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Schlumberger

C000 9A

Sonic Scanner Report

COMPANY	**JAMSTEC**
WELL	**C000 9A**
FIELD	**Kumanonada,offshore Kji peninsula**
PROCESS INTERVAL	**From 2756 to 3663 [m]**

CONTENTS

1. Introduction

The Sonic Scanner was run in open hole in C0009A well on 11-Jul-2009. According to request from clients, the following contents were processed.

- Extract accurate Compressional slowness, Shear slowness and Stoneley Slowness from Sonic Scanner data.

2. Sonic Scanner Overview

2.1 Tool Features

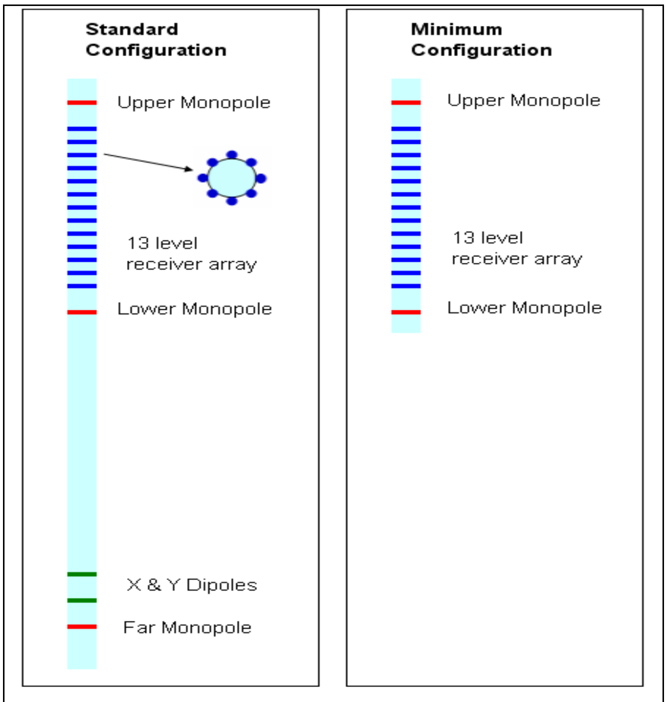

Figure 2-1: Sonic Scanner tool configurations

An improved estimation of sonic slowness and a comprehensive mechanical characterization of the wellbore rock rely on a complete characterization of the compressional and shear slowness in terms of their radial, azimuthal, and axial variations. The new modular sonic tool accomplishes them by incorporating improved monopole and cross-dipole transmitter technologies while featuring an extensive receiver array incorporating 13 axial levels with 8 azimuthal sensors each. Each receiver is individually digitized resulting in 104 waveforms per transmitter firing leading to an extremely reliable and accurate slowness estimation. This comes about through improved borehole-mode extractions/rejections and enhanced wavenumber resolutions at all frequencies. The Sonic Scanner tool has a receiver array consisting of 13 levels spaced 6 inches apart. Each receiver level is composed of 8 azimuthal elements. Each of the azimuthal elements is recorded and is later "modally decomposed" into either dipole or monopole waveforms.

Two short spacing monopole transmitters are located at 1 ft from either end of the receiver array. These are known as the Upper Monopole (MU) and Lower Monopoles (ML).

A Far Monopole (MF) is located 11 ft below the receiver array. The X and Y dipoles are located at 9 and 10 ft respectively below the receiver array.

The Sonic Scanner tool can also be run in a "minimum configuration" that does not include the far monopole or the dipoles.

The Sonic Scanner tool records six transmitter firings at every 6 inch depth interval while logging. These are:

MS1 mode = MU, Upper Monopole.
MS2 mode = ML, Lower Monopole.
MS3 mode = MF, Far Monopole.
MS4 mode = ST, Stoneley. This is a low frequency excitation of the Far Monopole.
MS5 mode = XDIN, XDOL. Inline and Offline recordings of the X-Dipole.
MS6 mode = YDIN, YDOL. Inline and Offline recordings of the Y-Dipole.

Note that the Offline waveforms are also often referred to as the Cross-line waveforms.

The MS3 mode is similar to the DSI P&S mode. The MS5 and MS6 modes are similar to the DSI Crossed Dipole mode.

2.2 Sonic Scanner Application

Formations exhibit wide, and sometimes complex, acoustical behaviors ranging from isotropic, anisotropic with its various mechanisms and significant radial slowness gradients. Radial rock property variations arise because of non-uniform stress distributions and mechanical or chemical near-wellbore alteration due to the drilling process. Anisotropy can be caused by intrinsic shale properties or external differential stresses. The critical data required to invert for these rock parameters underlying these acoustic behaviors are derived from the new tool through the use of broadband dispersion curves associated with propagating borehole acoustic modes.

