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REPORT ON NORTH AMERICAN VISIT

1967

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INTRODUCTION

The purpose of the visit was to study research trends in petroleum geochemistry, and laboratory techniques currently used in the study of the geochemistry of source rocks and formation fluids. These studies were undertaken in the Petroleum Division of the Fuels Branch of the Research Council of Alberta, under the personal supervision of Dr. B. Hitchon, petroleum geochemist in that division.

This report includes an account of my itinerary and studies overseas; notes on the impressions gained during the studies and during discussions with geologists and geochemists outside the Research Council; and a discussion on the organization of research teams in areas such as Alberta, with a long established prosperous industry, exporting both oil and natural gas, and in Australia with an infant industry not yet contributing a significant proportion of the country's requirements.

ITINERARY AND STUDIES

I left Canberra on 24th July, 1967 and arrived in Edmonton on 25th July (Canadian time). The remainder of the week was spent in meeting various members of the staff of the Research Council of Alberta. This included the Director of Research, Dr. E.J. Wiggins, and all departmental heads at that time in residence. Unfortunately, Dr. Hodgson, head of the Petroleum Division of the Fuels Branch, was resident in San Francisco, seconded to N.A.S.A. for between one and two years, and was not available at any time during my stay.

During a later period I met, and discussed the scope of the Fuels Branch operations with, Dr. H.W. Habgood, Chief of the Fuels Branch.

Dr. Shuji Kudo, chief geochemist of Japan Petroleum Exploration Company, was scheduled to visit Edmonton on 31st July for four days. Three days of this were spent in general discussion of the Athabasca tar sands in relation to hydrodynamics and organic geochemistry, between Dr. Hitchon (acting for Dr. Hodgson), Dr. Kudo, and myself. On the fourth day, 3rd August, I joined other members of Japex and its associates on a visit to the Great Canadian Oil Sands plant near Fort McMurray on the Athabasca River in N. Alberta. The party included Dr. Tsuri Nakazawa (geologist, Vice-President of Japex Canada Ltd.) Mr. L.C. Farmer (land consultant to Japex Canada Ltd.), and Dr. Kiyoshi Hasegawa (chief engineer and geophysicist of Sumiko Consultants Co. Ltd.). During the visit to Fort McMurray, discussions were held with Dr. E. Moss, a vice-president of Great Canadian Oil Sands, and Mr. McClements, General Manager of G.C.O.S. who is in control of the extraction plant. After the discussions we inspected the plant, unfortunately closed down after a fire caused by failure of a pressure gauge, and then discussed the plant with Mr. McClements. Although the plant was not due to be opened officially until September 1st, it had reached its production target of 45,000 bbl. of 42 A.P.I. crude oil per day when the fire occurred. Byproducts include 3000 tons of coke now being used in the electric power plant (which generates 70,000 kw daily) and 300 tons of sulphur, daily. Markets are readily available for both these products. At present this output is being maintained by treatment of up to 140,000 tons of sand daily, the average grade treated being about 5% hydrocarbons and the range from less than 1% to 19%. The average grade in the six square mile lease was not stated but reserves are claimed to be adequate to operate the plant for more than 30 years. The tailings from the plant consist of remarkably clean white quartz sand and extraction was stated to be effectively 100%.

From the 4th to the 12th August the time was spent in discussing analytical techniques with Messrs. Baker and Peake of the Petroleum Division; observing the preparation for analysis of samples from the Surat Basin, forwarded in anticipation of my visit; and discussing hydrodynamics with Dr. J. Toth, of the Groundwater Division of the Earth Sciences Branch, and Dr. Hitchon.

The sample preparation was routine work of the type undertaken in our own laboratories, although some of the Canadian equipment may be rather more sophisticated than our own - there is more need for it in a province with a highly prosperous oil industry. Many of the organic compounds being studied occur in concentrations of a few parts per billion and great care must be taken not to contaminate samples by contact with, for instance, perspiring fingers which could introduce hydrocarbons in sufficient quantity to swamp the original content.

