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Dipmeter Interpretation - More Accurate Structural Definition of the Pontian Sandstones of Lipovljani and Jamarice

PROCEEDINGS

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Ključne riječi: interpretacija dipmetra, deskriptivna statistika, orijentacija rasjeda, karakterizacija rasjeda, pontski pješčenjaci, Lipovljani, Jamarice, savska depresija, Hrvatska.

Abstract

Two pairs of wells have been chosen from the Lipovljani and Jamarice oil fields in the Sava depression in the south-west part of the Pannonian basin. Both wells from each field have a measured E-log, and one also has a high-quality diplog. The reservoir rocks are represented by folded and faulted Pontian sandstones. A combination of graphical interpretation and SCAT (Statistical Curvature Analysis Techniques) has allowed identification of both structural and fault plane dips. Defining the position of fault planes enabled the characterisation of normal and reverse faults, inclined in the direction of structural dip (or against it), and positioned either longitudinal, transverse or diagonal to the structure. The described technique can be fully utilised in the creation of a geological model aimed to finding the bypassed oil.

Sažetak

S naftnih polja Lipovljani i Jamarice iz savske depresije u jugozapadnom dijelu panonskog bazena odabrane su po dvije bušotine s elektrokarotažnim dijagramima od kojih po jedna ima još i vrlo kvalitetan diplog. Ovdje su kolektori, pontski pješčenjaci, borani i rasjedani. Kompleksnom interpretacijom - grafičkom i statističkom (SCAT), razlučeni su nagibi slojeva od nagiba paraklaza. Utvrđeni elementi orijentacije rasjeda omogućili su njihovu karakterizaciju na normalne ili reverzne, na protusmjerne ili istosmjerne, te na uzdužne, poprečne ili dijagonalne. Tako dobivena rješenja nezaobilazna su pri kreiranju geološkog modela s ciljem pronalaženja zaostale nafte.

1. INTRODUCTION

From the late seventies to the early eighties INA, the Croatian national oil-company purchased logging equipment from "Western Atlas", including the four-pad high-resolution dipmeter. In addition to giving an analogue output recorded on film, this equipment is capable of digital recording of data, and thus enables computer data-processing.

Dipmeter measurements were taken in several wells of Lipovljani and Jamarice fields. The physical and lithological characteristics of the Pontian sandstones, reservoir rocks in the aforementioned fields, resulted in good quality data with very closely spaced dip measurements. This suggested a method for the recognition and more accurate location of faults, and their orientation and influence on the geometry of reservoir rocks. Two typical wells from each field have been chosen to illustrate the method. The results of various statistical curvature analysis techniques are given, and show the successful definition of structural dips (dips of bedding planes), and their separation from differently spaced planes caused by tectonic deformation - fault planes presented by either simple surfaces or fault zones.

The oil fields of Lipovljani and Jamarice are located some 90 km east of Zagreb (Fig. 1b), in the south-western part of the Pannonian basin, in the Sava depression. In 1932 the first oil and gas explorations took place there. Uplifted structures were defined by seismic reflection lines in 1959. The drilling on Lipovljani commenced in 1960, and on Jamarice in 1964. In accordance with regional lithostratigraphic subdivision the productive horizons were named Janja Lipa, Kozarica and Bujavica sandstones (Figs. 1a, 4a), which chronostratigraphically fairly closely respond to the Pontian deposits.

The observable signs of faulting in the mentioned fields had previously drawn the attention of explorationists during the early 1970's. This was then documented by a detailed study of conventional E-logs, and the cases where the same layers were being repeatedly drilled through in one well, or an apparent hiatus in a

