The Resolution Revolution

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Introduction

PGS Exploration recently completed the acquisition and processing of the 3963 km^2 East Java MC3D survey, the latest of a series of high density 3D (HD3D) surveys acquired by PGS in the Asia-Pacific region. The M/V Ramform Challenger towed 12 streamers at 62 m separation, in dual-source shooting mode, providing a very small processing bin size of 12 x 15 m. This survey parameterisation was based upon several detailed phases of pre-survey planning, and enabled very high resolution processing in the most challenging of environments for seismic imaging - shallow targets with very steep dips.

Use of Ramform vessel technology allowed a very high streamer count to be towed at close separation, and with outstanding efficiency. Average daily production throughout the entire survey was in excess of 50 km^2. If all mobilisation, weather, obstruction, and logistical downtime are accounted for, effective production was still in excess of 35 km^2 per day (e.g. less than three months to complete 3000 km^2).

Interpretation Objectives

The 3963 km^2 high density MC3D (HDMC3D) survey is located over the North Madura Platform in the East Java Basin (Johansen, 2003), within the open North and Northeast Tanjung Lapak blocks (Figure 1), which are scheduled for offering in Indonesia's upcoming 4th Round. Of particular interest to interpretation is a thick and extensive carbonate platform deposited throughout the region in the Late Oligocene-Early Miocene. This is usually referred to as the Kujung Formation, which consists of three units. Kujung Unit I and II/III carbonates represent the main reservoir on the North Madura Platform, and occur on seismic data between 0.9–1.4 seconds TWT. The Kujung carbonate build-ups typically represent both circular and elongated patch reefs, although pinnacle reefs are occasionally present. Kujung Unit II/III carbonates, which are in the order of 400 m thick, are also widespread throughout the area. Seismic amplitudes are laterally discontinuous, apparently representing changes in depositional facies. Kujung Unit I reefs also have a complex

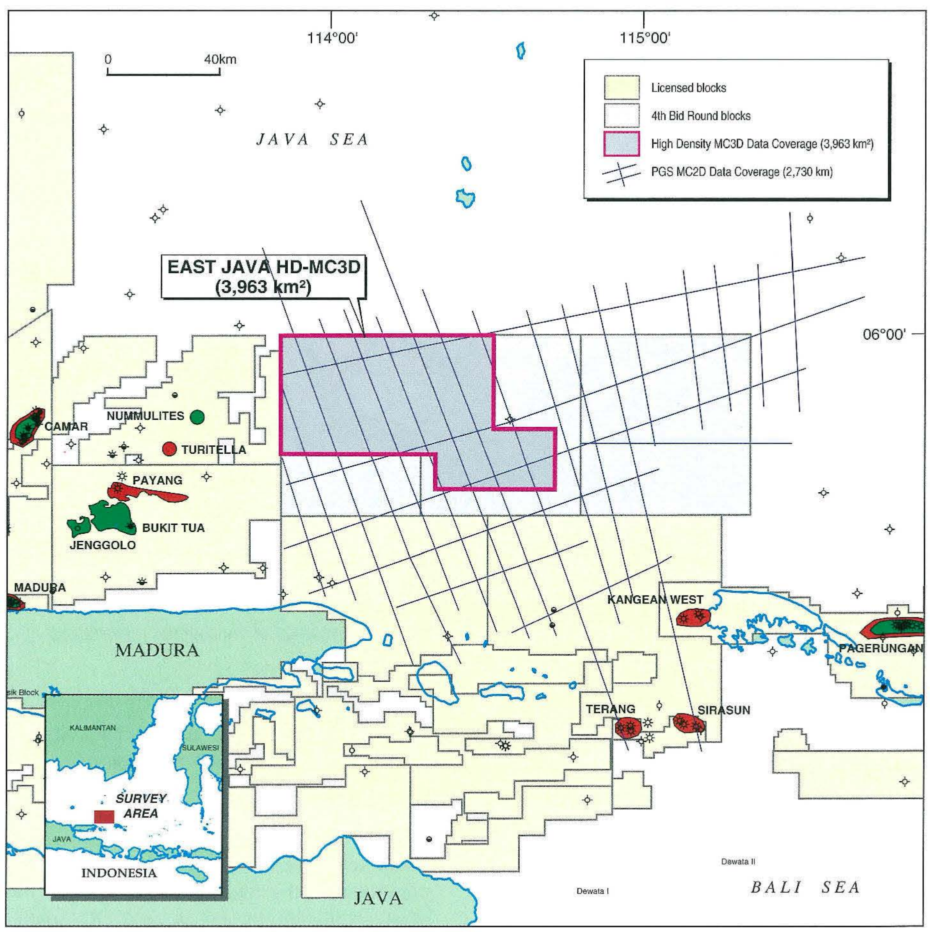

Fig. 1. Location map for the East Java HDMC3D survey. The survey is designed to cover several prospective leads identified on earlier 2D data.

