

WORKING WITH WIRELIN TECHNOLOGY

**Paul Worthington, Robertson Geo, UK, and
Brad Posner, Consultant, USA,** discuss the
development of a new open-hole oil and gas wireline
logging system for exploration and production wells, from
design through to engineering and manufacture

Outside of the major service companies, oil and gas wireline logging technology has been developing too slowly for many decades due to the domination and control of these large majors. The lack of market scope for independent companies has traditionally restricted R&D efforts to the majors, whilst smaller service providers have struggled to upgrade outdated

analogue equipment. Yet, against this market backdrop, the availability of quality logging tools is as critical as ever for assessing the potential of both new exploration and existing production wells.

British company, Robertson Geo, has collaborated with a North American oil and gas service organisation to create and bring to market a new digital solution for open hole evaluation, in a project which



Figure 1. An array of Robertson GeoKey logging tools.

Sensor	Offset (m)	Schematic	Description	Length (m)	O.D. (mm)	Weight (kg)
			CBHD-RG (000011) CABLEHEAD	0.56	62.50	5.00
CCL	11.40					
INC	10.94					
			TEL-RG (000008) TELEMETRY	2.61	63.00	31.00
GR	9.80					
MRES	9.48					
			LDT-RG (000006) LITHO DENSITY	3.12	63.00	57.00
DCAL	6.98					
LSDHV	6.78					
LSD	6.78					
HRDHV	6.60					
HRD	6.60					
SW2	6.60					
SW1	6.60					
NW3	6.60					
NW2	6.60					
NW1	6.60					
			CNT-RG (000003) COMPENSATED NEUTRON	2.16	63.00	28.00
CNLSC	4.56					
CNSSC	4.45					
A4X	2.59					
A4R	2.59					
A3X	1.98					
A3R	1.98					
A2X	1.75					
A2R	1.75					
A1X	1.52					
A1R	1.52					
			AIT-RG (000001) ARRAY INDUCTION	3.91	63.00	37.00
TTEMP	0.30					
TEMP	0.05					
Dataset: MULTI SERVICE						
Total length: 12.36 m						
Total weight: 158.00 kg						
O.D.: 63.00 mm						

Figure 2. The tool string, as depicted in the industry standard Warrior acquisition software.

aims to meet the numerous challenges posed by modern wells. The greater well depths and higher temperatures being tackled today are bringing new technical requirements for hardware, while producers need the full range of measurements from this technology, in a system that is as compact as possible in terms of length, weight and external diameter.

Robertson Geo and its US based development partner identified the key requirements of a competitive system development, participated in some initial field trials which culminated in the decision to proceed with the design of the Air Quad logging suite, as it was known over the course of the collaborative project. This extensive development has led more recently to the commercialisation of the Robertson GeoKey tool suite, a new family of slim, open-hole oil and gas logging technologies, born from the Air Quad project.

The success of an earlier technical collaboration in which analogue tool measurements were digitised downhole, led to the creation of a smaller, lighter Air Quad open-hole logging concept, similar to the industry familiar 'Triple Combo' suite of density, porosity, and induction resistivity measurements.

It was also recognised that two additional features would be critical – an Ultrasonic Gas Detector (UGD) and a fast-responding temperature sensor. These were necessary because the customer's major market was in boreholes which were air-drilled and logged, with little or no fluid present.

The collaborators identified that the currently available Air Quad kit was too big and heavy, approaching 15 m in length and over 300 kg at an OD of 3 5/8 in. A new 'fit for purpose' solution was needed, one that offered excellent reliability, measurement repeatability and easier field deployment.

Robertson Geo already possessed the in-house knowledge and resources to tackle the requirements of a new product design. Its development teams, equipment manufacturing expertise, logging tool verification facilities, test borehole and autoclaves were all on-site at its HQ in North Wales. These facilities were augmented through use of the Callisto Test Facility in Leicestershire, the major centre for wireline logging tool calibration and appraisal in Europe.

This background formed the basis of the partners agreeing to develop the new Air Quad combo. Subsequent commitment by Robertson Geo soon after, led to the expansion of the logging suite's initial capabilities by adding fluid-filled borehole measurements.

Timescale

The partners agreed a project schedule that included initially delivering one

working prototype system providing all the petrophysical measurements required of an Air Quad, in a modular suite, within two years.

Measurements were to match the accuracy, repeatability, and resolution of existing major wireline logging systems, within specific working limits.

Pressure and temperature specifications were to be sufficient for most mid-tier oil and gas logging operations worldwide (Figure 2).

