A Case Study on Using Mundu-Paciran Nannofossil Zones (MPNZ) to subdivide Mundu and Paciran Sequences in the MDA Field, East Java Basin, Indonesia

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ABSTRACT

The Husky-CNOOC Madura Limited (HCML) MDA-4 exploration well (2011) in the Madura Strait region targeted Globigerina limestones in the Mundu Sequence (3.8 Ma) and the Paciran Sequence (2.0 Ma). The MDA Field is covered by Merpati 3D Seismic (2005). Seismic features observed from the 3D volume include phase change or polarity reversal at the top of gas filled reservoirs of the MDA structure and DHI flat-spot approximating to the gas-water contact (GWC). The reservoirs are primarily planktonic foraminifera grainstones, packstones and wackestones that have been deposited as pelagic rains and were subsequently redistributed by sea floor bottom currents.

Differentiating the Mundu and Paciran Sequences relies heavily on biostratigraphy and chronostratigraphy, as there are no significant lithological features that can be observed between the sequences. This article introduces a method to construct detailed well correlations of the two sequences based on Mundu–Paciran Nannofossil Zones (MPNZ), using high resolution biostratigraphy events. The methodology uses varying nannofossil abundances in the interval NN18 (Late Pliocene) to NN11 (Late Miocene). The best reservoir performance in the study area may occur in the MPNZ-7 and MPNZ-6, which were deposited at the late stage of the depositional cycles.

INTRODUCTION

The Madura Strait Block (Madura Strait PSC) has a long history of exploration with the first well drilled back in 1970 (MS-1-1, dry hole, Cities Service Inc.). The last exploration well drilled before the block was acquired by Husky – CNOOC Madura Limited in 2008 was the MDA-3 well (1992, dry hole, MOBIL Madura Strait Inc.). The MDA-3 was an appraisal well delineating a reservoir boundary at the north of the MDA Structure.

Following a period of 19 years without exploration activity within the block, the MDA-4 exploration program was proposed and initiated during 2011 (Figure 1). The MDA-4 targeted the Globigerina limestones of the Mundu and Paciran Sequences. This well was a discovery, confirming a gas field and provided support for considering potential development options. Work continued with Project Engineering & Design (PED) preparation and approval. The final Plan of Development (POD) was approved by GOI in January 2013; two years after the well was drilled. This is possibly the fastest cycle of discovery to POD approval in the region.

