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Finding the Drilling Induced Fractures and Borehole Breakouts Directions Using Image Logs

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Abstract – *By interpreting the image logs, both the direction of drilling induced fractures that is parallel to the maximum horizontal in-situ stress direction and the direction of borehole breakouts that is parallel to the minimum horizontal in-situ stress direction can be calculated. In this work, 10 wells located in Gachsaran field will be selected, then the direction of drilling induced fractures and borehole breakouts will be found in these wells by using the image logs and the other geological log interpretation. This work will be done in order to both having a better understanding of structural geology in this field and also explaining the methodology by showing the selected log interpretation examples from this field.*

Keywords: Image logs, drilling induced fractures, borehole breakouts

1.0 INTRODUCTION

Gachsaran oil field is in the southwest of Iran (Figure 1) with an anticline structure, made of anhydrite/salt, 80 km long, 300m-1500m thickness, 8-18 km wide; it provides an excellent seal for the Asmari reservoir, the Pabdeh reservoir, the Gurpi reservoir and the other reservoirs (Figure 2) [1].

2.0 MATERIAL AND METHODS

The main data for this job are the image log data including the Formation Micro Scanner (FMS), Oil-Base-Mud Imaging (OBMI), Formation Micro Imager (FMI) and the Ultrasonic Borehole Imager (UBI). In this work, 10 wells (Wells number GS-A, GS-B, GS-C, GS-D, GS-E, GS-F, GS-G, GS-H, GS-I and GS-G), located in the Gachsaran oil field, will be studied.

Maximum horizontal in-situ stress (σ_{hmax}) direction is same as induced drilling fracture direction, and minimum horizontal in-situ stress (σ_{hmin}) direction is same as borehole breakout direction; both drilling induced fractures and borehole breakouts are created during the drilling operation [8].

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Drilling induced fracture and borehole breakout are different in images; the drilling induced fracture is in the form of a fracture seen by the images, oriented at 180 degrees from each side of the well, but borehole breakout is in the form of borehole elongation on the orthogonal calipers and as long dark regions on the images that are 180 degrees apart (Figure 3).

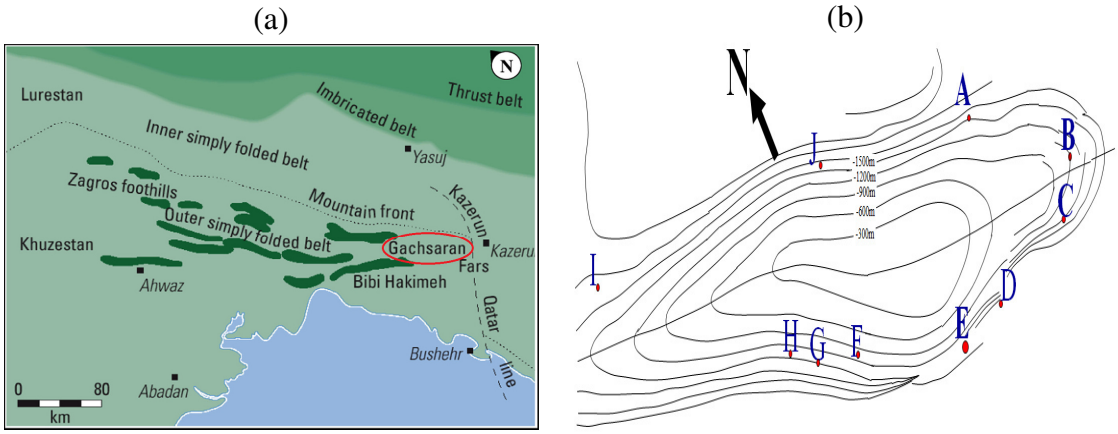

Figure 1: a) Location of the Gachsaran field [2]; b) UGC map of the Gachsaran field and the studied wells

Image log technology is a new technology that can characterize the oil and gas reservoirs in many cases such as structural analysis, fracture characterization, fault interpretation and in-situ stress analysis [3, 4]. These applications are still unknown to some researchers that are interested in learning the way that the in-situ stresses direction can be driven from image logs, so in this job using a case study and numbers of valuable log interpretation this process will be explained completely [5-7].

3.0 THEORY

The borehole breakouts are due to the hoop stress that this stress causes shear failure in the borehole, and the drilling induced fractures are due to the radial stress and this stress causes the tensile failure in borehole. By finding out the direction of induced drilling fractures and borehole breakouts from the image logs, we can find the direction of in-situ stresses.

In wellbore there are always hoop stress and radial stress; they cause drilling induced fracture and boreahole breakout, but it's depend on the rock strength in any part of wellbore that which one will happen. If the rock strength is low the drilling fluid will wash the rock and borehole breakouts will happen, but if the rock strength is high the drilling fluid will cause drilling induced fractures (hydraulic fractures) (Figure 4).

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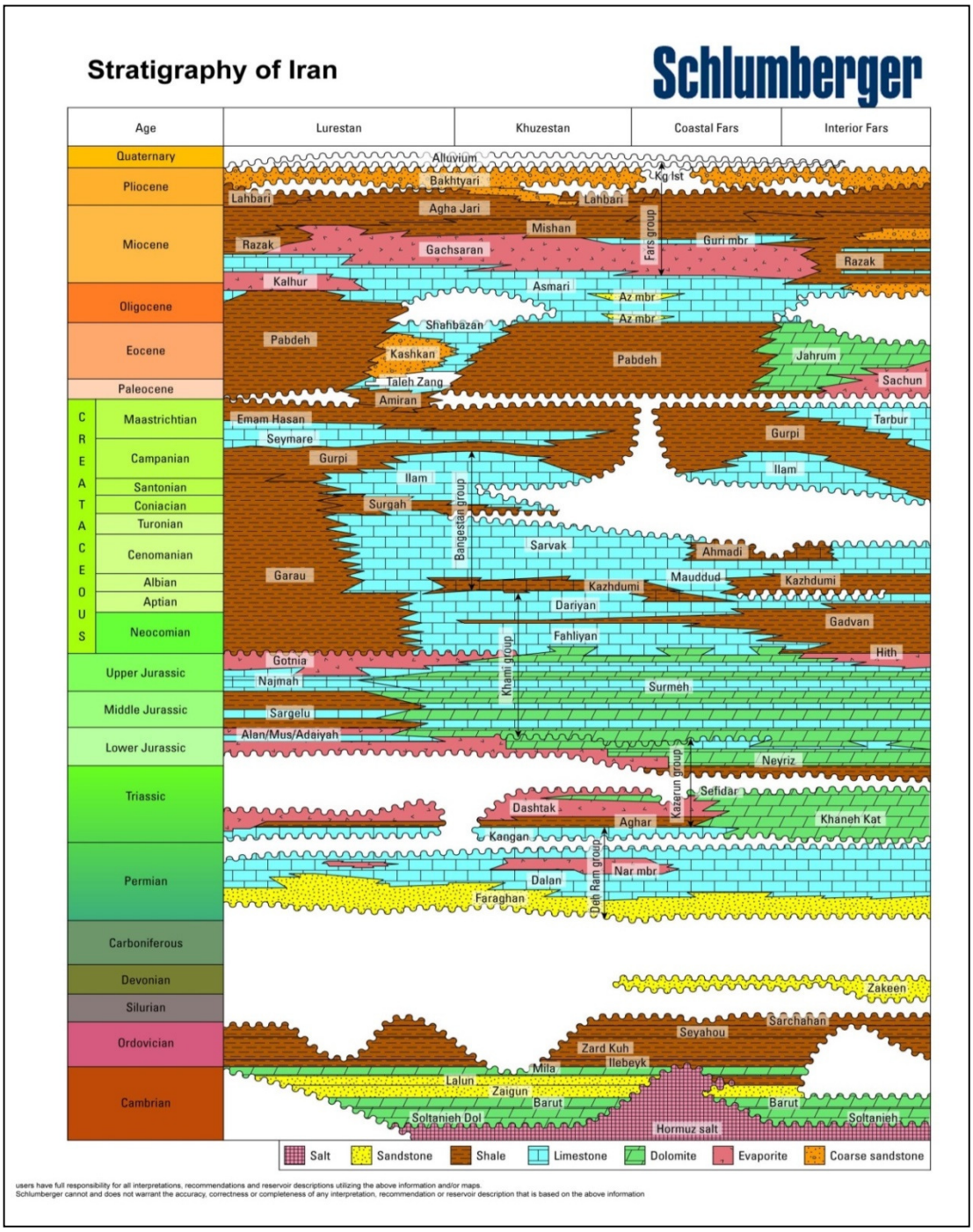

Figure 2: Picture showing the Gachsaran field overlying the Asmari, Pabdeh, Gurpi and other reservoirs, and stratigraphic nomenclature of rock units and age relationships in the Zagros basin [2]

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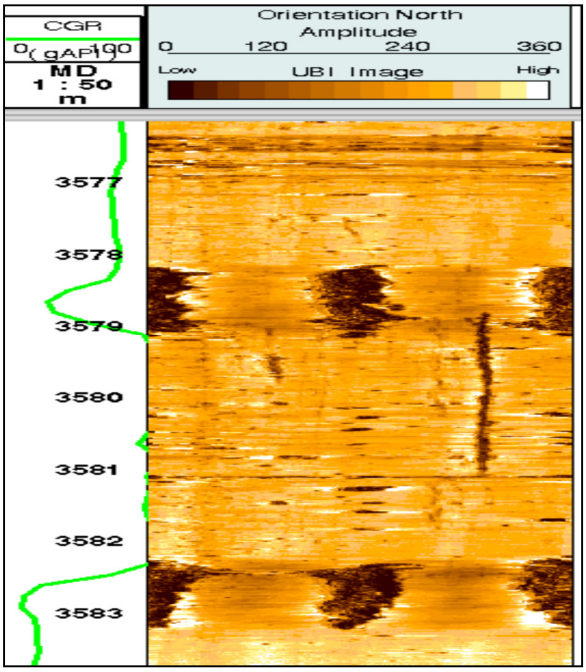

