Földtani Közlöny, Bull. of the Hungarian Geol. Soc. (1980) 110. 22—27

Development of petroleum prospecting methods before W. W. II.

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Introduction

The generally accepted birthday of modern petroleum industry is the *27th. August, 1859,* when the famous well of ,,colonel'' *Drake* came in at *Titusville*, Pennsylvania. The development of petroleum production began slowly, but soon became an impetus by the introduction of internal combustion engines. World petroleum production reached 94.3 million metric tons in 1900; 193.4 MMt in 1930; 250 MMt in 1945; 1000 MMt in 1960; 2000 MMt in 1968 and 3000 MMt in 1977.

It was generally accepted to speak about *petroleum industry,* since in the early days *crude oil* was the most essential substance looked for and *natural gas* was undesired, thus neglected. Nowdays it is more appropriate to use the expression: ,,natural hydrocarbons'', and *,,hydrocarbon industry''*. The prospecting for natural hydrocarbons underwent a relatively quick and spectacular development to satisfy exponentially groving hydrocarbon demands.

The period of primitive oil prospecting

Petroleum exploitation from *natural seepages* began several thousand years ago. Soon wells were hand-dug to increase the yields of the seepages. To reach bigger depths shafts were sunk, lined with twig mats, or timber planks. It is well known, that Chinese drillers could drill wells of several hundred meter depth already some two thousand years ago to produce brine and also natural gas as a fuel to get the salt out of the brine.

Drake's well gave impetus to a more intensive prospecting.

In Pennsylvania the oil seepages occur along the ,,*Oil-creek*'' suggesting further prospecting along creeks. The method was called ,,*creekology*''.

Soon it was discovered that the oil fields are arranged following each other in parallel lines forming trends, and oil hunters began to follow these trends *(,,trendology'')*.

The famous gusher of capt. *Lucas* (Lučić) at *Spindle-Top* was drilled on a flat mould. People began to survey for moulds by accurate levelling (*topographical prospecting*). Soon it was proved that these flat moulds are often the results of *salt plugs* lifting slightly the covering rocks; and the relation of oil traps to salt plugs was recognized.

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The period of geological surveying

The role of the geologist in Europe and in the U.S.A.

The science of geology was developed at first in Europe. Europe has a long tradition of mining and mining was the mother of geology. The work of the geologist in Europe was facilitated by more or less accurate topographical maps eliminating the tiresome work of topographical surveying. In addition the mines delivered aboundant subsurface material supplementing the data collected in surface outcrops, promoting the examination of the earth's crust to a considerable depth. European geology supplied reliable data for mineral prospecting and the same methods have been transferred to hydrocarbon prospecting when the need arose.

It is believed that the first petroleum geologist sensu stricto was the Swedish HJALMAR SJÖRGEN employed by the NOBEL Brothers in Russia around 1880.

At the beginning petroleum prospecting in the *U.S.A.* did not relay upon geological studies. The first geologists have been received by the technically minded prospectors with mistrust. This was due partly because some of the geologists were arguing vehemently with each other representing sometimes completely adverse opinions about the same subject.

The anticlinal theory

W. LOGAN (Canada) described in 1842 that oil seepages occur at the mouth of the St. Lawrence river along anticline axes. G. V. ABICH (Russia) stated in 1847 that the oil at Baku occures in anticlines. The theory was clearly outlined by STERRY HUNT (Canada) in 1861, and it was employed for practical petroleum prospecting by I. C. WHITE (U.S.A.) in 1882.

The *instruments* of anticline mapping were the compass and clinometer (the most advanced of which was the „Brunton pocket transit"), the Abbney hand level, later the oil-compass, the altimeter, the plane table with alidade and stadia rod, the prism, the steel metering tape, the geological hammer, a powerful magnifying lens and some other ancillary equipment.

Beginning with the twentieth *aerophotogrammetry* and *photo-geology* was more and more introduced making prospecting especially in remote areas faster. Of course aerophotography could not replace field work entirely since rock specimens and fossils had to be collected further-on for detailled observations and exminations. Yet aerophotography became one of the most important tools especially in desert areas.

Shortcomings of the anticlinal theory

The anticlinal theory yielded spectacular results. Giant fields have been discovered world-wide, yet not without some difficulties. For example in Persia the discovery of the huge fields was many years delayed by the fact, that there exists a discrepancy between surface and subsurface structures as a consequence of plastically deformed „salt formations" covering the reservoirs.