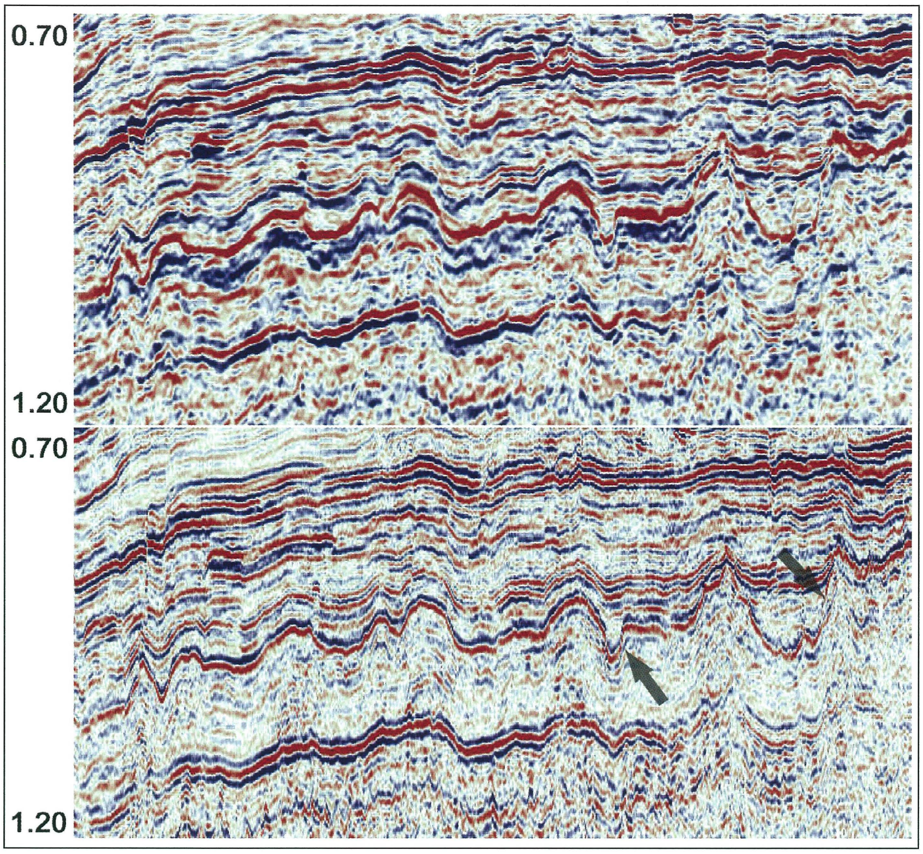

Fig. 2. Compared to existing 2D data (upper figure), the new HDMC3D data (lower figure) yields a significant improvement in resolution. On this 25 km data extract, steeply-dipping Kujung carbonate reef flanks are crisply imaged, testament to the virtue of very tight 3D spatial sampling during acquisition. As indicated by the arrows, steep dip imaging is improved on the new HDMC3D data.

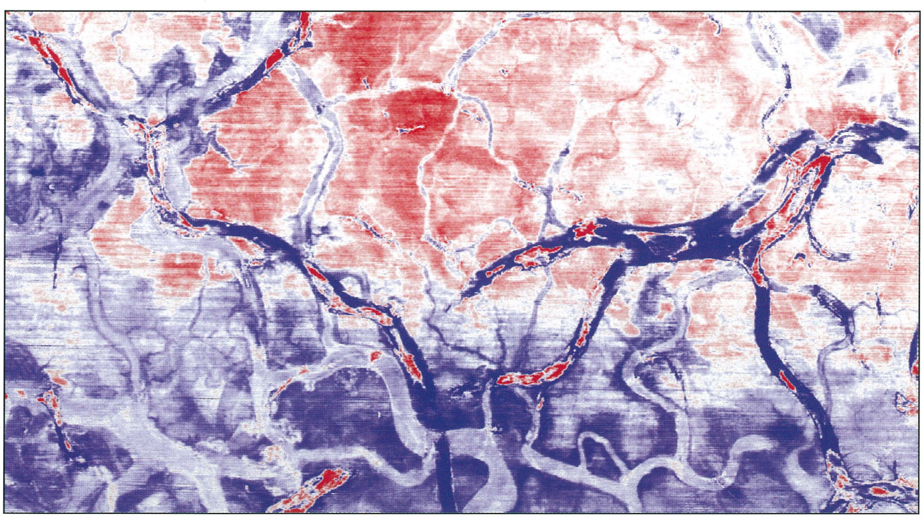

Fig. 3. Time slice from the East Java HDMC3D survey at 0.15 s TWT. Resolution of the complex meandering channel system is excellent. Horizontal scale =15 km.

internal architecture, where the reservoirs are often unpredictable. Karstification and dissolution effects are often pronounced, with frequent sink holes identified on the new HDMC3D seismic data. Overall, chaotic noise wavefields often dominate, reflecting the complex geometries of the various carbonate features.

