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DEPOSITIONAL PROCESSES AND FACIES ARCHITECTURE OF BALIKPAPAN SANDSTONE FORMATION, APPLICATION OF 3D DIGITAL OUTCORP MODEL (DOM) TO IDENTIFY RESERVOIR GEOMETRY AND DISTRIBUTION IN DELTAIC SYSTEM

(Proses Pengendapan dan Arsitektur Fasies Batupasir Formasi Balikpapan, Aplikasi 3D Digital Outcorp Model (DOM) untuk Mengidentifikasi Geometri dan Distribusi Reservoar pada Sistem Delta)

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ABSTRAK

Dalam beberapa tahun terakhir, teknik digitalisasi singkapan batuan adalah metode analisis yang detil menggunakan geo-software. Oleh karea itu, diperlukan integrasi singkapan dan data bawah permukaan untuk mengurangi ketidakpastian interpretasi bawah permukaan. Hal tersebut memberikan pemahaman tentang arsitektur dan geometri batuan pada sistem delta dan untuk menganalisis lengkap proses sedimentasinya. Penelitian ini dilakukan untuk mengetahui distribusi temporal dan spasial batupasir menggunakan kombinasi 3D Digital Outcrop Model (DOM) aplikasi dan pemetaan geologi konvensional Formasi Balikpapan di Cekungan Kutai. Studi kami berhasil mengungkapkan bahwa DOM adalah metode yang sangat baik untuk lebih memahami proses pengendapan dan arsitektur fasies dalam heterogenitas pada sistem delta. Skema klasifikasi dan metode yang disajikan dalam penelitian ini juga bisa digunakan untuk lingkungan sedimen lainnya di seluruh dunia.

Kata Kunci: *DOM, arsitektur dan proses sedimen, sistem delta, formasi Balikpapan, sedimentologi, reservoar.*

ABSTRACT

In recent years, digitalization of the outcrop technique is a powerful tool - for detailed analysis on the geo-software. Thus, the integration between outcrops and subsurface data for reducing the subsurface uncertainties. This provides the impetus to propose and accomplish a holistic understanding of the architecture and geometry of the deltaic system and to provide an exhaustive analysis of their sedimentary processes. This study investigates the temporal and spatial distribution of deltaic sandstone using a combination of 3D Digital Outcrop Model (DOM) application and traditional geologic mapping of Balikpapan Formation in the Kutei Basin. Our study has successfully revealed that DOM is an excellent method to better understand the depositional process and facies architecture within the heterogeneity of deltaic system. The classification scheme presented in this study is also applicable to other sedimentological settings worldwide.

Keywords: DOM, sedimentary architecture and processes, deltaic system, balikpapan formation, sedimentology, reservoir.

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I. INTRODUCTION

Outcrop analog studies support critical data for reservoir modeling which is challenging to obtain from conventional subsurface datasets. Conventional datasets used in reservoir modeling (i.e., seismic and well data) provide a deterministic architectural framework with specific facies and petrophysical information only at discrete positions (Fabuel-Perez, et al., 2010). The use of outcrop analogs for geological modeling describes an essential part of the information to understand architecture style and connections between facies and to investigate the internal distribution of porosity and permeability of reservoirs (Aigner, et al., 1996). The understanding architectural style of reservoirs and intercalated shale barriers in the fluvial-deltaic environment are an essential piece of data (Rohmana, et al., 2016). In recent years, the concern for digitalization of the outcrop has increased continuously, because using outcrop as the basis of a reservoir model can provide valuable information that conventional data cannot provide. This paper aims to provide a better knowledge of depositional processes and facies architecture in a deltaic system using Digital Outcrop Model (DOM) to identify reservoir geometry and distribution in deltaic system.

Geological Setting

Kutei Basin is located in the eastern part of Kalimantan containing about 14 kilometers-thick of Tertiary sedimentary column (Cibaj, et al., 2014). It is bordered to the South by Paternoster Platform and Adang Flexure Zone, Mangkalihat Ridge to the North, and Kucing High to the West, as the source of most of Neogene sediments (Cibaj, 2011; Figure 1). The basin is also considered to be one of the most productive sedimentary basins in Indonesia, generating hydrocarbons from Middle to Upper Miocene deltaic to marginal marine sandstone reservoirs (Cibaj, et al., 2007; Cibaj, 2011; Cibaj, et al., 2014).