Weekends were spent editing lengthy papers by Dr. Hodgson, Dr. Hitchon, and others, on Porphyrins, Hydrodynamics of the Western Canada Basin, and Geology of the West Canada Basin. Visits were made to the Edmonton Laboratory of the Alberta Oil and Gas Conservation Board and to the University of Alberta.

From the 13th to the 16th August was spent on a field trip to Calgary, Banff, and Jasper. Dr. Hitchon had to collect surface water samples for a joint project being undertaken with the University of Calgary and I joined him on what was an excellent opportunity to examine the Devonian and Cretaceous oil reservoirs of the Western Canada Basin in outcrop. In Calgary I was introduced to Dr. Simony, acting Chairman of the Geology Department of the University of Calgary; Professors Levinson and Klovan, also of the Geology Department; and Dr. R. Pow, Chief Geologist of the Oil and Gas Conservation Board. At this stage Dr. Hitchon had suggested that it would be expedient to defer my proposed visit to Calgary until the week of the Devonian Symposium. The introductions were made to relieve Dr. Hitchon of the need to accompany me during my main visit.

From 17th August to 2nd September I observed analyses for various hydrocarbon compounds and total Carbon, Hydrogen, Nitrogen, and Sulphur. Chromatographic methods of analysis were used for everything but the sulphur determination. Sulphur was determined by combustion in a small furnace and determination by titration of the SO_2 produced.

All the equipment used is in regular use in the various B.M.R. laboratories although some of the chromatographic equipment used in Edmonton may be more sophisticated than that at present in use here. On the other hand, this type of equipment is being improved so rapidly that items now on order for B.M.R. may be more advanced than the equipment being used by the Research Council. Discussions on general chromatographic techniques continued throughout the period but, owing to temporary staff shortages and the pressure of outside work, it was not possible to have a demonstration of thin layer chromatography. Discussions were also held with Mr. Peake on the solubilities and accommodation of hydrocarbons in water and the effect of salinity on the solubilities.

Towards the end of the period, results of the analyses became available for discussion. The consolidated results are not yet available because all parties concerned expressed a desire to study the results for several weeks before voicing any opinion and Mr. Peake wished to repeat some of his hydrocarbon analyses under slightly modified conditions. Moreover, Dr. Hitchon felt that some benefit would be derived from X-ray work and that thin sections ought to be described by the Research Council Sedimentologists. Provisionally it may be stated that the only result of potential significance was the identification of isoprenoids in the Moonie formation water. This is the first recorded occurrence. The organic content and hydrocarbon content of the samples of Evergreen and Back Creek Shales seemed to be abnormally low until I pointed out that many cores are cut simply for petrophysical data and that such cores tend to be restricted to sandy intervals. Moreover core recovery may be higher in sandy material than in shaly so that the sample was not necessarily truly representative. In fact the organic content was of the same order of magnitude as for sandstone in the Western Canada Basin and in other oil producing areas and no deductions about potential source value could be made from this. In the circumstances Dr. Hitchon would like to repeat the analyses using cuttings from shaly intervals. Samples have since been forwarded. Mr. Peake is interested in a reported technique for extracting and identifying individual steranes from suspected source rocks. There is some thought that the sterane content may be diagnostic for any crude oil derived from that source. Hence, by a comparison of steranes

from Moonie oil and the Evergreen and Back Creek Shales, it might be possible to establish a relation between the oil and the potential source. Other geochemists with whom I discussed this considered that the necessary techniques had not been developed and thought that Peake was unduly optimistic but agreed that, by making the attempt, an advance in technique might be made.

The programme was interrupted on Wednesday 30th August when I gave a short talk on the General Geology of Australia, the operations and organization of the Bureau of Mineral Resources, and the size of tenements in Australia.

Having arranged to meet Dr. Pow and other geologists before the Devonian Symposium in Calgary, I left Edmonton on 2nd September. The long weekend 2nd-3rd-4th September was spent discussing the implications of the work being done at the Research Council of Alberta with sundry geologists of Mobil, Amerada, and Imperial, Oil Exploration Companies, to whom I was introduced by Messrs. McKellar, McTaggart, and Pemberton (all of whom have been employed in the Australian Oil Exploration Industry). I also called on members of Japex to forward sundry references to Dr. Kudo and to discuss their operations. None of the Canadian staff had any knowledge of the Japex interest in New Guinea and I was already aware that their immediate concern was the Athabasca Tar Sands where negotiations were nearing completion.