Figure 3: The UBI image showing borehole breakouts and drilling induced fractures; the thin dark color region is drilling induced fracture, and the dark wide regions are borehole breakouts

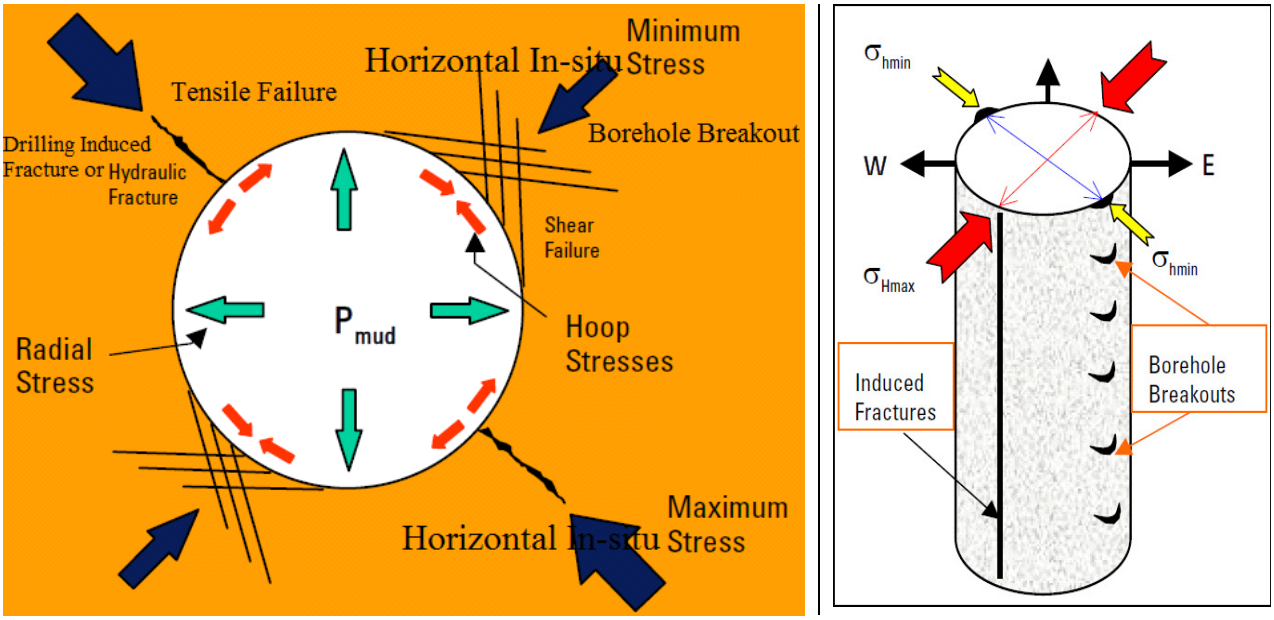

Figure 4: schematic pictures of the radial stress, tensile failure, drilling induced fracture (hydraulic fracture), maximum horizontal stress, hoop stress, shear failure, borehole breakout and minimum horizontal stress

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4.0 RESULTS

4.1 In-situ Stress Analysis for the Well Number GS-A

The FMI images showing borehole breakouts on the images facing northwest and southeast sides of the borehole. Thus they indicate WNW-ESE trending elliptical borehole breakouts that are aligned with σ_{hmin} (Figure 5). In this well the direction of σ_{hmax} is NNE-SSW.

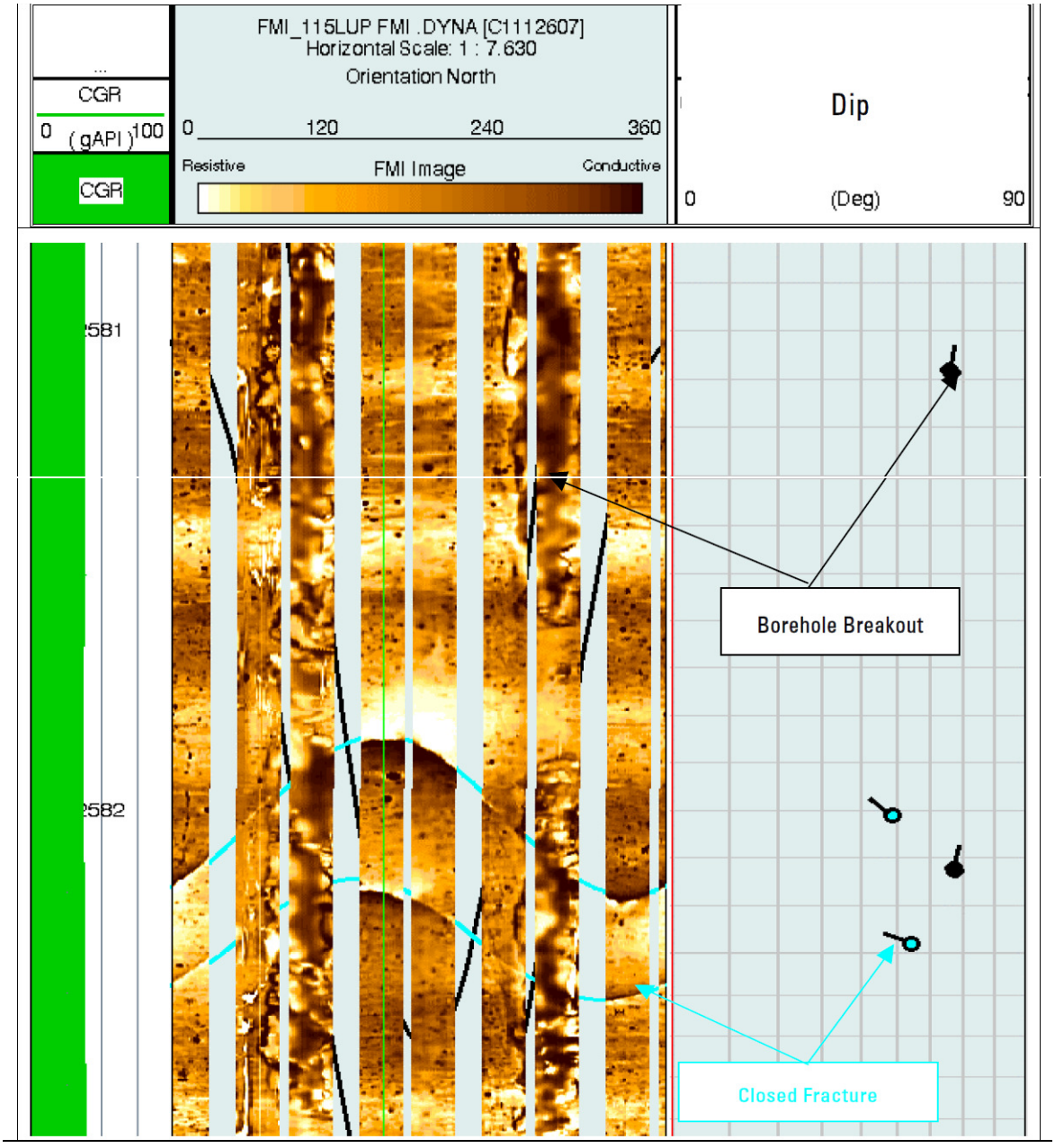

Figure 5: In well GS-A, the FMI images showing borehole breakouts on the images

4.2 In-situ Stress Analysis for the Well Number GS-B

The amplitude and the radii images of UBI show elliptical borehole breakouts in many zones. In some places only the first stage of borehole breakouts in the form of conjugate shear

fractures was identified. The cross-sectional slices of borehole radii across such intervals indicate the NE-SW orientation for the longer axis of the borehole breakouts (Figure 6). It indicates the NE-SW orientation for σ_{hmin} and the NW-SE orientation for σ_{hmax}.