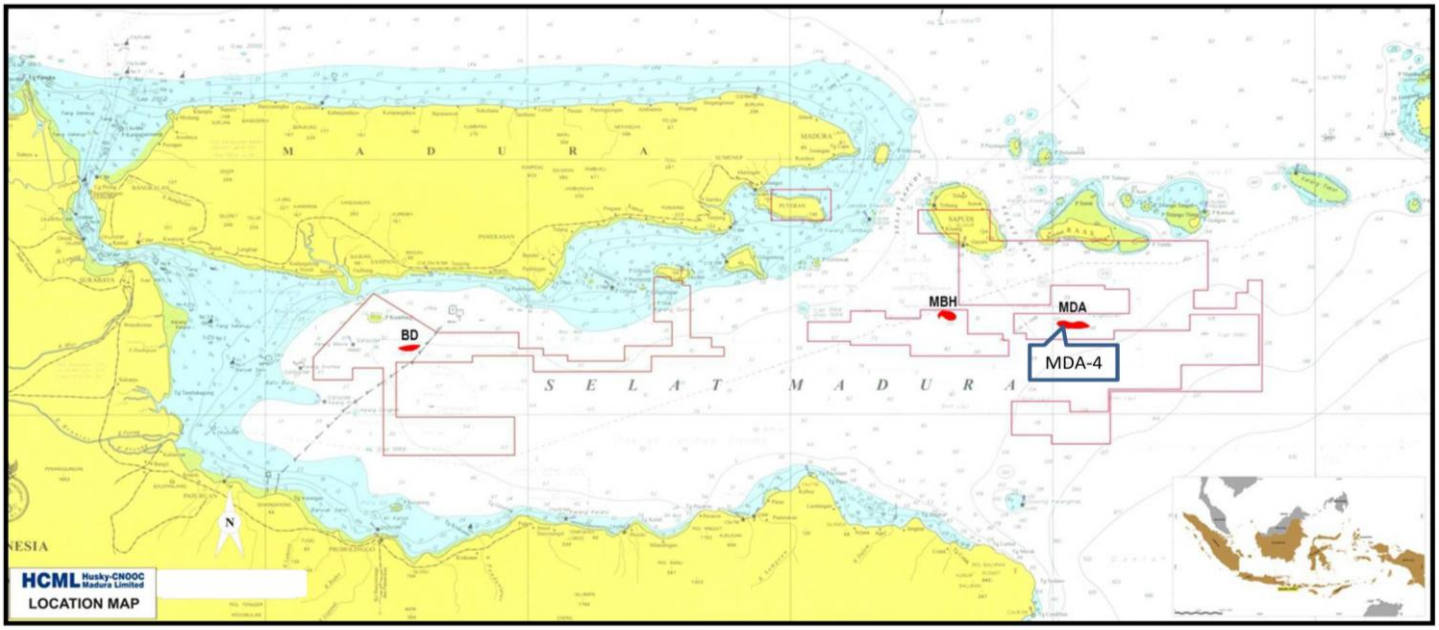


Figure 1. *Madura Strait PSC Block.*

The Mundu Sequence (3.8 Ma) and Paciran Sequence (2.0 Ma) (in East Java-Madura lithostratigraphy terminology they were known as Mundu and Selorejo Formations, respectively), consist primarily of planktonic foraminifera grainstones, packstones and wackstones. They are considered to have been deposited as pelagic rains and were subsequently redistributed by sea floor bottom currents. Differentiating the Mundu and Paciran Sequences relies heavily on biostratigraphy and chronostratigraphy as no significant lithological features can be observed from samples and logs between those two sequences. Detailed well correlation of MDA wells was generated based on Mundu–Paciran Nannofossil Zones (MPNZ), using high resolution biostratigraphy events. The methodology uses varying nannofossil abundances in the interval NN18 (Late Pliocene) to NN11 (Late Miocene).

REGIONAL GEOLOGY

The Madura Strait Block is located in the southern part of East Java Basin; a back-arc basin bounded to the west by Karimunjawa Arch and to the south by Java Volcanic Arc (Satyana et al., 2004; Figure 2). The basin deepens eastwards into the Lombok Basin while to the north of the basin shallows to become the Paternoster High (Satyana and Djumlati, 2003). The block is located in an offshore area between Madura Island to the north and the present-day East Sunda volcanic arc to the south.

The offshore area of East Java demonstrates an excellent example of Miocene – Recent structural inversion of a Paleogene extensional/transtensional basin system. The continued inversion and differential compaction during Plio – Pleistocene time is a further primary control on sedimentation. Seismic data show a complex structurally controlled sequence stratigraphy (Bransden and Matthews, 1992).

There are several reservoir objectives in the area, ranging from Eocene to Pliocene in age. The HCML MDA-4 well is one of many proposed exploration wells, targeting the Late Miocene – Late Pliocene reservoir (Figure 3). This foraminifera-dominated reservoir was encountered in many exploration wells in the East Java Basin and also developed in several onshore East Java areas.

Schiller et al (1994) suggested that there are at least two distinct types of Globigerina sand/limestone deposits in the East Java Basin, i.e.: planktonic foraminifera sands “drifts” deposited by bottom currents, which he considered as the dominant process; and less pervasive planktonic foraminifera “turbidites” deposited as submarine channel-fills and fans. The Globigerina limestone (GL limestone) in the MDA-4 well was interpreted as the result of pelagic rain deposition and subsequently redistributed by sea floor bottom currents. This process is similar to the “planktonic foraminifera sand ‘drifts’ deposited by bottom currents” that was proposed by Schiller et al (1994).

MDA FIELD

The MDA Field was discovered in 1984 by the Hudbay MDA-1 exploration well, drilled on a crest at the eastern part of the structure. This well was drilled to 4,016 feet subsea and tested 28 MMSCFD of gas. The discovery was confirmed by the MDA-2 exploration well, which was located about 250 m southwest of the MDA-1. The MDA-3 appraisal well was drilled at the northern edge of the structure; approximately 2 km northwest of the MDA-1 and MDA-2. The objective of the MDA-3 was to confirm a possible gas water contact at the northern edge of the field. The well was considered a dry hole due to poor reservoir quality.

The MDA-4 appraisal well was drilled in 2011 and it successfully confirmed MDA Field’s gas reserve. The well tested gas flow rates of 18.7 MMSCFD from Pliocene reservoir (Paciran Sequence) and 8.3 MMSCFD from Pleistocene turbidite reservoir of the Lidah Sequence.