The development would also include all system accessories necessary for a complete logging solution. This included cablehead adapters, radioactive source holders, centralisers/decentralisers, calibration hardware, and knuckle joints, necessary to calibrate and deploy the system across various well applications.

For data acquisition, Robertson Geo chose to implement the widely-used Warrior™ Acquisition software in conjunction with its own surface acquisition system and telemetry protocol. The use of acquisition software widely adopted across the industry would minimise the need for additional user training and provide a familiar, proven system interface.

Engineering and development

The tight timeline was the most challenging aspect. Design, testing, and manufacture all had to be accomplished within the agreed schedule. Robertson Geo possessed much of the expertise and knowledge in-house. However, the most demanding technical hurdles were in developing the UGD and array induction, both new to the company. The air-filled borehole posed other significant challenges as it greatly affected known tool responses from density and porosity measurements.

Most of the theoretical work and characterisation could be completed in the UK. However, the project also called for multiple trips to Pennsylvania to acquire the data in the specified air-filled environment and to verify functionality with the customer's truck, wireline cable, head, and acquisition systems. Measurement data acquired in the UK and in the Pennsylvania test well then required extensive Monte Carlo numeric processing to fully characterise the tool output. This work was undertaken by an industry expert

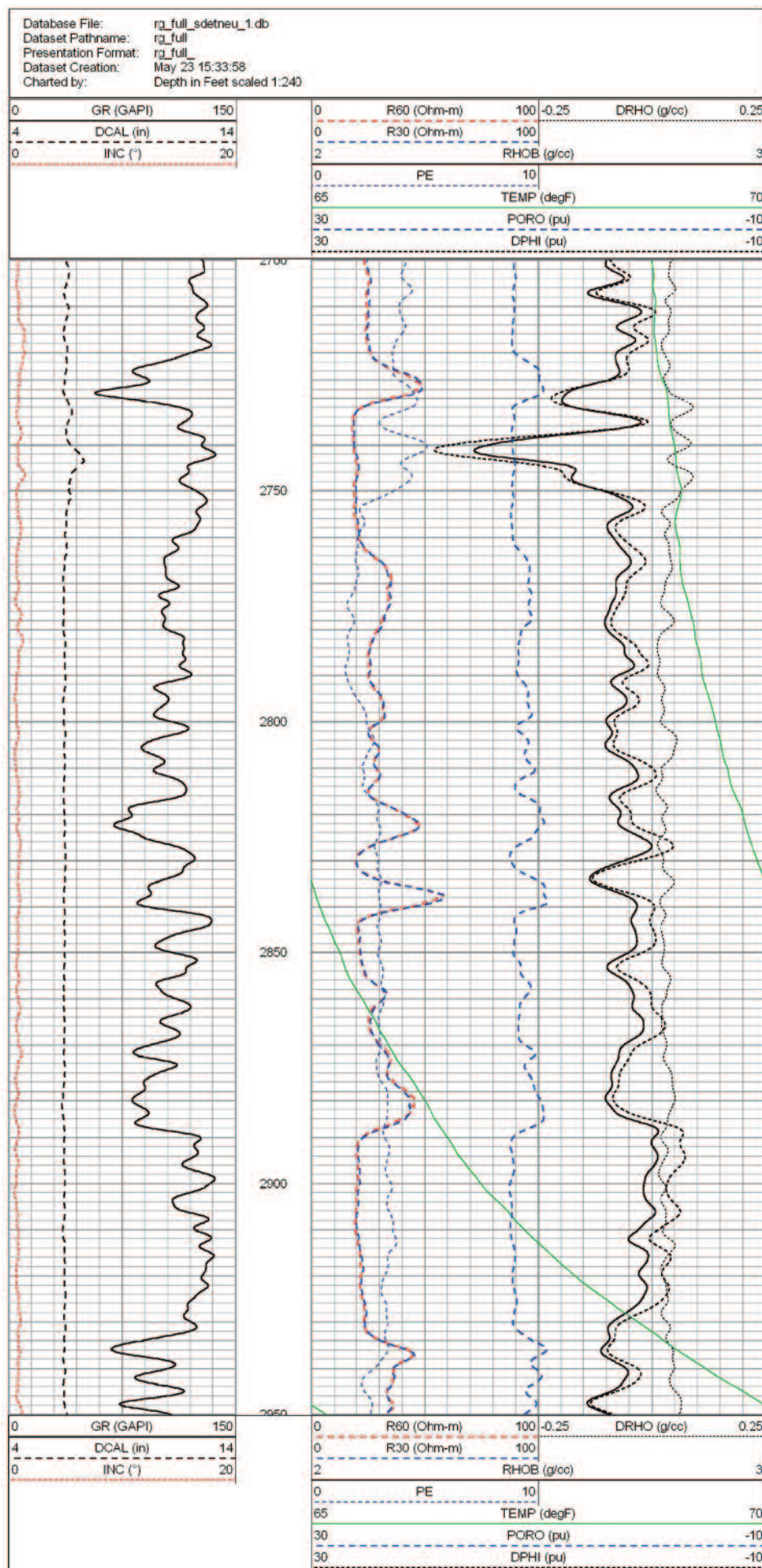


Figure 3. Data acquired from the Marcellus Shale Formation, Indiana County, Pennsylvania.

in specialist nuclear modelling, to generate and refine the final calibration algorithms. The Warrior software uses these algorithms to negate the need for traditional spine and rib plotting for the calculation of density and environmental corrections.

Once the physics of density and porosity measurements were established, the design and engineering of the modules could start.

The neutron porosity module was initially designed and tested with one thermal and one epithermal detector. However, the epithermal formation salinity correction proved to be complex to model and became challenging to incorporate into the Warrior software. As a result, the final version of the module contained two thermal detectors.

A challenge posed by the UGD arose from the Robertson Geo team's unfamiliarity with this measurement. It was required to detect the 'noise' of gas entry into the empty borehole through a fracture. The solution was to use two ultrasonic detectors and measure the differential – which also helped reject 'noise' from the tool itself in the empty environment.

Lithodensity (PE) measurements were also new to the company's project engineers so posed design challenges. An iterative process of development was pursued to understand the complexities of mechanical packaging and energy calibration requirements. Once again, the PE required further field trials to validate the Monte-Carlo derived output algorithms before acceptance of the design could be agreed.

One surprising aspect of the engineering design involved the array induction module. The air-filled hole allowed for a build-up of static electricity on the insulated section of the tool, which led to data spiking from electrostatic discharge. This was observed in the Pennsylvania test well, necessitating major design modifications.

