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Libya 2000 - A Review of Logging and Interpretation Problems

- a keynote lecture -

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مراجعة لمشاكل تسجيل وتفسير السرود: ليبيا 2000

كلود بويلدو

من مهام موظف الشركة الخدمية الجديد عند وصوله إلى أحد الدول المنتجة للنفط هو أن يُكيّف نفسه مع الظروف الجديدة المحيطة به، وكمحلل لسرود الآبار فإن شغله الشاغل سواء كان البئر مفتوحاً أو مغلقاً: هو جيولوجية المنطقة وتقييم المكامن وتحليل السرود.

عندما وصلت أول مرة إلى ليبيا في سنة 1961 كنا في منتصف مراحل الاستكشاف. وفي الفترة ما بين عامي 1968–1970 حصلت بعض الاكتشافات النفطية الكبيرة. وتمت مراجعة المشاكل المتعلقة بطرق تفسير سرود الآبار في ليبيا بمؤتمر تقييم الآبار الذي تم عقده عام 1970، وقد أثار دهشتنا وجود اكتشافات كثيرة في ليبيا لمكامن نفطية ذات خواص فيزيائية مختلفة من نفاذية منخفضة لصخور الكوارتزايت المتحولة والمتشققة وصخور رملية وأخرى جيرية ذات نفاذية عالية، ولا ننسى كذلك الزيت المستُخرج من صخور الجرانيت.

وعلى مدى ثلاثين عاماً فإن الشكل الهندسي وجيولوجية المكمن لم يتغيرا مع أن معظم المشاكل التي مررنا بها في الستينات والسبعينات مازالت موجودة مثل المكامن المتشققة ذات الطبقات الرقيقة، أما الظروف الأخرى فقد تطورت وذلك لثلاثة أسباب رئيسة:

- تعد ليبيا في عام 2000 دولة نفطية متقدمة.
- طرق الحفر والانتاج قد تغيرت.
- طرق تسجيل وتحليل السرود وكذلك تقييم المكامن قد تحسنت كثيراً.

Abstract: *The duty of a newly arrived service company person in an oil producing country is to familiarize himself with the conditions. As a log analyst his preoccupations will concern the borehole logging, both open and cased, geology, log and reservoir evaluation. When I was first arrived in Libya, in 1961, we were in the middle of the exploration phase. Later in 1968-70 I witnessed some of the large oil discoveries. During this period a review of logging and interpretation problems in Libya was presented in Well Evaluation Conference (W.E.C) held in 1970. It was interesting to note that in Libya we faced a large inventory of reservoirs with very different petrophysical properties, from low porous fractured quartzites to traditional shaly sands or highly porous carbonates, not forgetting some oil production from granite.*

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Over the past 30 years the geology and the reservoir geometry have not changed. Most of the problems experienced in the 60's and 70's are still persisting, such as OBM log evaluation, fractured reservoirs or thin layers. However other conditions have drastically evolved for 3 main reasons:

- *In 2000 Libya is a mature oil producing country*
- *Drilling and oil production concepts have changed*
- *Logging and log/reservoir evaluation have improved dramatically.*

Libya 2000

In the 60's and early 70's we were evaluating virgin reservoirs. Now, the more acute problems are associated with saturation monitoring in cased and in open holes owing to the presence of fresh water as a result of the water injection programs. Production logging should be associated with cased hole evaluation programs. To improve oil recovery we often face the problem of re-evaluating old logs. It is usually a matter of data gathering, log analyst education and evaluation software.

Drilling and Production Concepts

Nowadays many wells are drilled using OBM mud. More and more are drilled horizontally in order to improve production efficiency. A precise evaluation of the reservoir requires the use of adapted logging tools during drilling and also the need to adapt the log interpretation to such well geometry.

New Logging Technology

More tools, less trips in the well, computerized units, onsite evaluation... The evolution of the logging technology is astonishing. Borehole imaging tends to replace the traditional dipmeter measurements, but more is still to be obtained in this domain. The most impressive progress concerns the applicatiom of Nuclear Magnetic Resonance, Reservoir saturation through casing and Formation Testing.