SEISMIC CHARACTERISTICS

The MDA Field is covered by 80 sq.km of marine 3D seismic, which was acquired as part of a much larger Merpati 3D survey in 2005. In 2009, the data was reprocessed through Pre-Stack Time Migration (PSTM) and Pre-Stack Depth Migration (PSDM).

All seismic sections in this article are displayed on zero phase data and following SEG convention, in which positive reflection coefficient is displayed as peak and negative coefficient as trough.

Two Direct Hydrocarbon Indicator (DHI) features observed on the MDA structure, a polarity reversal at the top gas-filled reservoirs and a seismic flat-spot indicating the gas-water contact. These features helped reduce geological risk and increase confidence to drill.

RESERVOIR LITHOLOGY AND NANNOFOSSIL BIOSTRATIGRAPHY

The reservoir rocks in the MDA Field consist of the Mundu and Paciran Sequences (Figure 3). The sequences and chronostratigraphic labels follow the convention and descriptions of Goodall (2007). The Mundu Sequence is bounded by the T40 and T50 sequence boundaries (7.3 and 3.8 Ma, respectively). The Paciran Sequence is bounded by the T50 and T60 sequence boundaries (3.8 and 2.0 Ma, respectively). Within both sequences, there are series of bioclastic grainstones, packstones and wackestones. These reservoirs are in age equivalent and have the same lithologies as SANTOS’ Maleo Field (Triyana et al, 2007).