H. BÖCKH, the Hungarian geologist hired by Anglo—Persian Oil Co., selected six anticlines for first priority testing; Zeloi, Gach-Khaladj (where a duster has been drilled previously) Haft Kel, Agha Jari, Pazanan, Gach Saran. BÖCKH was avare of the structural discrepancies and while locating the first drilling near to the crest of surface anticlines, he suggested to drill 2—3 additional wells along in one profile line across the whole structure. Truly enough all first wells missed the structures and Böckh witnessed only the discovery of Haft-Kel by the second well, because he soon left Persia. Later on Agha Jari, Gach-Saran and Pazanan were proven to be giant oil and gas fields respectively, and the work at Zeloi lead to the discovery of Lali. Only Gach-Khaladj was a miss. Out of six other locations, designated by Böckh as of secondary importance, three became productive, two of them are not tested as yet and only one did not contain hydrocarbons.

The anticlinal theory was rejected by the geologists working in Pennsylvania, because it did not correspond Pennsylvanian geological conditions. The contradiction could be cleared only with advancing stratigraphical studies giving a new impetus to „*modern trendology*".

The difference between „*primary dip*" and „*secondary dip*" caused also rather much difficulties until the necessity of exact distinction has been recognized. As for instance in Hungary a big number of „brachy-anticlines" were mapped in the Pannonian-basin by F. Pávay-Vajna due to confusion between primary and secondary dips.

Missleading geological conceptions

Some geologists created theories and stuck to them as if they were dogmas. Again the example of Persia and Iraq can be mentioned.

H. Böckh quickly generalized the conditions observed in Persia and concluded that oil in Persia is bound to the *Asmari-limestone* of *lagoonal facies,* covered by the „*Miocene salt formation*". This theory adversely influenced prospecting in Iraq and delayed the discovery of the profilic Kirkuk-field.

In Hungary following discovery of huge quantities of natural gas in the Transsylvanian-basin, while prospecting for Potassium-salts, Böckh insisted that oil must be related to *Miocene salt formations* also in the Pannonian-basin. Intensive exploration, carried out since, proved that such a formation is non existent in the basin, yet some significant hydrocarbon pools were discovered.

Apparently some geologists did not arrive to proper conclusions based upon the above mentioned facts and still try to create „new" theories not supported by actual conditions.

Prospecting in areas covered by thick layers of undisturbed Neogene sediments

Soon the most significant anticlinal outcrops have been mapped and their oil pools discovered. Advanced sediment-geological work focused attention to the great plains, where no outcrops occured on the surface. To get more information about subsurface conditions *structural drilling with continuous coring* has been introduced. This method contributed to the discovery of many oil fields in the U.S.A., in Saudi-Arabia, in the U.S.S.R., and in many other areas. The method was successfully employed also in Austria immediately after W.W. II. by the Russian authorities discovering *Matzen* oil field.

The method could be employed very well in cases where adequate key-horizons were present.

Geophysical prospecting

Geophysical prospecting rendered a great help for petroleum prospecting in covered areas. The first geophysical instrument employed to this end was the *torsion-balance* developed by R. Eötvös and utilized for practical purposes by H. Böckh in the Transsylvanian-basin in *1912* to prospect for salt-plugs. The method was proved for petroleum prospecting on the Egbell (Gbely) oil field discovered in *1914* by drillings at the vicinity of natural gas seepages.

In the followings the torsion-balance became the most important instrument for petroleum prospecting in the Gulf-coast area (U.S.A. and Mexico), in the Ural—Emba district (U.S.S.R.) and in many other areas of the world.

The torsion balance was soon displaced by the simpler and faster *gravity-meter*, although this was less accurate, yet accurate enough for practical petroleum prospecting.

Gravity measurements were supplemented by magnetic anomaly measurements applying the *magnetic variometer* to distinguish the effects of igneous and some metamorphic rock masses in the depth.

The development of *seismic measurements* for practical petroleum prospecting began in *1914* (*Mintrop*, Germany). The „SEISMOS" Company, founded by Mintrop started actual prospecting in the U.S.A. and Mexico in *1923* by the *refraction method.*

The basic principles of *reflexion seismic* measurements were patented by R. Fassenden (U.S.A.) in 1921. They were improved and practically employed by J. C. Karcher (Geophysical Research Corp. U.S.A.) also in *1921* In *1935* the method was employed already in big scale yielding varying results. Under favourable conditions the results were rather accurate and reliable, but in many cases, as e.g. fractured carbonate rock structures, or depths under 2000 m the results were usually poor and questionable. (A more spectacular development of seismic methods began in the fifties only, with the improvement of electronics, yielding excellent results.)