INTRODUCTION

Libya subsurface is known to me, as I have worked there for two periods, in the 60's from Benghazi and in the late 60's and 1970 from Tripoli. Conditions have definitely changed. Names of fields like Amal, Ad Deffa, Gialo, An Nafoorah, As Sarir and others make me remember the hours spent on the logs for quality control, interpretation and discussions with the geologists and reservoir engineers. Logs were not as numerous as they are now and with the exception of the HDT (High Resolution Dipmeter) they were only recorded on film hence the necessity to digitize them, when studies, were performed on computer. Yes, indeed, in 1968 we had a computing centre in Clamart, France, the centre which was involved in the preparation for the Well Evaluation Conference held in Libya in 1970 (Fig. 1). In those years, logging problems were mainly concerned with bad hole conditions and a few OBM drilled holes. In interpretation we had the classical shaly sands, quartzitic formations, fractures, complex

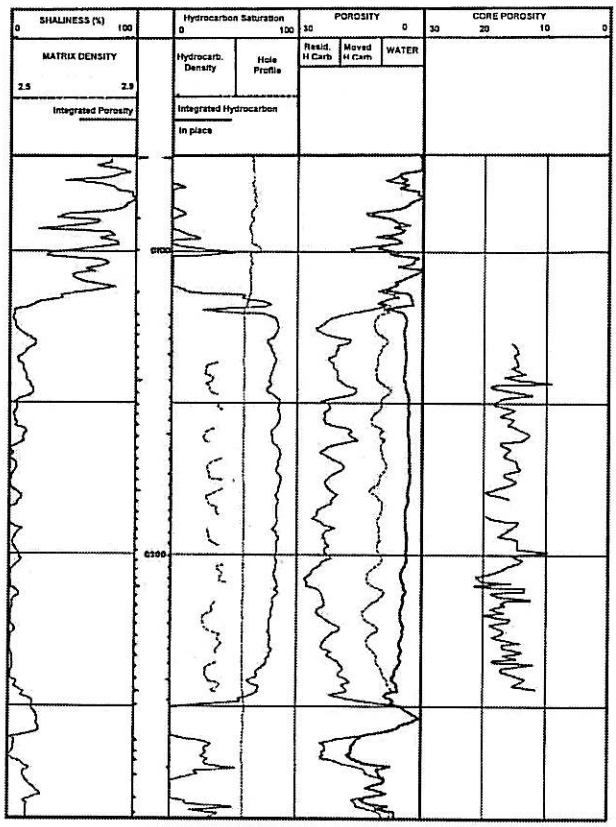


Fig. 1. 1970 Shaly sand evaluation.

lithology which included granite where hydrocarbons were present. In 1969 and 1970 the first borehole televiewer was introduced with the help of Joe Zemanek of Mobil Oil. It proved to be rather helpful to detect fractures (Fig. 2) and also, casing defects. Oil water contacts were observed behind casing with the help of the first TDT (Thermal Decay Time Log), with excellent results in Sarir. In Zelten the water movements were

