New Resistivity LWD Techniques for Unconventional Oil and Gas Wells*

Paul Sinclair[1], Li Anzong, Aaron Otteman, Alisha Wennecamp, Song Zhoucheng, He Zhigang, and Wang Degang

Search and Discovery Article #80424 (2014)**
Posted December 8, 2014

*Adapted from oral presentation given at Geoscience Technology Workshop, Unconventionals Update, Austin, Texas, November 4-5, 2014

[1]CBG Corporation, Austin, TX (psinclair@cbgcorp.com)

Abstract

A new type of logging tool has been used commercially during the last four years for geosteering and formation evaluation. It is unique in providing a true Azimuthal measurement in real time, which helps in predictive geosteering and imaging of bed boundaries. Of significant interest, it is designed for the many independent DD and MWD service companies so they can provide a superior product at a very competitive day-rate to second- and third-tier operators.

Laterolog types of tools are capable of accurate measurement of resistivity from 0.2 - 20,000 ohm.meters, enabling calculation of hydrocarbon saturation and placement of the well in the "sweet-spot". The new tool is also able to detect approach to a distant formation, estimate the resistivity, and indicate the direction in real-time. It can also provide imaging of contrasting formations and calculation of relative dip and strike angles. The new service is called the Geosteering Resistivity Tool (GRT).

The new tool has been used in the Bakken (North Dakota), Niobrara (Wyoming and Colorado), Bone Spring, Barnett and Wolfcamp (Texas), Montney (Alberta), Viking and Bakken (Saskatchewan), and the Mississippi Lime (Kansas and Oklahoma). It has also shown promise in Coal-Bed Methane (CBM) wells in the San Juan Basin (Colorado), and in Heavy-Oil fields in Alberta. Recently, successful drilling jobs in China have been run in the Tarim Basin, Sulige Tight Gas Sands, and HuaChi Field in Changqing. The tool is also being used in Western Siberia for re-entry drilling.

A description of the tool design, real-time geosteering display, and operation is presented. Some case-studies from North America and China will also be presented.

New Resistivity LWD Techniques for Unconventional Oil & Gas Wells

Speaker: Paul Sinclair PhD, President, CBG Corporation

Co-authors: Li Anzong, Aaron Otteman, Alisha Wennecamp, Song Zhoucheng, He Zhigang, Wang Degang

Date: September 16, 2013

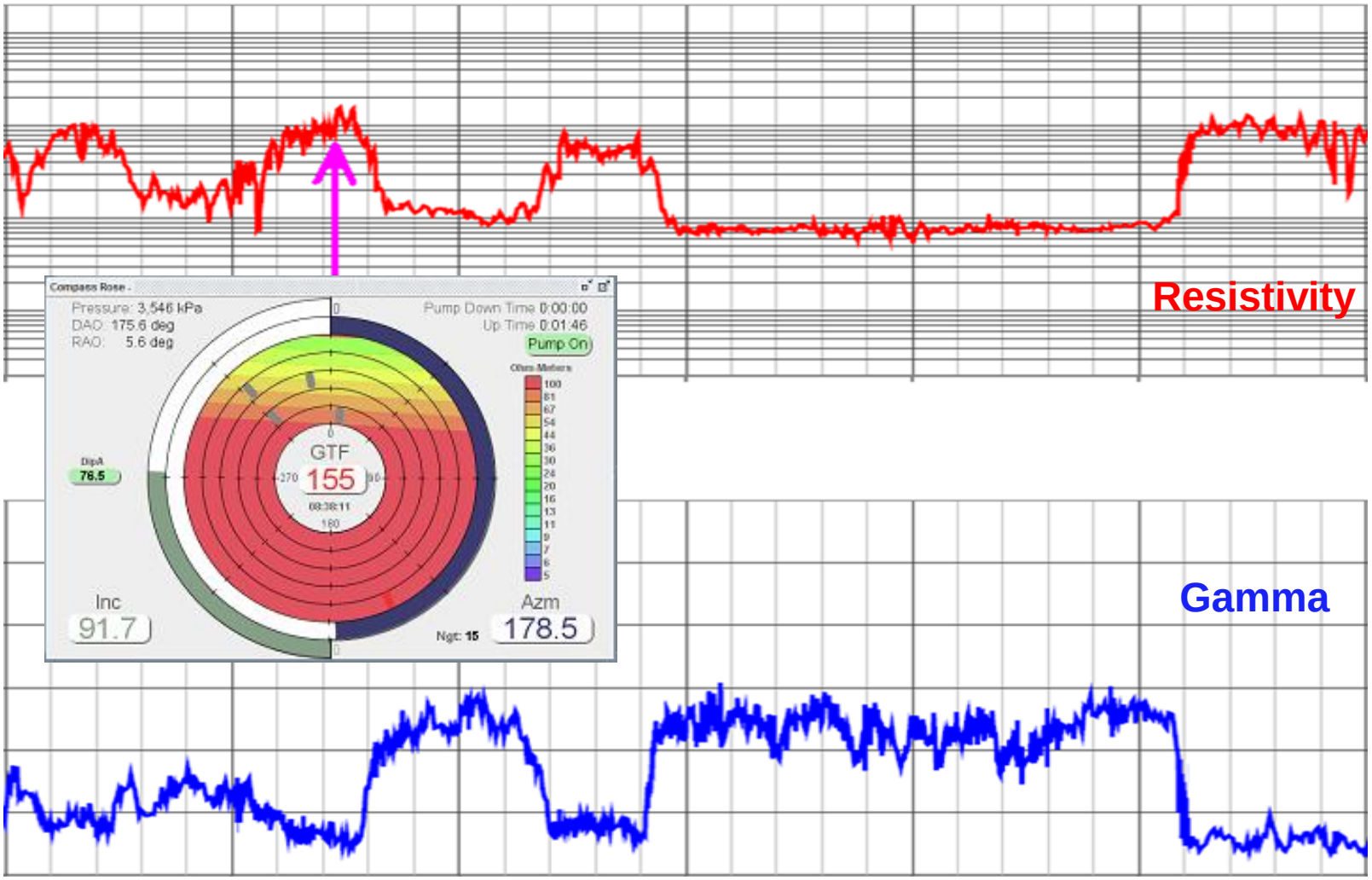
Agenda

1. Best technology for Geosteering drilling?
2. New Azimuthal Resistivity technology
3. Operational details
4. Case Studies - North America
5. Case Studies - China

1. What is the best technology?

- Electrical Resistivity is the best indicator of Hydrocarbons
- Used to calculate Oil or Gas Saturation
- Detects boundaries between high-resistivity and low-resistivity rock (e.g. reservoir and shale)
- Detects any water-contact (Gamma sensors do not do this)
- Resistivity sensors respond 10 times deeper into the rock than Gamma sensors