This testing and improvement process continued until all the technical obstacles had been overcome, final designs confirmed, and a prototype manufactured.

The final stage of project was to carry out extensive field trials with multiple customers in Pennsylvania, in air filled, open-hole conditions. Field trial results fed a process of continuous refinement of the suite's design, and enhancement of calibration performance until both partners were satisfied the Air Quad suite met all of the original design objectives.

Commercialisation

With the original system objectives achieved, the final design concepts were approved by both parties and manufacture of the Air Quad system commenced. The development partner purchased and deployed multiple suites of logging tools in the USA. Regular field use proved the system delivered on its brief of reliability and repeatability in an air environment. Known today as the GeoKey logging suite, the Air Quad collaboration has allowed Robertson Geo to make available to the industry a suite of value delivering logging technologies that were traditionally the reserve of the large integrated service companies.

Figure 4 shows a complete GeoKey Logging system.

Continuous improvement

Based upon customer feedback, further support and modifications were implemented as field performance informed product refinements. An example of this was a redesigned UGD to facilitate field replacement of the ultrasonic detectors. Robertson Geo also revised the tool designs to operate in fluid-filled boreholes. Using similar engineering methodology, and with the addition of dual laterolog, full wave sonic, microresistivity, and formation imagers, a complete fluid or air-filled well logging system is now available.

Opportunities to participate in field trials with major operators in Uganda and the Canadian oil sands led to further design refinements and vital performance benchmarking. The decades old logging cablehead, which had its origins in the original partner's equipment, required a complete re-design. A downhole tension measurement was added, and radioactive source strength in some environments required increasing to meet measurement specifications. Furthermore, refinements to measurements were implemented across both software and hardware to hone GeoKey system performance, to satisfy the benchmarks expected by the major operators. Critical to this success and ongoing development was having the proper licensing and experience to package, calibrate and deliver radioactive sources to customers. Subsequently, numerous systems have been deployed globally to a range of clients and in varied applications, proving credibility and adaptability of the GeoKey technology suite.

The end result of this major collaborative technology development is a family of slim open hole oil and gas logging technologies openly available to the global oil and gas markets.

Conclusion

GeoKey offers independent wireline logging companies technology solutions that provide a genuine alternative in the competitive marketplace in 2018. Access to top quality equipment is necessary for independent wireline logging entities if they are to keep pace with shrinking technological development cycles and compete for market share with the major service companies. ■



Figure 4. A complete GeoKey Logging system.