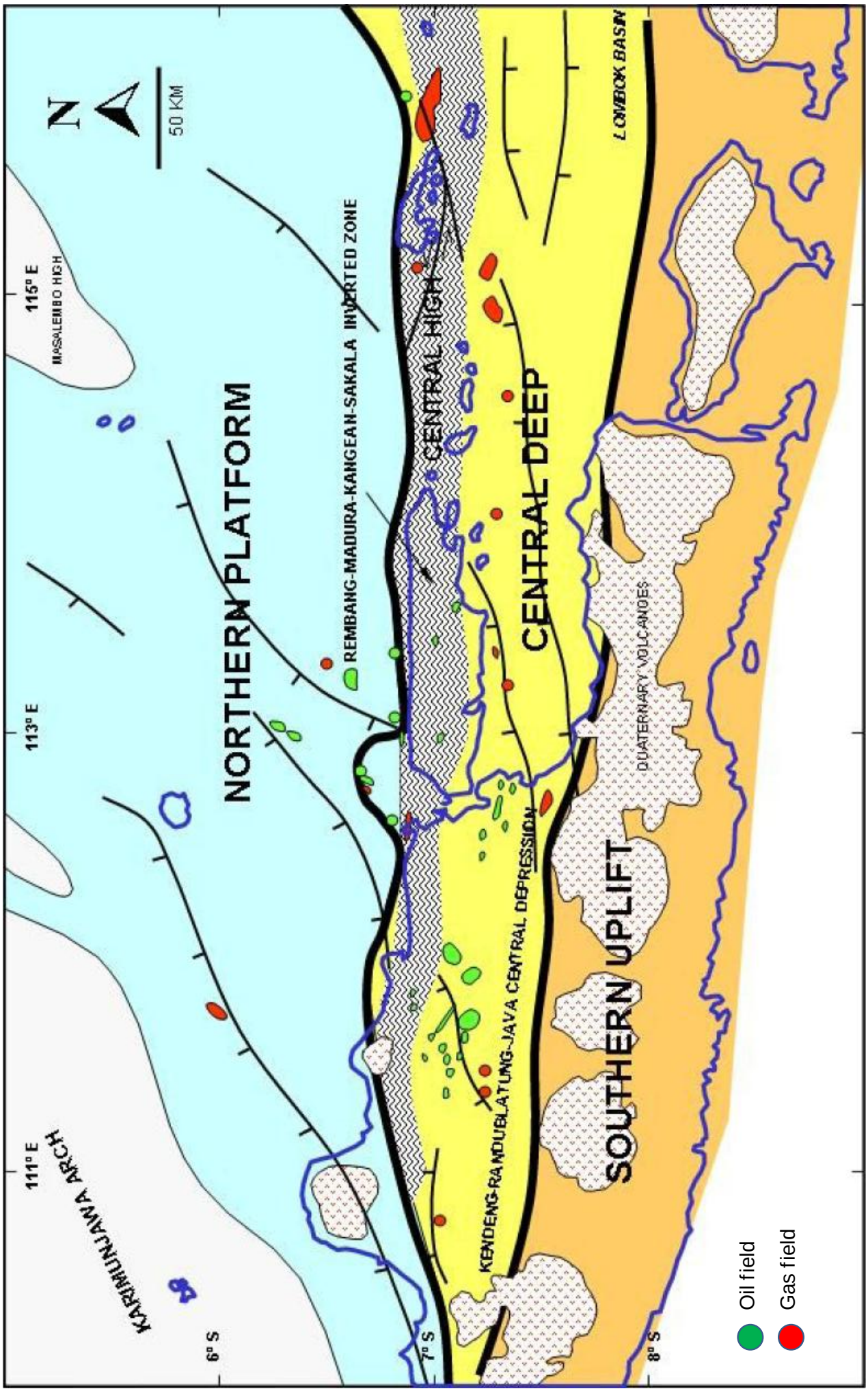


Figure 2. *East Java Basin geological setting (Satyana et al., 2004).*

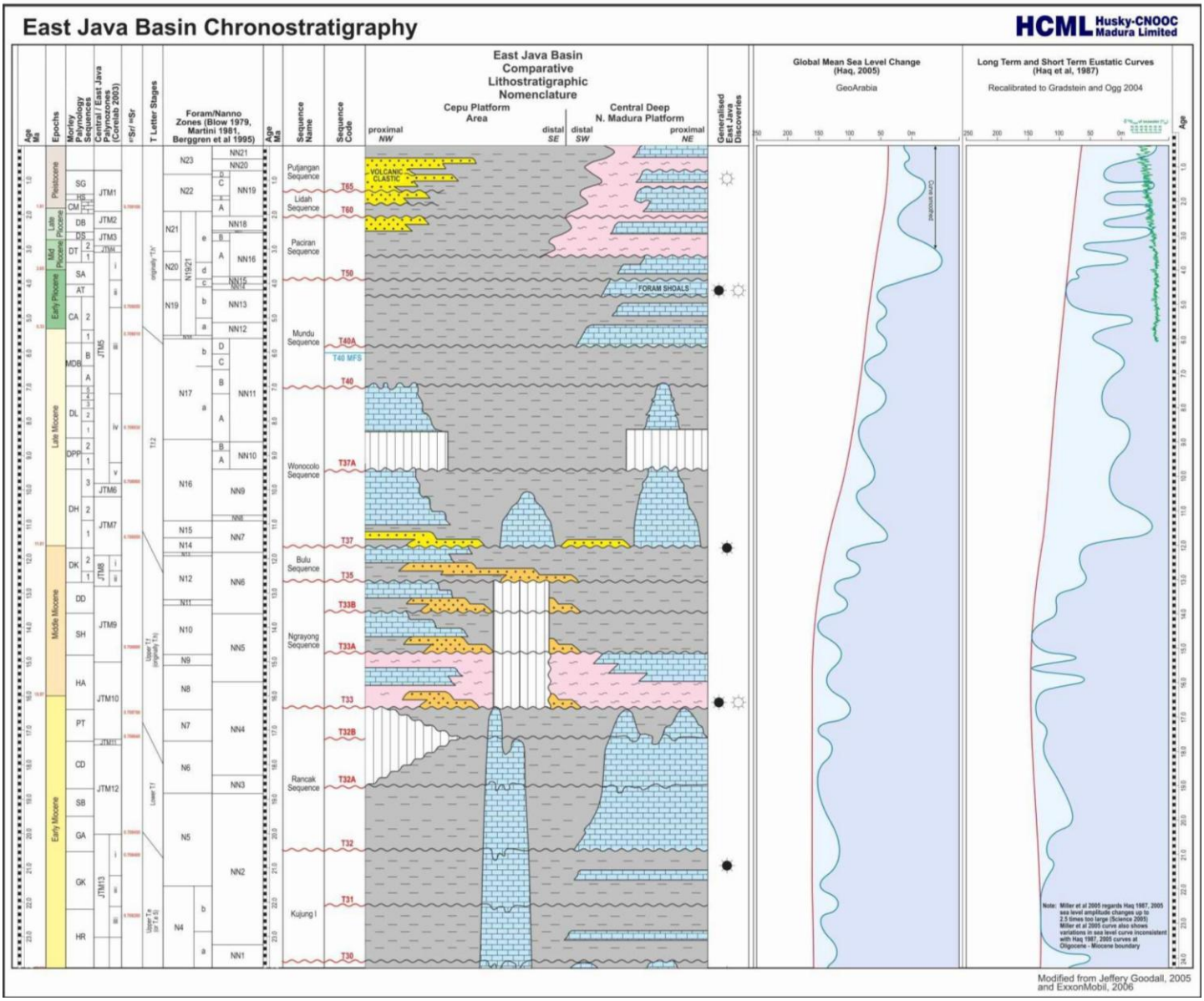


Figure 3. *East Java Basin chronostratigraphy.*

The foraminifera association of both sequences indicates that the water depth is approximating to the range 100-500 m, where planktonic foraminifera were deposited as "pelagic rain" and then were subsequently redistributed by sea floor bottom currents. This process resulted in the grainstone, packstone, wackestone observed in the wells to show distinct, rhythmic coarsening-upward cycles. A similar depositional process took place in SANTOS' Oyong and Maleo Fields (Iriska et al., 2010), which are located 150 km and 70 km, respectively, to the west of the HCML MDA Field.

Differentiating these Mundu and Paciran Sequences relies heavily on biostratigraphy and chronostratigraphy, as there are no significant lithological features that can be observed from samples and logs of those two sequences. The methodology used was initially invented and developed by Goodall (2007), with varying nannofossil abundance relative to sequence boundaries in the interval NN18 (Late Pliocene) to NN11 (Late Miocene) helping to define a rigid stratigraphical framework.

The detailed correlations in the MDA Field were constructed using high resolution biostratigraphy events of the Late Miocene- Pleistocene MPNZ (Mundu – Paciran Nannofossil Zones). This method is generated based on cutting data from four wells and also conventional cores of MDA-3 and MDA-4. The subdivisions are as follows (the youngest zone is mentioned first):

MPNZ-8: Pleistocene age bounded by T60 and T65.

MPNZ-7: The first downhole occurrence of *Discoaster brouweri* with less abundant *Sphenolithus abies* and any other nannofossil. This zone has reworked materials from older stratigraphy.

MPNZ-6: The first downhole occurrence of common-abundant small *Reticulofenestrids* and in-situ *Sphenolithus abies* is used to date this event. The absence or significantly decreased (downhole) occurrence of *Gephyocapsa* is also noted in this subzone.

MPNZ-5: This event is recognized by the first downhole occurrence of (super) abundant small *Reticulofenestrids*.

