Click to view slide presentation

EA Combination of Deep-Reading and Near-Wellbore-Scale Measurement in Accessing Thin Layer Facies of a Carbonate Reservoir*

Adrean Pudyaksa[1], Hendri Harsian[1], Takefumi Shibuya[1], Ni Made Wilasari[2], Olivia Azwar[2], and Ihsan Taufik Pasaribu[2]

Search and Discovery Article #42511 (2020)**
Posted March 2, 2020

*Adapted from extended abstract prepared in conjunction with oral presentation given at 2019 AAPG Asia Pacific Technical Symposium, The Art of Hydrocarbon Prediction: Managing Uncertainties, Bogor, (Greater Jakarta), Indonesia, August 7-8, 2019
 DOI:10.1306/42511Pudyaksa2020

[1]Kangean Energy Indonesia Ltd., Jakarta, Indonesia (adrean.pudyaksa@kangean-energy.com)
[2]Schlumberger, Indonesia, Jakarta, Indonesia

Abstract

The first development well drilling campaign in the Sirasun Field targeted the grainstone facies layer in the Paciran (Mundu) carbonate reservoir. The Paciran reservoir exhibits variation in facies, with lithologies from fine grain marl and wackestone to permeable packstone and grainstone. The grainstone facies shows the best reservoir properties, which is the main target layer.

In this drilling campaign, three horizontal wells were drilled with geosteering well placement technology. The well placement objective of these development wells was to land and steer the well inside the grainstone facies layer. There were some challenges due to the complex geological conditions, which was approximately 5 to 15 ft vertical thickness of grainstone layer and uncertainties in lateral distribution or structure and vertical depth.

A series of simulations were performed to identify fit-for-purpose technology to overcome the challenges. The feasibility and risk assessment suggested an electromagnetic-based reservoir mapping-while-drilling service, which would be able to map the prominent markers for the target zone layer. The deep measurement of the reservoir mapping-while-drilling service gives significant advantages to achieve the steering strategy of steering the well inside the grainstone target when its position is uncertain. The local geology variation along lateral section, such as in the formation dip, was considered in the risk assessment, which proposed a hybrid approach of reservoir mapping while drilling, near-wellbore formation resistivity images, and cuttings information to enable maintaining the well inside the grainstone facies layer.

The combination of the reservoir mapping-while-drilling service, with its deep detection, and formation resistivity images enabled placement of the wellbore inside the target grainstone zone successfully. Reservoir mapping while drilling mapped the top and bottom of the grainstone

facies layer and helped to detect the relative well position within the target zone. The formation resistivity image was integrated with reservoir mapping-while-drilling inversion to capture facies distribution and reservoir geometry.

The successful application of reservoir mapping while drilling in combination with the logging-while-drilling formation resistivity image on this project contributed to well deliverability by optimizing the well placement in the production section.

Introduction

The Sirasun Field is a part of the offshore Terang-Sirasun-Batur (TSB) Field complex and is located in Kangean block, East Java province (Figure 1). This field was discovered as a biogenic gas reservoir in the Upper Pliocene Paciran carbonate member of the Mundu Formation with the drilling of the S-1 exploration well in 1993. The other wells which are S-2 and S-3 wells were drilled as appraisal and delineation wells in the Sirasun structure.

Sedimentological studies showed the Paciran carbonate formation in the Sirasun Field was composed of four major facies. These are the foraminiferal grainstone facies, foraminiferal packstone facies, bioturbated foraminiferal wackestone facies, and transgressive calcareous shale facies. The foraminiferal grainstone facies has a planar crossbedded structure composed of well-sorted coarse grains and is a generally good reservoir. The foraminiferal packstone facies is composed of globigerinid foraminifera with a small amount of illite matrix and glauconite in one specific interval. The bioturbated foraminiferal wackestone facies is composed of globigerinid foraminifera with abundant illite matrix and some argillaceous content in the upper part of the carbonate sequence. The calcareous shale is often absent; when present, it has a thickness of less than 10 cm. (Hadiyanto et al., 2010).

The gross reservoir thickness of the Paciran carbonate formation in this field is approximately 300 to 400 ft. The grainstone facies layer that is the target for well placement is only 5 to 15 ft thick based on data from offset wells (referred to Exploration Well S-1 and S-2). Three horizontal wells were planned in the Paciran carbonate reservoir of the Sirasun Field as a development campaign. The well placement objective of these three wells was the grainstone facies layer which was expected as the best performance in the reservoir.

