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A Highly Integrated Logging Tool String Platform Express

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عمود مجسات تسجيلات الآبار ذات الترابط العالي Platform Express

فابرايس أوران

لقد تم إعادة هندسة عمود المجسات في أجهزة تسجيلات الآبار السلكية، بحيث أصبح ذا طبيعة ترابطية أو تكاملية تحت اسم (Platform Express) وتم إدخاله إلى ليبيا حديثاً.

ويمتاز هذا العمود بتصميم يجعل حزمته الالكترونية وتصميمه الميكانيكي أكثر نجاعة، حيث أنه أسرع من عمود أجهزة تسجيلات الآبار السلكية المعتادة والمستخدمة حالياً، ويعطي إجابات اعتمادية أفضل، كما أنه أكثر كفاءة عند الآداء.

في الواقع، فإن قياسات المقاومة الكهربائية وقياسات المسامية قد تم تحسينها وزادت قدراتها الاستيعابية بحيث تشمل قياس المقاومة الدقيقة والصور الوصفية والقياسات المتحركة. وقد دمجت هذه المجسات الجديدة في عمود أقصر له نصف طول ونصف وزن الأجهزة المعتادة. كما تضاعفت سرعتها التسجيلية بحيث أصبحت ضعف سرعة الأجهزة المعتادة وبنفس وضوح المعلومات. حيث أن العمليات اللوغاريثمية الخاصة بتصحيح أخطاء السرعة والتعويض عن تأثيرات حفرة البئر، يتم إجراؤها في الحال، أي في نفس وقت القياس.

كذلك، فإن مجسات أو أجهزة قياس المقاومة الضحلة والكثافة، قد حُملت على لوح إنزلاق أقصر مزود بمفصل مرن يساعد على تحسين عملية التصاق الوسادة الحاملة لهذه المجسات مع جدار البئر، ويظهر جهاز قياس الكثافة، لاقطا ثالثاً لزيادة اعتمادية القياسات بقدر عال. بالإضافة إلى أن تسجيلات الآبار التقليدية والتي تستخدم في الاستنتاجات البيتروفيزيائية، ذات درجة وضوح رأسية عالية.

الجزء الأول من هذه الورقة يفصل خواص عمود المجسات ويبين مدى الاستفادة النوعية للبيانات من هذا التصميم الجديد ويتبع في ذلك تتابع المجسات، من أعلى إلى أسفل، جهاز أشعة جاما والنيوترون وجهاز الكثافة والمقاومة الضحلة وجهاز قياس المقاومة ذات الرؤية الرأسية العالية، والجزء الثاني من هذا البحث يركز على حالة دراسية حقيقية من ليبيا.

Abstract: *The standard wireline logging tool string has been re-engineered into an integrated string named the 'PLATFORM EXPRESS', introduced recently to Libya. The string features more robust electronic packaging and mechanical design. It is faster than the existing standard logging string, provides better answers and reliability and is much more efficient to run.*

Indeed the traditional suite of resistivity and porosity measurements has been upgraded and expanded to include micro-resistivity, imaging and tool movement measurements. The new sensors are integrated into a shorter tool string that is less than half the length of the standard one, weighs half and its logging speed is double for the same

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resolution of data. New algorithms such as speed-correction and compensation for borehole effects can be run in real-time. Shallow resistivity (R_{xo}) and litho-density sondes are mounted on a single shorter skid which is articulated by a flex joint for improved pad contact against the borehole wall. The litho-density tool shows a third detector that increases significantly the measurements reliability.

Also traditional logs used in petrophysical interpretation can be produced with a high vertical resolution.

The first part of this paper details the tool string features and shows how data quality benefits from the new design. It follows the string sequence i.e. from top to bottom the gamma ray-neutron tool (HGNS), the litho-density and shallow resistivity tool (HRGD*), and the high resolution resistivity tool (HALS*). The second part focuses on an actual case study from Libya.*

INTRODUCTION

Platform Express is the name of Schlumberger's re-engineering of wireline logging technology. The word Platform represents the concept of a platform of integrated sensors rather than a set of individual tools screwed together into a very long tool string. The new sensors are integrated in both the hardware itself and the measurement. The word Express refers to the tool efficiency. It results from higher logging speeds and faster well-site processing turnaround.

