science and engineering themselves These start with the earth's gravitational, magnetic, electrical, acoustic or seismic and fluid flow properties Exploration teams have to collect the raw data through high precision instruments and process these through elaborate computer systems to generate an overall picture To this has to be added whatever can be gleaned from surface geology, photogeology, remote sensing imageries, palaeontology, palynology, petrology, sub-surface sample studies and reservoir engineering It is a long list but many specialisations are involved and ultimately it takes the form of a very high powered team work

At the end, the various alternative possible pictures produced by this elaborate process have to be analysed, synthesised and decision taken on how to proceed with the next exploratory step This aspect is reasonably covered in a talk I had prepared a few years back on "Exploration Strategy for Petroleum" which was later published in the July 1994 issue of the Journal of the Geological Society of India Extracted below are some of the important points on petroleum generation and accumulation brought out in that note

a) A marine environment is not essential for the formation of petroleum This can take place in widely ranging conditions, from fresh water to marine, and from a fairly wide range of organic materials Most of the paraffinic crude oil, for example, are believed to be derived from terrigenous material
b) The organically rich finer elastics and biologically produced carbonates are regarded as the more common petroleum source rocks Purely inorganic sources are not ruled out
c) To be converted to petroleum hydrocarbon liquids, the organic material entrapped in the above has to be subjected to a range of time cum temperature conditions, often referred to now-a days as the 'oil-window' Maturation and palaeo-temperature studies of organic-rich sediments can sometimes provide a clue to whether, where and when petroleum forming *kitchens* are likely to have been developed
d) In any large basin area, the local depressions which have restricted conditions at the bottom (where little replenishment of oxygen takes place) can be better locations for the generation of hydrocarbons This is not however an essential pre-requisite and with rapid burial, petroleum can also form in basins with otherwise highly oxidising conditions
e) For petroleum accumulations to occur, some of the reservoir rocks available should have had access to areas favourable for petroleum formation at the appropriate geological times concerned, and adequate porosity /permeability must be retained through the subsequent phases of diagenesis and compaction
f) There is a tendency for petroleum accumulations to get concentrated in certain specific types of geotectonic regions (platform areas, hinge belts, central regions of basins within cratons where gravity is the controlling tectonic force, etc)
g) Within a petroliferous basin, the accumulations have often a tendency to occur in progressively younger horizons towards the basin centre Gulf of Mexico and NE-Assam are examples
h) Hydro-dynamics and differential entrapment may be important in the precise location of accumulations
i) Petroleum does not always need an anticline in which to accumulate, even minor changes in the slopes of beds and/or permeability can lead to the formation of accumulation
j) Petroleum accumulations formed through the controlling mechanism of a given set of geological conditions, in any basin often tend to occur in clusters with the individuals ranging in size from large to small With sound geological approach to exploration, the 1 digest accumulation would often be the first or the second to be discovered The subsequent ones would tend to be progressively smaller
k) In any single basin, there may be more than one such cluster, each needing to be discovered separately and each controlled by a different set of conditions In their geographic distribution, the individual clusters may be totally separate or may partially overlap each other
1) Certain classes of heavy crude occur close to land surfaces both past and present Termed by some as 'unconformity oil', their presence can often indicate the existence of better oil away from the unconformity surface or the outcrop concerned
m) Age-wise, petroleum accumulations have been found in sediments ranging from Cambrian to the Pleistocene At times, petroleum formed in a basin has also found reservoir conditions and have accumulated in the metamorphic basements and in igneous sills So far, only minor attention has been

paidtotheProterozoic.but now that evidence of life is well established from formations of this age, these may also need more attention in any search for oil.

n) Maturation of coal beyond the stage where it has 83% carbon, leads to the release of methane which can then either remain there trapped within the coal seam itself, or move to a nearby reservoir rock. Conceptually, it is also possible to have accumulations of inorganically derived methane.

o) Some accumulations can be very unorthodox. In Lake Kivu (Africa), for example, the bottom water has dissolved in it enough methane to provide a theoretical reserve of the order of 57 trillion cubic metres. Together with this, there is also around 190 trillion cubic metres of $C0_2$ and 4 trillion cubic metres of nitrogen.

p) An important matter to remember in any search for oil is that, not all the oil discovered so far has been through well planned exploration. A substantial quantity has been found accidentally by people following at that time no acceptable guidelines whatsoever. In fact, in many instances, the development of concepts on where to look for oil has followed rather than preceded the discoveries concerned. One therefore needs to make an allowance for one's 'ignorance factor' in formulating any scheme for exploration.

As already implied, the above does not constitute an exhaustive list. Many other associations have been noted, but these cannot always be extrapolated and used as exploration guides in other areas. For example, it has been stated that the shear patterns produced by deep-seated wrench faults have influenced the linear distribution of petroleum traps in many areas extending from Alaska, through California to Columbia-Venezuela. A similar association has also been noted from the Gulf of Guinea but it is not clear whether this is a special feature pertaining to some local areas only or it has a much more general application. Likewise, most of the oil-rich belt in Indonesia and its adjoining region, occurs on the inner side of their island arc belt systems, behind the frontal mountain belt of the Indonesian Plate. Whether a similar association can be expected in all places where two plates have collided is not clear. Then again, there is the growth fault controlled roll-over anticline regime which has been found to contain a lot of oil in certain delta environments like the off-shore Nigeria, but we do not seem to be clear about the key combinations that has produced this. May be, a combined geological cum statistical analysis will produce the clues that are required to make these relations more widely useable.

In any case, even the guidelines formulated on the above concepts can only lead to the delimitation of the types of environment where oil has been found so far. In addition, there must be other categories of areas, also favourable, in which no discoveries have been made, and which may continue to remain excluded if guidelines are only sought from the past.

To these, one could add Coal Bed Methane (CBM), Gas (Methane) Hydrates, and Deep Sea Prospects. Coal Bed Methane Prospects depend upon the amount of both biogenic and thermogenic gas absorbed and adsorbed in coal, and on the extent these can be desorbed and produced economically. The quantity theoretically present can be high, but the amount that can be economically extracted may be more modest. The coal constituents with relatively high hydrogen, which form alginites and exinites, generate more gas. Coal seams with a larger internal surface area, through micropores, cleats, joints and fractures, have greater methane adsorption/desorption capability, and are thereby more likely to be commercial.

The natural gas hydrates are crystalline ice-like solids in which the gas molecules (primarily methane) are encased in the interstices of hydrogen bonded water lattice. These are stable only within a narrow range of low temperature and high pressure. Kuldeep Chandra's paper in the Indian Journal of Geology (Dec. 1997) records much useful information on both CBM and Gas Hydrates. The estimated global resources of methane in gas hydrates has been recorded there as 20,000 TCM, which is 70 times that of conventional natural gas. In India, the pressure-temperature constraints keep its potential existence restricted to the deep offshore, where (under favourable conditions of methane supply) it could occur as clogging the pore spaces within a narrow sub-bottom range between 1000 to 3000 metres isobath. In this state, it could act as a seal, below which normal gas accumulations may also occur. Very large volumes of hydrates may be present, but the problem lies in developing a technology for controlled production which will not upset the delicate hydrate stability condition.

Ancient basins (faulted, folded or otherwise) forming parts of the present day continents or islands have long been targets of exploration for petroleum. In time, exploration and production activities have extended to the offshore continental shelves and semi-enclosed seas like the Lake Maracaibo, Gulf of Mexico and the North Sea. Over the years, these have extended to the deep seas, adjoining the Continental shelves, wherever these are

giving any indications of having thick sediments. The Atlantic Ocean (offshore Brazil) and a number of other places have already proved productive. New to join the hunt are Bay of Bengal and the Arabian Sea. The Bay of Bengal has an enormous sub-marine fan, which is around 5000 m thick at the head of the bay, and around 3000 m thick at the equator. This is not of a uniform thickness. The whole basin has a number of highs and lows, breaking it into a number of components with wide variations in the thickness of sediments,. The younger sediments have been laid by a sub-marine distributary system spreading out from the Swatch of No Ground near the outfall of the Ganga-Brahmaputra drainage system. The major channel carrying this submarine flow is about 180 metres deep and has a width of upto 27 km between the levee crests.

The deep sea accumulations are expected to have largely the same type of geological control as in the on-shore and continental shelf but the reservoir development may have to depend more on the primary and the redistributed turbidites as well as on the mode of development of the submarine fan, and on how the basin floor has responded in terms of horst, graben and sub-basin formation.

Direct Indications of Oil

The above gives a brief outline of how petroleum and its related hydrocarbons form, migrate and where its accumulations are most likely to occur. To help in this search, there are also occassionally some direct indicators. Firstly, there are the micro-seepages of gas which come up vertically from the accumulations below. Normally, the process of molecular diffusion of methane is very slow (about 6.674 years x square of the depth in feet) and there would be little chance of any Tertary oilfields from showing up this way from depths greater than 3000 feet. Water sqeezed out from compacting sediments however can come up much faster and bring up some methane as well in solution. These ought to show up as surface anomalies, but in many areas the dissolved vertically migrating gases can get swept away by the hydro-dynamically moving water in the intervening layers. Buried oilfields can sometimes show up as radioactive and other haloes, but these too may be swept away by the lateral movement of water in the intervening layers.

In an area of low gravity changes, large gas fields may show up as mild features on gravity surveys, but usually these would be masked by stronger changes in the gravity field due to other causes. The presence of low to moderate pressure gas can reduce the seismic veloicity in sediments. This can produce a strong reflection (known as a Flat Spot) at the gas/water contact of a thick gas zone at depths less than 6000 ft. At greater depths the gas is more compressed, the velocity contrast is much reduced, and the contact may not show up. There are a variety of seismic techniques which, under favourable circumstances, can give some idea of the fluid contents of a strong sesimic reflector. Modern time-series, 3-D seismic surveys (i.e. 4-D survey) can bring out changes in the relative fluid contents with time. In marine seismic surveys, in the tropical belt, the presence of gas hydrates may show up through an ocean bottom simulating reflector or BSR. Information from all these naturally have to be ploughed back into the overall synthesis for the evaluation of prospects.

The Ultimate Tasks in Oil Finding

In the search for petroleum, one thus needs to reconstruct the basin geometry, its geotectonic framework, its depositional environment, the likely source rocks, the likely *kitchens*, the likely migration pathways, and where the migrating mass may have accumulated. All these, after taking into account their known favoured associations and any direct indications of gas or oil. The work involves many specialised branches, in the intricacies of which the geologist as such may not know all the details. He would of course be expected to understand the outputs, what they mean, what are the limits of their probability, and what alternatives are possible. Likewise, the other specialists have to imbibe enough geology to understand the basis of what they are trying to measure and display.

Without these, the exploration teams would be unable to arrive at an overall synthesis and recommend the kind of agreed programme on which management can take major investment decisions. Interestingly, as specialisation has grown and massive investments have been made on equipment and interpretational infrastructure, the petroleum majors seem to have been finding it increasingly difficult to make many dicoveries on their own. They seem instead to be finding it cheaper and less risky to buy into properties already discovered by others. In fact, globally there have not been many discoveries of large new oil/gas fields since the 1960s, and most of the rise in proved and probable reserves has been coming from extensions to and reappraisal of old oil/gas fields.

PETROLEUM RESOURCES

Conventional Crude Oils

These are the common types of crude oils which are processed in the refineries to give us the products we commonly use. In order that they can maintain their current economy, as also have a long range perspective, the

industry operates on the basis of two types of assessments The current economy (including the ability to raise Bank finance) is ensured by operating on the basis of conservatively estimated proved and probable reserves The long range perspective is taken care of by prognosticating what ultimately discoverable resources one may be dealing with Of this, what is believed to have been discovered (and produced) is only a part

On the basis of the limited directions from which one could hope to make discoveries, the globally prognosticated resources of petroleum were expected to be around 500 billion US bis during the mid-1940s From 1947 to 1958, studies on the Habitat of Oil produced many new ideas and the estimate of prognosticated resources rose sharply to about 2000 billion US bis Thereafter, the more realistic estimates have remained at around 2000±500 billion US bis, equivalent to around 265±65 billion tonnes By 1 1 1996, the Industry had already discovered about 1789 billion US bis or about 245 billion tonnes, and out of the above had been able to produce about 772 billion US bis or roughly about 105 billion tonnes

As on 1st January, 1993, the equivalent figures for Natural Gas were

Prognosticated Resources	11567 5 xlO^{12}	eft
Already Produced	1750 2 xlO^{12}	eft
Additional Identified Reserves	5136 OxlO^{12}	eft
Awaiting Discovery (on Modal Probability Rating)	4681 3 x 10^{12}	eft

The corresponding situation in India was

a) Prognosticated Resources of Oil & Oil equivalent Gas at 95% probability (as estimated on 1 1 1992) — 13 56 billion tonnes
b) Established Reserves of Oil & Oil equivalent Gas as at 1 1 1994 — 1 401 billion tonnes
c) Cumulative production of Oil & Oil equivalent Gas to 31 12 1993 — 0 664 billion tonnes

Globally, the known resources of conventional crude oil and natural gas are not evenly distributed About 65% of the proved reserves of conventional crude oil (as at the end of 1995) occurs in the Middle East The two American continents, which account for 14% comes next Russian Federation, Europe, Africa, Indonesia Malaysia and many other countries also have substantial oil reserves, but these add upto only the balance 21%

In natural gas, the maximum proved reserves are in the Russian Federation (about 1700 trillion cub metres as at the end of 1995) This is about 34 5% of the total The two American continents have another 503 trillion cub metres or 10 2 % The rest is shared by the other countries

In age, the occurrences range from the Teitiaiy down to the Proterozoic By and large, a limited amount of tectonic disturbances help in migration and formation of petroleum accumulations, but excessive disturbances lead to their seeping away Ancient deposits, subject to multiple phases of folding and faulting do not consequently have many large accumulations preserved

Heavy Oil and Tar Sands

Very large deposits of asphaltic heavy oil and sands, impregnated with such oil (i e tar sands) exist in many countries The best known example is perhaps the Athabaska tar sands These are presently in use (either directly or as a fuel or after hydrogenation or after emulsification with water) on a relatively small scale Very large resources exist The total may be of the same order as that of the conventional crude oil The whole future of these resources depends on the extent to which these can be mined and converted into marketable products economically

Oil Shales

Deposits of asphaltic, pyrobituminous shales, otherwise known as oil shales are present in many continents On being heated, in a closed retort, these can produce a distillate resembling crude oil Depending upon the richness of the organic matter, the yield can vary from 4 to 50% of the rock by weight Improved yield and product quality can be obtained if distillation is carried out in a stream of hydrogen

The world production of oil from such shales used to be in the region of 350 million US bis per year in the early 1970s Most of this was from China The present position is not known

It has been estimated that there could be around 2500 billion tons of oil-in-place in known accesible oil-shale deposits, which are capable of yielding 10 to 40% of their weight in oil This is much larger than the ultimately recoverable reserves of conventional crude oil But, how much of this can be availed of would depend upon the extent to which the many attendant environmental, mining and processing problems can be economically overcome

Gas Hydrates

As already mentioned, there is believed to be around 20,000 TCM of methane locked up globally in gas hydrates Their development poses many problems

CONCLUDING REMARKS

Starting from being an important energy source for fuelling the Industrial revolution, petroleum has developed into a vital necessity for all of us Through refining and other chemical processes, it is now routinely converted into special fuels, lubricants and a wide range of petro-chemicals (from textile fibres and artificial leather to structural material) which have become essential to our living Amongst the fuels, the most important are those that can generate a very high level of power from light weight engines In conjunction with electricity, these have revolutionised our transportation cum mobile power sector, and has made activities like flying in heavier than air vehicles possible

The entire subject of petroleum - where and how it forms, and accumulates, how to look for and produce it - is naturally very complex This paper has aimed at presenting a brief outline of the entire spectrum without trying to go into the intricacies of each detail It also deals with the geology of petroleum only up to the stage of its occurrence once discovered Thereafter, it has to be economically recovered from its reservoir This process involves taking maximum advantage of the nature of the reservoir and of the various forces within it, which either support or provide impediment to the flow of fluids present Depending upon the circumstances, and the wisdom with which the situation is met, the recovery attained may range from as low as 10% to as high as 60-80% This takes us to another complex domain- ie that of reservoir engineering and management This aspect has not been covered in the present note Anyone so desirous will find an introduction to this topic in the author's paper on "Improved Oil Recovery" published in the Journal of the Geological Society of India, v 57, no 5, March, 2001

To maintain its focus on the general aspects, the paper has avoided getting involved in too many details The measurement of petroleum fluids is however an area where some details cannot be avoided These have therefore been provided in the Appendix Selected bibliography of reading materials to assist those who may wish to go deeper into the subject has been provided For the rest, one would need to go into text books on geophysical and geochemical surveys, as well as on reservoir engineering

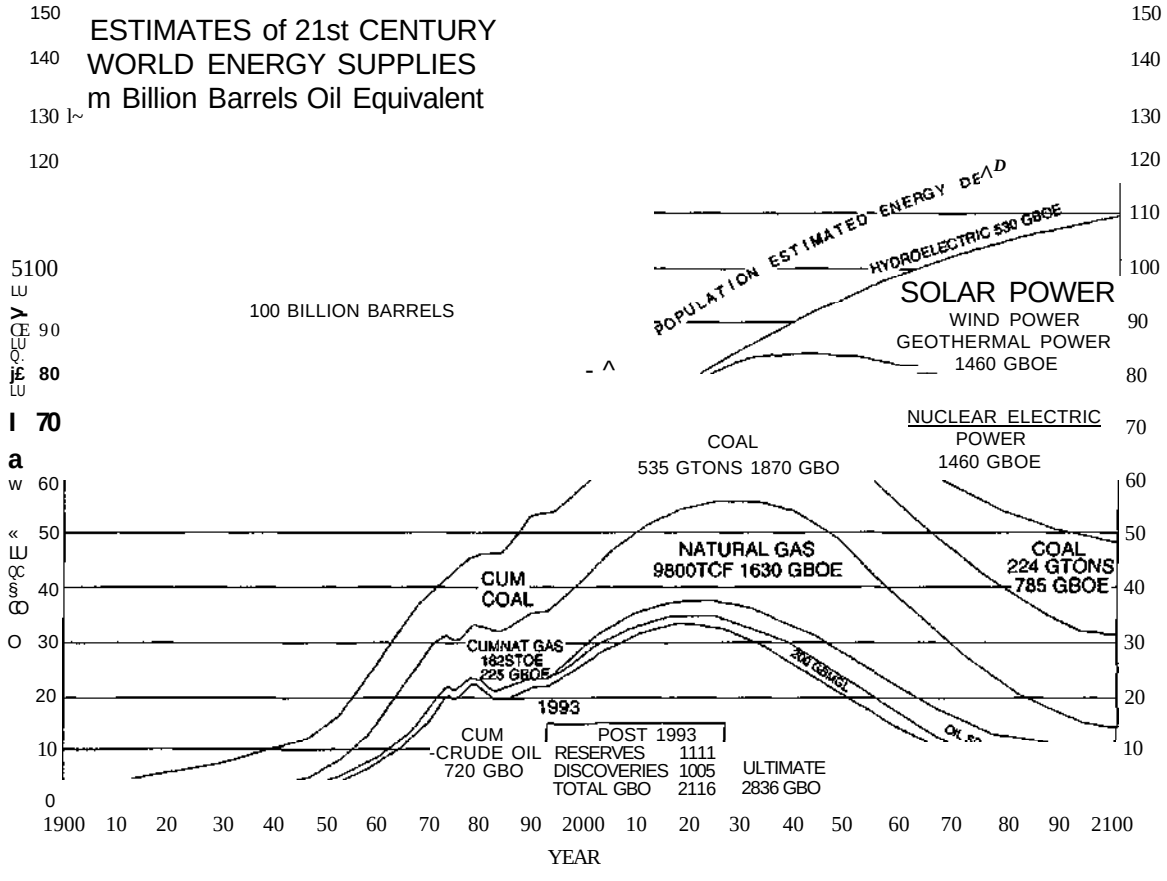

Fig.6. Estimates of 21 st century world energy supplies *(after* J D Edwards, AAPG bulletin, v 81 no 8, August 1997)

There are considerable misgivings amongst the petroleum economists as regards how long the conventional oil/gas supplies will last Many feel that the foreseeable supplies will be unable to support the present growth rate in consumption beyond the 2020s or at best the 2030s The decline in the availability of natural gas is expected to follow a few years later Provided adequate thrust is given, mankind should however be able by then to fall back upon the other non-conventional sources outlined above (Fig 6)

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Appendix

Mensuration

Crude Oil

As crude oil comes up from its underground reservoir to the surface, it releases some gas and shrinks in volume Us density also undergoes a corresponding change (1e increase) The magnitude of the change depends upon differences in temperature, pressure and the amount of gas released dunng its movement from the reservoir to the stock tank at the surface The latter is normally used as the standard of reference, and the ratio Reservoir volume/Stock Tank Volume is referred to as the "Formation Volume Factor or FVF

The noimal units of measurement are either Cubic feet or cubic metre or barrels (either Impena! oi US)

1 cu metre	= 1 x 3 2808430 cu ft = 6 289793 US bis = 5 499223 Imp bis	= 35 31467 eft
1 Imp bl	= 6 4217567 eft	= 1 14376 US bis = 40 Imp gallons
lUSbl	= 5 6146 eft	= 0 87431 Imp bis = 42 US gallons
1 Imp gallon	= 0 160544 eft	= 1 200948 US gallons
1 US gallon	= 0 1336809 eft	= 0 832675 Imp gallons

With widespread international operations, it is now-a days more common to use the US units

Crude oils can be heavy or light depending upon the relative amounts of lighter and heavier hydrocarbons present This is reflected in the crude oil's density or specific gravity The lighter the oil, the lower is its density or SG The industry however, likes to use another term called "API Gravity', which goes up with increase in the lighter hydrocarbon constituents

The relation is "API = 141 5 / SG (at 60/60° F) - 131 5

Thus, a crude oil with a SG of 0 833 will be referred to as 38 37° API, and that with a SG of 0 88 as 29 3° API

Since 1 Imp bl of water weighs 400 lbs, 1 Impblof any crude will weigh 400 x SG / 2204 6225 = 0 181437 x SG tonnes

Likewise, each US bl will equal 0 15863 x SG tonnes or 6 304/SG will equal the number of US bis per tonne A 38 37° crude will thus weigh 0 151137 tonnes per Imp bl and 0 1321387 tonnes per US bl under Standard conditions

Gas

Gas is measured in terms of Standard eft and Normal cu metres, but the Standards can differ from user to user In UK and USA, the standard eft is referred to 60° F and 30 inches (762 mm) of mercury under wet conditions, but the normal cubic metre (i e Nm^1) is referred in terms of 0° C and 760 mm of mercury under dry conditions As a result, 1 Nm^3 of gas equals 37 879 Std eft, instead of the conventional (35 31467 eft), if both the standards were to be identical There are, however, operators who do not always observe these distinctions and conversion of their figures from m^3 to eft can be in error by as much as 7 26%

Gas densities are normally described in terms of its specific gravity in relation to air, each eft of which (at 60° F and 1 atmosphere pressure) weighs only 0 7644 lbs The lightest hydrocarbon gas is methane (CH_4) It has a SG in relation to air of 0 554, l e 1 Std eft of Methane weighs 0 7644x0 554 = 0 4235 lbs The next heavier hydrocarbon gas is ethane *(C_3U_6)* It has a SG of 1 038 and weighs 0 79345 lbs/Std eft Propane (C_3H_8) which comes next has a SG of 1 522 and weighs 1 16342 lbs/Std eft Natural hydrocarbon gases are primarily methane with varying amounts of the higher hydrocarbons and would usually have a *SG* range of around 0 56 to 0 8 depending upon its origin and the collection - distribution system, l e , unless some CO, and nitrogen are also present

Hydrocarbon gases do not totally follow the ideal Gas Law in their compression or expansion It is necessary to add a collection factor called "z' or the "Gas Compressibility Factor' to allow for this deviation This converts the gas equation to PV/T = Z nR where n and R are constants Depending upon the gas density and its pressure-temperature regime, "Z" can usually vary from 0 5 to a little over 1 ^

Oil Equivalence of Gas

This is normally done in terms of calorific value 1 Std eft of dry methane has a *gross* calorific value of 1012 BTU The net calorific value, after allowing for the heat absorbed by the products (primarily H.,0) is about 912 BTU The field's gas, normally has some higher hydrocarbons as well, which gives it a net calorific value of around 1000 BTU This would give it an oil equivalence of around 1045 Nm^3 per tonne There are ofcourse some variations and figures of 1000 to 1100 NmVtonne have often been used

Gas/Oil Ratio or GOR

This is an important ratio related to many oil well or oil field s production behaviour It comprises partly of the ratio between the oil and the gas that is coming out from its solution, and partly of the free (and released) gas within the reservoir that is also flowing directly and contnbuting to the gas production It can be either as Vol/Vol or Std eft /bl (Imp or US) or NmVbl

GOR vanes over the life time of oil wells and oil fields To the extent, it can be kept under control, the free gas and the gas freed/released within the reservoir helps to displace more oil into the well and helps improve recovery of the oil The ability to forecast the future pattern of GOR variation also helps in better planning and utilisation of the produced gas

Imperialism, Geology and Petroleum: History of Oil in Colonial Assam

ARUPJYOTI SAIKIA

In the last quarter of the 19th century, Assam's oilfields became part of the larger global petroleum economy and thus played a key role in the British imperial economy. After decolonisation, the oilfields not only turned out to be the subject of intense competition in a regional economy, they also came to be identified with the rights of the community, threatening the federal structure and India's development paradigm. This paper is an attempt to locate the history of Assam's oil in the large imperial, global and national political economy. It re-examines the science and polity of petroleum exploration in colonial Assam.

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> Assam has not escaped the fate of the newly opened regions of having its mineral resources spoken of in the most extravagant and unfounded manner with the exception of coal.
>
> – H B Medlicott, Geological Survey of India

The discovery of petroleum in British North East India (NE) began with the onset of amateur geological exploration of the region since the 1820s. Like tea plantations, exploration of petroleum also attracted international capital. Since the last quarter of the 19th century, with the arrival of global technology, the region's petroleum fields became part of a larger global petroleum economy, and, gradually, commercial exploration of petroleum became a reality. It was a time when geologists had not yet succeeded in shaping an understanding of the science of oil and its commercial possibilities. Over the next century, the Assam oilfields played a key role in the British imperial economy. After decolonisation, these oilfields not only turned out to be the subject of intense competition in the regional economy, but also became centrally identified with questions of community rights. Immediately after independence, the Indian state encountered political opposition to its stake on oil from Assam. This happened at a time when the share of natural resources between the province and centre was still not well-defined. Such opposition continued until a later period, when an economic blockade, with the aim of restricting oil flows outwards from Assam, was successfully imposed as part of the assertion of regional politics. This also became a counter in the political negotiations between the Indian state and its federal province.

The subject of imperial exploration of petroleum and its production in colonial and post-colonial period still awaits adequate examination. Western scientists and industrialists began to pay serious attention to petroleum only in the middle of the 19th century, after oil was discovered in the American continent and promised profits, though it was yet to become a popular energy replacement to coal.[1] Technological innovations in petroleum exploration and its conversion into various energy components were still at a rudimentary stage and there remained suspicions about its ability to replace existing energy sources. Indian historiography has paid marginal attention to imperial histories of petroleum exploration and the dense social histories which unfolded subsequently. This historiography also rarely takes notice of this significant partnership between geological explorations and its commercial dimension as well as its career into the world of science and technology.[2] While the existing official historiography of oil companies in NE India portrays a heroic picture of incidental discovery of oil in the dense jungles, swamps and river

valleys way back in the 19th century, the works on Assam's colonial economy hardly address the issues of science and imperial politics, though they recognise the impact of oil.[3] Oil, as a natural resource, continued to have serious repercussions on the post-colonial polity, but these went beyond the scope of these works. This paper seeks to locate Assam's oil in the larger imperial and global political economy. It begins with a re-examination of the science and polity of geological exploration, which led to the discovery of petroleum in colonial Assam, and examines how such exploration became a part of the larger imperial economy leading to conflicts over the right to control this natural resource.

Minerals in the Colony

The role played by the colonial science of geology in shaping the scope of imperialism is now well known. The earth science, geology as it came to be known, played a crucial role in establishing the colonial and post-colonial empire's technological superiority over untapped mineral resources.[4] By the middle of the 19th century, the study of rocks, fossils and other mineral resources had acquired more status than a "provincial pastime". This was the result of the formation of the Geological Survey of India (GSI) in 1856, which played a significant role in directing state intervention towards a professional growth of metallurgy. Since then it acquired the status, not only of a national science, but an essential ingredient of imperial science shaping the fate of the India's natural resources.[5] The East India Company (EIC) officials were not sure of the possible effectiveness of geological explorations in India. Such initial unwillingness was the consequence of two simultaneous developments: some British copper and coal operators did not want their commercial interests jeopardised by a possible discovery of Indian minerals, and a number of company officials also believed that India should primarily remain an agricultural country.[6]

The region's mineral resources did not go unnoticed before the British imperial push. Minerals like gold were key elements in political negotiations in the Ahom-Mughal conflict. The Ahom rulers too negotiated with the Naga tribes for getting access to salt-brine. Much later in the 1750s, the French traveller Jean-Baptise Chevalier found both the working of gold sands in the river-beds and commanding display of gold in the royal palaces, despite the poverty of the people.[7] But this early enthusiasm never converted to real prospects for the Europeans. The discovery of tea and the realisation of this plant's ability to create wealth for the British empire was, however, accompanied by a parallel investigation of coal and other mineral resources. Coal was already an important resource through which imperial Britain had already expressed its technological superiority.

The empire engaged Assamese scholars who had knowledge of the region's natural resources to chart out its mineral resources. An illustrative, and frequently referred, example was that of Maniram Dewan Datta Baruah, a pre-colonial noble who had foreseen opportunities in British capital, but soon explored for his own purposes. It was Maniram who prepared a systematic narrative of local procedures of gold collection from the river-beds. As the EIC administration came to know about this, further explorations to confirm its viability were taken up. Maniram's report on gold washing in Assam was a result of these enquiries.[8] But soon it was realised that gold washing and collection would not be a viable project, though further investigations into the gold retaining capacities of upper Assam rivers were also made. A fresh attempt was made by E T Dalton and S F Hannay in 1855 to estimate the auriferous deposits of these rivers.[9] They travelled up the Brahmaputra; one primary goal was to locate the "original rock containing the gold in situ". But they found that "the deposits became less and less rich as they penetrated farther into the hills" which forced them to return.

Failure of this venture never discouraged the colonial explorers to further expand their search for other mineral resources. They kept their eyes open for prospective discoveries of coal, lime and any other mineral. In the fourth quarter of the 19th century, coal was being commercially produced in eastern Assam. This came as a major respite for the already flourishing tea-plantations. Coal was found not only in the eastern districts of Assam, but was fairly well-distributed.[10] Coal allowed commercial enterprises and British capital to penetrate deep into the region. British interest in coal was crucial to the colonial investments in tea-plantations and forest resources. However, the discovery of oil had an exclusive impact on the future polity and economy of Assam.

Colonial Science and Polity

The possible existence of petroleum in eastern Assam was first noticed in the early 19th century. This actually preceded the significant finding of tea plants. While tea plants were noticed only in the 1830s, one of the first recorded notices of petroleum deposits was earlier, in April 1825, a year before the EIC concluded the Treaty of Yandaboo with the Burmese to occupy Assam. R Wilcox, an army lieutenant and geologist, was the earliest observer of oil in an upper Assam village.[11] Wilcox's survey of Assam showed the many possibilities of geological discoveries in the region.[12] Wilcox's survey carefully noticed both the geological formations and mineral resources of the region. His chance notice of oil was no less dramatic. This occurred while he was surveying river Burhi Dihing at a place called Namchik. He noticed seepage of oil and bubbling gas at a place called Supkhong. Wilcox, describing the possibility of petroleum deposits in upper Assam, later wrote,

> There were two beds, one at a little higher level than the other, but both on the plains, filled with liquid mud of various degrees of consistence. One was twenty or thirty feet across, and the other larger. In the middle, where bubbles of air are seen constantly rising to the surface, the mud is nearly white, and is there in a more liquid state. On the edges green petroleum is seen floating, but it is not put to any use by the Singphos – neither is the coal.[13]

Wilcox's observation is significant for at least two reasons. First, he initiated the long process of finding petroleum near coal-beds in this region. Whatever may have been his initial observation, it did not take long for others to realise that petroleum could be found near coal-beds. The possible connection, by source of origin, between coal and petroleum came for serious investigations by British geologists in the second half of the 19th century. Second, Wilcox's assertion that local communities had no use for these minerals significantly helped the colonial state in asserting

an exclusive claim on these resources. As further explorations took place in the following decades, many others too noted that the local populations hardly had any use for oil, though in other minerals there were elaborate local traditions of use. Wilcox's findings did not have any impact in those early days of colonial rule even though the EIC regularly arranged elaborate schemes to locate commercially viable minerals.

Several others followed Wilcox's chance encounters with oil. These included botanical surveyors, military personnel or commissioned travellers, who noted the richness of mineral resources in the region's geology. Their findings were reported in the *Journal of Asiatic Society of Bengal (JASB)*. This helped bring these findings to the notice of the government. For instance, in 1828, C A Bruce, usually credited with locating the indigenous tea plant in eastern Assam, reported how he came across several oil seepages upstream of a place called Makum. Unlike his discovery of the tea-plant and its consequences, his observation on oil hardly had any durable impact. In 1837, William Griffith, botanist and explorer, reported oil in the plains close to the Naga Hills beyond the river Noa Dihing. Griffith observed that the colour of the liquid was green to bluish white, which indicated the presence of naphtha. Compared to his predecessors, Griffith was more confident of a distinct character associated with the liquids that he had come across. In the same year Adam White, a Major in the British Indian army, also noticed "several springs of petroleum" close to the river Namrup. White too indicated that the local communities had no use for this resource.[14] White's survey was followed by that of S Hannay, a geologist in the service of the EIC who found "petroleum rising from some of the coal outcrops".[15]

Hannay's observations of 1838-39 were further confirmed by F Jenkins, a front ranking administrator of the EIC and a captain in the army. Jenkins reported that "oil flowed into the pools in the water-course, and four or five seers were collected in a few minutes".[16] Another round of exploration was taken up by Hannay in 1845. He explored a limited area close to Jaipur, near Silchar. His principal aim was to "find a bituminous rock like that of Pyremont, a sample of which he had been supplied with". Though he was unsuccessful in this principal mission, Hannay could collect "earthy and indurated sandy asphalt" along with ordinary oil from a place called Nahar Pung.[17] Later on, F R Mallet, reviewing what Hannay had found, wrote, "these specimens were no doubt of earth and sandstone impregnated with inspissated petroleum". Such amateur encounters continued. For instance, about a decade and half after Hannay's exploration, G Dalton, an army officer, reported oil finds at Namchik and Makum in 1854. Similarly, S E Peal, a tea planter, mentioned oil springs near Margherita in 1879. Along with amateur explorations, the first attempt at drilling for oil in Assam was made in 1854. A European speculator, John H Wagentreiber, was the first entrepreneur to take steps to exploit oil in Assam. He got a 10 years lease over a tract of land between Bappapoong and Namchik in 1854. However, the venture met with failure.

All these findings, as mentioned earlier, could not escape the fate of Wilcox's own discovery. There is little doubt that everybody proceeded along the line followed by Wilcox and looked for the possibility of finding petroleum near established coal-beds. While there does seem a pattern in these efforts, it may not be possible to state that they were aware of the common ancestry of coal and petroleum. It was only in the early 20th century that geologists were able to confirm their assumptions about the possibility of finding coal and petroleum together.