A reservoir zonation and the geological marker for the facies were established by log responses and reservoir property data from offset wells. There are eight reservoir zones from the top of the carbonate formation to the gas-water contact (GWC) (Figure 2). Zone 4 is the main target zone layer for this development plan. Marker C represents the top of zone 4, and marker D is the bottom of zone 4. In core samples, the grainstone layer has been described as coarse-grained and well-sorted with foraminifera and planar crossbedding. Well log analysis of the grainstone facies layer, zone 4, shows this grainstone layer is characterized by a high resistivity value, a significant crossover in the density-neutron log, a high gamma ray that is possibly due to glauconite and a high amount of foraminiferal remains in the upper part. This zone 4 could be correlated across all of the offset wells. However, the geological markers and reservoir zones that were identified in offset wells could not be identified on seismic data, except for the top of the Paciran carbonate and marker A, due to the limitation of seismic resolution and gas effect.

For the objective, the challenges identified with three categories: thin target thickness, depth uncertainty, and lateral uncertainty. To achieve the objective, it was necessary to overcome these challenges, otherwise the wells could have possibly failed into missing the target and not having enough lateral length. This paper will focus on discussing well I-3, one of the horizontal wells in this development well drilling campaign. The only available offset well data close to well I-3 was well S-3.

Method

A series of assessments were run to analyze the optimum solutions to overcome all challenges. The assessment showed that conventional log conveyed with logging while drilling (LWD) measurements approach cannot be used for well placement operation due to its limited depth of investigation. The common industry log measurement depth of investigation is in the range of near wellbore scale; therefore, the tool does not get a response on log signature until penetrating the formation. There is uncertainties in the horizontal section such as lateral formation structure. From this reason, the indication of the target marker detected by an LWD conventional log will delay decisions and actions due to the shallow depth of investigation.

A reservoir mapping-while-drilling service was proposed, which could provide a deep detection measurement. The reservoir mapping-while-drilling service has the capability to detect the boundary distance up to 100 ft from the wellbore (Seydoux et al., 2014). The reservoir mapping-while-drilling solution was also proposed in combination with near-wellbore-scale formation resistivity images to steer the well in the target layer facies and overcome the local lateral uncertainty.

Accessing Thin Facies Reservoir in Well I-3

Pre-job Simulation and Preparation

Several simulations were run and analyzed to see the response on the well plan and on geological assumptions. Based on the evaluation of the formation dip and structure, the apparent formation dip is expected to be generally flat, since the well was planned to be almost perpendicular to the formation dipping direction. On the other hand, the location of well I-3 was near the crest of the structure and there was an uncertainty in the formation dip along the wellbore. In addition, there was also a formation depth uncertainty due to the limitation of seismic resolution.

All of the possible scenarios were analyzed to formulate the well placement strategy. The resistivity curve profile from the offset well indicated a cyclical curve from marker A down to the bottom of the formation, and its resistivity value has small contrast with the range from 5 to 7 ohm.m. The gamma-ray response of the grainstone was expected to be high based on the offset well data.

As a result of simulations, Reservoir mapping-while-drilling inversion was expected to be able to map the top and bottom of the target layer and also continuously mapped marker A. Thus, the entire reservoir structure was expected to be captured. In conjunction, formation resistivity image could provide the bed dip indication within the target zone. The capability of the reservoir mapping-while-drilling service to map the top and bottom of the target layer gives an overview of the relative well position inside the target layer; the formation resistivity image gives a detailed information at the wellbore scale based on the image profile with cutting up and cutting down feature. Moreover, the reservoir mapping-while-drilling inversion result and the formation resistivity image were also important in identifying the facies (Figure 3). This information would be critical for the steering decision in the lateral section as there is an uncertainty in lateral facies distribution.

Execution Stage

After the well was successfully landed inside the target grainstone layer, reservoir mapping while drilling was able to map the top and bottom of the target zone continuously in the lateral section; it was also able to map the top of marker A as far as 40 to 45 ft above the trajectory. The formation resistivity image result in the lateral section was used to identify the structural tendency and define the actual dip angle along the wellbore as the complement of the information given by the reservoir mapping-while-drilling service result.

At the beginning of the lateral section, drilling was executed by following the plan and holding inclination at 90°.

After around 300 ft drilled ahead, the reservoir mapping-while-drilling inversion result showed that the bore hole assembly was in the less-resistive zone. The reservoir mapping-while-drilling inversion mapped the high-resistivity layer above it; the formation resistivity image showed a darker color which indicates low resistivity with cutting-down feature at a low incident angle. Based on these data, it was interpreted that well trajectory was scratching the bottom part of grainstone layer. The trajectory was then adjusted based on real-time data evaluation; it was decided to build the inclination up to cut up the formation and keep away from the bottom part of grainstone layer.