MPNZ-4: Defined by the first downhole occurrence of few-common *Sphenolithus abies* and/or medium *Reticulofenestrids*. The first downhole occurrence of few-common *Dictyococcites spp* also characterizes the event.

MPNZ-3: This event is marked by the first downhole occurrence of abundant *Sphenolithus abies*.

MPNZ-2: This event is characterized by the maximum abundance of *Reticulofenestrids* and/or *Sphenolithus abies* during the Early Pliocene.

MPNZ-1: This event is coincident with the first downhole occurrence of in situ *Discoaster quinqueramus* (also used to mark the Late Miocene - Pliocene boundary) and the first downhole occurrence of *Reticulofenestra rotaria*. A downhole significant increase of medium *Reticulofenestrids* and the absence of in-situ *Dictyococcites spp*. are also noted at this subzone.

CONCLUDING REMARKS

Inversion in Madura Strait region that took place in the Late Miocene created "humps" on the sea floor. The forams were deposited as "pelagic rain" and were re-distributed in the area by strong currents coming from the Indian Ocean through the Bali Strait. These currents created a clinoform structure around the seabed located at relatively higher position from its surrounding. The evidence of this clinoform can be seen at MPNZ-6 relationship between MDA-1 and MDA-2st wells (Figure 5).

Based on the MPNZ subdivision, the top of MPNZ-7 in the MDA Field occurs within the Selorejo Formation (Figure 6). The Selorejo Formation is based on lithostratigraphy, which means the formation top does not necessarily coincide with time event. The upper reservoir interval of the MDA Field is younger than the MPNZ-7 and it lies within the lower part of MPNZ-8 (Lidah Sequence, Late Pliocene - Early Pleistocene). This interval was interpreted as part of reworked materials from older deposits.

The MPNZ-7 was only encountered in the MDA-3 (northern edge of the structure) and MDA-4 (western portion of the structure), which is believed to be composed of reworked sediments from the eastern portion of the structure. This interpretation is supported by the fact that MPNZ-7 deposit was not encountered in MDA-1 and MDA-2ST (Figures 4, 5 and 6).