The research area is located in the vicinity of Bukit Damai Indah residence in Balikpapan, where Middle Miocene sediments crops out containing a series of alternating shale and sand of Balikpapan Formation (Nuay, et al., 1985). The outcrop is described as Upper Balikpapan Formation, contributing exposures varying from 5 m up to 11 m thick and lateral extent of 200 meters; an excellent analog to the actual reservoir in the Mahakam Delta.

II. METHODOLOGY

The datasets used for this research are formed of both digital and field data.

- Fifty digital photographs consisting of both aerial and terrestrial perspective covering the whole outcrop were acquired using a DSLR camera and professional drone.
- Sixteen primary coordinates were taken as the main reference points
- Geological data acquisition covered four primary sedimentary logs with many identifiable short sections.
- Fifteen structural measurements.
- Over sixty paleocurrent measurements.

Digital datasets used to develop the 3D geocellular model are included in digital photographs and GPS outcrop coding (Figure 2). All photos

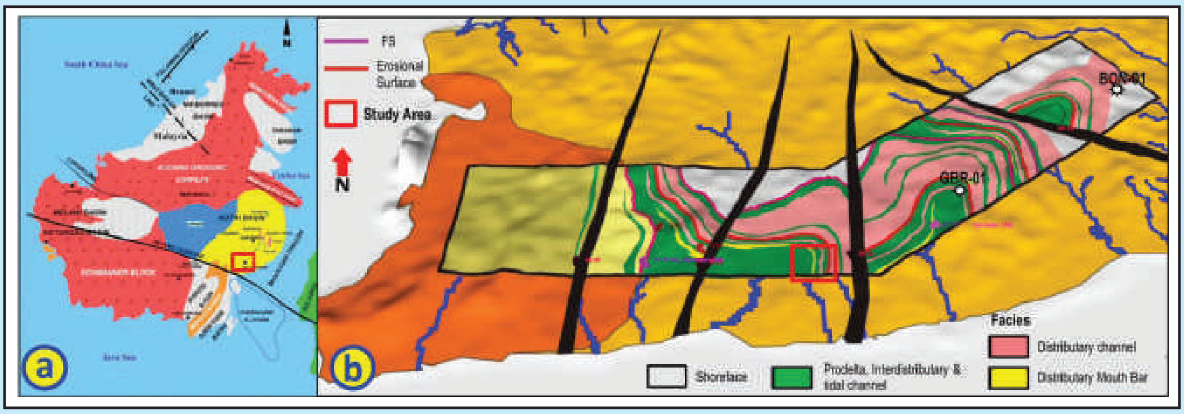

Figure 1
(a) Regional tectonic setting of Kutai Basin (modified from Nuay, et al., 1985) and (b) Detailed surface facies and structural map of Klandasan area in Soutern Kutai Basin, the study area is highlighted by redbox.