After 500 to 600 ft drilled ahead, the resistivity image showed a cutting up feature followed by a lighter color with high resistivity; this showed that the trajectory was already positioned back in the good reservoir layer. Formation dip was evaluated based on the reservoir mapping-while-drilling inversion and on the processed image dip-picking result. Results from both methods showed that formation dip was generally dipping up 0.1 to 0.3°. The trajectory inclination was adjusted to make it parallel to the formation dip (Figure 4).

In the lateral section, the resistivity image showed crossbedding feature in the carbonate lithologies. This crossbedding was formed by grain transported by paleocurrent, that bedding is easily identified with glauconitic content. Bedding dip angles were varied, with azimuth direction mostly to the south-southeast (Figure 5). It showed very good developed paleocurrent bedding (crossbedding) within the globigerinid grainstone. The offset well core data proved this crossbedding feature seen in the grainstone facies (Figure 6). These observations and a cutting survey result were also integrated to identify facies. This facies identification was also referred for the trajectory adjustment.

The integrated approach with reservoir mapping-while-drilling inversion and high-resolution formation resistivity image was enabled to successfully maintain the well bore inside the target zone and accomplished the target lateral length within the sweet zone.

Conclusion

The combination of reservoir mapping-while-drilling and the near-wellbore-scale formation resistivity image enabled capture of the target grainstone facies layer and to optimize the trajectory for steering. This successful steering process on this project contributed to increase well deliverability by placing the wellbore inside the sweet spot of the production section. Information that was acquired by reservoir mapping-while-drilling and the resistivity image provided also a great control for the actual well position within the target zone and enabled maintaining the trajectory mostly in the middle of the zone. This hybrid approach has helped to achieve the objectives and overcome all of the challenges.

Acknowledgments

The authors would like to thank Kangean Energy Indonesia and Schlumberger management for the permission to publish this paper and the AAPG committee for the opportunity to present this work.

References Cited

Hadiyanto, N., D.E. Sartika, F. Deliani, and O. Takano, 2010, Integrated 3-D Static Reservoir Modeling of Upper Pliocene Paciran Carbonate in the Sirasun Gas Field, Kangean Block, East Java Basin: Proceedings of the Indonesia Petroleum Association, 27th Annual Convention.

Seydoux, J., E. Legendre, E. Mirto, C. Dupuis, J.M. Denichou, N. Bennett, G. Kutiev, M. Kuchenbecker, C. Morriss, and L. Yang, 2014, Full 3D Deep Directional Resistivity Measurements Optimize Well Placement and Provide Reservoir-Scale Imaging While Drilling: SPWLA 55th Annual Logging Symposium, Abu Dhabi, United Arab Emirates, 18-22 May.