Geosteering using Resistivity



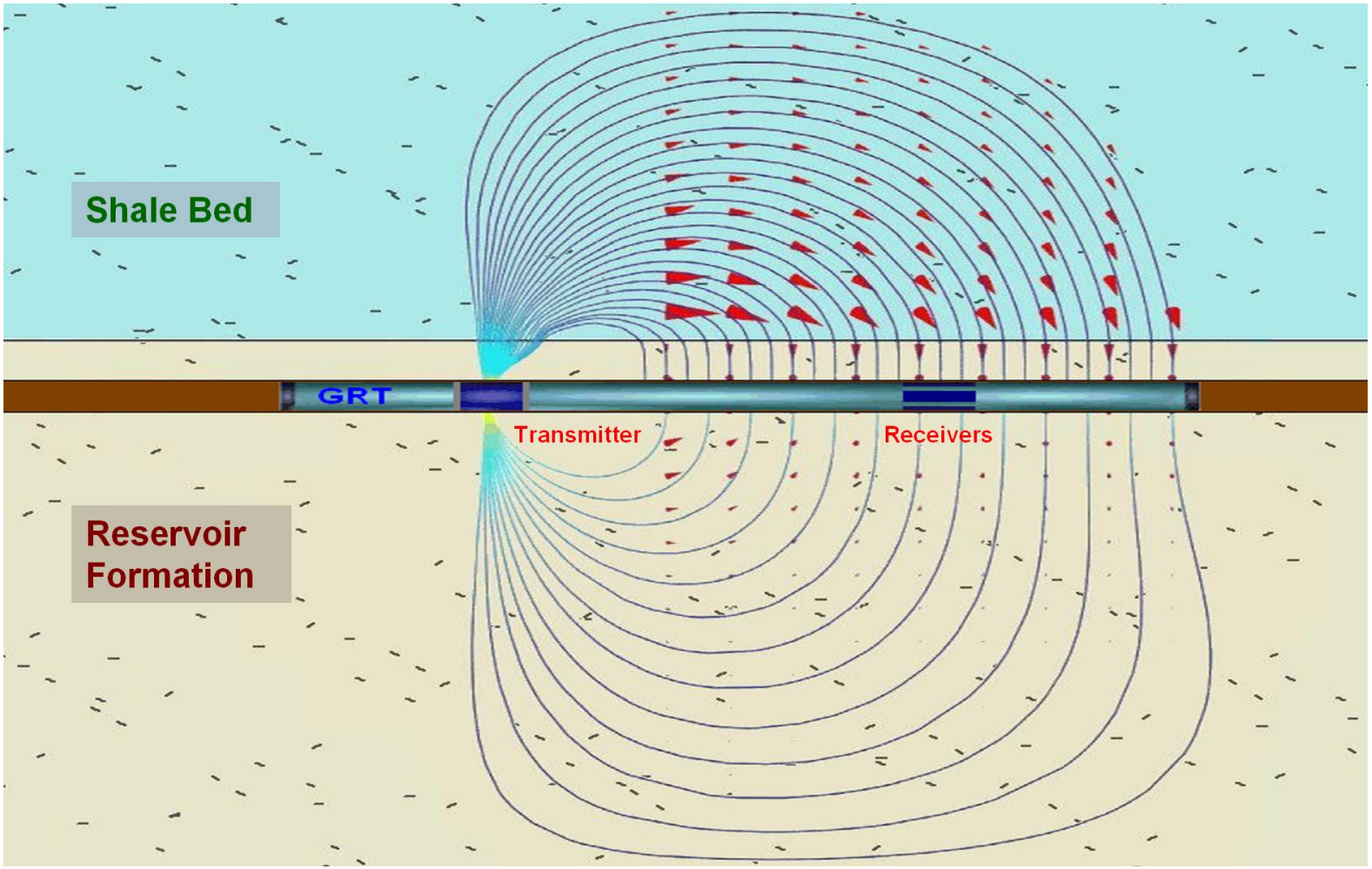
Azimuthal Resistivity Tool shows a visual image on a real-time Display (sees bed boundary ahead!)

2. Geosteering Resistivity Tool (GRT)

ICRSM

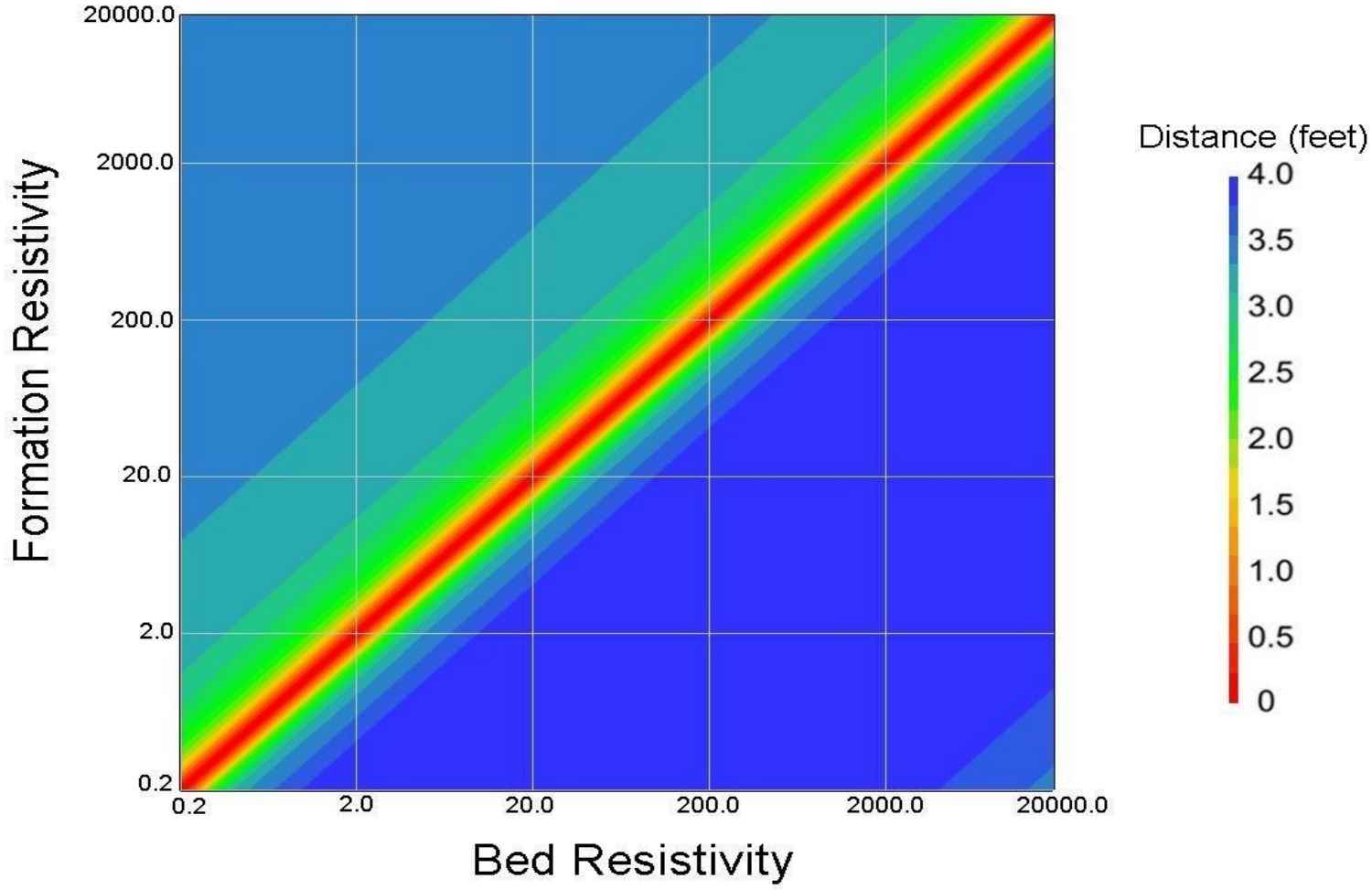
- Azimuthal Resistivity is the key for successful Geosteering
- The Low-Frequency Azimuthal Laterolog type is ideal for conventional and unconventional formations
- The well can be drilled along the path of Maximum Hydrocarbon Saturation (Sweet Spot)
- Real-time data presentation eliminates difficult log interpretation

GRT Theory



More current flows to upper receiver electrode, Indicating resistivity and direction of shale.

Detection Distance



Maximum bed-boundary detection distance is about one meter from the borehole for contrast > 3:1