Tuesday 5th September was spent at the Alberta Oil and Gas Conservation Board head office in Calgary. Most of the laboratory work done there is routine work similar to that done by B.M.R. Petroleum Technology Laboratory and to that being done in the Research Council. The main function of the board is to police exploitation of Alberta's oil and gas reserves and I felt that an investigation of such activities would need several weeks of study, particularly of legislation. Although the Conservation Board is held by many people to be a model of its kind, and conservation may become necessary in Australia, I felt that the short time available would be better spent on geological discussions and on research into the history of Canadian oil exploration.

I attended the Devonian Symposium from the 6th to 8th September, attending as many readings as possible and visiting the recently opened Research Centre at the University of Calgary. Although the Symposium was excellently organized, it was spoiled by the speakers. Every person reading a paper seemed to be imbued with the desire to impress the audience with his own erudition. Every speaker read notes for the full time available and several ignored the microphone. Consequently, important points were not stressed, little time was available for discussions, and many of the audience dozed. Admittedly, discussion periods were organized in the evenings but these were not very satisfactory because it was necessary to choose between sections and then perhaps listen to much material of no interest until such time as the paper of personal interest was discussed. After the symposium ended, as Dr. Hitchon was not available on the 12th September, I flew to Vancouver instead of returning to Edmonton, and tried to re-arrange my return flight to Australia, cancelling all flights scheduled after completion of my tour in San Diego. I was advised to complete my arrangements in San Diego.

I left Vancouver as scheduled on 12th September and arrived in Anaheim the same day. The evening of the 12th and the whole of the 13th were spent discussing theories of source rocks and hydrocarbon migration with Drs. Gussow and Copelin of Union Oil Corporation. Whilst with Dr. Gussow I attended a lecture by, and was introduced to, Professor Chukhrov, of the Moscow Academy of Science, who was lecturing on clay mineralogy. On the evening of 13th September Dr. Gussow left for San Francisco.

On 14th September I flew to San Diego and visited Dr. B. Nagy at the Scripps Institute of Oceanography, University of San Diego. The 14th and 15th September were spent discussing source rocks and the reliability of work being done on them. Dr. Nagy had just returned from a visit to Europe and was available for only a short discussion but all his associates were available.

I also discovered that it was not possible to complete my travel arrangements in San Diego but had to forward my ticket to Los Angeles. The earliest firm reservation was on Friday 22nd September. In the circumstances I arranged to return from Farmington direct to Los Angeles on the evening of the 20th so that I would have a full day for confirming reservations.

A separate report has already been submitted on my visit to the Gasbuggy Symposium at Farmington, New Mexico, on the 19th and 20th September.

IMPRESSIONS ON RESEARCH TRENDS

The following notes summarize my impressions of the work being done on source rocks.

A vast amount of evidence has been accumulated to support the following views held not only in Edmonton but throughout most of the North American oil industry.

"1.

Hydrocarbons may be present in almost every conceivable environment although those associated with reservoir rocks amount to only between one and two percent of the total quantity of hydrocarbons in the sedimentary basins. Although natural hydrocarbons are ubiquitous, they are surprisingly few in number and most of them tend to be common to all crude oils. This coincidence implies that all crudes are derived by similar processes from similar materials. Differences between crudes from various parts of the world are proportional more than chemical.

2. The four main groups of hydrocarbons compounds fundamental to animal and plant life are proteins, carbohydrates, lipids, and pigments. All of them can be broken down either into hydrocarbons of the type found in crude oil or into trace hydrocarbon complexes which are known to occur in crude oil.

The lipids include waxes, fatty acids, steroids, and isoprenoids. Although the study of these in relation to natural crude is still in its infancy, it is known that the isoprenoids are particularly widespread and they are being studied in increasingly great detail.