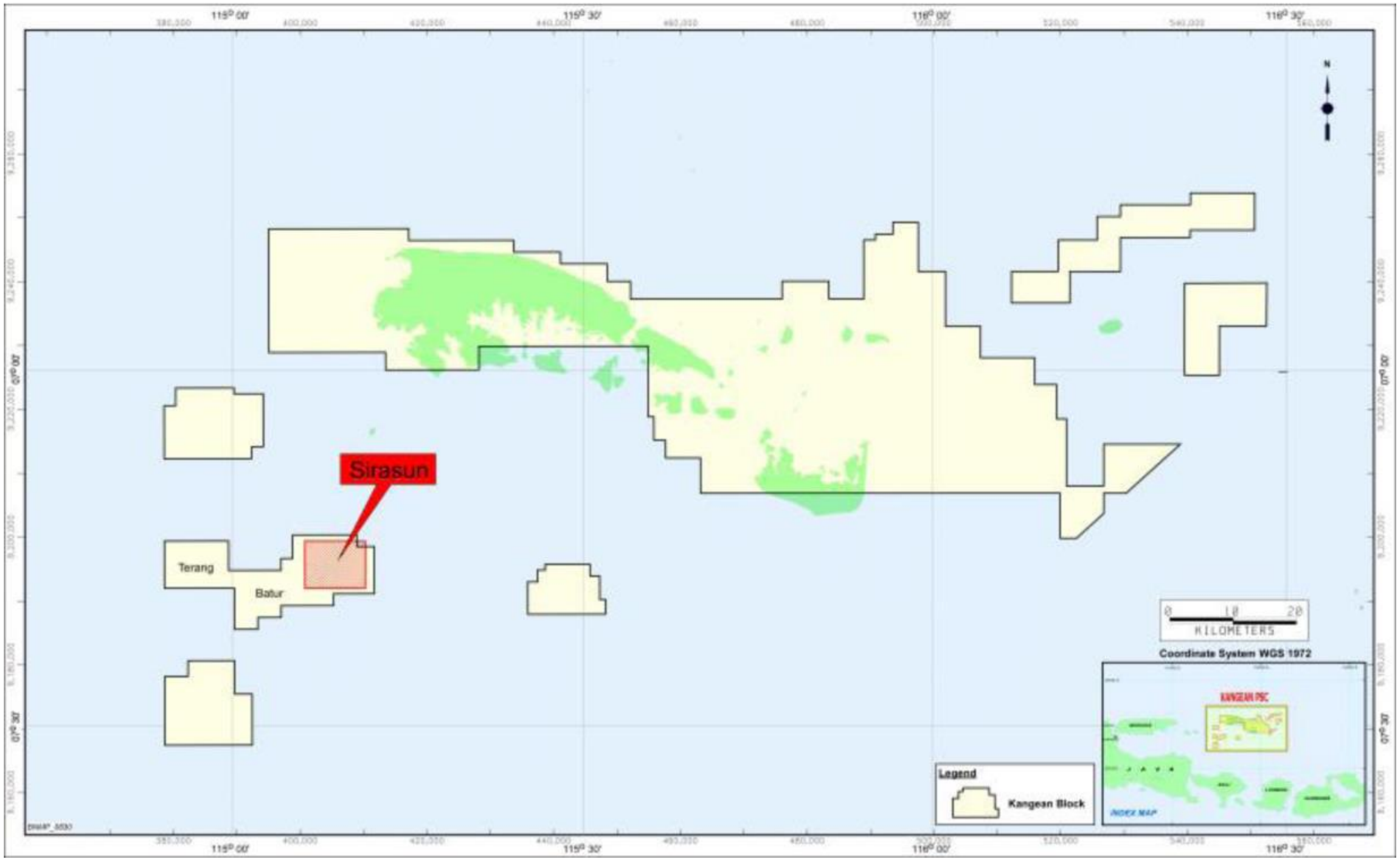

Figure 1. Index map of Kangean Block. Sirasun Field (red highlight) is part of the Terang-Sirasun-Batur fields located in southwestern Kangean Block.

