PS Real-Time Resistivity Images Using High Data-Rate Telemetry in Papua New Guinea*

Rob Stevens[1], Leo Blawan[2], and Harris Khan[1]

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[1]Oil Search Ltd., Level 22, 1 Bligh Street, Sidney 2000 NSW, Australia (LeoJilan.Blawan@halliburton.com)
[2]Halliburton Ltd., Level 26, 1 Bligh Street, Sydney 2000 NSW, Australia

Abstract

Papua New Guinea has very complex geology due to its location at an active tectonic plate boundary in the Asia Pacific region. Low resolution seismic in the Papuan Fold Belt has led to a high degree of uncertainty in the structural geology, which in turn makes identifying and targeting the location of oil and gas bearing reservoirs extremely challenging.

High resolution borehole images from both logging while drilling (LWD) and wireline conveyed logging tools have been used to identify the presence and orientation of key structural features which aid in geological mapping and geomechanical modeling. LWD imaging tools such as the Azimuthal Focused Resistivity (AFR™) have been run in Papua New Guinea for more than ten years and the results have been critical for the project successes to date through an enhanced understanding of structural geology. Data acquisition using LWD has been preferred over wireline conveyance as the data is obtained soon after drilling whilst the hole has not been exposed for too long. Tectonic stresses and long formation exposure time can cause the well bore to deteriorate, making wireline runs operationally risky and often leading to poorer quality data impacted by borehole breakout.

However, due to limitations with real-time bandwidth using traditional mud pulse telemetry systems, until recently only recorded LWD image data obtained 'post-run' has been available for interpretation. This meant any well path trajectory changes could only be made in the next hole section or after making dedicated trips to retrieve data. The decision-making process being reactive rather than proactive.

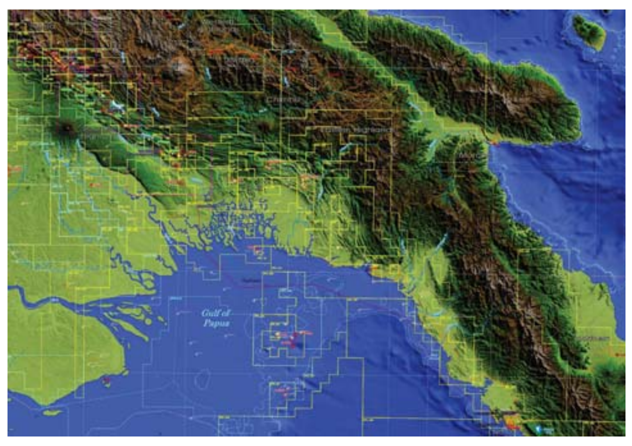
On a recent development well in the Usano Field, a new High Data Rate (HDR) telemetry system was introduced to allow real-time transmission of larger data sets and higher resolution AFR images without sacrificing accuracy or negatively effecting the rate of penetration. This JetPulse™ HDR service also uses mud pulse telemetry but is capable of transmitting up to 18 bps of physical data. Traditional mud pulse telemetry systems were only capable of transmitting up to 3 bps.

The new system enabled 16 bin real time images to be transmitted at >3 sample per metre data-density, together with other formation evaluation and drilling dynamics data. The operator was able to perform accurate real-time dip picking for enhanced early structural geological and reservoir understanding. The real-time LWD image data compared well with recorded LWD image data, clearly identifying structural features such as bedding, faults, fractures, unconformities and borehole breakout orientation.

The improvements in real-time image data quality from faster telemetry have the potential to bring significant cost savings, reduced risk and improved efficiency in wellbore placement as the search for hydrocarbons in Papua New Guinea extends to increasingly complex locations.

REAL -TIME RESISTIVITY IMAGES USING HIGH DATA RATE TELEMETRY IN PAPUA NEW GUINEA

Overview



Papua New Guinea has very complex geology due to its location at an active tectonic plate boundary in the Asia Pacific region. Low resolution seismic in the Papuan Fold Belt has led to a high degree of uncertainty in the structural geology which in turn makes identifying and targeting the location of oil and gas bearing reservoirs extremely challenging.