The string shows general features that improve significantly the acquisition reliability. In the meantime, each tool integrated in the string shows its own characteristics that also increase data quality.

TOOL FEATURES

From the operations standpoint, this new tool string brings major advantages. First, the Platform Express string consists of four major sections that make up a total length of 38 ft and which weighs 690 pounds – less than half the standard logging tool string. Figure 1 shows the relative lengths of the standard logging string and the Platform

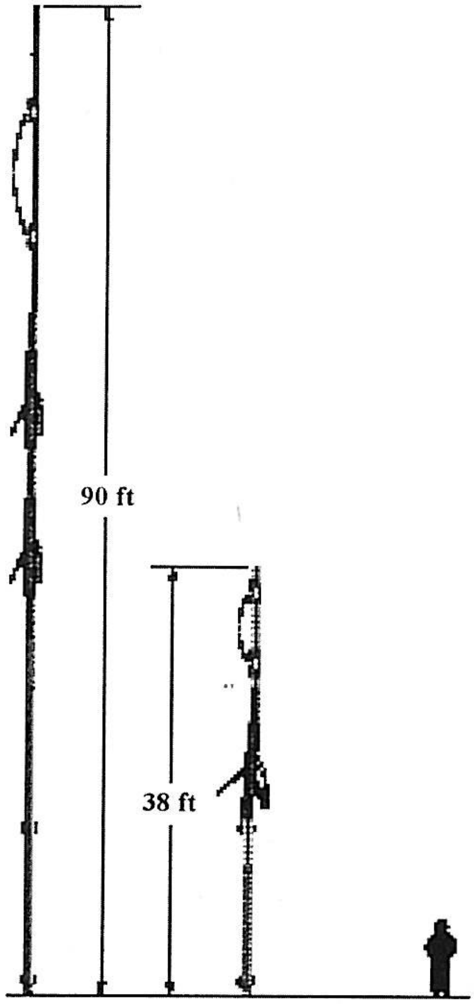

Fig. 1. Comparison of standard logging string with the Platform Express

Express. This shorter length allows it to successfully traverse short radius-of-curvature wells and wells containing severe doglegs. It requires, also, much less rathole than the previous generation of tools and helps reduce rig time in a significant manner[1]. The logging speed has also been increased to 3600 ft/h (double the speed of the standard logging suite limited to 1800 ft/h) without any loss in data quality.

Greatly enhanced reliability is an additional Platform Express benefit that reduces down time. New temperature and shock qualification standards have been achieved with the new design. Indeed, much more rigorous shock testing standards have been performed to qualify the Platform Express tool (as an indication, each tool has to survive 2000 shocks of 250 g's for 2 ms). The Platform Express is the only wireline tool in the industry that meets these standards for shock.

Over a wide range of environmental conditions in field tests conducted in Argentina, Canada, Indonesia and Saudi Arabia, Platform Express delivered almost failure free performance and reliability was over 3 times higher than the conventional suite of logs.

The Platform Express system implements the most advanced speed correction algorithms on the raw acquisition data, prior to any processing to provide basic outputs. This method ensures more accurate resolution matching of the measurements. Indeed, previous depth-matching techniques could not always perform correct depth-matching and resolution-matching of the data.

The integrated single-axis accelerometer measures acceleration along the tool's z-axis with a new and more precise acquisition method. This enables the depth along the borehole trajectory (measured depth) to be computed more accurately and for data to be indexed with respect to this speed-corrected depth. The speed correction is applied in real time to produce depth-matched data at the time of acquisition.

Environmental correction is also a service run in real time at the well site. Usually this type of correction is performed after acquisition and is often based on assumptions made about the well bore conditions instead of using direct measurements (temperature, pressure and properties of salinity, resistivity and density).

The Platform Express introduces environmental corrections with measured inputs rather than assumed values. An evaluation of the error on the correction is also computed to assess the correction validity. The environmental corrections are applied to speed-corrected data to produce high quality data.