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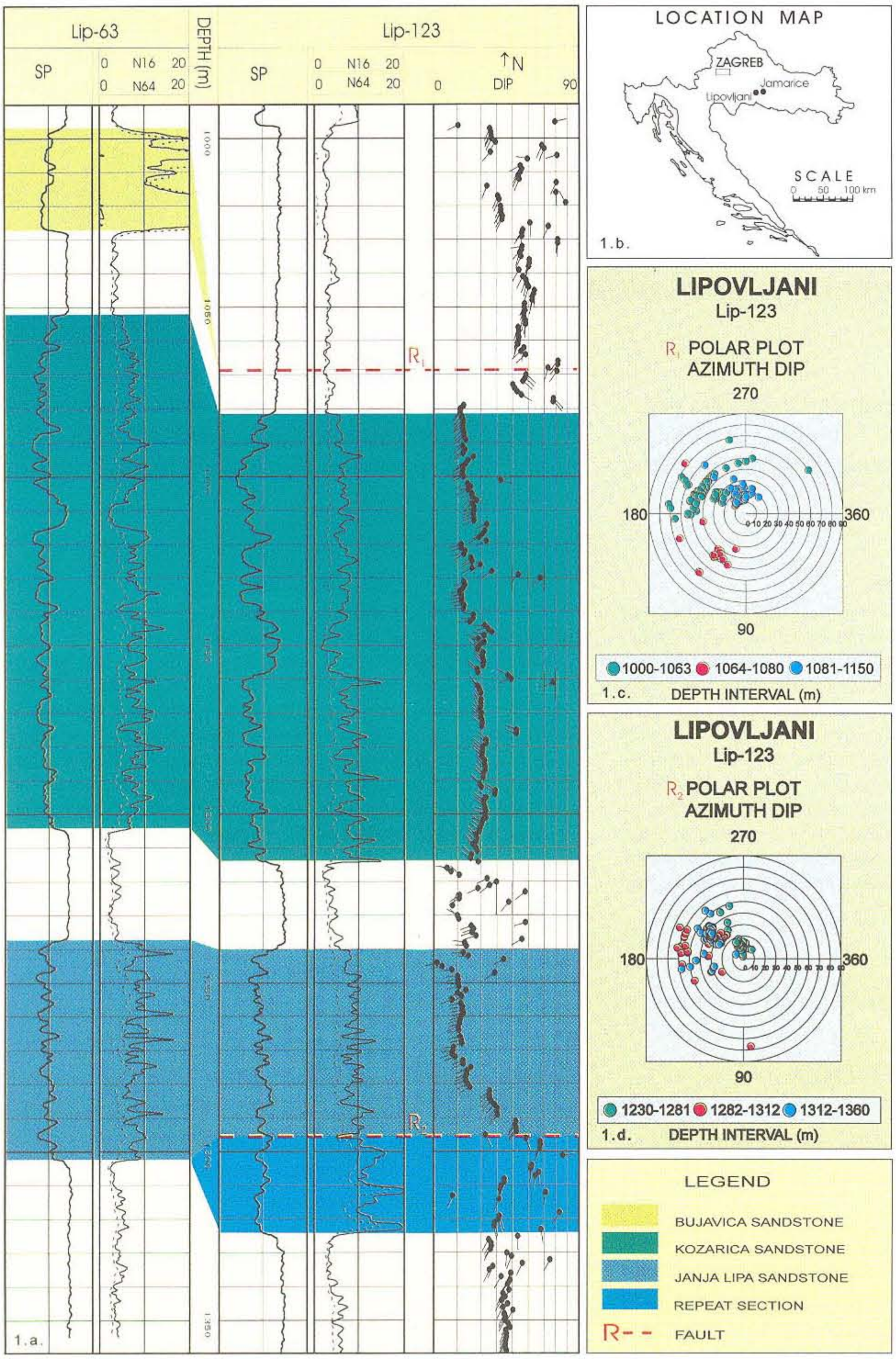

Fig. 1 a) Correlation scheme Lip-63 Well - Lip-123 Well; b) location map; c) Lip-123 Well R_1 Azimuth Dip Plot; d) Lip-123 Well R_2 Azimuth Dip Plot.

well nearby were explained by tectonics (TUFEKČIĆ, 1970; HERNITZ & ŠIMON, 1975; JANČIKOVIĆ, 1977).