3. Operational Details

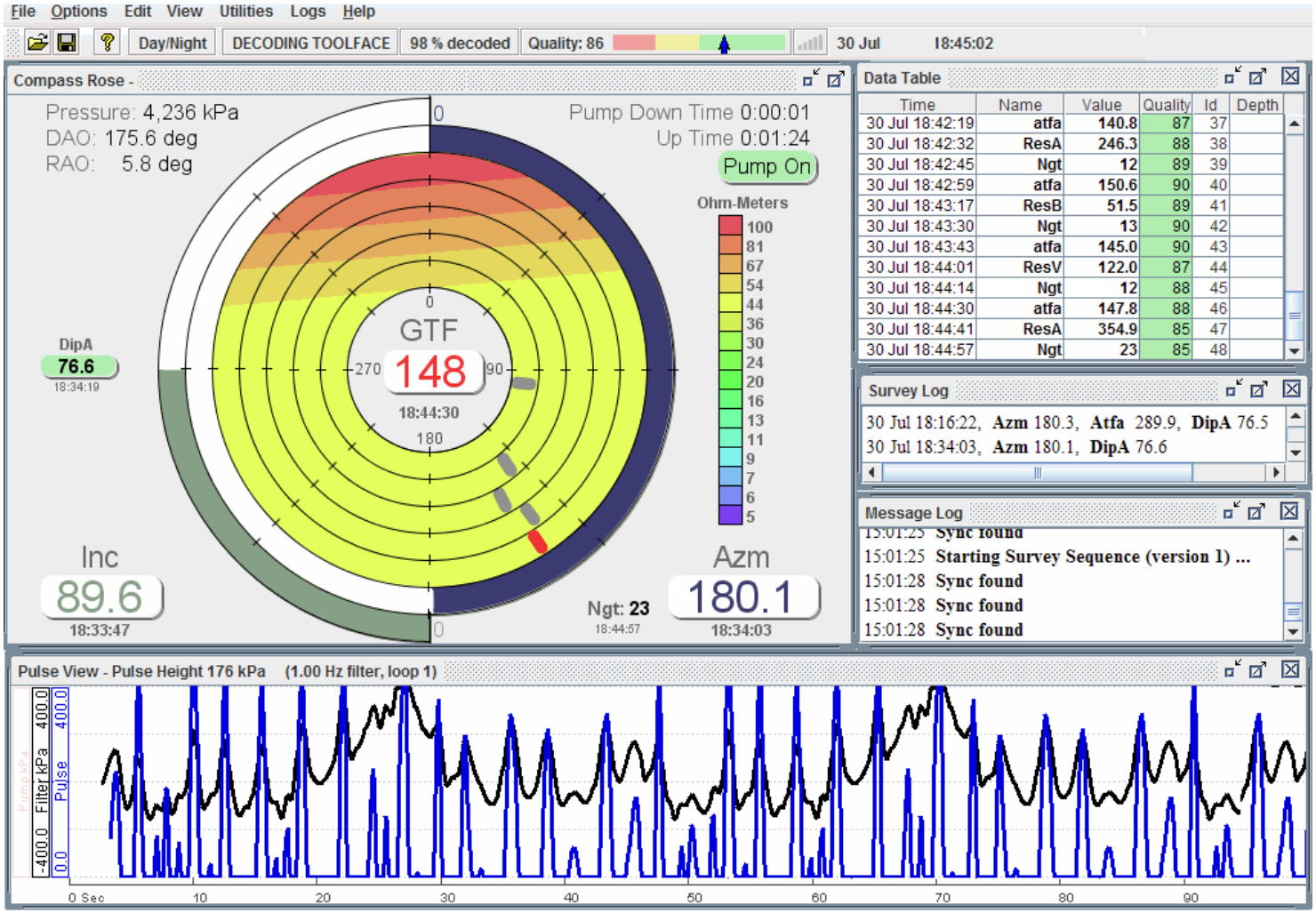
- Lowering the cost of drilling is very important for horizontal wells
- A simple and reliable tool is more useful than a complex and expensive one, if it is accurate
- Advanced software enables geologists and drilling engineers to use the data to steer the well without need for log analysis
- High-resolution data makes logs comparable to the best wireline tools

GRT Design

Azimuthal Laterolog uses a special collar with probe-based Data-processing electronics, Gamma sensor, Inclinometer, and a 16-day Log Memory inside

Combines with industry-standard directional sensors, batteries and a mud-pulser, to make a cost-effective alternative that fits the market

Real-Time Graphical Display

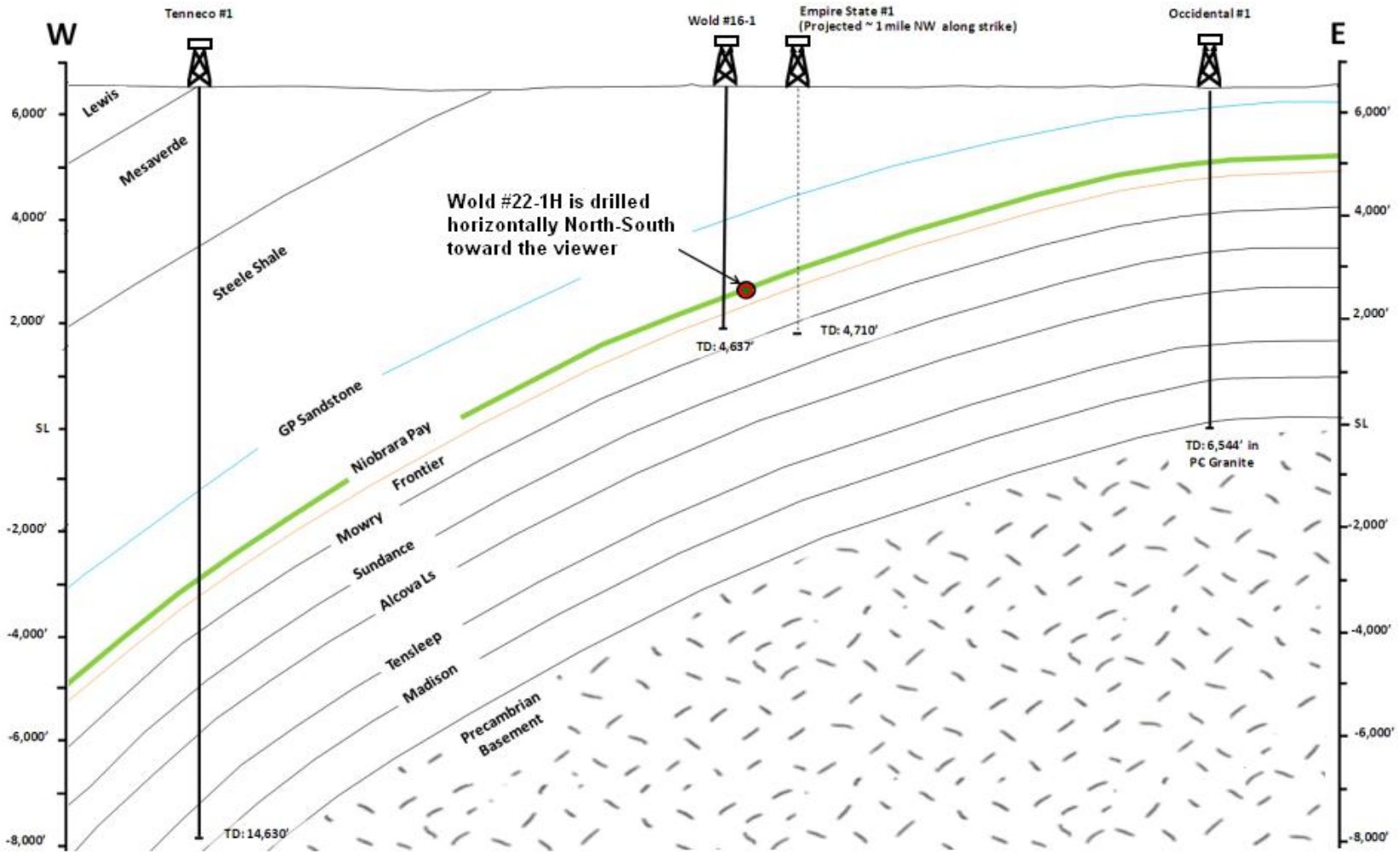


Color-coded Resistivity inside Compass-Rose image shows approach to overlying bed boundary