GSI and Arrival of Geology

Years of amateur discoveries would influence the nature of investigations taken up by the GSI when it was formed in 1856, though the nature of mineral exploration acquired a distinctly professional character. This began right in 1865 when H B Medlicott of the GSI studied the mud from the eastern Assam localities.[18] Medlicott research brought good news about the presence of petroleum deposits.[19] He suggested that as yet, only thin layers of petroleum had been "skimmed off" by the Assamese, "everything was in a state of nature".[20] Crucial to his investigation was the commercial possibilities of the petroleum deposits. He noticed two favourable indications: "copius discharge of gas" and "non-discharge of water" while he also noted some contrary indications, which called for a careful testing in the face of the "disturbed condition of the rock". Based on Medlicott's findings, James Goodenough, belonging to the Calcutta based Mckillop, Stewart and Company, was awarded a right to explore petroleum over a larger tract of land in eastern Assam in November 1866. Goodenough initially drilled three bores which yielded oil, often oil and water intermittently. Some wells yielded 650 gallons per day giving further hope for the commercial exploration of petroleum. With this yield increasing to 2,000 gallons per day, the prospect for commercial exploration of these areas seemed much brighter.

The next 20 years did not see much activity on the oil front despite Medlicott's recommendation that "experimental borings should be sunk there to practically test the value of the oil accumulations". However, by the 1870s, the GSI had completed extensive explorations of the coal bearing localities of Assam. In the meanwhile, surveyors continued to speculate on the resemblance of coal- and petroleum-bearing areas. Decade later, an enquiry into Burma's oil deposits convinced GSI about the connection between coal and petroleum in this region.

Samples from various borings only indicated the presence of blue clay. Whether this presence of blue clay indicated oil was still not confirmed, but it caused some excitement for the geologists at GSI. The initial breakthrough in assessing the quality of petroleum in Assam came in 1874, when Theodore W H Hughes, of the GSI, tested samples procured from the spring owned by Goodenough.[21] An analysis of petroleum from these springs gave some positive results. A fragmentation of the petroleum sample suggested that the first six portions contained lamp oil. The samples also carried a higher specific gravity, a key parameter in determining the character of the petroleum content. The seventh and eight portions from the fragmentation contained solid paraffin. Hughes thought that these two layers could be commercially separated for specific purposes. More importantly, Hughes said that as the findings of petroleum in the United States and Canada had given fresh impetus to the production of coal-oils, such a

profitable application of technology could also be used in British India. Nonetheless, Hughes' findings clearly indicated the commercial possibilities of Assam petroleum.

R A Townsend, the superintendent of Petroleum Works in Baluchistan, further examined Assam's oil deposit in 1888. For the GSI, it was a crucial to get some convincing results from an "experienced" specialist. Despite the convincing quantity of oil deposits in the sample areas, Townsend had doubts about the "satisfactory proportion of burning oil on distillation". At the same time, he did not hesitate to claim that "the illuminating value of the crude oil can only be ascertained from the oil measures below the surface which have not been exposed to atmospheric influences". But a 3% presence of petrol was not still a matter of enthusiasm and the GSI thought that "until petroleum from below has been examined, it will be as well as not to examine what is as yet unproven".

Despite this early enthusiasm, the commercial viability of oil deposits in Assam remained a matter of conjecture. As late as 1920, the GSI again admitted that, "this area has not yet been adequately tested, it is still unknown, whether there are deep oil-sands of commercial value".[22] The prospective enterprise, however, was free from certain worries of another 19th century colonial investment; the troubles with labour in the tea-plantation. While the petroleum industry was largely a mechanised sector, the prospect for getting both the skilled and unskilled workers was fairly high. Compared to tea-plantation, it was not a labour-intensive industry. There were trained technicians from England, Bengal and Assam, while limited manual labourers could be recruited from near the drilling localities.

Geological investigations were marred by "unfavourable" conditions. For instance, many in the GSI felt that the dense vegetation of the region was a serious hindrance. Scarcity of fossils was another impediment, but it was not unique to the region alone. Extensive searches in Burma too resulted in few fossils.[23] Further, compared to the experience of early days of colonialism, the access to interiors had also improved. Thomas Henry Digges la Touche of GSI, carried out further investigation towards a holistic understanding of the region's geology. Crucial results appeared from Burma with "large collection of fossils" and this convinced the GSI to get specialists for further investigations of Assam. The discovery of oil became a boon for coal exploration too since it was believed that the presence of oil implied the possibility of good varieties of coal. This was apparent, for example, while undertaking a survey to find out a possible Assam-Burma railway route. R A Way who was entrusted with the preparation of a report on this had commented that "with oil wells in the vicinity of coal workings, the manufacture of a very high class of compressed coal briquettes should become practicable".[24]

By 1894, parallel petroleum explorations in places of north-west India had shown poor results.[25] In fact, till the first decade of next century, the total output from the Punjab region remained within 2,000 gallons. Results from Assam, despite the claimed possibilities, were still low, and this was blamed on the geologists who, despite the presence of crude in an area covering over 100 miles, had not made production a reality. In January 1894, R D Oldham, a leading scientist of the GSI, while speaking to scientists at the Imperial Institute in London, blamed unskilled labourers and wrong and haphazard choice of fields for such failure. Oldham had no doubt that the quality and quantity Assam's coal and oil reserves would remain unsurpassed within British India. Oldham informed his audiences about the profitable findings in Burma. Thus, both Assam and Burma, according to him, held great possibilities for future oil production in the British empire, but needed help from the government. Oldham suggested that a survey of areas of Assam and Burma for oil exploration should be given high priority, while rules and regulations should be adopted, at the same time, to give mining concessions in these areas.

Beginning of Commercial Ventures

The commercial initiative to extract petroleum was taken by the Assam Railways and Trading Company (hereafter ARTC) from 1881. The company was formed for constructing a railway line in the province and was granted a lease over 30 square miles for petroleum exploration. It formally acquired the rights of exploration agencies in 1884.

As the prospect of extracting petroleum became brighter, the company began the process of acquiring a licence to explore in Digboi. The area they indicated had recently been declared a reserved forest. At that time, the revenue from the forest appeared brighter compared to the possible future revenue from petroleum. Therefore, the Assam government was unwilling to give the licence for petroleum exploration. In fact, the chief commissioner of the province came out openly against any such move to grant a licence.[26] The ARTC had no option but to pressurise Dufferin, the viceroy. The very tone of its request was indicative that the ARTC did not want this highly prospective chance to be forfeited. Finally, the provincial administrator could not resist and the ARTC acquire the licence in 1888 to exploit oil in the area now known as Digboi field. Another speculator was the Assam Oil Syndicate (AOS). With the commencement of commercial exploration, till the end of the century, oil was sent to for refining to Margherita, at a few miles distance which had a small refinery.[27]

Both the ARTC and the AOS went through an intricate process of negotiation to retain control over the existing land leases. Bureaucratic and commercial interests of the influential members of the AOS played a significant role in providing the new company with exclusive rights to explore oil. By 1897, the clauses became clear which would be instrumental in the making of a new company by taking over the property of the AOS.[28] By the end of the century, the ARTC signalled its willingness to do away with the exploration and drilling of oil in eastern Assam. The company did not want to lose its technical operation which would come handy in future. The impending news of the formation of an exclusive oil exploration and refining company was also in the air. One of the complex things that the ARTC needed to sort out was to negotiate with the Assam government for acquiring land leases with prospective oil deposits. The Assam Land Revenue Regulation of 1886 removed several ambiguities of land rights and essentially allowed land leases for the

oil-speculators. In 1899, the British Indian government further issued rules to govern licence and mining leases in several parts of the country. The new rules allowed the government to retain rights over the minerals and granted concessions for exploration. Annual licence was given to prospective speculators without any exclusive or preferential rights. Exploration in unoccupied and unreserved land was, however, not prohibited. With the liberal licence regime, the number of such grants also increased rapidly.

While the Assam administration was unsure about the advantages of further oil exploration compared to coal exploration,[29] by end of the 19th century, the stakeholders in Assam's oil were convinced about their prospects. They knew that it would be possible to explore and market Assam oil commercially. Some of the early anxieties were over. The GSI could safely claim that despite Assam's oilfields being commercially less prospective than the Burmese oilfields, it could claim priority in age. The occurrence of oil in both Assam and Burma was analogous too. As such these minerals were lying "along a narrow strip or belt of country running parallel to a river valley of which it forms a part", they had no doubt that minerals were to be found in tertiary rocks "succeeded by a considerable belt thickness of soft, coarse, fluviable sandstone containing fossilised wood". Years later, the GSI confirmed the assessment of the speculators when it stated, "the belt of tertiary rocks, stretching from the north-east corner of Assam for about 180 miles south and west, shows frequent signs of oil nearly always in association with coal and sometimes associated with brine springs and gas jets". Extensive exploration and big commercial prospects changed the face of Indian mineral exploration. Petroleum had already acquired a significant status as a priority mineral in India.[30] In 1899, the Assam Oil Company (hereafter AOC) with a capital of £3,10,000 was formed to amalgamate the joint capital of both the ARTC and the AOS. Its initial capital outlay was £4,50,000, a meagre amount compared to the investment in tea-plantation.

AOC and the Imperial Economy

Early in the 20th century, the European press began to report the expansion of investor interests in oil. After this, geological challenges could not hinder the region's petroleum deposits being entrapped within the imperial political economy. The AOC declared a profit of £18,960 in 1904. Later, the first world war created an unprecedented increase in the demands for oil.

With the commercial production of petrol and other products in Digboi, petrol was sold in limited quantity within the province. The larger portion of wax, "of fine quality with a melting point of as high as 135° F" was sent to England. There was a good reason for quality wax being produced in Digboi. Already the fractional distillation demonstrated a high percentage of wax and it was claimed that "one of the heaviest ever found in world". Apart from petrol and wax, Digboi began to produce jute-batching oil, kerosene and fuel oil. Till the end of 1911, a total of 32.4 million gallons of crude oil was refined. This was much lower than the Yenangyaung field in Burma which produced 1,400 million gallons in that period.

It was during the first world war that the United States began to produce huge quantities of petroleum for its consumption, more than 60% of the world share, which gave it an unparallel position in the world market.[31] This was also supported by the movement of global oil prices which also increased the flow of capital to this sector. There was already a better transport system in the Atlantic to reach the crude oil to the international markets. Though comparatively at a lower scale than that of the US, even British capital began to flow into the oil markets. British India, at that time, had only a marginal share of 10,00,000 tons which was less than 1% of the total global oil production.

At the end of the first world war, with good prospects of an international oil market, the AOC began to emphasise restructuring and re-strengthening of the geological department of the company. By 1920, with the great boom created by the first world war, the Assam oilfields attracted more international attention. But despite this the AOC could not make a good profit from its Digboi fields till 1925 when it began to report a growth in its profit.[32] Intensive drilling operations began from 1922.[33] The AOC claimed that this was achieved despite the shortage of "native efficient labour". The AOC also hired trained scientific staff like geologists from the Burma Oil Company (BOC). The company continued to apply for licences in various other areas which showed signs of oil reserves. This also meant that the rights over some areas which had been explored and had already been relinquished. Over the years, though the AOC began to concentrate essentially on Digboi, it also, gradually, diverted its attention to other areas. As such exploration required financial investment and careful geological exploration preceded any such attempt. Additional money required for new exploration was generated on loan from the international market.

A couple of decade after its formation, the AOC had three distinct forms of activities: production and refining of crude oil and the distribution and sale of the refined products. But the company was still struggling to overcome various initial difficulties in every field of its operation. For the next couple of years, the primary task of the company remained essentially focused on the important dimension of proving the productive capacity – oil-bearing capacity of the wells which would have an important bearing on the crude oil position of the state. To expedite drilling in a number of speculative fields, a rotary outfit was sent from London to Assam.[34] Proving the contiguous character of a few separate oil-bearing regions had remained the core scientific concern of the AOC.

There was a growing competition for prices of kerosene, the product which was most sought after by the general customer. By the end of the first quarter of the 20th century, the AOC began to look for markets beyond the traditional markets in Assam to sell their kerosene. This was mostly necessitated by the increased volume of kerosene production. It was a difficult time for the AOC to face the increased instability in the world oil prices, especially with the increased global participation of oil companies whose intense international competition was mostly done by "rate cutting". At the same time, there was a general feeling of trust on the future prospect of India's petroleum industry by the first decade of its operation.

Forming a Partnership: AOC and BOC

Despite profits earned in the wake of first world war, the AOC could hardly sustain its commercial operations independently against the aggressive US-based oil companies. The best possible option for it was to seek a joint venture with another British oil company, both commercial and technological. The logistical operation of BOC and years of technological cooperation encouraged the AOC's management to seek further support for its future works from the former. The BOC, initially formed in 1886 and restructured in 1902, had monopoly control in British Burma, which acquired substantial rights in the Assam oilfields a couple of years earlier and had already expanded its territorial limits to Burma, Assam and Punjab.[35] While oil exploration in the south-east Asian soils had already made a significant headway.[36] The BOC was under possession of the rich oilfields of Irrawati and by the first decade of the 20th century, it was in a position to provide good dividend to its shareholders. The BOC also had drilling rights over 500 acres of lands in southern Assam.[37] The BOC had already declared its intent for aggressive expansion into the crude oil market of British India:

> We have devoted a fair proportion of our profits to this exploratory and testing work because your directors have recognised that it in the interest of the company and of the oil industry of Burma and India that we should do so. After all crude oil is the life blood and very existence of the company, and I am sure you will all agree that no stone must be left unturned in order to try and discover fresh sources of supply, particularly in Burma and India where the company both holds such a commanding position in the market and possesses all the transport, refining and marketing organisation required to deal with a large production of crude oil.[38]

This meant that the BOC would vigorously pursue oil in "every area of reasonable geological promise". The only method to prove and disprove this speculation was the technology of drilling. Even finding of oil does not necessarily mean the commercial viability of extracting oil. The BOC geologists had also predicted that compared to the existing estimate of oil capacity of Assam fields, the possibility was much higher. And the BOC at this stage began to contemplate staking more claims in the affairs and properties of the AOC. With this intention, in 1920 the BOC offered £2 cash for each AOC share.[39] Alternatively, the BOC suggested, the shareholders of AOC could opt for two share of BOC for nine shares of AOC. Despite the chaotic nature of oil prices, taxes on oil remained uniform which was a matter of serious concerns for the BOC. After its amalgamation with the BOC, the AOC could fight out these core issues more elegantly. However, what remained most central to the oil industry was the great unevenness in equilibrium in the supply- and demand-side of the industry. The first few decades of the oil industry saw uncontrolled and speculative production, resulting in great instability in the oil prices. Concerns existed about the actual limited reserves of oil, but it was generally believed that new exploration and discoveries would work as a deterrent to any probable decline in the oil capacities.[40] Faced with growing concern raised from various platforms, Britain began a political move to control the production of crude oil.

By 1927, a couple of years after AOC came under the direct management of the BOC, it became clear that there was little likelihood of the company adding to its existing resources. Prices of petroleum products remained volatile and unpredictable as before adding innumerable miseries to various oil companies. In the next year, the rate-cutting wars had severely threatened AOC with its potentially small capital. The geographical location of Assam leading to unfavourable transport became another concern for the company.

One possible way to escape these economic uncertainties was to gain greater political clout within the provincial government. This could be done by gaining privileges similar to those enjoyed by the tea-plantation lobby. The AOC also tried to carve out more space within Assam's legislative political domain. Protracted political battles ensued claiming such privileges as that of Assam plantation lobby. However, despite intense lobbying they could not secure such a place within the political machinery. On the eve of the second world war, the oil industry came under severe labour unrest. A series of labour strikes disrupted the production of oil. This unravelled the role played by the Indian state and political class in this industry.[41] This also ensured a conflict of interest between the provincial Congress government and imperial interests.

During this time, like its colonial counterpart the tea-plantation, the oil sector also remained crucially dependent on imperial capital mechanism. The Indian government reacted slowly; it had no other way, but to handle the oil economy, with a careful eye at international flows of capital.

Afterwards

At independence the Indian consumers were still primarily dependent on imported petroleum. After that the Government of India (GOI) tried to pursue a policy of "developing oil resources under the exclusive control of the state". An industrial policy clearly indicated that the management of the oil resources would be under the public sector, but the government was yet to formulate a policy towards its effective control.[42] There was an attempt to control various foreign oil companies, but in reality the GOI could hardly exert firm control over them. At the same time, independent India's oil policy came under harsh criticisms of the World Bank, which had already began to regulate international economic policies.[43]

In the absence of a widely accepted production and distribution policy in petroleum, the Assam provincial government

played a crucial role in the evolution of a temporary but independent oil programme within the emerging, but yet unstable, Indian federal polity. As the rights over the regional natural resources were yet to be clearly formulated, the Assam government asserted its rights to negotiate with the AOC. Accordingly, the Assam government renewed the AOC's exclusive licence for geological exploration in 1950. Another year later, in 1951, still pursuing an independent oil policy, the Assam government extended another mining lease to AOC to explore oil in Naharkatiya of eastern Assam. After a couple of years of exploration, in 1953, more oilfields were discovered, which were commercially viable. This encouraged the AOC to further renew its licence with the Assam government. The Assam government renewed licences to the AOC on the condition that the Indian government's share in the new venture would be limited at 33.5%.

With the increasing interest of the GOI in the country's oil resources, a committee was formed to look into the matter of the rights of Indian government and various contested oil policies.[44] The committee suggested that the crude oil from Assam should be processed and refined at another location. The committee suggested Calcutta, also agreed upon by the AOC, as the favoured site with Barauni as the next possible site. A site in western Assam could be considered only if political circumstances compelled to do so. As it became clear that Assam would not have a refinery in the beginning of the Second Five-Year Plan, widespread public protests emerged. Political parties across their ideological stand came together to articulate Assam's unwillingness to share oil with the entire country. A public coordination committee was formed to spearhead a movement ostensibly aimed at having a new refinery in Assam. The new refinery would be supplied with crude oil from eastern Assam. Legislators in the state assembly raised their concern of Assam's claim for oil eloquently in the floor of the assembly: The Indian government's decision to establish the refinery at Barauni was challenged by the Assam government and all the parties representing the hills and the plains stood united for the cause supported by the people of Assam who actively participated in the movement led by the All Assam Refinery Action Committee.[45]

A resolution that the refinery should be established in Assam was taken in the legislative assembly in April 1956. The popular movement was jointly spearheaded by the leadership of the opposition party and the All Assam Oil Refinery Action Committee. Under popular pressure and the constant negotiation by the Assam government, the GOI decided to appoint an expert committee to resolve the question of the location of the refinery. Though the committee was a relief, people were apprehensive about the committee, a sentiment reflected in the vernacular press. In October 1956, the action committee met Prime Minister Jawaharlal Nehru, during his visit to Assam. They represented their demand that the committee should work towards establishing the refinery in Assam and the objectives of the committee should have been to find ways to overcome the hurdles.[46] The technical and commercial angles of setting up of the refinery had already been discussed by the AOC and Assam had already protested against it.

By June 1957, the GOI decided to set up the refinery in Barauni against the popular demands of Assam. This was sure to raise

further political outburst. By June 1957 all the members of the Assam Legislative Assembly came together to stand by the cause. The assembly was convinced that the refinery was even technically and commercially possible in Assam. The members argued that the refinery was essential for the economic development for Assam as it would generate petroleum-based industries and have a wider developmental impact. An Assamese legislator, substantiated this view by drawing a similarity with west Asian countries. The Assamese socialist leader Hareswar Goswami had no doubt that even if such claims were categorised as "parochial", he would "suffer to be parochial rather than to live in a house where I have no rights over my belongings". He added that retention of oil inside Assam was a "question of regional development" and he appealed for a united stand on this issue. The demand for a refinery was not merely confined to the legislative politics but the protest drew a large popular participation. The ideological apparatus of this outrage was directed largely by the Assamese middle class. The condemnation of the state against these protests was feeble. Finally, under tremendous pressure from a member of the central government, the GOI decided to agree to a separate refinery to Assam apart from the one at Barauni.[47] The pipeline which was constructed for carrying out this oil was one of India's major international engineering cooperations.

At the close of the previous century the Indian government had strongly asserted that minerals and their development play a significant role in its programme of national development. In doing this, the role of the State and technology has been clearly outlined. In Assam, the oilfield townships have come to symbolise the prosperity of the Assamese elite. On the other hand, oil has also emerged as one of the key "regional" resources with claims of exclusive nationalistic rights. Oil exploration came to be seen as a major example of Indian internal colonialism.

NOTES

1 Several works have discussed on the aspects of oil exploration in the age of imperialism.

2 Jones has discussed the steps taken by the Indian state in shaping India's oil policy in pre-Independent period G G Jones, "The State and Economic Development in India 1890-1947: The Case of Oil", *Modern Asian Studies*, Vol 13, No 3 (1979), pp 353-75.

3 H K Barpujari, *The Comprehensive History of Assam*, Vol 4, Assam Publication Board, Guwahati, 1990 is among works which were published in the 1990s but failed to look comprehensively at the complex issues of science and technology, imperial competitions, imperial and federal politics, etc. For instance, we know little about the transfer of technology to Assam refinery from western institutions or to what extent this important industrial unit benefited from an alliance with the Burma Oil Company.

4 David Cahan, *From Natural Philosophy to the Sciences: Writing the History of Nineteenth-Century Science* (Chicago: University of Chicago Press), 2003; Simon J Knell, *The Culture of English Geology, 1815-1851: A Science Revealed Through Its Collecting* (Farnham, United Kingdom: Ashgate Publishing Company), 2000.

5 For an excellent account of the 19th century science of geology and its works in the different parts of the world see, David Cahan, op cit. For an account of the British geology in the 19th century, see Simon J Knell, op cit. Also, Roy Porter, *The Making of Geology: Earth Science in Britain, 1660-1815* (Chicago: Chicago University Press), 1972.

6 David Arnold, *Science, Technology and Medicine in Colonial India* (Cambridge: Cambridge University Press), 2004, 44-46. Arnold, however, fails to locate the intensive, though chaotic, search for mineral resources in eastern India closely. For instance, as discussed in the following section search for gold became part of company administration much earlier.

7 Jean Baptiste Chevalier, *The Adventures of Jean-Baptiste Chevalier in Eastern India, 1752-1765: Historical Memoir and Journal of Travels in Assam, Bengal, and Tibet*, translated by Caroline Dutta-Baruah and Jean Deloche (Guwahati: LBS Publishers), 2008.

8 Maniram Dewan, "Native Account of Washing for Gold in Assam", *Journal of Asiatic Society of Bengal*, Vol 7, 1838.

9 E T Dalton and S F Hannay, "Note on Recent Investigations Regarding the Extent and Auriferous Deposits of Assam", *Abstracts of Reports by Memoirs of the Geological Survey of India*, 1855.

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11 R Wilcox, *Memoir of a Survey of Assam, and the Neighbouring Countries Executed in 1825-6-7-8*, Asiatic Researches, Vol XVII, pp 314-467.

12 The British home intelligence notified the visit of Wilcox in its report, *The Asiatic Journal and Monthly Miscellany*, p 380.

13 Wilcox, op cit.

14 F R Mallet, "On the Coal-Fields of the Naga Hills Bordering the Lakhimpur and Sibsagar Districts, Assam" in *Memoir of Geological Survey of India*, Vol 12, Part II, 1876.

15 S F Hannay, *Journal of the Asiatic Society of Bengal*, Vol VII, 1838, p 368.

16 C F H Jenkins, *Journal of the Asiatic Society of Bengal*, Vol VII, 1838, p 169.

17 F R Mallet, op cit.

18 T H Holland, "Sketch of the Mineral Resources of India", *Report on the Geological Survey of India* (*RGSI*), 1908, p 24.

19 H B Medlicott, "Note on the Occurrence of Petroleum in India", *RGSI*, 1921-22, p 185; H N Kaul, *K D Malaviya and the Evolution of India's Oil Policy* (Delhi: Allied Publishers), 1991, p 18.

20 H B Medlicott, "The Coal of Assam Results of a Brief Visit to the Coal-fields of that Province in 1865 with Geological Notes on Assam and the Hills to the South of It", *Memoir of Geological Survey of India*, Vol 4, 1865, pp 382-442.

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22 E H Pascoe, "Petroleum in the Punjab and North-West Frontier Province", *Memoirs of the Geological Survey of India*, 1920.

23 Annual Report, *RGSI*, Vol VII, Part 1, 1873, p 6.

24 R A Way, "Assam-Burma Connection Railway Surveys, Hunkong Valley Route", *Report and Approximate Estimate*, Calcutta, 1896.

25 *The Times*, 19 January 1894, p 4, column C.

26 W A Lawthropp, *The Story of Assam Railway and Trading Company Limited 1881-91* (Citation not available).

27 *The Story of Assam Railway and Trading Company Limited*, pp 44-54.

28 Letter from H St P Maxwell, Commissioner of Assam Valley Districts to the Secretary to CC, Assam, 22 September 1897 in File No, Revenue, A, Nos 127-43, October 1897.

29 Note, Edward Gait, to Secretary, Revenue, A, June 1894.

30 T H Holland, op cit, pp 21-22.

31 *The Times*, 22 January 1915, p 6, col F.

32 *The Times*, Tuesday, 27 May 1924, p 26, col F.

33 Statement of Sir John Cargill, chairman of AOC, *The Times*, Tuesday, 27 May 1924, p 26, Issue 43662, col F.

34 *The Economist*, 17 July 1915.

35 For a broad outline of the Burma Oil Company, see Thomas Anthony Buchanan Corley, *A History of the Burmah Oil Company: 1866-1924* (London: Heinemann), 1983.

36 G M Lees, "The Search for Oil", *The Geographical Journal*, Vol 95, No 1 (January 1940), pp 1-16.

37 *The Economist*, 18 June 1921.

38 Speech of Sir John Cargill, Chairman, Burma Oil Company Ltd, quoted in *The Times*, 28 April 1911, p 7, col E.

39 *The Economist*, 18 June 1921.

40 The BOC chairman was forthcoming in giving a grim picture of what was in the stake: "There is going on, too, all the time natural decline inherent in the fact that whatever the world's resources are they are being consumed while no process of replacement is going on; in recent years in the United States at any rate, and I suppose also in Roumania, a feature uncompensated for by fresh discoveries of deposits of consequence" quoted in *The Economist*, 15 June 1935.

41 For an outline of the labour strike in Digboi see, Dipankar Banerjee, *Labour Movement In Assam – A Study of Non-Plantation Workers Strikes Till 1936* (Delhi: Manohar), 2005 and Amalendu Guha, *Planter Raj to Swaraj: Freedom Struggle and Electoral Politics in Assam 1826-1947* (New Delhi: Tulika Books), 2006.

42 Kaul, op cit.

43 Consequent to this strong international criticism the GOI entered into a new agreement with the BOC which allowed BOC to have only 50% equity and also allowed all financial investment made by BOC for oil exploration as income tax deductible, *The Times*, 2 June 1961, p 12, col A.

44 The committee consisted of Jawaharlal Nehru, K D Malaviya, Krishna Menon, G B Pant, Morarji Desai, T T Krishnamachari, Swaran Singh along with a representative of Planning Commission.

45 Under the leadership of Hareswar Goswami and Hem Baruah, both leaders of the Praja Socialist Party.

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47 Unpublished seminar paper, Ditee Moni Barua.

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Performance of Digboi Refinery Modernization Project From Geotechnical Aspects — Investigation and Observations

Gokul K. Bayan

CSIR-North East Institute of Science & Technology, India

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PERFORMANCE OF DIGBOI REFINERY MODERNIZATION PROJECT FROM GEOTECHNICAL ASPECTS – INVESTIGATION AND OBSERVATIONS

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ABSTRACT

Digboi Refinery is the world's oldest refinery in simple form which is producing oil since 1889 till present with its modernized setup. Its first well was dug manually during 1889 and crude oil was found at 54m depth only. This phenomenon has encouraged establishing an industry on oil producing business, and accordingly a form of first refinery was comeout in 1889.

The Digboi Refinery modernization project was taken up in large scale in order to overcome the technological obsolescence of the old refinery. Subsequently a number of other major projects were undertaken by Assam Oil Division to further revamp and modernise Digboi Refinery, which is in fact commissioning during 2007 onward as a completely modernizied refinery.

Geotechnical investigations for this modernization project was started during 1987 and completed during 1992. As a whole the investigation works were completed under time bound work of three different phases of investigations with various engineering requirements. Besides laboratory investigations, field investigation includes mainly boreholes with SPT, DCPT, SCPT, VST, CBRT and Block vibrations tests. After careful studies, based on the field and laboratory investigations various types of shallow and deep foundations were suggested. Design and constructions were made based on the suggestion provided more particularly to overcome the problems pertaining to the high seismicity of the area and potential to dynamic liquefaction point of view and executed the same at site accordingly. Observations were made till date are found highly satisfactorial to engineering aspects.

INTRODUCTION

History of Digboi Refinery in General

Digboi Refinery is located in far northeast corner of Assam, India. Its geographical location includes an area of latitudes 27°23′N to 27.38°N and longitude 95°38′E to 95.63°E. It has an average elevation of 165 metres above msl. It is situated 510 km north east of Guwahati city the central place of North East Region (NER) of India.

More than a century ago just before the World War I, history of oil business was begun in the midst of the dense and malaria infested jungles by a band of intrepid pioneers searching for black gold. Italian Engineers, commissioned by the Assam Railways and Trading Company, which established Tea Gardens, Coal Mines and Timber Mills in the NER of India, accidentally discovered oil at Digboi. Accordingly, the first commercially viable well in India, known locally as well No.1, was successfully drilled in September, 1889 and first model refinery in India was built and commissioned in December, 1901 to supplant a small "betch-still" refinery in Margherita. Figure 1(a, b & c) depicting some aspect of premitive refinery.

When oil was discovered in Digboi there was no habitation in its immediate neighborhood. The jungle was dark and swampy. The forest was so thick and the undergrowth so dense that sunlight could never reach the ground. Once oil was found, the dense jungle made way for the growth of the oil industry in India. 'Dig-boy-dig', shouted the Canadian engineer, Mr W L Lake, at his men as they watched elephants emerging out of the dense forest with oil stains on their feet. This is possibly the most distilled – though fanciful – version

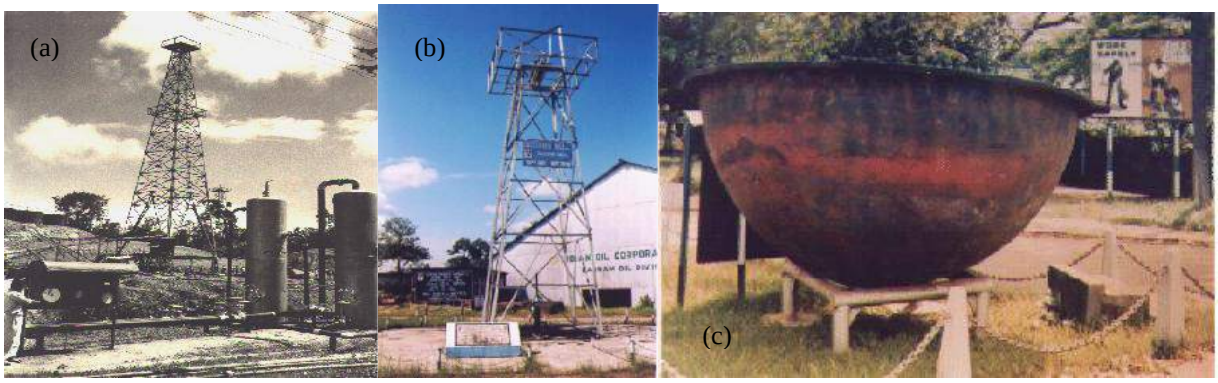

Fig. 1 Depicting old refinery (1889-1901) as (a) Digboi Refinery at the initial stages (b) First Commercial Viable well in India locally known as Well No.1 (c) "Betch-still" use in Margherita Refinery Unit

Fig. 2 Depicting present day (2007) Modernised Digboi Refinery

of the legend explaining the sitting and naming of Digboi. Over the past 100 years, Assam Oil Division and the petroleum industry of India with Digboi as its nucleus has been very much a part of this existing period. While looking back on the past with respect and to the future with confidence, it is here how Digboi Refinery was successful in meeting the needs and challenges of the times, and how Digboi Refinery played a role in shaping and developing history over the past 100 years. Digboi is now Headquarter of Assam Oil Division of Indian Oil Corporation Limited.

The Earliest recorded to the existence of oil in India is found in the memories and dispatches of the Army Officers who penetrated the jungles of Upper Assam since 1825. Lt. R. Wilcox, Major A. White, Capt. Francis Jenkins, Capt. P.S. Hanney -- they all saw at different times, petroleum exuding from banks of the river Dehing. Mr. C.A. Bruce (1828) and Mr. H.B.Medicott (1865) of the Geological Survey of India also saw oil while prospecting for coal in Upper Assam. Mr. Goodenough of McKillop, Stewart & Co. Calcutta was the first in India to start a systematic programme of drilling for oil in November,1886, at Nahorpung about 30 miles south east of Dibgoi, just seven years after the World's first commercial oil well was drilled in 1859, by Col. William Drake in Pennsylvania, USA. This hand dug well-first oil well in India was drilled upto 102 feet and proved dry. However, the second well, struck oil at Makum near Margherita, about 8 miles from Digboi. The Assam Railways & Trading Company while extending the Dibrugarh-Sadiya Railway line upto their coal fields in 1882 came across oil seepage near work sites around present Digboi. Although drilling for oil first began in 1886, by Assam Railways and Trading Company, it was not until 1889 that the first commercially viable well was struck at Digboi. India's petroleum industry thus started taking shape with the commercially successful discovery of oil in Digboi. Assam Oil Company (AOC) was formed in 1889 to take over the oil interest of the Assam Railways & Trading Company and the Assam Oil Syndicate, who had carried out the early drilling in the area. The Digboi refinery, commissioned in December, 1901 is today India's oldest operating refinery. The Digboi oil field produced close to 7,000 barrels per day (1,100 m^3/d) of crude oil at its peak, which was during World War II. Over the 100 years it has undergone a transition from being an age old refinery to one with state-of-the-art technology comparable to any modern refinery.

Present Day Digboi Refinery

Digboi Refinery Modernization Project (DRMP) was started during 1987 with its soil investigation work. It was taken up in large scale in order to overcome the technological obsolescence of the old Digboi refinery. Subsequently a number of other major projects were undertaken by Assam Oil

Division (AOD) to further revamp and modernise old Digboi Refinery. This includes the Wax Hydro-finishing Unit (WHU), the Solvent Dewaxing and Deoiling Unit (SDU), Hydrotreater, Vacuum Residue Short Path Distillation (VRSD). Subsequently, Digboi refinery has been awarded the ISO-14001 and OHSMC certificates (Fig. 2). Digboi is now Headquarter of AOD of Indian Oil Corporation Ltd.

Geotechnical Investigation in Brief at DRMP

Geotechnical investigation carried out for the DRMP site on behalf of General Manager, Indian Oil Corporation Ltd (IOCL), Assam Oil Division, Digboi. The investigations for DRMP site were carried out in three phases viz, preliminary investigation for 12m depth, investigation for additional requirement for 25m depth and final investigation (phases II) for 21 m depth. Field investigations were carried out in the months of July to August 1987, January to April 1988 and June to September 1989 respectively. Figure 3 (a&b) shows the overall Digboi refinery with proposed DRMP site depicting the locations of almost all kinds of field tests carried out during that period in plan and sectional elevation respectively. The whole investigations were time bound and the interim reports for the final investigations were submitted as per tight schedule drawn up by the Chief Project Manager, IOCL, (AOD). Whole DRMP site is subdivided for through investigation into 15 numbers of sub-area based on the actual structures to be constructed therein. The sub-areas and the field tests carried out with in them are as under:

1. Filter water reservoir unit (H-1 and H-2).
2. D.M Tanks and plants area (B-4, B-5, H-3 and SCPT-15)
3. Utility sub-station area (BH-11 and H-4)
4. Power plant area (B-6, H-5, H-6, H-7, H-8 and SCPT-14)
5. C.W pumps, C.W.F and Cooling tower unit (B-7, H-9 and SCPT-13)
6. F.W Tank unit (H-10, H-11 and SCPT-11).
7. F.W. Power house unit (BH-10 and SCPT-12).
8. Compressor station and Nitrogen plant unit (BH-9, B-7, H-12 and H-13).
9. Fire station unit (H-14)
10. Control room and substation unit (BH-6, H-15 and SCPT-10).
11. Reformer unit (Entire area was an uneven land having ridges and depressions covered by surface water and vegetation which includes H-16, H-17, H-18, H-19, SCPT-8 & 9, DCPT-1 & 2).
12. V.D.U and C.D.U unit (Entire area was an uneven marshy and sludgy land having ridges & hillocks and depressions covered by surface water and vegetation which includes BH-1, B-2, H-21, H-22, H-23, SCPT-5,6,7 and DCPT-3&4).
13. Feed stock tank and Dyke unit (B-1, H-24, H-25, SCPT-1, 2, 3 & 4, DCPT-5&6).
14. Pipe track area (Entire area was an uneven land having ridges and depressions enters into the existing refinery plant which includes H-26, H-27, H-28 & H-29).
15. Cement godown plant unit (Bh-4 BH-5 and SCPT-16).