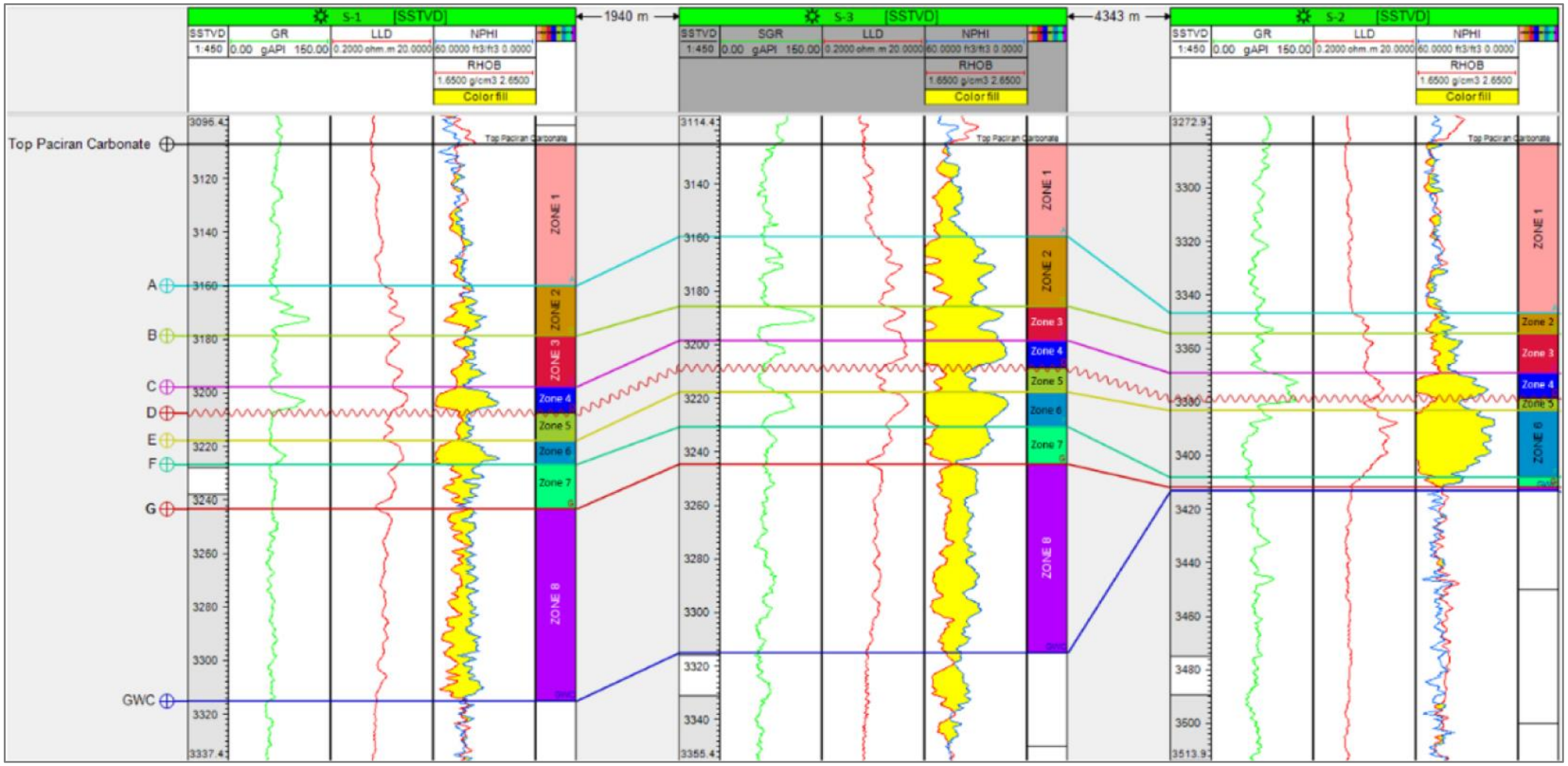

Figure 2. Well-to-well correlation flattened on the top of the Paciran carbonate among the three S wells showing reservoir zonation based on log response and reservoir properties for support of the development drilling.