4. Case Studies – North America

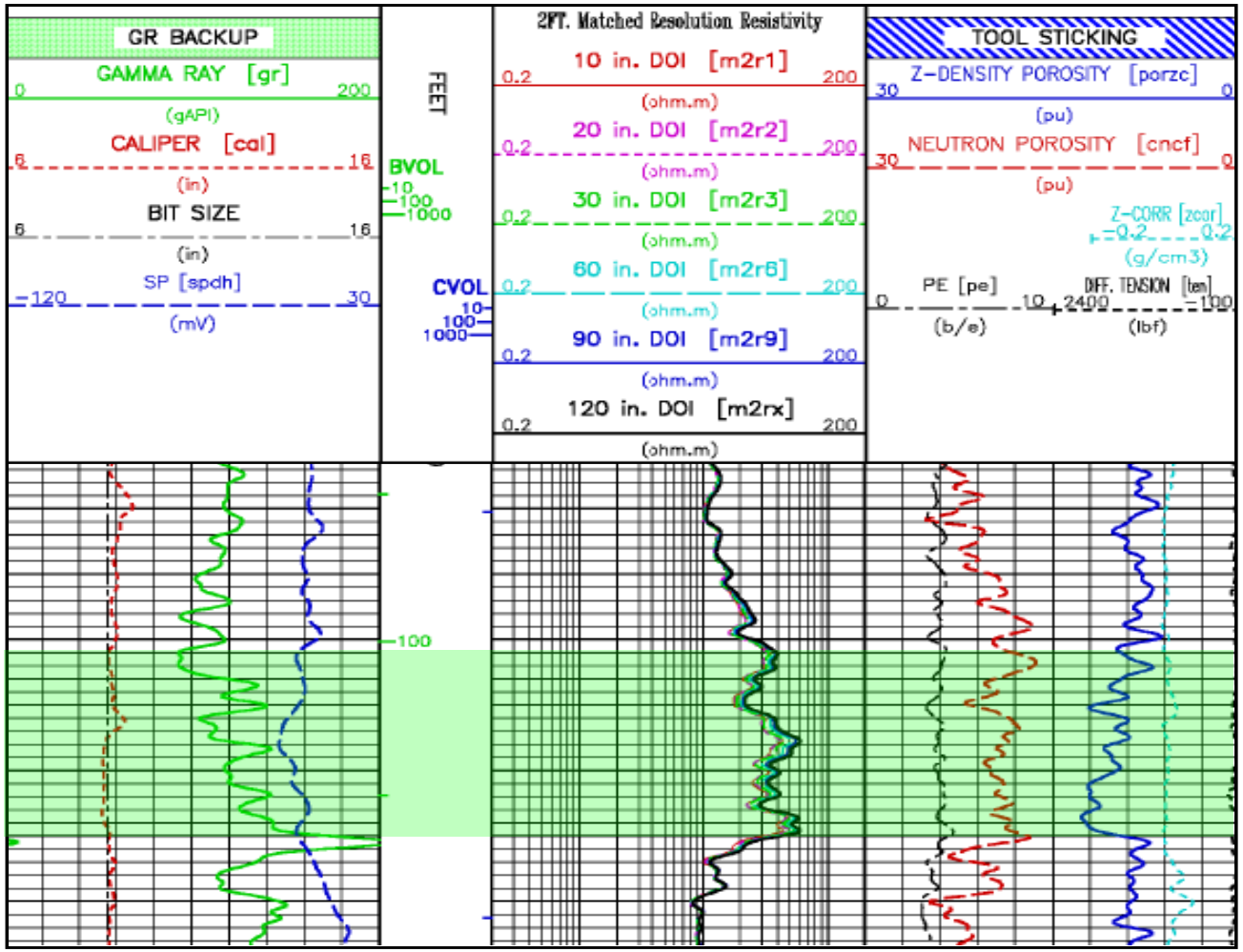
GRT has been used successfully in the Bakken, Niobrara, Montney, Viking, Barnett, Wolfcamp, Woodford, Mississippi-Lime, and Fayetteville.

Niobrara shale-oil well in Wyoming, USA



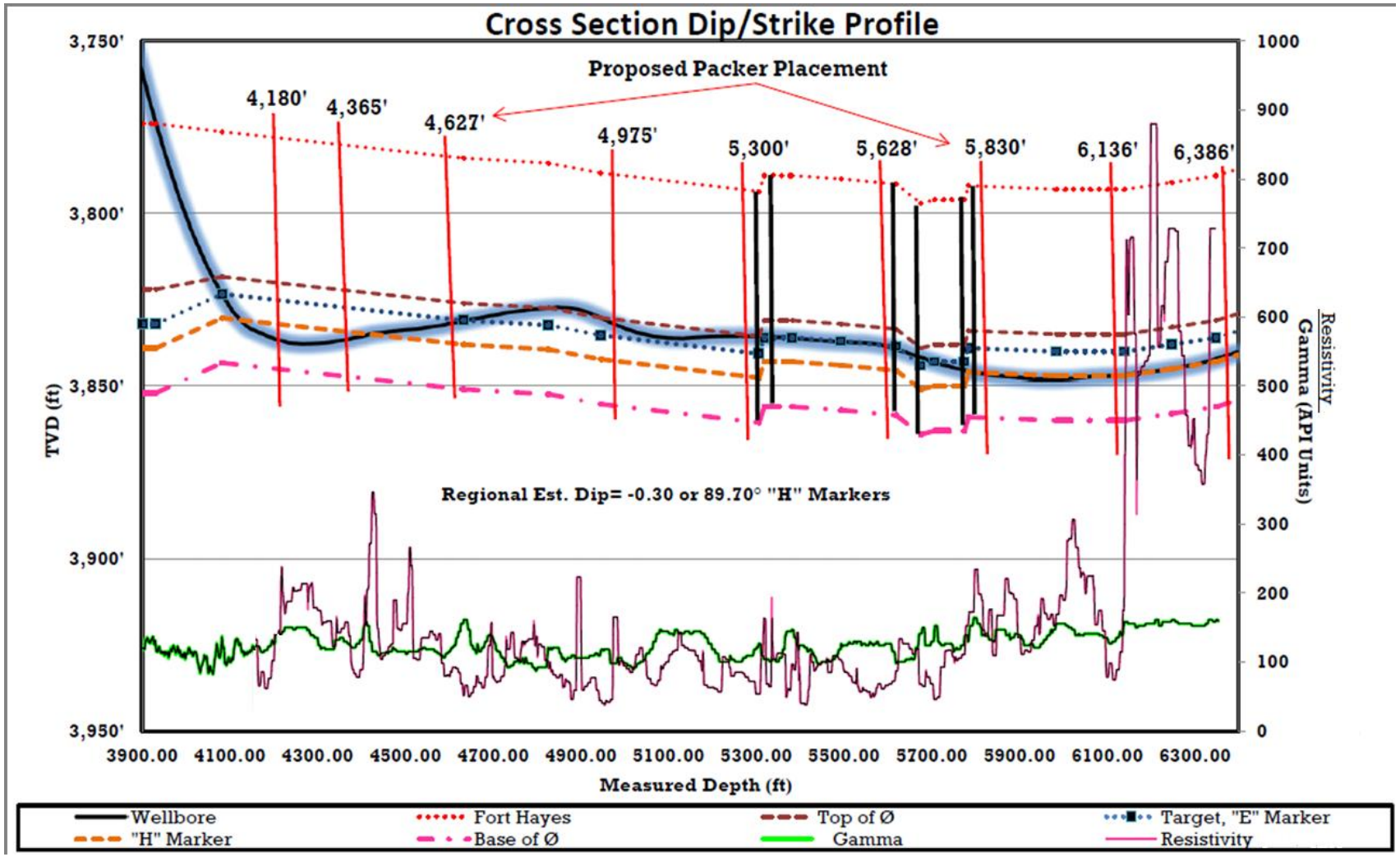
Niobrara shale is on top of a thin limestone target formation with 22° transverse dip-angle.

Niobrara shale-oil well in Wyoming, USA



Offset well has 8.5 m. payzone with 3:1 contrast to overlying rock. Gamma shows no useful change.