Based on internal reservoir characteristics, the MPNZ-7 deposit in MDA-3 has less porosity and permeability compared to similar reservoir in the MDA-4; and this corresponds to the increase of mud content in the MDA-3. Hence, the facies changes relative to the west of the structure during MPNZ-7 time. It is interpreted that the MDA-3 reservoir was deposited by less winnowing compared to the reservoir in the MDA-4, due to the relatively low position in the structure.

Based on the above interpretation, it is suggested that the best reservoirs are the MPNZ-7 and MPNZ-6, which were deposited at relatively high position in the depositional setting.

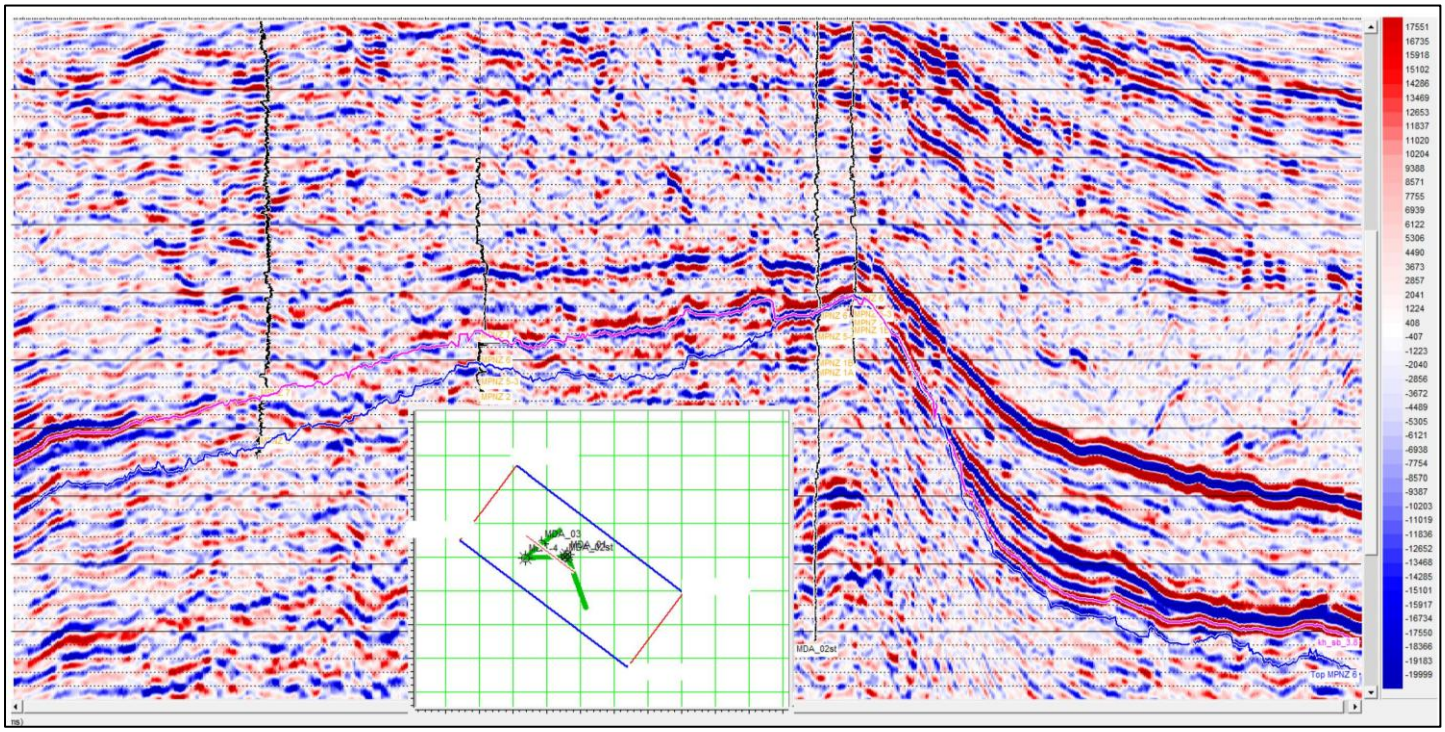


Figure 4. *Seismic amplitude cross section showing top MPNZ 7 and MPNZ 6 with facies change between MDA-4 and MDA-3 (MPNZ 7 age) and MDA-1 and MDA-4 (MPNZ 6 age).*