The new Sonic Scanner acoustic scanning platform provides advanced types of acoustic measurements, including borehole compensated monopole with long and short spacing, cross-dipole, and cement bond quality. These measurements are then converted into useful information about the drilling environment and the reservoir, which assists in making decisions that reduce overall drilling costs, improve recovery, and maximize productivity.

Regardless of the formation type, the Sonic Scanner platform design overcomes earlier acoustic measurement barriers to successful formation characterization and quantification because it

- uses a wide-frequency range that enables characterizing formations as homogeneous or inhomogeneous and isotropic or anisotropic
- uses long- and short-monopole transmitter-receiver spacing
- is fully characterized with predictable acoustics.

Earlier technologies attempted to operate close to the tool’s low-frequency limit, or they depended on previously acquired formation information to anticipate formation slowness prior to data evaluation.

The wide-frequency spectrum used by the Sonic Scanner tool allows data capture at high signal-to-noise ratios and extracts maximum data from the formation. This design feature also helps ensure that data are acquired regardless of the formation slowness. The monopole transmitters have enhanced low-frequency output over the entire range of sonic frequencies; and the dipole transmitters are designed for high-output power, high-purity acoustic waves, wide bandwidth, and low power consumption.

The Sonic Scanner receivers feature a longer azimuthal array than other acoustic tools; i.e., 13 stations and 8 azimuthal receivers at each station. With the two near-monopole transmitters straddling this array and a third transmitter farther away, the short- to long-monopole transmitter-to-receiver spacing combination allows the altered zone to be seen and provides a radial monopole profile.

Main Applications

1. Geophysics
    - Improve 3D seismic analysis and seismic tie-ins
    - Determine shear anisotropy
    - Input to fluid substitution

2. Geomechanics
    - Analyze rock mechanics
    - Identify stress regimes
    - Determine pore pressure
    - Evaluate well placement and stability

3. Reservoir characterization
    - Identify gas zones
    - Measure mobility
    - Identify open fractures
    - Maximize selective perforating for sand control
    - Maximize safety window for drawdown pressure
    - Optimize hydraulic fracturing

4. Well integrity
    - Evaluate cement bond quality

3. Sonic Scanner Processing

3.1 General Processing Overview

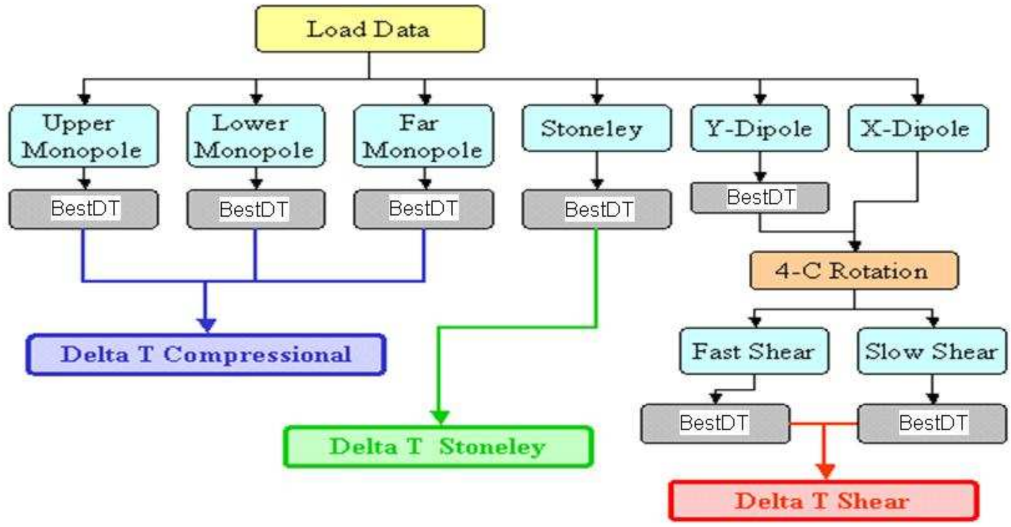

Figure 3-1: Sonic Scanner processing flowchart to obtain DT compressional, DT shear and DT Stoneley from open hole data

This processing chain is the standard processing used to obtain all the formation DT's and is a pre-requisite for any additional processing steps that may be done. The additional processing steps that can follow include (a) anisotropy evaluation (b) monopole radial profiling (c) dipole radial profiling (d) 3D formation anisotropy (e) stoneley fracture analysis and (f) stoneley permeability analysis.

3.2 Borehole Environment

Figure 3-2 shows an overview of caliper (HD1 and HD2), hole deviation curves (DEVI) and tool tension curve (TENS) with Resistivity curves and VDL from P&S Model. The tool tension Curves (TENS) presented in first track (Depth Track) indicates that the logging tool motion is not always smooth, the tool was sticked in some intervals. Irregular tool motion will affect all logging data, especially for FMI image data. When the tool moves irregularly downhole (stick-slip), then the cable at the surface is still moving constantly, and the data sampling rate and depth are determined by the surface cable movement.