2. RESULTS OF DIPMETER ANALYSIS

The diplog of well Lip-123 has been chosen from the field Lipovljani together with E-log of Lip-63 for correlation purposes. The depth interval from 1000 to 1350 m is shown (Fig. 1a). Correlation of log-measurements (N16, N64, SP) from these closely spaced wells depicts substantial differences in the lithological composition and thickness of individual sandstone bodies. It is, for example, noticeable that the Bujavica sandstone drilled by Lip-63 well was totally absent in Lip-123. In contrast, the Janja Lipa sandstone is some 20 m thinner in Lip-63 than Lip-123. The dip plot of Lip-123 clearly shows a change of dip angle and azimuth in two positions (Fig. 1a). On the polar plots of azimuth and dip of planar elements from chosen intervals (Figs. 1c and 1d) a concentration of patterns is apparent, illustrating the structural dip in the hanging wall and in the footwall, together with the orientation of the fault plane itself. This way of dip plotting doesn't show the depth of individual dips, which is possibly confusing to less experi-

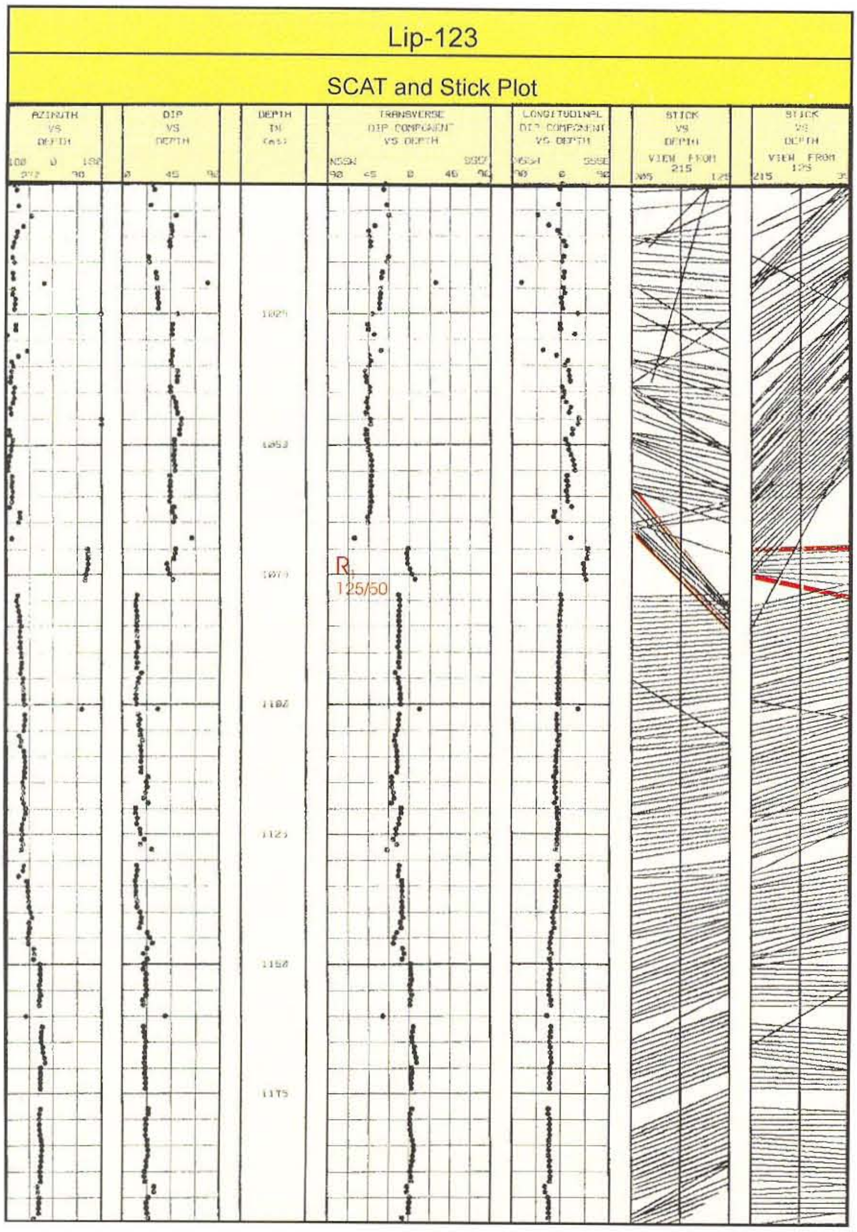

Fig. 2 Lip-123 Well R_1 SCAT and Stick Plot.

