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Sigma saves hot well evaluation offshore India

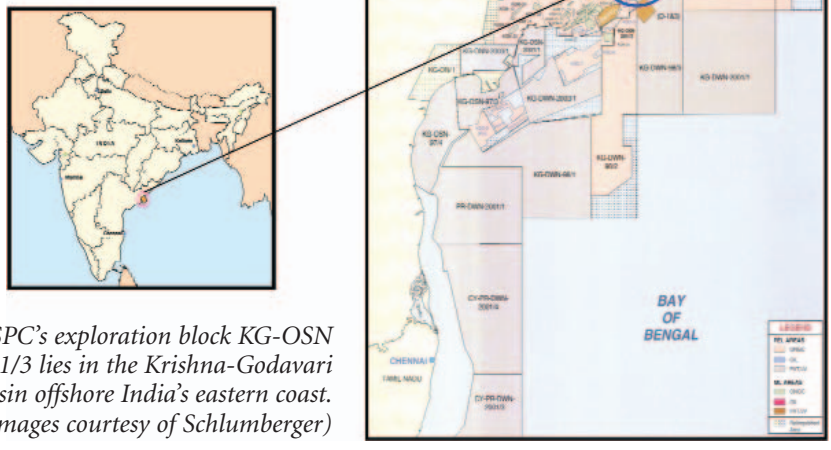
Lack of resistivity data in HP/HT well does not deter explorationists in their quest for energy.

AUTHORS

Theodore Klimentos *and* ***Arathi L. Mahesh****, Schlumberger;* ***M.Y. Farooqui*** *and* ***B.K. Behera****, Gujarat State Petroleum Corp.*

Obtaining good resistivity data can be tricky in areas plagued by well stability problems, complex geology, or high-pressure/high-temperature (HP/HT) conditions. The Gujarat State Petroleum Corp. (GSPC) encountered all three circumstances when it sought to drill a wildcat to establish gas production on a frontier block in the Krishna-Godavari (K-G) Basin offshore India's eastern coast. It would be India's deepest offshore well.

The challenge: Find a way to obtain accurate formation evaluation data without resistivity measurements to confirm the presence of hydrocarbons and then optimize the perforation strategy. The solution: Develop an innovative formation evaluation technique using a logging tool that obtains dual porosity measurements to determine lithology and detect gas, and then run spectroscopy logs to determine water saturation. The result: Identify the deepest major gas discovery offshore India, which tested at 14 MMcf/d.



GSPC's exploration block KG-OSN 2001/3 lies in the Krishna-Godavari Basin offshore India's eastern coast. (Images courtesy of Schlumberger)

Background

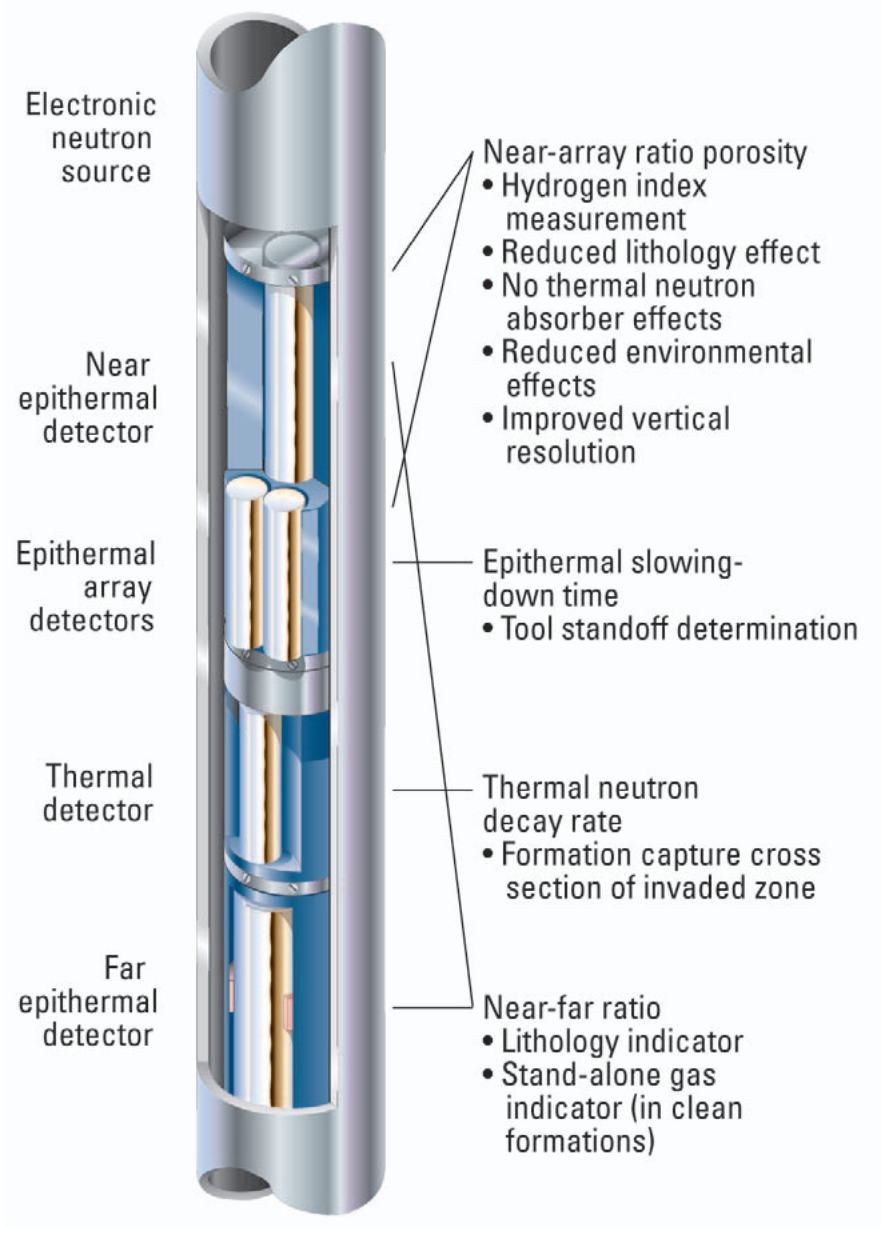
As gas production has declined from India's main producing area offshore its west coast, GSPC committed to exploring a shallow-water frontier block offshore the east coast in the K-G Basin. The commitment included 14 wells within the first exploration phase. Four of these wells were prioritized, each as a means to test a different geological concept.