Depending on the borehole conditions, the vertical resolution of the different measurements can greatly improve the log analysis. All of the Platform Express sondes are able to produce high-resolution measurements at a standard logging speed (3600 ft/h). The high-resolution data can help in a better indication of lithology, permeability and saturation changes in the formation.

A quick-look lithology indicator is also produced by combining a clay volume content (based on Gamma Ray – GR - or Spontaneous Potential – SP -) and the Photo-Electric Factor – PEF. This gives a type of lithology at each measured depth in order to observe lithology changes in the formation. This can be also used for effective well-to-well correlation. The tool string is also combinable with all of the other existing tools available in the wireline logging domain.

TOOL STRING

From top to bottom the Platform Express is made of the gamma ray-neutron tool (HGNS*), the litho-density and shallow resistivity tool (HRGD*), and the high-resolution resistivity tool (HALS*). Figure 2 shows the tool string and its measurements.

HGNS

The 9 ft, 5 inch long Highly Integrated Gamma Ray Neutron Sonde provides in one tool both standard gamma ray and neutron porosity measurements. Robust and shock-resistant packaging and new electronics have been added to improve reliability. The sonde includes the single z-axis accelerometer for speed correction. The HGNS also provides the telemetry interface for the entire tool.

The neutron detectors use an internal reference source for auto-calibration that eliminates the need for equipment at the well site. This enhancement saves time

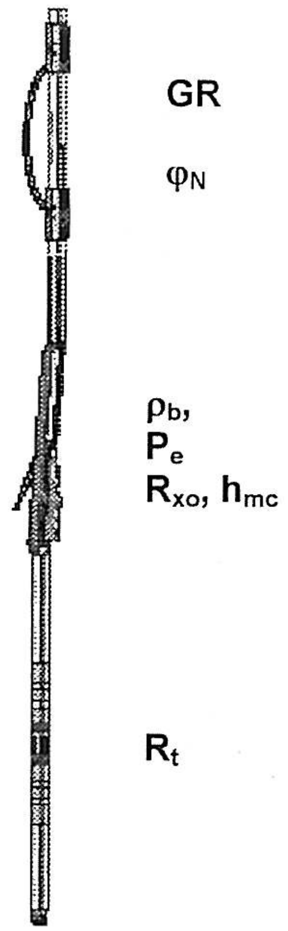

Fig. 2. Platform Express tool string.

and reduces the number of radioactive sources brought to the well.

HRGD

The High-Resolution measurements of the Platform Express include the three-detector density/PEF and the MCFL* (Micro-Cylindrically Focused Log) based R_{xo} (shallow resistivity) measurement. The sensors for both measurements are located on the same skid that is pressed against the formation. The pad is 30% shorter than the present generation Litho-Density tool.

Figure 3 shows the pad design. Flex joints are built in to allow the sonde to hinge or bend slightly as the tool travels into and out of rough hole sections. A second pair of arms is used to apply force directly to the back of the skid to keep its face pressed against the wall when the caliper arm hits a ledge. The upper link between the skid and the sonde body prevents the upper end of the skid from striking borehole restrictions abruptly and it also serves as a fishing link between the skid and the sonde body. Altogether the shorter pad, an additional back-up arm and the use of flex joints deliver significantly improved measurements in rough and deviated holes.

The MCFL electrodes are mounted on the surface of the pad, sandwiched between the short- and long- spacing detectors of the Three-Detector Litho-Density sonde (or TLD). Both sensors provide an estimation of stand-off (or mudcake) parameters, with the MCFL R_{xo} device providing a MicroLog-like measurement as well.

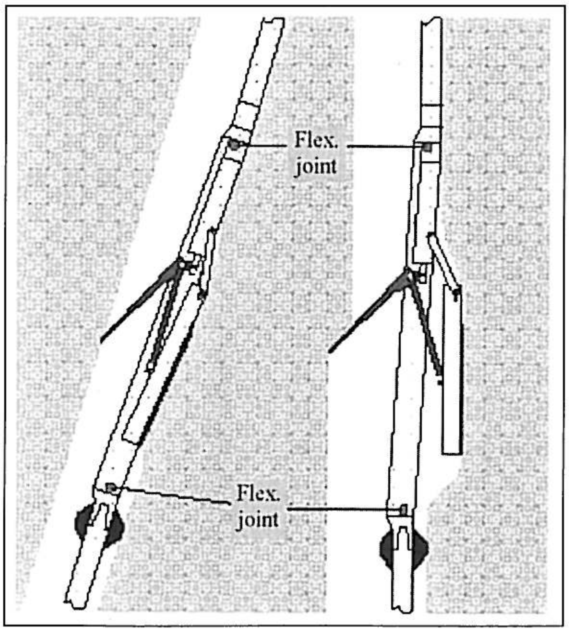

Fig. 3. HRMS pad.