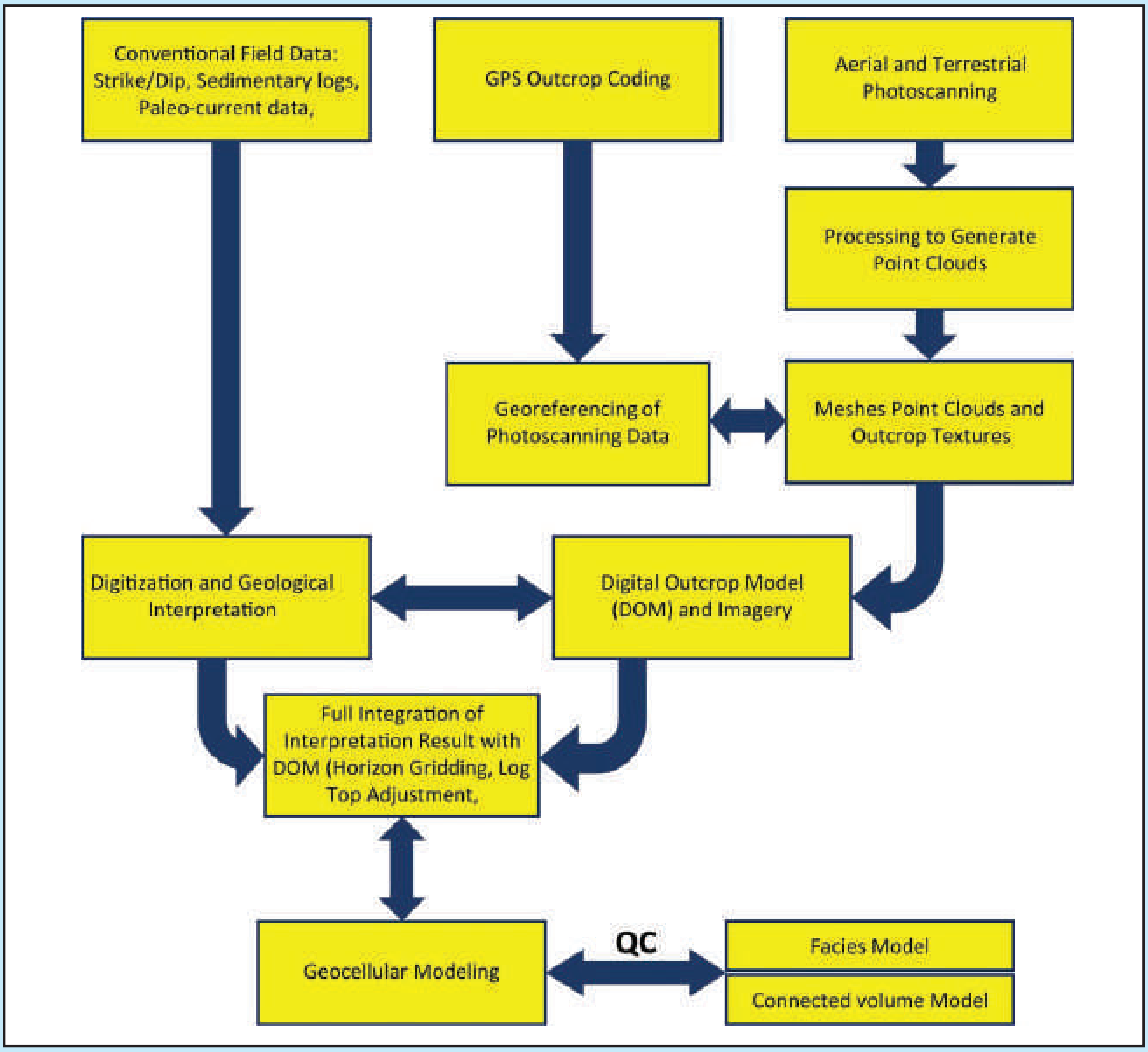

Figure 2
Digital outcorp model (DOM) method with geomodeling workflow.

taken will be linked, then processed to become point clouds. Coordinate points will also be bound as the primary reference for the digital photos. The result is a Digital Outcrop Model (DOM) that contains point clouds according to the coordinates in XYZ format. This DOM that contains point clouds is inserted into the VRGS to generate an outcrop intensity attribute and a triangular gridding mesh to extract outcrop surface. The outcrop filtered attributes outcrop texture color that helps to interpret the layers and architectural elements.

Facies Architecture

There are four lithofacies based on observations in the research area, namely stratified medium sandstone (SS), lenticular very fine sandstone to siltstone (LNS), flaser and wavy fine sandstone (FWS) deposited in distal mouth bar complex, and laminated shale (LMC), laminated siltstone (LMS) deposited in delta front. From stratigraphic measurements found four stacking pattern A, B, C, and D (Figure 3), with characteristics:

- Stacking pattern A: characterized by quartz sandstone, brownish gray, very fine-fine sand, well rounded, well sorted, ripple with cross-stratification, quartz dominated with FeOx concretion, coarsening upward.
- Stacking pattern B: characterized quartz sandstone, brownish gray, very fine-medium sand, well rounded, well sorted, ripple with cross-stratification in the top and middle, flaser-lenticular in the low part, quartz dominated with FeOx concretion, abundant Ophiomorpha ichnofacies, coarsening upward. Also found Interlaminated sand-shale, brown-gray, very fine sand, well rounded, well sorted,