The borehole (the second track) is quite good from 2797m to 3366m. But the borehole below 3366m is rugose and washout from the caliper curves HD1 and HD2. The HD1 and HD2 from a single PPC tool sample the calipers at 2 azimuths same as C1 and C2 from FMI tool. The quality of all logs are affected by the sticking and bad borehole conditions.

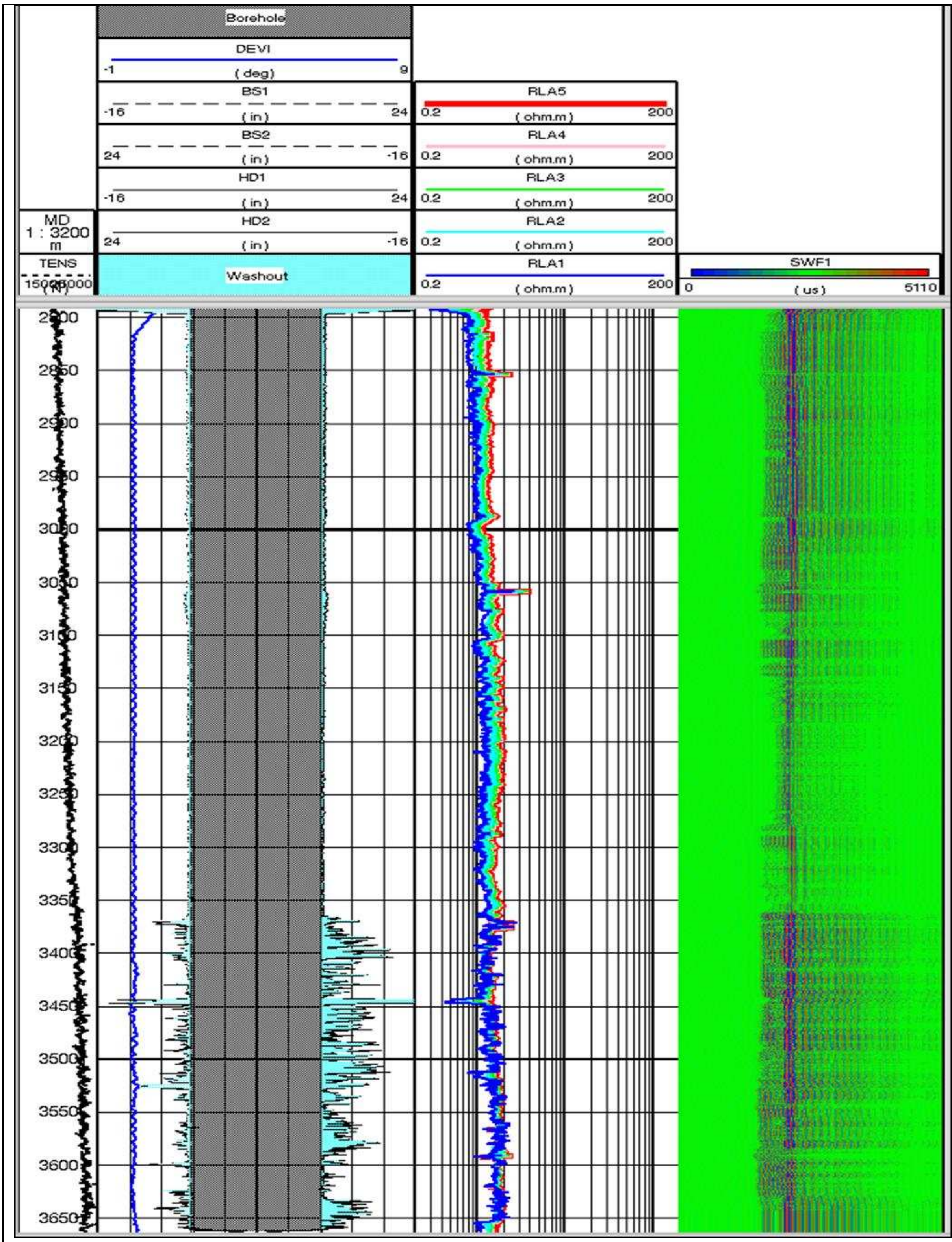

Figure 3-2 overview of borehole

3.3 Formation Sonic Slowness Process Overview

The BestDT module is designed as an interactive program with a smart parameter selection, good graphical guidance, and user friendliness. The module provides answer products which are equivalent or better in quality and performance than the previous existing modules (Sonic STC chain). In addition to this, BestDT can edit an existing slowness log curve in a graphical user interface without running any process for the purpose of modifying a field result. The BestDT consists of five major parts; Parameter Selection, Zoning, Pre-Filtering, Delta-T Computation, and Finalization.

