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From the Field to the Model
Bernard Tissot's Path

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This short article is not aimed to comment the long career of B. Tissot, but to single out certain periods of his professional life that were probably decisive. Of particular interest are the years in which he practiced the profession of oil explorer, and the transition period between these years and his entry into the profession of researcher into the scientific problems associated with the genesis and migration of oil.

One is first naturally inclined to try to understand the reasons for his attraction to Earth Science. After graduating from the *École des Mines de Paris*, he decided to take the Geology option at *École nationale supérieure du pétrole et des moteurs (ENSPM)*, and ended with a degree in Advanced Geology Studies at the *Université de Grenoble* in 1955. This was concerned with a "Geological study of the Massifs of Grand Galibier and Cerces" *(Fig. 1)*, hence with true alpine geology. It demanded to be in good form because when he lived in the chalet of the French Alpine Club of Monestier and only possessed a bicycle, it was a real grind to reach the study zone in the Galibier Massif. The answer to our initial question is simple: the quality of geology teaching at *École*

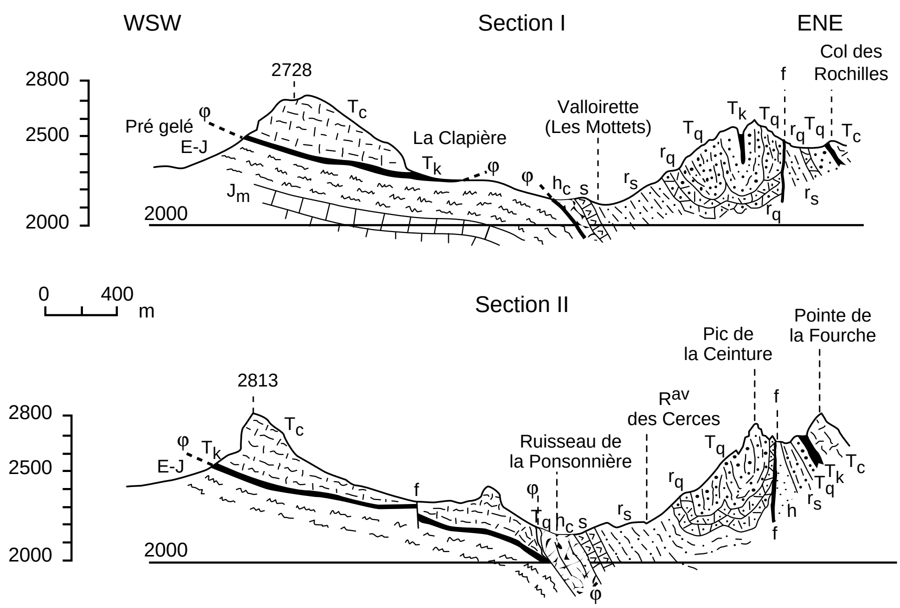

Figure 1

Two cross-sections issued from one of the first works published by B. Tissot about the geology of the Grand Galibier and Cerces Massifs in the "zone briançonnaise".

des mines de Paris by Professors J. Goguel and M. Lemoine was the direct cause of this leaning toward Earth Science.

THE ROUTE OF THE OIL EXPLORER

Following his period at *ENSPM*, B. Tissot joined *IFP* in 1955 in the *Bureau of Geological Studies (BEG)*, *IFP*'s arm for conducting studies in oil exploration worldwide for governmental agencies and oil companies. He started out in the Paris Basin with M. De Myans d'Archimbaut, working for *Gaz de France* on the Beynes gas storage facility, and for *Mobil* on the southwest of the Basin, an unpropitious area for the accumulation of oil and gas, but where *GDF* eventually built the world's biggest storage facility of this type, the *Chemery* facility.

Then came his first mission outside France. In 1956 and 1957, B. Tissot investigated the petroleum potential of New Caledonia. Outstanding field work followed with a detailed mapping in a region featuring highly complex tectonics. Only a good geologist could discern the big picture, identify the unseen thrusts and decide whether the sedimentary series observed at the outcrop were right side up or upside down. Naturally, the petroleum possibilities of the region appeared very mediocre, but the mission was the first that B. Tissot carried out from start to finish, as manager, coordinating the field work and the laboratory investigations which he had requested.