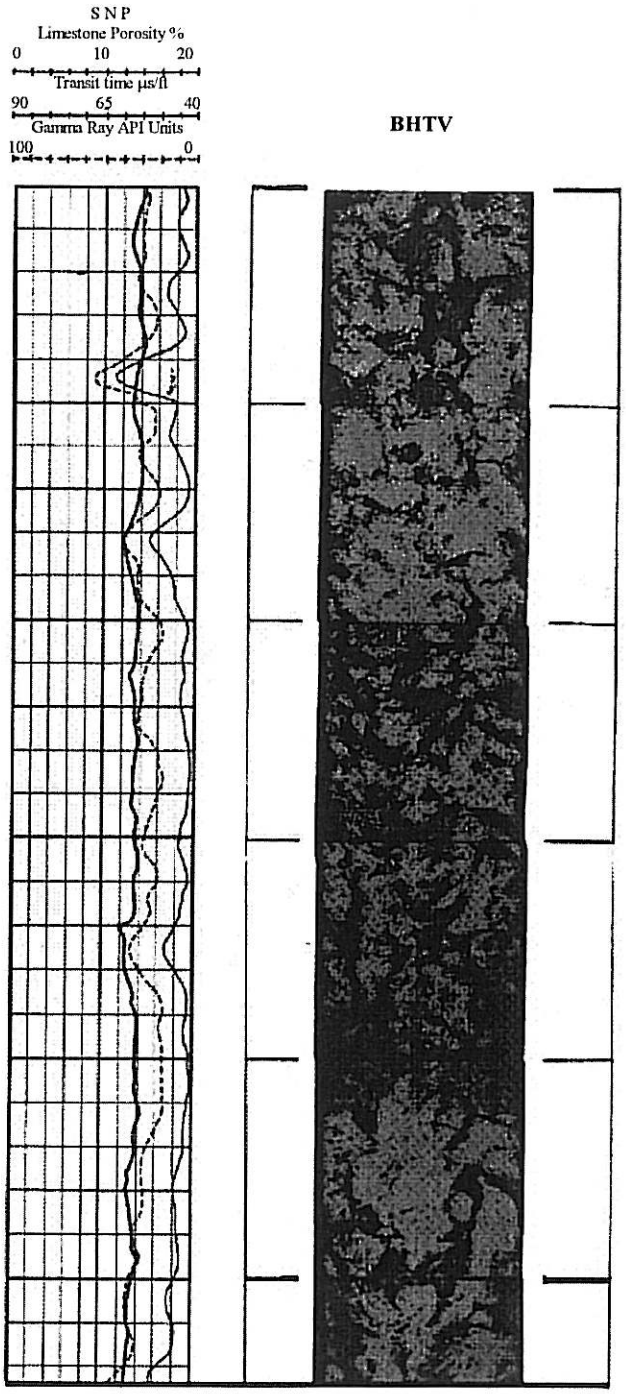


Fig. 2. Fractured hard rock.

detected using an induction tool run in observation wells cased with plastic casings.

LIBYA 2000

30 years have passed since my last assignment in Tripoli, and although I have had the opportunity to visit Libya a couple of times, I needed to refresh my memory. However, most of the fields I have known, if not all, are still producing, but conditions have drastically changed as the result of 3 main factors:

1. Libya – a Mature Oil Producing Country

Many of the producing fields are now over 30 years old. Depletion has mainly been compensated by water flooding and water injection programs, in the very early times of the production, like in Intisar Reef. The waters used can have a salinity equivalent to the one of the original interstitial water but more frequently the injected water is rather fresh. Producing zones and others will be invaded with such water and behind casing, in the pores, 3 fluids are present: the remaining hydrocarbons, the formation water and the flushing fluid. The traditional Thermal Decay Time tools have difficulty to evaluate the precise percentages of oil and water, the answer being the domain of spectral analysis using a Reservoir Saturation Tool.

When wells are drilled through zones affected by injected waters, the evaluation becomes complicated considering that in the so-called invaded zone 4 fluids are present: the remaining hydrocarbons, the "irreducible" formation water, some injected water and the mud filtrate. A solution was proposed in the late 70's[2] which asked to drill these new wells with a mud having the same resistivity as the original interstitial water (Rw) and being, when convenient, even doped with boron (Borax).

Secondary/tertiary recovery programs require often a re-evaluation of old data. Old logs will be interpreted, a task taken with some anxiety by the computing centers: difficult to collect the information, logs to be controlled for log quality before digitization, borehole corrections to be applied... Log analysts have to be re-educated to perform these tasks but also the modern software programs have to be adapted.

Formations of the Hamada field have fresh formation water, a situation often encountered in the Far East. Great care is then required in the choice of the drilling fluid and consequently in the choice of the resistivity logging tools. Depending of the ratio Rmf/Rw a laterolog or an induction device will be used but, in any case, a SP curve of good quality will have to be recorded, generally the only way to get a fair estimate of Rw.

Some of the problems met in the 60's are still present despite the great improvements in the

measurements. Thin, multilayered reservoirs are difficult to interpret owing to the diversity of logging tool characteristics mainly in their difference in vertical resolution. More difficulties are even to be expected when such reservoirs are drilled with OBM muds, missing the opportunity to run laterolog type devices or high-resolution resistivity imaging.

Low porous fractured quartzitic formations in the At Tahady field present serious difficulties in the interpretation of the logs owing to the low intergranular porosity. If the fractures are fairly well detected using borehole imaging only a range of the fracture porosity can be obtained.

To my surprise, I have heard mention of a recent rare case of very deep invasion observed in the Elephant field and also of oil production from relatively low resistivity zones, which when evaluated, show high computed water saturation incompatible with the water-free oil production.