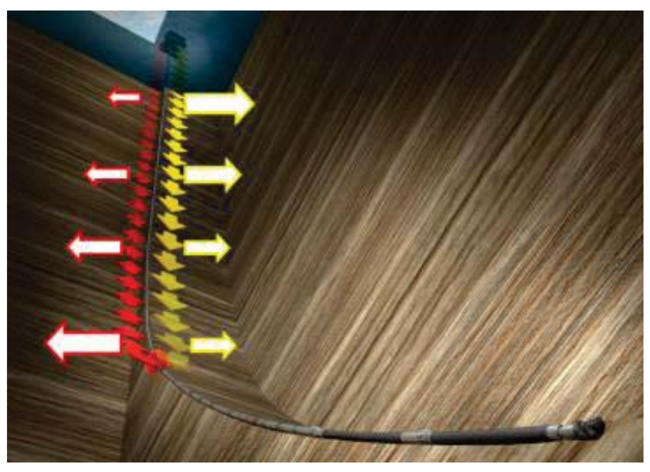
LWD Imaging Tool

High resolution borehole images from both logging while drilling (LWD) and wireline conveyed logging tools have been used to identify the presence and orientation of key structural features which aid in geological mapping and geo-mechanical modelling. LWD imaging tools such as the Azimuthal Focused Resistivity (AFR™) have been run in Papua New Guinea for more than ten years and the results have been critical for the project successes to date through an enhanced understanding of structural geology.

The AFR™ provides shallow, compensated laterolog resistivity measurements with 3 different depths of investigation. It also provides high resolution images up to 128 bins in recorded mode (16 bins in real time) and has the capability of providing at bit resistivity measurement as well.

8” and 6-3/4” Azimuthal Focused Resistivity (AFR™)

Telemetry Systems



Electromagnetic Telemetry (EMT)

The basic function of any telemetry system is to transmit MWD/LWD data to and from the sensors located at the end of the bottom hole assembly. In recent years, technological advances in MWD/LWD technologies have been a step change in helping operators overcome complexities in drilling directional wells and to be able to make fast, informed decisions in real time. This in turn reduces risks of nonproductive time, improve the overall well construction costs whilst obtaining high quality data to maximize asset returns.

There are 2 common types of telemetry systems used for real time MWD/LWD data transmission in Papua New Guinea namely; electromagnetic telemetry (EMT) and mud pulse telemetry.

EMT systems can transmit data at very high rates of speeds using continuous EM waves up through the drill string.

Mud pulse telemetry transmits downhole data to surface using pressure pulses in the mud system. One such system involves annular venting of mud flow from the drill string creating a negative pressure pulse which is detected by the pressure transducer on surface.

JetPulse™ Mud Pulse Telemetry

Data Acquisition

Data acquisition using LWD has been preferred over wireline conveyance as the data is obtained soon after drilling whilst the hole has not been exposed for too long. Tectonic stresses and long formation exposure time can cause the well bore to deteriorate, making wireline runs operationally risky and often leading to poorer quality data impacted by borehole breakout. In addition, wireline runs will have to be conveyed downhole via drill pipe on highly deviated wells resulting in additional rig costs as well.

LWD wireline replacement technology has also advanced in recent years with more complex sensors being added to the bottom hole assembly thus pushing traditional mud pulse telemetry systems to its bandwidth limits. Rotary steerable systems have also become more intelligent with on-the-fly steering adjustments and real time diagnostics.

Due to this limitation with real time band width using traditional mud pulse telemetry systems, until recently, only recorded LWD image data obtained ‘post-run’ has been available for interpretation. This meant any well path trajectory changes could only be made in the next hole section or after making dedicated trips to retrieve data. The decision-making process being reactive rather than proactive.