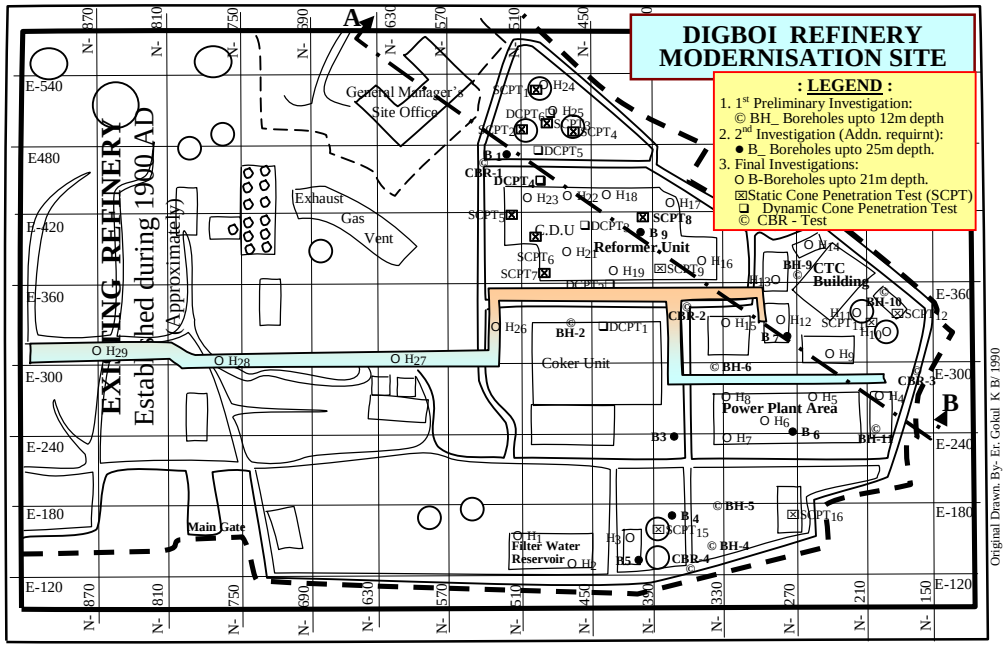

Fig. 3(a) Showing the then proposed DRMP site and part of Existing Digboi Refinery during 1989

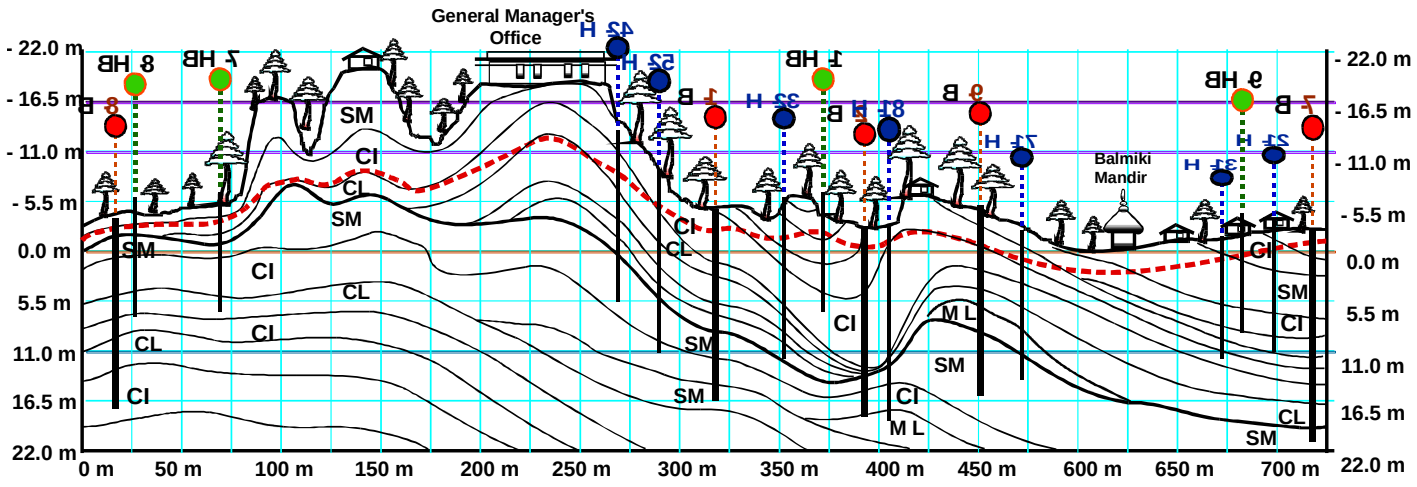

Fig. 3(b) Sectional view through A-B line in Fig. 3(a) showing the proposed DRMP site and part of existing Digboi Refinery

It was revealed from the investigations that the subsoil mainly consists of fine grained soil of low and medium plasticity to non-plastic silty-sand. No coarse grained sand or gravel deposits were found. Soil pockets filled with very soft clayey silt or silty-sand, oily substances, decomposed or semi-decomposed vegetation were also found in some areas. Void of soil mass was identified in some locations which is the result of dynamic soil liquefaction due to old earthquakes. Safe Bearing Capacity (SBC) of the investigated subsoil was found in the range from 1.5 to 7 t/m^2 at various depths and the values with respect to 25mm, 40mm and 60mm settlements were recommended for isolated footings of different sizes. Pile foundations of different types were recommended for some areas with heavy loading structures due to poor bearing capacity at shallow depths and to overcome the liquefaction zones. Consolidation properties of the subsoil, the time for 90% settlement and historical loading conditions of the areas were also established. Settlement characteristics including consolidation and elastic settlements at centre and periphery for R.C.C. circular oil storage tanks were calculated in detail and recommendations for reduction of high degree differential settlements were included. Recommendations regarding site preparation including placement and compaction of fill materials required to bring the uneven hilly site level to final grade level and for road pavements were also furnished.

GEOTECHNICAL INVESTIGATION IN PARTICULAR

Description of Site and General Geology of DRMP Site

The site for the proposed (during 1987) Digboi Refinery Modernisation Project (DRMP) is situated on the southern part of the existing Digboi Refinery plant. Tinsukia-Ledo railway line and the State P.W.D. road touch the proposed site in western side. Digboi railway station is located near the south-west corner of the site.

The topography of the entire site is characterised by small hillocks and valleys with depressions partly filled up by surface water and jungles (Fig. 3.b). Location of boreholes (marked as BH, B and H) and other field tests for the three stages investigations are shown in site plan (Fig. 3.a) along with the refinery building units of various natures.

General geology of the DRMP site comprises of small hillocks forming the part of the Nagahill ranges. The highest hillock is about 200m high above mean sea level (msl). The structural formation of top of the area is mainly laminated bends of clay, silt and sand-stone of recent age of alluvium deposit and the bed rock is of Barail group of Oligocene to Pliocene age. The bed rock is characterised by a sharp anticline runs in WSW-ENE direction and both the flanks having different dips ranging from 90° to 60^0. General geology and seismic activity of DRMP site is furnished in Appendix.

Detail Scopes of Works for Thorough Investigations

Whole investigations were carriedout under two major different phases, viz., Phase-I.a: Preliminary Investigation, Phase-I.b: Additional requirements and Phase-II: Final investigation.

Scopes of Field works 1. Preliminary Investigation under Phase-I.a, covered the following scopes of field works, location of which are shown in Fig. 3(a&b).

(a) Boreboles (designation BH): 11 nos upto the maximum depth of 12m.
(b) Dynamic cone penetration tests (DCPT) upto 12m - 9 nos.
(c) Standard penetration tests (SPT) in each borehole upto the depth of boring.
(d) Collection of disturbed and undisturbed samples from boreholes.
(e) Collection of soil and water samples from boreholes for chemical analysis.

(f) Observation of ground water table.

Scopes of Field works -2. Investigation for additional requirements under Phase-I.b covered the following scopes of field works, location of which are shown in Fig. 3(a&b).

(a) Boreholes (designation B): 9 numbers upto a depth of 25m.
(b) SPT in 8 boreholes upto the depth of boring.
(c) DCPT upto refusal - 1 no.
(d) Collection of disturbed and undisturbed soil samples from the boreholes for laboratory analysis.
(e) Observation of ground water table.

Scopes of Field works - 3. Final investigation in Phase-II covered the following scopes of field works location of which are shown in Fig. 3(a&b).

(a) Boreholes (designation H): The position of 24 nos of boreholes (21m depth) were fixed based on actual location of the proposed structures (Fig. 3.a).
(b) SPT and collection of disturbed and undisturbed soil samples from boreholes for laboratory analysis.
(c) Static cone penetration test (SCPT) – 16 nos.
(d) In-situ vane shear test - 7 nos.
(e) Field permeability test - 2 nos.
(f) Field CBR test – 4 nos.
(g) The electrica1 resistivity test and dynamic soi1 tests
(h) DCPT (6 nos).
(i) Observation of ground water table.

Scopes of Laboratory works. Following laboratory investigations works were performed for almost all phases of investigations:

(a) Grain size analysis by
  (i) Sieve analysis test, and
  (ii) Hydrometer analysis test
(b) Atterberg's limits test
(c) Natural moisture content test
(d) Bulk density (Dry and wet density) test.
(e) Specific gravity and void ratio test.
(f) Triaxial compression test
  (i) Drained test and
  (ii) Undrained test
(g) Direct shear test.
(h) Unconfined compression test.
(i) Permeability test.
(j) Uniaxial consolidation test.
(k) Proctor density test
(l) CBR test
  (i) 4-days Soaked CBR and
  (ii) Unsoaked CBR
(m) Chemical analysis of soil and water samples

Scopes of works for Recommendations. Following recommendations were prefixed for the 3 stages investigations.

(a) Geological information of the region.
(b) Past observation and historical data, if available for the area or other areas with similar soil profile or for similar structures in the surrounding area if existing.
(c) A set of longitudinal and transverse soil profiles connecting various boreholes shall be presented in order to give a clear picture of the areas to show the variation of subsoil.
(d) Recommended type of foundation for various structures duly taking into account the tolerable settlements, presence of ground water table also minimum depth of foundation.
(e) Net safe bearing capacities of strata for various widths of square foundation of sizes 1m, 1.5m, 3m, 3.5m, 6m and 10m for proposed foundation depths of 1m, 2m and 3m below normal ground level for an allowable settlement of 25mm, 40mm and 60mm. The backup calculation shall be appended in the report.
(f) Ultimate settlement from consolidation properties and time for 90% settlement shall be determined, immediate settlement and bearing capacities from SCPT shall also be recommended (as per minutes of 1st meeting held among IOCL (AOD), EIL and RRL-J on 22 & 23 August, 1989 at Digboi).
(g) Recommended type of piles, size and pile capacities in vertical, lateral and pullout based on soil parameters if piling is considered necessary.
(h) Comments on chemical nature of ground water and soil with due regard to its potential ill-effects on concrete and steel and firm recommendation on protective measures. Also remedial measures for sulphate attack due to acidity shall be dealt in detail giving clear practical recommendations.
(i) Recommendations regarding design and construction of roads and other paved structures and also suitability of soil for back filling foundation;
(j) Recommended laboratory CBR values for filled up soil and field CBR values for both soaked and unsoaked conditions. The compaction characteristics of soi1 proposed to be used for filling below road pavements and back filling of foundations have to be furnished.
(k) Recommendation related to site preparation including, classification, placement and compaction of fill materials required to bring the general site level to final grade level if so required. Recommendations regarding excavation, stabled slopes for excavation, dewatering and method of dewatering if warranted.
(1) Recommendation regarding co-efficient of permeabi1ity of various subsoil strata based on laboratory and in-situ permeability test.
(m) All field and laboratory test results plotted against depth as wall as in tabular form.
(n) Tank settlements both at centre and periphery are to be computed. If the soil investigation calls for ground improvement in view of the above requirements, suggestion regarding method of ground improvement should be furnished in the reports.
(o) A preliminary examination regarding susceptibility of Sub-soil strata to liquefaction in the event of earthquake.
(p) Comments on chemical nature of ground water and soil with regard to their effect on concrete and steel.

RESULTS OF FIELD AND LABORATORY TESTS

Result of Various investigations in General

Boreholes and Other Tests. The whole investigations include 44 numbers (nos.) of boreholes, 16 nos. of SCPT, 16 nos. of DCPT, 7 nos. of field vane shear test, 4 nos. of field CBR test, 2 nos. of field permeability tests, 2 Block vibration tests and electric resistivity tests were carriedout as per relevant IS: codes of practices to ascertain the geotechnical soundness of the proposed DRMP site along with SPT in each boreholes upto depth of refusal. Laboratory investigations cover almost all possible tests. Recommendations cover all forms of requirements of the designers. It is not possible to present all the tests result and recommended values with suggestions here in this paper. Hence, representative values of various tests results were prepared and are given in tabular form in Table 1 for comprehensive understanding of the geotechnical sounding of the then proposed DRMP site.

CBR-Value Tests: Similarly, Table 2 gives an account of the comparison of field and laboratory CBR values.

Table 1. Geotechnical properties of some Borehole locations (Phase –II, only) of DRMP site

Srl. No. (for this table)	Borehole (H) wise location & Depth (in metre) of undisturbed soil Samples	Evaluated Specific gravity of samples	Field moisture content 'W' in %	Field Bulk density (Wet) 'γ' in gm/cc	Grain size analysis (By Sieve & Hydrometer analysis)						Type of soil (Symbol as per ISI Code)	Oedometer Consolid-ation Properties			Shear parameters from Triaxial Quick test		'N-Value' from SPT (Excluding … correction)		SBC. of Subsoil for Isolated Footing of (1m x 1m) size at (1m) depth for (40mm) Settlement.
					size in mm			Content in %											
					p. c. passing through sieve			Particle Content											
					4.75	0.60	0.075	Sand	Silt	Clay		C_C	K x10^{-5} cm/min	$\sqrt{t_{90}}$ min	C in kg/cm^2	ϕ in degree	Un-corrected	Corrected	
	Borehole (H-1) 1. 1.65-1.60	2.561	22	1.97	100	98	75	28	56	16	MI	0.155	5.34	2.00	0.25	15.0	-	-	6.0 t/m^2
	Borehole (H-7) 2. at 1.65-1.95	2.620	27	1.95	100	85	50	-	-	-	CL	-	-	-	0.34	4.4	-	-	
	3. at 4.65 – 5.10	2.580	31	1.95	100	89	69	29	53	18	CL	0.230	4.51	2.05	0.48	0.0	10	6	5.5 t/m^2
	4. at 7.65 – 7.95	2.600	24	1.98	82	59	13	-	-	-	CL	-	-	-	0.08	27.0	7	11	
	5. at 13.65 – 14.15	2.680	19	2.14	100	98	49	30	57	13	CL	0.089	87.0	2.50	0.38	14.0	17	22	
	Borehole (H-10) 6. at 1.60-2.05	2.630	33	1.98	100	96	72	-	-	-	CI	-	-	-	0.22	10.5	-	-	
	7. at 3.20 – 3.65	2.610	31	2.00	100	97	75	18	59	23	CI	0.228	4.78	3.15	0.33	7.5	11	6	4.0 t/m^2
	8. 6.16 – 6.60	2.600	25	1.98	100	99	97	-	-	-	CI	-	-	-	0.30	8.0	8	8	
	9. at 9.25 – 9.70	2.570	22	1.99	100	98	87	-	-	-	ML	-	-	-	0.16	28.0	18	23	
	Borehole (H-17) 10. at 1.50-1.95	2.600	36	1.92	100	98	76	-	-	-	CL	-	-	-	0.17	3.0	-	-	
	11. at 4.55 – 5.00	2.570	22	1.98	100	99	96	-	-	-	SM	-	-	-	0.00	31.5	12	11	4.0 t/m^2
	12. at 7.50 – 7.80	2.640	26	1.96	100	84	71	3	93	4	MI	0.136	4.74	1.32	0.44	5.0	15	19	
	13. at 10.60 – 11.0	2.590	20	1.99	93	81	20	-	-	-	MI	0.187	5.51	2.70	0.00	34.2	27	37	
	Borehole (H-21) 14. at 6.55-7.00	2.610	23	2.16	99	93	78	0	93	7	ML	0.273	3.65	3.16	0.50	8.0	12	15	6.0 t/m^2
	15. at 12.05 – 12.50	2.630	24	1.99	100	97	94	-	-	-	CI	0.228	7.73	1.23	0.57	6.5	17	30	
	Borehole (H-24) 16. at 4.25-4.60	2.630	40	1.90	100	90	63	1	97	2	CI	0.239	11.4	1.30	0.53	5.7	19	17	9.5 t/m^2
	17. at 7.20 – 7.50	2.610	34	2.03	100	92	85	-	-	-	CI	0.174	6.85	1.85	0.40	0.0	17	20	
	Borehole (H-26) 18. at 1.85-2.30	2.600	28	1.92	87	68	57	27	65	8	CL	0.261	12.4	1.25	0.18	7.5	1	1	
	19. at 5.15 – 5.60	2.550	20	1.88	100	87	58	-	-	-	ML	-	-	-	0.05	15.0	6	7	4.0 t/m^2
	20. at 7.55 - 8.00	2.570	19	1.89	100	82	44	-	-	-	SM	-	-	-	0.00	21.3	11	13	
	21. at 11.85-12.30	2.590	37	1.85	100	100	91	6	93	1	CI	0.282	9.89	1.75	0.11	12.3	19	25	
	Borehole (H-29) 22. at 1.90-2.35	2.620	33	1.94	100	98	86	22	78	0	CL	0.218	5.42	2.62	0.25	6.0	10	7	4.0 t/m^2
	23. at 4.20 – 4.50	2.560	24	2.00	100	98	28	-	-	-	SM	-	-	-	0.00	26.4	9	13	

Table 2. Represents field and laboratory CBR - value with Proctor's densities

Location of tests (As per Fig.1)	Type of sub soil	Laboratory Test Results				Field CBR-values at depth (in m)
		OMC in %	MDD in gm/cc	CBR-Values		
				4-days soaked	Un-soaked	
1. CBR-1	CI	17	1.65	6	8	1.24 at 0.25
2. CBR-2	CI	15	1.62	7	8	1.29 at 0.30
3. CBR-3	CI	17	1.53	5	8	1.29 at 0.20
4. CBR-4	MI	17	1.66	3	8	1.48 at 0.25

Chemical Tests: Results of chemical test of soil and water samples are another aspect of the investigation. Value varies extensively w.r.t their locations. The reasons for such variation may be the DRMP site is closed to existing refinery which runs for about 80 – 90 years before investigations. Table 3 and Table 4 give such values respectively.

Table 3. Result of the Chemical analysis of Soil samples of DRMP site

Constituent determined (in percentage (%) basis)	Location of soil sample marked as				
	B-5 at 10.7m	B-8 at 14.7m	B-8 at 21.6m	H-18 at 4.65m	H-22 at 10.7m
1. Moisture content	1.15	2.10	3.50	3.01	4.43
2. Loss of Ignition	3.10	4.30	5.10	5.10	6.25
3. Organic matters	8.10	4.10	2.35	0.20	0.51
4. Crude oil & Wax	2.80	1.50	0.50	0.07	0.02
5. Water soluble salt	0.20	0.21	0.35	0.20	0.32
6. Silica as SiO_2	58.50	67.10	65.50	66.30	60.72
7. Total Iron as Fe_2O_3	3.85	5.50	4.50	12.50	6.30
8. Aluminium as Al_2O_3	16.10	11.50	13.50	11.65	18.10
9. Calcium as CaO	0.50	0.35	0.65	0.50	1.32
10. Magnesium as MgO	0.75	0.41	0.90	0.20	0.90

Table 4. Result of the Chemical analysis of water samples of DRMP site

Constituent determined	Location of water sample in				
	BH-2	BH-3	BH-6	B-1	B-9
1. pH values	7.72	7.63	8.51	9.93	8.30
2. Turbidity on silica scale as SiO_2 (in ppm)	8.00	560.0	3.20	8.50	6.10
3. Total solid (in ppm)	84.00	7759.0	482.00	756.00	210.0
4.Phenolpthalein alkalinity as $CaCO_3$ (in ppm)	Nil	Nil	20.00	85.00	25.00
5.Methyl orange alkalinity as $CaCO_3$ (in ppm)	17.00	20.00	105.00	132.00	85.00
6. Calcium as Ca (in ppm)	6.84	5.32	55.48	48.00	21.00
7. Magnesium as (in ppm)	1.37	0.92	3.21	28.00	15.00
8. Total hardness as $CaCO_3$ (in ppm)	45.50	102.00	180.65	211.00	215.0
9. Iron content as Fe (in ppm)	2.30	42.30	4.80	2.00	1.50
10. Sulphur as SO_4 (in ppm)	50.00	Not	Not	15.50	12.00
11. Chloride (in ppm)	2.80	4.80	9.80	3.50	2.10
12. Specific electrical conductance(in Mhos)	-	-	-	856.00	124.0

Settlements for Tank foundation. In the investigation, calculation and estimation of the oil storage tanks of different sizes bears another aspect of the total efforts. In the tank location subsoil encounters are mostly soft or loose layers for which the immediate i.e. quick settlements reveals very high grade of settlements. Since all the foundations of tanks are RCC, hence, it demands minimum differential settlements. The estimated values of differential settlements for all forms of tanks are presented in tabular form in Table 5.

Table 5. Differential settlement of Circular Oil Storage Tanks in DRMP site

Description of Oil Storage Tanks				Calculated Settlement of Tank base and edge (in millimeters)						Differential settlement in term of radius of Tank
Marked as	Located by Boreholes & SCPT	Load intensity in t/m^2	Diameter of tank in (metre)	Consolidation		Immediate		Total settlement		
				at Centre	at Edge	at Centre	at Edge	at Centre	at Edge	
Tank-1	H-24 & SCPT-1	16	18 ϕ	273.1	72.1	90.94	43.98	354.04	116.08	1/36.3
Tank-2	H-25 & SCPT-2&3	16	18 ϕ	325.4	91.9	90.90	43.98	416.34	135.88	1/32.1
Tank-3	H-25 & SCPT-3&4	16	18 ϕ	524.9	148.8	225.42	89.49	750.32	238.29	1/17.6
Tank-4	H-10 & SCPT-11	16	18 ϕ	231.1	57.8	344.10	195.40	575.20	253.20	1/27.9
Tank-5	H-11 & SCPT-11	16	18 ϕ	384.1	127.0	344.10	195.40	728.20	322.40	1/22.2
Tank-6&7	H-3, B-5 & SCPT-15	13	15 ϕ	375.9	114.5	568.13	239.64	944.03	354.14	1/12.7

Table 6. List of net SBC recommended for isolated footings for some unit areas of structures within DRMP site

Serial No.	Area of Structures & Remarks on investigation	Boreholes and other tests carried out	Depth of Foot-ing at	Sizes of Square footing	Net SBC (in t/m^2) for limited settlement of		
					25 mm	40 mm	60 mm
1.	Filter water reservoir unit: Remarks: The site shows differential settlement. Subsoil near H-1 is better & denser than that near H-2. Due to presence of 2.5m thick soil layer carrying oily and undecomposed materials the SBC reduces	H-1 & H-2	1m	1m x 1m 3m x 3m 6m x 6m 10m x 10m	5.5 4.0 - -	6.0 5.0 - -	8.5 6.0 2.5 -
			2m	1m x 1m 3m x 3m 6m x 6m 10m x 10m	7.0 3.5 - -	8.5 5.0 - -	10.0 7.5 - -
2.	V.D.U and C.D.U. unit: Remarks: This unit site will be founded on a quit uneven and marshy land in present state. Despite having the area covered by SCPT-5, 6 & 7 is on the slope of a hillock. Areas near H-21, 22 and 23; and DCPT-3 & 4 are on the ridge of marshy & sludgy, the subsoil condition is quite stiffer and denser except the surface condition of DCPT-3&4. The depth of surface water was found 650 mm above NGL and the maximum thickness of very soft layer of silty soil were found 1350 mm. The area shows differential settlement.	H-21, H-22, H-23, B-2, BH-1, SCPT-5, 6 & 7 and DCPT-3&4.	1m	1m x 1m 3m x 3m 6m x 6m 10m x 10m	5.0 2.8 1.3 -	6.0 4.0 2.0 1.3	7.5 6.0 3.0 2.0
			2m	1m x 1m 3m x 3m 6m x 6m 10m x 10m	6.0 2.8 1.3 -	7.5 4.5 2.0 1.3	8.0 6.5 3.0 2.0
			3m	1m x 1m 3m x 3m 6m x 6m 10m x 10m	7.0 3.0 1.3 -	8.0 4.6 2.0 1.3	9.5 7.0 3.0 2.0

Table 7. List of bearing capacities and type of pile foundations for some unit of DRMP site.

Sl. No. and Area of structural unit along with various field tests covered	Capacities of Piles in Tonnes			
	Safe Load from shear parameters			(From SCPT point resistance) Safe load in compression
	In Compre-ssion	In Tension	In Shear	
For 6.0 m long – 400 mm dia. Under reamed Pile				
1. Filter water reservoir Unit: (H-1, H-2 & SCPT-15)	29.75	13.5	3.3	55.0
2. Fire station unit: (H-14)	28.71	13.5	3.3	-
3. F.W. Pump House unit: (BH10 & SCPT – 12)	22.70	13.5	3.3	43.0
4. Utility sub-station: (BH-11 & SCPT-14)	29.20	13.5	3.3	54.0
5. VDU & CDU Unit: (H-21, 22 & 23; and SCPT – 5, 6 & 7)	28.70	13.5	3.3	51.0
6. Pipe track area: (H-26, 27, 28 & 29; and SCPT – 7)	28.71	13.5	3.3	53.0
For 15 m long – 450 mm dia. Bored pile				
7. Compressor station: (H-12 & 13; and SCPT–10)	102.0	21.0	4.0	128.0
8. Control room complex: (H-15 and SCPT -10).	100.0	21.0	4.0	128.0
9. VDU & CDU Unit: (H-21, 22 & 23; and SCPT – 5, 6 & 7).	100.0	21.0	4.0	113.0
10. Pipe track area: (H-26, 27, 28 & 29; and SCPT – 7.	100.0	21.0	4.0	113.0

Estimation of SBC and Recommendation. On the other hand, the estimation of net SBC for shallow foundations where ever demands by the then proposed structures, were calculated unit area wise based on field and laboratory investigation data at par guidance of the relevant IS: codes of practices. For instances, Table 6 is giving such values of recommended SBC. It is evident that SBC values reveal poor to very poor magnitudes. Similarly, Table 7 gives the list of various pile capacities of different kinds of piles.

Dynamic Properties from Block Vibration Test. On the other hand, the dynamic properties of the subsoil in particular specified locations of DRMP site depicting another picture of the general geotechnical aspects as well as dynamic aspect of subsoil.

It was observed and found that the layers of silty-sand situated closer to the foundation level of a structure provides more damping effect than that of non-existence. Table 8, Table 9 and Table 10 give an account of this aspect [Bayan & Kalita, 1992].

PROBLEMS IDENTIFIED AND THEIR SOLUTIONS

Pertaining to the total geotechnical investigations carried out through 3 phases to estimate the geotechnical sounding of the then proposed DRMP site, it identified many problems which were evidencing by the field and laboratory test results reported in details in the original geotechnical investigation report for DRMP [Bayan, at el, 1990]. Of many, followings

are countable:

- Bearing capacities and settlements. The whole DRMP site bears poor to weak safe bearing capacities. Table 6 evidences some examples. For simple light structures improvement of SBC was done by soil replacement and mechanical compaction. But for heavily loaded structures like VDU, CDU, etc. piling were constructed. Table 7 gives an account of the capacities of two different pilings based on the shear parameters and SCPT results. Pile foundations were provided as suggested for almost all kinds of medium to heavy loaded structures but with a little variation. The variation is in the type of piling. Instead of bored in-situ-caste piling, power driven in-situ casting piles with steel casing were installed upto required depth. Such variation was made to take care of those areas where the site is susceptible to liquefaction due to high earthquake (Appendix). On the other hand, to reduce the differential settlements in tanks area (Table 5), soil replacement and simple mechanical compaction were adopted with normal type of tank foundation, which is differ from that kind of building foundation.

- Seismicity and dynamic liquefactions: Traces of old liquefaction were recognised by SPT in some boreholes during investigation in closer to H-19 and SCPT – 8 of DRMP site. About 2.0m free fall of SPT pipe was recorded by me on the spot during 1991, which carries evidence of existence of void (i.e. cave) created by dynamic liquefaction due to old earthquakes underneath the surface at about 8.8m depth. The evidence has closer acceptance by SPT values of H-19 and observed values of SCPT – 8. Figure 4 shows the part of the SCPT – 8 of DRMP site. Hence, evaluation of seismicity and ground acceleration of DRMP site is an important aspect which is given in Appendix in brief.

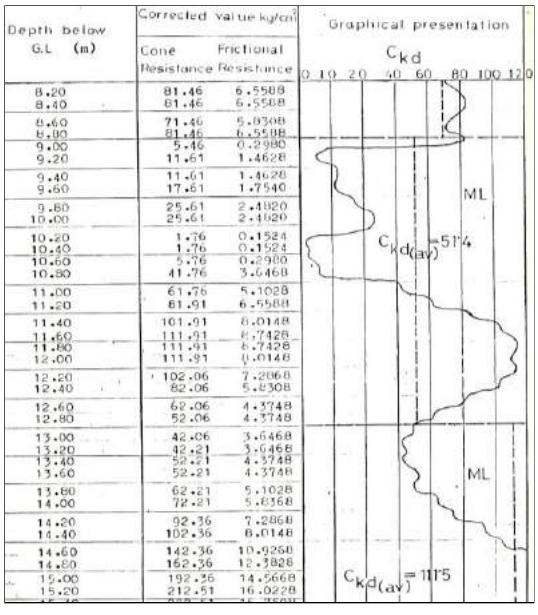

Figure 4. Static cone penetration test result for SCPT – 8 (Termination depth 15.4 m)

Table 8. Elastic properties of subsoil DRMP site from vertical Resonance Test

Eccentricity Setting 'θ' In degree	Natural frequency f_{nz} in cps	Coefficient of elastic Uniform Compression C_u in kg/cm^3	Coefficient of elastic Non-Uniform Compression C_ϕ in kg/cm^3	Damping co-efficient of soil
For Location-1 (Result from Vertical Resonance Test:				
40	39	17.960	18.094	0.636
104	39	17.960	18.094	0.705
140	39	17.960	18.094	0.760
For Location-2 (Result from Vertical Resonance Test:				
40	38	17.046	17.172	0.605
104	38	17.046	17.172	0.816
140	40	18.888	19.028	0.537

Table 9. Elastic properties of subsoil DRMP site from horizontal Resonance Test

Eccentricity Setting 'θ' in degree	Second higher Natural frequency f_{nz} in cps	Coefficient of elastic Uniform Shear C_γ in kg/cm^3	Coefficient of elastic Non-Uniform Compression C_ϕ in kg/cm^3
For Location-1 (Result from Horizontal Resonance Test:			
40	26	1.196	2.408
104	25	1.106	2.228
140	30	1.593	3.207
For Location-2 (Result from Horizontal Resonance Test:			
40	26	1.196	2.408
104	25	1.106	2.228
140	30	1.593	3.207

Table 10. Elastic properties used for Dynamic computation

Eccentric Properties (Coefficient of)	For 10 Sq.m base area only in kg/cm^3	For (6.45x3.6=) 23.22 Sq.m base area in kg/cm^3
Elastic Uniform Compression C_u in kg/cm^3	6.024	1.3988 x 10^4
Elastic Non-Uniform Compression C_ϕ in kg/cm^3	18.094	4.2014 x 10^4
Coefficient of elastic Uniform Shear C_γ in kg/cm^3	0.371	8.615 x 10^4

- Chemical test of soil and water. It is ascertained from the results of tests (Table 3 & 4) that the DRMP site bears higher pH values, which indicates more acidic action of water and soil. Hence it may cause harm to concrete as well as in reinforcing steel bars of RCC. As a solution to such chemical problem, lime was added round the

foundation trenches to neutralise the high value of acidic subsoil during development of the DRMP.

OBSERVATIONS

During and after the construction of various substructures of DRMP units, followings have been observed:

- During leveling uneven ground of the then proposed DRMP by cutting down the hillocks (Fig. 3.b), all kinds of marshy land, soil layers with decomposed, undecomposed vegetation and oily substances have been removed and filled up with good soil reveals from the uphill ground.
- All forms of pile foundations are power driven in-situ-caste pile with steel casing with recommended values.
- Foundation trenches were well treated by lime.
- No great earthquake has rocked the DRMP site during and after development of DRMP till date with estimated magnitude of 7.5 M Richter or more. Hence, foundation tilting or subsidences is not found reveal till date.
- It is expected that all the foundation of each unit of present DRMP (Fig. 2) will behave well with expected high earthquake of magnitude closer to M 8.6 Richter (Appendix).
- Tank foundations are behaving uniformly revealing no differential settlement till date.

CONCLUSIONS

With the results of very high grade and meticulous geotechnical investigations the then proposed DRMP site was developed with modern techniques. Hence, the present study may reveal the following conclusions:

1. It was a challenging job for geotechnical as well as design engineers to develop DRMP in such a site having subsoil comprises hillocks of laterite soil, plain ground dumping with 100 years fully run refinery wastage materials including decomposed and un-decomposed vegetations, fully marshy land of organic matters bearing surface water of 1.5m to 2.0 m depth. Hence, 3phase geotechnical investigations were made to identify the weaknesses..
2. It was also a special challenging job for civil engineers to develop DRMP in a site having fully susceptible to liquefaction with existing voids and caves underneath the subsoil created by old earthquakes, that situated in a very high seismic zone (Zone V of IS:code of practices) with component of horizontal ground acceleration is 0.10g.
3. All constructions of substructures were built as per suggestion of remedial measures with modern tools and technology. Hence, it is expected that there will not occur any breach of foundation in future.

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Bayan G. Kakati, Borthakur B C, Nambiar MKC, Barua P, Biswas A, and Kalita U C, [1990], "Geotechnical Investigations for Digboi Refinery Modernisation Project", Technical report No. An/112/C/1989, Applied civil engineering division, Regional Research Laboratory (CSIR), Jorhat; Assam; India; pp 1-392.

Bayan G. Kakati and Kalita U.C. [1992]: Detail analysis and design of foundation for vibratory machine in weak soil of Assam. *Proc. Indian Geotechnical Conference (IGC-'92),* December, Calcutta, Jadavpur University, pp 214-218.