The sonic scanner data, especially, Dipole model needs to be reprocessed with different filters using BestDT model. The data quality of Sonic Scanner is a challenge for traditional STC (Slowness-Time-Coherence) processing as the borehole well alternation happened in some intervals. So SFA (Slowness-Frequency Analysis) method is the best choice to extract the high quality slowness from Dipole. STC and dispersion analysis allow depth frames to be translated into a continuous log. STC indicates that the data is coherent across the array, but does not indicate if the data match the physics of measurement. SFA allows the user to determine if the overlayed STC log, matches the physics of measurement and hugs the left edge of the dispersion projection. The left edge would represent the low frequency limit of the dispersion plot and thus match physics.

Using multishot option of processing in BestDT is to improve vertical resolution and the quality of the slowness which is better than the results from wellsite.

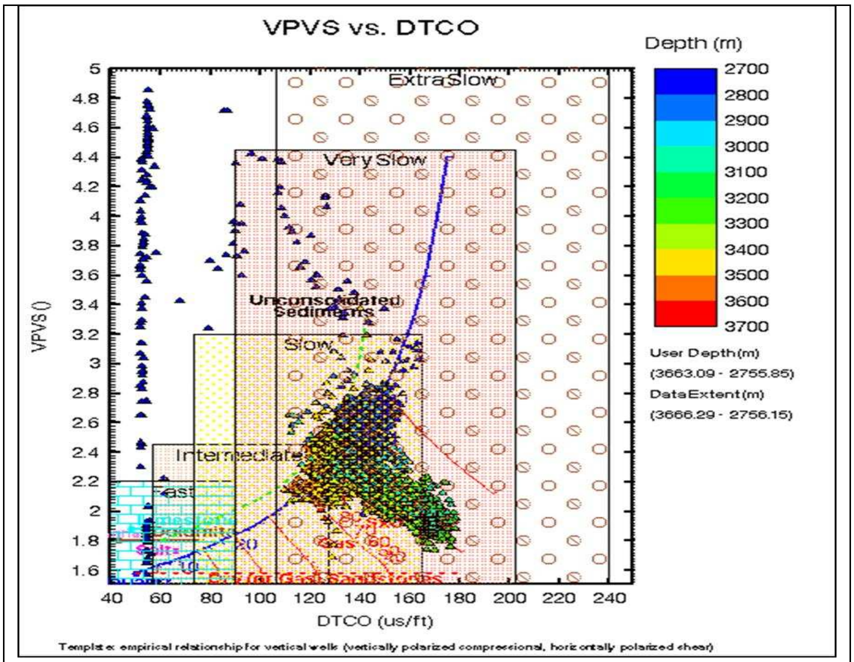

Fig.3-3 Formation Type Advisor

The Fig. 3-3 show the cross plot of DTCO (Compressional Slowness) VS VPVS (the ratio of Compressional Velocity and Shear Velocity), all the data from DTCO and VPVS are located at the middle of plot, it shows the type of formation are slow formation and the division of formation types for BestDT processing is shown in Fig. 3-4, Sonic Scanner data was processed based on the division of formation types. On the other hand, DTMUD (Mud slowness) used for BESTDT processing is 181 [us/ft] and the caliper input to BestDT is HDAR which is average caliper from Sonic Scanner PPC.