Attempts have been made to use EMT as a high speed telemetry system for the purpose of transmitting real time AFR™ images. EMT though reliable and able to transmit at high data rate (up to 10 BPS) is limited by battery power and experiences signal attenuation as the well deepens.

Inception

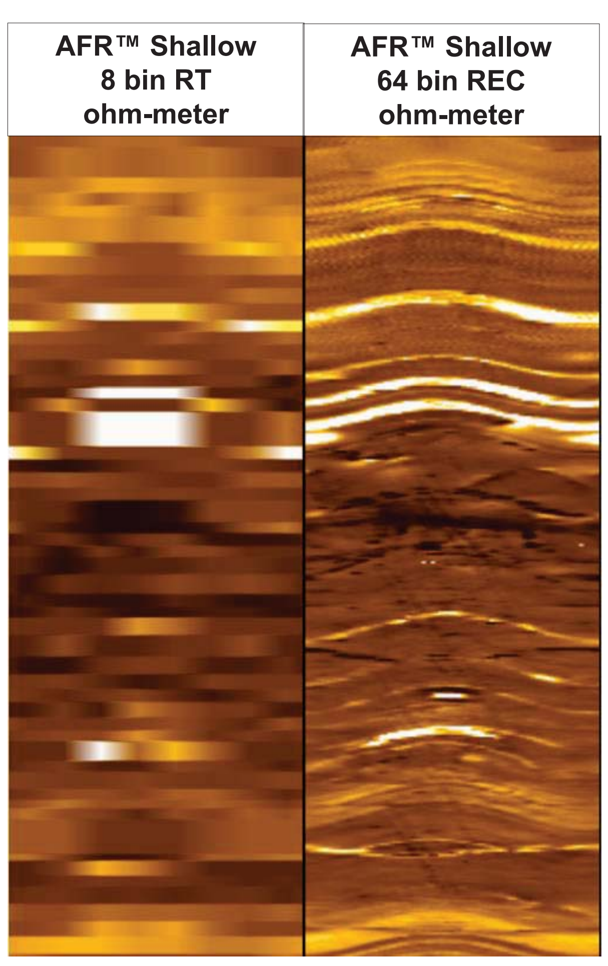
In 2014, the first attempt was made to transmit AFR™ 8 bin RT image using the annular venting mud pulse telemetry system in the Mananda field. Telemetry speed was ~ 3 to 5 BPS and the quality of the real time image was average. The lack of resolution made it difficult to identify bed boundaries. Not having enough data points in real time also challenged the confidence of the real time dip direction calculations.

The effectiveness of the real time data for dip interpolation was dependent on several factors namely:

- »Resolution of the data (Higher data rate and higher azimuthal bin rate)
- »Hole conditions
- »Characteristics of the features being interpolated
- »Angle of the well to the features of interest.

Despite the setbacks, it provided a blue print for future attempts. Lessons learned include:

- »Increasing telemetry speed
- »Controlled rate of penetration
- »Increasing AFR™ azimuthal bins from 8 to 16



8 bin AFR™ RT Image vs 64 bin AFR™ REC Image

High Data Rate Telemetry

On a recent development well in the Usano field a new, High Data Rate (HDR) telemetry system was introduced to allow real time transmission of larger data sets and higher resolution AFR™ images without sacrificing accuracy or negatively effecting the rate of penetration. It uses mud pulse telemetry but is capable of transmitting up to 18 bps of physical data.