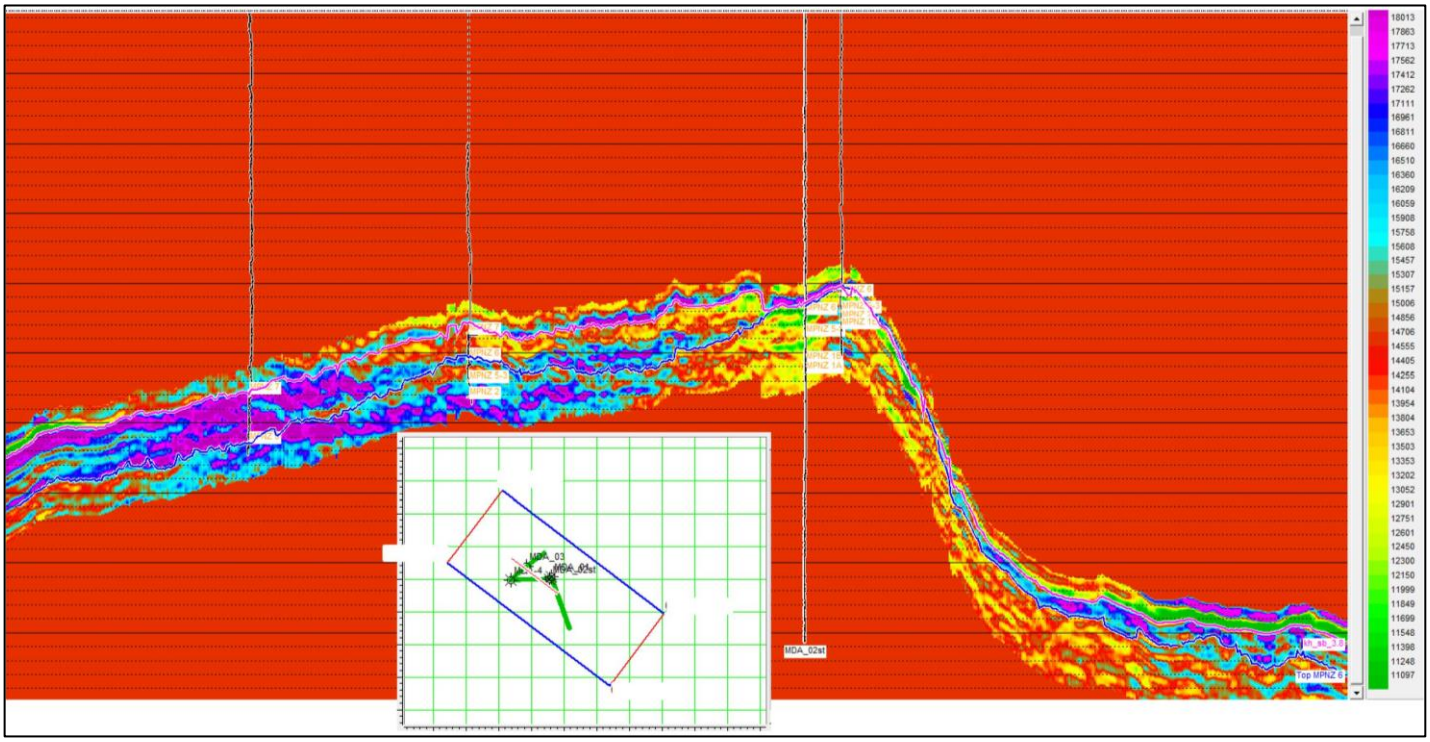


Figure 5. *AI cross section showing top MPNZ 7 and MPNZ 6 with facies change between MDA-4 and MDA-3 (MPNZ 7 age) and MDA-1 and MDA-4 (MPNZ 6 age).*