Bore-hole geophysics

Electric well logging was introduced by the Schlumberger-Brothers in *1919* at *Pechelbronn* (France). It was further developed by them in the *Caucasus* area (U.S.S.R.) and since *1929* also in the U.S.A. Resistivity, spontaneous potential, long normal, and lateral, further on caliper, dip and temperature measurements have been developed before 1945. Experiments were carried out also with induction logging.

Radioactive well logging was developed first in the U.S.A. Howell and Frosch (Humble Oil and Refining Co) introduced *Gamma-ray* logging (1939) and B. Pontecorvo *neutron* logging (1940).

A more or less simultaneous development of the above mentioned surface and subsurface geophysical methods followed also in the *U.S.S.R.*

Subsurface geological mapping

Bore hole geophysics improved *geological correlation* in addition to some classical geological methods, such as *micropaleontology* and *heavy mineral analysis*.

By better correlation the geometry of the reservoirs could be determined more accurately. In addition to lithological, paleontological, stratigraphical and facies examinations, core-analysis (porosity, permeability, water saturation and connate-water measurements), supplemented by several technical measurements, promoted more reliable reserve estimations and made technical endeavours for higher ultimate recovery possible. All of these laid the foundation of what is called today *reservoir engineering.*

The data obtained by the integral interpretation of the above mentioned measurements and examinations have been presented by different *subsurface maps*, such as contour- isopach- or isochore, isolith, lithofacies, biofacies, isoporosity-, isopermeability-, isobar-, reservoir fluid saturation-, edge and bottom water maps and the like, giving a full picture about the reservoir.

In consequence *petroleum geology* was divided into two branches: *exploration geology* and *exploitation* (*production*) *geology.*

Stratigraphical traps

The integral interpretation of geological and geophysical results lead to the recognition of the importance of stratigraphical traps. Nowdays, most of the anticlinal traps being already discovered, stratigraphical traps are delivering a considerable part of world's hydrocarbon production.

Geochemical methods

Before W. W. II. some geochemical exploration methods have been developed aiming at *direct* hydrocarbon discovery. These endeavours remained unsuccessful, yet laid the foundation for *modern hydrocarbon geochemistry* as a more recent development after W.W. II., examining the habitat of natural hydrocarbons with relation to origin, migration and accumulation.

Petroleum exploration methods applied in Hungary before W.W.II.

Hungarian hydrocarbon prospecting was much influenced by the ,,anticlinal theory" and by the ,,Miocene salt formation" theory. The utilization of the torsion balance for practical geophysical prospecting began first in Hungary. Torsion balance and magnetic measurements were carried out by the *Roland Eötvös Geophysical Institute.* Gravimetric measurements have been greatly extended by utilizing gravimeters (type Heiland—Truman—Howell and Thyssen—Bornemisza). These measurements were carried out by the *European Gas and Electric Co.* (EUROGASCO), by the *Hungarian—American Oil Co.* (MAORT) further on by the companies ,,*SEISMOS*" and ,,*PRAKLA*" (Praktische Lagerstättenforschung), both German, for the *Hungarian—German Oil Co. Ltd.* (MANÁT).

Seismic measurements were completed by *Humble Oil Co.*, by „*SEISCOR*", by *Carter Oil Co.* (all U.S.A.), by „*SEISMOS*" and by „*PRAKLA*". The *R. Eötvös Geophysical Institute* also completed some experimental measurements with an equipment of its own construction. The 6 to 14 channels equipments utilized, and the interpretation methods employed, corresponded the technical level of those years.

Well logging was carried out by the branche office of the *Schlumberger Co.* residing first at Vienna and later at Nagykanizsa.

Experimental structural drilling of the counter-flush method was carried out at Biharnagybajom. Due to the lack of proper key-horizons correlation was difficult, yet the position of outpinching sand lenses indicated some kind of buried-hill structure coinciding fairly well with the gravitational anomaly, and proven later by seismic measurements.

While the Budafa and Lovászi oil fields, discovered first, were of the anticline type (very gentle though), the small Hahót field was a buried limestone block. Exploration in the Great Hungarian Plain directed attention to the significance of stratigraphical and compaction traps formed over buried mountains of the basement rocks.