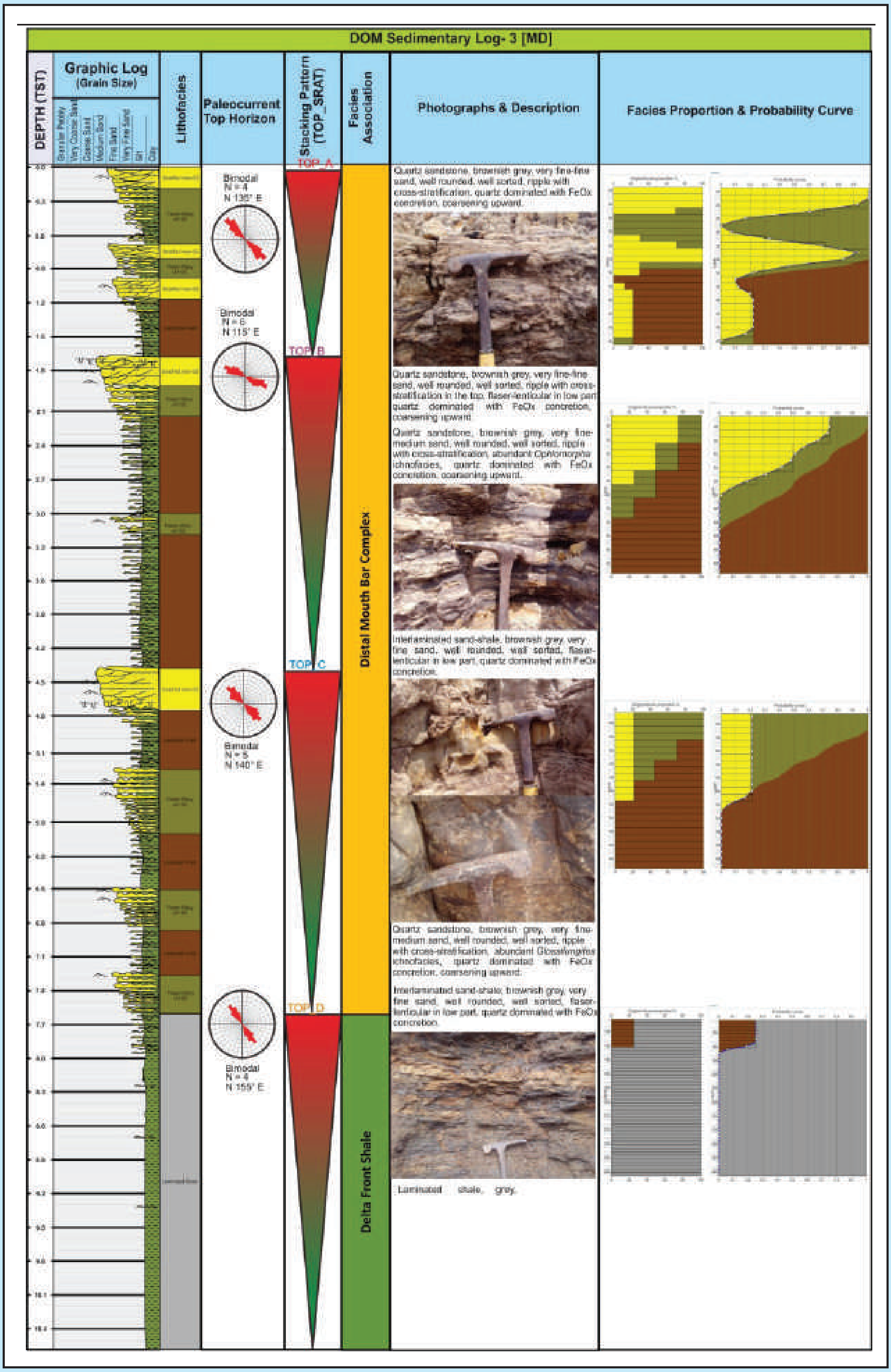

Figure 3
Sedimentary log (log-3) showing general stratigraphic information of the study area (texture, structure, paleocurrent, lithofacies, facies association, stacking pattern, facies proportion and probability curve).