In 1958 and 1959, he did his military service, with an assignment to *Compagnie d'Exploration Pétrolière (CEP)* at Fort Platters: alongside other *BEG* colleagues he was mostly busy locating exploration boreholes.

On April 1st, 1960, he headed for Australia with his wife for a three-month stay, and returned after three years with a family, two daughters born in kangaroo land. This time, the task was to investigate the Australian sedimentary basins with a team of 22 to 23 persons. Following a short visit by M. Guillemot and M. Trümpy, B. Tissot was the Manager of this party, where laboratory studies, photogeology, petrography and interpretation of seismic lines went hand in hand. After the three-year spell, Dr Trümpy and B. Tissot presented a review of recent developments in prospecting in Australia, and proposed a list of the main onshore and offshore prospects. There isn't much to add today concerning this list.

These years dedicated to oil exploration were followed by some technical disappointment, because B. Tissot found that the geological data had been insufficiently used and that the boreholes were most often installed exclusively on a reflection seismic anomaly. Besides, the lack of scientific knowledge about the mode of formation of the oil and gas and their accumulation in the reservoirs, explained why judgments on the potential of the basins were essentially based on reasoning by analogy. The result was a low wildcat success ratio (1 to 10).

THE SCIENTIFIC JOURNEY

In 1964, B. Tissot began his career as a scientist, participating in a think tank on the research program of the *Geology Division* which became effective in June 1965, ultimately giving rise to a sweeping reorganization of this sector.

The genesis of oil and gas and the formation of reservoirs became priority topics of the division, *CEO R. Navarre* having demanded that these problems be resolved by *IFP* scientists. A number of positions taken in this program are worth recalling.

"The training of geologists, at least in France, is still primarily too naturalistic. This is manifested by the fact that more importance is ascribed to the description of the outward signs of phenomena (sense of observation) than on the search for their intimate mechanism. Given the development of geology, this results in the accumulation of an infinite number of observed facts, of no use to anyone because ignorance of the underlying processes makes it impossible to decide which of these facts is significant.

Thus in the specific field of petroleum geology, the existence of a relationship between the presence of organic matter and the occurrence of oil, the migration, and the accumulation of oil in preferential zones, are facts of observation. And yet until now, no one has derived a valid explanation of the formation of oil and gas reservoirs.

For knowledge to advance, it is critically important to stop focusing the effort on a naturalistic description of the basins and reservoirs, but rather on an understanding of the mechanisms involved. And this happens to be the only method for determining the general laws to open up new methodological perspectives for exploration.

For the geologist, this necessary progress in the fundamental knowledge of geological processes demands not merely the renunciation of his initial qualities as an observer, but the simultaneous development of knowledge in the field of the mathematical, physical and chemical sciences. It is only by a permanent back and forth process between the observation of nature and the critical analysis of phenomena in the laboratory, that one can succeed in formulating hypotheses reflecting the observed facts.

Furthermore, even with respect to purely analytical work, it is undeniable that an effort exploiting all the resources of physics and chemistry must be made to enhance the meaning and accuracy of the measurements. For example, at a time when chromatography and mass spectrometry are used to characterize components of an oil, it is curious to find that one can often adequately characterize an oil by a global property, such as a distillation curve, a density or a molecular weight.

A systematic effort must therefore be pursued, both to develop more objective methods of observation, and to acquire the basic knowledge of the processes involved."

This attitude perfectly expresses the approach pursued by B. Tissot to address research into the genesis of hydrocarbons.

It is interesting to note that upon the establishment of this new program, the *Geology Division* included the *Bureau of Geological Studies* and a "Research" section with a matrix organization.

The first step was a critical bibliography of the genesis of hydrocarbons. The aim was to estimate the possibilities of laboratory investigations and field observations of the specific conditions in which sedimentary organic matter is converted into hydrocarbons. Hence the first phase implied a critique of the hypotheses formulated and their replacement by new ones.

From autumn of 1965, with some intensification in 1966, the main conclusions were available to guide subsequent research. The central model was a thermocatalytic hypothesis (geothermal energy, inorganic catalysts). We can recall some of the conclusions of this analysis.