Niobrara shale-oil well in Wyoming, USA

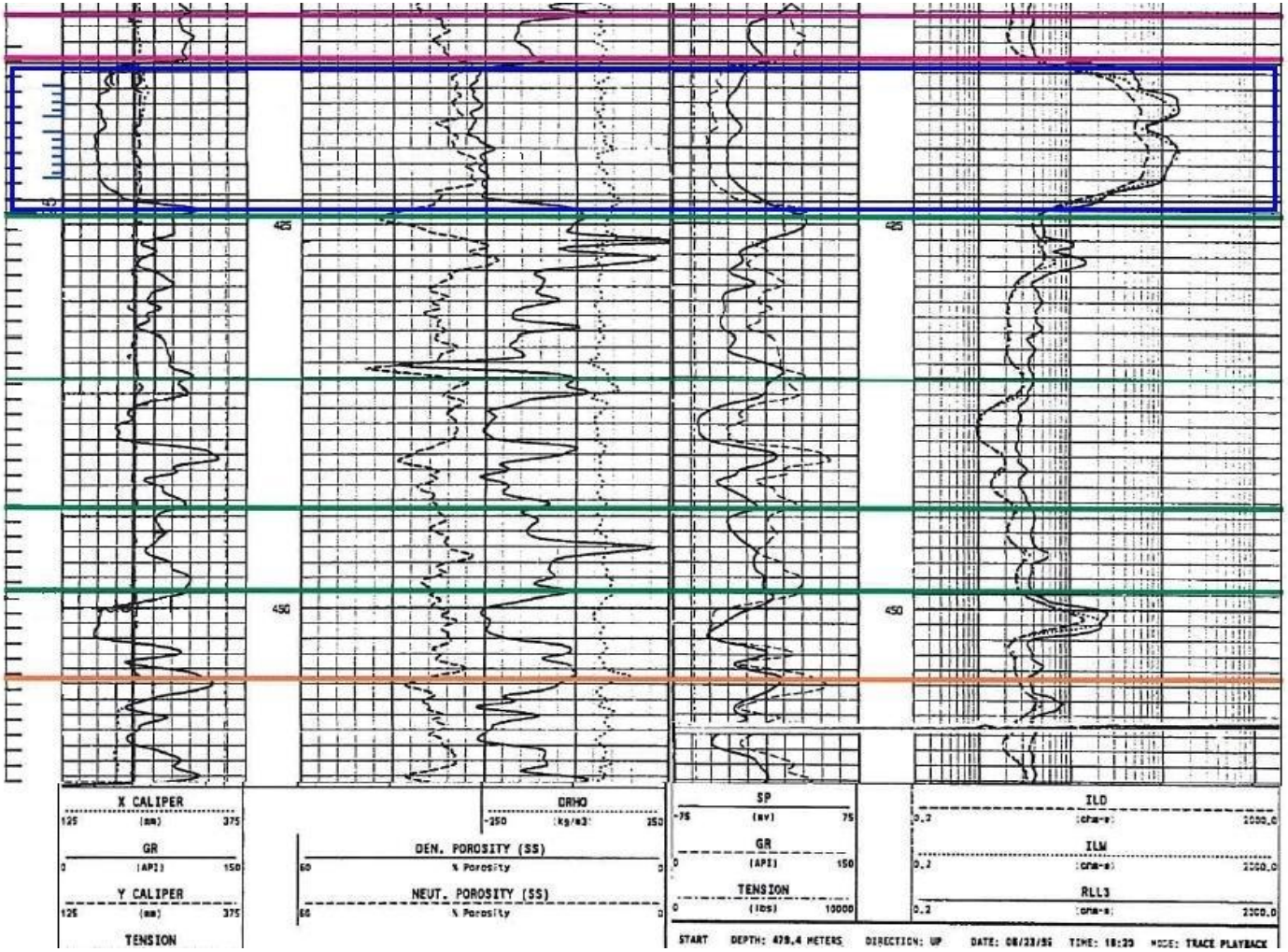


Borehole stayed in target zone for 98% of the well. Final 60 m fractured zone filled with oil.

Heavy-oil well in Alberta, Canada

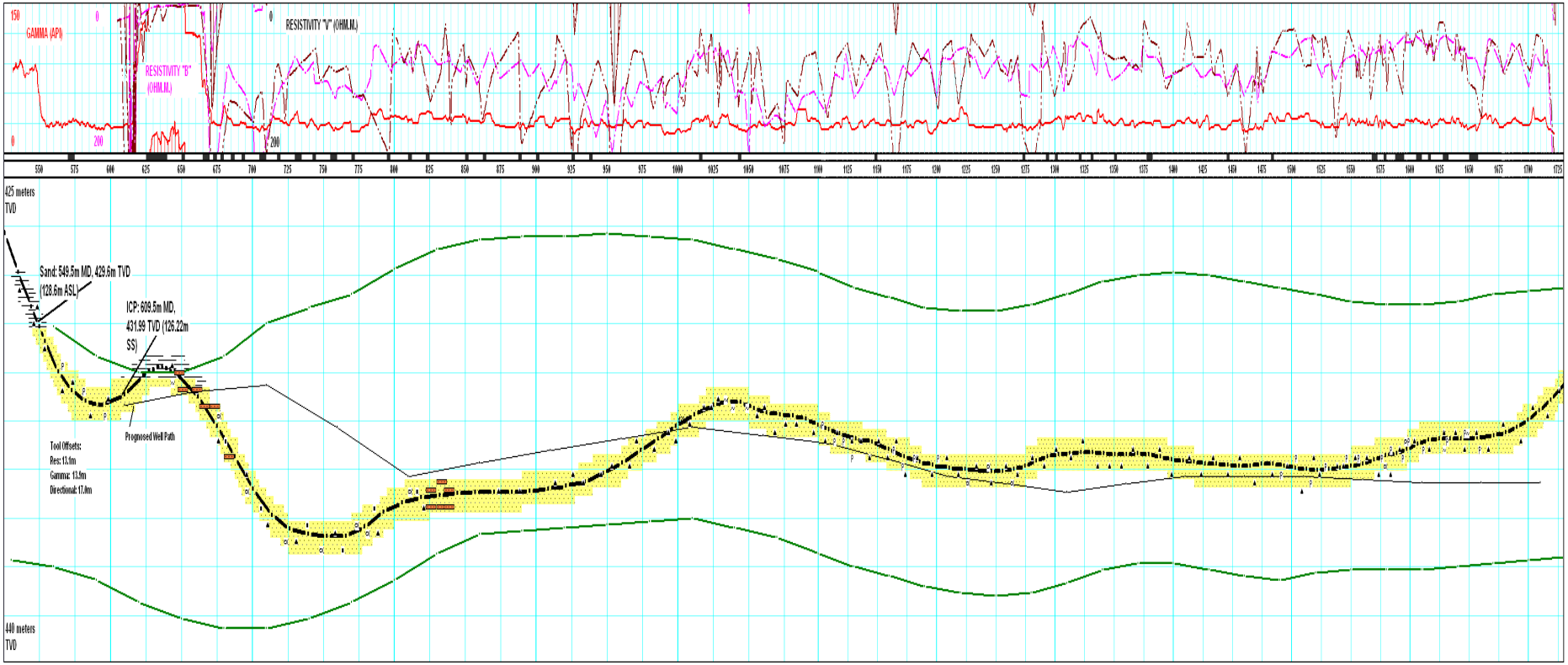
Shallow (420 m.) laterals are drilled with a Super-Single rig and completed in a few days.

Heavy-oil well in Alberta, Canada



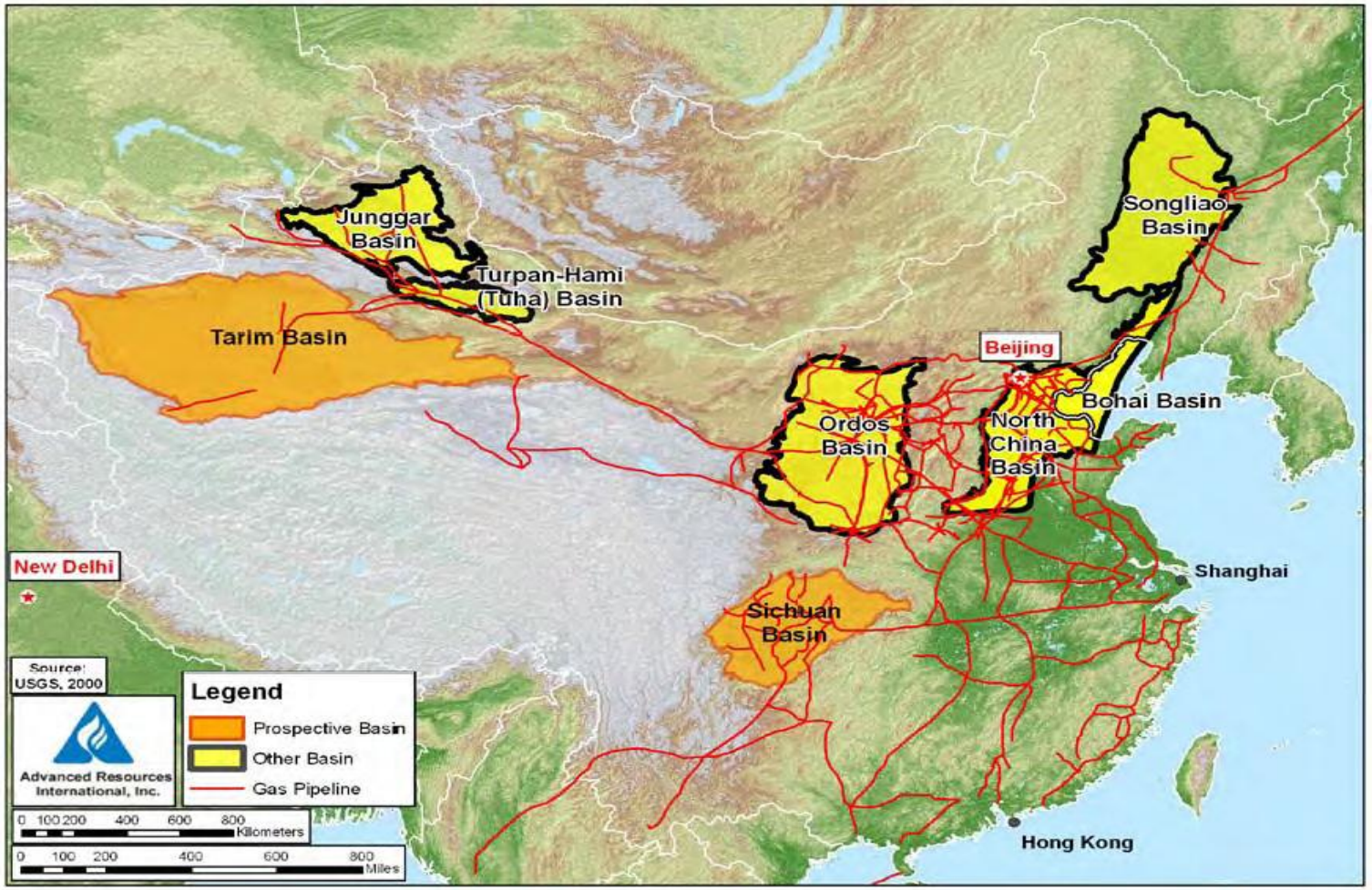
Target has 100 ohm.m. resistivity with good contrast to 3 ohm.m. upper and lower shales.