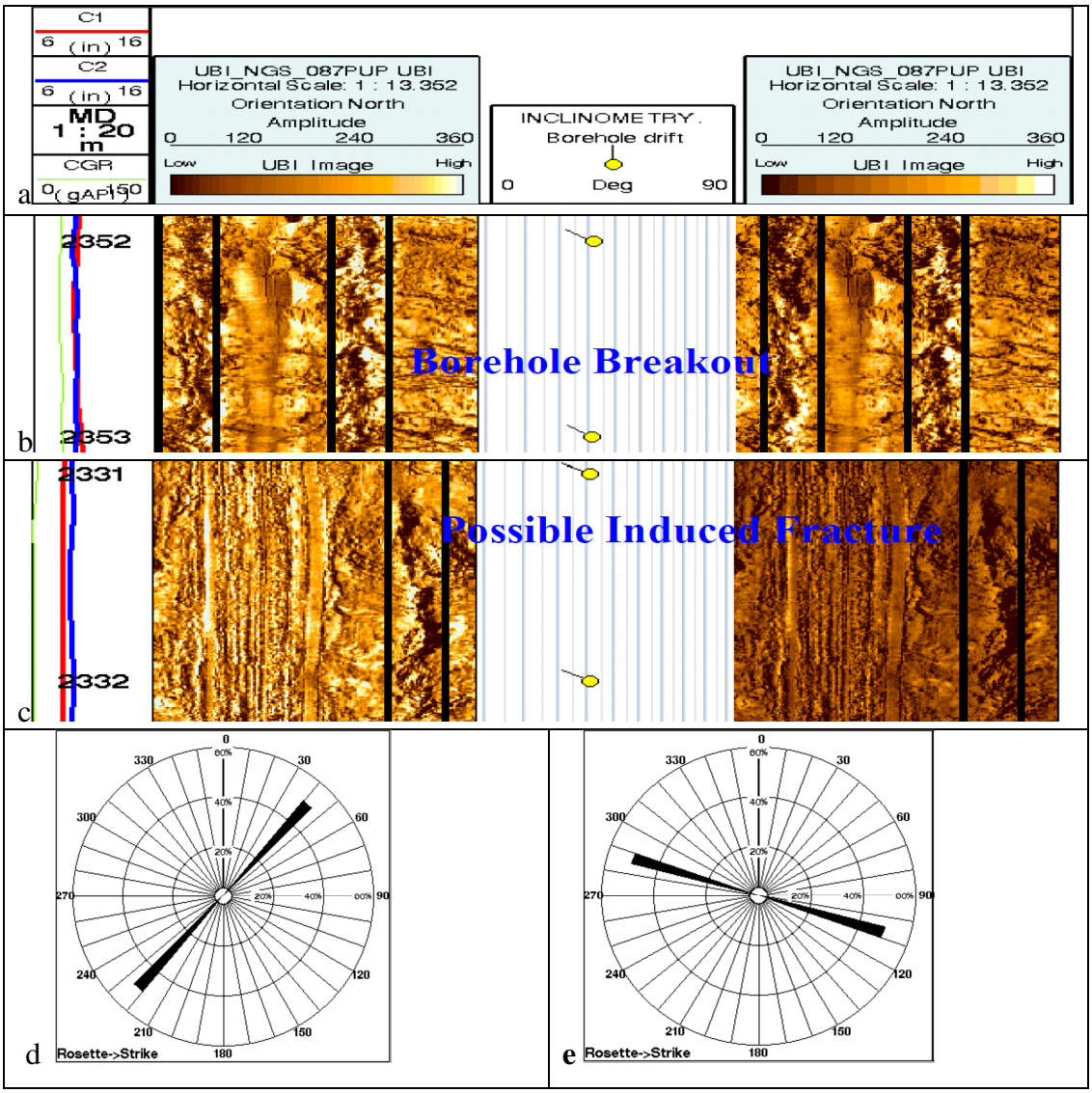

Figure 6: a) UBI log header in well GS-B; b & c) UBI images show borehole breakouts striking almost NE-SW, which is parallel to σ_{hmin}, and the orientation of the drilling induced fractures that is WNW-ESE to be parallel to σ_{hmax} orientation; d) strike of σ_{hmin} in Schmidt projection & e) strike of σ_{hmax} in Schmidt projection

4.3 In-situ Stress Analysis for the Well Number GS-C

A cross-sectional slice of the borehole radii at 2512m and a spiral plot / down-looking pipe view across the 2512m-2512.3m depth indicate the WNW-ESE orientation for the longer axis of the borehole breakouts (Figure 7). Such breakouts represent shear failure of the formation exposed to the wellbore. The borehole breakouts indicate the WNW-ESE orientation for σ_{hmin} and the NNE-SSW orientation for σ_{hmax}.

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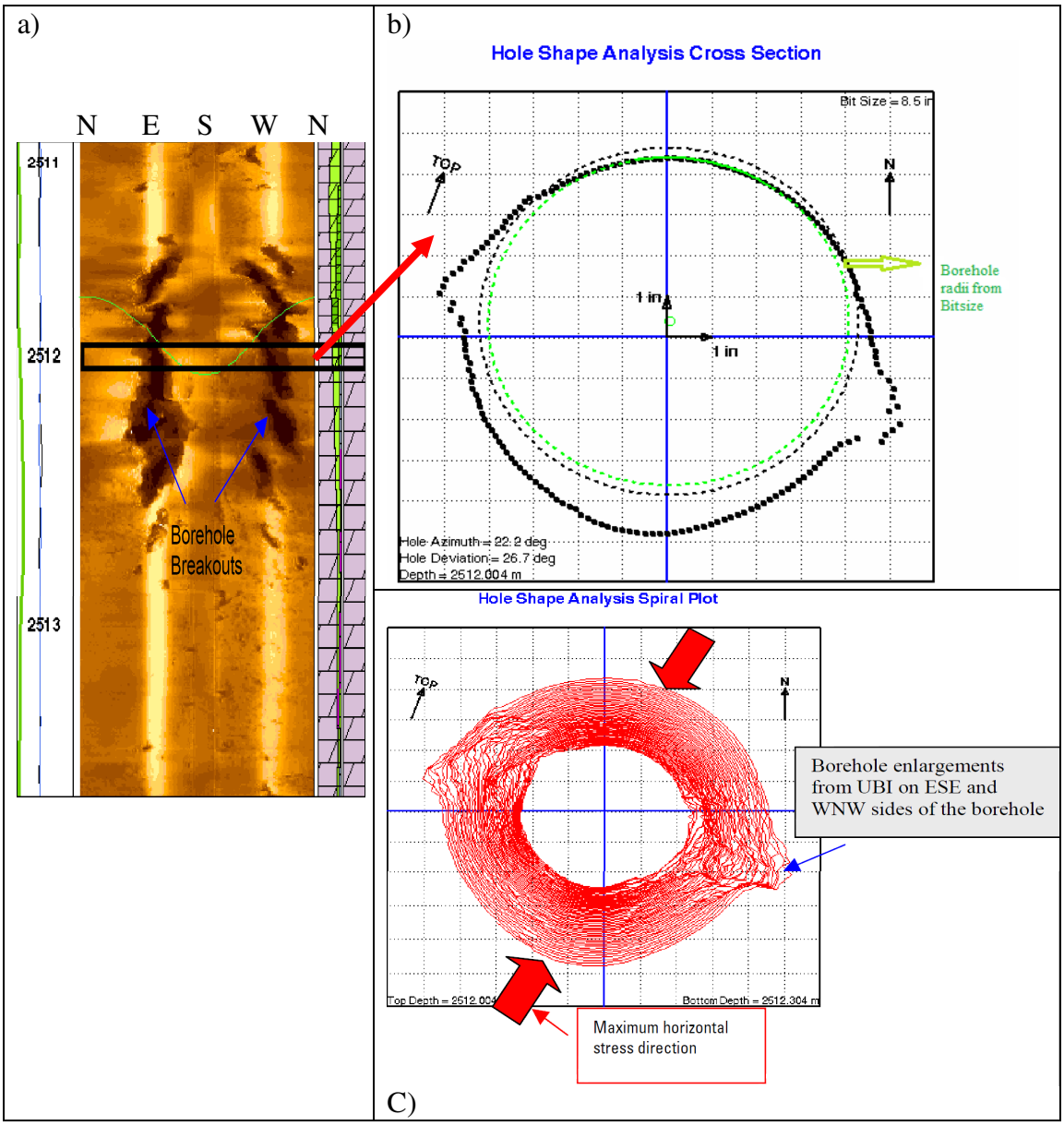

Figure 7: a) In well GS-C, the UBI image of the borehole radius showing borehole enlargements (breakouts – black vertical stripes) around WNW and ESE sides of the borehole in the well GS-C; b) and c) The pipe's down-looking view of the borehole radii from the UBI

4.4 In-situ Stress Analysis for the Well Number GS-D

The amplitude and radii images of UBI show elliptical borehole breakouts in most part of the borehole. A composite plot of the borehole breakout's azimuth and their magnitude indicates change in the orientation of the longer axis of the borehole breakouts. In the zones of the borehole deviation, the dominant orientation for their longer axis is the NE-SW direction (Figure 8).

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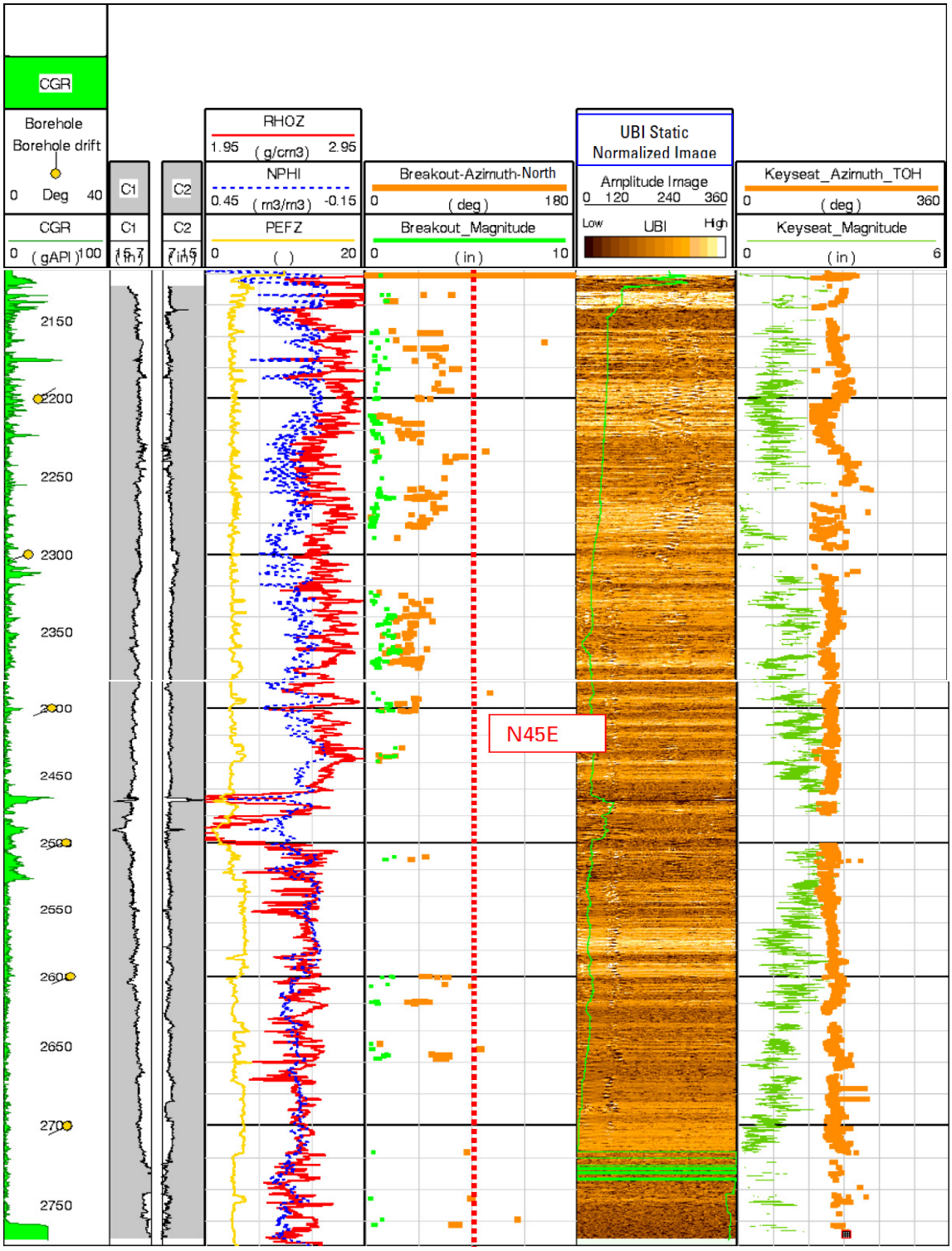

Figure 8: In well GS-D, the composite plot of calipers and full set logs showing the borehole breakout and key seat azimuths and magnitudes which were derived from UBI images. The average breakout azimuth is N45E for the intervals with well deviation less than 20 degrees.