"If we refer to thermodynamic considerations, it appears that there is no reason to impose a time limit on the mechanisms examined. For each system of organic components and water, in a given set of physicochemical conditions, an equilibrium state exists, which the system probably does not reach, but towards which it will evolve insofar as the temperature is elevated and adequate catalysts are present. If the conditions change—especially the temperature and pressure with burial depth—the equilibrium position and the rate at which the system tends towards it, change, and the organic mixtures therefore evolve.

Subsequently, the age of the sediment in the formation of oil of the hydrocarbons does not appear to represent a restricted condition. One can very well agree that a sediment will remain for a long time at an insufficient depth and temperature, eventually reaching such conditions. Or even that having already supplied hydrocarbons and being subsequently placed at greater depth and high temperatures, it can supply even more. This would also help explain numerous reservoirs connected with an unconformity, where the rock rich in organic matter presumed to be the source of oil, is located under the unconformity and the erosion (Hassi-Messaoud, for example), which appears difficult in the case of an early genesis.

Similarly, it must be considered that wherever the oil is found, from the moment when it is mobile, the transformations can continue as attested by experiments on the evolution of crude oils under the influence of temperature, pressure and inorganic catalysts. In particular, it is unsure whether in the case of certain reservoirs, the migration has not concerned a product that is quite different from the present crude.

These remarks once again underscore the importance of the geological and physicochemical history of the formations, source rock and reservoir alike. On the completion of this study, if we single out the main steps of the genesis of petroleum accumulations, from the deposition of organic matter to the segregation of the oil in a reservoir, we find that some of the favorable factors are definitely associated with the specific composition of the source rock, while others, at least equally important (temperature, pressure, fluid expulsion law) are associated with the geological and physicochemical history of the fraction of basin considered."

The next step was particularly important, because as early as 1966, it helped establish the influence of temperature and pressure by observations on the Toarcian of the Paris Basin and by laboratory experiments. These results were presented by M. Louis and B. Tissot to the 7th World Petroleum Congress in Mexico in 1967.

"The choice of the Toarcian of the Paris Basin as a source rock makes it possible:

– to effectively investigate the influence of temperature and pressure because the other parameters vary only slightly (age, composition of the rock and depositional environment);
– through the ability to reconstruct the geological history of burial, to demonstrate the importance of the thermal history of the sediment *(Fig. 2)*;
– to clarify the role of different components (hydrocarbons, resins, asphaltenes, MAB extracts and insoluble organic matter).

The importance of these results for prospecting is immediately evident: for a formation where the organic matter and its mineral support have a given composition, a temperature exists above which the yield of the hydrocarbon formation reactions rapidly increases. Given the geothermal gradient and the reconstruction of the burial history, zones which have never been raised to this temperature are of no petroleum interest, even if they are rich in organic matter."

The results of the observations and experiments on the Toarcian of the Paris Basin enabled a decisive breakthrough, this time with the passage to mathematical modeling. In 1968 B. Tissot wrote a report on the "Preliminary Data on the Mechanisms and Kinetics of the Formation of Oil. Computer Simulation of a Reaction Flow Sheet", published in 1968 in *Revue de l'IFP*.

We can quote the conclusions here:

"It was therefore possible, starting with the results of observations and experiments on the Toarcian of the Paris Basin, to construct a simplified reaction flow sheet, and then simulate the conversion on a computer. The consistency of the overall results demonstrates that the reaction flowchart and the kinetics employed are compatible with reality. We thus had a model to represent natural phenomena and to contribute to their analysis.

The use of such a tool helps explicitly introduce the time and temperature parameters, in other words, the entire geological history of the sediment after its deposition, instead