The K-G Basin features a horst-and-graben topography buried beneath late Cretaceous clastics. Late Cretaceous to early Paleocene tilting of the Indian subplate caused a major transgression that accelerated the depositional rates of the proto-Krishna and Godavari river systems. As the coarse clastics infiltrated, the result was strong passive-margin progradation. Consequently, the basin is prone to a complex array of intersected formations and fault zones.

Results from two of the wells in the initial four-well program in the northern part of the block yielded little optimism for commercial hydrocarbons; so the exploration focus shifted to a deeper play in the south in hopes of locating intact seals. One of the remaining two locations, KG-08, was modified to test both remaining concepts, a deep one and a shallow one, from a single well. Its success was deemed critical for the exploration program to make further progress.

Drilling in the K-G Basin is exceptionally challenging, with stuck pipe, high pressures and temperatures, circulation losses, and overpressured zones being common complaints. Bottomhole conditions in the GSPC drilling program included an HP/HT environment of 12,000 psi and 410°F (210°C).

GSPC needed accurate formation evaluation data such as porosity, lithology,



Neutron detectors in the APS tool are positioned eccentrically, borehole-shielded, and focused toward the formation.

and water saturation to ascertain the presence of hydrocarbons and to choose the best perforation depth intervals.

Problems with tool sticking, however, made it impossible to obtain resistivity data from the deep KG-08 well, which was more than 16,404 ft (5,000 m) deep.

Logging solutions

Schlumberger's Xtreme HP/HT well logging platform was used along with elemental capture spectroscopy (ECS) logs to identify the most promising gas-bearing zones in the KG-08 well. A critical tool in the Xtreme suite for this effort was the accelerator porosity sonde (APS). The tool provides epithermal neutron porosity and Sigma measurements. In fact, because of the lack of resistivity logs in this instance, the APS Sigma log was the only gas indicator available.

Neutron detectors in the APS tool are positioned eccentrically, borehole-shielded, and focused toward the formation. This allows for epithermal neutron porosity measurements without having to make significant environmental corrections, while also providing hydrogen index information. Pulses of 14-MeV neutrons are generated from an electronic neutron source, and two porosity measurements are made based on detector signals placed at far and medium spacing. The former is more like a conventional thermal neutron porosity measurement approach, and the latter is not as sensitive to formation grain density and thus relates directly to the formation's hydrogen index.

Comparing these two porosity measurements helps in evaluating lithology and detecting gas. At the same time, the formation capture cross section, or Sigma log, can be measured according to the rate of thermal neutron decay.

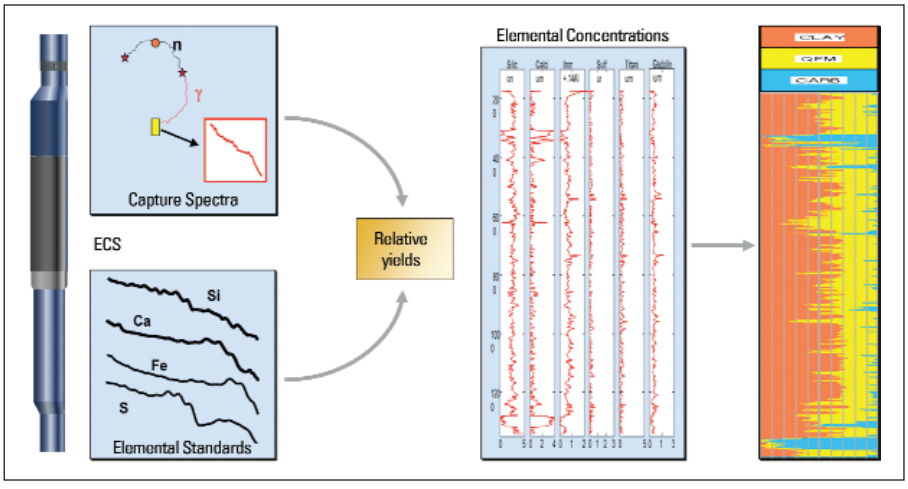
ECS method

The ECS sonde, using a typical americium beryllium neutron source and a bismuth germanium oxide crystal to measure relative elemental yields based on neutron-induced capture gamma ray spectroscopy, provides accurate lithology, grain density, clay volume, and matrix Sigma. These data were used together with the APS Sigma log to ascertain water saturation in the formation probed by the KG-08 well.