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Breakout azimuths in intervals with inclination higher than 20 degrees do not represent the exact orientation of breakouts. In such cases, breakout orientations need to be corrected

Their orientation in the zones (For example, the lower half of the well trajectory) of a well's deviation greater than 20 degrees does not reflect the true orientation of borehole breakouts. A correction needs to be applied to get the true orientation of borehole breakouts in such situations. Such breakouts represent the shear failure of the formation exposed to the wellbore. Borehole breakouts indicate the NE-SW orientation for σ_{hmin} and the NW-SE orientation for σ_{hmax}.

4.5 In-situ Stress Analysis for the Well Number GS-E

Two drilling induced fractures are observed in the upper section of the Asmari reservoir at 2508m and 2543m. The strike direction of these fractures is N45E-S45W, which roughly indicates that the orientation of σ_{hmax} around the well is NE-SW and the orientation of σ_{hmin} is NW-SE (Figures 9 to 11).

4.6 In-situ Stress Analysis for the Well Number GS-F

No drill-induced fractures were observed in this well. However, a number of elliptical borehole breakouts, due to the shear failure of the borehole wall, are observed in the lower interval of the well at 2324m-2450m (Figures 12 and 13). Only a few such features are identified in the remaining interval of the Asmari formation. The large majority of these elliptical breakouts have their longer axis orientation in the NW-SE direction, which indicates that the orientation of σ_{hmin} around the well is NW-SE and the orientation of σ_{hmax} is NE-SW.

4.7 In-situ Stress Analysis for the Well Number GS-G

The borehole breakouts were observed in this well. They are almost in whole interval and most of them exist in Gurpi and Pabdeh formations. There are 5 induced fractures with a N15E-S15W strike that show the direction of maximum horizontal in-situ stress (Figures 14 and 15). The large majority of these elliptical breakouts have their longer axis oriented in almost the WNW-ESE direction, which indicates the orientation of σ_{hmin} around the well, therefore the orientation of σ_{hmax} will be almost in the NNE-SSW.

4.8 In-situ Stress Analysis for the Well Number GS-H

The borehole breakouts were observed in the whole interval of the well and most of them exist in the Gurpi and Pabdeh formations (Figures 16 and 17). The large majority of these elliptical breakouts have their longer axis orientation in almost N-E direction, which indicates that the orientation of σ_{hmin} around this well is almost N-E and the orientation of σ_{hmax} is N-S (N33E-S33W for σ_{hmax} and N57W-S57E for σ_{hmin} to be more precise).

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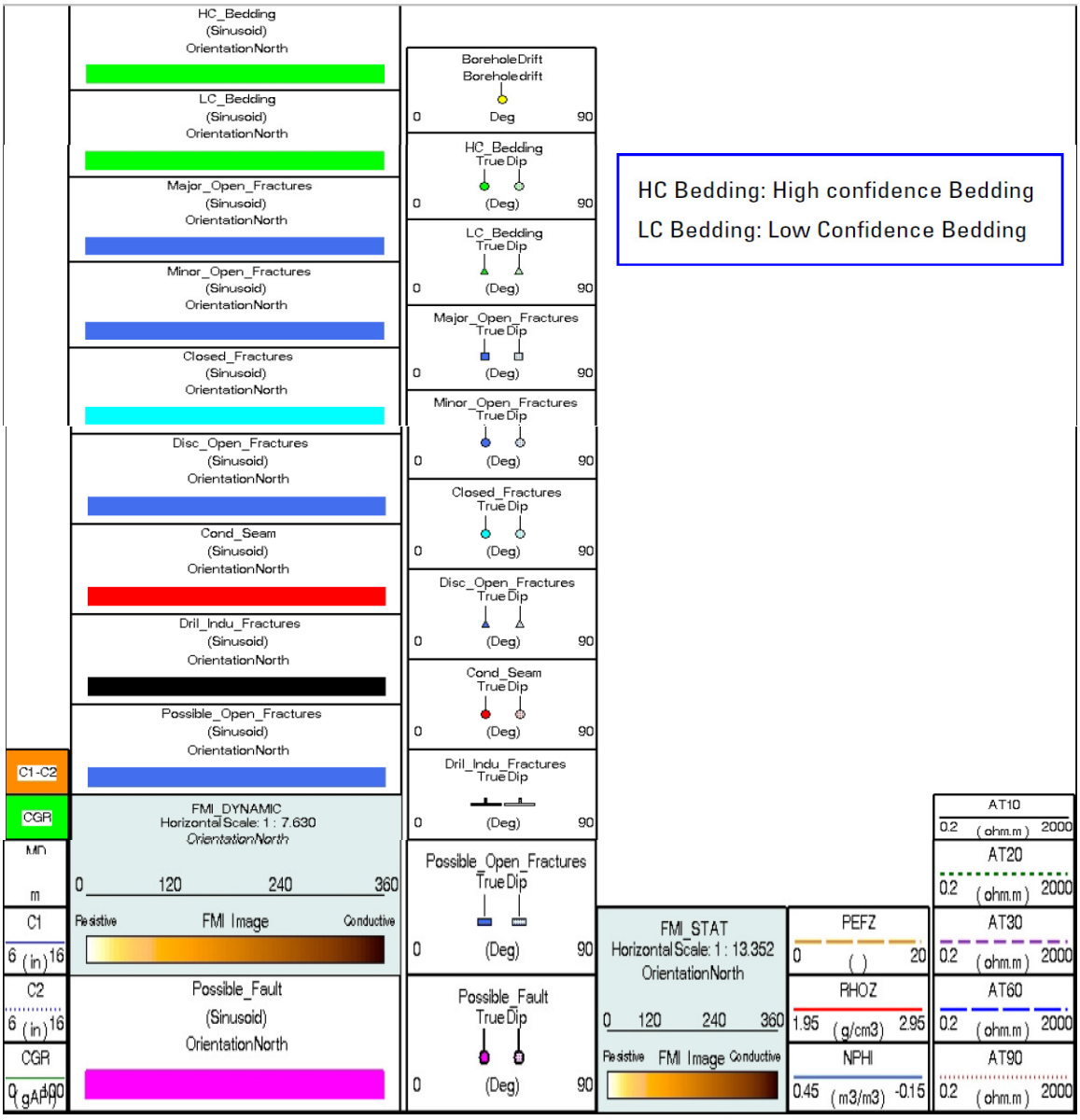

Figure 9: Header details for figures 10 and 11

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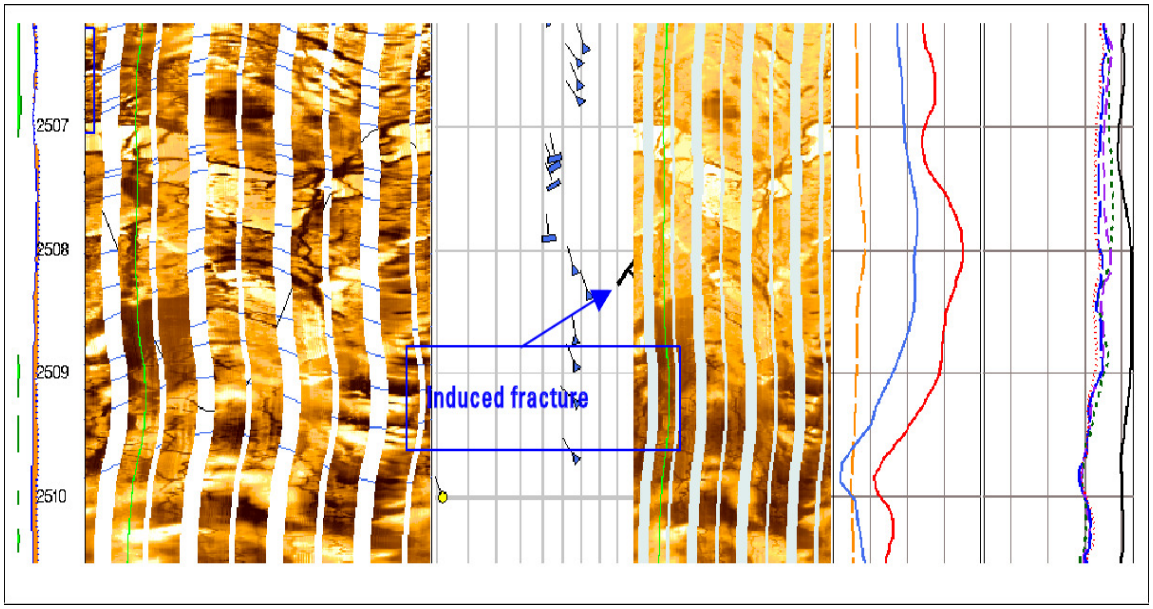

Figure 10: In the well GS-E images shows the NE-SW trend for the drilling induced fractures in depth 2508m; header is given in figure 9