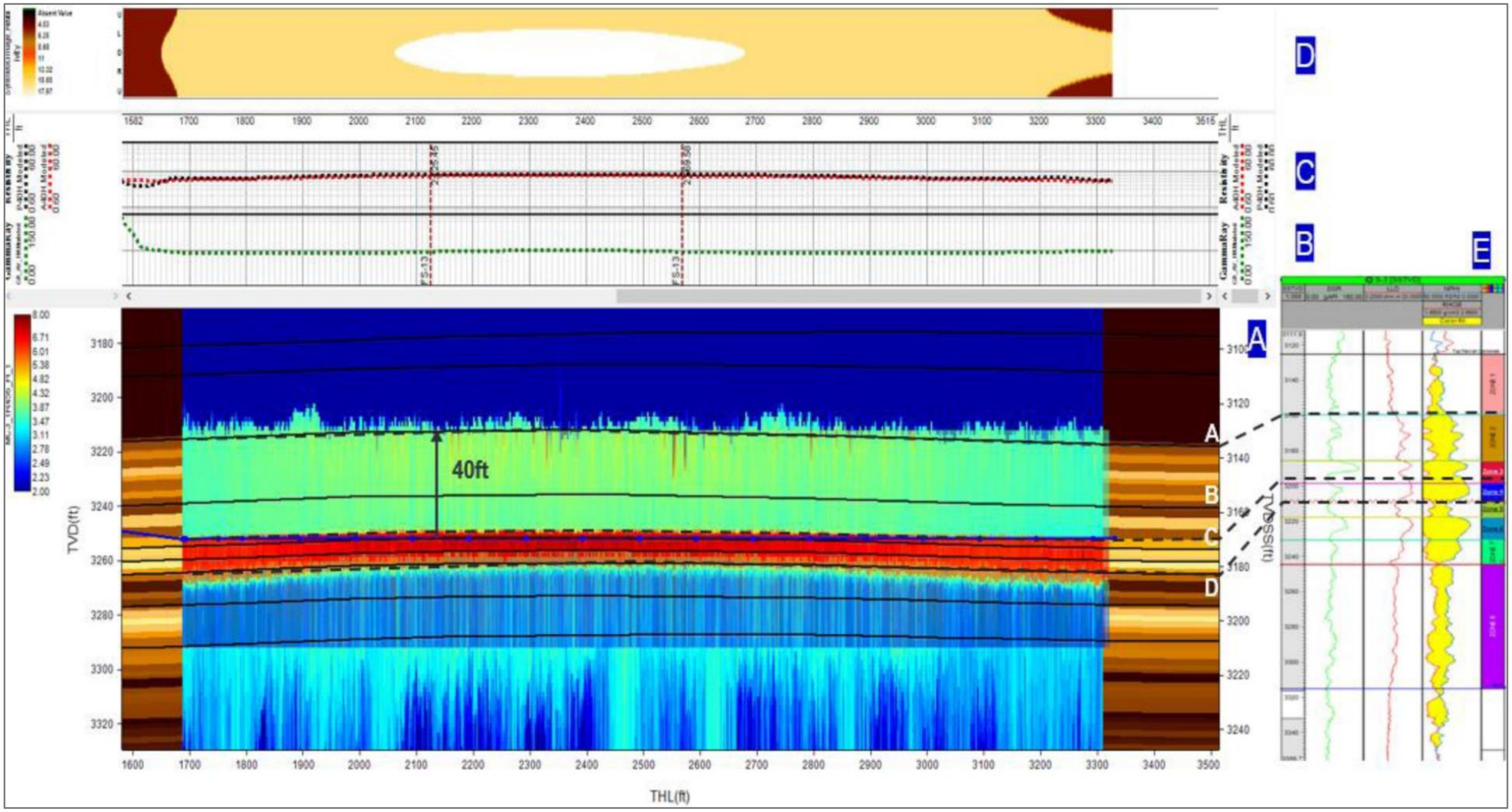

Figure 3. (A) Pre-job reservoir mapping-while-drilling inversion result on well I-3. Reservoir mapping while drilling was able to map the top and bottom of the thin grainstone; it was also able to map marker A as far as 40 ft above the trajectory. (B) Gamma Ray forwarded log. (C) Resistivity forwarded log. (D) Resistivity image showed a clear bed boundary feature. (E) Offset well log S-3.