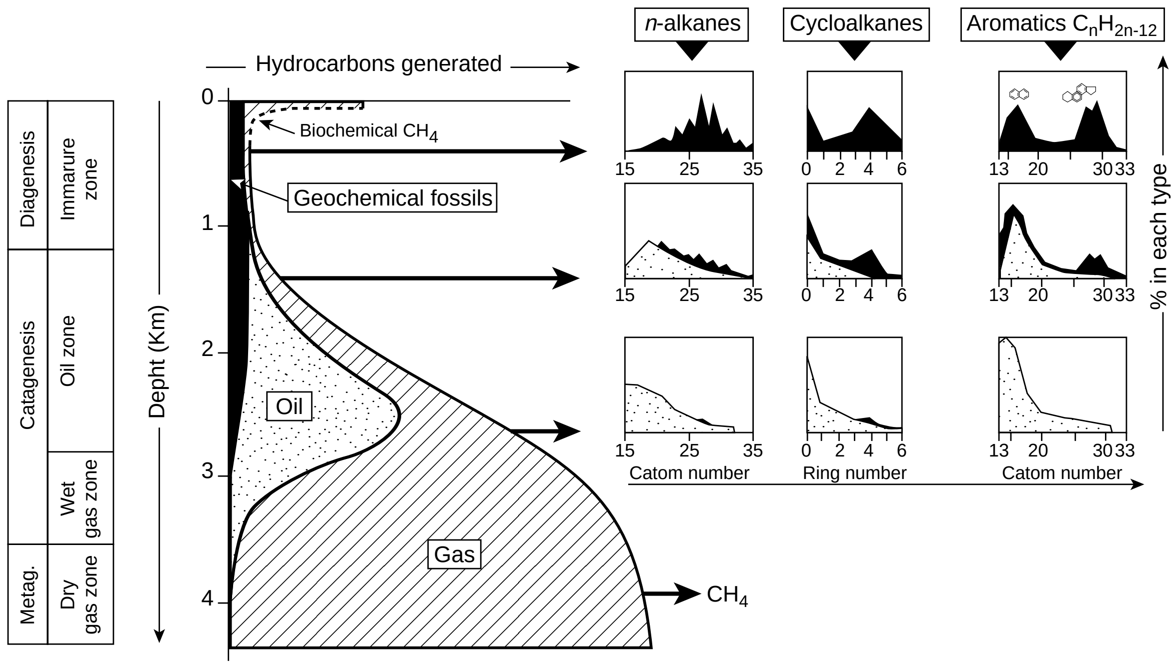

Figure 2

One of the most famous diagrams published by Bernard Tissot and co-authors illustrating the burial/maturation and hydrocarbons composition relationship. This concept was at the root of the further developments in petroleum organic geochemistry.

Tissot and Welte (1978) (2nd edition 1984) *Petroleum Formation and Occurence*, Springer Verlag.

of merely considering a specific episode (maximum burial depth or present depth). Besides, it becomes possible to separate the respective influence of time and temperature, which was hitherto impossible.

In terms of prospecting, this tool helps to simulate every point of the basin investigated, and with a good approximation, the quantities of oil formed since the time of deposition until today. We can thus determine the most favorable zones, in other words, those where the source rock has been the most productive. It is naturally easy to take account of the organic matter contents and the thickness of the formation.

We can also consider the generalization of this model to other formations, and to other sedimentary basins, to contribute to prospecting. This aspect is the subject of another publication. It suffices to have measurements on a small number of core samples (to adjust the constant specific to the formation concerned), a reconstruction of the geological history of the basin, and an evaluation of the geothermal gradient.

Finally, the use of the model supplies the preliminary data, still approximate, on the time and rate of the formation of oil. A comparison of these data with the age of the structural movements will perhaps, in certain basins, help to identify the most favorable traps."

It was therefore in four years, from 1965 to 1968, that the major steps were completed:

– choice of a mechanism based on a critical bibliography;
– demonstration of the influence of temperature and pressure by observations and experiments on a natural case: the Toarcian of the Paris Basin;
– mathematical modeling.

Investigations then naturally continued, particularly on the migration of oil and gas and the modeling of petroleum systems, first with one dimension (Genex) then with two dimensions (Temis 2D) and finally in three dimensions (Temis 3D).

B. Tissot, Head of the *Geochemistry Department* of *IFP* from 1965 to 1979, was the driving force of these investigations and the leader of an entire team. They spawned the development of a new discipline: organic geochemistry and its application to the exploration of oil and gas.

The work done at *IFP* had huge repercussions, not only in the scientific world but also in the oil companies, such as *Total, Exxon, Shell,* and *Chevron.*

This influence led B. Tissot to become Scientific Director of *IFP* in 1979, and then, from 1988 to 1995 Director of Research and Development, and finally Deputy Executive Officer. But that is another story.

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