Heavy-oil well in Alberta, Canada



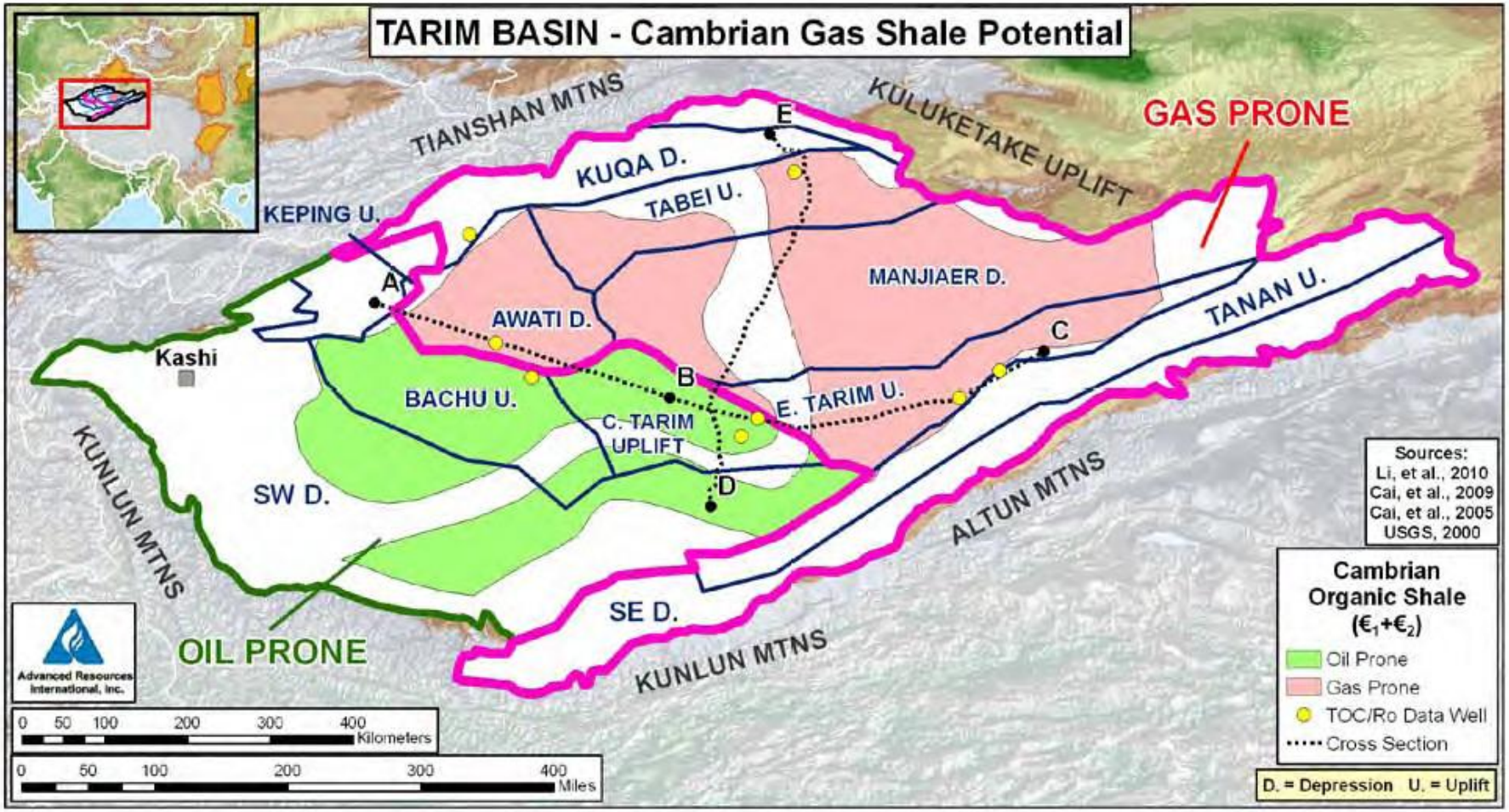
Upper sand-shale boundary unexpectedly located close above the landing point, causing slight excursion into water-wet shale, but most of the borehole is in the sweet-spot and productive.

5. Case Studies - China



GRT has been used successfully in the Tarim Basin, Sulige gas field & Changqing(Ordos Basin)

Tarim Basin

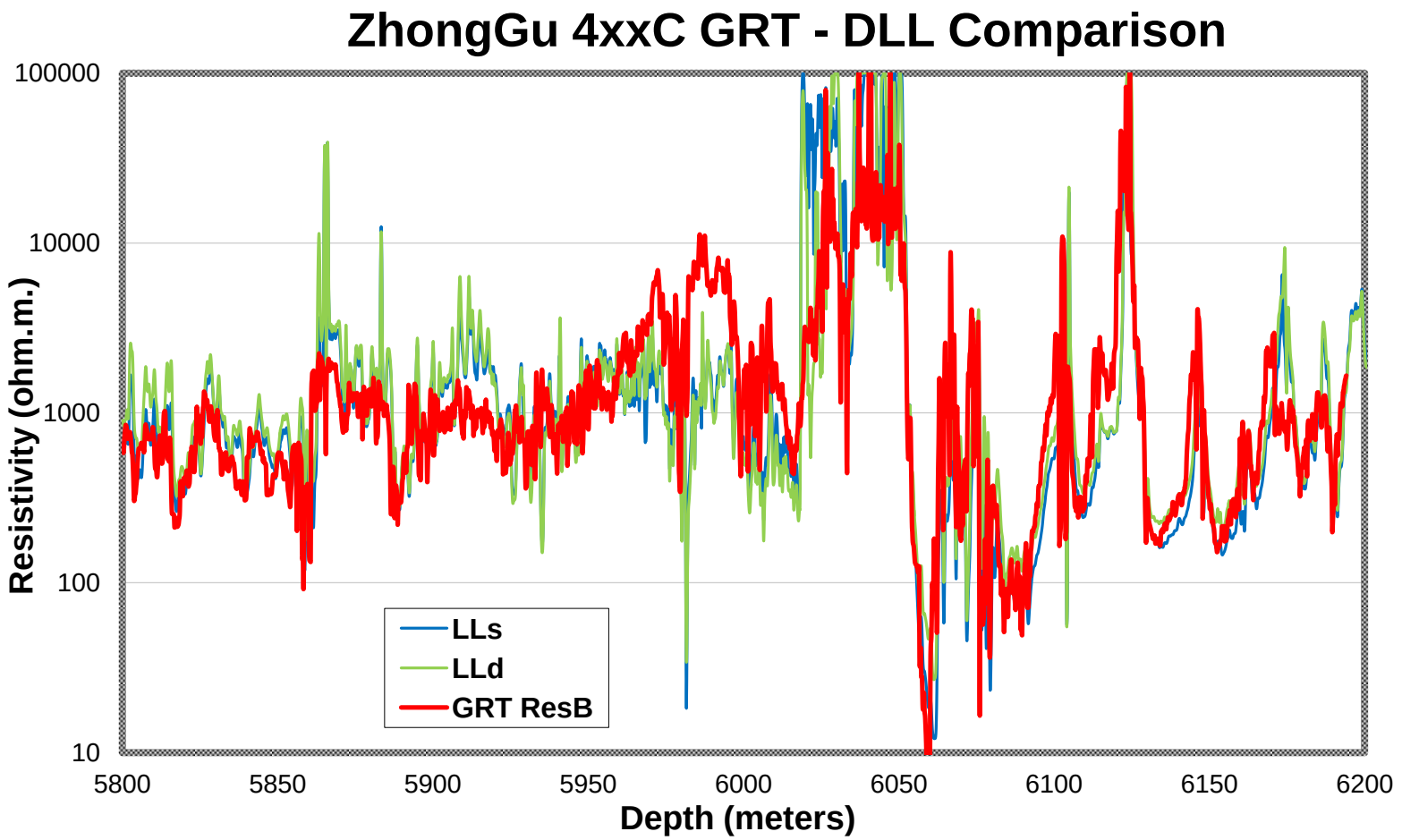


Tarim Basin is in the Taklamakan Desert of Xinjiang province - a very remote location!