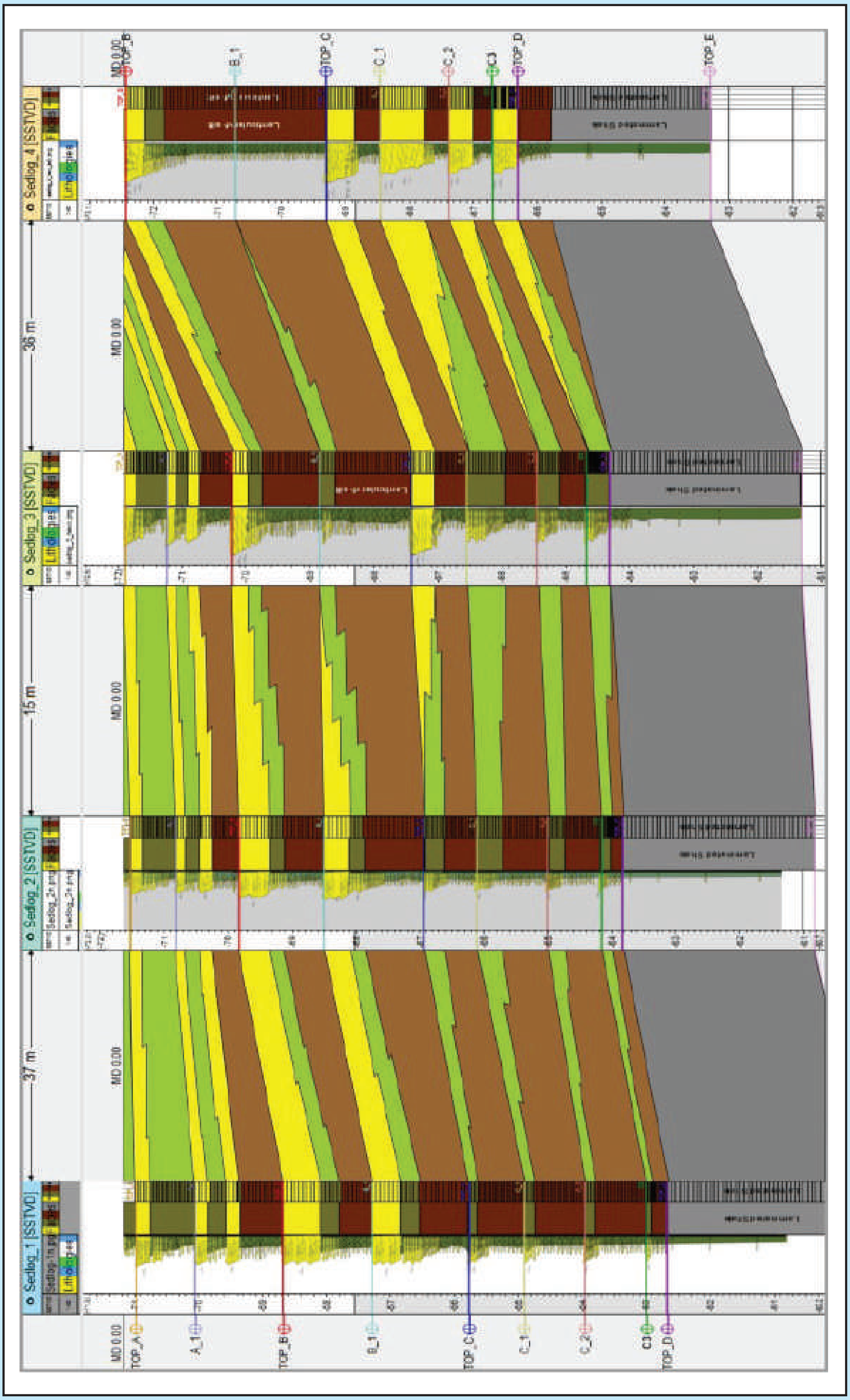

Figure 4

Validation between field observation and facies model. (note: track 1 and represents field description, track 3 represents upscaling model form geocullar, and track 4 represents connected volume model.

flaser and lenticular bedding in the low part, quartz dominated with FeOx concretion.

- Stacking pattern C: quartz sandstone, brown-gray, very fine-medium sand, well rounded, well sorted, ripple with cross-stratification, abundant Glossifungites ichnofacies, quartz dominated with FeOx concretion, coarsening upward. Then Interlaminated sand-shale, brown-gray, very fine sand, well rounded, well sorted, flaser and lenticular bedding in the low part, quartz dominated with FeOx concretion.
- Finally, stacking pattern D is laminated shale, gray with the absence of sandstones.

Based on the lithofacies and stacking pattern, there is two facies association, Distal Mouth Bar Complex (A, B, C) and Delta Front Shale (D) (Figure 3).

