Two Dimensional Display of Well Logs of High Deviation Wells

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Summary

Well logs of deviated wells are generally displayed against measured depth along vertical axis. TVD log is the display of logs against True Vertical Depth. It is the log corrected for vertical shortening and thus gives the true depth of various zones identified by log motifs. However, TVD log does not take in to account the horizontal drift. This creates problems in log correlation of dipping beds. Two-dimensional displays of well logs resolve such problems and helps in proper correlation of logs. In conventional display of logs for every depth point there is a single value of each log in the recorded section. Two-dimensional display of logs involves TVD, Horizontal drift and the value of the log recorded. A simple technique is evolved for generating a two-dimensional log using co-ordinate geometry on Excel sheet. The generated log can be displayed using any software for log data display.

Introduction

TVD log of a deviated well shows various zones at the depth at which they are met in the drilled section of the well. All the zones seem to be stacked vertically below the surface location of the well. Figure-1 shows a theoretical example. An inclined well drilled from surface location 'A' passes through various zones dipping right. All these zones are met in a vertical well drilled from location 'B'. TVD log of inclined well when correlated with that of 'B' gives an impression of dip angles lower than the actual dip. This is the case of well 'A' drifted towards well 'B'. Incase the well 'A' is drifted away from well 'B' beds will appear to be dipping at an angle higher than the actual dips from such correlation. In fact horizontal drift of 100 m results in shifting of structural position of a zone by 8.7 m if beds are dipping at an angle of 5 degree. So for proper correlation it is necessary to display the log in two dimensions.

Methodology

Conventional display of well logs is a plot of depth along vertical axis and log values along horizontal axis. These two axes are independent. Depth scale can be 1:200, 1:500 or 1:1000 while the log values plotted on horizontal axis may be on same scale for all the depth scales. Two-dimensional display of logs is the plot of log curve along the well trajectory. Depth, instead of vertical axis is plotted along an axis inclined to vertical. So depth axis is dependent on both vertical (TVD) and horizontal (drift) axes. Log values are to be plotted normal to the depth (well trajectory). Each point on log curve is represented by two co-ordinates. These co-ordinates depend on the following-

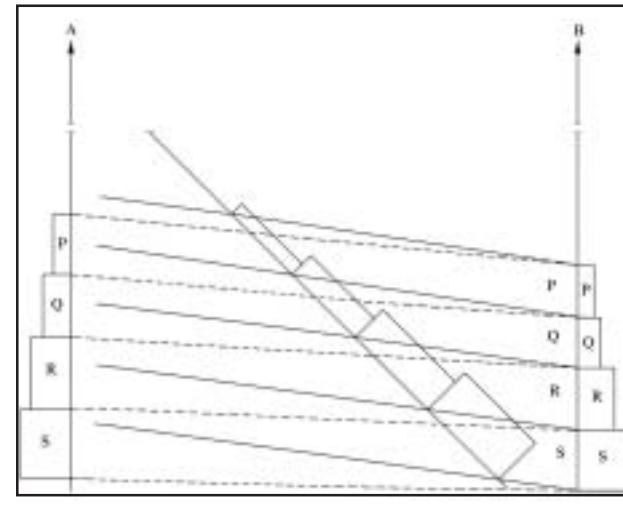

Figure - 1

1. Log value
2. Log Scale: Linear or Logarithmic and maximum amplitude required in centimeters.
3. TVD, Horizontal drift and Bore-hole inclination at the recording depth.
4. Depth and drift scale.

Required position of the curve whether above or below the well trajectory.

Table-1 shows a dummy log data of an inclined well. Measured depth is given in column 1 and inclination is given in column 2. The values of log curve 'A' are given in column 5. Figure-2a depicts the conventional display of the log against the measured depth. The well inclination is 45 degree. Figure-2b depicts the two-dimensional display

Table 1:

Depth	Angle	Tvd	Drift	A	Y	X
400	45	400	0	2	396.4645	3.53554
410	45	407.0711	7.071081	2	403.5355	10.60662
420	45	414.1422	14.14216	10	396.4645	31.81986
430	45	421.2133	21.21324	2	417.6777	24.74878
440	45	428.2844	28.28432	2	424.7488	31.81986