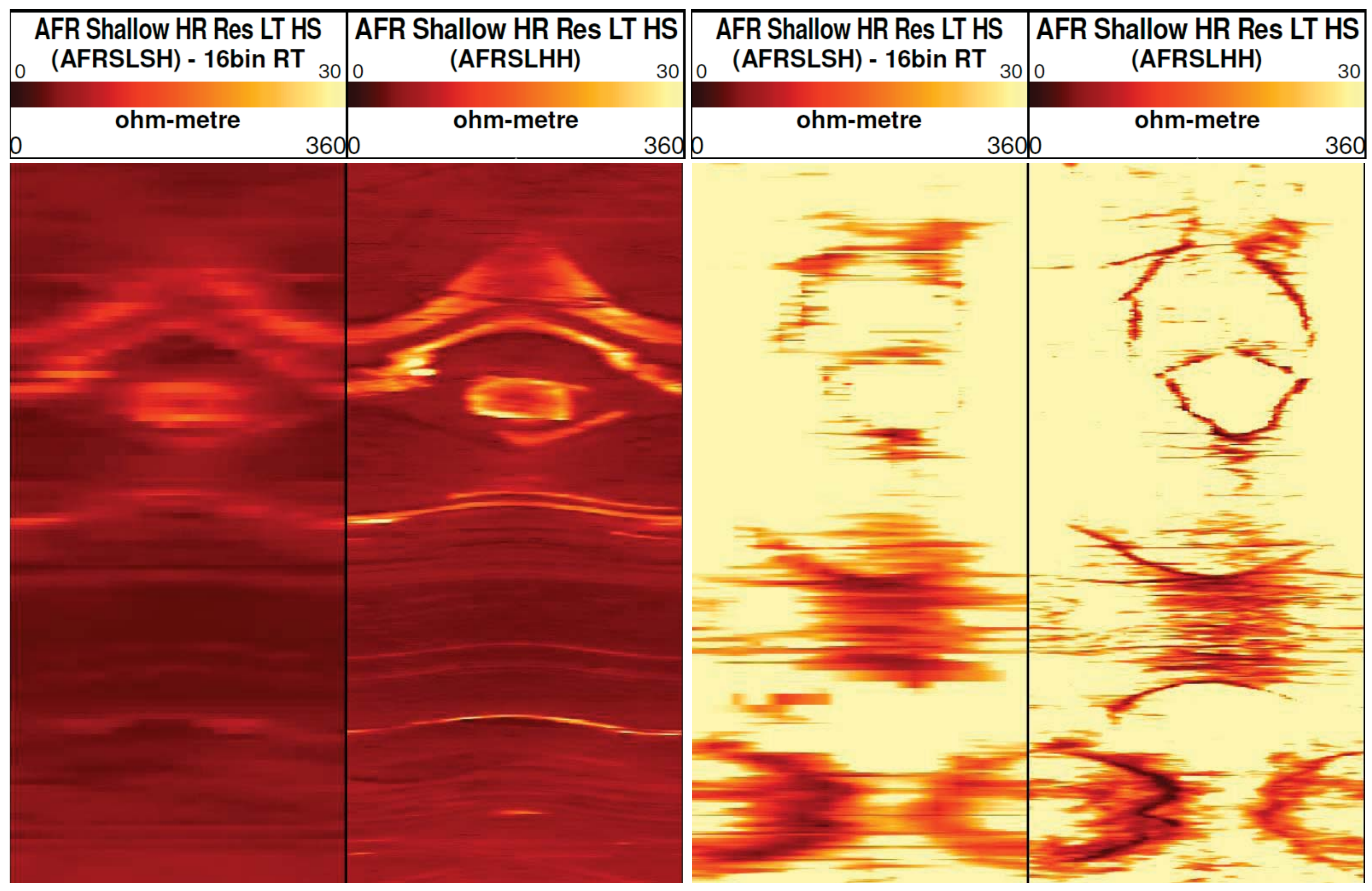
The new system enabled 16 bin real time images to be transmitted at >3 sample per meter data density together with other formation evaluation and drilling dynamics data.