It was clear prior to acquisition of new 3D seismic data that a special emphasis upon the resolution of highly-variable, steeply-dipping (in excess of 60°) features was required.

Survey Parameterisation and Results

Many acquisition and processing parameters contribute to the issue of resolution, but the most significant by far is tight 3D spatial sampling. Tight 3D spatial sampling allows the preservation of a large frequency bandwidth throughout all stages of processing, and allows optimal signal-to-noise seismic imaging. Seismic noise is an insidious beast, whose many forms are often underappreciated. A particularly relevant example concerns the noise that arises when aliased seismic data is input to multi-channel processing operations—notably pre-stack migration. Aliased data creates migration noise, which degrades the signal-to-noise quality of all seismic events, reducing event continuity, and destroying resolution. Based on detailed pre-survey planning, a 15 m cross-line bin size was determined as a critical prerequisite for high resolution seismic imaging of the steep Kujung carbonate flanks. Examination of the processed data (Figures 2–5) confirms the pre-survey expectations.

The high signal-to-noise quality and excellent resolution of the East Java HDMC3D data is testament to the virtues of tight 3D spatial sampling, and the HD3D acquisition method. The new HDMC3D seismic data has revealed the presence of numerous, often complex prospects on both the upper and lower Kujung levels, as well as on the deeper Basement/Ngimbang levels. Migration pathways can thus be interpreted, and detailed prospectivity analysis is possible.

A common frustration with 3D acquisition is that high-quality resolution observed on existing 2D data is not observed at a comparable standard on new 3D data. Ideally, we desire the 3D structural imaging power of the 3D method, combined with high resolution in all directions. As conventional 3D acquisition typically samples four to six times more finely in the shooting (inline) direction, resolution is compromised in the cross-line direction. In Figure 2, previous 2D data (acquired by PGS in 2002) is compared to the new HDMC3D data acquired in 2003. Resolution is actually significantly improved in the new HDMC3D data, demonstrating how 3D pre-stack migration benefits from tightly sampled 3D data being input, free of aliasing.

Figure 3 presents a migrated time slice at 0.15 s TWT. Note the almost total absence of any acquisition footprint, even at such a shallow depth. The resolution and definition of complex meandering channels systems is quite startling, testament to the resolution power of the HD3D acquisition method in dual-source shooting mode. Figure 4 presents a deeper time slice (1.0 s TWT), intersecting the Kujung carbonate features. Again, resolution is excellent, evidenced also in the interpreted 3D surface plotted in Figure 5. Frequency analysis indicates primary event frequencies in excess of 80 Hz throughout the target region, before any Q compensation or spectral whitening.

Conclusions

Overall, the HDMC3D data has enabled a detailed interpretation of the complex limestone reservoirs, revealing numerous prospects and leads along the North Madura Platform within both Kujung I and II/III carbonates. Some of these structures may have structural closures of greater than 100 km² (Johansen, 2003). A powerful demonstration is made that very high resolution is only achievable when tight 3D spatial sampling is the centrepiece of acquisition.

Acknowledgements

Thanks to PGS Marine Geophysical for permission to publish this data and to the members of the East Java HDMC3D QC committee for their project management.

References

Johansen, K.B., 2003, Depositional geometries and hydrocarbon potential within Kujung carbonates along the North Madura Platform, as revealed by 3D and 2D seismic data, accepted by the 29th Annual IPA Convention & Exhibition, Indonesia, October 14-16, 2003.

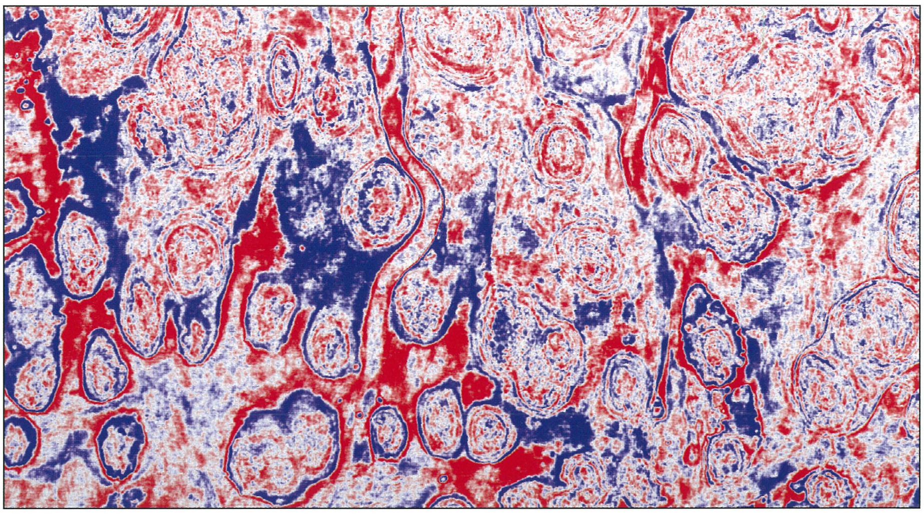

Fig. 4. Time slice from the East Java HDMC3D survey at 1.0 s TWT. The Kujung carbonate features are highly complex in distribution, demanding a high resolution 3D seismic acquisition and processing strategy. Refer also to Figure 5.