Sequential Indicator Simulation (SIS) method used to constructed Facies model and obtained the actual shape and precise dimension for each lithofacies. The vertical and lateral scale of lithofacies from the sedimentary log holds an integral part in facies modeling (Figure 4). Therefore, it is critical to have detailed field observation to be able to predict the facies scale during a simulation. The orientation of deposition is necessary to be applied in the variogram and distribution model. For example, the paleocurrent measurement of wavy-flasher lithofacies is N105°E to N115°E. The sedimentary structure that can be measured to determine the trend of deposition in the upper lobe distributary mouth bar. The parameter used in this modeling is net-reservoir lithofacies filtered by each subzone, and present comparable color that expresses continuity. heterogeneities and reservoir behavior will be able to observe within a single outcrop and use as an analog to the subsurface model (Figure 5 and 6).

Depositional Process and Paleocurrent

LNS and FWS Lithofacies at Distal mouth bar complex show sediment deposition under low energy conditions. The fluctuations in sediment discharge and the presence of flaser and lenticular bedding sedimentary structures indicate that sediments deposition was affected by tidal

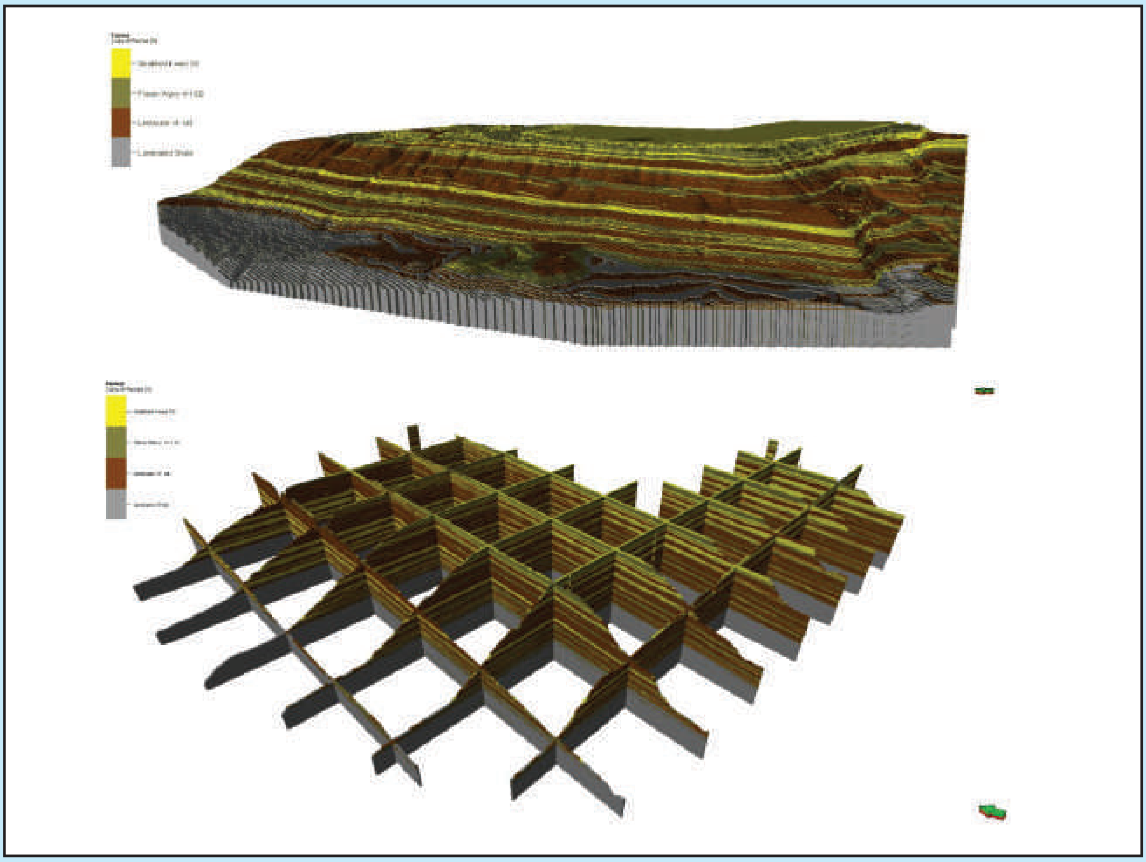

Figure 5
Facies modelling in DOM, filtered by outcorp surface and fence diagram of facies architecture produced from vertical slice of 3D geocullar.