Tarim Oilfield GRT test

GRT was run in a 6200 meter (20,400 ft.) well followed by a wireline Dual laterolog.

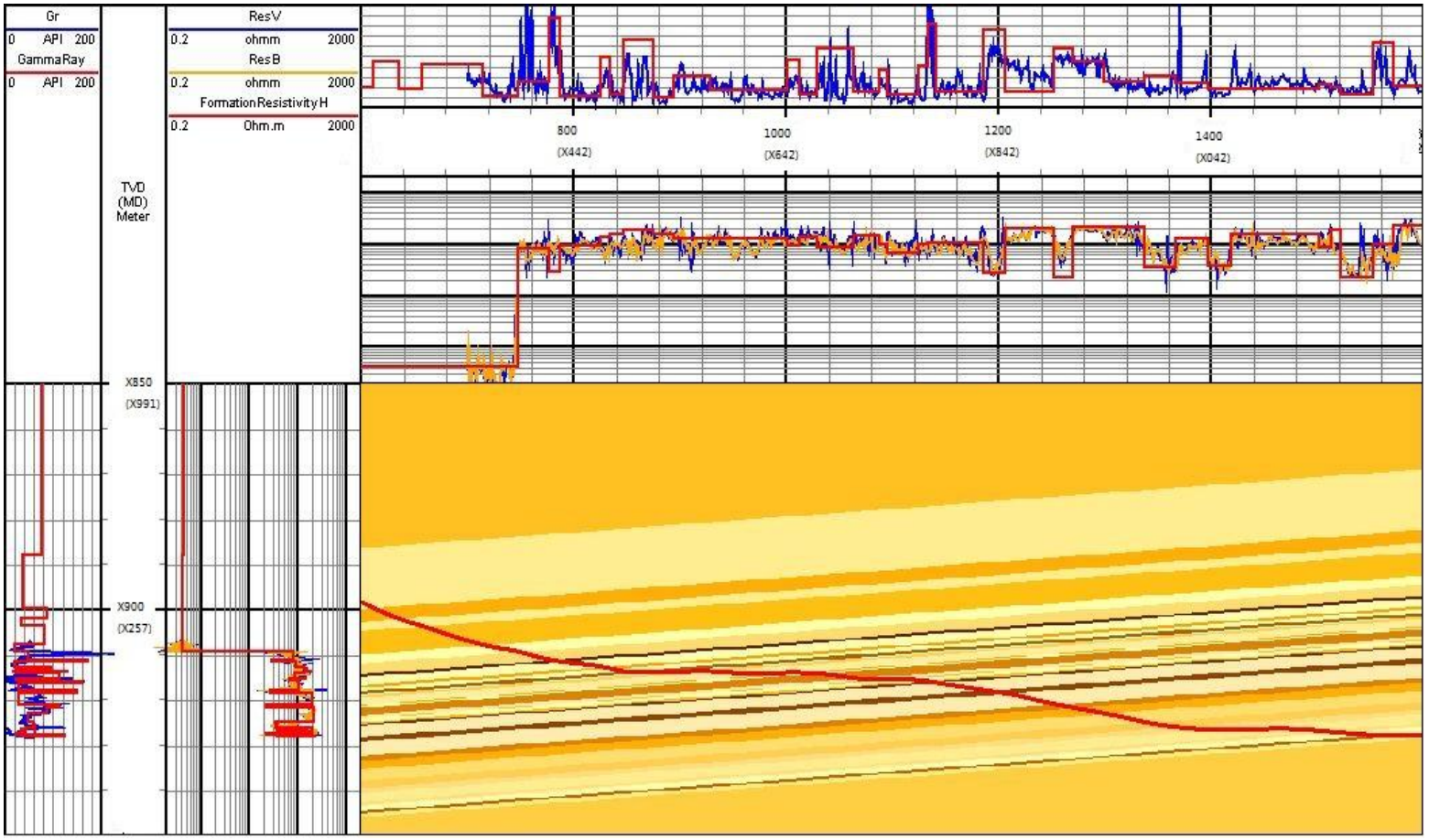
Carbonate Gas-well in Tarim Basin



High-resistivity target is 100 – 20,000 ohm.meters

Memory log from GRT shows good correlation with wireline Dual-Laterolog, and could replace it.

Sulige tight gas sands

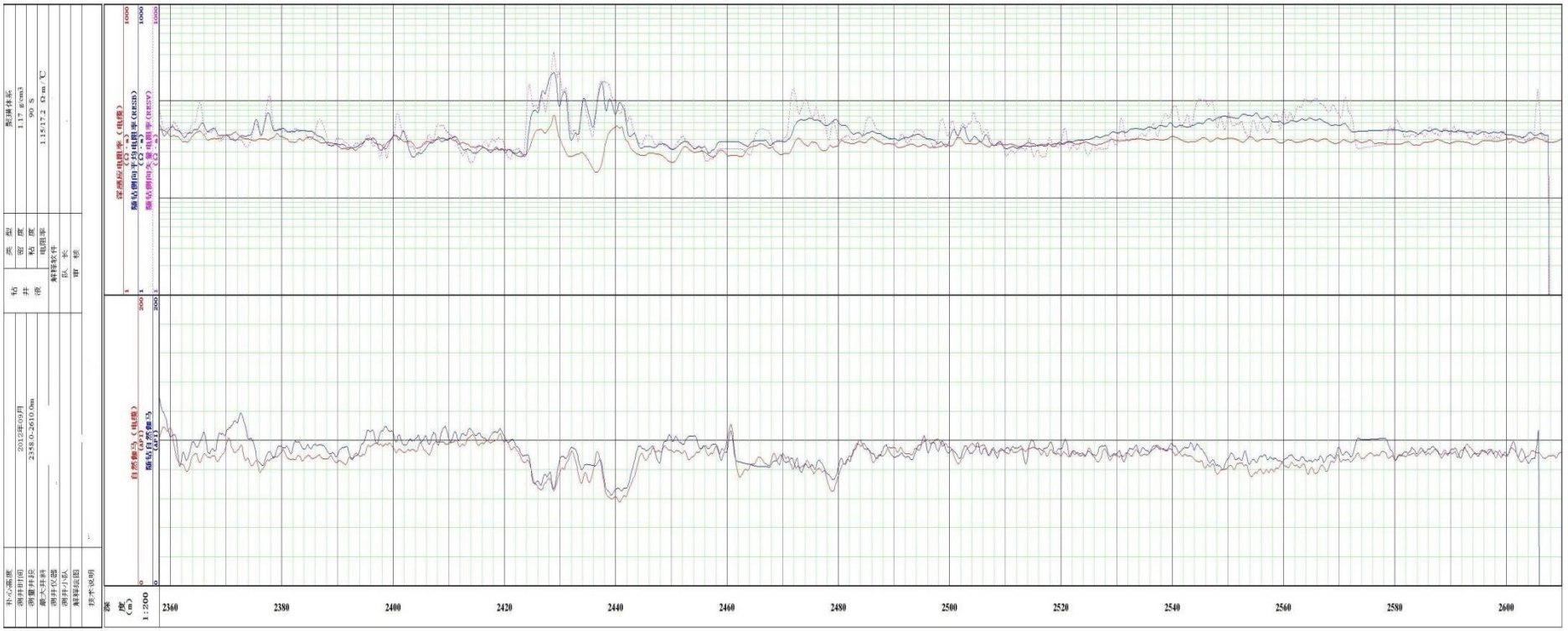


Thin sand-shale sequences 20 - 200 ohm.m. have nano-Darcy permeability. LogXD software computes bed-boundaries & layers using forward tool model