APPENDIX

Geology and Seismicity Around Digboi Refinery

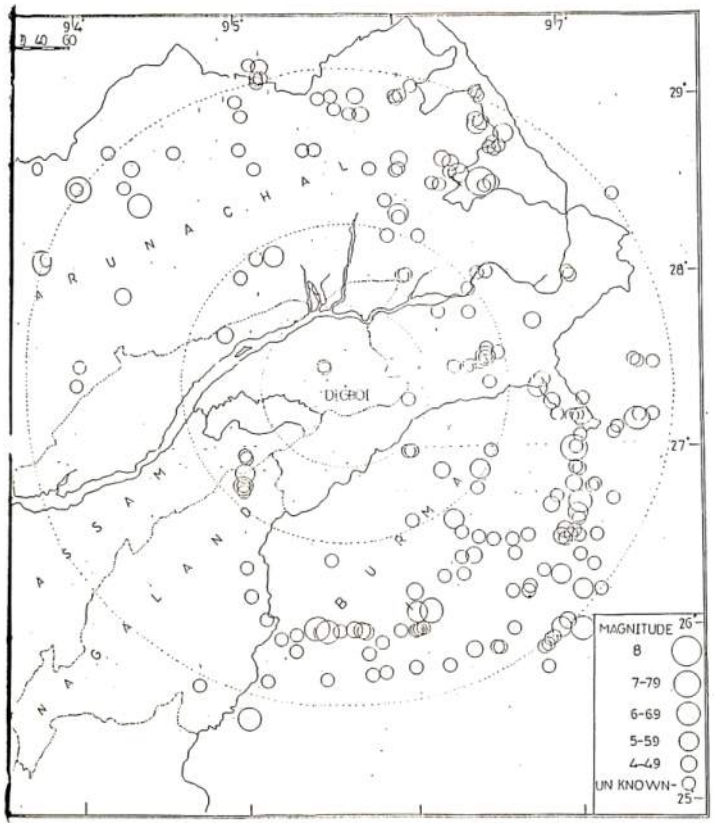

Figure A-1. Seismic Activity Map of the Digboi Oil Field (Earthquakes considered during a period of 1906 to 1986)

Seismic Activity. North eastern region (NER) of India is

seismically very active and was the seat of several large earthquakes in the past. The most important are being the 1897 (M 8.9 R), 1950 (M 8.6 R) and 1988 (M 7.2 R) earthquakes. The proposed site also falls within the seismically active zone of NER of India. To examine the nature of seismic activity a list of earthquakes occurring within a radious of 200 km from the DRMP site during a period of 1906 to 1986, were prepared and presented accordingly. Figure A-1 represents the whole seismic activity within this period i.e. upto 1986 data.

Considering the possible limitation of the accuracy and completeness of records in the past of the country the list seem to reflect the general behaviour of seismic activity. The data set for the last 24 years (1963-86) is more or less complete and was subjected to least square fitting, following the formula [Gutenberg & Richter, 1963-86] as below:

$$LogN = a - bM \quad \cdots \quad Eq.A-1$$

where, N is the number of earthquake, M is the magnitude and 'a' and 'b' are constants. After replacing the values of constants the formula becomes

$$LogN = 6.703 - 1.003\, m_b \quad \cdots \quad Eq.A-1.a$$

By using the above relationship, the return period for earthquake mb = 5.0, 5.5, …, and 7.0 were calculated and are given in tabular form in Table A-1.

Table A-1. Estimated return period of different earthquake in and around DRMP

Magnitude	Return period in years
5.0	0.5
5.5	1.5
6.0	5.0
6.5	16
7.0	50

Geology of DRMP site. Digboi is situated on low hills forming the northern end of the Tipam range, one of the foot hill range of the Naga hills. The geological structure of Digboi is characterized by sharp anticline south of the Naga thrust. The crest of the anticline runs in WSW-ENE direction and both the flanks having a dip of about 90^0 and the southern flank shows variable dip upto the maximum of 60^0 (Fig A-2). In the eastern sector the dip varies 30^0 – 40^0 (Fig A-2). The hade of Naga thrust is 40^0 – 45^0 from the vertical. The Naga thrust is not seen at the surface being concealed by alluvium. Figure A-3 showing the cross section along the crest of Naga thrust.

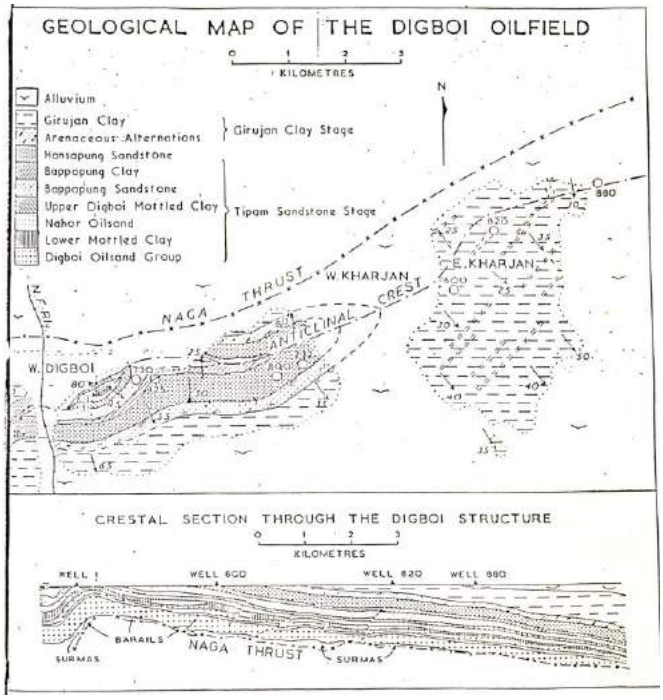

Fig. A-2. Geological Map of the Digboi Oil Field [After Mathur and Evans, 1964]

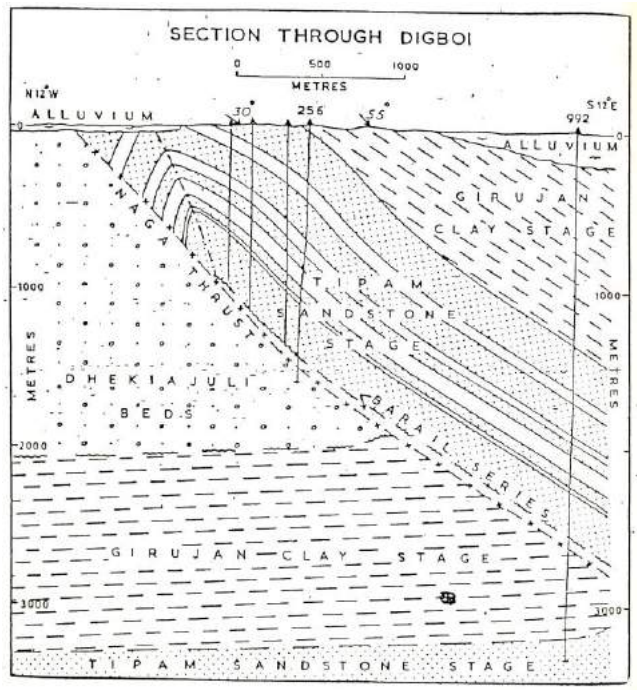

Fig. A-3. Sectional Map of the Digboi Oil Field through Digboi Anticline [After Mathur and Evans, 1964]

Estimation of Ground acceleration for DRMP

In engineering design and construction seismic zone requires consideration of resisting the maximum stress developed due

to earthquake acceleration. Assessment can be made for different earthquakes which may affect the site and results used as guide for structural design criteria. Owing to the total absence of any instrumental data on ground acceleration for this region having DRMP site empirical formula connecting ground acceleration, distance of source and magnitude of earthquakes are used. For the proposed DRMP site it was computed the 'a' for :

(1) An earthquake of magnitude M 8.6 R occurring about 140 km away and

(2) An earthquake of magnitude M 7.05 R occurring along fault 80 km away from the proposed site. For calculation the magnitude is taken as M 7.5 R.

Acceleration 'a' is calculated by taking the well known Assam earthquake of 15th August 1950 (M 8.6 R) and 26th August 1950 (M 7.05 R) as references, which were occurred at an epicentral distance (D) of 140 km and 80 km from the proposed DRMP site respectively. Hypocentral depth below surface for both is taken as 25 km. Thus calculation of 'a' with respect to these earthquakes using different empirical relationships is given in tabular form in Table A-2.

(a) According to the formula proposed by Cornell the ground acceleration 'a' at the site may be expressed by

$$Log_{10}a = \frac{I}{3} - 0.5 \quad \cdots \quad Eq.A-2$$

Where $I = 2.16 + 1.45M - 2.45\log D \quad \cdots \quad Eq.A-2.a$, here M=8.6 and 7.5, D=140 km and 80 Km

The estimated acceleration according to the equation Eq. A-2 is 0.4g and 0.19g respectively (Table A-2).

Similarly, following the above data the estimated acceleration according other well known different formulae were found out and tabulated in tabular form which are given in Table A-2.

RECOMMENDATION FOR SEISMIC ACTIVITY

From the geo-seismic analysis of foregoing consideration the following recommendations and observations may be made:

- The most important geological structural features are the Naga thrust which passes north of the Digboi area. Though no earthquakes of large magnitude occurred in the vicinity of the proposed site along the Naga thrust, earthquakes of high magnitude occurred in other regions of the same thrust during the last thirty years. For instance, M 7 Richter earthquake of 26th August 1950 (26.8^0 N, 95.0^0E) may be mentioned.

- Very few earthquakes of magnitude above M 5 Richter originated from the epicentral distance of 100 km from the DRMP site.

- The available historical records of major earthquakes in the vicinity of the region is that of the 1950 Assam earthquake (M 8.6 R) which originated 140 km to the north-east of the then proposed DRMP site. According to the isoseimal map on the MM scale, the DRMP site appears to fall within isoseismal of VIII – IX.

- The ground acceleration 'a' computed for the two reference earthquakes of M 7.5 R and M 8.6 R are 0.12g and 0.09g. The average value of 0.10g corresponds well with the soil type III obtained for the DRMP site.

Table A-2. Estimated values of ground acceleration for the structures of the then proposed DRMP as per various formulae

According to the formula proposed	Acceleration at DRMP site	
	for M=8.6	For M=7.5
by Cornell: $Log_{10}a = \frac{I}{3} - 0.5 \quad \cdots \quad Eq.\ A-2.$ Where $I = 2.16 + 1.45M - 2.45\log D$	0.4g	0.19g
by Kanai : $a = \frac{10B}{T_P} \quad \cdots \quad Eq.\ A-3$ Where $T_P = 0.25\ Sec$ and $B = 0.61M - \left(1.66 + \frac{3.6}{D}\right)\log D + \left(0.167 - \frac{1.83}{D}\right) \cdots Eq.\ A-4$	0.06 g	0.10g
by Esteva and Rosenblueth: $a = \frac{110e^{0.8M}}{D^{1.6}} \cdots Eq.\ A-5$	0.04 g	0.04g
by Gutenberg, Richter and Benioff: $a = a_0 F_D \cdots Eq.\ A-6$, where $\log a_0 = -2.1 + 0.81M - 0.027M^2 \cdots Eq.\ A6.a$ $F_D = 1.25 \Big/ \left(1 + \frac{D}{Y_0}\right)^n$ and by considering $Y_0 = 77\ Km$ *and* $T_P = 0.25\ Sec$, $n = \left(1 + 1 \Big/ 2.5T_P\right) = 2.6\ Sec$	0.06 g	0.06g
By using the Curves for ground acceleration and distance relationship developed by Seed et al.	0.07 g	0.08g
Average acceleration for use:	0.12 g	0.09g

DOCUMENT- 7

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Digboi Batori

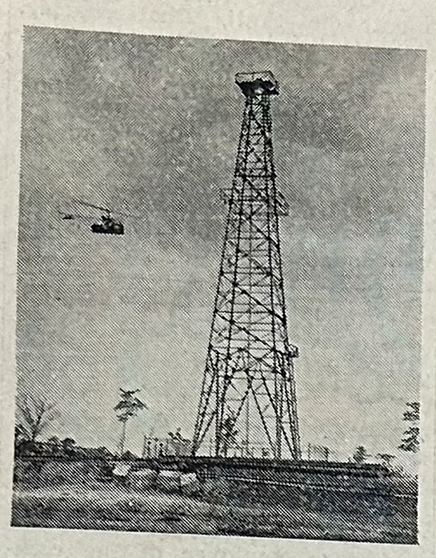
House Journal of the Assam Oil Company

VOL. III | DIGBOI, FEBRUARY 1956. | No. 2

We Drill INDIA'S DEEPEST WELL

See Story on Page 7

Nahorkatiya Well No. 1.



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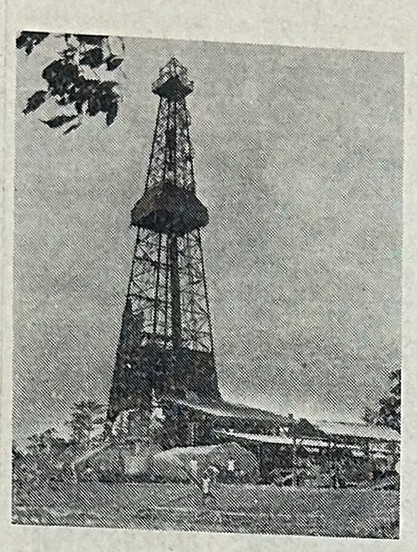

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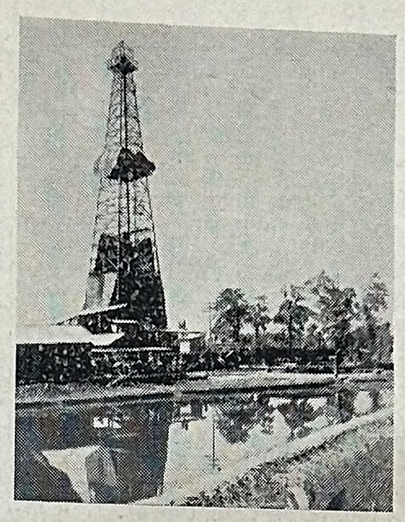
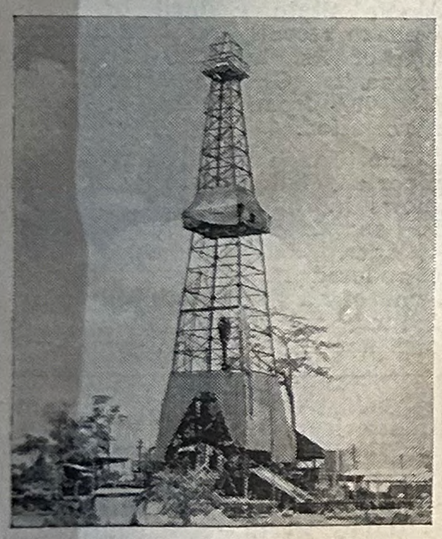
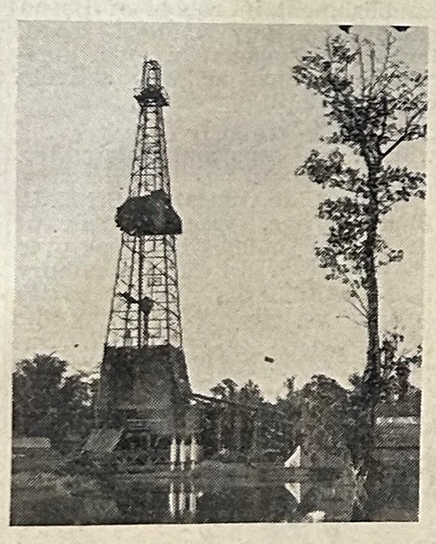


Nahorkatiya Well No. 4.

OIL COUNTRY!



Nahorkatiya Well No. 5 (No oil).



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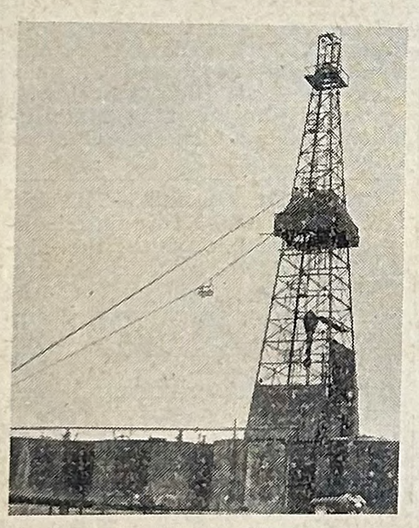

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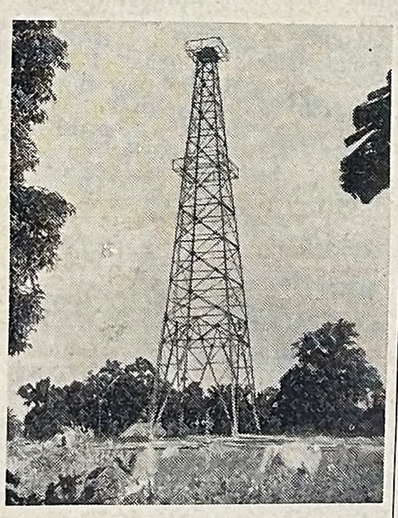
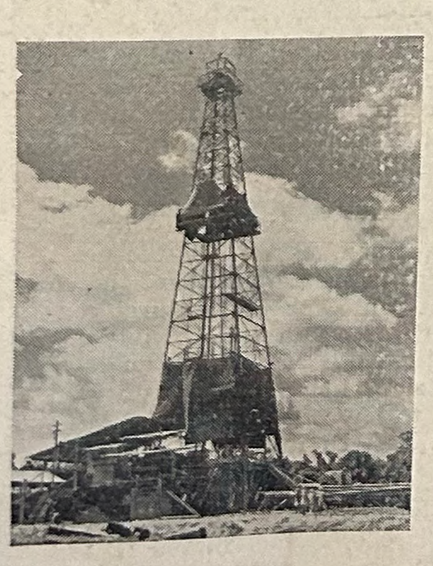
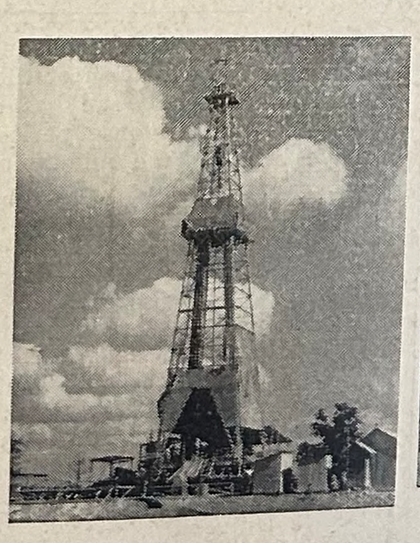


Nahorkatiya Well No. 8.

Nahorkatiya Well No. 9 (No oil).



Nahorkatiya Well No. 10 (No oil).



Nahorkatiya Well No. 11.

Well No. 12 (Naoholia). (Still drilling)

AND STILL THE WELLS GO DOWN.

ON TO No. 18

Drilling Starts At Well No. 14 This Month

THE PICTURES on this page show the derricks of 12 Assam Oil Company wells in the Nahorkatiya area of Upper Assam. Eight of these wells were successful in finding oil, three turned out to be failures, and one (Well No. 12, at Naoholia) is still drilling as we go to press.

Another well, Nahorkatiya No. 13 (not pictured here) was "spudded in" on 12th January and is now drilling ahead at a depth of more than 3,500 feet.

Well No. 14 is due to begin drilling about the middle of this month (February). March will see the start of the first test well in the Moran area, for which a remodelled and more powerful drilling outfit is now being prepared in Digboi.

No. 11 Is A Winner

The most recent success is Nahorkatiya Well No. 11, which struck oil in sandstone rocks at a depth of nearly 10,000 feet in mid-January. This well, started on 26th November, was completed on 2nd January at a total depth of 10,360 feet. For its depth it is the fastest well ever drilled in India.

Four more sites in Upper Assam have been chosen for drilling. Number 15 will be an exploratory well at Tengakhat —the second (after No. 12) in the Hugrijan prospecting licence area—and Nos. 16, 17 and 18 will be development extension wells in the neighbourhood of Nahorkatiya.

Digboi's Yield Up

The main Digboi oilfield, where drilling continues steadily but on a smaller scale than elsewhere, is giving a higher production of crude oil than ever before (except for a brief spell during the last war). Total crude oil output in Assam at the present time (Digboi and Nahorkatiya combined): approximately 280,000 gallons a day. A further rise in production is expected.

("One Million Tons A Year"— see page 3)

REPUBLIC DAY SCENES IN DIGBOI

Tinsukia, Nahorkatiya and Other Operational Areas Salute Flag On Big Day

THE SIXTH ANNIVERSARY of the Indian Republic was celebrated with great enthusiasm in January, and there was hardly anyone in the oiltown who did not take part, in one way or another, in the day-long rejoicings.

Celebrations took place also at the AOC Tinsukia Installation, the Nahorkatiya, Naoholia and Moran prospecting areas, and elsewhere.

Digboi's celebrations began with a Republic Day dinner at Digboi Sports Club on 25th January.

Early next morning a procession began by the local Congress Committee and this marked the opening of the town's official Republic Day programme.

Mr. A. W. Scott, Acting General Manager of the Assam Oil Company, hoisted the national flag at Digboi Sports Club while club members sang the national anthem. After the flag-hoisting ceremony was over children were presented with sweets—a customary feature of the celebrations.

Digboi Indian Club

A similar ceremony was held at Digboi Indian Club where Sri K. B. Bhattacharjee hoisted the national flag. Distribution of sweets to children followed.

At the Gandhi Maidan Sri D. C. Deb Sarma, President of the Digboi Kendriya Congress Committee, hoisted the national flag in tune with the national anthem, and the Digboi Urban Company of the Territorial Army accompanied by boy scouts and girl-guides of the town and the Vivekananda Vidyalaya band marched past. The meeting, which followed, was addressed by Swami Asokananda of the Bharat Sevasram Samaj.

An exhibition of children's drawings, paintings and handicrafts, organised by the Digboi district branch of the Indian Council of Child Welfare, was opened by Mrs. A. W. Scott at the Indian Club. The exhibition remained open until 29th January and attracted a large number of people.

Test Matches

After the early morning honours to the national flag various programmes began in different parts of the town. At the refinery ground an "International" cricket test, India versus the U.K., was played in the presence of a large number of spectators. Results: U.K. won by 25 runs.

About 300 members and guests of the Digboi Indian Club attended the Republic Day luncheon in the club hall. An exhibition badminton match followed.

Another interesting event in the Republic Day programme was the "International tennis match" played at the Sports Club. Results: India won by three matches to two.

At the Jubilee Ground an exhibition hockey match was played between a Punjabi XI and the Jogapani T. E. XI.

The Kendriya Congress Committee opened a Harijan teaching class in Digboi on 16th January.

Illumination of the Gandhi Samadhi and singing of "Ramdhun" at dusk attracted many people to this open air meeting place in Digboi. A variety show held at the Digboi Indian Club, which was also specially illuminated for the occasion, was another evening entertainment.

Flag-hoisting ceremonies and meetings were held also at the Digboi Muslim Institute, Ramkrishna Sevasram, Digboi Boudha Bihar, Sikha Prachar Samity, AOC Geological Department's Bungalow No. 15 and many other places in the town.

At Tinsukia

The Republic Day was celebrated at the AOC Installation, Tinsukia, with an elaborate programme. In the morning the flag was hoisted at the AOC employees club premises by Sri S. B. Biswas, the vice-president of the club. The national anthem was sung by local girls under the leadership by Smti. N. L. Nath. Sweets were distributed to children after a public meeting held at the club.

Moran

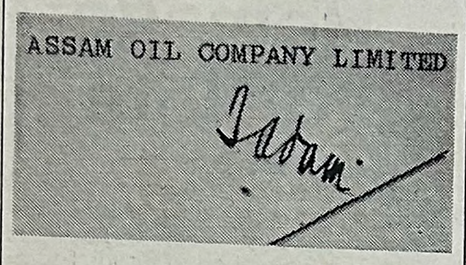
Volley ball and badminton competitions were the main events of the afternoon programme here, and in the evening the club was elaborately illuminated.

Assam Oil Company employees at Moran celebrated the day by decorating the camp and hoisting the national flag in the morning. After this there were games, wrestling and other displays of physical fitness. Badminton and volley ball matches were played in the afternoon and attracted crowds of spectators from the neighbouring villages. Songs from Indian films, amplified by a loud speaker, entertained the inhabitants of the camp during the day.

STUDYING PROGRESS.—Dr. H. M. E. Schurmann, international oil expert and Geological Adviser to the Burmah group of oil companies, paid a visit to Digboi in the middle of January to have discussions with AOC technical staff on recent developments in the continuing search for more oil in alluvial areas of the Assam Valley. He toured the Nahorkatiya area and reported later that he was highly impressed with the progress that had been achieved in this area since his last visit two years ago. In our picture he is seen with Mr. A. B. Das Gupta, AOC Geologist, Digboi.

MR. T. ADAM RETIRES

A man whose signature on letters has speeded more oil industry supplies on their way to the East than anyone now on the



company's staff retired at the end of 1955 after 43 years' service. He is Mr. T. Adam, head of the London office's Stores Department.

Mr. Adam

Mr. Adam began his career with the company in Glasgow and came down with the office when it moved to London in 1919. At that time the company had premises in Throgmorton Avenue and Great Winchester Street, the move to Britannic House—its present home—taking place in 1925.

Mr. Adam headed the Stores Department when Mr. A. C. Baird retired in 1950.

Man versus Pests.—Mr. K. M. Ryves Hopkins, from the Shell Petroleum Company, is in Digboi to arrange the marketing in Assam and elsewhere of the Shell range of chemicals (aldrin, dieldrin, endrin, etc.) used for the control of pests and diseases in tea cultivation and agriculture. The chemicals will be distributed throughout the State by The Burmah Oil Company (India Trading) Ltd., Digboi, and its Agents.

THE FACTS ABOUT THE TARGET OF—

"A MILLION TONS OF OIL A YEAR"

The Task Ahead In Assam

HOPES FOR PARTNERSHIP OF GOVERNMENT & A.O.C.

LAST MONTH, as the nation prepared to celebrate the sixth anniversary of Republic Day, eminent scientists at the meetings of three different scientific institutions were reviewing recent developments in, and the future promise of mineral prospecting in India. Tributes were paid to the devoted enthusiasm of men engaged in geological work, and some speakers, referring directly to the petroleum industry, expressed the hope that Assam would soon supply a large part of India's oil requirements.

A figure of one million tons of Assam crude oil a year was mentioned as the "immediate target" for the prospectors to aim at, but it was emphasized that this target was not yet in sight.

ONLY A BEGINNING

The truth about the million tons target is that until a sufficient number of exploratory wells have been drilled—and this may mean many more than the eight successes and three failures already completed—no-one can give any figure for the potential production of oil from the Assam Valley alluvial area.

One million tons of oil a year would meet more than a quarter of India's total requirements of petroleum products and to produce that amount many wells will ultimately be required. The output of the Digboi oilfield, plus that of Nahorkatiya, is expected to total approximately 4,00,000 tons in 1956 (thus setting a new record for the indigenous petroleum industry) and this is the present limit of the company's refining and transportation facilities.

To warrant special measures being taken to improve these facilities substantial reserves must be proved and increases in the means to produce them are necessary. These are among the factors which are being studied preparatory to forming the new rupee oil company.

In this transition stage, while the additional wells needed to produce the extra throughput are being drilled, some of them will have to remain shut in.

Measuring Reserves

Meanwhile, the exploration effort is directed to proving, or measuring, the possible reserves of oil in Assam available for the future.

The task here is to drill exploratory wells to extend the area already known to be oil-bearing. Mr. P. Evans, Geological Adviser to the Burmah group of oil companies, described the operations in these terms when addressing the Geology Section of the Indian Science Congress at Agra last month.—

"The oil reserves so far proved at Nahorkatiya are useful but there is nothing to suggest reserves comparable with Persia, Iraq or Arabia, and much to indicate the contrary.....The search must be continued by drilling on a number of structural highs in various parts of the Upper Assam Valley, and in this work the Assam Oil Company geologists hope to be in partnership with the geologists of the Government of India.

"A beginning has been made; that is all. An area (of a few square miles) has been proved to be oil-bearing and a rather greater area can be regarded as probably oil-bearing. We may expect that some of our exploratory wells designed to find the extent of the proved area, by coming in as successful producers, will increase the known oil.

"A few such successful out-step wells (or wells on structures away from Nahorkatiya) would bring us within sight of what might be taken as our immediate goal; a potential of a million tons a year. This is not possible from what we have already proved, and it is a matter of the utmost urgency to press forward to this first goal, and then to some greater target figure. We have a long drilling campaign ahead and must be prepared for more disappointments in our search for further successes. . . . ."

Concluding his address to the Geology Section of the Congress Mr. Evans referred to the excellent work of the Assam Oil Company's geologists and geophysicists, some of whom, he said, were well known to members of his audience. "Recruited from all parts of India —north, south, centre, east and west— they have brought a varying training and experience to Assam, where they have developed with the years into a team who have deserved success and have now achieved it. I am sure that we all wish them still greater successes in their continued efforts to find the oil reserves the country needs."

Mr. Evans

We would like to add our tribute to all the drillers, engineers, production men, and other technicians who have so notably contributed to the achievements at Nahorkatiya.

Table Tennis Champions.—The following are the results of the open 1955 Table Tennis Championships played at the Digboi Sports Club recently: Singles: Winner, M. G. Menon (Sports Club); runner-up, N. Chakraborty (Indian Club). Doubles: Winners, N. Chakraborty and Biswas (Indian Club); runners-up, M. G. Menon and K. B. Kanuga (Sports Club).

MORAN

GETTING READY FOR THE FIRST TEST WELL

MORAN PROBLEMS.—Top. Mr. W. Buchanan (right) Driller-in-Charge at the Moran well which is to start drilling this month, sorts out a snag with the help of Sardar Karan Singh, Rig-building Supervisor (centre) and Mr. S. Walker, Engineer-in-Charge. Centre. The AOC bridge across the Derai river, near the Moran camp. Lower picture shows the housing area built for the test.

Visitors were Mr. Maclachlan, who is taking over from Mr. Gowan at Delhi, and Mrs. Maclachlan. The new Delhi Representative of the Company met a number of Assam officials and was also granted an interview by the Governor. The next day the Maclachlans attended a cocktail party given by the Shillong Representative at his residence.

Sri B. N. Barua came here recently from Digboi on duty.

* * *

The Company has recently acquired a "desirable property" here. "Rikynti," one of the nicer bungalows in Shillong, is now the residence of the Shillong Representative.

* * *

The weather is now dry and sunny in Shillong. In a flash the winter seems to have gone. The next month will not be as pleasant as February was. The March wind is imminent and rains may follow.

* * *

Our Shillong Representative's broadcast on "oil prospecting," transmitted from the Shillong studio of All India Radio, Gauhati, on 9th February, obtained considerable mention in the Shillong and Calcutta newspapers.

NEW PHASE IN ASSAM VALLEY OIL SEARCH

THIS MONTH sees the start of a new and important test of petroleum possibilities in the Assam Valley. At Moran, a deep test well, or "wildcat," is to be drilled, beginning about 22nd March, and the distance of its location from the current area of operations at Nahorkatiya and Naoholia marks the opening of a fresh phase in the Assam Oil Company's prospecting operations.

Moran No. 1 Well, in the more recently-granted of the two new AOC prospecting licence areas, is designed to prove the presence—or absence—of oil in underground rocks further down the alluvium-covered valley than anyone has explored by the drill. Although the location for the well is based on geophysical reasoning (following extensive seismic survey carried out in recent years in this and other areas) it remains for the drill to provide the absolute answer.

In view of the importance attaching to this "outside test" the company hopes that the drilling operations will be given a ceremonial start by a distinguished visitor.

Meanwhile final preparations for the test are being made. Roads and bridges, newly-built to take truckloads of heavy equipment to the site from Digboi, are ready. Drillers, drilling crews, engineers and other staff are already at the site, living in a newly-constructed housing area near the well. Water and electricity have been laid on and communications between the camp and Digboi established.

The well may be taken to a depth of 12,000 feet or more in a full test of oil possibilities, and the drilling outfit in use was recently remodelled in Digboi to provide power and pump capacities for drilling to depths of about 15,000 feet.

NEWS FROM TINSUKIA INSTALLATION

Sri P. C. Choudhury, posted as Junior Works Assistant in the AOC Installation, Tinsukia, on 27th June, 1955, was confirmed in the post last month.

Sri P. R. Deb was transferred to Tinsukia on 13th February to take over from Mr. H. Bailey, Installation Engineer, who is proceeding on leave this month.

The apprentices of the AOC Installation, Tinsukia, and the students of the AOC Primary School, Tinsukia, celebrated the Saraswati puja on 16th February with great enthusiasm.

Happy Event.—A daughter was born to the wife of Sri A. K. Roy, a clerk of the AOC Labour Bureau, on 29th January.

MR. LAURIE RETIRES

Mr. K. S. Laurie, Senior Assistant General of the AOC, retired last month after 25 years' service in the East.

Mr. Laurie joined Burmah Oil in 1930 and was posted initially to Rangoon. After a few weeks he was transferred to Digboi. He remained there until early 1932, following which he served again in Burma and also in Chittagong. In 1946 he returned to Rangoon as manager of The Burmah Oil Company (Burma Trading) Ltd., and two years later was in Chittagong at the head of the BOC's Pakistan Trading organisation. Thereafter he served in Karachi, later returning to Rangoon for a time, and came back to Digboi in 1953. For the first few months he was Senior Assistant Special and then became S.A.G.

Mr. K. S. Laurie

In 1949 Mr. Laurie was elected President of the Chittagong Chamber of Commerce. For his work in this field and other services to the commercial community he was awarded the O.B.E. in 1950.

NEW CLUB FOR BOC CALCUTTA

Calcutta office staff have recently formed a club, known as the BOC Recreation Club. Sri S. H. Uttam Singh, Agent of the Company is the ex-officio president, and the following members have been elected as office-bearers for 1956-57. Secretary, Sri B. S. Chakraborty. Assistant Secretary, Sri A. K. Mukherjee. Treasurer, Sri B. K. Das. Committee members, Sri V. P. Mukundan, Sri J. C. Paul, Sri H. K. Mitra, Sri D. J. Currie and Sri M. C. Chakraborty.

The club has begun its activities with indoor games and a library section.

* * *

Sri B. N. Kushary was promoted to Acoounts Assistant in the Calcutta office on 1st January. Sri Kushary joined the company in 1939 at Chittagong and was transferred to Calcutta in 1949.

ASSAM'S FAMOUS NAME

"Digboi has made the name of Assam famous to the world," said Sri Mohendra Mohan Choudhury, President of the Assam Pradesh Congress Committee, in a speech at Digboi on 1st February.

The occasion was the laying of the foundation stone of a new building for the Digboi Congress Bhaban, which will go up on a site close to the Jubilee Ground and the AOC Welfare Office.

After laying the stone, Sri M. M. Choudhury addressed a public meeting, appealing in his speech for public support in strengthening the Congress organisation and raising the standard of living of the people. Referring to the oil industry which had spread the fame of the State far and wide, he observed that there was every possibility of finding more oil in Assam and that already there was talk about opening a second refinery. He hoped that the new refinery would go up in the State

(Continued in next col.)

WORLD'S DEEPEST WELL

THE drilling of the world's deepest well (22,559 feet, or nearly 4¼ miles, in mid-December) is estimated to cost between one-and-a-quarter and two million U.S. dollars (Rs. 83½ to 95½ lakhs).

The record-breaking well, which has penetrated the earth to depths never before explored, is in Louisiana U.S.A., and the drilling equipment and boilers were mounted on two huge barges sunk to the bottom of marshes to provide a firm foundation for the operations.

An advertisement in the Oil and Gas Journal gives these further interesting facts about the well (all information as of 28th November, 1955).—

Drilling began on 26th February 1955....Total drilling time (to 22,209 feet), 205 days ...Total testing time, 71 days ...Total elapsed time, 276 days .....Bottom hole pressure, 20,650 lbs. per sq. inch...Temperature at the bottom of the hole, 350°F...Time required to pull the entire string of drill pipe to the surface, replace the drilling bit and reset the pipe in the hole, about 11 hours...The drill pipe stretches about 20 feet at extreme depth.

The Oil and Gas Journal reported in its issue of 19th December that the underground pressures at the bottom of the well were the greatest ever measured in any oil-drilling operation. Since passing the old depth record of 21,842 feet on 9th November the drilling crews were drilling ahead smoothly at 40 ft. per day, and there were reports of oil shows at great depth.

(Continued from col. 4)

since there was no big industry here as in other States of India.

About the AOC Sri Choudhury said he was pleased to note that good relations existed between employees and management and hoped they would further improve.

Sri Choudhury was accompanied by Sm. Padma Kumari Gohain, President of the Dibrugarh District Committee, and Sri Dalbir Singh Lohar, M.L.A.