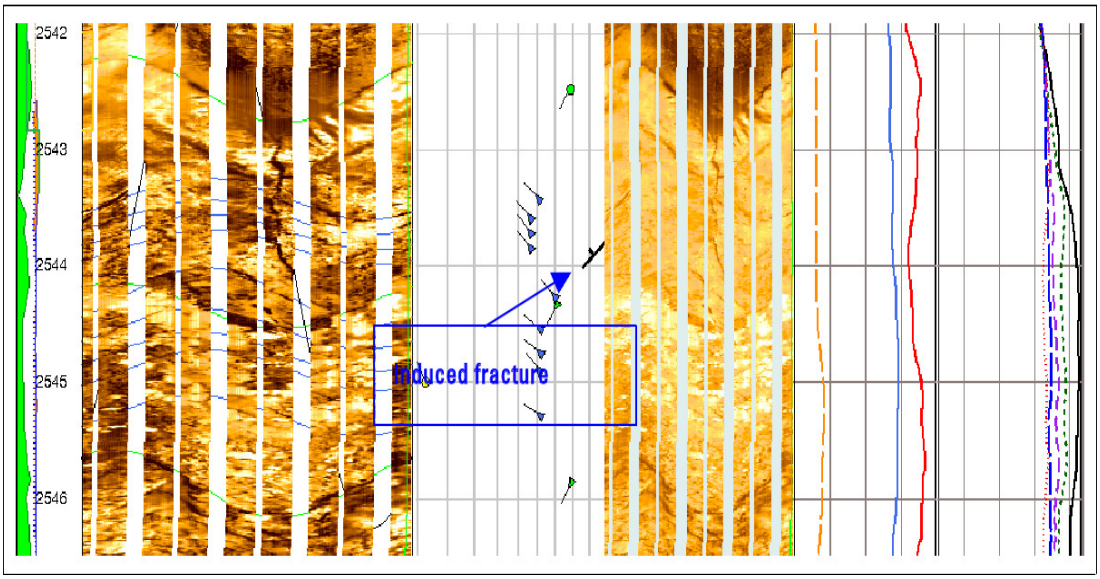

Figure 11: In the well GS-E images shows the NE-SW trend for the drilling induced fractures in depth 2543m; header is given in figure 9

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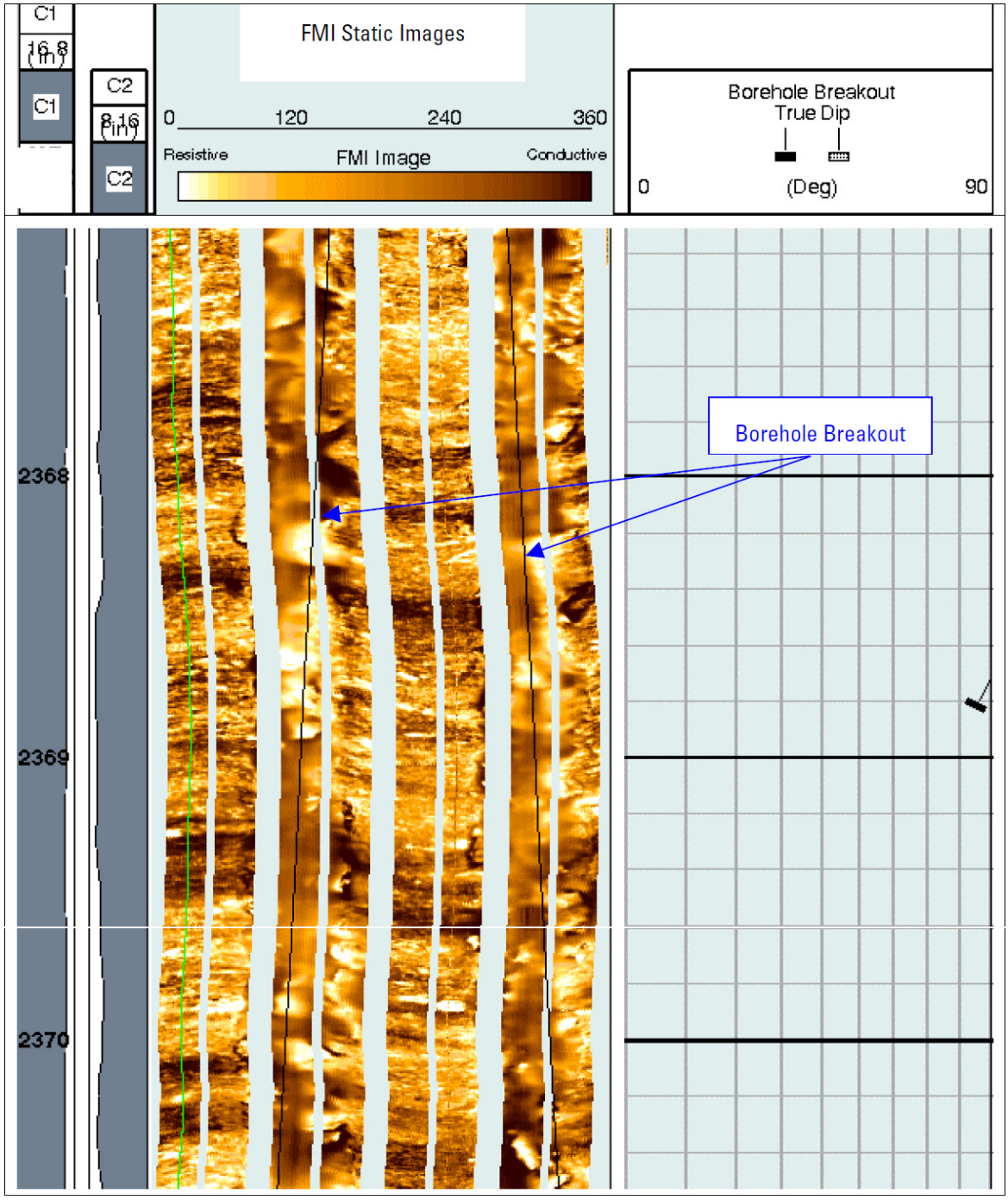

Figure 12: In the well GS-F, the FMI images showing borehole breakouts on the images facing northwest (N60W to be more precise) and southeast (S60E to be more precise) sides of the borehole. Thus they indicate N60W-S60E trending for σhmin

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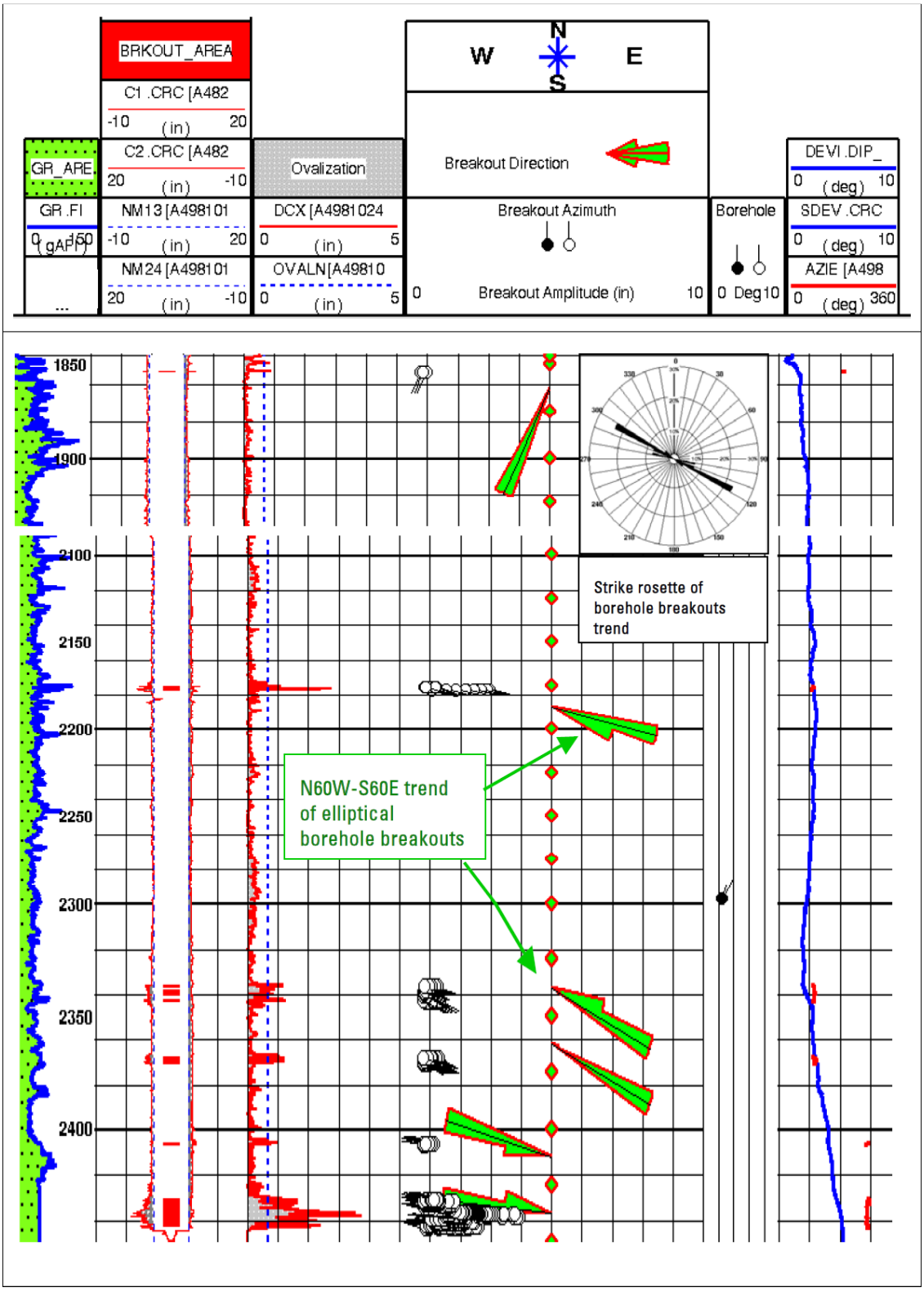

Figure 13: In well GS-F, the logs showing dominantly N60W-S60E trending for borehole breakouts in Asmari formation. The breakouts were mostly observed in lower section. According to them the orientation of σhmin is N60W-S60E and the orientation of σhmax is N30E-S30W