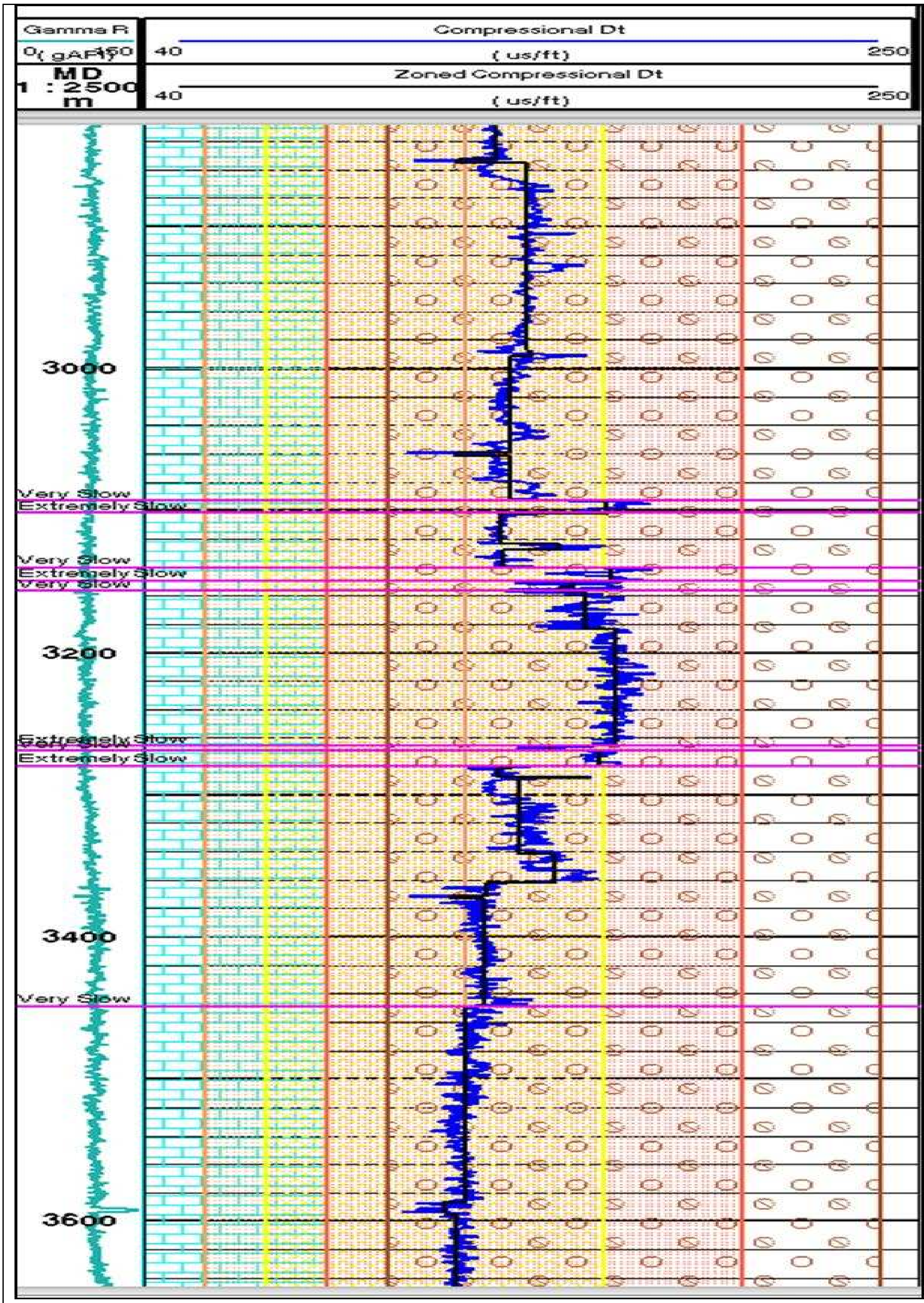

Fig. 3-4 Division of Formation Type

The Fig. 3-5 is Quality Control(QC) plot for MF (Monopole Far) model, the main purpose for this plot is quality checking.

The third track of QC plots is to display low and high filter band, center frequency logs (Stack_Cenfrq) and spectra (SPEC), the logs in blue (left side curve) are for compressional slowness, the logs in red (right side curve) are for shear slowness. If the center frequency matches with the peak of the stacked spectrum, it indicates the processing parameters are optimum for the data and the quality is fine.

The fourth track of QC plot is to display a Slowness/Time projection and slowness logs with error bars. If the slowness matches with the highest coherence displayed in red color, the quality of slowness is good.

The Fifth Track displayed is SFA slowness frequency analysis. In SFA, a dispersion curve is generated at each depth from the recorded waveforms, slowness versus frequency information of the dispersion curve is projected onto the slowness axis, and then the slowness projection at each depth is plotted as a log versus depth. The estimated slowness log from time-based coherence processing is then overlaid on the SFA projection. For dipole flexural signals, if the estimated slowness log lies at the lowest limit of the SFA projection, then the estimated slowness matches the low-frequency limit of the dipole flexural signal and the slowness log is correct. The log is correct because it is consistent with the dispersion curve that describes the data.

The curves displayed in track No.4, No5, No.7 and No. 8 are compressional slowness from receiver array and transmitter array, respectively. The track No. 9 is to display Waveform and Integrated Transit Time (TICS-Compressional Integrated Transit Time).

Other QC plots are similar as MF QC plot, please see the Fig. 3-6, Fig.3-7 respectively. The coherence of slowness in QC plots are high and continues, which show the quality of Sonic Scanner is good and the slowness extracted from Sonic scanner are reliable.

Due to the formation is soft and slow, so the quality compressional slowness can be extracted from MF model, Shear slowness can be extracted only from Dipole model.

Stoneley wave is more sensitive to borehole conditions, so the Stoneley slowness is effected by the washout, especially for the interval below 3366m, so Stoneley wave doesn’t accurately reflect the truth of formation in bad borehole intervals.