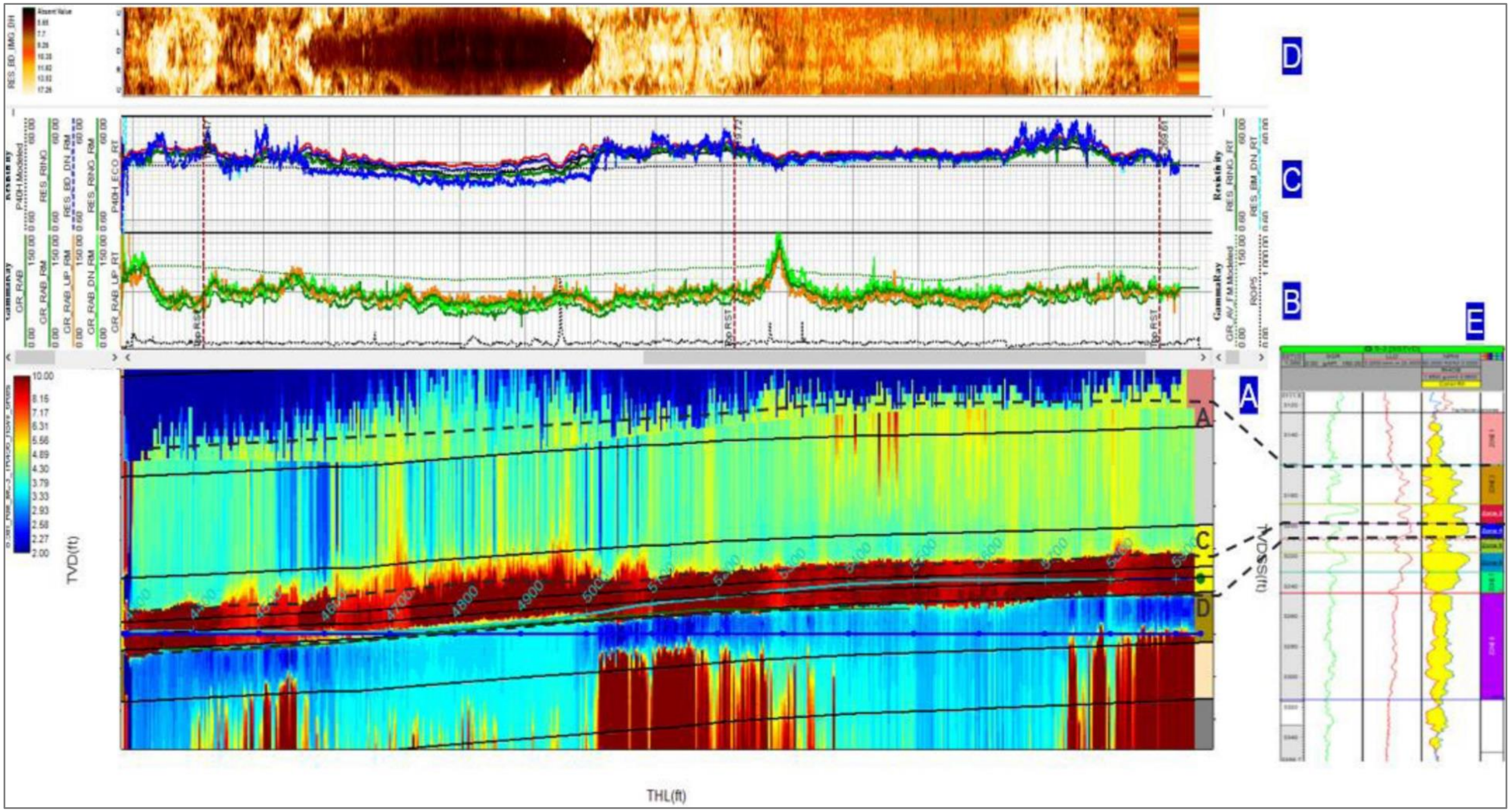

Figure 4. (A) Real-time curtain section of reservoir mapping-while-drilling inversion results in well I-3; the reservoir mapping-while-drilling service was able to map marker-A and the top and bottom of the grainstone (marker C and marker D). (B) Gamma-ray log. (C) Resistivity log. (D) Resistivity Image log. (E) Offset well log S-3.

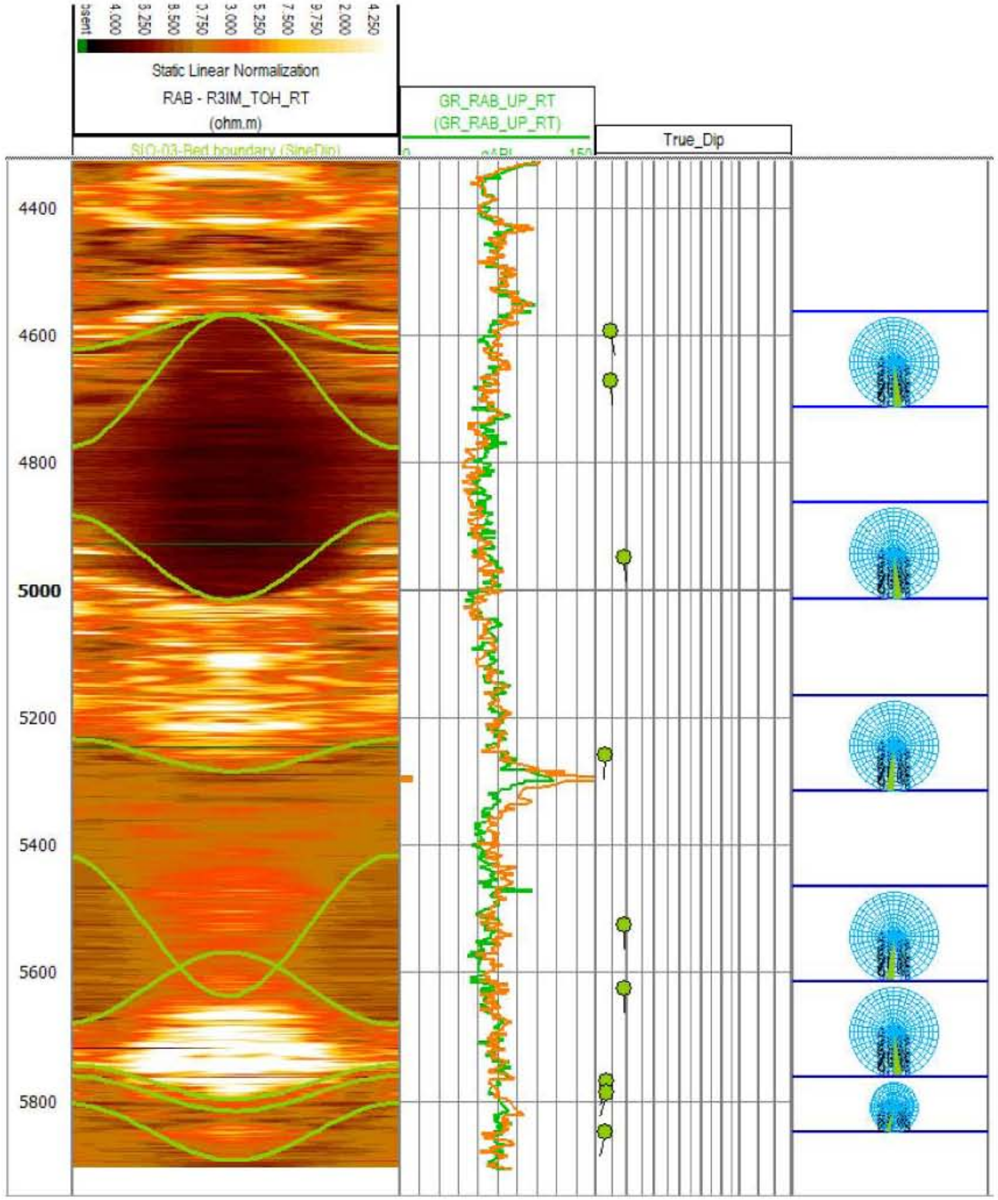

Figure 5. Resistivity image dip-picking result showed the dip magnitude was varied, with the azimuth mostly to the south-southeast. The crossbedding feature was dominantly present in the lateral interval.