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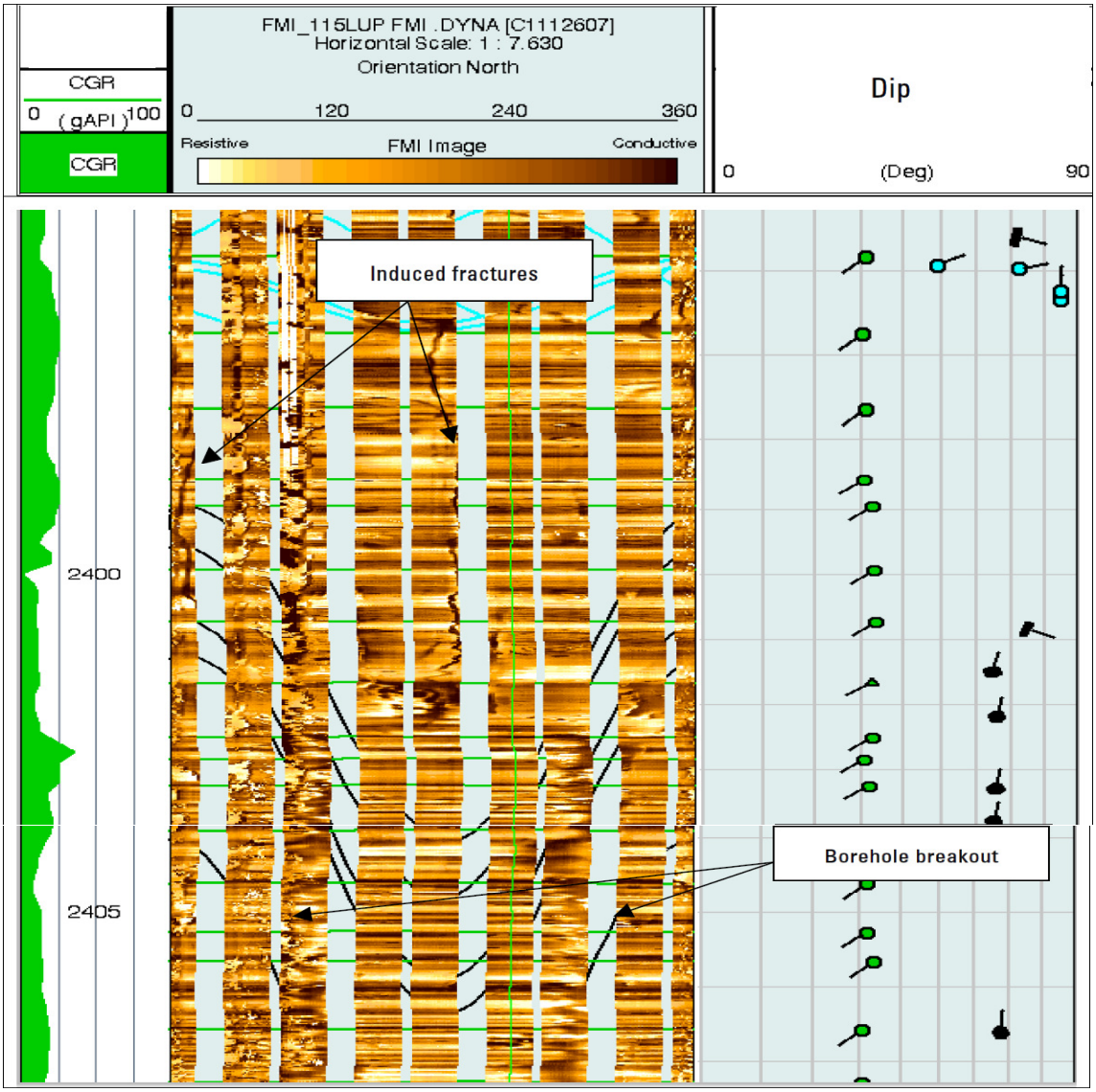

Figure 14: In well GS-G, FMI images showing induced fractures in the upper part of the figure (2395m-2402m) and borehole breakouts in lower part (2402m-2407m). They have 90 degrees difference in the azimuth

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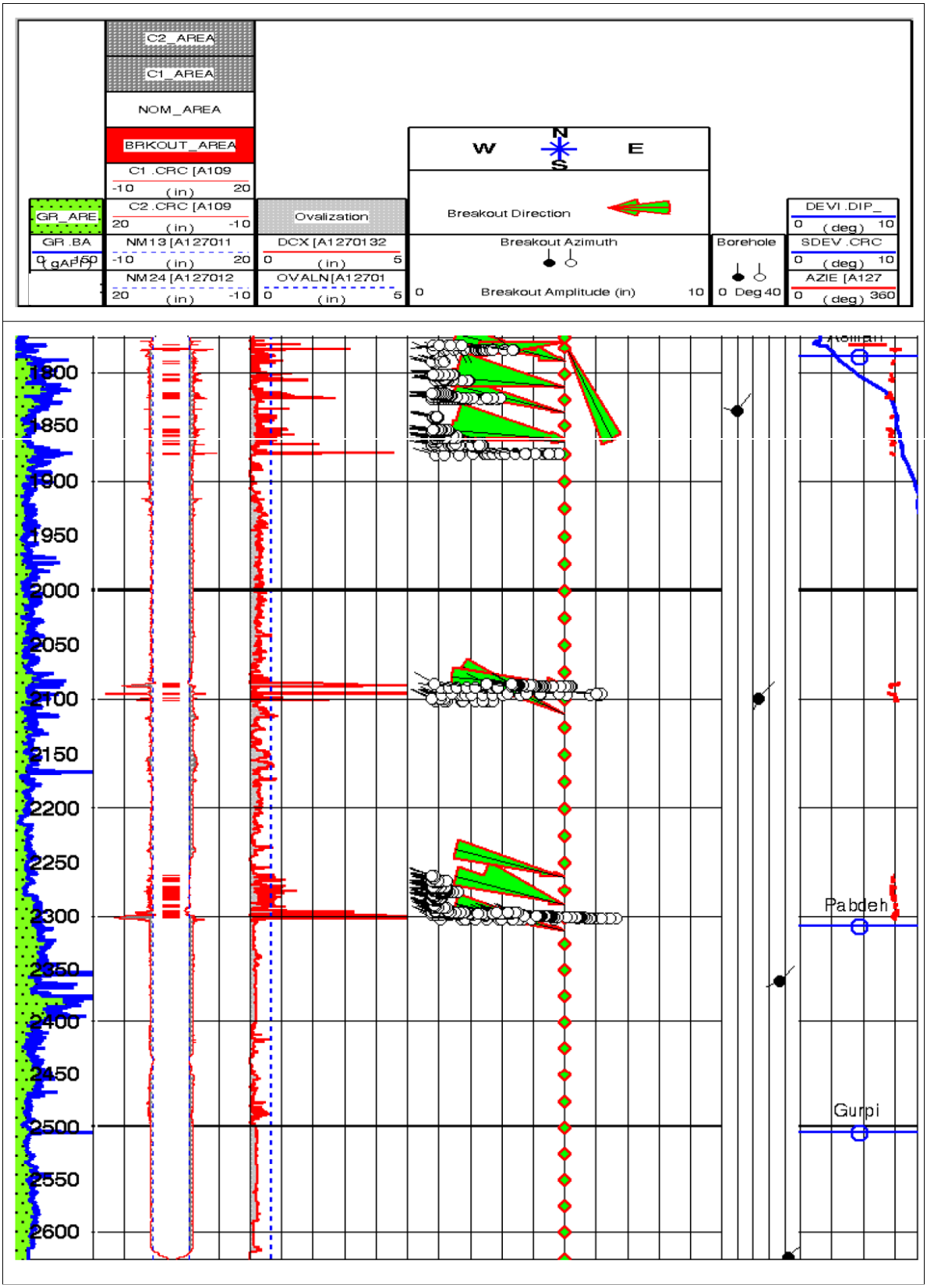

Figure 15: In well GS-G, the logs showing the WNW-ESE trend for borehole breakouts in the Asmari formation. According to them the orientation of σ_{hmin} is WNW-ESE and the orientation of σ_{hmax} is NNE-SSW

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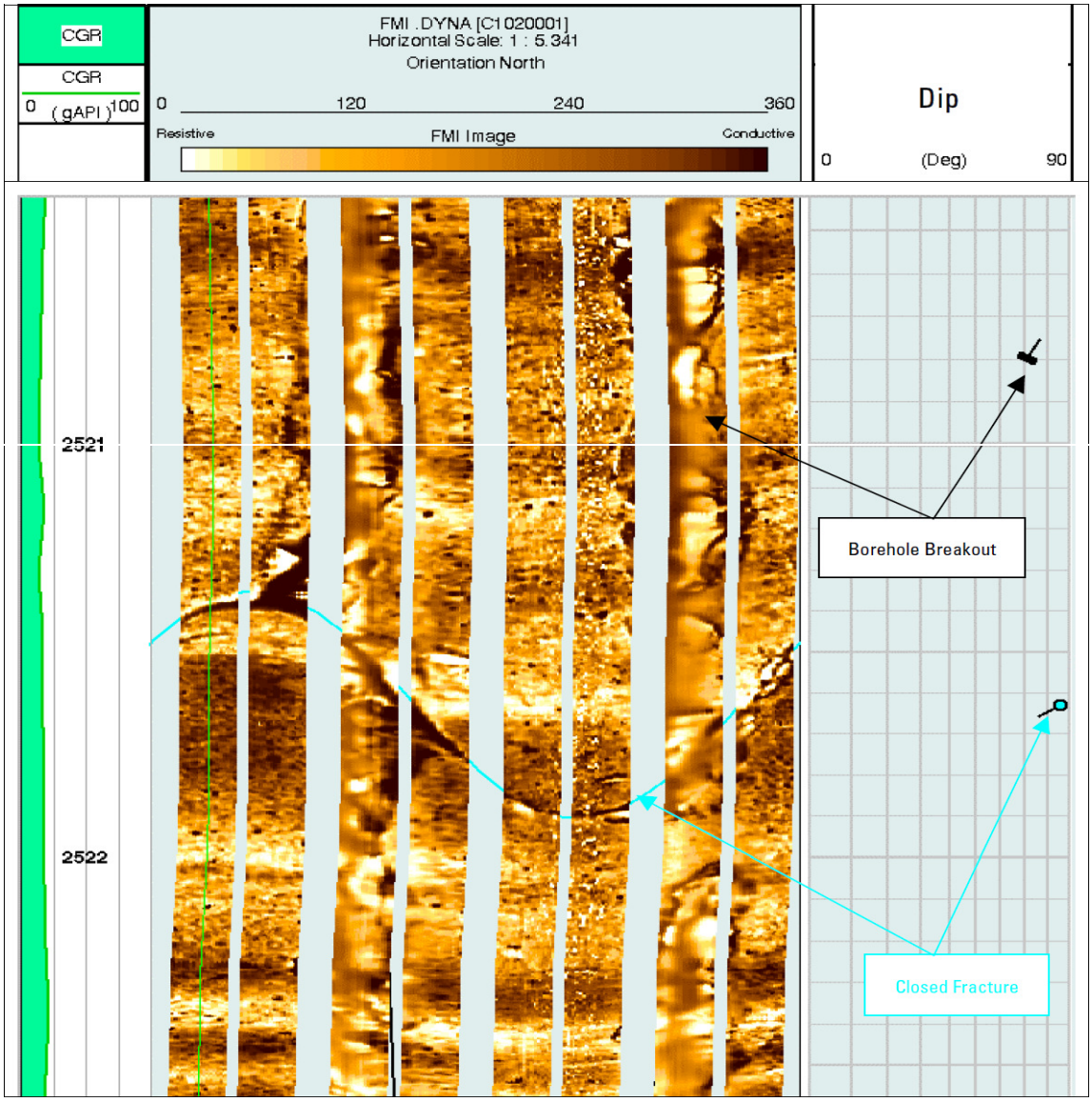