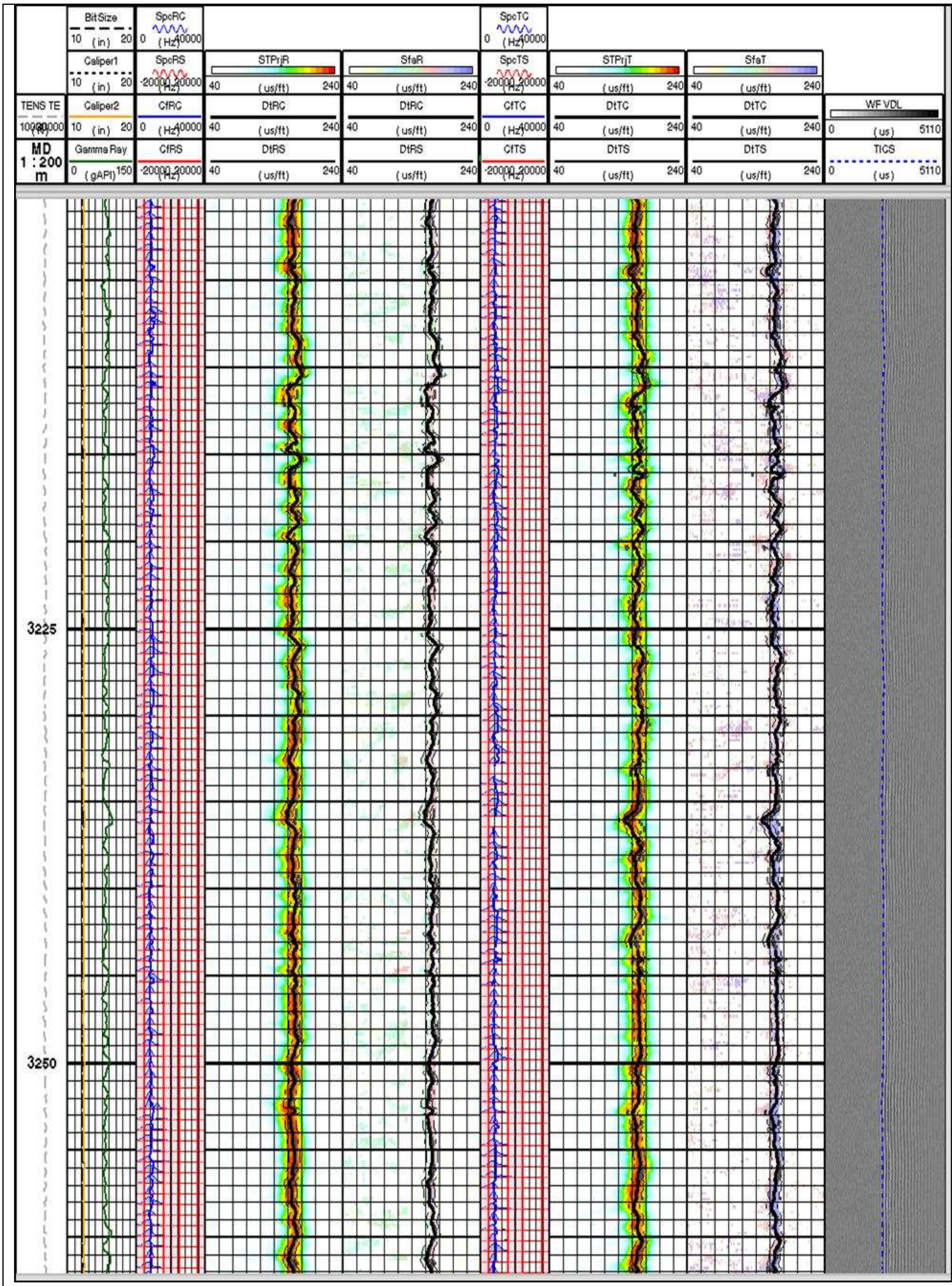

Fig.3-5 MP&S model QC Plot

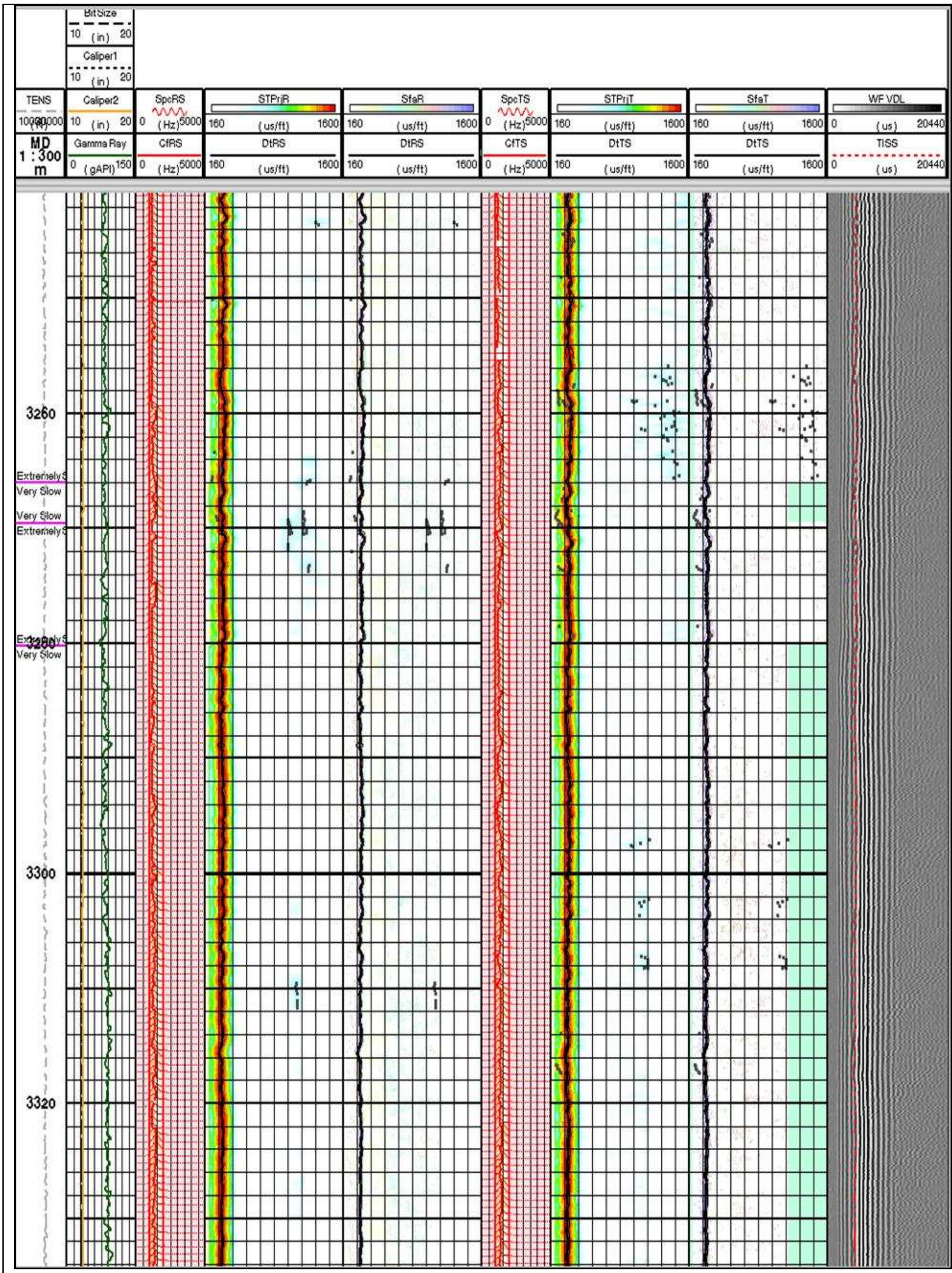

Fig.3-6 Stoneley model QC Plot

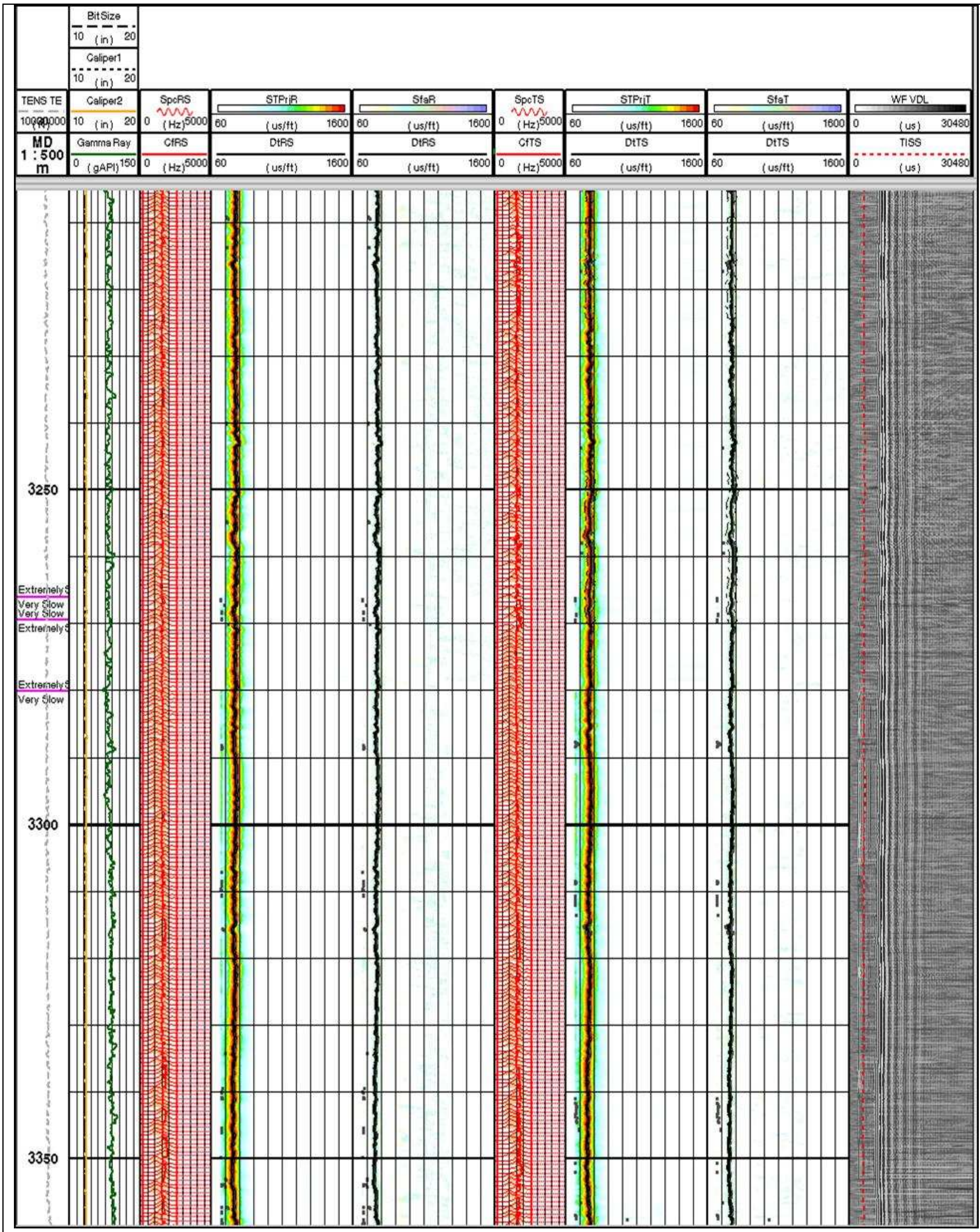

Fig.3-7 Dipole model QC Plot

4 Summary

1) All possible waveforms were acquired in Open Hole. All Waveforms were found to be of very good quality, except few intervals with very large bore hole size.
2) DT-Compressional : The monopole waveforms contain very good formation arrival and the DTCO results are very good
3) DT-Shear: The dipole waveforms contain decent formation arrival. After detailed analysis on dispersion plots, also considering the borehole alternation in some intervals, best processing results were obtained using MSPI processing rather than STC. MSPI processing is based on dispersion analysis by curve fitting technique to compute the correct shear slowness.