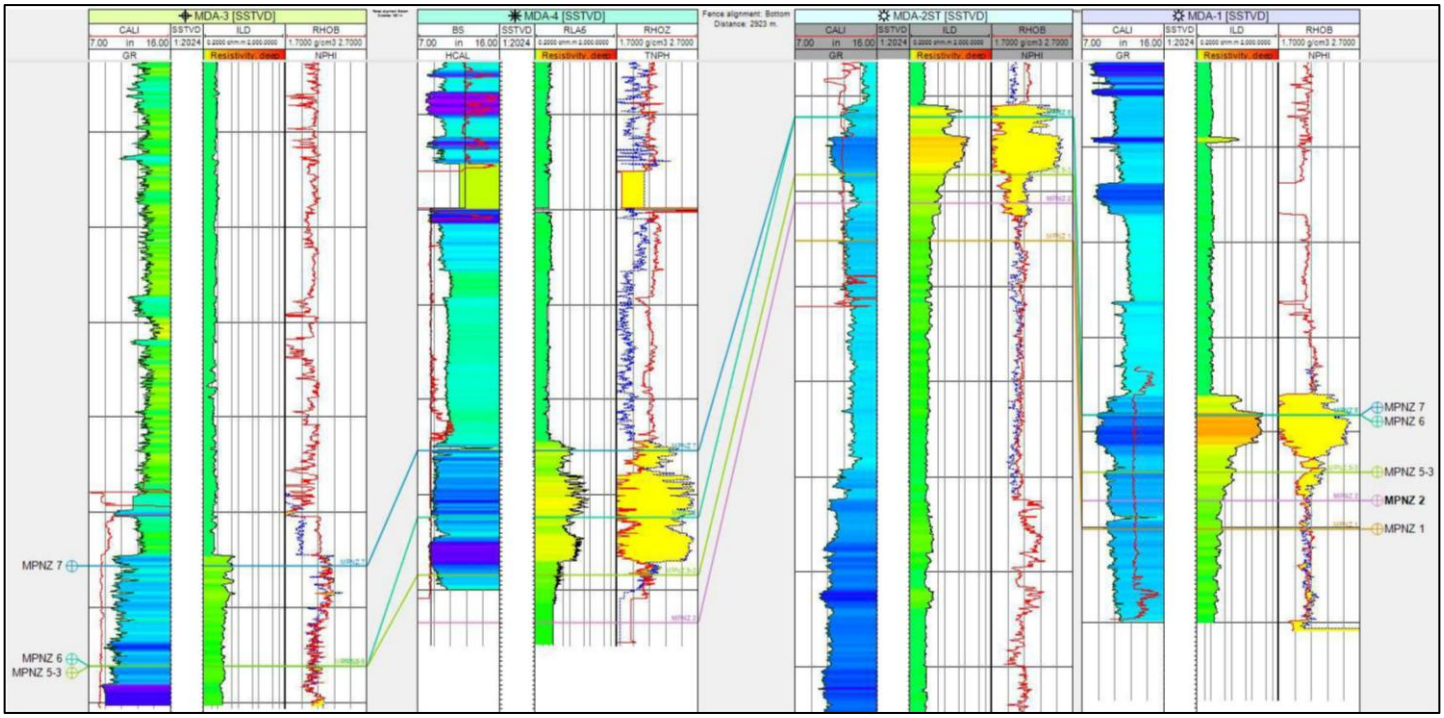


Figure 6. *Well correlation between MDA wells.*

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REFERENCES

Bransden, P. J. E., and Matthews, S. J., 1992, Structural and Stratigraphic Evolution of The East Java Sea, Indonesia: Proceedings Indonesian Petroleum Association 1992.

Goodall, J. G. S., 2007, Madura Basin Stratigraphic Study, Joint BPMigas/Santos internal study.

Iriska, D. M., Sharp, N. C., and Kueh, S., 2010, The Mundu Formation: Early Production Performance of An Unconventional Limestone Reservoir, East Java Basin – Indonesia: Proceedings Indonesian Petroleum Association 2010.

Satyana, A. H., and Djumlati, M., 2003, Oligo-Miocene Carbonates of the East Java Basin,

Indonesia: Facies Definition Leading to Recent Significant Discoveries: AAPG International Conference 2003.

Satyana, A.H., Erwanto, E., and Prasetyadi, C., 2004, Rembang-Madura-Kangean-Sakala (RMKS) Fault Zone, East Java Basin: The Origin and Nature of a Geologic Border, Indonesian Association of Geologists 33rd Annual Convention, Bandung 2004.

Schiller, D. M., Seubert, B. W., Musliki, S., and Abdullah, M., 1994, The Reservoir Potential of Globigerina Sands in Indonesia: Proceedings Indonesian Petroleum Association 1994.

Triyana, Y., Harris, G. I., Basden, W. A., Tadiar, E., and Sharp, N. C., 2007, The Maleo Field: An Example of The Pliocene Globigerina Bioclastic Limestone Play In The East Java Basin – Indonesia: Proceedings Indonesian Petroleum Association 2007.