Figure 16: In well GS-H, the FMI images showing borehole breakouts on the images facing northwest (N57W to be more precise) and southeast (S57E to be more precise) sides of the borehole. Thus they indicate N57W-S57E trending elliptical borehole breakouts that are aligned with σ_{hmin}

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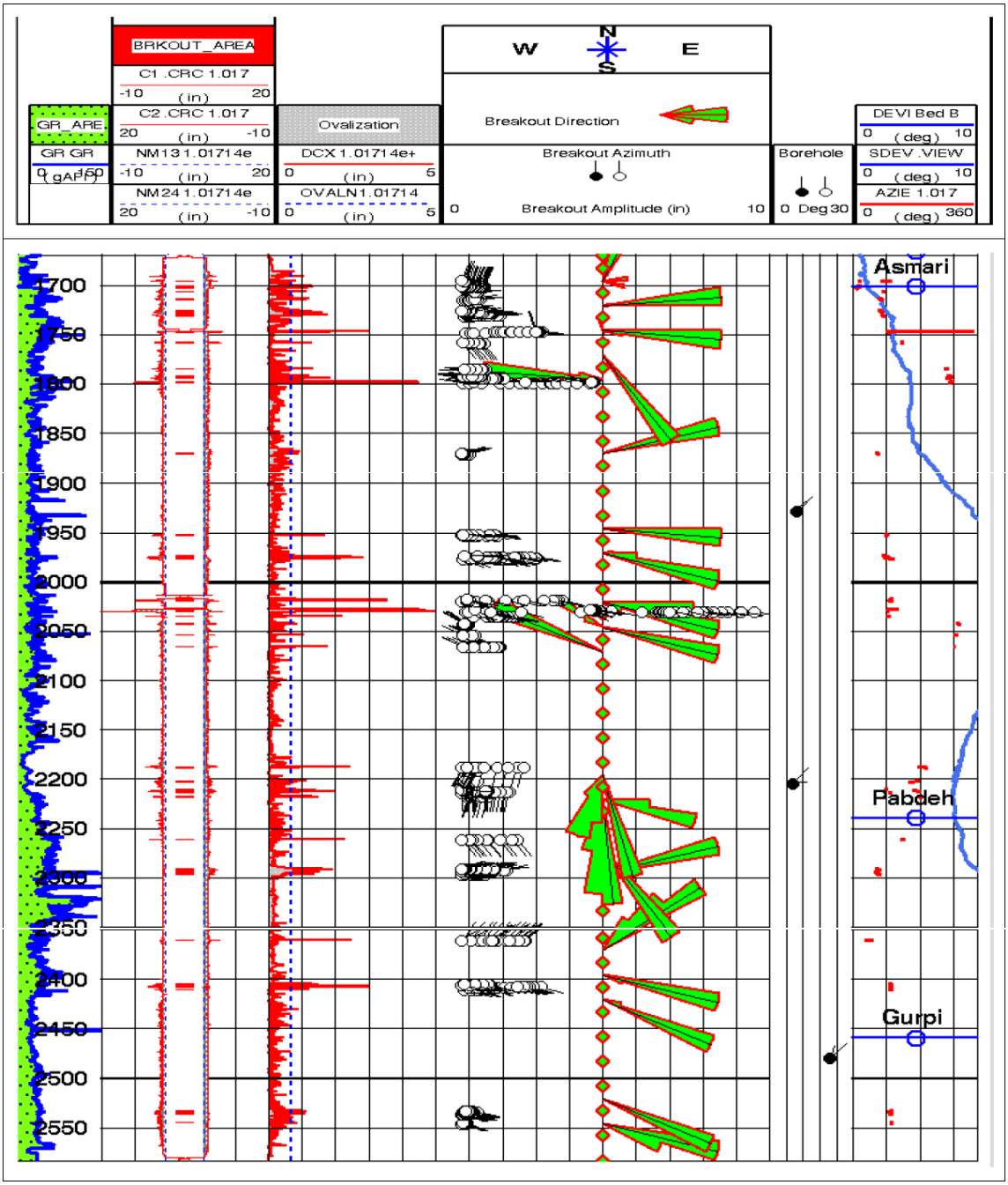

Figure 17: In well GS-H, the logs showing E-W trend for the borehole breakouts in the Asmari formation and the NW-SE trend in the Pabdeh and Gurpi formations. The breakouts were mostly observed in the Pabdeh formation. The borehole trend in Pabdeh formation is slightly different from the Asmari formation. According to them the overall orientation of σ_{hmin} is N57W-S57E and the orientation of σ_{hmax} is N33E-S33W

4.9 In-situ Stress Analysis for the Well Number GS-I

The amplitude and radii images of the UBI do not show elliptical borehole breakouts in the Asmari formation, but a few drilling induced fractures were identified (Figure 18). The orientation of the induced fractures is nearly N10E-S10W. It indicates the N10E-S10W orientation for σ_{hmax} and the N80W-S80E orientation for σ_{hmin}.

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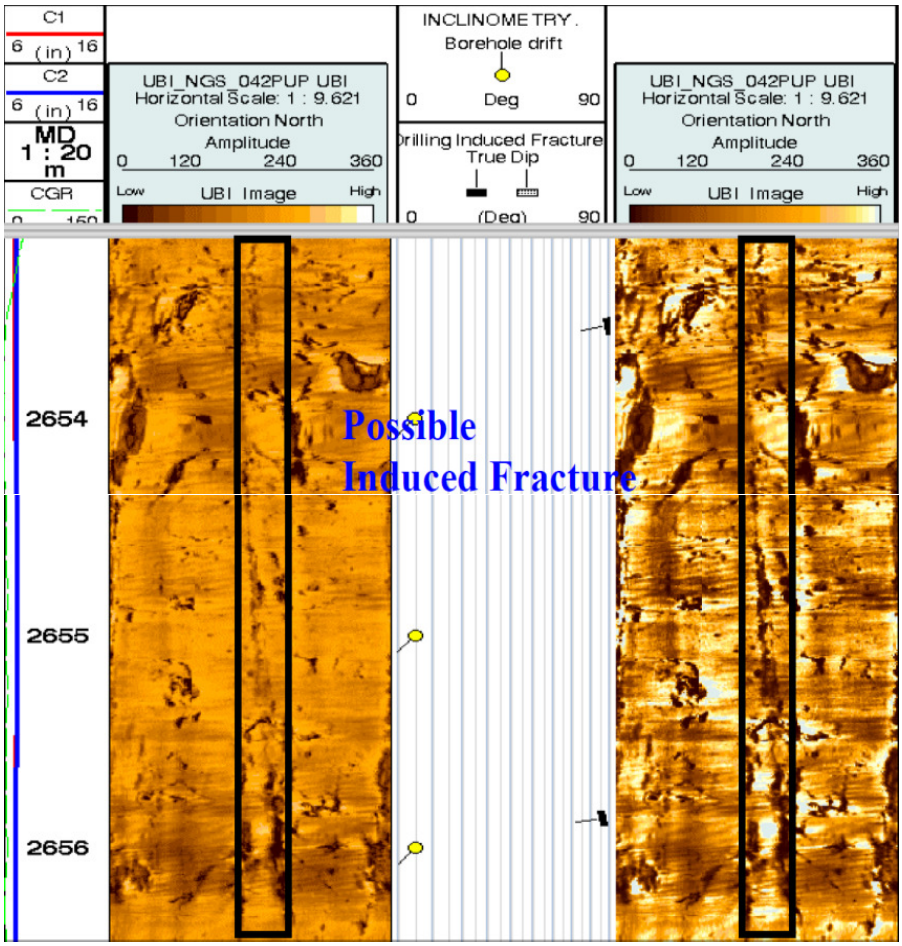

Figure 18: The UBI image showing drilling induced fractures in the well GS-I

4.10 In-situ Stress Analysis for the Well Number GS-J

The FMI images show induced fracture on the images facing northeast and southwest sides of the borehole. Thus they indicate NNE-SSW trending elliptical induced fractures that are aligned with σ_{hmax} (Figure 19). The direction of σ_{hmin} is NNW-SSE.