Changqing (Gansu) drilling test

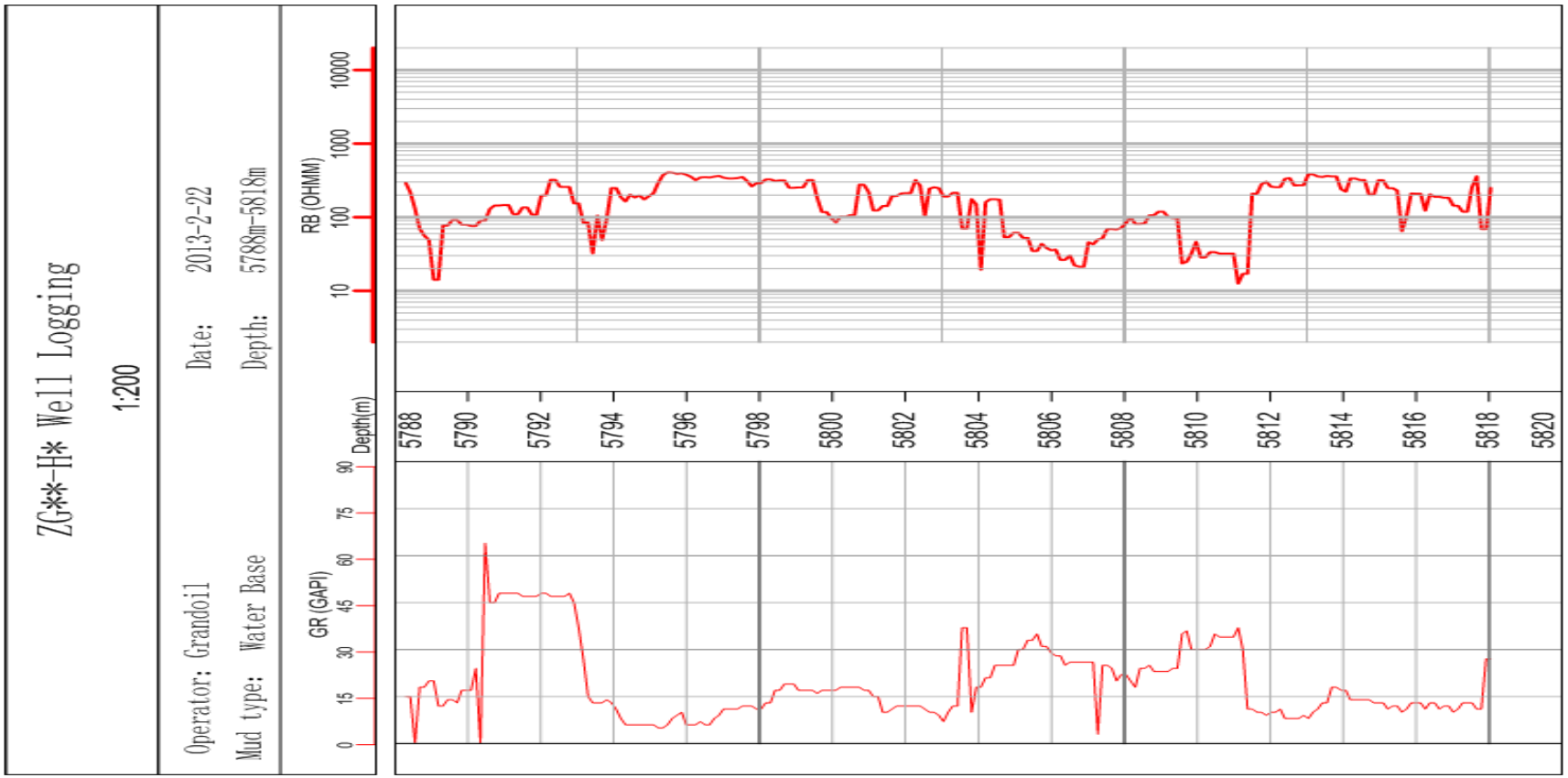
Total MD was 2983 m. with TVD of 2182 m. and lateral length 600 meters. GRT used to steer within the target formations for 188 hours.

Changqing (Gansu) drilling test



GRT resistivity compared with Dual Induction wireline tool. From 2424 – 2464 m. and 2520 – 2600 m. the ILD reads incorrect low resistivity. GRT works more accurately in thin horizontal beds

TaZhong oilfield (Tarim) drilling test



GRT was run in horizontal well that successfully completed and produced gas. The log shows the high-rate build section before the lateral was started.

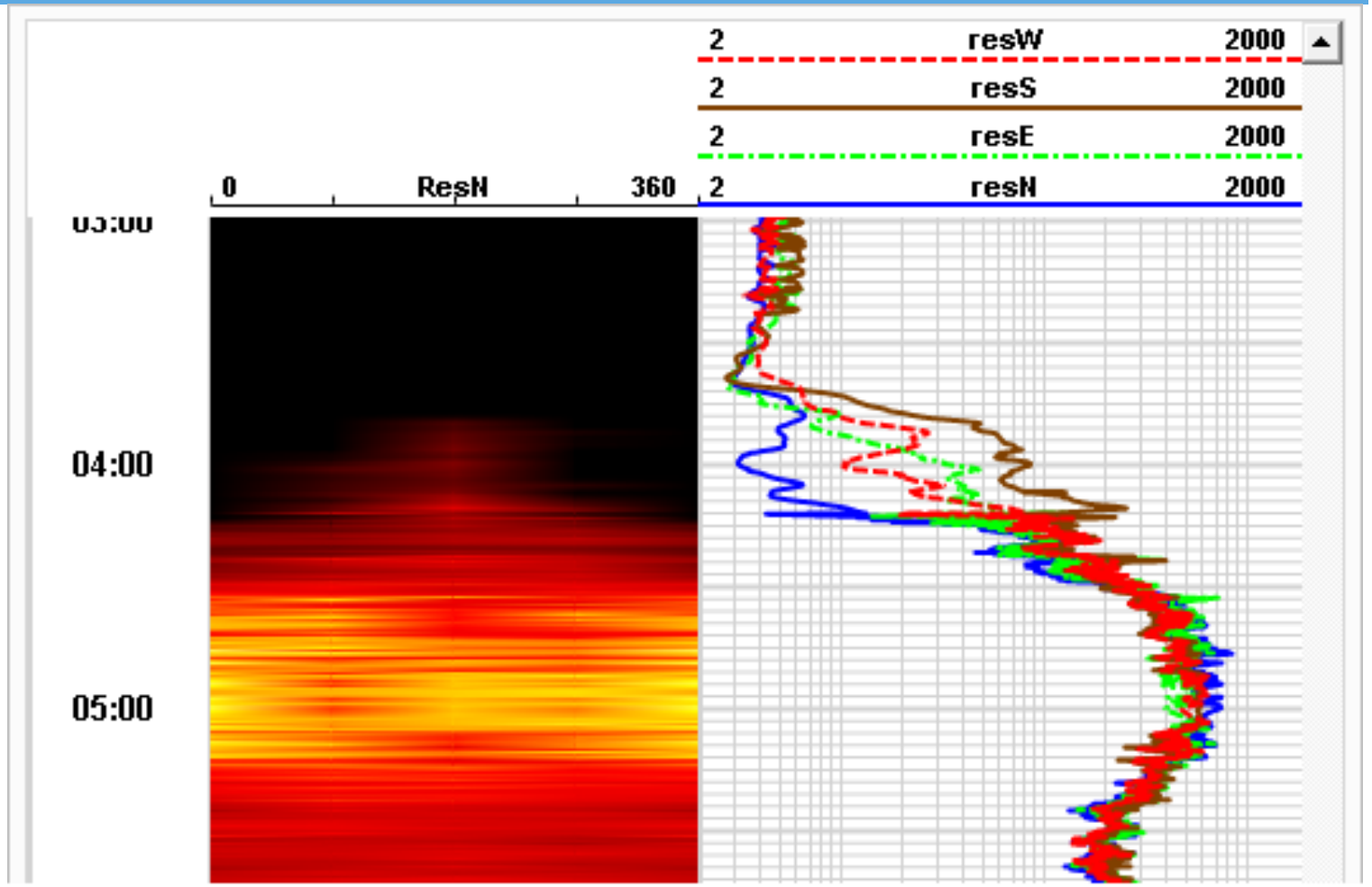
TaZhong oilfield (Tarim) drilling test

Flaring of produced gas from successful well.
Tarim has potential to be a world-class field.

Conclusions

1. We hope that we have shown how cost-effective Azimuthal Laterolog resistivity technology can add value to drilling operations.
2. We thank the engineers and technicians that developed the new service, and the oil companies that gave permission to publish the case-studies.

Recent Experience



This example from Mississippi Lime shows how resistivity imaging and dip calculations are possible from the four basic measurements.