2. Drilling and Production Concepts

Seldom used in the 60's and 70's except in special cases, OBM muds are now widely used for more drilling efficiency and borehole stability. In Libya, in 1999, 70 wells were drilled with such muds. Three domains of logging and log interpretation still suffer from the presence of a non-conductive fluid in the well bore:

- the resistivity logging of high resistive zones
- the evaluation of zones of variable and unknown Rw
- the dipmeter and resistivity imaging

However, modern induction tools will provide a satisfactory measurement of the conductivity down to 1 mmho, a value that satisfies most of the formations. Unfortunately, the SP curve cannot be recorded, a severe handicap in the case of unknown formation water. Note that, in this domain of OBM interpretation, the Electromagnetic Propagation Tool can provide an evaluation of the flushed zone and be of some help for further fluid saturation estimation. Borehole imaging is obtained from an ultrasonic device when borehole conditions allow but it has not yet the resolution obtained from resistivity imaging. Also the present OBM dipmeters have not the accuracy of the previous High Resolution Dipmeter using button electrodes.

Over the past 15 years, the number of horizontal wells (mainly offshore) has dramatically increased and the trend is irreversible. In the past we had what were called the highly deviated holes which, to be logged with traditional logging tools, required to be attached and pushed down the logging tools with the drill pipes. This was called TLC jobs (Tough Logging Conditions) and it was really tough. Nowadays, horizontal wells are logged with tools integrated into the drill collars, as close as possible to the drilling bit, tools built to give a response practically identical to the response of the conventional tools. However, some differences exist owing to a few factors: the invasion is not as deep as at the time of the open-hole logging and the borehole affects the measurements in a different way.

The logging, while drilling, has 2 main objectives: to provide the driller with a direct, nearly real time, information concerning the trajectory of his well and to give the geologists and reservoir engineers the necessary information concerning the formation parameters and the geometry of the reservoir. If these 2 objectives are well achieved with the modern fleet of LWD tools the interpretation of the data remains a difficult task, considering the fact that the tools are positioned horizontally within the layers.

Unfortunately owing to the lack of such equipment, horizontal wells drilled in several fields in Libya (An Nafoorah, Al Bouri...) are not logged today.

3. New Logging Technology

Over the past 3 decades only a few new logging concepts have been introduced in the list of measurements. The logging tools have dramatically improved in terms of reliability, accuracy, length, combinability and application. None of the tools used in the 70's had such performance. Only 2 measurements have survived: the SP curve and the natural gamma ray curve-often replaced by the natural gamma ray spectrometry. The logging logistic evolved from a logging cab full of panels, power supply, a huge

9 "galva" camera to the Platform Express truck fully computerized allowing the recording of most of the tools in one trip in the well and on-site interpretation when not in real time. The logging industry has taken advantage of all the progress made in the miniaturization of the electronic and sensors, microprocessors and data transmission over a piece of equipment which has not changed since its introduction in the early 50's (the 7 conductors steel cable). All the tools have taken advantage of these developments, in particular those recording huge quantities of data mainly due to the high sampling rate, such as the borehole imagers both resistive and acoustic, the array devices of the induction or sonic.

Some of the modern logging tools have not been introduced yet in Libya. Water saturation through casing in presence of fresh water can only be made with tools which do not rely only upon chlorine estimation like the Thermal Decay Time Log. Porosity, saturation and permeability estimations are now benefiting from the use of Nuclear Magnetism tools. And as I said before logging while drilling equipments are badly needed.

CONCLUSION

I hope and expect that the latest modern logging tools will be introduced in Libya in the near future. They will help to solve the various problems mentioned before. In the mean time engineering centers are developing and testing new logging equipment. For example, a High Resolution Laterolog Array will provide more measurements and information in highly resistive fractured formations. For OBM muds better dipmeter tools are being developed to offer an efficient dip computation and, in the future, a borehole image. Cased hole evaluation will take advantage of a cased hole formation resistivity measurement. It will show water intrusion and also detect previously missed oil-bearing zones. The observation of fluids movements between wells will be achieved with an array of electrodes placed along the casing of observation wells, and electrodes able to detect a waterfront from distances of 30 to 100 meters. Further developments are expected in logging while drilling tools such as a nuclear magnetism device.

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