The TLD is called a backscatter density measurement because it uses a third detector located only 2 inches from the source. The response of this detector helps characterize the shallow zone of investigation in the presence of rugose hole or thick mudcake.

TLD logs are similar to conventional Litho-Density measurements but the higher statistics and superior pad application result in faster logging speeds and more accurate density and photo-electric factor data. The new mudcake density and tool stand-off estimates help improve the environmental corrections applied to the logs. Figure 4 shows the density and PEF measurements in a test pit where the true values are known (limestone and dolomite). Only high resolution logs show very good accuracy in thin beds.

The processing algorithm employed for the Platform Express Three-Detector density device

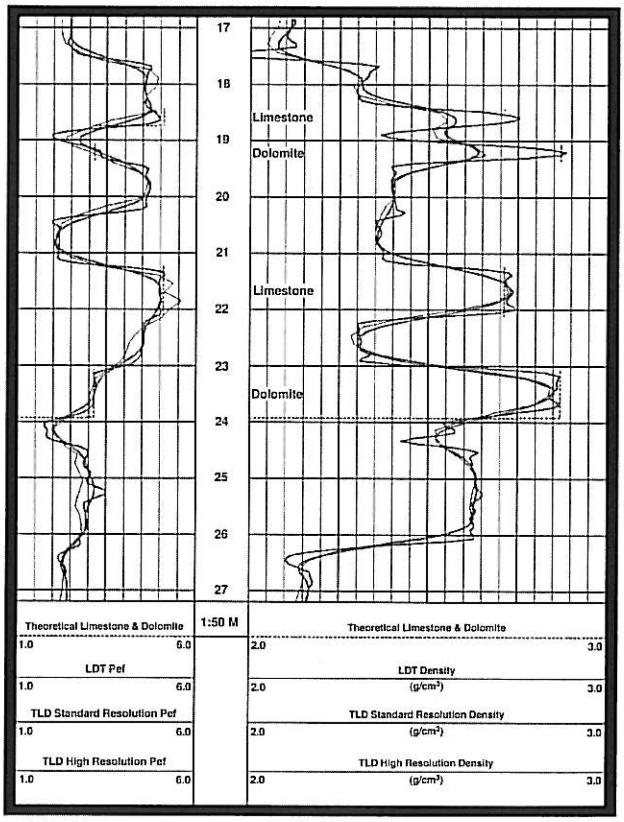

Fig. 4. Density in a test pit.

differs from the traditional spine-and-ribs approach of previous density tools. The spine-and-ribs algorithm is, in fact, a simple inverse model that permits the formation parameters (density and PEF) to be calculated directly from the count rate measurements.

However, with data from three detectors such a simple inversion is not possible. Instead a forward model is defined that is a prediction of the count rate measurements, calibrated and corrected for borehole effect, given the physical parameters (density and PEF of the formation, and PEF of the mud and mudcake thickness). Given this forward model the desired physical parameters are obtained through the resolution of an inverse model.

HALS

The 16 ft long High-Resolution Azimuthal Laterolog Sonde has an azimuthal array that bears overall resemblance to the previous resistivity laterolog tools, but rather than implement a scaled down version, the dimensions were re-optimized to minimize performance loss as a consequence of the substantial length reduction [2]. Four types of resistivity measurements are possible: conventional deep and shallow, and high-resolution deep and shallow resistivities. The tool delivers 12 " vertical resolution and a deep and shallow-reading azimuthal resistivity images of the formation, as well as the ability to estimate mud resistivity.

The main uses of the azimuthal images are determining formation dips and correcting true resistivity in dipping beds, detecting and evaluating fractures and estimating azimuthal anisotropy particularly in deviated/horizontal wells.