Using SpectroLith lithology processing of spectra from neutron-induced gamma ray spectroscopy tools to process the ECS data, it was possible to accurately estimate elemental concentrations. The ECS log-derived grain densities and clay volumes agreed with the core measured values in the KG-08 well. These data, in turn, were used to refine the Sigma log interpretation and thus solve for water saturation.

Validating the methodology

The validity of this approach was subse-



It was possible to accurately estimate elemental concentrations using SpectroLith lithology processing of spectra from neutron-induced gamma ray spectroscopy tools to process the ECS data.

quently tested and confirmed over a shallower section where resistivity logs were available. The two petrophysical models agreed well, with resistivity and without resistivity using APS Sigma and ECS logs.

In addition, the APS-Sigma quick-look gas detection method was implemented. This approach entails using near and far epithermal count rates together with the formation Sigma log and a "K" factor. The quick-look model was adjusted to accommodate the well's porosity ranges; this resulted in improving the identification of gas zones.

Using an innovative interpretation technique based on APS, Sigma, and ECS logs enabled GSPC to accurately determine lithology, porosity, and gas saturation in HP/HT conditions. Consequently, it was possible to identify the zones with the greatest potential for hydrocarbons, select the optimum perforation intervals, and then flow test them at rates of as much as 14 MMcf/d.

In addition, by incorporating data from the dipole sonic and the other available logs, including the new APS-Sigma-ECS methodology, together with the drilling data, it was possible to develop a mechanical earth model. This model served to explicitly describe the relative rock strength and stress state for the stratigraphic section penetrated by the KG-08 well. By capturing the critical geomechanical data needed for well construction and wellbore instability management, the model was useful in predicting pore pressure and confirming the capability to drill directionally around a platform proposed for installation on the K-G block.

Success

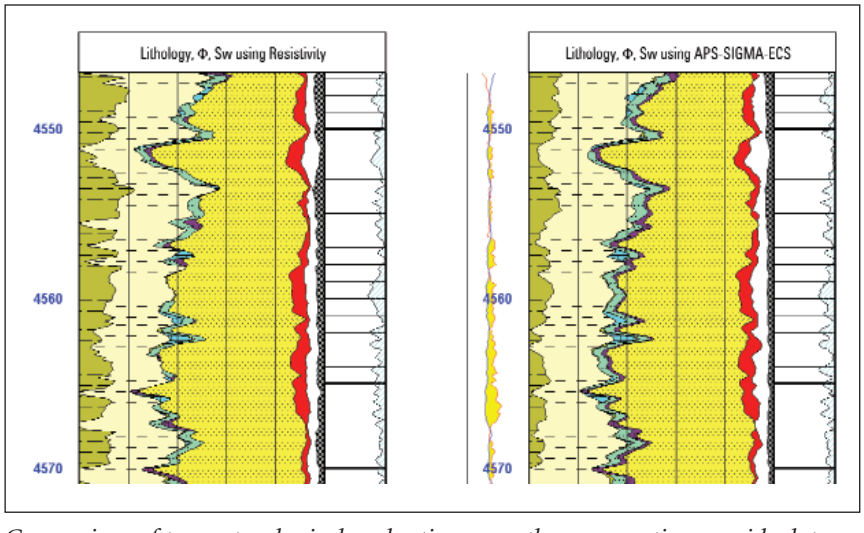
Prior to the program described here, no well had been planned in the K-G Basin with a total depth (TD) greater than 13,123 ft (4,000 m).

With this program, wells were envisioned that would have TDs of more than 16,404 ft. Extreme downhole HP/HT conditions were encountered: 410°F and 12,000 psi.

This concept involved a combined APS-Sigma-ECS log interpretation to accurately ascertain lithology, porosity, and gas saturation. With these data in hand, it was possible to select the ideal perforation intervals in the KG-08 well.

Success was demonstrated in flow tests of the most promising potential hydrocarbon-bearing zones that reached rates as high as 14 MMcf/d. This approach allowed India's deepest major offshore discovery well to be drilled and validated a novel, fit-for-purpose methodology for formation evaluation in the absence of resistivity logs.

This methodology is a promising new addition to the toolkit of exploration and production companies that find themselves dealing with the increasingly common challenge of HP/HT downhole conditions. H&P



Comparison of two petrophysical evaluations over the same section provide data with resistivity (left) and without resistivity using the APS-Sigma-ECS method (right).

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