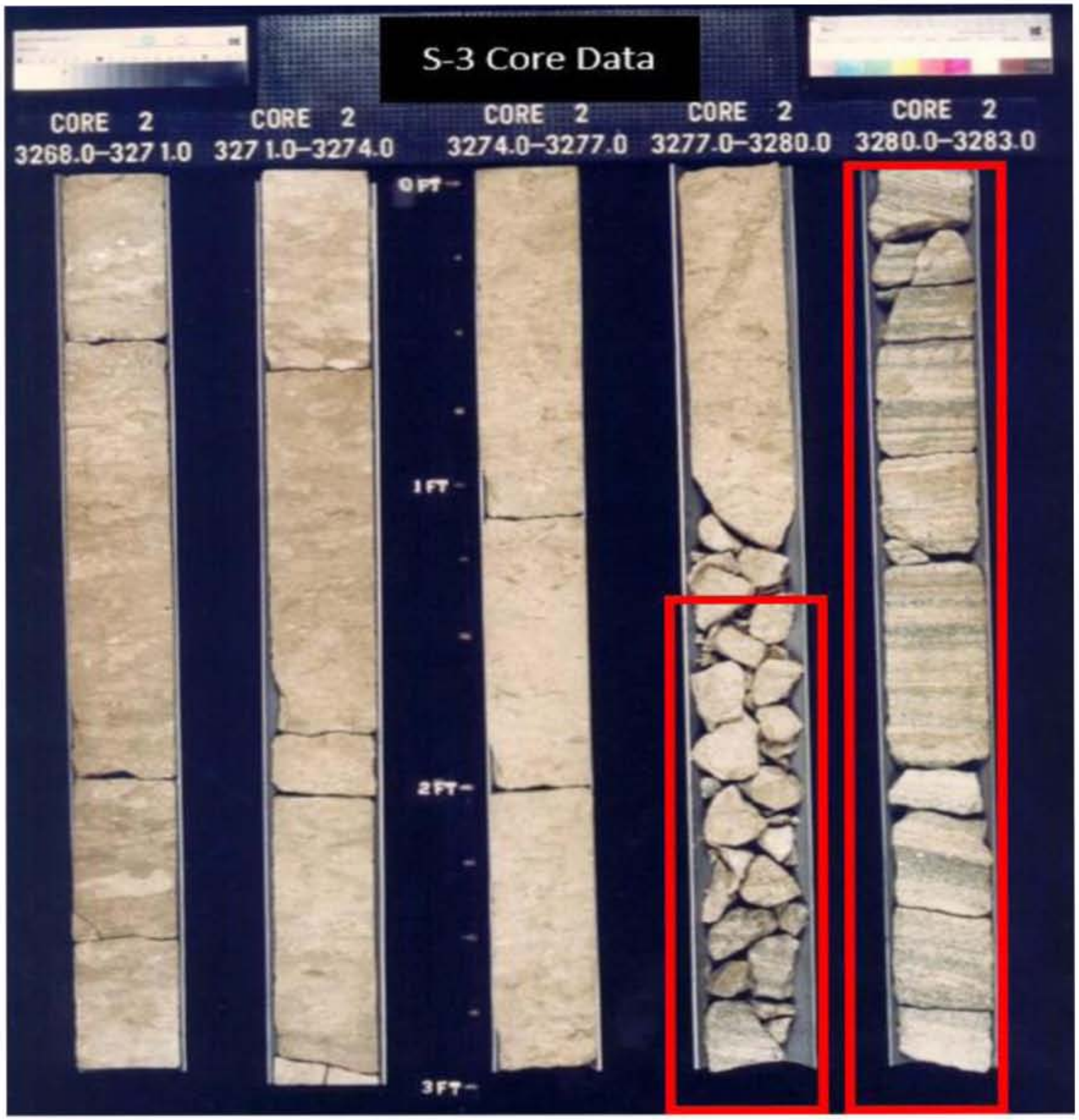

Figure 6. Core data from offset well S-3; the crossbedding feature was shown on the core data result as highlighted in the red square as a grainstone interval.