Data Compression and On Demand Real Time Data List

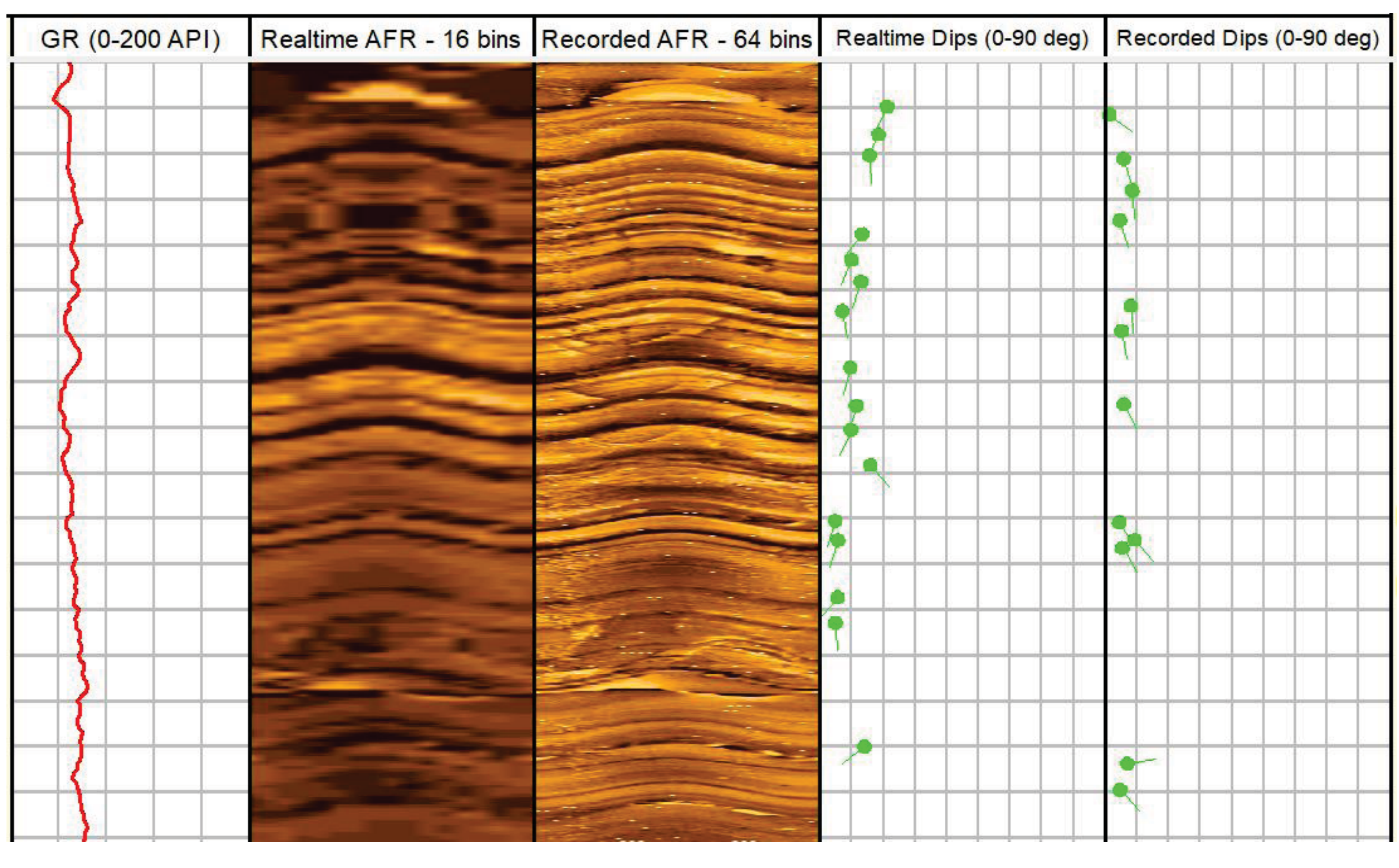
The effective data rate can be improved by applying compression to the downhole data before transmitting it to surface. Real time data items are also grouped into Variable Data Format (VDF) lists. Up to 8 distinct VDFs can be pre-defined appropriate to the required operation (Drilling, Wiping, Enhanced Data Rate etc.)