4) Stoneley wave is more sensitive to borehole conditions, so the Stoneley slowness is effected by the washout, especially for the interval below 3366m, so Stoneley wave doesn't accurately reflect the truth of formation in bad borehole intervals.
5) On some intervals, the Dt-Shear processed from XD and YD indicates the presence of anisotropy (intrinsic or stress) as well as borehole alteration. It is recommended to process for fast and slow shear using Alford rotation and do formation anisotropy analysis.

A. Array Codes

CODE	Explanation
CHRP	Label Peak Coherence, Receiver Array, Compres - Monopole P&S
CHTP	Label Peak Coherence, Transmit Array, Compres - Monopole P&S
DTCO	Delta-T Compressional
DTRP	Delta-T Compressional, Receiver Array - Monopole P&S
DTTP	Delta-T Compressional, Transmitter Array - Monopole P&S
CHR3	Label Peak Coherence, receiver Array - Monopole Stoneley
CHT3	Label Peak Coherence, Transmitter Array - Monopole Stoneley
DT3R	Delta-T Stoneley, Receiver Array - Monopole Stoneley
DT3T	Delta-T Stoneley, Transmitter Array - Monopole Stoneley
DTST	Delta-T Stoneley - Monopole Stoneley
CHREX	Label Peak Coherence, Receiver Array - Expert Mode
CHTEX	Label Peak Coherence, Transmitter Array - Expert Mode
DTEXR	Delta-T Shear, Receiver Array - Expert mode
DTEXT	Delta-T Shear, Transmitter Array - Expert mode
DTSM_SLOW	Shear Slowness of Slow Shear Waves
DTSM_FAST	Shear Slowness of Fast Shear Waves
FSH_AZIM_OVERALL	Overall estimate of fast shear azimuth
MAXXENE_OVERALL	Overall estimate of maximum cross energy
MINXENE_OVERALL	Overall estimate of minimum cross energy
SLOANI	Slowness based anisotropy
TIMANI	Time based anisotropy
HD1	Hole Diameter 1
HD2	Hole Diameter 2
STTC_DF	Stoneley Transmission Coefficient from Dipping Fracture Model
STTC	Stoneley Transmission Coefficient
STRC_DF	Stoneley Reflection Coefficient from Dipping Fracture Model
STRC	Stoneley Reflection Coefficient
FWID_DF	Fracture Width from Dipping Fracture Model
FWID	Fracture Width
STQFCT	Stoneley Quality Factor
FPERM_DF	Fracture Permeability from Dipping Fracture Model