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Digboi Batori

House Journal of the Assam Oil Company

VOL. III DIGBOI, MAY 1956. No. 5

ONE-PAGE GUIDE TO OIL PROSPECTING IN ASSAM

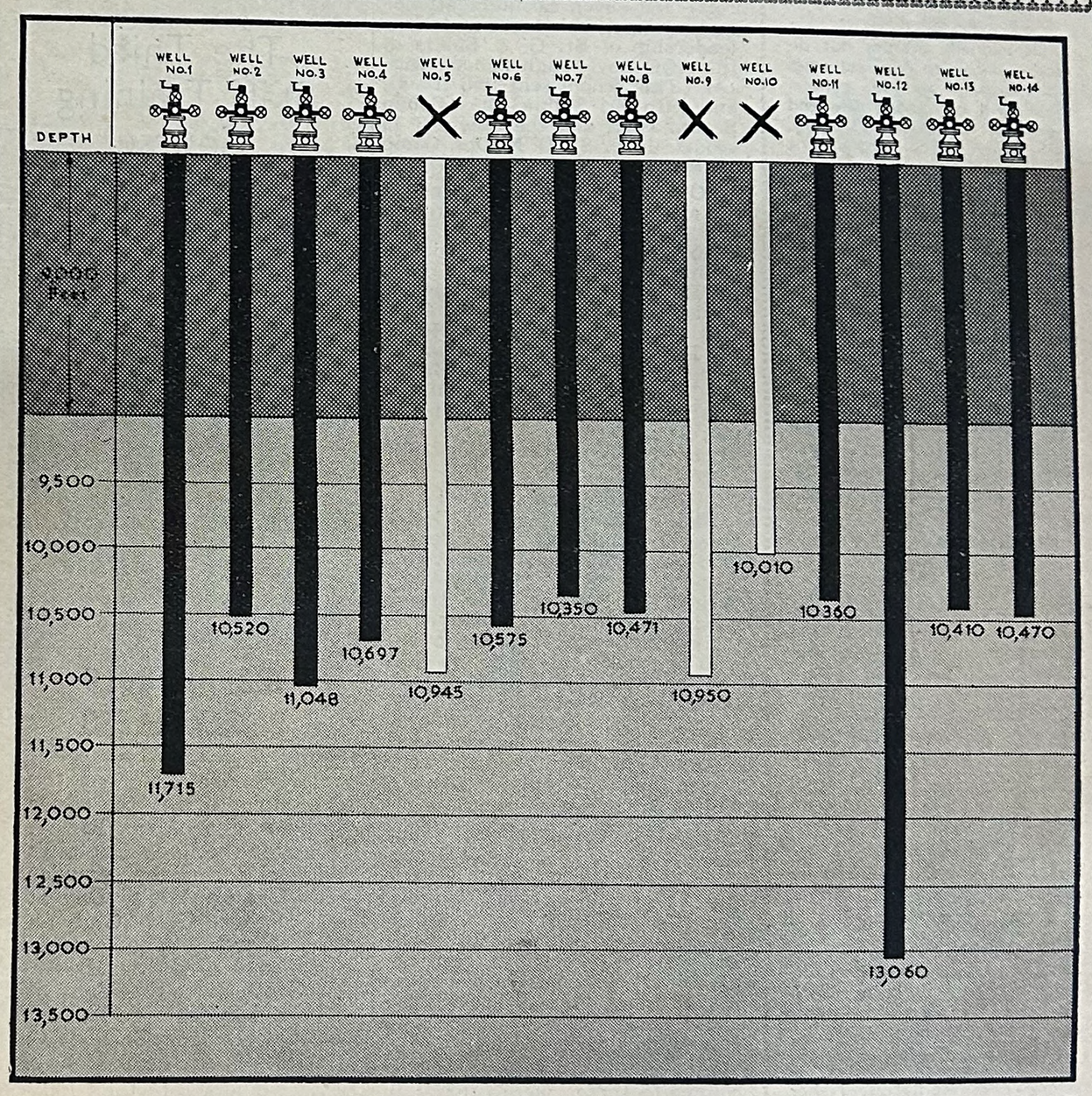
AOC DRILLING IN THE VALLEY

Do YOU Know These Facts About India's Proved Oil?

THIS CHART shows at a glance how the Assam Oil Company has searched for, and found, new sources of oil in India during the past three years. It is a record of bold endeavour in a field which concerns everyone. It is also a design for the future, for the results so far achieved are only a beginning.

Since mid-1953, fourteen wells have been completed in the alluvial areas of the Brahmaputra Valley of Upper Assam. Two more wells are drilling at the time of going to press—one in the Nahorkatiya area and another at Moran. Other wells are on the way.

Nowhere else in India can be seen such a concentration of oil industry effort. Nowhere else is there such a determined acceptance of the risks facing all petroleum explorers. See how unpredictable the chances are, even in a proved oil area. Of the 14 wells so far drilled three have been crossed off as failures. It cost a lot of money to drill those "dry holes," which were, however, located on the best of scientific reasoning.



Consider, too, the depth to which drilling must go to find out where Nature has hidden her petroleum deposits. The average depth of these 14 wells is 10,827 feet, or more than two miles. Put together these wells add up to a total depth of over 28 miles.

Soon the advances made by Assam oilmen in recent years will be matched by the efforts of explorers elsewhere in India. Already there are plans for a powerful new oil partnership with the Government of India, which has been following with close interest the progress of prospecting in the Valley.

Here are some more facts about Assam's proved oil areas.

The oil lies deep in the earth. The rocks which contain oil in the Assam Valley are buried far below the surface. No ordinary drill could reach them. The job calls for the strongest drilling machinery, the toughest tools, the finest skills.

Not every well finds oil. Some wells are bound to be failures, particularly in Assam where geological conditions underground are extremely complex. As the chart shows, there have been three failures already in the 14 wells drilled.

You can't poke a stick into the ground to find oil. The Brahmaputra Valley of Upper Assam is flat and featureless. The rocks which geologists look for when surveying for oil possibilities are all covered over by layers of alluvium (sand and silt) many thousands of feet thick. All the clues to oil are hidden.

Science shows the way. The discovery of oil in the valley is an achievement of geophysical science. No-one could foretell its presence, but the painstaking work of scientists, surveying whole areas of the valley with delicate instruments, eventually led to locations being chosen where oil might be found by drilling. Some locations were successful. Surveys are still in progress today.

First in the valley. Oil in the Brahmaputra Valley was first discovered by the No. 1 Test Well at Nahorkatiya, completed at a depth of 11,715 feet in 1953. Proof of oil there not only led to further drilling in the same area but also opened the way for widespread geophysical surveys to continue more hopefully down the valley. Moran, for example, is one area where the site for a Test Well (now drilling) was chosen on the evidence of geophysical surveys.

What about the successful wells? As each new oil well is completed, the drillers move on and the production engineers take over. Successful wells are fitted with a Christmas tree (a branching assembly of pipe and valves) to control the output of oil and gas. After production tests the wells are shut in pending further developments.

The main effort is in the valley. The Digboi oilfield continues to give good production (even in the 66th year of its life) and new wells are occasionally drilled in it to maintain a steady throughput of crude to the AOC refinery. But the major effort of drilling is down the valley in the alluvial areas.

New chapter in an old story. The AOC has been looking for more oil for a long, long time. Wherever the geological picture looked promising, wells were drilled. The Digboi field was the mainstay, but it would not last for ever. The search was carried to many different places in the State, but in 40 years of exploring and drilling no lasting, paying success was achieved. Then, when the future looked dark, a deep well was drilled at Nahorkatiya and hopes began to rise.

Where do we go from here? Drilling continues at Nahorkatiya and Naoholia to find the extent of the oil bearing rocks in each direction. This will take many more months to prove. At Moran the job is only just starting. Nobody can forecast what the result will be. Oil or no oil, only the drill will tell.

The State of a Thousand Wells. —About 1,000 wells have been drilled in Assam since the discovery of oil at Digboi in 1890. This figure includes wells in the Digboi oilfield, exploratory wells in the foothills of the Naga range, and the more recent wells drilled in the Brahmaputra Valley. Of course, not all the wells in the Digboi oilfield are producing oil today: many were exhausted years ago.

LATEST NEWS OF DRILLING

Depth of latest drilling wells in the Assam Valley at the time of going to press :

Moran Test Well: 6,697 ft.
NHK Well No. 16: 9,415 ft.

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Digboi Batori

House Journal of the Assam Oil Company

VOL. III | DIGBOI, JUNE 1956. | No. 6

AOC SCHOOL PRIZEGIVING DAYS

Full Details In Next Month's Issue

ONE MILLION TONS

NHK Oil Prospects For "At Least 20 Years to Come"

THE PROSPECT of Nahorkatiya being able to provide a million tons of oil a year for India "for at least 20 years to come" is mentioned by Sir Kenneth Harper, Chairman of The Burmah Oil Company Ltd., in his review of prospecting and oilfield development operations in India during 1955.

This estimate refers only to the area so far proved by the Assam Oil Company in its Assam Valley prospecting programme, which began in 1951 with the start of drilling operations at Nahorkatiya Well No. 1. Latest well to be completed in the valley is No. 16. The "million tons a year" figure does not include output from the Digboi oilfield.

Complicated Structure

The full text of the section of the Chairman's speech dealing with oil exploration in India is as follows: "Drilling results at Nahorkatiya have confirmed previous expectations that the structure is geologically complicated but I am pleased to say that on the whole they have been successful.

"Potential production in the area so far proved is judged to be sufficient to maintain a refinery throughput of one million tons a year for at least twenty years. Discussions are being held with the Government of India regarding the formation of a rupee company with Indian participation to take over and develop the oilfield at Nahorkatiya and certain other concessions in Assam.

"Additional refining capacity will be required. The location of this and the transportation of the crude oil are subjects which are also under discussion with the Government of India."

Elsewhere in his statement, which has been circulated with the Directors' annual report, the

(Cont'd. on page 2, col. 1)

A NEW NAME IN THE ASSAM VALLEY OIL SEARCH

TENGAKHAT

A COUNTRY BUS ON A COUNTRY ROAD IN ASSAM. IN THE DISTANCE, WHERE THE PADDY FIELDS END IN A PATCH OF JUNGLE, THE TALL DERRICK RISES CLEAR ABOVE THE TREES. THIS IS TENGAKHAT, SITE OF THE NO. 15 WELL IN THE ASSAM VALLEY WHERE DRILLING OPERATIONS WILL START IN THE MIDDLE OF THIS MONTH. ON THE RIGHT OF THIS PICTURE ARE THE OFFICES AND LIVING QUARTERS OF THE MEN WHO WILL DRILL TWO MILES INTO THE EARTH IN SEARCH OF MORE OIL FOR INDIA. AT THE TIME THIS PICTURE WAS TAKEN TWO MORE WELLS IN THE ASSAM OIL COMPANY'S PROSPECTING PROGRAMME WERE BEING DRILLED, ONE IN THE NAHORKATIYA AREA AND THE OTHER AT MORAN. AVERAGE DEPTH OF THE WELLS IS TWO MILES.

10 Pages of News and Pictures of Assam Oil

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Digboi Batori

House Journal of the Assam Oil Company

VOL. III DIGBOI, SEPTEMBER 1956. No. 9

Independence Day Pictures On Pages 4 & 5

DEEPEST IN SUB-CONTINENT

MORAN TEST WELL SETS NEW RECORD

The Moran test well in Upper Assam has broken all drilling depth records in this sub-continent, having reached a depth of 13,739 feet (more than 2½ miles), thus becoming one of the deepest wells in Asia. Arrangements are now being made for production tests and it is hoped that these will be successful.

The previous record-holder was Well No. 12 in Naoholia, Hugrijan. This well, also situated in Upper Assam, was drilled by Assam Oil Company drillers to a depth of 13,060 feet.

This first well in Moran, a tea area between Sibsagar and Lakhimpur Sub-divisions, was drilled by a very powerful diesel driven outfit recently remodelled and improved by AOC technicians.

This outfit originally had the distinction of drilling the now famous discovery well at Nahorkatiya (11,715 feet) in 1952-53.

THE MORAN TEST WELL.—Two photographs of the deepest well—the Moran No. 1. The well has reached a depth of 13,739 feet, more than 2½ miles.

AOC Presents Seismic Model To Sri Malaviya

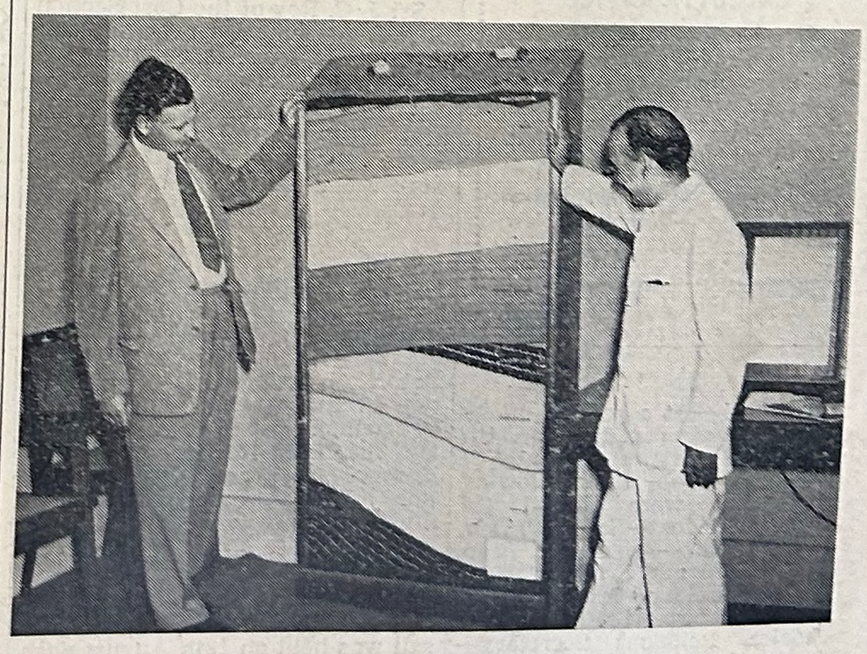
AT A CEREMONY in the room of Sri K. D. Malaviya, the Union Minister for Natural Resources, on 9th August Mr. Maclachlan presented a working model of seismic operations to the Minister on behalf of the Directors of the Assam Oil Company Limited.

The presentation was attended by the officers of the Ministry and by Sri N. K. Advani of the Assam Oil Company. In making the presentation, Mr. Maclachlan said that with the gift went the best wishes of the Directors and the Company for the success of the Government's new Oil and Gas Commission

Mr. Maclachlan explained the working of the model, which is a replica of that which was on display at the AOC stall at the Indian Industries Fair, and said that much of the evidence which had led to the finding of the Nahorkatiya oilfield had been based on results obtained from the seismic method.

In reply the Minister thanked the Directors for the gift and said that the model would join others which would explain graphically to the people of the country the intricacies of modern oil exploration.

In token of acceptance of the model the Minister pressed the button and showed how the shock waves travelled from the earth's surface to the harder strata and back again thus indicating where oil might be located.



THE PRESENTATION CEREMONY.—This model of Seismic equipment and its working was presented to Sri K. D. Malaviya (right), Union Minister for Natural Resources, by Mr. W. P. G. Maclachlan on behalf of the Board of Directors of Assam Oil Company, in New Delhi on 9th August. The model will form part of a Scientific Museum being set up by the Ministry of Natural Resources and Scientific Research. (Photograph taken by the Public Relations Officer of the Ministry).

2½ MILLION TONS OF OIL A YEAR FROM NAHORKATIYA

AOC Senior Geologist Announces Probable & Proved Reserves

"THE PROVED AND PROBABLE RESERVES in the Nahorkatiya area are sufficient to plan a production target of two and a half million tons of oil per year together with about 45 million cubic feet of gas per day, equivalent to about 0.6 million tons of fuel oil per annum, a large part of which could be utilized for industrialisation of Assam,"—announced Mr. W. B. Metre, Senior Geologist of Assam Oil Company, in his presidential address at the 32nd Annual General Meeting of the Geological, Mining and Metallurgical Society of India held at the Great Eastern Hotel, Calcutta, on 28th September.

Mr. Metre continued, "The declining Digboi production is likely to average 0.3 million tons per year during the next few years. On present evidence, therefore, we can expect to meet 56 per cent of the present estimated crude requirements in the country. This will be a very great improvement on the present production of about eight per cent of the total consumption." The above estimates do not include the proved but unestimated pools of part of the Hugrijan area near Naoholia, where oil has been found and the Moran area which is expected to be oil bearng.

Referring to the other areas in the Assam Valley Mr. Metre thought that several of them may be promising but pointed out that it is only by drilling in them that we can expect to ascertain whether oil is present or not. Similar considerations apply to the several large alluvial areas in the country, specially part of West Bengal, the extensive Ganges Valley and the alluvial tracts of Rajasthan, Saurashtra, etc. and also the exposed areas where the Oil and Natural Gas Commission have carried out very systematic geological and geophysical surveys and are due to undertake drilling operations.

Don't be Impatient

Though Mr. Metre sincerely hoped that these efforts to find more oil in the country will meet with early success, he warned his audience not to be impatient and pointed out that Oil Exploration needs considerable patience and an overdose of optimism besides much experience and great technical skill.

Speaking about the stupendous risks in the oil industry Mr. Metre referred to the drilling of over 200 deep and shallow holes in the country including a very large number of test wells, outside the Digboi and now extinct Badarpur Field, before the discovery of oil at Nahorkatiya, where 19 wells had so far been drilled, including five "wild-cats," of which only two had been completed as successful producers.

The president gave a short history of the Assam oil industry since oil was observed by some explorers who penetrated the thick jungles of Upper Assam in about 1825 and he said that oil exploration in Assam had had great advantage over the other possible areas in India in that Assam had a long start on geological and geophysical investigations. "Our present aim is to attain or approach self sufficiency in petroleum for the entire country and to effect a large saving of foreign exchange. Until we find oil to meet the country's growing requirements. Unless much more drilling is done in all the promising areas (and we hope to do this during the next two or three years) we cannot say whether or not oil is present in other areas. But I can assure that if the oil is there we shall find it."

Tribute to Sri Malaviya

Earlier in his address Mr. Metre referred to the birth of the Oil and Natural Gas Commission and paid tribute to Sri K. D. Malaviya, Minister for Natural Resources and Scientific Research, for taking the bold step towards making the country self sufficient in crude oil and its products. He also praised Sri A. M. N. Ghosh, the Founder Director of the Oil and Natural Gas Directorate and now a member of the Commission, who had already put in quite a lot of hard work and had shown an exceptionally high degree of organising ability.

3% DIVIDEND ANNOUNCED

Co-op Society's Annual General Meeting

THE 23rd annual general meeting of the AOC Indian Staff Co-operative Society Ltd was held on the evening of 8th September at the Indian Club hall. At the beginning Sri M. P. Abel, Chairmen of the Society, requested the house to observe three minutes' silence in honour of the members who had passed away during the year.

The Chairman in his address said that the Society invested a sum of Rs. 50,000 in the Government of India 3¾ per cent Loan 1974 in July this year and arrangements were completed in August to invest another sum of Rs. 50,000 in the same. As the Society had surplus funds, the Chairman said, the Managing Committee recommended the amendment of bye-law No. 46 of the Society "to extend the limit of loan facility up to a higher figure than Rs. 1,000." The Government audit for 1949-1955 was completed during the year and amounts due to the members for the years 1949-1954 were credited to their respective accounts. The amount for 1955 would now be credited, he declared. The sales of the Stores branch during the year increased by Rs. 86,417, making a total of Rs. 3,44,622.

The Honorary Secretary and Treasurer read out their reports. The Secretary said that the total number of members at the end of the year was 1,977. The Society was approached by the Assam Co-operative Sugar Mills Ltd. to participate in the Sugar industry. They gathered facts and figures regarding this and requested the incoming committee to examine this further.

The Honorary Treasurer announced that from the loan business and investments the Society derived an income of Rs. 61,884/9/- during the year, and the net profit stood at Rs. 10,624/11/-. He declared that the dividend to members for the year was 3 per cent on thrift deposit. A sales rebate of Rs. 2/8/- out of the profit made by the Stores branch was also announced.

Tea was served and the meeting terminated at 11.30 p.m. with a vote of thanks to the chair.

The following officer-bearers were elected for th eyear 1956-57:

Sri R. C. Bhattacharjee—Chairman, Sri N. Chaudhuri—Secretary, Sri K. B. Bhattacharjee—Treasurer, Committee Members—Sri W. B. Metre, Sri P. C. Barua, Sri B. M. Chopra, Sri U. R. Mukherjee, Sri K. K. Bose, Dr. B. K. Barman, Sri P. P. Anandan, and Sri M. P. Abel, Internal Auditors—Sri S. C. Choudhury and Sri P. N. Das.

AT THE ANNUAL GENERAL MEETING.—The members of the AOC Indian Staff Co-operative Society met at the annual general meeting of the society on 8th September with Sri M. P. Abel in the chair. The meeting was followed by a tea-party. Our photograph shows some of the members who attended the meeting.

Festivals This Month

WITH DURGA PUJA now only a few days away, preparations for this important Hindu festival are reaching their climax and shops are keeping the doors wide open till late hours of the night.

The great popularity of this festival is perhaps accounted for by the fact that it is usually takes place at the beginning of autumn, known as "hemanta" in this part of the country. Hemanta lasts from the middle of October till the middle of December and it is regarded as the loveliest season of the year, particularly in Digboi.

Among the Bengali community, Durga puja forms the most popular of all Hindu festivals; it continues for three days and is the greatest holiday of the year. Other Hindu communities also observed the festival with due solemnity.

Two other important festivals which follow the Durga Puja are the Lakshmi puja—the worship of the goddess of prosperity and the Kali puja—the festival of lights. The Kali puja which is also known as "dewali" is the most

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Digboi Batori

House Journal of the Assam Oil Company

VOL. III DIGBOI, DECEMBER 1956. No. 12

JAN. 12

IS A.O.C. SPORTS DAY IN DIGBOI

MR. MALAVIYA, NATURAL RESOURCES MINISTER, TELLS M.P.s ABOUT ASSAM'S NEW OIL TARGET:

3 MILLION TONS A YEAR BY 1959!

AIM FOR 1962 IS 5 MILLION TONS

MR. K. D. MALAVIYA, Minister for Natural Resources, Government of India, told members of Parliament in New Delhi last month that it would be possible to produce three million tons of oil a year from Assam by 1959. By 1962, the Minister hoped, indigenous production would amount to five million tons per annum.

As stated at the annual general meeting of the Geological, Mining and Metallurgical Society of India in Calcutta in September, the proved and probable oil reserves in the Nahorkatiya area of the Assam Valley were capable of an estimated yield of 2½ million tons of petroleum (crude oil) a year for many years to come. It was made clear to the meeting, which was attended by the nation's foremost mineral experts, that this assessment did not take into account either the Hugrijan area (near Naholia) where oil had been proved; or the Moran area, of which, since the first test well was still drilling at the time, it could only be said that oil might be found there.

Since this "2½ million tons a year" assessment was calculated the AOC's non-stop drilling programme has resulted in some further exploration successes—particularly at Moran where the No. 1 Well has recently been found to be a good producer. But the estimation of "proved and probable" reserves of oil here, as in any "new" area, waits upon the completion of more wells.

Drilling continues in the Assam Valley, and a new well, No. 983, is also going down in the East Kharjan section of the Digboi oilfield.

Saving Foreign Exchange

When Mr. Malaviya was reviewing the progress of oil exploration before M.P.s in Delhi he said it was important that India should become independent in oil, for crude oil imports were costing the country many crores of rupees yearly in foreign exchange. He agreed that it was necessary to get the newly-found Assam oilfield working as quickly as possible.

SPECIAL OFFER

A chart showing the progress of AOC drilling in the Assam Valley from 1953 ((when the Nahorkatiya No. 1 Discovery Well was completed) to mid-November 1956 is published on page 7 of this issue of Digboi Batori. Copies of the chart, specially printed on art paper, may be obtained from the Publicity Department.

NHK 20

Newest well in the Assam Valley is No. 20, which began drilling on 6th November. No. 22 was also drilling last month. Well No. 21 was finished in October.

Rumanians at Jawalamukhi

Commenting on Indian Government's own oil exploration activities Mr. Malaviya, according to newspaper reports, said that drilling would start in the Jawalamukhi area of East Punjab under the guidance of Rumanian drillers in a few days. It wiuld probably be necessary to drill to a depth of 9,000 feet.

Also, geophysical survey work was in hand for the Jaisalmer area, while in the Cambay region there was a programme for structural drilling with the help of Russian equipment and Russian drillers. Surface surveys would be undertaken in the Gangetic valley after the results of the recent Canadian aero-magnetic survey there.

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REPUBLIC DAY PICTURES IN THE NEXT ISSUE

WORK GOES AHEAD

The second well at Moran reached a depth of 4,541 feet on 22nd December and drilling is going ahead.

The depth of Well No. 20 was 10210 feet on the same day and that of Well No. 23 was 4,863 feet.

Rigging down at Well No. 22, which was drilled earlier, was in progress. As soon as the construction of bridges are complete on the road to location 11A rig-builders will move to this new location.

NEW OIL COMPANY FOR NAHORKATIYA AREAS

AGREEMENT BETWEEN GOVERNMENT & ASSAM OIL COMPANY DRAFTED

We are now able to announce that negotiations with the Government of India have reached the stage where it has been possible to prepare a draft agreement regarding formation of a new oil company in Assam. This, of course, is still subject to ratification on both sides.

Sri K. D. Malaviya, Union Minister for Natural Resources, announced in the Lok Sabha on 18th December that agreement had been reached between the Government of India and the Assam Oil Company regarding formation of a Rupee Company in Assam.

The object of the new Rupee Company, he added, would be to carry out exploration as well as production of crude oil from Nahorkatiya area.

The following is the full text of the statement made by Sri Malaviya :

"I am glad to inform the House that, subject to final ratification, an agreement has been reached between the Government of India and the Assam Oil Company regarding the formation of a Rupee Company in Assam to carry out exploration and production of crude oil in Nahorkatiya area. The house will recollect that negotiations have been going on for nearly a year for formation of this Company following the issue of prospecting licences for Nahorkatiya extension, Hugrijan and Moran areas to the Company subject to conditions that mining leases will not be issued except to the new Rupee Company in which there will be participation of Indian capital.

"According to the agreement reached, a new Rupee Company will be formed in which 33.1/3 per cent of share capital will be contributed by the Government of India and 66.2/3 per cent by the Assam Oil Company. The memorandum and articles of association of the Company will be as approved by the Government of India, and will contain provision for the appointment of special directors on behalf of the Government who will be entitled to reserve, for approval of the Government, important matters of policy including such matters as contracts and agreement with persons in foreign States, disposal of oil and oil products in India, appointment of foreigners etc. In particular, it has been agreed that the price of crude oil produced by the new Company will be fixed only with the approval of the Government of India and I am glad to announce further that the crude oil that will be needed for the proposed refinery to be set up in the eastern part of our country will be sold at a concessional price. This concessional price will be fixed in due course with the consent of the Government.

"Other important features of agreement are that the new Rupee Oil Company will provide certain facilities for training of technical personnel, and foreign exchange required for project will be found by contributions of the AOC to its share of share capital in sterling. The control which the Government has arranged brings this enterprise into accord with revised industrial policy of the Government of India.

"Some of the details that flow from this agreement have still to be examined and approved by the Government."

Jamtala Badminton Club.—A Knock-out Competition organised by the Jamtala Badminton Club, Digboi, is expected to begin on 14th January. The club league began on 13th December. The following members have been elected for the Knock-out Competition Committee : Sri A. K. Bhattacharjee and Sri H. S. Dey (Joint Secretaries), Sri A. C. Chakrabarty (Treasurer) and Sri R. K. Aich, Sri B. Kakoty and Sri R. Sarkar (committee members).

MORAN No.2

UP GOES THE DERRICK, DOWN GOES THE PIPE

MORAN NO. 2.—This is the second well at Moran, a tea area between Dibrugarh and Sibsagar subdivisions in Upper Assam. Drilling of the well began on 8th December and on 22nd December it reached a depth of 4,541 feet. The first well in the area was drilled to a depth of 13,739 feet.

...O ATTEND ...DAY AT ...'S CLUB

AOC SPORTSMAN

A. C. Banerjee of the AOC ...tores Department is a keen ...portsman and likes to play ...ricket—his favourite game, ...ootball, volley ball and bad-...inton.

It was Banerjee who captur-...d 7 wickets for 19 runs at a ...atch played between the ...gboi Sports Club (he played ...r this club) and Shillong XI ...st year in the Assam capital. ...e also scored 45 runs (not ...t) against the Ranji Club.

Banerjee began his cricket ...areer in the Dacca School ...ournament in 1939. He had ...e opportunity to receive ...aching from Sri A. Bose, ...acle of Shivaji Bose, the open-...g batsman of the Bengal ...am. His record overs of ...owling in a match against ...illong United XI in 1954 was ... overs in the first innings ...ithout change) and the bow-

A NEW FILM ON OIL

GOVT. UNIT IN ASSAM

A unit of the Films Division, Government of India, arrived at Digboi on 2nd January for shooting a documentary film on oil. Sri Biren Dass, Director, Sri O. P. Arora, cameraman, and Sri D. N. Chandekar, Assistant cameraman, were in the party.

The film, the title of which is not decided yet, will show some scenes of oil exploration in Jaishalmer, Jwalamukhi and West Bengal, besides the actual drilling scenes of Digboi and Moran. The Unit took some shots of the discovery well at Nahorkatiya also.

It is learnt that the proposed documentary will not be longer than 2,000 feet, although the unit has already taken more than 8,000 feet of film in different locations.

Except for the first day of their stay in Digboi the unit experienced good weather for shooting the film.

The film is expected to be released in June and we shall try to obtain a copy for Digboi as soon as possible thereafter.

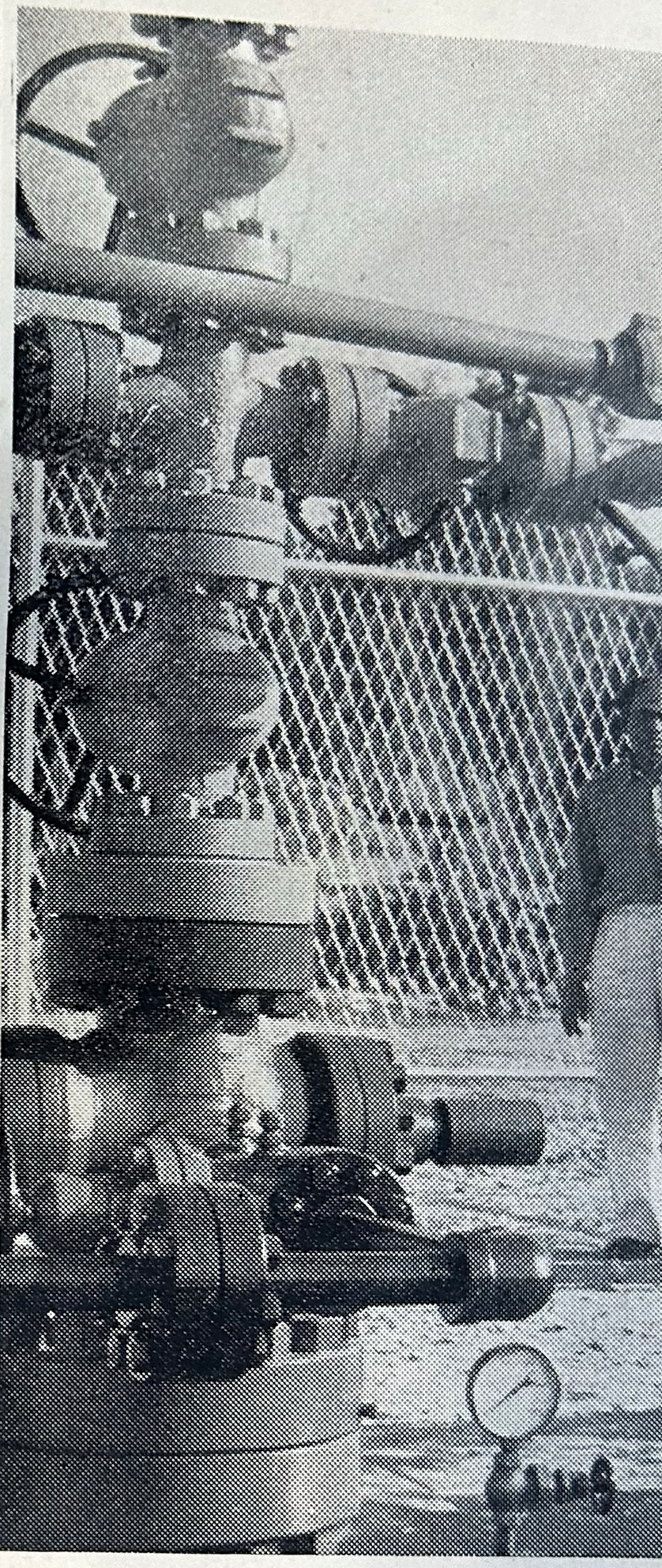
(Continued from Col. 1)

and the team-work deserved high praise.

Among other who took part in the play were Smti. Jharna Dutta as 'Maa,' Smti. S. Das as 'Mili,' Sri Gopal Sen as 'Tupe,' Sri Arun Bose as 'Ganen,' Smti. Bela Banerjee as 'Gopa,' and Sri Samar Choudhury as 'Kamalesh.'

Sri Arun Bose directed the stage-play.

Location ...



THE STAR HERE IS A "CHRISTM... of the Films Division, Government ...katiya and Moran last month fo... photograph shows Sri Biren Dass ... Arora, cameraman and Sri D. N. C... at Moran No. 1, the deepest

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VOL. IV | DIGBOI, MARCH 1957. | No. 3

RESULTS OF AOC EMPLOYEES' ESSAY CONTEST TO BE ANNOUNCED NEXT MONTH

MORAN NO. 2.—The above picture which represents the two major industries of Assam—oil and tea—was taken near the latest well at Moran, a tea area between Sibsagar and Dibrugarh sub-divisions of Upper Assam. The well, seen in the centre, was drilled to a depth of 12,065 feet. The first well in the area, Moran No. 1, the deepest well in the sub-continent, was drilled at a site about two miles away from this well.

THE SECOND WELL AT MORAN FINDS OIL

Signs of oil were encountered below 11,200 feet in the newly-completed second well at Moran, a tea area between Sibsagar and Dibrugarh sub-divisions of Upper Assam. Currently preparations are being made to ascertain whether a higher sand at about 10,780 feet, is also oil-bearing.

This well, Moran No. 2, when tested for production, yielded oil from sandstone rocks at a depth of 11,292 feet and thus became the deepest producer in the India-Burma and Pakistan sub-continent.

It may, however, be recalled that the first well at Moran, drilled to a depth of 13,739 feet, is still the deepest well in this sub-continent.

Dri'ling of Moran No. 2 began on 8th December, 1956 and was completed on 2nd February, 1957, at a total depth of 12,065 feet. Preparations at the site of the next well, Moran No. 3, are progressing satisfactorily and the location is ready to receive the drilling equipment from Well No. 2. Unfortunately when running in to perforate the oil string, three of the guns used for this purpose were left at the bottom of the hole and this has resulted in some delay in the testing of the higher sand and has consequently delayed the move to Well No. 3.

Clearing of jungle and earth work at the location selected for Moran No. 4 were completed recently. Gravelling of the approach road began in the middle of February.

In Nahorkatiya area the latest well, Well No. 23, which completed drilling to 10,122 feet on 9th January, also struck oil. Drilling is proceeding at Well No. 25 but at Well No. 24 progress was delayed when 165 feet of the pipe used to rotate the bit broke off and was left at the bottom of the hole at 9,000 feet from the surface. Attempts to recover the 'fish' were unsuccessful and a new hole is being drilled below about 8,000 feet.

AOC PUPILS' SUCCESS IN STATE M.E. EXAM.

A Girl & A Boy Top The List of 46,000 Candidates

TWO PUPILS—A GIRL AND A BOY—of Assam Oil Company schools in Digboi brought honour to the AOC schools by topping the list of successful candidates in the State's Middle School examination held in November, 1956.