5.0 DISCUSSION

In Gachsaran field, Wells number GS-A, GS-C, GS-E, GS-F, GS-G, GS-H and GS-I almost follow the NE-SW direction for maximum horizontal in-situ stress direction, and NW-SE for minimum horizontal in-situ stress direction. It shows that for this field, the direction of maximum horizontal in-situ stress is NE-SW, and the direction of minimum horizontal in-situ stress is NW-SE.

The In-situ stresses direction for the wells number GS-B and GS-D are quite different from the other wells, and the reason might be the effect of fault, fold and diapirism near these wells (Figure 20). For these two wells, further structural analysis and fault interpretation are needed to find out the exact reason for this difference.

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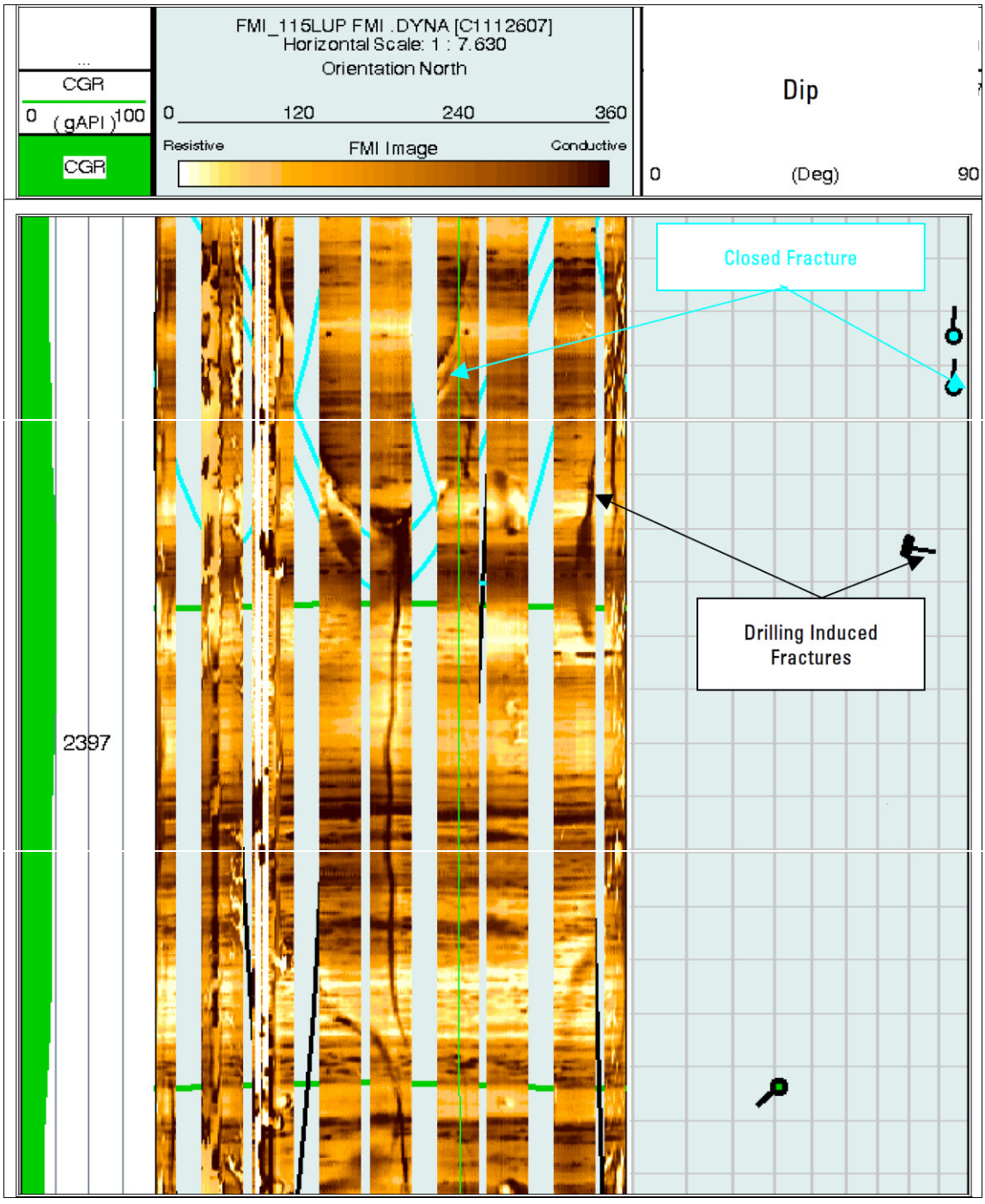

Figure 19: The FMI images in well GS-J showing induced fractures

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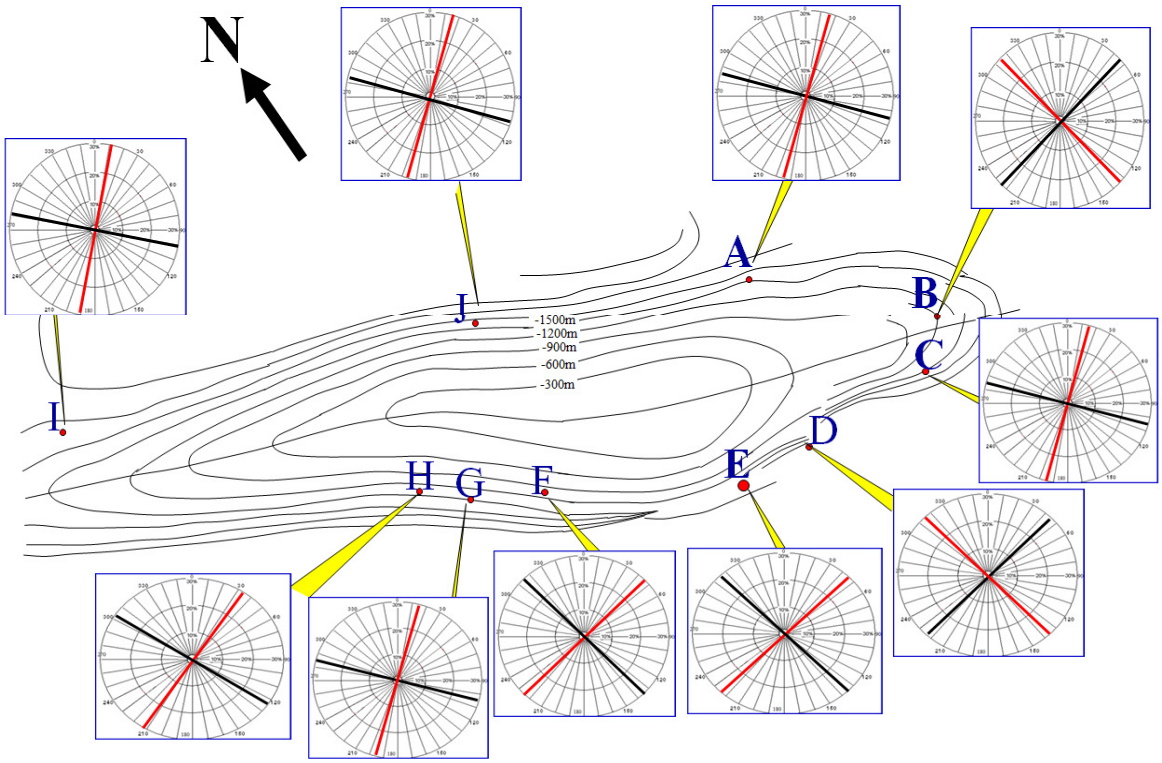

Figure 20: σ_{hmin} direction (black color) and σ_{hmax} direction (red color) for all the studied wells in Gachsaran field

6.0 CONCLUSION

This work found out the direction of drilling induced fractures and borehole breakouts of Gachsaran field, NE-SW for drilling induced fractures (maximum horizontal in-situ stress) and NW-SE for borehole breakouts (minimum horizontal in-situ stress). By having the result of this job, any hydraulic fracturing operation, EOR operations, drilling operations and the other operations in this field can be planed more accurate.

REFERENCES

[1] F. Khoshbakht, H. Memarian, M. Mohammadnia, Comparison of Asmari, Pabdeh and Gurpi formation's fractures, derived from image log, Journal of Petroleum Science and Engineering 67 (2009) 65-74.

[2] M. Alizadeh, Z. Movahed, R. Junin, W.R. Wan Sulaiman, M.Z. Jaafare, Fault interpretation using image logs, Applied Mechanics and Materials 695 (2014) 840-843.

[3] Z. Movahed, Enhanced reservoir description in carbonate and clastic reservoirs, Presented at the SPE Asia Pacific oil & Gas Conference and Exhibition. Jakarta, Indonesia, 30 October-1 November (2007).

Journal of Advanced Research in | Vol. 10, No. 1. Pages 9-30, 2015
Applied Mechanics ISSN (online): 2289-7895

[4] M. Alizadeh, Z. Movahed, R. Junin, W.R. Wan Sulaiman, M.Z. Jaafare, Image logs application for locating faults in oil and gas reservoirs, Advanced Research in Applied Mechanics 3 (2015) 1-8.

[5] W. Lina, E. Yehb, J. Hungc, B. Haimsond, T. Hironoe, Localized rotation of principal stress around faults and fractures determined from borehole breakouts in hole B of the Taiwan Chelungpu-fault Drilling Project (TCDP), Tectonophysics 482 (2010) 82-91.

[6] X. Nie, C. Zou, L. Pan, Z. Huang, D. Liu, Fracture analysis and determination of in-situ stress direction from resistivity and acoustic image logs and core data in the Wenchuan Earthquake Fault Scientific Drilling Borehole-2 (50–1370 m), Tectonophysics 593 (2013) 161–171.

[7] Z. Movahed, R. Junin, Z. Safarkhanlou, M. Akbar, Formation evaluation in Dezful embayment of Iran using oil-based-mud imaging techniques. J. Petrol. Sci. Eng. 121 (2014) 23-37.

[8] B. Aadnoy, R. Looyeh, 2011. Petroleum Rock Mechanics, Drilling operations and Well Design. GULF Publishing Company, Houston, Texas, United States.