The pigments, chlorophyll (vegetable) and hemin (animal), contain the porphyrin molecule which, in fact, is the basic structural unit of respiratory catalysts throughout the vegetable and animal kingdoms. The most common metallic complexes are the nickel and vanadyl porphyrins. These two porphyrins, which have been found in recent sediments and in sediments 2,700 x 10^6 years old, are remarkably stable under geological conditions not involving metamorphism.

Because of this stability and the fact that, although their molecules could be rearranged in several hundred thousand different ways, they occur both in plane and animal life and in natural hydrocarbons, it is assumed that naturally occurring porphyrins have a common origin in plant or animal life.

3. Amongst the higher n-alkanes in natural petroleum there is a slight to marked preference for those with odd carbon-number molecules. Oilfields in which such a preference does not occur are extremely rare.

The same preference has been noted in n-alkanes derived from plants and it is assumed, therefore, that the n-alkanes in crude oil are, in part, plant derived. Disagreement with this seems to be based on inadequate data. So much work is being done on petroleum geochemistry that workers cannot keep up to date simply through reading published matter. Close personal contact is necessary to avoid the effects of publication time-lags.

4. As belief in the biogenic origin of petroleum grows stronger, attention has been directed first to the problem of migration and then of accumulation. It is universally accepted that, whatever the original source of crude oil, it has migrated into reservoir beds from that source. If a biogenic origin for petroleum is accepted, the source beds must be the finer grained sediments since these are the ones in which the organic matter is known to occur. It has been calculated that the pressure needed to move a globule of oil through such sediments is several thousand times as great as the pressure generated by hydrodynamic gradients. Consequently

it is clear that the oil must migrate in solution unless it is formed entirely before being forced out by compaction of sediments. This latter possibility has been ruled out by examination of sediments in all stages of compaction. Much work is being done in Edmonton on hydrocarbon solubilities and the extent to which hydrocarbons can be accommodated in water other than by solution. Solubilities have been found to be higher than expected and accommodation beyond normal solubility has been observed. The concensus of opinion is that migration of petroleum takes place in a hydrodynamic system with the hydrocarbons in solution or accommodation.

5. Because of the apparent importance of hydrodynamics and the widespread occurrence of organic matter in sediments, there is a tendency in Edmonton to regard source rocks as of minor importance. This may be an illusion because such a small team must, of necessity, concentrate on one or two major problems and the problems selected are confirmation of biogenic origin, and movement and entrapment mechanisms. However, statistics from the Western Canada Basin encourage the Edmonton approach. It has been calculated that between 500 and 1000 billion barrels of oil could have been transported in solution at a concentration of one part per billion by the water which has passed through the basin since the end of the Cretaceous and that for such a volume of oil, an average content of only one part per million of available hydrocarbons in the rocks would be necessary. Such figures seem possible of attainment because oil solubilities may be as high as 300 ppm. Clearly it is more important to decide whether organic matter can yield petroleum hydrocarbons and be moved hydrodynamically than to decide whether one particular rock is a better source rock than any other.

6. Although there is abundant evidence to support the view that migration is hydrodynamic, there is little evidence to indicate the mechanism for entrapment. Possible causes for precipitation of oil from solution are osmosis, salinity changes, temperature and pressure variations, mineralogical variations, and capillary effects. Much work is being done on all these factors, mostly through solubility studies.

However, the present position is that the dominant factor in precipitation of petroleum hydrocarbons from aqueous solutions is not known for any basin, field, or single oil pool, and a vast amount of research is necessary before the problem of accumulation can be solved. Present studies indicate the importance of salinity and pressure in Alberta but the relation between these and oil accumulation is not yet established nor have any other factors been ruled out as unimportant.