Smti. Manidipa Chakraverty of the AOC Girls' High School stood first among 46,000 candidates who appeared in the examination from all over the State. Sm. Pradip Kumar Bhattacharjee of the AOC Boys' High School became second in the examination.

Smti. Manidipa Chakraverty.

Sm. Pradip Bhattacharjee.

Out of the 46,000 candidates, it is reported, 36,000 appeared in Groups I and III (which included English) of whom 24,554 came out successful. The percentage of success was 68.1.

(Continued on Page 10)

SRI N. D. MAHANT TAKES OVER FROM MR. BONNER

New Production Superintendent

SRI N. D. MAHANT assumed the duties of the Production Superintendent of the Assam Oil Company on 3rd February. His predecessor, Mr. W. D. Bonner, retired last month after nearly 29 years service with The Burmah Oil Company. Mr. L. C. Bond took over the duties of Acting Assistant Production Superintendent.

Sri Mahant, who joined the company in 1930 as an Assistant in the Production Department, belonged to the first batch of students who passed out from the Indian School of Mining, Dhanbad. He was also a science graduate of the Government College of Lahore.

Sri Mahant.

In 1936 he was given complete charge of a production section in Digboi and was made a Production Foreman. Then he worked for six years in a gas section. In 1950 and 1951 he acted as the Assistant Production Superintendent for some time and in 1953 he was confirmed in the job.

Mr. Bonner's Farewell

At a pleasant function held in the Production Office on 30th January Sri Mahant, on behalf of the supervisory and clerical staff, presented to Mr. Bonner a travelling clock, a cigarette lighter and two pieces of Assam silk handwork. Sri S. S. Kainth read and presented a framed address to Mr. Bonner recording the appreciation of his work done for

Mr. Bonner.

(Continued on Page 10)

NEW COMPANY FOR ASSAM OIL

(Continued from Page 1, Col. 5)

the Memorandum of Agreement.

Mr. Watt left for a short visit to Digboi on 18th April; and Mr. Kanuga left for Jwalamukhi on 19th April where he represented the company at the spudding in of the Government Oil & Natural Gas Commission's maiden test-well.

During the visit, Mr. Smith and Mr. Drysdale stayed with Mr. Gowan in Nahor House. Their visit was a busy one in every way and there were many social functions to which they were invited. The High Commissioner for the United Kingdom gave a lunch party, and among the guests were the High Commissioner for the U.K. in Pakistan, Sir Alexander Symon; the High Commissioner for Pakistan in India, Mian Ziauddin (who later gave an informal dinner party for us); and senior members of Government including Sir Raghavan Pillai and Sri Y. N. Sukthankar.

Next night Sri R. K. Ramadhyani had a party on the lawn of his house is Safdarjang Road where we had the pleasure of meeting the Minister, Sri K. D Malaviya; and also Sri K. C. Reddy, the Minister for Production.

Sunday Lunch

Mr. Gowan gave a Sunday lunch party at Nahor House for senior Government and U.K. High Commission officials.

And on 17th April, the day when agreement was finally reached, Sri Y. N. Sukthankar, the Cabinet Secretary and Chairman of the Oil Negotiating Committee, gave a lunch party in the magnificent Ashoka Hotel for all who had taken part in the negotiations plus other prominent Government officials and businessmen. A delightful and fitting party to mark the culmination of these months of negotiating.

Before he left for London, Mr. Smith called on Sri Bishnuram Medhi, also visiting Delhi, and was happy to be able to tell him that agreement had been successfully reached.

Cabinet Changes

The Rupee Company agreement is the headline news for this month, and has occupied most of our time—work-time and play-time—up to Easter. But 17th April was a day of far-reaching importance not only for our company but for India as a whole, for on that day the portfolios in the new Cabinet were decided. There had been much speculation in Delhi, and in the event the changes actually made caused less excitement than their precedent rumours. Sardar Swaran Singh has charge in the Cabinet of the new Ministry of Steel, Mines and Fuel; and Sri K. D. Malaviya becomes Minister of State of that Ministry, so that our happy association with him remains intact.

Nahor House Repairs

Nahor House is having a "face lift"—and by the noise of workmen hammering you would think the whole house was being pulled down. "Business as usual"—but not made easier by noise nor by the entry of hot April air through what used to be the staircase window and is now a gaping hole.

A.O.C. Scholarships

April saw the selection board for our and Burmah-Shell's U.K. Scholars. Some ten scholars were selected out of about sixty interviewed.

VISITORS FROM FAR & NEAR

A number of important Government officials from Delhi who were on a tour of the North East Frontier Agency area visited Digboi on 16th April and went round the AOC refinery. Later they were entertained to tea by the General Manager of the Assam Oil Company at the Refinery Staff Room.

The following were in the party.—Sri M. S. Siva Raman, I.C.S., Advisor, Programme Administration, Planning Commission; Sri S. N. Gupta, Senior Research Officer, Planning Commission; Dr. R. J. Kalamkar, Additional Agricultural Commissioner, Government of India; Dr. T. R. Tewari, Assistant Director of General Health Services, Government of India; Sri O. K. Moorthy, Officer on Special Duty, Ministry of Home Affairs; Sri G. Lal, Additional Consulting Engineer to the Government of India; Col. G. S. Puri, Development Commissioner of the N.E.F.A., Sri Sohan Singh, Assistant Educational Advisor, Ministry of Education; and Sri W. S. Ryanjah and Sri K. D. Menon, Assistant Political Officers of N.E.F.A.

Two visitors from Burmah-Shell, Mr. Trenear-Thomas of General Manager's Office, Bombay; and Sri J. Chopra of the Calcutta Branch office also came to Digboi last month. On 11th April Mr. Trenear-Thomas gave an interesting talk on the "Growth of the demand for petroleum products and the influence of the National plan" at the Publicity Department hall to senior members of the staff of the Assam Oil Company.

Another important visitor to the Assam Oil industry was the Assistant High Commissioner for Pakistan in India, who went round the oilfield and refinery (and also visited the AOC hospital) at the end of March.

Among other visitors to the oiltown last month was Mr. D. K. Basu, area manager of Ibcon Ltd.

FIRST GOV'T WELL SPUDDED IN AT JAWALAMUKHI

Drilling Near Famous Temple

THE FIRST test drilling by Governmental agencies in the Second Five Year Plan programme for oil exploration in India was spudded-in at Jawalamukhi in the Kangra Valley of Punjab State last month.

The Governor of the State, Sri C. P. N. Singh, inaugurated the operations on 20th April by setting in motion the machinery of a Rumanian drilling outfit erected on a 3,000 foot-high spur of a hill in the Shivalak range.

Designed to go to a depth of about 11,000 feet the well is expected to provide valuable information about underground geological conditions in this area of the Punjab. Twenty-one Rumanian drillers and an equal number of Indian understudies are employed on the operation. Other tests for oil and natural gas possibilities in the area will follow.

The location of this first "reference" well is 55 miles from Pathankot railway station and about a thousand feet above the Jawalamukhi Temple—where a natural gas flame, regarded as sacred, has been burning for ages past.

"Good Luck" Messages

The start of drilling was marked by a ceremony during the course of which many messages of good wishes for the success of the operations were received and Sri K. D. Malaviya, Minister of State in the Ministry of Mines, Steel & Fuel and Chairman of the Oil and Natural Gas Commission, made a speech.

Mr. K. B. Kanuga of the AOC General Manager's office in Digboi represented the Assam Oil Company at the inauguration ceremony and contributed the following account of the event for Digboi Batori.—

"This was indeed an important day, for the Government of India were embarking on one of the biggest gambles—searching for oil—which hitherto in India has been undertaken chiefly by private enterprise, and the occasion was celebrated in the most befitting manner.

"All the guests were first received at the main camp of the Test where they washed off the dust and dirt they had picked up en route to Jawalamukhi, and a hot cup of tea was awaiting them. Cars left for the drilling site (about two miles from the main camp) at about 11.15 a.m.

A Happy Minister

"The placed hummed with activity. The organisers were very busy receiving guests and conducting them to their seats. A huge shamiana was put up and this was gaily decorated. There were Press reporters, photographers, movie men, tape recorders—all set to go into action as soon as the function started.

"The Minister, Sri Malaviya, arrived in advance of the Chief Guest (the Governor of Punjab) and went round shaking hands with guests. He was indeed a very happy man, and this was a great day for him. The function started with Sri Ghosh of the Oil and Natural Gas Commission reading out messages from Mr. Nehru, Prime Minister of India: Mr. R. P. Smith, Assistant Managing Director of The Burmah Oil Co. Ltd.; and Mr. D. C. Robertson, General Manager of the Assam Oil Co. Ltd.

Mr. Nehru sent a message saying that the test was a new and major step in the search for petroleum in India—"the beginning of a great venture," and everyone wished it success.

"Mr. Smith's message said: 'On behalf of the Board of Directors of The Burmah Oil Company Ltd., who through their subsidiary, the Assam Oil Company, are the only oil company actively engaged in exploring for oil in India, I send you best wishes in this your initial venture in oil exploration.'

"Mr. Robertson's message was as follows. 'Myself and all in the Assam Oil Industry send good wishes to the Minister and to the drillers at Jawalamukhi and sincerely hope that the exploration operations there will result in success.'

Assam Valley Discoveries

"Sri Malaviya in his speech laid great emphasis on the fact that this drilling of a deep well was only 'reference drilling' and that people should not expect any startling results from this first well. He went on to say that many more such wells might have to be drilled, and the Government of India were determined to carry on with this work. He thanked all the foreign countries who were helping the Government of India in this work of searching for oil in different parts of India.

"After the Minister's address the Governor presented his speech in which he wished the Government's enterprise great success and assured the Oil and Natural Gas Commission of all the assistance they might require from the Government of Punjab State during the operations. He also mentioned the recent discoveries of oil by the Assam Oil Company at Nahorkatiya and Moran. "Exploring for oil against great odds sharpens the edge of adventure," he declared.

"At the end of his speech the Governor was conducted to the drilling rig where he pressed the switch to start the diesel outfit. He was then taken round, had the drilling technique explained to him, and saw the laboratory, etc.

"Among the prominent people present were the Chief Minister of Punjab, Sardar Rarewala; the previous Chief Minister of Pepsu and East Punjab and now one of the Ministers of East Punjab, and a number of Punjab M.L.As.

"From the site we came back to the main camp where a buffet luncheon had been arranged. There were about 200 guests.

The Legend Of The Lamp

"Before returning to Delhi via Hushiyarpur and Jullundur, I went to see the famous temple of Goddess Jwala, known locally as Jwala Devi.

"As the Governor was also visiting the temple later in the evening, the route was lined on both sides by Scouts, Girl Guides, and local men and women nicely dressed. I saw the famous flame and the golden shade which is reported to have been presented originally by the great Moghul Emperor Akbar.

"Legend has it that when Akbar the Great, during his wanderings, reached this place he tried to put the flame out by water; having failed in his attempts he was so much struck by this miracle that he presented a gold shade for the flame weighing about one maund and ten seers. However, having done this, he became proud and showed his vanity at having given such a handsome and costly present for a Hindu Goddess. The Goddess became annoyed at this and, lo and behold!, the shade turned from gold into a worthless metal. A shade, reported to be the original shade, is still kept there and is shown to visitors."

BAD WEATHER HITS DIGBOI

Most of the latter half of April was marked by heavy rain in Digboi, 2.75 inches being recorded on 20th April—the end of a week in which rain fell every day. Severe storms occurred at night and company electricians were kept busy on Sunday, 21st April, repairing damage to lines caused by trees uprooted in the high winds of the previous evening.

Nearly 10 inches of rain fell in the week 14th to 20th April bringing the total since 1st January to 19.32 inches. Maximum temperature: 84° Fahrenheit on 20th. Minimum temperature 63° Fahrenheit on 19th.

REFINERY VISITORS.—The Assistant High Commissioner for Pakistan in India, Jonab Ataullah, who visited Digboi on 30th March, is seen here with Mr. J. M. Doherty, Acting Works Manager of the AOC refinery, who showed him round. In this picture they are seen in the Staff Room of the refinery. The Assistant High Commissioner also toured the oilfield and visited the AOC hospital.

W. Bengal Oil Search.—Drilling for oil has started at Burdwan under the Indo-Stanvac oil exploration project. The search is being conducted by the Standard Vacuum Oil Company under an agreement with the Government of India, signed in 1954. According to this agreement, 10,000 sq. miles of land were allotted to the company for exploration. The Government, acting through the Union Ministry of Steel, Fuel, and Mines, has 25% of the shares in the venture.

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Digboi Batori

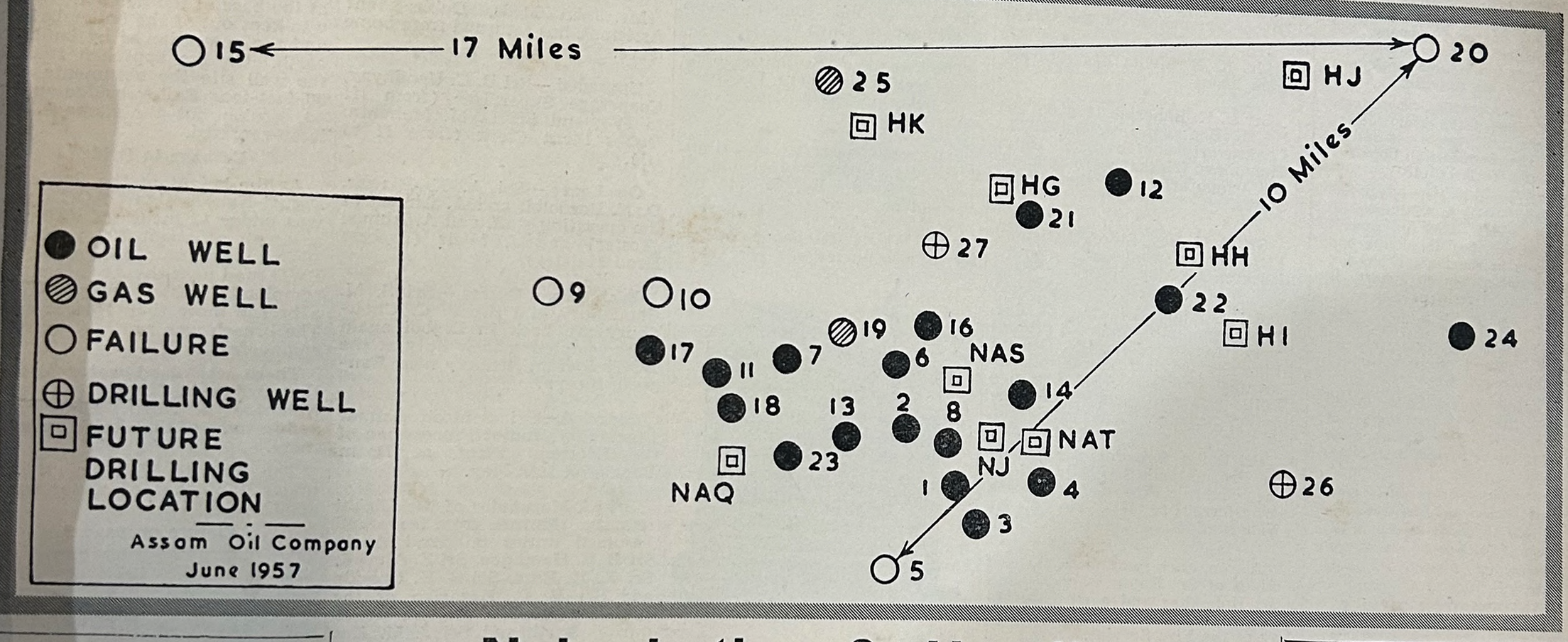
House Journal of the Assam Oil Company

VOL. IV DIGBOI, JUNE 1957 No. 6

FLOODS AND OIL

Story On Page 2
Pictures
On Page 9

THE PATTERN OF DRILLING FOR OIL IN THE BRAHMAPUTRA VALLEY, ASSAM



Nahorkatiya & Hugrijan

THIS CHART illustrates the present-day pattern of exploratory and development drilling by the Assam Oil Company in the Nahorkatiya and Hugrijan prospecting licence areas of Upper Assam. The Moran oil area, where two deep exploratory wells have been completed as producers and a third is now drilling, is not included.

The solid black circles indicate wells capable of commercial production of crude oil; shaded circles show wells from which natural gas may be produced.

Although it appears from the chart, which is not to scale, that many of the wells lie close together, in fact the spacing between them is considerable. A visitor would rarely have two derricks (production or drilling) in his view at the same time.

Two wells were being drilled at the time the chart was prepared—No. 26 (in the lower right-hand portion) and No. 27 (all by itself in the centre).

Nine locations have so far been chosen for drilling in the future. Five of these lie in the Hugrijan prospecting licence area, the others in the Nahorkatiya P/L. Further locations are selected as the drilling programme proceeds.

Well No. 19, in the centre of the chart, is shown as a well capable of yielding gas only. Similarly No. 25 where so far, despite repeated tests, no commercial production of crude oil seems possible.

Well No. 20, in the top right-hand corner of the chart is shown as a failure. Some signs of oil and gas were found here but results of the thorough tests carried out to date indicate that commercial production is unlikely.

Altogether there have been five costly failures thus far in the drilling programme, which continues non-stop in both the Nahorkatiya-Hugrijan area and the Moran area, about 25 miles to the West as the crow flies.

G.M's SUCCESSOR ARRIVES IN DIGBOI

Mr. W. P. G. Maclachlan

Mr. D. C. Robertson, General Manager of the Assam Oil Company since 1953, retires in mid-June after 29 years of service with the oil industry in the East.

He will be succeeded by Mr. W. P. G. Maclachlan, who was recently AOC Representative in

Delhi and who has served for many years in different spheres of the parent Company. G.M. and G.M. designate are seen together in the above photograph, taken at the Main Office in Digboi late last month.

Goodbye Party.—Digboi Sports Club members are saying farewell to Mr. and Mrs. Robertson at a tea party at the club on 5th June at 4-30 p.m.

World Oil.—Crude oil output in the world reached a record figure in 1956—835 million tons for the year.

New Refineries.—The largest refinery expansion now in hand in an oil importing country East of Suez is in Japan where additional capacity totalling nearly five million tons is to be provided by local and foreign concerns. Plans for refineries in the Philipines and in Ceylon are under study. In India, Caltex's plant (at Vizag) comes on stream this year. Additional refinery capacity may, however, have to be provided to treat the crude from the newly discovered oil areas in northern Assam.—*Petroleum Press Service.*

More Room For BOC.—Adding to the office accommodation of the Marketing Department of The Burmah Oil Company (India Trading) Ltd. in Digboi a new building on the Main Office hill is nearing completion and will be opened some time this month.

Recitation Contest.—A recitation competition of Tagore poems was held at the India Club, Digboi, on 15th May. The result of the contest was announced when "Rabindra Jayanti" was celebrated.

New Seismographic "Camera."—A 20-year research effort on the part of Gulf Oil Company scientists has resulted in the development of a new seismographic "camera" to be used in future oil exploration. The new instrument translates sound waves produced by small underground dynamite charges into light patterns which are recorded on rolls of moving film. The filmed light patterns are said to provide the geologists with a "picture" of underground conditions.

FAST WORK AT WELL 27

NEW RECORD

THE FOURTH YEAR of the Assam Oil Company's non-stop drilling programme in the Brahmaputra Valley began last month with the start of operations at NHK Well No. 27.

This new well, which was spudded-in on the night of 20th May, lies to the north of the No. 1 Discovery Well. No. 26, to the east, was also drilling at that date (depth on 23rd May: approaching 10,000 feet) and this is the first occasion that two steam-powered drilling outfits have been in use at Nahorkatiya at the same time.

Another well spudded-in in May was Moran No. 3, where operations began on the 6th of the month. Casing was cemented at 4,513 feet and drilling is continuing.

Gas Pipe Line

The gas line from Nahorkatiya to Digboi was completed early last month and after cleaning and testing was brought into commission on 17th May.

During routine operations at Nahorkatiya Well No. 27 last month AOC drillers completed a total of 1,425 feet of new hole in one eight-hour shift.

This achievement, which constitutes a new record in drilling speeds for the company, took place during the 6 a.m.—2 p.m. shift on 22nd May.

In 24 hours a total of 3,095 feet had been drilled at No. 27.

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Digboi Batori

House Journal of the Assam Oil Company

VOL. V | DIGBOI, FEBRUARY 1958. | No. 2

SPORTS DAYS

Full Results In Next Month's Issue

OUTLOOK : BRIGHT

ONE of the things that happen when an announcement about the formation of a new oil company is made is that other oil companies around the world sit up and take notice. And one of the first questions they ask is: "What are the new concern's prospects?"

Happily, Oil India will be able to give a most satisfactory reply to such questions. For a unique feature of this new company is that it starts off with the proof that oil in commercial quantity exists underground—as confirmed by most of the 36 deep wells drilled in the different areas it will develop.

Oil companies do not usually start that way; they usually have to risk their money in looking for *possible* deposits—and often this takes years and a lot of "dead" expenditure on dry holes. The AOC can justly feel proud of the part it played in discovering Nahorkatiya and Moran, but the high price it has had to pay, in costly failures in other parts of Assam, should not be overlooked.

Now a lot more money will be spent, and possibly risked, by the new venture. Much more work has to be done, and aside from drilling wells there are roads to be constructed, jungles to be cut, rivers bridged, houses built and communications of all kinds installed or improved. The laying and equipping of the pipe line to carry O.I.L.'s crude just to the first (Assam) refinery will be higher than average for such projects in India because of the distance from supply and materials bases.

In a way, therefore, the task in Assam remains the same as it was before the new venture was formed. More oil must still be found, and more capital provided for developing the fields. But now there is this important difference. With the signing last month of the agreement to form Oil India a bold business partnership has been established, in which the party controlling the concessions joins hands with the party possessing the skills, experience, and organisation for their development to the common good.

Such a combination of resources promises a bright future, and it is our fervent wish that Fortune may continue to smile on the new company.

Such a partnership is, moreover, truly in accord with times, and—as was graciously acknowledged in New Delhi last month—adaptability to changing conditions has always been a strong feature of our long life and work in India.

BORN LAST MONTH—A NEW OIL COMPANY WITH PROVED ASSETS AND A FINE FUTURE!

OIL INDIA LIMITED

IN THIS ISSUE

Scenes of the operational areas in the Assam Valley where the new rupee company, Oil India Ltd., will work are pictured on pages 6 and 7.

* * *

Sardar Swaran Singh's visit to Assam Oil Industry —Page 5.

* * *

State Governor drills a Moran Well—Page 4.

* * *

Pictures of our pavilion in the Congress exhibition held at Gauhati—Page 9.

"GOOD LUCK TO O. I. L."

An unexpected but nonetheless pleasing feature of the Oil India Ltd. agreement signing ceremony in New Delhi on 14th January was the speech of welcome and good wishes to the new company made by Sri N. R. Pillai, Secretary General to the Ministry of External Affairs, Government of India.

After all the documents had been signed Sri Pillai said: "We have just witnessed a signing ceremony the effect of which will have an important impact on India's economic life. Few concerns have had such a long experience in India as Burmah Oil.....Apart from efficiency the most essential factor in any concern is adaptability to the changing times, and the company has shown itself capable of that. The fact the BOC has come to a co-operative arrangement with the Government is a matter of very great gratification to all of us, and we wish good luck and a good future to the new company."

Sri Pillai's remarks were greeted with applause, and then

(Continued in Page 3)

NEXT STEP IS REGISTRATION AND INCORPORATION

WITH AIR reconnaissance over the Assam section of the pipe line route completed and the new rupee company agreement signed, Oil India Ltd. now awaits incorporation and registration formalities before it is invested with its assets and embarks on the next stage of development of the oil resources of Nahorkatiya, Hugrijan and Moran.

Thirty-six wells have been drilled in what will become O.I.L.'s area to date and the new company's first operational task will be to arrange pipe line facilities to transport crude oil from the area to the terminal of the proposed public sector refinery in Assam. Construction work on this formidable undertaking cannot however begin until a detailed ground survey of a likely pipe line route, including studies of possible Brahmaputra River crossing, has been made—whereupon the consultants' final report on the project will be considered by the Government of India.

Meanwhile, to save as much time as possible, plans are being considered by the A.O.C.'s parent company (The Burmah Oil Company Ltd.) for pipe, pumping station equipment and other materials required for the transportation of O.I.L.'s crude oil to the Assam Refinery.

As announced by Sardar Swaran Singh, Minister for Steel, Mines and Fuel, in the Lok Sabha in December, Oil India Ltd. will construct pipe line facilities from the new areas all the way to Barauni, in North Bihar (where the second public sector refinery will be erected), the foreign exchange cost of providing the pipe line to the first, or Assam, refinery being loaned to O.I.L. by the B.O.C.

(Continued in Page 3)

THE NEW COMPANY

(Continued from Page 1)

Oil India Ltd. will be incorporated and registered in the State of Assam with an authorised capital of Rs. 50 crores divided into 5,00,000 shares of Rs. 1,000 each. Two-thirds of the capital will be provided by the B.O.C. and one-third by the Government of India.

The Signing Ceremony

The signing of the agreement to form the new rupee company, the full name of which is Oil India Private Ltd., took place in New Delhi on 14th January with Mr. R. P. Smith, Managing Director of The Burmah Oil Company Ltd., signing for the Burmah Oil and Assam Oil companies and Sri K. K. Sahni, Joint Secretary of the Steel, Mines and Fuel Ministry, signing for the Government of India.

Press and news-reel cameramen photographed the signing ceremony, which took place in the Minister's room at the Secretariat. Besides Sri Sahni and Mr. Smith those present were Sri N. R. Pillai, Secretary General, Ministry of External Affairs; Sri S. S. Khera, Secretary, Ministry of Steel, Mines and Fuel (Department of Mines and Fuel); Sri S. Ratnam, Secretary, Ministry of Finance; Mr. W. A. W. Clark, Acting High Commissioner for the U.K.; Mr. G. J. MacMahon, U.K. Senior Trade Commissioner and Mr. W. P. G. Maclachlan, General Manager of the Assam Oil Company Ltd.—all of whom were seated at the long table at which the documents were signed. Others present were Sri S. K. Mukherjee, Deputy Secretary in the Steel, Mines and Fuel Ministry; Sri S. R. Sundaram, Under-Secretary of the Ministry; Sri S. N. Sen, Solicitor to the Government of India; Sri K. B. Kanuga of the Assam Oil Company Ltd., Digboi; Mr. A. C. Gowan, AOC Representative in Delhi; Mr. M. J. Ordish of Orr, Dignam & Co., Calcutta; and Sardar S. S. Marwah, an assistant in the Ministry of Steel, Mines and Fuel.

The ceremony was completed when Sri Sundaram and Mr. Maclachlan added their signatures to the documents as witnesses, and after tea and coffee had been served there was a brief interlude for informal discussion before the party dispersed.

Government Lunch Party

On the same day the Government held a luncheon party for Mr. Smith at the Ashoka Hotel in New Delhi. This was attended by all those present at the signing ceremony and additionally by Sri B. K. Nehru, Secretary of the Finance Ministry; Sri S. Bhoothalingam, Secretary, Department of Iron and Steel in the Steel, Mines and Fuel Ministry; Sri M. R. Sachdev, Secretary, Ministry fo Works, Housing and Supply, Sri K. V. K. Sundaram of the Law Ministry; Sri R. K. Ramadhyani, Secretary of the Ministry of Information and Broadcasting; Sri H. C. Mahindra, Branch Manager of Burmah-Shell, New Delhi; Sri P. A. Gopalkrishnan, Joint Secretary in the Cabinet Secretariat; Sri K. N. Kaul, Joint Secretary in the Ministry of Steel, Mines and Fuel; Sri N. S. Mani, Joint Secretary, S. M. & F.; Sri P. K. Guha, Deputy Petroleum Officer, Sri K. K. Roy, Assistaant Petroleum Officer; Sri C. P. Jacob, Under-Secretary, S. M. & F., and Sri I. P. Tewari, Information Officer of the Steel, Mines and Fuel Industry.

Between the conclusion of the signing ceremony and the holding of the Government's lunch party there was just time, back at Nahor House, for a toast to the health of the New Rupee Company to be drunk by the staff of the AOC's Delhi Office. Mr. Smith proposed the toast and all wished success and long life to Oil India Ltd.

14TH JANUARY 1958. THE O. I. L. AGREEMENT IS SIGNED

SIGNING THE 'OIL INDIA' AGREEMENT.—Mr. R. P. Smith, Managing Director of The Burmah Oil Company Ltd., and Sri K. K. Sahni, Joint Secretary of the Steel, Mines and Fuel Ministry, signing the agreement for the formation of the rupee company to develop the new oil areas in the Brahmaputra Valley of Upper Assam. At the table (from left) are Mr. W. P. G. Maclachlan, AOC General Manager, Mr. G. J. MacMahon (Senior UK Trade Commissioner), Mr. W. A. W. Clark (UK Acting High Commissioner), Mr. Smith, Sri Sahni, Sri N. R. Pillai, Secretary General, Ministry of External Affairs; Sri S. S. Khera, Secretary, Ministry of Steel, Mines and Fuel, and Sri S. Ratnam, Secretary, Ministry of Finance. Behind the table (from left) are Mr. A. C. Gowan (AOC New Delhi), Sri S. K. Mukherjee, Deputy Secretary in the Steel, Mines and Fuel Ministry; Mr. M. J. Ordish (Orr, Dignam & Co., Calcutta); Sri K. B. Kanuga (AOC Digboi); Sri S. R. Sundaram, Under Secretary in the Steel, Mines and Fuel Ministry, Sri S. N. Sen, Solicitor to the Government of India, and Sardar S. S. Marwah, an Assistant in the Steel, Mines and Fuel Ministry.

Early in the morning of "Agreement Day" a group photograph was taken of all at Nahor House, including secretaries, drivers and bearers, and copies of these pictures were later distributed to those in the group as a souvenir of the occasion.

Evening Party

In the evening of the same day, Nahor House was the scene of a large party at which Mr. Smith, Mr. Maclachlan and Mr. Gowan were hosts to all the Government officials who had attended the signing ceremony and to other distinguished guests in the capital.

And so, with good wishes on all sides, concluded an eventful day.

NHK WELLS

Latest well to start drilling in the Nahorkatiya area of the Assam Valley is NHK No. 31, which was spudded-in on 5th January.

No drilling speed records will be attempted at this location as cores (samples of underground rocks penetrated by the drill) will be taken to enable an up-to-date assessment of geological conditions to be made.

Locations for Wells 32, 33, 34, 35 and 36 are being prepared at Nahorkatiya.

GOOD LUCK!

(Continued from Page 1)

Mr. R. P. Smith, Managing Director of The Burmah Oil Company Ltd., replied saying: "On behalf of the BOC and the AOC I am grateful for the kind sentiments that have been expressed. This agreement is a solid achievement for both parties, and where our efforts will count now is in making the new company a success. I am confident that it will be a complete success, in the interests of both the Government of India and the Burmah Oil Company, and that Oil India Ltd. will live up to expectations."

OVER THE RIVER—To Nahorkatiya Well No. 31, a picture taken during last month's visit to the Assam Oil industry of Sardar Swaran Singh, Minister for Steel, Mines and Fuel, Government of India. With the Minister (seen on the left in this picture, which also shows the new NHK well in the background) are Mr. Maclachlan, Mr. Wachter, Mr. Saikia (O.C., Digboi Police) and Government officials.

14TH JANUARY 1958. THE O. I. L. AGREEMENT IS SIGNED

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State Governors As "Drillers"

THE ASSAM OIL CO., LTD.

DAILY DRILLING REPORT.

Well No 179 Date 2

Bit Size and Type	Casing Dmr.	Casing Total Lengths	Casing Column Feet	Formation From	Formation To
15 3/4" FT			—	20'	

Drilling
Laurie Hammond
Governor of Assam
5th Feb 1928

THIRTY YEARS AGO.—Sir Laurie Hammond, then Governor of Assam, signed this drilling report in 1928. (See Columns 4 and 5 for the drilling report signed by Sayid Fazl Ali, the present Governor).

GOVERNOR IS "DRILLER."—Sayid Fazl Ali, Governor of Assam, sits at the controls of Moran Well No. 7 and prepares to drill five feet of new hole.

STATE GOVERNOR IS 'DRILLER' AT NEW MORAN WELL

INVITATIONS to become honorary oil drillers have long been a feature of the programme for welcoming distinguished visitors to the scene of AOC drilling operations, and when the Governor of Assam, Sayid Fazl Ali, stepped up to the controls of Moran Well No. 7 on 10th January he repeated a little ceremony that dates back to the early days of the Digboi oilfield.

Thirty years ago this month a similar ceremony was performed at AOC Well No. 179, then the newest well in Digboi, the honorary driller on that occasion (5th February 1928) being Sir Laurie Hammond, then Governor of Assam. The drilling log signed by Sir Laurie that day has hung in the AOC's main office ever since, and now it is joined by the report signed by His Excellency Sayid Fazl Ali, who drilled five feet of new hole at Moran No. 7.

A comparison of the two records shows how the job of oil exploration and development has changed in that time. The objective of Digboi Well No. 179 was a mere 1,660 feet; that of Moran No. 7 is 11,000 feet or more.

D.I.C.'s Welcome

The Governor, who was accompanied by his wife, travelled to Moran by road from Dibrugarh with Mr. Maclachlan, and on arrival at the AOC camp the party were met by Sri A. S. Mukherjee, Driller-in-Charge.

Well No. 6, then being perforated, was the first site to be visited, and after Sri Mukherjee had explained the drilling technique to the Governor the party drove to the Moran camp where a guard of honour mounted by personnel of the company's Fire Service was reviewed. Coffee was then served, and a little later the visitors went on to the new well, No. 7, where they met Mr. P. G. Rouquette, the Driller-in-charge there.

Here the Governor, in the presence of a large gathering of workers, put on a safety helmet and protective gloves and set the drilling machinery in motion. After five feet of new hole had been drilled the ceremony concluded with the Governor signing the "daylight tour" report and inspecting the rig.

Sayid Fazl Ali's visit was highly appreciated by all at Moran (including people from the nearby tea gardens) and the AOC staff at the new well hope that the occasion will bring good luck to the operations there.

REFINERY RECORD

Crude oil throughput to the AOC refinery in Digboi in 1957 totalled 1,13,969,000 gallons—an increase of 9.5 per cent on the previous year's throughput and a record for the company.

As in past years roughly half the refinery's outturn of products was consumed in the BOC marketing areas of Assam, the balance going to markets in other parts of India—chiefly the north and north-eastern regions.

Panitola Tennis.—Byrne and Holden won the Men's Open Doubles at the Panitola Meet on 18th and 19th January. Runners-up were Rao and Surinder Singh. Mixed American Tournament, Section 1: Mr. Warner and Mrs. MacGregor. Section 2: Mr. and Mrs. Lancaster.

G REPORT FROM WELL NO Moran 7 DATE 10TH JANUARY, 1958

LING OF FORMATION	BITS OR CORE HEADS ON	TYPE	SIZE	REAMING FEET	REAMING HOURS	DRILLING FEET	DRILLING HOURS
NE	1	EDECO	12¼"			57	1·25
		"555" J	1				
T			TOTAL				

DEVIATION — PREVIOUS READING — AT

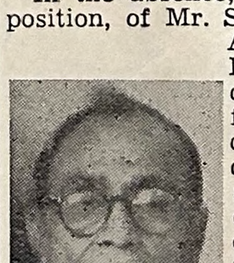
PULLING OUT, RUNNING IN — DETAILS	FEET DRILLED	TIME FROM	TIME TO
	5		
DRILLER			

FIVE FEET DRILLED.—Sayid Fazl Ali, Governor of Assam, sig this after he drilled five feet of Well No. 7 at Moran last month.

CALCUTTA BOC OFFICE ACTIVITIES

Three employees of our Calcutta office—in order of age, Sri D. N. Bose, Sri B. Mukherjee and Sri S. R. Chakrabortty—retired from the company's service at the end of December. To bid them farewell a party was held on the 30th.

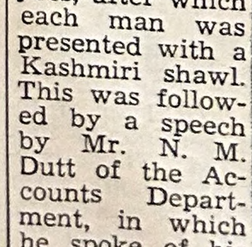
In the absence, owing to indisposition, of Mr. S. H. Utamsingh, Agent, Mr. K. N. Menon presided over the function, and to open the proceedings he gave a brief outline of services of each of the retiring employees.