enced analysts. The "azimuth vs. dip" cross-plot allows singular dips to be traced to their precise depth so that their "origin" can be controlled. Generally speaking, in this way patterns analysed with the help of a cross-plot will show a Gauss normal distribution, whereby dips from one side of the fault or another are put into one or more stochastic groups. In the case of Lip-123, not only a vertical but also a horizontal displacement can be deduced from the differences in the dip azimuth (Fig. 2). Furthermore, it is only possible by cross-plot to precisely define the position of the transverse and longitudinal plane, marked by structural dip and well axis. A series of related cross-plots is shown on Fig. 2. These are: Mercator projection of azimuth vs. depth, "dip vs. depth", the transverse and longitudinal dip component vs. depth and the two most characteristic perpendicular stick plots vs. depth. Thorough analysis of the cross-plots allowed calculation of the thickness of the deformed intervals and, more importantly, the dip and azimuth of fault planes. In Lip-123 two faults are documented - R_1 with a fault plane 125/50 on 1070 m and R_2 positioned 190/60 on 1298 m. The first fault is younger, normal, inclined against the structural dip and diagonal to the structure (Fig. 3), the other is older, probably reverse, inclined in the same direction as the structural dip but steeper than bedding dip values.

Well-log correlation between Jam-74 and Jam-160 showed marked differences in sandstone thickness (Fig. 4a). The dip plot of Jam-160 shows well-marked discontinuities of both dip and azimuth at depths corresponding to the positions of reduced sandstone thickness as defined by E-log correlation with Jam-74. These discontinuities are also observable on the Mercator projection of azimuth vs. depth, as well as on the "dip vs. depth" plot (Fig. 5). It is also noticeable that both the transverse and longitudinal dip component have similar discontinuities at the same depths. The patterns at 1203 and 1250 m have an inclination opposite to the disconti-

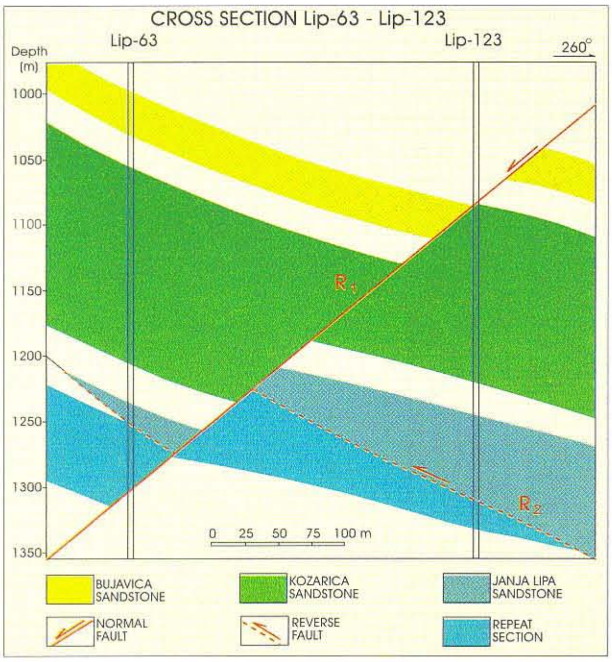

Fig. 3 Cross section Lip-63 Well - Lip-123 Well.

nuities located at 1280, 1308 and 1355 m respectively. This is due to the spatial position of faults that are appropriately shown in the chosen sections. Figures 4b, c, d, e and f show azimuth vs. dip cross-plots from Jam-160. The positions of fault planes are as follows: R_1 with 220/55 at 1203 m, R_2 with 290/45 at 1250 m, R_3 with 145/50 at 1280 m, R_4 with 75/45 at 1308 m and R_5 with 90/65 at 1355 m. Based on the relationship between the structural dip and orientation of fault planes, faults R_1 and R_2 are diagonal with fault planes inclined in the same direction as the structural dip, R_3 and R_4 are diagonal with inclination against the structural dip, while fault R_5 is longitudinal to the structure and inclined against the structural dip. All the faults have normal displacement. These solutions are essential in finding the so-called "bypassed oil", especially in the phase of building a complex geological model (BASSIOUNI & VELIĆ, 1996; PRELOGOVIĆ et al., 1995) in order to explore for oil and gas more economically.

3. CONCLUSION

The interpretation of very dense dipmeter data requires certain skill and experience. Only by utilisation of a number of graphical and statistical techniques can satisfactory and unambiguous results be obtained. Examples of two pairs of wells from the Lipovljani and Jamarice fields, with intensively folded and faulted sandstone reservoirs, are used for the illustration of how structural dips can be discerned from the fault planes; how the fault plane orientation can be defined; and finally how the character of a fault can be deduced.