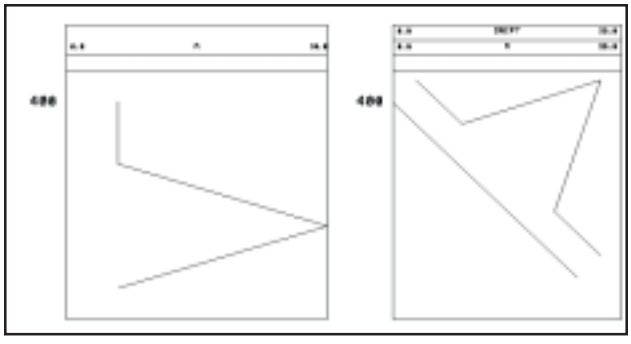

Fig. 2A **Fig. 2B**

of the same log. Each point on log curve in figure-2b is represented by co-ordinates (X,Y) given in the last two columns of Table-1. Co-ordinates (X,Y) have been evaluated TVD, Drift and value of the log involving all the five dependency factors mentioned above. Various equations used for the evaluation of co-ordinates are given below:

$X = Drift + P * COS\ \theta$

$Y = TVD - P * SIN\ \theta$

For curve position above the well trajectory, and

$X = Drift - P * COS\ \theta$

$Y = TVD + P * SIN\ \theta$

For curve position below the well trajectory.

Where

θ is the inclination angle,

$P = \alpha * A$ and

'α' is a factor dependent on log range and TVD/ Drift scale

For example if 'A' is the resistivity log to be plotted above with cycle thickness of 2 cm in the range 1 – 10 ohm-m, and TVD/drift scale is 1:500 that is 1cm equivalent to 5m then

$\alpha = (2 / \log 10) * 5 = 10$

$P = 10 * \log (R)$

Similarly if GR log is to be plotted below the trajectory with 2 cm covering from 0 - 100 API then

$\theta = (2 / 100) * 5 = 0.1$

$P = 0.1 * (100 - GR)$

Field Example

Figure – 3 depicts the logs of a highly inclined well - Z. The angle of inclination is about 70 degrees. Resistivity and Gamma Ray logs have been plotted normal to an axis inclined to vertical at 70 degree. Resistivity is shown above the inclined axis and Gamma Ray curve below the axis. True vertical depth (TVD) is on vertical axis and Horizontal drift is along horizontal axis. TVD/ drift scale is 1:1000. So co-ordinates of each point on each curve were generated using above equations. As the plot is for the purpose of correlation, the absolute log values are not important. Log features are used for correlation of various zones.

Constant azimuth was maintained during the drilling of inclined section. So log curves in two dimensional are smooth.

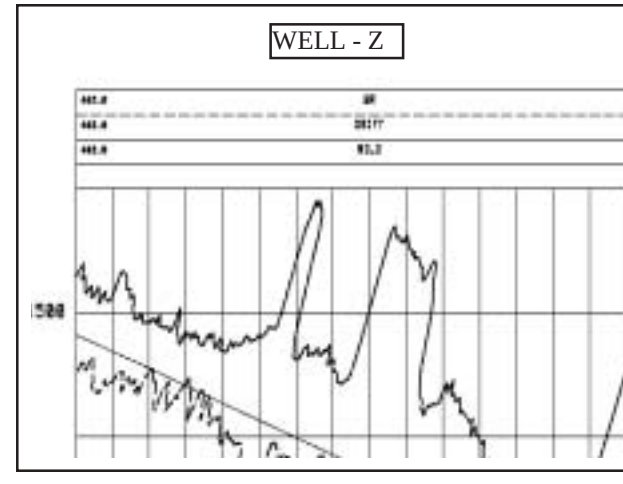

Fig. 3: Two-dimensional display of Resistivity (continuous curve) and Gamma Ray (Broken curve) logs of a highly inclined well. Angle of inclination to the vertical is 70 Deg. in the section shown. The azimuth has been maintained during drilling.

Conclusions

1. Two-dimensional display of well logs of inclined well is required for correlation with the logs of vertical wells.
2. Co-ordinates for each point on log curve for two-dimensional display can be generated using simple equations.
3. Co-ordinates are dependent on recorded value, depth/ drift scale and type of display (linear or logarithmic).
4. Generated co-ordinates can be plotted using any software for Log Data Display.

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Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.