Sri Bose

Sri D. N. Bose began his career as a typist with Bulloch Brothers were at that time looking after the affairs of the BOC in the Chittagong area. When the BOC established direct operations there in 1928, Sri D. N. Bose, joined the Group. During the Second World War, all but two clerical grade employees, including Sri D. N. Bose, were transferred from Chittagong to Masimpur office—and shortly thereafter, in 1944, Mr. Bose's connection with the and is therefore planning to start a typing institute.

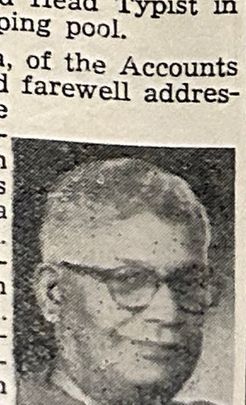
Sri B. Mukherjee also began his career with Bulloch Brothers in Chittagong, but some even years after Sri Bose, in 1924, and in a different line, as an Accounts Clerk. He too joined the BOC in 1928, and after seeing service at Masimpur came to the Calcutta office in 1949. Mr. Mukherjee, although originally from East Bengal, has settled down in Calcutta.



Sri Mukherjee

S. R. Chakrabortty was a comparative newcomer to the BOC having joined in 1928 as a stenographer in Karachi. His services with the company were terminated in 1941 when activities in the Karachi area were curtailed, and he rejoined in Calcutta in 1945 as Stenographer and Head Typist in charge of the typing pool.

Sri S. C. Guha, of the Accounts Department, read farewell addresses to the three retiring employees, after which each man was presented with a Kashmiri shawl. This was followed by a speech by Mr. N. M. Dutt of the Accounts Department, in which he spoke of his



ASSAM OIL WEATHER

After a long spell of dry w ther—too dry for some l gardeners of the station—at end of the old year, January c along with a patch of thund clouds over the hills, and e in the morning of the 6th th was a heavy fall of rain follo later by high winds and a c in the night temperature to degrees Fahrenheit on the 7th

In the first week of the m the maximum and minimum peratures were around 74 an degrees Fahrenheit respecti with an afternoon humidity c per cent.

Total rainfall for 1957 amo ed to 136.20 inches.

NOTE. *Keeping up with the cu trend in India the AOC Refi Laboratory's charts now re weather data in the metric sy but the measurements in i and Fahrenheit are shown a side the centimetres, millim and degrees of centigrade.*

Sahara Riches.—The "l gold" of the Sahara desert last beginning to flow to the from the oil wells inland. arrival by pipe line at the head on 8th January the first tank cars of crude were atta to a goods train bound for Ph ville. The French authorities precautions against rebel at

ডিগবই বাতৰি

Digboi Batori

House Journal of the Assam Oil Company

VOL. V | DIGBOI, AUGUST 1958. | No. 8

FIRST ARTICLE OF OUR NEW SERIES "STORY OF OIL" ON PAGE 5

UNION MINISTER AT NAHORKATIYA.—Sri Manubhai M. Shah, Union Minister for Industries, Ministry of Commerce and Industry, Government of India, visited Digboi and Nahorkatiya on 7th July. Our picture, taken at Nahorkatiya, shows Sri Shah (second from right) with Messrs. J. N. Hazarika, Member of Parliament; K. P. Tripathy, State Industries and Commerce Minister, M. R. M. Porter, Acting Fields Superintendent, Nahorkatiya, and K. B. Kanuga, the Acting General Manager of the Assam Oil Company.

CENTRAL & STATE MINISTERS VISIT ASSAM OILFIELDS

TOUR ROUND REFINERY & NAHORKATIYA CAMP

Sri Manubhai M. Shah, Union Minister for Commerce and Industry, paid a short visit to Digboi and Nahorkatiya on 7th July.

Sri Shah was received at Digboi by the Acting General Manager of the Assam Oil Company, Sri K. B. Kanuga, and had luncheon with him at the Bungalow No. 43. In the afternoon he visited the Digboi oil refinery and met Mr. J. H. Purdie, Acting Operations Manager, Sri A. Subramani, Acting Works Manager, and Mr. M. G. Brien, Chief Engineer, Refinery. After an inspection at the refinery the minister left for Nahorkatiya to visit the oil wells there.

Sri Shah was received at Nahorkatiya by the Acting Fields Superintendent, Mr. M. R. M. Porter, and was shown around the oil wells. He was then taken over to see the oil operations at the South bank and was entertained to a tea party.

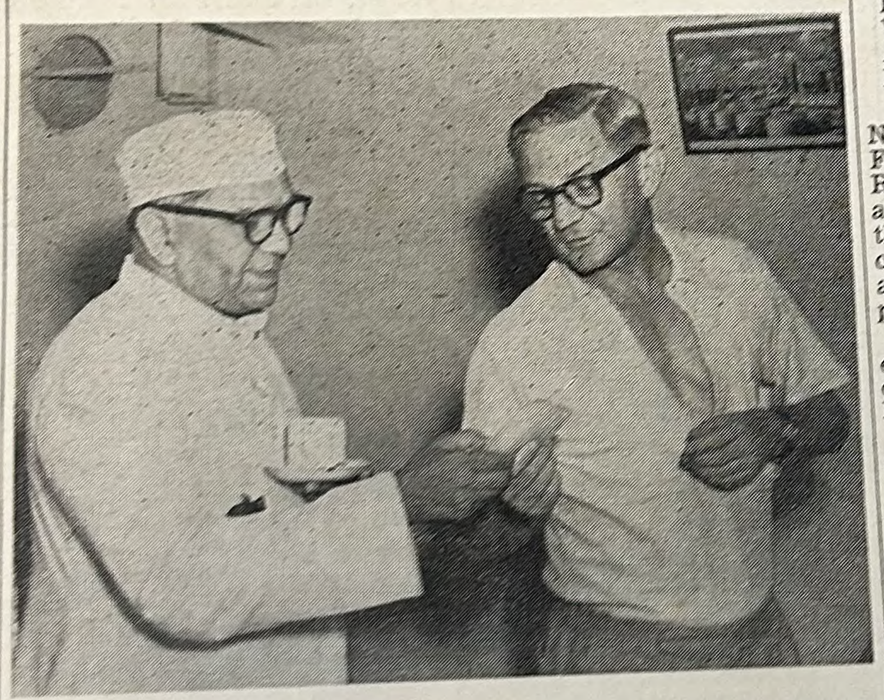
The Union Minister also inspected the pipelines carrying crude oil from Nahorkatiya oilfields to Digboi.

Sri K. B. Kanuga accompanied Sri Shah throughout his tour of the Assam Oil industry. The minister was also accompanied by Sri K. P. Tripathy, State Industries Minister and Sri J. Hazarika, a member of Parliament.

Another recent visitor to the oiltown was Sri Fakhruddin Ali Ahmed, the Judicial and Finance Minister, Government of Assam. He arrived at Digboi on 24th June and stayed with Mr. and Mrs. W. P. G. Maclachlan, at the Bangalow No. 1. He was shown round the refinery, the AOC Hospital and the S.G.I's office at Digboi. Sri Ahmed addressed a public meeting held at the India Club premises on 25th June.

Other visitors to Digboi were—Mr. D. K. Basu (Ibcons), Mr. J. B. Nandy (Nandy & Co.), Mr. D. G. Evered (Newman Hender & Co.), Messrs. Merjanov and Dumax (Rumanian oil experts), Mr. V. L. A. Descu (Interpreter), Mr. K. R. Gandhi (Junior Engineer, Ministry of Commerce and Industry), Messrs. Malovich and Pall Jackson (Geophysical Service International), Mr. S. Banerjee (Regional Officer, Labour Bureau, Calcutta); and Mr. K. Sen (Grant Advertising Inc., Calcutta).

A group of N.E.F.R. officials visited Digboi last month and met a number of AOC officials at the General Manager's office. The railway officials were Messrs. Hardip Singh, Ranjit Singh, P. Anthony and Varadachari, Sri Kanuga, Sri S. S. Ghosh, Mr. E. W. Humphreys, Mr. B. Buchan, Mr. J. H. Purdie, Sri P. K. Chaudhuri and Sri P. K. Deb from the AOC attended the meeting.



STATE MINISTER VISITS OILTOWN.—Sri Fakhruddin Ali Ahmed, Minister for Finance, Community Projects, Judicial and Legislative, came on a short visit to Digboi in the last week of June. He was shown round the town, oilfield and the refinery. The picture above shows Sri Ali examining a piece of wax with Mr. J. H. Purdie, AOC Works Manager.

WELL NO. 34 DRILLED IN 25 DAYS

ANOTHER SUCCESS AT NAHORKATIYA

UNDETERRED BY the steaming heat and periodic rainstorms, common in Assam during these months, the Assam Oil Company drillers, drilling crews, geologists and engineers, among many others, are working round the clock this month at three wells in the Brahmaputra Valley oil areas.

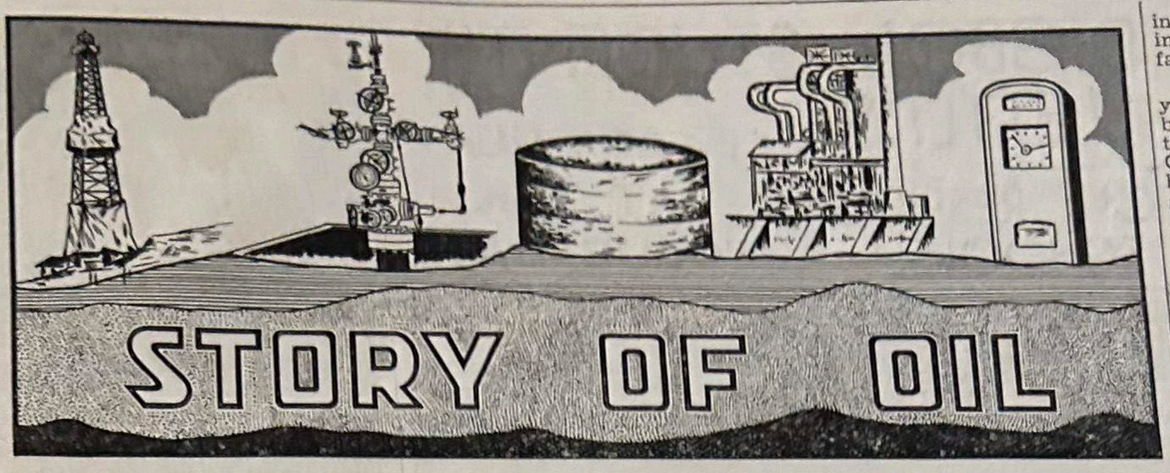
Well No. 34 at Nahorkatiya, completed in 25 days at a depth of 10,358 feet, demonstrates the speed of work in the valley. Production test carried out in the well on 22nd July confirmed that it is a good producer. The number of oil wells in the area, including this well, is now 23. The remaining 11 wells include two gas wells and five dry-holes, as already reported. Four wells, which have not yet given any indication of possible commercial production, await further prolonged testing which cannot be carried out until receipt of some modern equipments required for the purpose.

Erection of derrick, including the derrick platform, derrick floor, suction tanks and mud ditches was completed at Well No. 35 at the time of going to the Press. This well is expected to be spudded-in in early August.

The production test of the Well No. 9 at Moran, which was completed at a depth of 11,695 feet recently, is in progress. Three ranges which were tested so far, had to be plugged back as no indication of commercial production were obtained from them.

Digboi Golf Club.—Mr. D. McD. Thomson and Mr. W. A. M. Sherman again tied in the play off of the Earl Fuller Cup. Mr. W. McK. Holmes won the July Bogey and Mr. G. Wharton was runner-up. The semi-final of the P. J. Bowl will be played off.

RAILWAY OFFICIALS AT DIGBOI.—A view of the meeting of the railway officials held at the AOC General Manager's office last month.



ORIGIN OF PETROLEUM

IN PREHISTORIC TIMES much of what we know now as dry land was covered by warm seas. Giant trees and jungle plants and countless millions of tiny marine creatures flourished on the edges of the swampy, shallow waters. Their remains, when they died, fell to the bottom of the sea and were buried in layers of sediment.

As age upon age went by the original sea floors were folded or broken by tremendous movements of the earth's crust. Mountain ranges were pushed up. Parts of the earth cracked and slipped down to become valleys and basins. Tidal waves invaded the land to form new seas. Old sea beds emerged as new continents.

The history of oil is a part of the history of this past world. To understand the theory as to how oil originated we must also know the growth and development of the structure in which it is found today. The youngest crude oil is believed to have formed a little over 10 million years ago and the oldest about 440 million years before. Thus the story of oil is as old as time itself.

Chemically, petroleum is a complex mixture of hydro-carbons formed by a combination of two elements—Hydrogen and Carbon. The oil is generally associated with gas and water.

The Origin

For many years an acute controversy raged over the origin of petroleum. Opinions varied whether oil is of an organic origin or if originated from inorganic matter. No one is sure as yet how oil originated.

The most generally accepted theory and supported by evidence is in favour of an organic origin. In general terms, it is now believed that oil was formed by slow chemical or biochemical decomposition of the remains of lowly forms of organic life of the prehistoric animals and plants entombed in sedimentary rocks. Marine water sediments, rich in organic matter, are a necessary condition for the formation of oil.

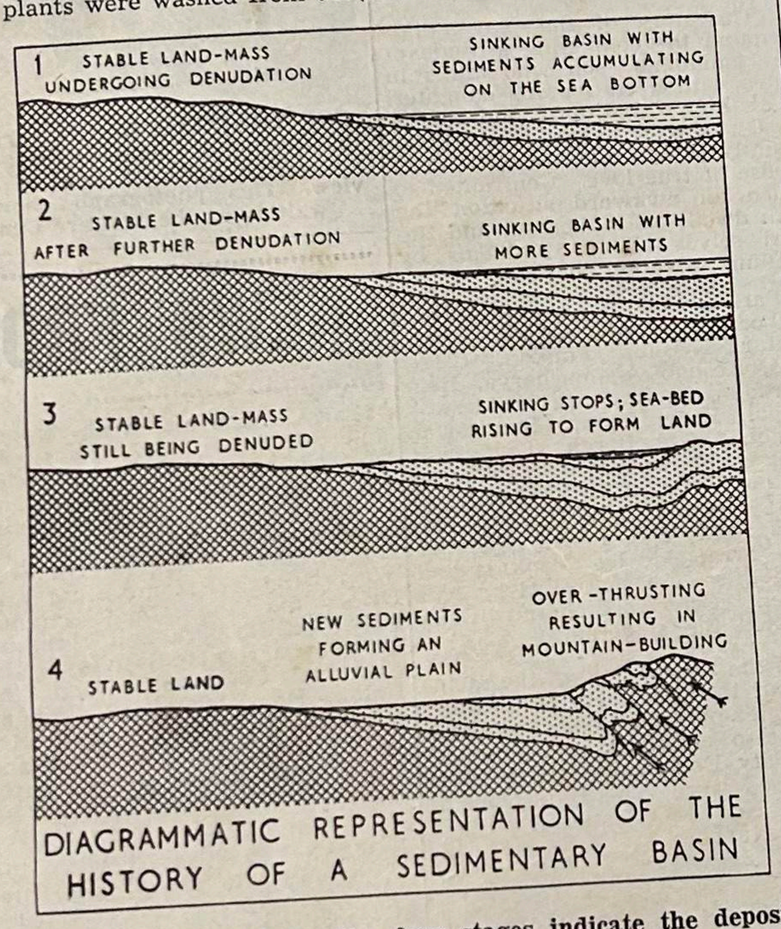
In order to visualize this condition we must imagine seas warm and rich in a prolific sub-marine vegetation and animal life. Those countless millions of sea-creatures depended for their food upon marine plant life into which the sun continuously poured its energy. This buried energy was another factor essential for the origin of oil.

In the gradually changing earth, much of its surface that is now dry land, was covered by seas. The changes in the earth crust occurred mainly due to two powerful forces, internal and external, acting upon the surface of the earth from within or outside. These two forces were also no less responsible, or in fact inevitable, for the formation of oil.

The internal forces of heat and pressure working within the earth acted upon the earth's outer shell causing some areas to sink, others to buckle or fold. The wrinkles on the earth were similarly caused by changes in temperature, wind, rain and snow. All these combined forces filled up the "Valleys" of the world or washed away the "hills".

Thus, during this vast span of time and across changing epochs, the remains of prehistoric animals and plants were washed from the lands into the seas. Bodies of marine animals also settled down to the bottom mingling with the sea-weeds and grasses. Rivers and streams further deposited other loose materials into the sea. Thus age after age, a huge mass of sediments with mud and sand was built up layer upon layer.

In course of time the fine sediments which continued to settle on the sea floor increased in weight and exerted a tremendous pressure on the lower strata. This caused the sediments to become more compressed and finally solidify. Thus mud became shale, sand became sandstone and the skeletons of marine animals became limestone.



DIAGRAMMATIC REPRESENTATION OF THE HISTORY OF A SEDIMENTARY BASIN

SEDIMENTARY BASIN.—The four stages indicate the deposition of a great thickness of sediments and the building of a mountain range on the site of a sedimentary basin.

The heavy weight of these rock layers through the years and centuries squeezed out the juice of the dead plants and animals lying on the bottom. The juice that was thus squeezed out was preserved by salt water. Subsequently, this organic material was transformed into compounds of hydrogen and carbon which we now know as oil and gas. The combination of heat, pressure and the action of bacteria which were not dependent upon oxygen and could function in the bowels of the earth were the joint factors for this transformation.

Thus, as coal has been called the 'Fossilized Sunlight', that fell on the land areas of the ancient world so petroleum may also be so called for the sunshine buried in the seas.

The newly-formed oil oozed out of the muds in which they were generated into the nearest layers of porous rocks. These porous rocks which were generally either sandstones or limestones held the oil as if in a sponge.

Earth Movements

Throughout the millions of years during which all these events occurred, many structural changes took place on the earth. Like a living being our mother earth also seemed to have stretched and relaxed and developed wrinkles. Rocks on the earth-crust were folded, bent, distorted or crushed in an extraordinary variety of ways as a result of such earth movements.

As the earth-crust rose and fell, mountain ranges formed and disappeared; in some places cracks developed—and where the land sank, ancient ocean waters rushed in to form seas between mountains. It was within these shallow sea-basins that maximum marine sedimentation took place and within them our modern oil-fields are located. The locations of such old sea-beds are now fairly well-known. They occur almost in every region of the earth.

Parts of the continent of India have shown proofs of such ancient marine sedimentary rocks. Waves of ancient seas once rolled over Assam, and close to the growing Himalayas and Naga Hills in the Brahmaputra Valley, the oil-pools of Digboi, Nahorkatiya and Moran began forming some million years ago.

It is believed much of what is today North and South America were once submerged under water and thus oil-bearing rocks originated there. From the locked-up oil reservoirs of this region now comes nearly half of the oil for the world.

What is now the Middle East—Iran, Iraq, Saudi Arabia and Kuwait, where some of the largest oil reservoirs are now located, were also ocean-beds in ancient time.

The face of the earth is still changing, although the changes can hardly be noticed in one's lifetime. Hills and mountains are still worn down by wind and rain and earthquake, rivers flood and change their courses and shore-lines are built anew or eaten away by shifting currents. Both internal and external forces are incessantly working on the surface of the earth.

If we could compress a million years into a single day we would be able to see the rapid changes taking place over the earth. Oceans would then dry up, new high mountain ranges would rise, great continents would appear from under water or sink down beneath the waves.

As the pressure of the added silts, sands and clays increased, the newly formed oil in the sediments below oozed out into more porous rocks and layers. After centuries these basins no longer continued to sink nor receive more sediments. They were pushed upward by internal forces within the earth, and subsequently the whole mass was raised above the level of the sea, and mountain ranges or lands were formed. Subsequently, these were subjected to immense forces which crumpled and tilted the layers, rupturing and folding them into the complex structures we see today.

As a result of density differences, gas occupied the highest part of the structure, oil the middle and water below.

Since the fluids in the rocks were always under pressure from above and since gas dissolves in oil due to the pressure, the oil in the structure always contain some amount of gas in its solution.

But if the gas was in greater quantity than could be kept in solution in the oil the excess gas filled the highest part of the structure forming what is known as a "Gas Cap."

The Oil Traps

When the layers of rock became tilted by processes of mountain-building, the stratified rocks were thrown into a series of folds or anticlines. The crests of these anticlines became traps for oil and gas. The most usual type of oil accumulation is under such anticlinical conditions.

Another type exists when the oil is concentrated along the edge of a wedge. Such an occurrence is called as a stratigraphic trap or shore-line oilfield.

Other types were caused by an intrusive body of salt giving a domed structure to the adjacent strata, or where the movement of the sandstone layers was sealed due to faulty structure of the earth.

Thus two conditions are most essential to hold petroleum in its reservoir :—

(1) There must be a suitable 'Cap-rock' or seal to prevent the escape of oil into higher layers.

(2) A structural or 'stratigraphic closure' to trap the oil and prevent its further movement within the layer.

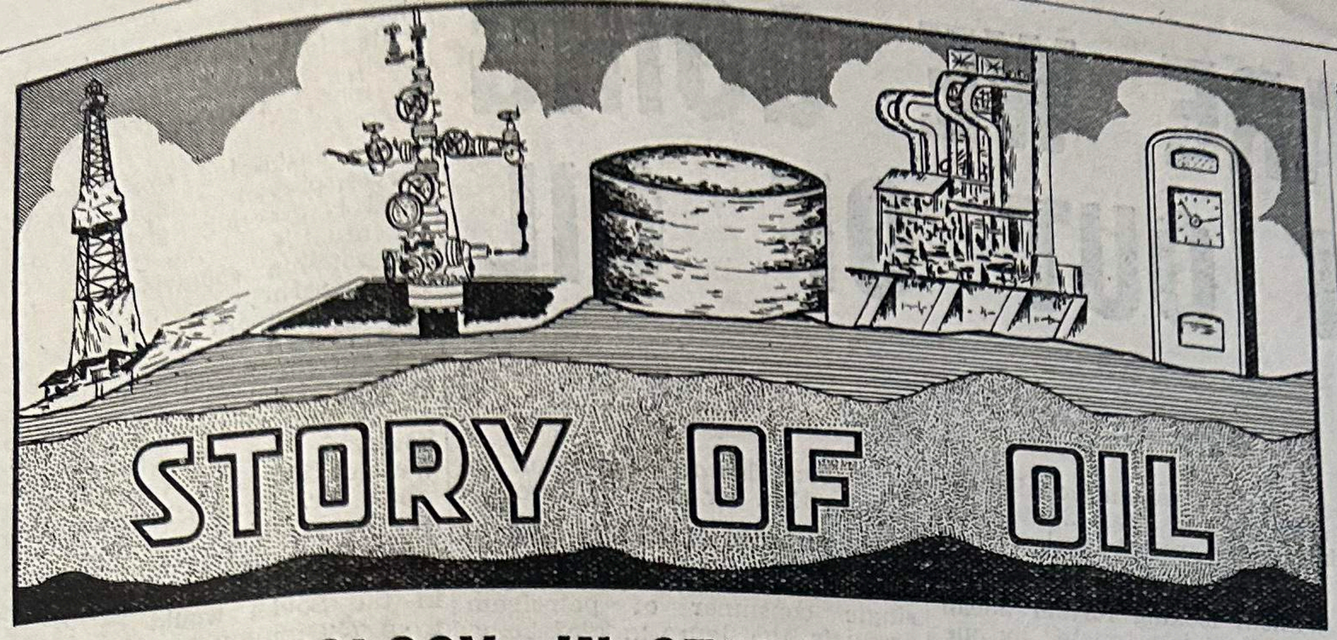
Triplets Born at AOC Hospital.—Wife of Sri L. S. Bhuiyan of the Tinsukia Installation gave birth to a triplets (two sons and one daughter) at the AOC Maternity Hospital, Digboi, last month.

FOLDING OF THE EARTH'S CRUST

FOLDING OF THE EARTH'S CRUST.—The internal forces of heat and pressure working within the earth and the external forces like rain, wind and snow cause the outer surface to sink, buckle or fold.

CONCENTRATION OF OIL IN AN ANTICLINE

OIL IN ANTICLINE.—In an anticline, as above, oil occurs in the pore-spaces of the highest part of the porous sand, water occupies the lower part of the structure. The other common types of oil traps are the fault, and the stratigraphic trap.



GEOLOGY IN SEARCH FOR OIL

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Oil in the ground is not found in pools, as is commonly believed. It occupies tiny little void spaces between the grains of solid looking but porous rocks quite often in association with some saline or brackish water.

Since oil is lighter than water, it tends to float up through these void spaces and migrate along the porous rock unless it is stopped by some form of blockage or other. All the droplets of oil, floating up through the porous rock, then start to accumulate against this blockage and form what is called an 'oil-pool'. The geological structures where such blockages exist are called 'traps'.

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It must also contain suitable beds of porous rocks like sandstone to act as oil-reservoirs. Another important condition is that the strata must be folded by nature into a suitable pattern to trap the oil and allow accumulation in an important amount.

Igneous or metamorphic rocks cannot be source rocks but they can act as reservoir rocks. Oil has been won from serpentine in the Thrall Field of Texas and from the contact of an igneous intrusion with sedimentary rocks in the Furbero field of Mexico. The reserves, and the recoveries, however, are not spectacular.

Primitive Exploration Methods

The present day highly scientific methods of exploration were wholly absent in the past and no information regarding the geological nature and formation of rocks was utilized in the hunt for oil. There were various guessing tricks and superstitious devices for locating an oil site.

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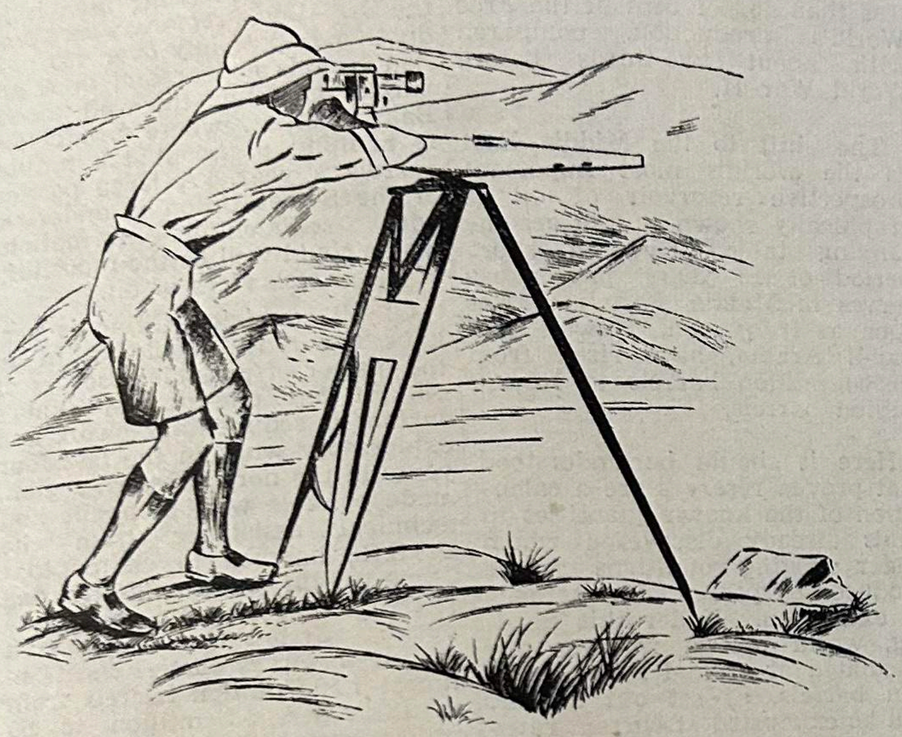

Yet another interesting method was the Doodlebug, which was nothing more than a tin-can on one end of a chain and held above a likely spot on the ground. If the can whirled round on the chain, oil was supposed to be found there.

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Rock Hound, The Geologist

In modern days oil exploration normally begins with a geological survey and the geologist determines if favourable conditions for oil accumulation exist in a given area. The duties of a petroleum geologist are extremely varied. Some of these are: study under the microscope of rock cuttings; study of fluorescence of samples; making and correlating well logs; "sitting on a well" (i.e.) remaining at a drilling well to secure data and give geological advice; making or interpreting geophysical evidence; apprising production; estimating reserves, etc.

The geologist explores enormous tracts of land in search of prospective oil structure and to find out if in the past geological conditions have favoured the formation of oil. His preliminary surveys can give sufficient information to enable a distinction between those areas which are worth the expense of further prospecting and those which can at once be rejected. The normal geological approach involves a great deal of specialized effort in order to meet the peculiarities of local conditions.

The oil geologist usually starts his work by compiling a comprehensive geological map and an intensive study of the structure of the rock layers. This surveying can be divided into two parts. It is first necessary to know if geological conditions favoured the generation of oil. This entails regional examination of the exposed layers of rock—an activity which has earned the geologist the nick-name of 'Rock Hound', and also a search for the tell-tale clues of oil or asphalt seepages, gas emanations or deposits of natural wax.

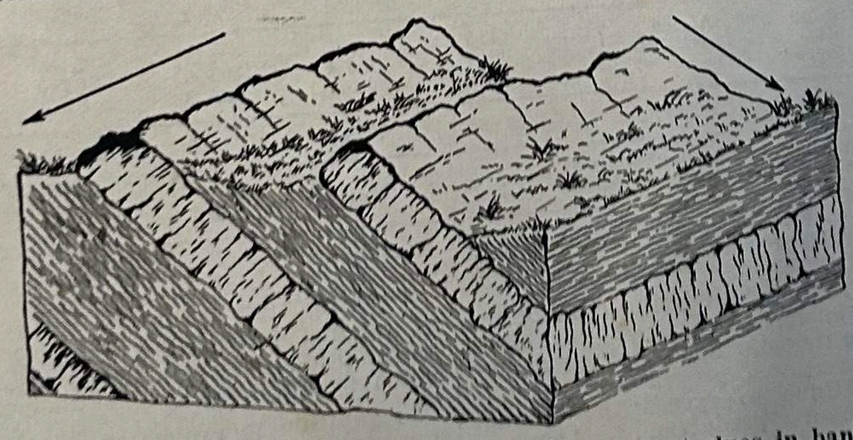
If conditions seem to be favourable, the rock structure must be further examined for possible oil accumulation therein. The delineation of these structures constitutes the geologist's most exacting task. He may find his best clues in banks of rivers and streams or in quarries and cliffs where layers of rocks are exposed. The inclination or 'dip' of these beds and the direction in which the beds extend or 'strike' may then be measured and clues for tilted structures may also be found. These points are important, for careful observation of the physical character of the rocks helps effective correlation with beds exposed elsewhere.

In areas where exposures are frequent, the field-work is comparatively straightforward. But the site of former sedimentary basins is frequently marked by low-lying areas or alluvial plains and in such areas the evidence of the rock structure is completely obscured from view by a mantle of alluvium, marsh or tropical forest. In such cases other methods have to be called into use for geological study and for supplementing the deficiencies of the surface picture.

Aerial Survey

Normally, the geologist starts his work with an aerial survey. For compilation of the geological map, hundreds of photographs are taken from the air. The technique of aerial photographic mapping has been increasingly used especially for conducting the search in new territories.

The photographs guide the geologist by showing the most reliable topographic base and vegetation pattern of the regions. This helps further detailed ground surveys. The stereoscope is a great aid in obtaining a three dimensional view of the region covered by the photographs. With the help of this instrument geological evidence is made visible even in densely wooded regions and by examination of pairs of photographs, correlations of formations can be made.



DIP AND STRIKE.—The geologist may find his best clues in banks of rivers and streams or in quarries and cliffs where layers of rocks are exposed. The inclination or 'dip' of these beds and the direction in which the beds extend or 'strike' are helpful for effective correlation.

Other Sciences

Where the structure as exposed at the surface does not provide sufficient information, geological data as revealed by the deeply drilled wells becomes very useful. This type of work is called sub-surface geology.

Fossilised remains of ancient plants and animals in the rock are an important clue to the period in which the rock was formed. They also throw light on the prevailing environmental conditions and this is of great significance in petroleum geology. The man who makes a scientific study of fossils is called a palaeontologist and those who specialise in the study of plant fossils are palaeobotanists.

That branch of geology which deals with the genesis and constitution of rocks is called petrology and the scientist who studies these phenomena is a petrologist.

Both petrology and palaeontology are of very great help in establishing satisfactory correlations of sub-surface formations.

When all surfaces of geological information have been exhausted, the next step in the hunt for oil is to explore deep beneath the surface. The physical method of investigating the sub-surface structure of the earth is called geophysics.

Oil Reserves and Resources

Reserves or 'proved reserves' as they are often called mean the underground stock of oil which has actually been discovered. Resources or 'ultimate resources' refer to the total quantity of oil, both discovered and undiscovered, and which may be produced in the future on the basis of most scientific guess possible.

There are a great number of areas on the earth where conditions seem to be particularly favourable for the occurrence of oil.

The proved reserves of the land area bordering the Gulf of Mexico and Caribbean Sea which include parts of the United States, are estimated to be of 28 thousand million barrels. From this area has come 40 per cent of the oil the world has used so far.

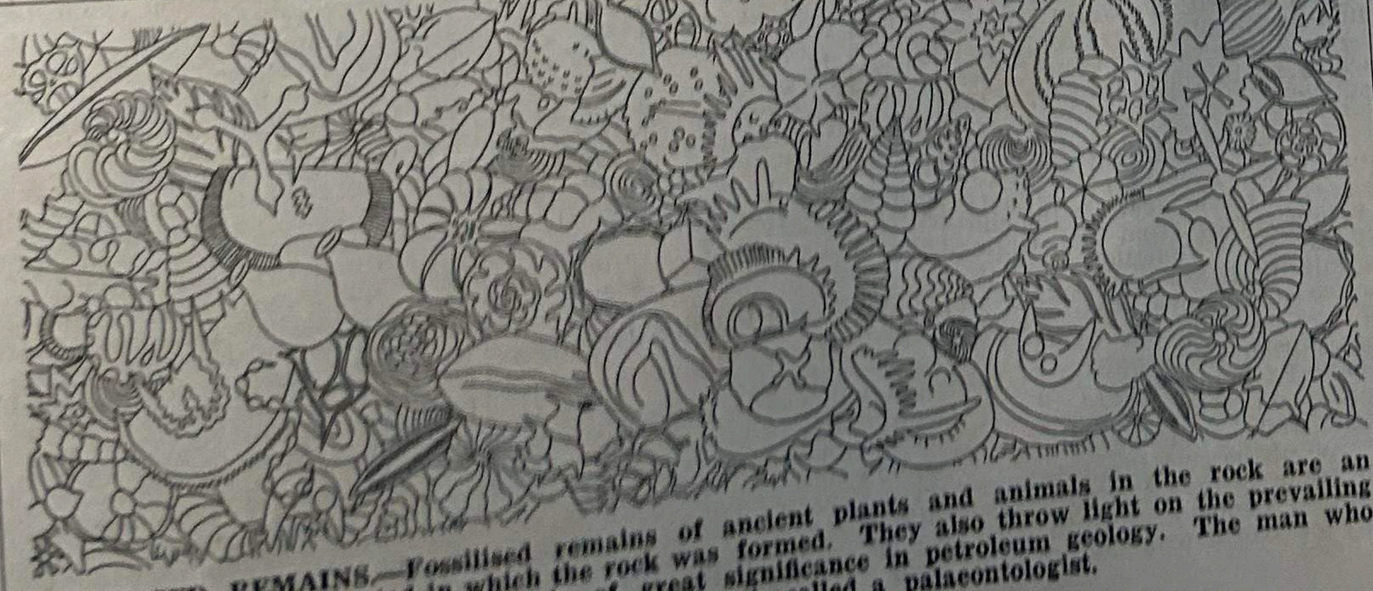
Another great petroleum region lies in the Middle East bordering the eastern end of the Mediterranean Sea, the Caspian, Red and Black Seas and the Persian Gulf. Here are the rich deposits of Iran, Iraq, Saudi Arabia, South Western Russia, and Kuwait.