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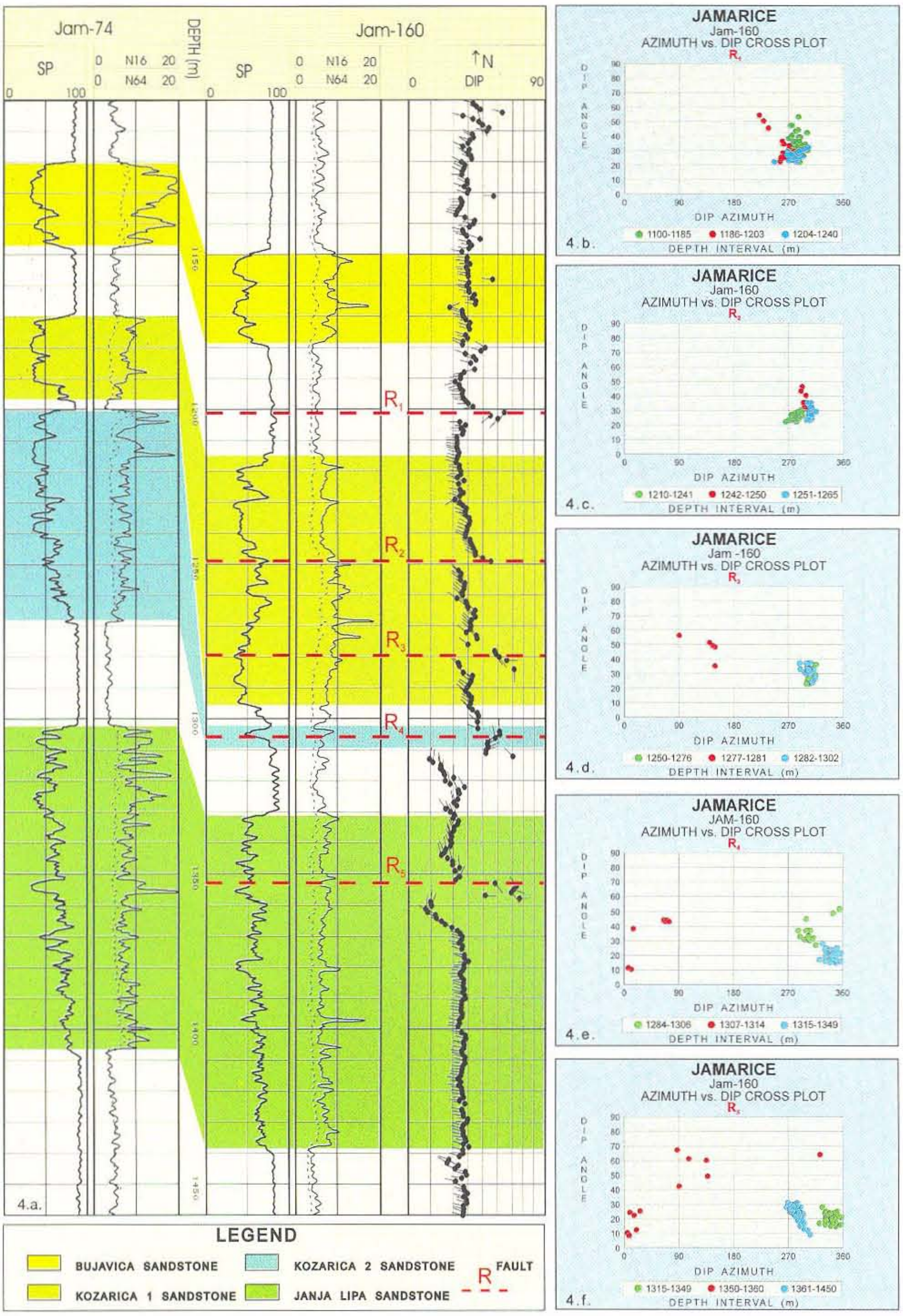

Fig. 4 a) Correlation scheme Jam-74 Well - Jam-160 Well;
b) Jam-160 Well R_1 azimuth vs. dip cross plot;
c) Jam-160 Well R_2 azimuth vs. dip Cross Plot;
d) Jam-160 Well R_3 azimuth vs. dip cross plot;
e) Jam-160 Well R_4 azimuth vs. dip cross plot;
f) Jam-160 Well R_5 azimuth vs. dip cross plot.