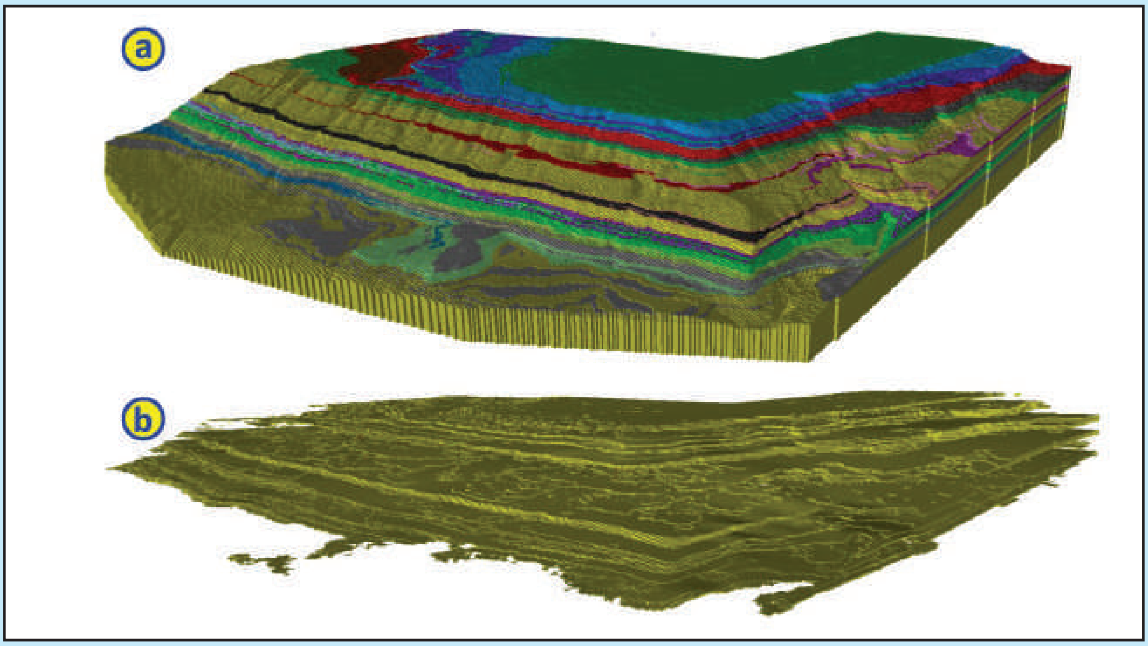

Figure 6
(a) Full static connected volume, note that each color represents connectivity of each lithofacies and characteristics; (b) net-reservoir lithofacies filtered by stratified sandstones as the best representatives of reservoir.