Borehole corrections to the High-Resolution Laterolog Sonde are available in real time at the well site. Figure 5 shows the corrections of borehole effects on the different resistivity logs (removing invasion appearance).

The importance of these real-time corrections is illustrated by this example from Indonesia, covering two different resistivity ranges. The standard- and high-resolution curves are presented

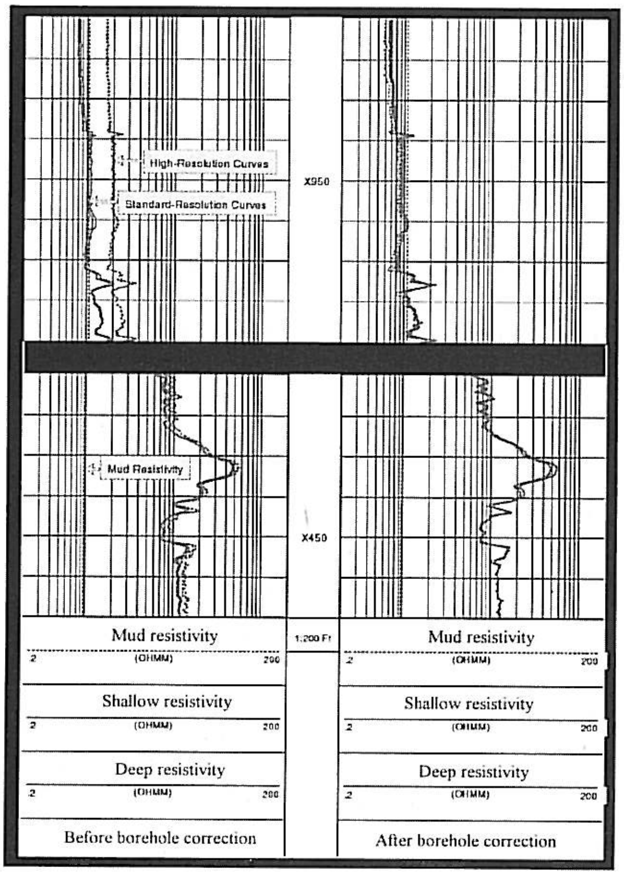

Fig. 5. HALS borehole corrections

both before borehole corrections, in the left track, and after, in the right track. The HALS mud resistivity measured is presented in both tracks.

Note from the data before borehole corrections that the separation between the standard- and high-resolution curves in impermeable zones, indicative of the magnitude of borehole corrections, increases as the ratio of apparent resistivity to mud resistivity decreases. Note, also, that in these low-contrast conditions, the borehole corrections to high-resolution data are very significant. After borehole correction, there is an acceptable overlay between the deep and shallow resistivities at both resolutions over these generally impermeable intervals.

EXAMPLE FROM LIBYA

Platform Express has been recently introduced to Libya. The example studied here was recorded with the same string as described previously but sonic measurements have also been added to the tools to provide the usual transit time log.

The general data set shows partially washed-out zones. Figure 6 shows the effect of speed correction on nuclear measurements in one of these zones. On the first track is plotted the caliper and both gamma ray curves (speed and non-speed corrected); the second track shows the cable tension; the third and fifth tracks are showing the nuclear curves (density and porosity) before and after speed correction. The lithology column logs in the fourth and sixth tracks follow the same logic.

The tension curve is clearly showing the tool sticking between X670 and X720 ft. The effect of speed correction is then clearly visible on the density curve. The lithology column is obviously