DISCUSSION OF TEAM ORGANIZATION

The Research Council team engaged on Petroleum research consists of one physical chemist, two organic chemists, and one geologist, with several technical assistants. However, advice and assistance was readily available from other members of the Research Countil staff such as for instance, Dr. J. Toth, who is a leading authority on hydrodynamics; all other laboratories and technical staff could be utilized if need arose. The team works individually and collectively. For instance, Mr. Peake is currently experimenting on the passage of aqueous solutions of hydrocarbons through sand columns and has succeeded in precipitating hydrocarbons in the sand only by injecting saline water into the sand column. This is one of several projects being undertaken by Mr. Peake who may be called upon to conduct analyses for any of the team. Dr. Hitchon, the geologist of the team, is studying the relation between petroleum deposits, salinity of formation waters, lithology, and hydrodynamics, in the Western Canada Basin, and is co-operating with Dr. Hodgson, the physical chemist, in a study of porphyrins. Co-operation with outside research workers is common and joint projects are in hand with several universities. Although their work may have to continue for many years before the problems of hydrocarbon accumulation are solved, several significant discoveries have been made. The experience in Alberta shows that salinity may actually be an indication of flushing although many Australian exploration companies regard saline formation waters as indicative of the absence of flushing of reservoirs by meteoric water. Formation waters with a salinity of 30% are known in Alberta and salinities generally are so high that water of 5% salinity (compared with sea water at 3.5%) was being discussed as "fresh water". It has been proved that the high salinities are caused by solution of evaporite beds under hydrodynamic conditions. The chance of encountering and

identifying connate water in a basin under hydrodynamic conditions is incredibly remote. However, the current (and the Research Council) view, rapidly gaining acceptance over most of North America, is that accumulation is caused by groundwater flow and that flushing is only significant where it can be demonstrated to have been complete.

The team, as at present constituted, is ideal for working on a well-explored basin in which the main problem is analysing the data to explain oil occurrences and perhaps locate those deposits which have not yet been discovered. By the end of 1965, drilling in Alberta was near the 10,000 well mark and has since passed that figure. The study of the basin has reached a stage where only minor adjustments need to be made to geology, and the team can concentrate on statistical data. In fact, I think that the position now is that the Research Council could indicate those unexplored areas of the Western Canada Basin in which lie the best hope for further discoveries.

The Research Council team does not include either geophysicists or reservoir engineers. A geophysicist in unnecessary because the area is so thoroughly explored (well density is 20 sq. miles per well) that the only useful function left for a geophysicist is to locate drill targets precisely - a task outside the scope of the Research Council. Reservoir engineers are not used simply because their normal function is not relevant to regional basin studies. In fact, it was implied that their basic training, at least up to 1962 or 1963, was not suitable for such studies and there is no doubt that the regional studies are better undertaken by either water engineers or physical chemists and geologists with training in hydrodynamics, where such are available, as they are in Edmonton.

The results obtained to date, although not yet fully publicized, are most impressive but I do not think that such a team would be so successful in an Australian context.

The Edmonton objective is to ascertain accumulation controls in a known oil province from which a vast quantity of data have been obtained. The aim with the Australian sedimentary basins is to assess the future potential of any basin on information which

is adequate only for broad generalizations. Drilling densities may be measured in hundreds of square miles per well as opposed to an Alberta density of 20 square miles per well. Few wells drilled in Australia have been pressure tested at enough horizons to allow good hydrodynamic sections to be drawn, whereas the Canadian wells are tested regularly throughout the total depth. The Western Canada basin is tectonically simple in comparison with several of the Australian sedimentary basins with their associated sub-basins. Consequently, an Australian basin study must be based on geophysical data to an abnormal degree. Even gravity and aeromagnetic data cannot be discarded in the attempt to locate sub-basins beneath the main sedimentary basins. Sections through basins tend to be seismic sections supplemented by outcrop data on the basin margins and by a few wells. No basin is so thoroughly studied that only one geologist is needed to summarize the known geology in a few weeks, whereas several comprehensive accounts of the Western Canada basin are readily available.

Data on hydrocarbons both as petroleum and source material are extremely scanty, nor is the raw material available for a team of chemists to study.

An Australian team clearly needs the service of geophysicists for some structural interpretation and to aid in correlation between widely spaced wells; geologists to undertake stratigraphic, sedimentation, structural, and geomorphological studies; and a chemist to undertake both organic and physical chemistry studies. Some members of the team must be capable of assessing hydrodynamic data and interpreting electric logs. Finally, an Australian team would have to concern itself with not one major basin but with several basins of different sizes, origins, economic importance, and states of development. Only as any one basin proved to be hydrocarbon rich would a team working on that basin tend to follow the same path at the Research Council and then only as economic development of the basin permitted.

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