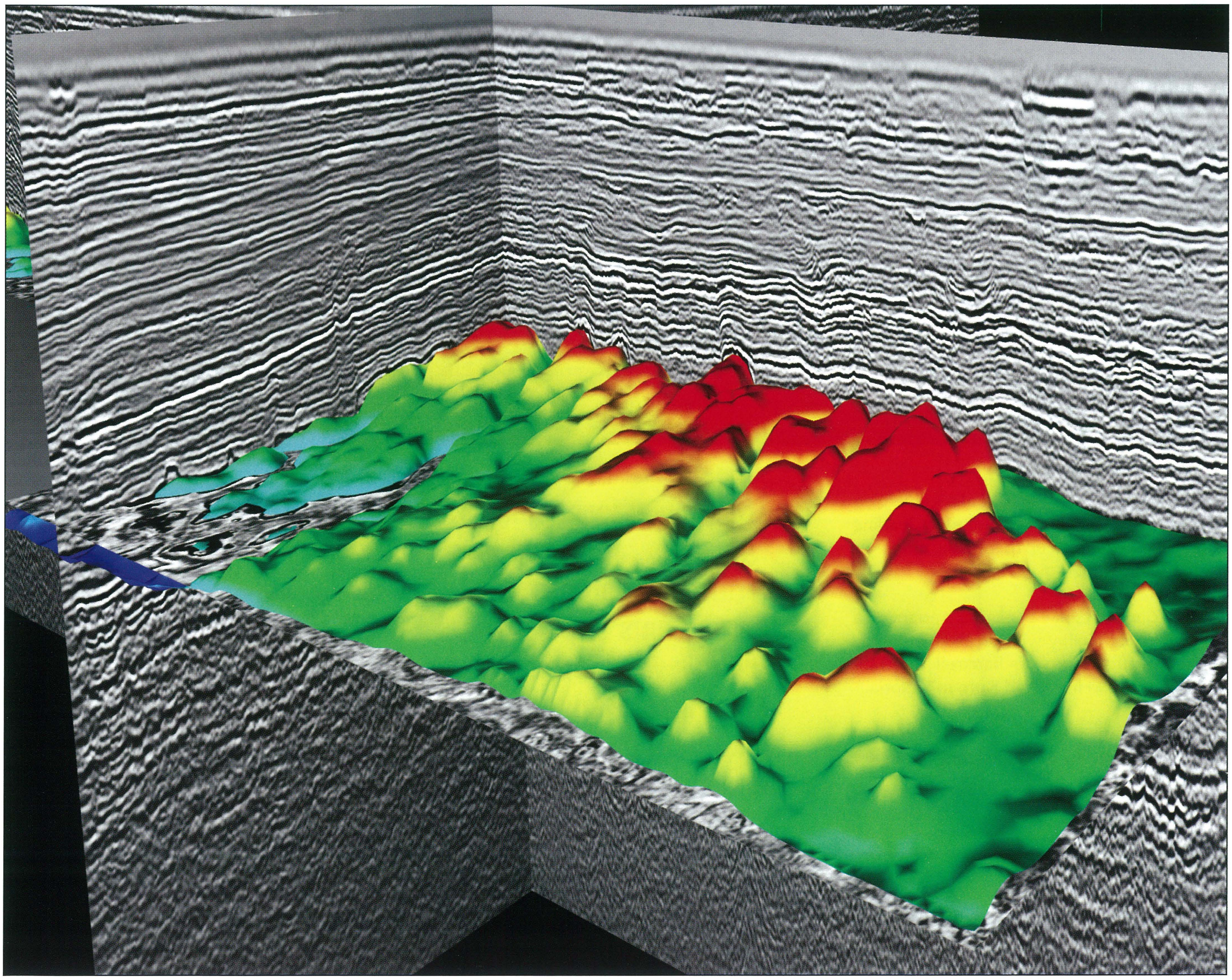

Fig. 5. 3D perspective plot from the holoSeis™ immersive visualisation and interpretation system. The Top Kujung I surface interpreted here (~ 1.0 s TWT) reveals the density and complex distribution of carbonates throughout the HDMC3D survey area.