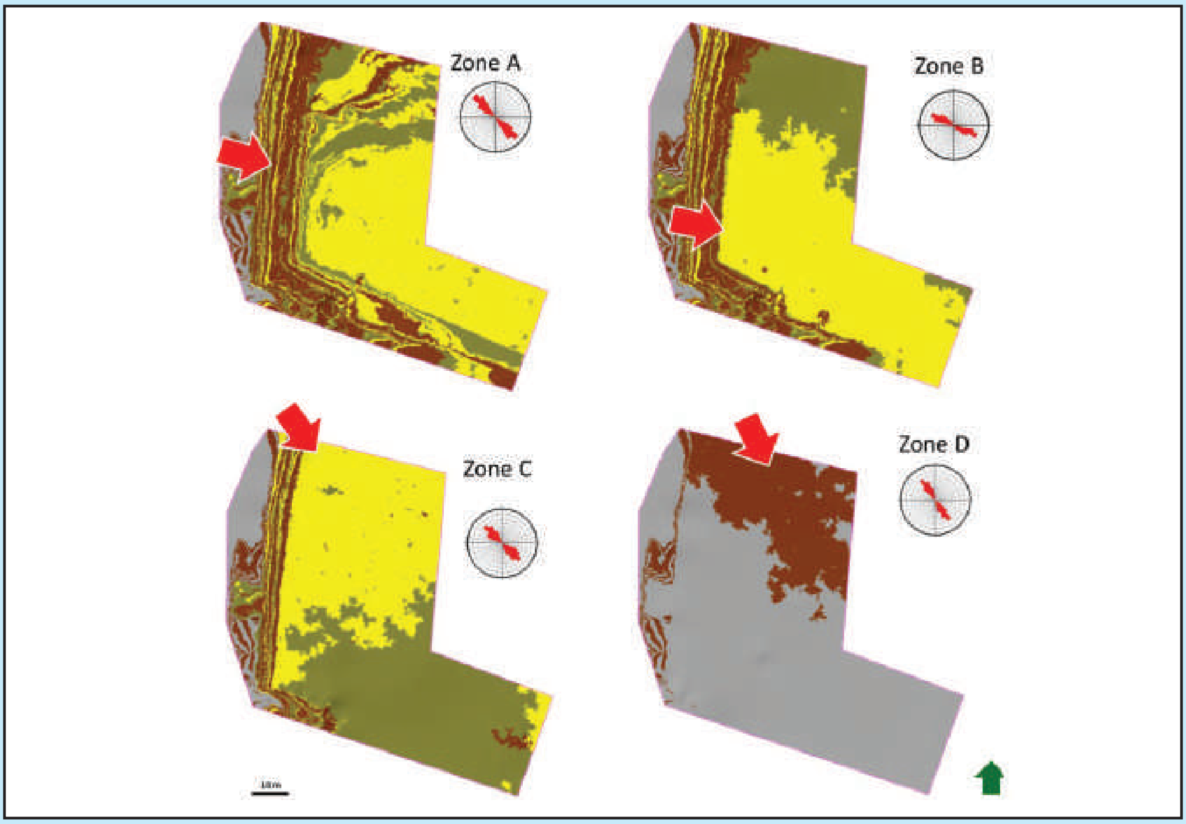

Figure 7
Horizon slice of stratigraphic surface show the depositional trend of distal mouth bar show general progradation towards southeast direcetion.

currents. Delta front with LMC and LMS lithofacies was deposited during high-discharge with slow sedimentation rates. The depositional trend of prograding distal mouth bar based on horizon slice of stratigraphic surfaces (Figure 7). Deposition trend was moved dynamically; however, it shows general progradation towards Southeast direction.

III. CONCLUSIONS

Based on the investigation, there are two facies association, i.e., Distal Mouth Bar Complex and Delta Front Shale. These facies models and architectures were successfully created using the DOM method, even using 3D DOM we can create a paleogeographic model from an outcrop This paper proves the capability to give a new perspective to investigate depositional processes and facies architecture using 3D DOM. DOM can be used as an alternative approach for reservoir modeling using surface data with high resolution that cannot be achieved using traditional data.

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REFERENCES

Aigner, T., **Asprion, U.**, **Hornung, J.**, **Junghans, W.-D.**, & **Kostrewa, R.**, 1996. Integrated outcrop analogue studies for Triassic alluvial reservoirs: Examples from Southern Germany. Journal of Petroleum Geology, October, 19(4), pp. 393-406.

Cibaj, I., **Lambert, B**., **Zaugg, P.**, **Ashari, Untung**, **Dal, Jacques-Antoine**, & **Imbert, P.**, 2014. Stratigraphic Stacking Patterns of the Mahakam Area, Lower Kutei Basin, East Kalimantan, Indonesia. Proceeding, Indonesia Petroleum Association.

Cibaj, I., 2011. Channel-Levee Complexes in a Slope Turbidite Series of Lower Kutei Basin, East Kalimantan.. s.l., Indonesian Petroleum Association.

Cibaj, I., **Syarifuddin, N.**, **Ashari, U.**, **Wiweko, A.**, & **Maryunani**, **Khoiril A**.,2007. Stratigraphic Interpretation of Middle Miocene Mahakam Delta Deposits: Implications for Reservoir Distribution and Quality. s.l., Indonesian Petroleum Association.

Fabuel-Perez, . I., Hodgetts, D. & **Redfern, J.**, 2010. ntegration of Digital Outcrop Models (DOMs) and High Resolution Sedimentology-Workflow and Implications for Geological Modeling Oukaimeden Sandstone Formation, High Atlas (Morroco). Petroleum Geoscience, May, 16(2), pp. 133 - 154.

Nuay, E. S., **Astarita, A. M.** & **Edwards, K.**, 1985. Early Middle Miocene Deltaic Progradation in the Southern Kutai Basin. s.l., Indonesian Petroleum Association.

Rohmana, R. C., **Fardiyansah, I.**, **Taufani, L.**, **Budiman, A**., & **Gunawan, A.**, 2016. Digital Outcrop Model (Dom) and High-Resolution Sedimentology of Balikpapan Deltaic Sandstone: Perspective of Heterogeneities In Thin-Bed Reservoir. s.l., Indonesia Petroleum Association (IPA).