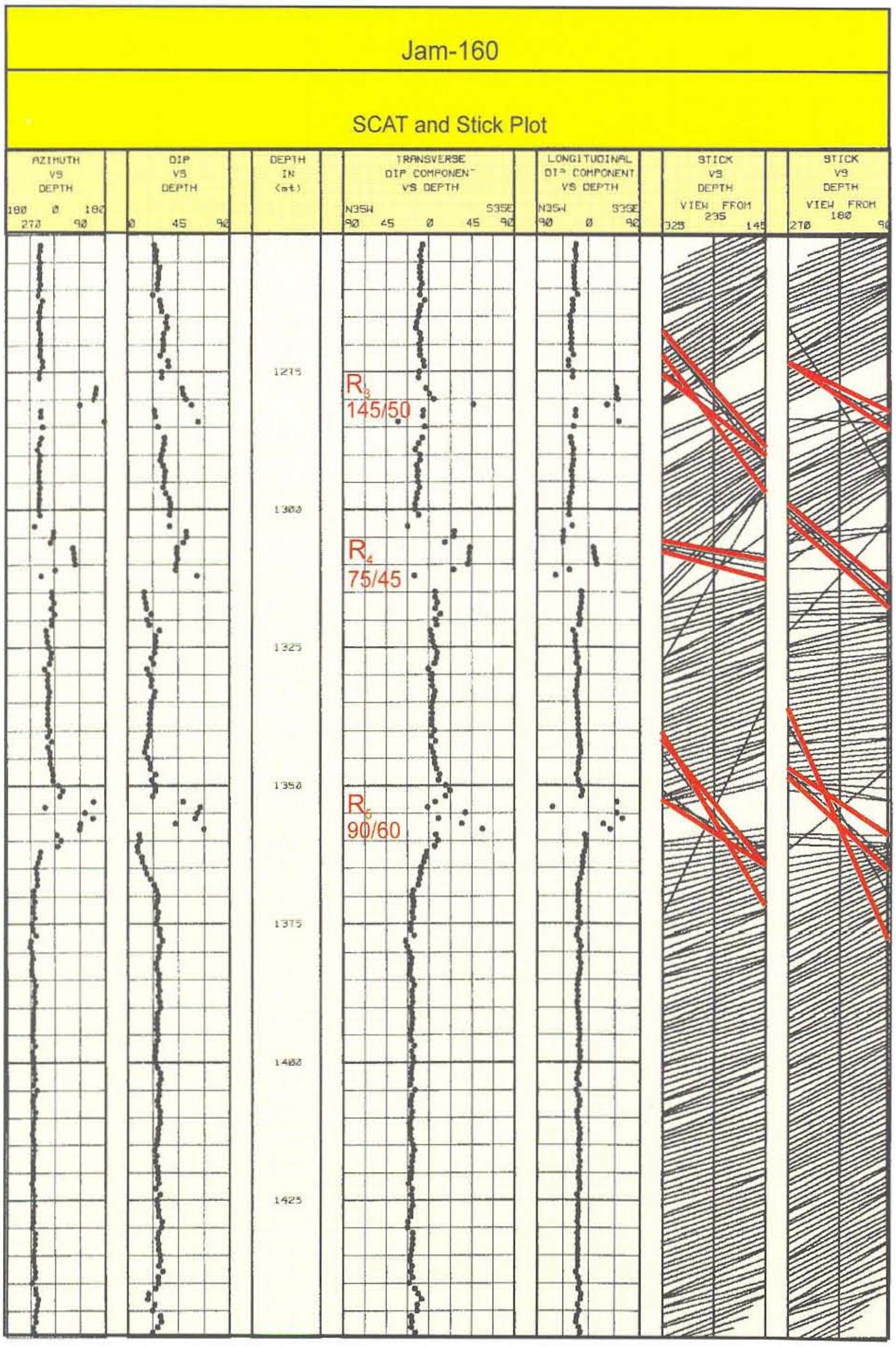

Fig. 5 Jam-160 Well R_3-R_4-R_5 SCAT and Stick Plot.