It has been estimated that the Middle East has proved reserves of some 75 thousand million barrels. Commercial production from oil deposits in Iran began in 1908, Iraq in 1934, and Saudi Arabia in 1940. This region has shown itself to be perhaps the world's greatest storehouse of petroleum.

There is another petroleum region lying between Asia and Australia and made up of the islands of the East Indies. The chief fields are on Sumatra, Java and Borneo and has proved reserves of over two thousand million barrels.

In addition to these areas there are other oil regions of varying importance scattered throughout the world.

Discoveries of new fields have constantly added to the proved reserves of the world. Some of the known reserves are found to be larger than first supposed.



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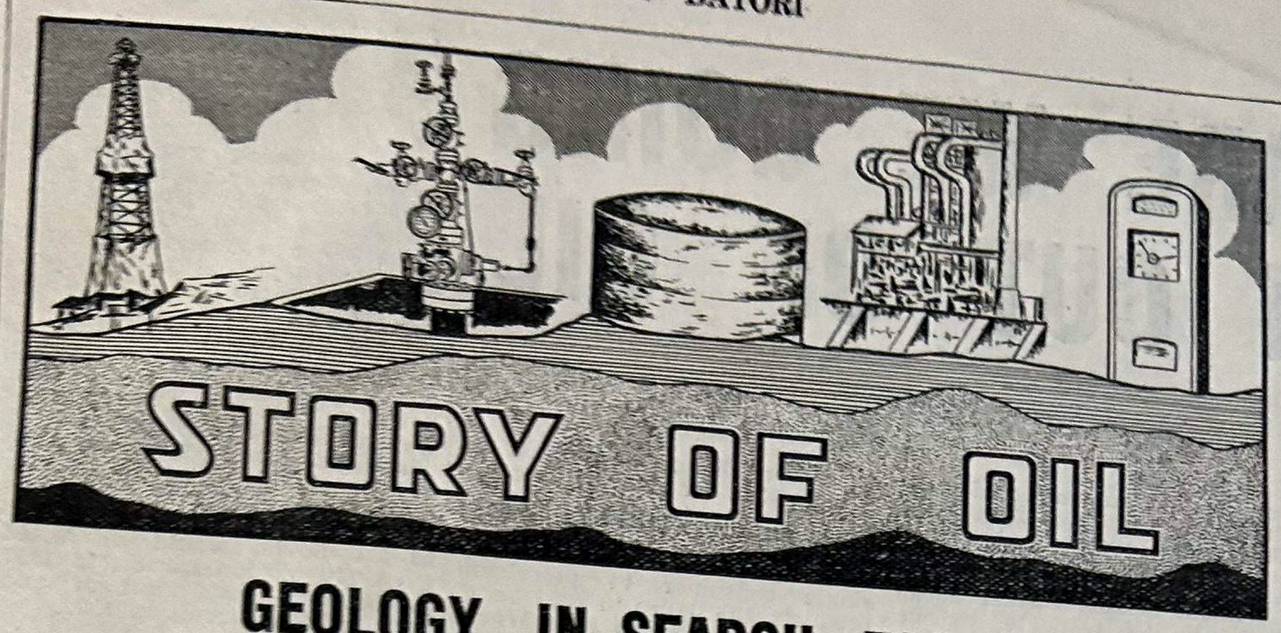

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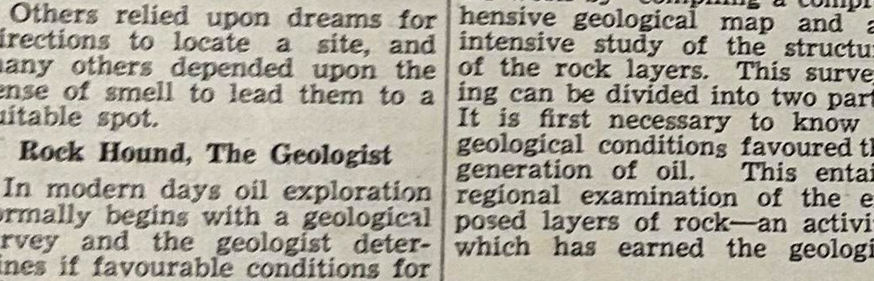

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Rock Hound, The Geologist

In modern days oil exploration normally begins with a geological survey and the geologist determines if favourable conditions for oil accumulation exist in a given area. The duties of a petroleum geologist are extremely varied. Some of these are: study under the microscope of rock cuttings; study of fluorescence of samples; making and correlating well logs; "sitting on a well" (i.e.) remaining at a drilling well to secure data and give geological advice; making or interpreting geophysical evidence; apprising production; estimating reserves, etc.

The geologist explores enormous tracts of land in search of prospective oil structure and to find out if in the past geological conditions have favoured the formation of oil. His preliminary surveys can give sufficient information to enable a distinction between those areas which are worth the expense of further prospecting and those which can at once be rejected. The normal geological approach involves a great deal of specialized effort in order to meet the peculiarities of local conditions.

The oil geologist usually starts his work by compiling a comprehensive geological map and an intensive study of the structure of the rock layers. This surveying can be divided into two parts. It is first necessary to know if geological conditions favoured the generation of oil. This entails regional examination of the exposed layers of rock—an activity which has earned the geologist the nick-name of 'Rock Hound', and also a search for the tell-tale clues of oil or asphalt seepages, gas emanations or deposits of natural wax.

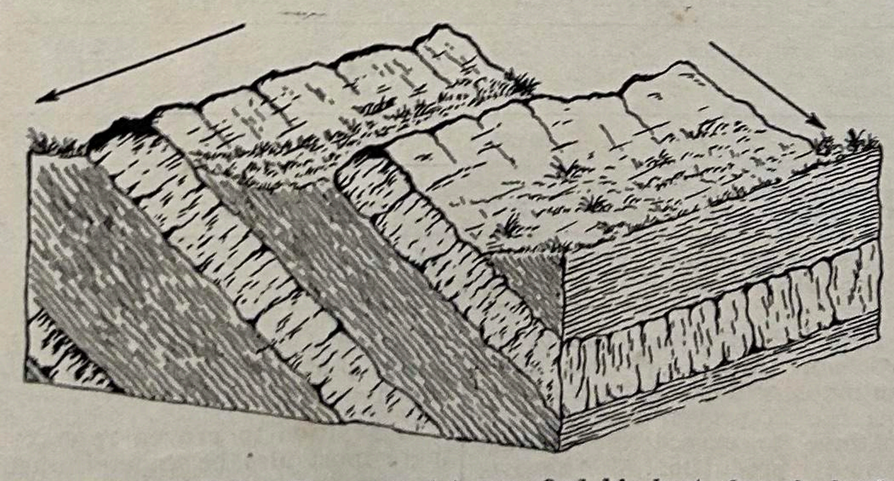
If conditions seem to be favourable, the rock structure must be further examined for possible oil accumulation therein. The delineation of these structures constitutes the geologist's most exacting task. He may find his best clues in banks of rivers and streams or in quarries and cliffs where layers of rocks are exposed. The inclination or 'dip' of these beds and the direction in which the beds extend or 'strike' may then be measured and clues for tilted structures may also be found. These points are important, for careful observation of the physical character of the rocks helps effective correlation with beds exposed elsewhere.

In areas where exposures are frequent, the field-work is comparatively straightforward. But the site of former sedimentary basins is frequently marked by low-lying areas or alluvial plains and in such areas the evidence of the rock structure is completely obscured from view by a mantle of alluvium, marsh or tropical forest. In such cases other methods have to be called into use for geological study and for supplementing the deficiencies of the surface picture.

Aerial Survey

Normally, the geologist starts his work with an aerial survey. For compilation of the geological map, hundreds of photographs are taken from the air. The technique of aerial photographic mapping has been increasingly used especially for conducting the search in new territories.

The photographs guide the geologist by showing the most reliable topographic base and vegetation pattern of the regions. This helps further detailed ground surveys. The stereoscope is a great aid in obtaining a three dimensional view of the region covered by the photographs. With the help of this instrument geological evidence is made visible even in densely wooded regions and by examination of pairs of photographs, correlations of formations can be made.



DIP AND STRIKE.—The geologist may find his best clues in banks of rivers and streams or in quarries and cliffs where layers of rocks are exposed. The inclination or 'dip' of these beds and the direction in which the beds extend or 'strike' are helpful for effective correlation.

Other Sciences

Where the structure as exposed at the surface does not provide sufficient information, geological data as revealed by the deeply drilled wells becomes very useful. This type of work is called sub-surface geology.

Fossilised remains of ancient plants and animals in the rock are an important clue to the period in which the rock was formed. They also throw light on the prevailing environmental conditions and this is of great significance in petroleum geology. The man who makes a scientific study of fossils is called a palaeontologist and those who specialise in the study of plant fossils are palaeobotanists.

That branch of geology which deals with the genesis and constitution of rocks is called petrology and the scientist who studies these phenomena is a petrologist.

Both petrology and palaeontology are of very great help in establishing satisfactory correlations of sub-surface formations.

When all surfaces of geological information have been exhausted, the next step in the hunt for oil is to explore deep beneath the surface. The physical method of investigating the sub-surface structure of the earth is called geophysics.

Oil Reserves and Resources

Reserves or 'proved reserves' as they are often called mean the underground stock of oil which has actually been discovered. Resources or 'ultimate resources' refer to the total quantity of oil, both discovered and undiscovered, and which may be produced in the future on the basis of most scientific guess possible.

There are a great number of areas on the earth where conditions seem to be particularly favourable for the occurrence of oil.

The proved reserves of the land area bordering the Gulf of Mexico and Caribbean Sea which include parts of the United States, are estimated to be of 28 thousand million barrels. From this area has come 40 per cent of the oil the world has used so far.

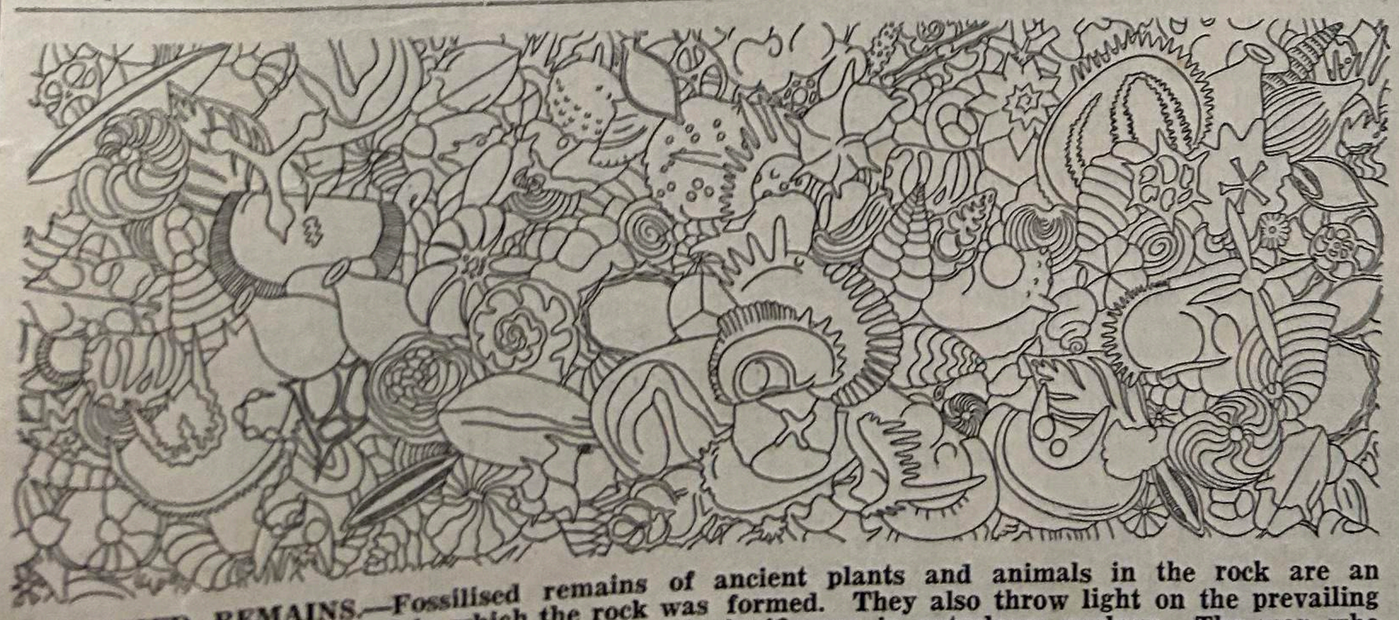
Another great petroleum region lies in the Middle East bordering the eastern end of the Mediterranean Sea, the Caspian, Red and Black Seas and the Persian Gulf. Here are the rich deposits of Iran, Iraq, Saudi Arabia, South Western Russia, and Kuwait.

It has been estimated that the Middle East has proved reserves of some 75 thousand million barrels. Commercial production from oil deposits in Iran began in 1908, Iraq in 1934, and Saudi Arabia in 1940. This region has shown itself to be perhaps the world's greatest storehouse of petroleum.

There is another petroleum region lying between Asia and Australia and made up of the islands of the East Indies. The chief fields are on Sumatra, Java and Borneo and has proved reserves of over two thousand million barrels.

In addition to these areas there are other oil regions of varying importance scattered throughout the world.

Discoveries of new fields have constantly added to the proved reserves of the world. Some of the known reserves are found to be larger than first supposed.



FOSSILISED REMAINS.—Fossilised remains of ancient plants and animals in the rock are an important clue to the period in which the rock was formed. They also throw light on the prevailing environmental conditions and this is of great significance in petroleum geology. The man who makes a scientific study of fossils is called a palaeontologist.

WHEN ARE WE GOING TO RUN OUT OF OIL

IT is known that the world's reserves of oil are limited and cannot, therefore, serve our needs indefinitely. How imminent is the time when there will be no more crude oil available? How large are the world's proven and estimated reserves of petroleum? These questions become pressing in the light of our certain knowledge that the next quarter of a century will see a tremendous increase in world demand for all forms of energy.

It is, of course, quite a simple matter to estimate how long proven reserves of oil will last, by considering them in relation to the current rate of consumption. For example, it is estimated that proven reserves of oil throughout the world, including U.S.S.R. and its satellite countries, amount to around 265,000 million barrels. On the basis of the current rate of world consumption of all petroleum products of 18,520,000 barrels a day in 1957, existing proven reserves of oil would be exhausted in 39 years.

This calculation is, however, of academic interest only, for the reason that the consumption of petroleum products throughout the world has been increasing at an average rate of 8 per cent compounded since 1940, and will almost certainly continue to increase further; and that every year, the existence of higher and higher reserves of oil are proven, which so far have taken care of the quite fantastic increase in demand over the last quarter of a century.

Likely Increase in Demand

In the first place, it is useful to consider what may be the likely increase in demand for oil in the foreseeable future. The future demand for oil must be considered in relation to the demand for all forms of energy, which is expected to rise, according to reliable authorities, by approximately 3 per cent per annum compounded. The current world demand for energy is about two-and-a-half-times what it was in 1920.

The three main sources of energy are coal, oil and hydro-electricity. The most significant feature about these three is that the relative contribution of coal to total energy supplies has fallen from about five-sixths in 1920 to approximately one-half today. Oil has improved its position as a contributor of approximately 17 per cent of the world's energy to 41 per cent, and hydro-electricity, despite the enormous capital expenditure involved in constructing power plants, now provides 8 per cent of the world's energy, compared with 3 per cent 38 years ago.

These figures illustrate the trend which everyone knows is going on. Oil has almost completely displaced coal as a fuel for ships, while in railway transport, both oil-fired steam locomotives and diesel-electric locomotives are taking an increasing place in the world's railway systems because of their greater efficiency and greater economy. In road transport, petrol and diesel oils are virtually the only fuels used.

Assuming that world energy requirements increase at the rate of 3 per cent per annum compounded, they would be one-and-three quarter times their present level by 1975, which is possibly as far ahead as can reasonably be considered the future. But just to be a little rash, and look ahead 40 years (which is a very long time in this world of rapid change), a continued increase of gross energy requirements at 3 per cent per annum would make them, by the year 2,000, four times their present level.

Sufficiency of Reserves

Without looking further ahead than 1975, it is estimated by one American oil economist, Dr. Joseph E. Pogue, that by that date world energy demands will require the production of at least 33 million barrels of oil a day, which is about double the record world production of 17,671,000 barrels a day in 1957. Having regard to the present size of the oil industry, with its vast ramifications over the whole civilized world, the prospect of a doubling of production over a mere 17 years is quite staggering.

There would be little point in seriously considering a doubling of production of oil unless there were sufficient reserves to meet the drain, for oil drilling is after all an extractive industry, similar to mining, and supplies on any normal reasoning cannot be expected to last indefinitely. An estimated consumption of 33 million barrels a day in 1975 is clearly beyond the capacity of producing fields, at their present stage of development, to meet. There will, therefore, need to be a great expansion of producing fields accompanied by a widening of proven reserves.

ESTIMATE OF WORLD PROVEN RESERVES

*(Millions of Barrels)

LOCATION	As at Jan., 1944	As at Jan., 1950	As at Jan., 1955	As at Dec., 1957
U.S.A. ...	20,064	25,909	29,297	33,000
Venezuela ...	5,600	9,500	10,198	16,000
Rest of Western Hemisphere	1,886	3.101	5,358	9,005
TOTAL AMERICA ...	27,550	38,510	44,853	58,005
MIDDLE EAST—				
Iraq ...	4,000	5,250	14,146	25,000
Iran ...	5,000	7,000	27,102	32,000
Kuwait ...	4,000	11,000	30,000	60,000
Saudi Arabia ...	2,000	9,000	30,816	45,000
Others ...	500	163	1,826	7,501
TOTAL MIDDLE EAST ...	15,500	32,413	103,890	169,501
Europe and Africa ...	293	583	917	2,183
Russia and Satellites ...	6,157	4,614	10,090	26,200
Others ...	1,195	1,577	2,659	8,578
TOTAL ...	50,695	77,757	162,409	264,467
Number of equivalent years at current consumption rates	22.4	23.0	32.7	39.1

*1 barrel=35 imperial gallons or 42 U.S. gallons.
7.5 barrels=1 long ton of average crude oil.

Here indeed is the crux of the problem. Experience has given the industry hope that the annual increase in proven reserves will continue to exceed the average annual production. Whenever there have been fears about the possibility of oil reserves being exhausted, new fields have been discovered and new reserves proven. The discovery of vast reserves in the arid deserts of the Arabian Peninsula, which superficially was the last place that one would expect oil to be found, altered the world oil picture overnight. There could well be new discoveries in the future, which again could transform the outlook.

The most significant aspect of the discovery of new proven reserves in recent years is the shift in importance from the United States and Venezuela to the Middle East as a repository of future oil supplies. Today about 20 per cent of the world's oil comes from the countries of the Middle East, and 60 per cent from North and South America. It might well be in the future, as a result of the depletion of American resources or a sharp increase in world demand, or both, that the Free World will have to rely to an overwhelming extent on the Middle East for most of its oil.

Importance of Middle East

The United States is the largest single consumer of petroleum products, the figure in 1957 being about 55 per cent of Free World consumption. In the same year, it was responsible for something less than 46 per cent of the Free World's production, compared with about two-thirds before World War II.

The shift to the Middle East as the world's most important prospective reservoir of oil is graphically shown in the accompanying table. Over a short period of 13 years, proven reserves in Middle East countries such as Iraq, Iran, Kuwait and Saudi Arabia, have risen from 15,500 million barrels to 169,500 million barrels.

Here it should be understood that proven reserves are a calculation of the known quantities in fields already discovered which under existing conditions can be produced by present-day methods of extraction. Under this heading, world proven reserves are calculated at around 265,000 million barrels, as set out earlier, will be exhausted at current rates of consumption in 39 years, but set against foreseeable rates of consumption they could be depleted by 1975.

In addition to proven reserves, there must also be undetermined amounts of oil existing outside the so-called proven areas, together with large amounts still awaiting discovery in the extensive potential oil-bearing areas of the world. A large portion of Australia, for example, consists of sedimentary rocks, a geological formation where oil, if it exists, will be found. So far, all efforts to find oil in commercial quantities in Australia and Territories have not met with success, but that is not to say that it will not ultimately be found here. After all, success came in the Middle East and in Canada only after years of frustrating, disappointing and costly search.

U.S.S.R. and Satellite Countries

Estimates of unproven oil reserves naturally do not have the same value as proven figures, but as a matter of interest it is worth mentioning that in 1954 the world's ultimate recoverable reserves were placed at 600,000 million barrels, an estimate which excluded the Continental Shelf. More recent data suggests that a re-assessment of the estimate, including the Continental Shelf, could well place reserves at more than 1,000,000 million barrels.

In considering world oil reserves, proven or unproven, little heed is generally given to the potentialities of the U.S.S.R. and its satellite countries, for the reason perhaps that statistics and information are so difficult to obtain with the present reluctance of the Soviet authorities to give information. The potential oil wealth of the U.S.S.R. was, however, brought before the Western World in November last when Mr. Khrushchev, speaking at the jubilee session of the Supreme Soviet in Moscow, predicted that crude oil production in the Soviet would be raised from 750 million barrels in 1957 to between 2,500 million and 3,000 million barrels in 1972.

The main producing area is in the Ural-Volga regions, where production is probably over 450 million barrels a year and in Azerbaijan, including the well-known Baku district, where production is running at about 120 million barrels a year. A large portion of the Soviet Union is underlain with sedimentary formations which could well be the repository of large reservoirs of oil.

Of all countries, China is perhaps the most problematical in the matter of possible reserves of oil. At least one-third of China's surface is sedimentary basin, and exploratory work in the last four years in the north-western region, made possible with economic and technical assistance from the U.S.S.R., has led to claims that China might be potentially one of the richest oil countries in the world. Claims are made that proven reserves have risen to almost 1,500 million barrels from an estimated 50 million to 60 million barrels in 1950, with probable reserves amounting to nearly 20,000 million barrels.

Future will Tell

These figures are not found in the tables of the Western oil economists and only the future will show if these claims can be substantiated. As one commentator says "a correct assessment of China's oilfield potential will become possible after the results of a serious exploratory programme have become available and evaluated". But in comparison with reserves, China's production rates are lamentably low, and in 1957 the country stood at the bottom of the oil-producing countries, with an output of only 30,000 barrels a day.

The important feature about estimates of reserves, both proven and unproven, is that their steady increase has paralleled the actual experience of production in the industry. Year by year, the rate of discovery has been, and continues to be, considerably higher than the rate of withdrawal. This process cannot, it is true, continue indefinitely, but on the most pessimistic estimate it does suggest that there will be ample oil available to meet increasing world energy needs until we move into the age of atomic power.

Everyone is agreed that ultimately atomic or some other kind of newly-discovered power will have to take over the provision of energy when either coal or oil, or both, becomes either exhausted or too costly to utilize. That is mainly a matter for the future, for the development of nuclear energy for peaceful purposes is still only in its infancy.

However, at this stage some estimates have been made about the role which nuclear energy will occupy in the power picture in Britain and the United States by 1975, and these suggest that by then it will have displaced neither coal nor oil as a major contributor of energy. In the long run, there is little doubt that nuclear power will be the main provider of world energy.

In Britain, where the development of nuclear power over the next 20 years is likely to be well above the average of the world, the British Government estimates that by 1975 nuclear power will provide the equivalent of about 40 million coal tons. The present consumption of energy in Britain in all its forms is estimated at about 250 million coal tons a year, and by 1975 this could rise to somewhere around 400 million coal tons a year. Therefore, on these calculations, atomic energy is unlikely by 1975 to be providing more than 10 per cent of Britain's needs and the average for the world would certainly be much lower.

The British Government's estimates are broadly in line with those of the National Planning Association, a non-profit-making, privately-sponsored economic research organization in the United States, which forecast that by 1980 nuclear sources would supply about 9 per cent of total energy consumed in the United States. Oil at twice its 1955 volume would account for 41.5 per cent and natural gas 23 per cent, representing a rise of more than two-thirds in volume.—*From "Petroleum Gazette" June 1958.*

BUDDHIST FESTIVAL

Ashari Purnima At Digboi

DISCIPLES of Tathagata the Buddha assembled at the Digboi Buddhist Temple recently to celebrate the Ashari Purnima festival with due pomp and solemnity. On this full moon day Gautama Buddha renounced all worldly pleasures and preached his first sermon at Sarnath after attainment of the "supreme wisdom."

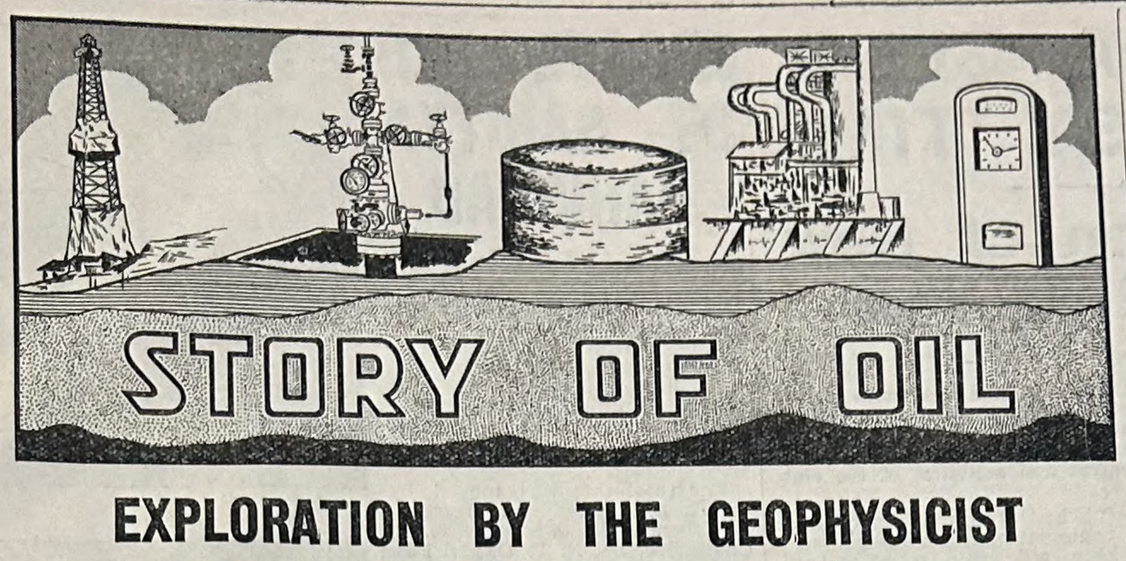
An elaborate programme of religious functions was gone through and the holy teaching of the Lord were reiterated on the occasion. The people were reminded of the Buddhist ideal that those who follow the Buddha and his doctrine of Dharma and Sangha will not be reborn as insects or animals, nor have to suffer hereafter in hell, but shall reborn in the domain of the gods to enjoy perfect bliss.

The ceremony started with flag hoisting at the Buddha Bihar in the morning. It was followed by kirton, utsarga and worship. Another feature was Pinda-dan to Bhikkhu Sangha. In the afternoon a religious meeting was held and a Panchasila-pradan ceremony was performed. Other items in the programme were pradip puja, kirton and light refreshment.

* * *

At the annual general meeting held on 30th July at the Buddhist Temple premises with Rev. Buddhananda Bhikshu on the chair new office bearers of the Digboi Bouddha Bihar Samity were elected. They were Sri Tara Kinkar Barua—President; Sri Hemendra Lal Barua—Vice President; Sri Manindra Lal Barua and Sri Sudhir Ranjan Barua—Joint Secretaries; Sri Mati Lal Barua and Sri Amulya Ratan Barua—Assistant Joint Secretaries; Sri Jogesh Chandra Talukdar—Cashier; Sri Parimal Bikash Barua—Auditor. Sri Sudarsan Bikash Barua, Sri Birat Kumar Barua, Sri Himangshu Bimal Barua, Sri Kamini Kumar Barua, Sri Pradut Kumar Barua, Sri Rahul Bikash Barua, Sri Rabindra Lal Barua, Sri Sukendu Bikash Barua, Sri Rajani Mohan Barua, Sri Priya Nath Barua and Sri Jogendra Lal Barua—Committee Members.

Film Show.—Sri K. Ramchandani, a chemist of the AOC Refinery, organised a film show at the Sports Club, Digboi, on 1st August. Films screened were—Charlie Chaplin, Laurel and Hardy—mixed comedy; Sindbad the Sailor—colour cartoon; Magic Drum, Human Fishing Boat, Can You Guess, Birds, Beasts and Insects, and Travelogue colour films. The show was well attended.



EXPLORATION BY THE GEOPHYSICIST

IN THE SEARCH for prospective oil bearing structures the amount of information that can be gained from the study of the earth's surface is very limited. Thick blankets of soil or alluvium frequently keep the rocks obscured from our view and the underlying concealed strata cannot be mapped by geological work on the surface. In such cases the geologist has to call on the assistance of the geophysicist for help in probing deeper into the earth. By geophysics is meant any physical method of mapping and investigating the deeply buried layers of rock structures in the earth's crust. Geophysics does NOT tell us if oil is present or not. It merely indicates the existence or non-existence of structural conditions favourable for the accumulation of oil.

Geophysical methods of prospecting are based on magnetic, gravimetric, seismic or electrical principles, each of which has some advantages in certain circumstances. The geophysicist's main tools in the look-out for possible oil bearing rock formation are the magnetometer, the gravimeter and the seismograph. With the help of these instruments and methods he makes extensive surveys to 'feel' below the earth to find if conditions suitable for oil accumulation exist in a given area.

The Magnetic Method

The magnetic method in a geophysical survey consists of measuring the earth's magnetic field. Variations in the magnetic attraction may be corelated to the distribution of rocks of different magnetic properties.

Sedimentary rocks which may contain oil are less magnetic than the harder rocks which contain no oil. Again, where there are dense rocks relatively near the surface, the magnetic intensity will be higher.

The instrument used in magnetic survey is called the Magnetometer. It measures accurately the magnetic field and helps in obtaining data on which to base further estimates as to the potentialities of the rocks as possible oil-traps. This tiny bomb-like apparatus is relatively new in the field of geophysics and was developed during World War II for submarine reconnaissance work.

The heart of the magnetometer is little bigger than a cigarette and has a magnetically sensitive electronic element. Its unusual abilities record variations in the magnetic attraction which in turn indicates change in the composition or formation of the earth's crust.

In air-borne magnetometer survey a small magnetometer is mounted in an aeroplane which flies back and forth with navigational precision at a fixed altitude over a predetermined area. The meter is attached in a tabular case to the tail of the surveying plane, and in its operation great care is taken for prevention of any interference by the metal in the plane.

While in flight the magnetometer constantly measures the magnetic intensity which is a function of the distance and magnetic property of the rock formations in the underground strata. These measurements are transmitted electrically to the cabin of the plane where they are recorded automatically on special instruments.

The record appears on a roll of graph paper as a faint continuous red line. When the survey over the required area is completed the huge rolls of sheet are handed over to the petroleum scientists for further study. Geologists and geophysicists use the data for preparation of large-scale contour maps to determine the shape of the strata and discover the position of oil bearing formations. These maps represent only the first step in the exploration for oil.

The air-borne magnetometer survey compresses into a few hours, a job that would normally take a field unit months to complete—and it does so at a relatively lower cost.

To get a clearer picture of the few possibly favourable areas indicated by the magnetometer, the geophysicist further uses additional precision instruments such as the gravimeter and seismometer.

The Gravity Survey

The gravimetric method, depends on the use of highly scientific sensative instruments such as pendulums, gravimeters or torsion balances. Invented by a Hungarian scientist, Baron Von Eotvos, the torsion balance was first used for oil finding by Dr. H. de Bockh, also a Hungarian. These instruments measure the earth's force of gravity in a given area.

Gravity is the pull of the earth upon an object. The earth does not have the same gravitational force in all places. Distribution of rocks of different density and weight in the underground strata causes variations in the pull. Heavy and dense rocks exert a greater pull than rocks which are lighter and less dense. Rocks near the surface also pull harder than rocks of the same kind and size at greater depth. A man weighs more when he stands on granite rocks than when he stands on sandstone.

By mathematical analysis of the presence and magnitude of such variations in the gravitational pull over an area, evidence as to the position of the buried rock structures beneath the various points in the earth's surface could be detected or even mapped.

The most useful instrument in a gravity survey is the gravimeter which has a mass of delicate parts and jewel bearings. With its exceedingly delicate mechanism, this highly sensitive apparatus can measure even the slightest differences in the pull of gravity. The measurement offers an X-ray view of the underground strata and thus helps the prospectors in locating what may be a trap for possible oil accumulation.

In field operations of a gravity survey party, the geophysicist demarcates an area which, on the basis of earlier rapid reconnaissance, appears to be promising. The surveyor places a tripod on the ground in position and on it the gravimeter is placed and carefully levelled. When everything is still, he switches on a light inside the meter. He then peers through the eyeglass on its top and on a field sheet notes detail readings of the variations in the gravitational force. With the readings of the gravimeter a special kind of map is prepared showing the variations in gravitational attraction. The final result appears on another map as a series of lines similar to contour lines.

Seismic Survey

One of the most essential devices for studying deeply buried strata is based on seismic principles. The more widely used method in the seismic survey depends on the type of echo sounding which show the structural attitude of various reflecting horizons in the underground structure. Sound is rather like a rubber ball which rebounds more strongly from, say, a hard concrete wall than from a soft cushion. Thus the sound wave is reflected better when it strikes hard beds like limestone rather than soft ones like shale and sandstone. An important principle on which the seismic method is based is the fact that rock materials vary in respect to the speed with which they transmit elastic earth waves.

The principal instrument used in a seismic survey is the seismograph—an instrument for measuring and timing vibrations of the earth's tremors. It is the same kind of instrument that is used for detecting earthquakes, sometimes at a distance of thousands of miles. In oil prospecting, artificial miniature earthquakes are created in the area under investigation, by drilling shallow holes in the ground and setting off dynamite blasts at their bottoms. The explosions send energy waves down into the earth much like the waves in a pond when a stone is thrown into it. These shock waves are reflected back to the surface from different layers of rock formations. There are strong reflections from hard rocks and weak reflections from softer or less consolidated rocks. As the waves return back they are recorded by the seismograph as wavy lines on a strip of photographically treated paper.

The fundamental concept of the reflection method of seismic surveying is that specific sub-surface strata and contacts, down to depths amounting to many thousands of feet, can be detected by their specific relations on records obtained at different locations in any desired area.

Since sound always travels at a certain known speed, the recording of the time required by shock waves in coming back provides many important clues. The time taken for a sound wave to reach a certain depth and return to the surface may be taken as a measure of the distance travelled by the wave. In principle it is similar to the ruse a hunter employs to ascertain, by firing a shot, how far he is away from the mountains. The exact time that elapses from the moment the shot was fired to the moment of the echo coming off the mountain offers the hunter an idea of the distance. Similarly, the time difference between the dynamite shock and the echo at a number of different points helps find the depth of the underground layers. The time taken for the individual shock wave to reach particular rock layers and return to detectors at the surface is roughly proportional to the depth of the reflecting strata. Since earthquake waves travel rapidly in relatively soft rocks and return to the surface from shallow strata in a shorter time than from deeper strata, an analysis of their varying reflections may often afford informations, regarding the nature and composition of the concealed rock layers.

By setting off several explosions at a number of points the geophysicist can have a fairly reliable picture about the characteristics of the underground disposition of the rocks. Each layer of the strata may thus be identified and mapped by judging the intensity of the sound reflections of the shock waves made by the explosions. And by recording the time they take in reaching the surface the depths of the rock formations can also be accurately measured.

The instrument that picks up the reflection of the sound waves is called a geophone, which is rather like a gramophone pick-up. Geophones are set in the ground at surveyed intervals with cable connections to the recording instrument. The feeblest earth movement, even that of footsteps in the neighbourhood can be picked up and converted in the geophones to electrical energy and be traced in the photographic recording on a seismogram.

The shallow shot-holes bored for the explosions can be of further use to the geologist. The drill cuttings are examined and interpreted by a palæontologist. The approximate age of the underground rock formations may be determined from them and other geological data may also be revealed.

Computation of Results

When the above three types of survey are completed all the results are then computed, corrected and analysed. By comparing the logged informations of

(Continued on page 8)