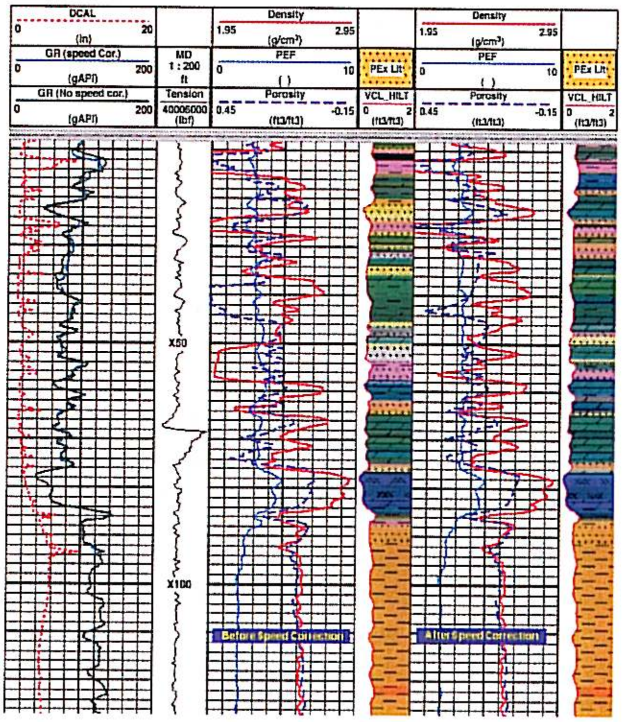

Fig. 6. Speed correction on nuclear data.

affected in the same manner: the first estimation of lithology shows non-negligible changes after speed corrections.

Figure 7 shows the recorded and recomputed logs along with formation volume analysis: the caliper and computed stand-off on the first track; shallow and deep resistivities with standard and high resolutions in the second track along with the R_{xo} curve; the deep resistivity image on the third track; the lithology quicklook on the fifth, the nuclear measurements (density-PEF, porosity) on the fourth and sixth track and the computed volumes in the last track.

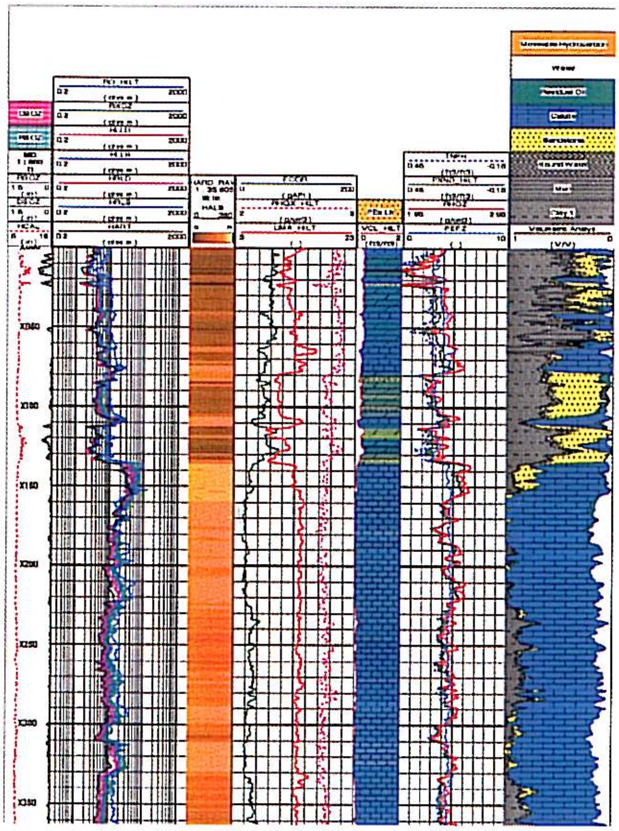

Fig. 7. Platform Express answer.

The lithological column shows good correlations with the formation volumes analysis. At the well site, both lithological column and speed- and environmentally corrected logs are available. It enables a quicklook interpretation with fairly reliable results.

CONCLUSION

The Platform Express tool string is designed to provide several services: First, it integrates the standard logging measurements in one string to provide the fundamental logs from a single run. The tool is designed in a robust way; its logging speed is double the standard one and the tool features shorter and lighter characteristics that allow data acquisition in hostile environments in a more reliable way (like short-radius wells).

Secondly new algorithms have been implemented that enable in real time speed and environmental corrections to produce ready-to-interpret data at the well site. A lithological column is also output at the well site to help identify the formations of interest.

Data quality also benefits from the Platform Express design: high-resolution logs enable thin beds analysis; resistivity images are produced; the pad integrating density and R_{xo} measurements give better answer owing to a flexible joint that improves the pad contact against the well-bore surface. The overall tool string is a new standard in Libya that already proved worldwide to be very efficient.

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