Variable Data List	Real Time Data
VDF 1	Compressed Real Time Image and LWD Data (6 to 10 BPS)
VDF 2	Slower Rate Compressed Real Time Image and LWD Data (<6 BPS)
VDF 3	Enhanced Rate Real Time Image and LWD Data (>10 BPS)
VDF 4	Real Time LWD Data Only (No Image)
VDF 5	Steering and Drilling Optimisation Only

This allowed on demand changes to transmission speeds to enhanced real time images for more accurate dip picks and the confidence to geosteer based on the changing real time dips. Fractured networks, sub seismic anomalies and also orientation of borehole breakouts are clearly revealed.



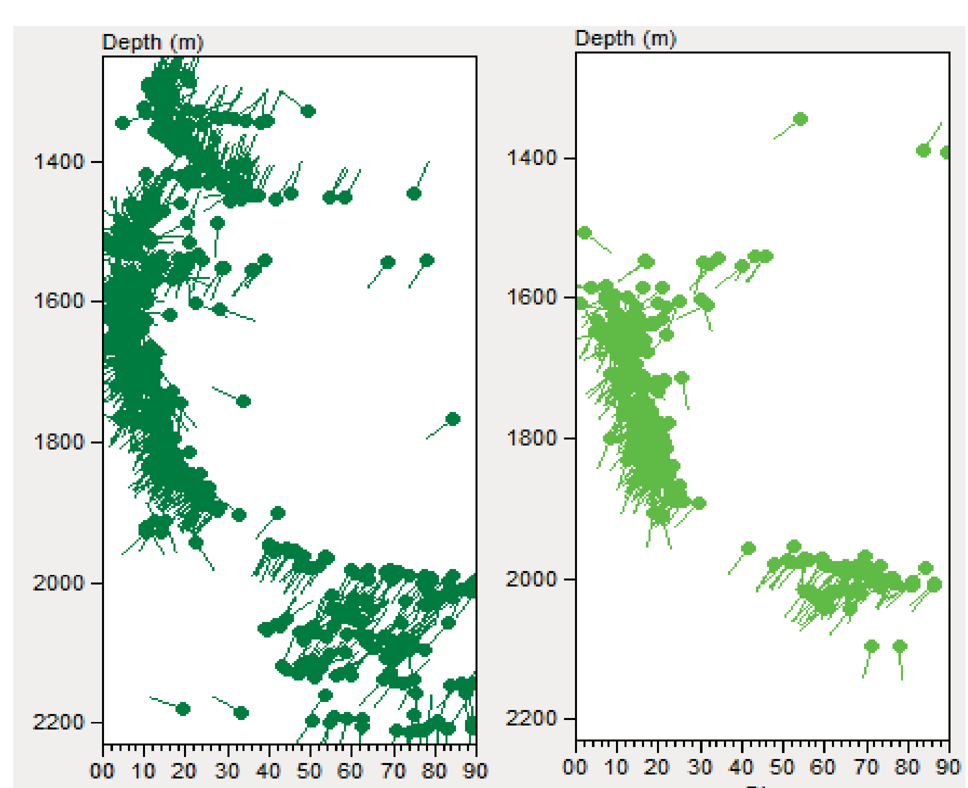
16 bin AFR™ RT Image vs 64 bin AFR™ REC Image (Vugs and fractures)



16 bin AFR™ RT Image (Data Compression) vs 64 bin AFR™ REC Image

Real Time Vs Recorded Memory Dips

Structural dip information was critical to the interpretation and update of the geological model in this structurally complex field. Bedding trends from 16 bins real time and 64 bins recorded data were comparable through sections of relatively uniform bed dip. In heavily faulted or fractured sections, the 64 bin memory data was much more reliable. The geological information gathered from real time images, although of lower resolution, contributed to geosteering decisions in quantifying the true dip shortly after penetration. Acquired image logs, petrophysical and geological information were reviewed and integrated in the reservoir model.



REC Dips (Dark Green) vs RT Dips (Light Green)

Conclusions

The improvements in real time image data quality from faster telemetry have the potential to bring significant cost savings, reduced risk and improved efficiency in wellbore placement as the search for hydrocarbons in Papua New Guinea extends to increasingly complex locations.