EAGE

117

MODERN SEISMIC DATA REVEALS POTENTIAL FOR A DEEPER PLAY IN NORTH MADURA, EAST JAVA, INDONESIA.

M. Farouki<1>*, A. Bromley<1>, D. Cavalin<1>

<1> PGS

Summary

The East Java Basin is a prolific hydrocarbon province in Indonesia in which exploration plays have typically targeted the pinnacle reefs of the Oligocene-Miocene Kujung carbonates. Robust imaging of the deeper section however has historically been challenged due in part to the limited bandwidth of conventional seismic data. A further challenge arises from the imaging artefacts introduced at the overlying Wonocolo carbonate platform, where the slow velocities of deep channel incisions are in strong contrast with the fast carbonate velocity. Pre-stack depth migration can be used to address this issue, but requires a velocity model with sufficiently high spatial and temporal resolution to precisely capture such velocity variations. To this aim, Full Waveform Inversion is used in the velocity model building. Whereas legacy data in the basin has struggled to image deeper than the Kujung level, seismic acquisition and imaging methods are now providing data with greater bandwidth and deeper penetration of signal. In Madura, the deeper Eocene Ngimbang formation as well as basement are now much better resolved, opening up the potential play in the Ngimbang clastics.

Introduction

Exploration plays in the East Java Sea Basin have typically targeted the pinnacle reefs of the Oligocene-Miocene Kujung carbionates, where there have been multiple successful tests. Robust imaging of the deeper section and basement, however, has historically been a challenge for legacy seismic surveys. Modern seismic acquisition and imaging methods are now providing seismic data with greater bandwidth and deeper penetration of signal. In Madura, the deeper Eocene Ngimbang formation as well as basement are now much better resolved, opening up the potential play in the Ngimbang clastics. A number of technology advances in marine seismic acquisition and imaging contribute to this uplift; these include dual-sensor broadband acquisition, and velocity model building for depth migration using Full Waveform Inversion, FWI, (Ramos-Martinez et al., 2011, 2016).

Structural setting

The East Java Basin area has been one of the most prolific hydrocarbon provinces in Indonesia, and it is the most structurally and stratigraphically complex of the Indonesian back-arc basins situated on the margin of the Sunda craton. The basin extends east to west, and includes a number of distinct structural zones (Figure 1). A series of NE-SW trending half-grabens branch off to the north: these include the Muriah trough, the Tuban-Camar trough, the Central-Deep depression, and the Sakala sub-basin. The half-grabens are separated by extensive structural highs: the North Madura platform, the JS-1 ridge, and the Bawean arch.

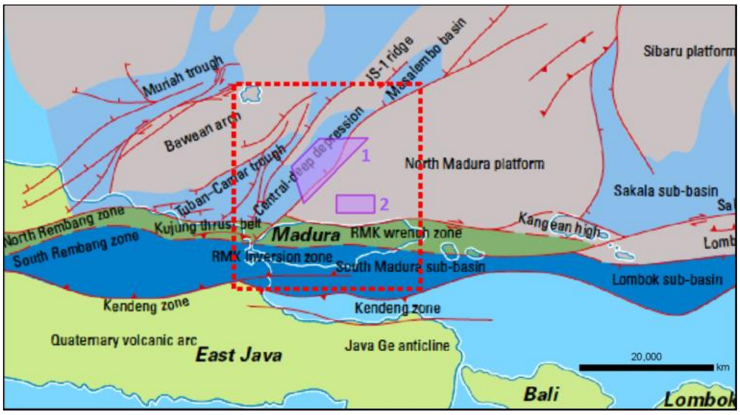

Figure 1. The structural setting of the East Java Basin, also showing (purple polygons) the location of the MC3D Survey Areas 1 and 2.

Stratigraphy

The stratigraphy of the East Java Basin is described in Figure 2 (from Nugraha et al., 2016). Discoveries within the Oligo-Miocene carbonates reflect the effectiveness of the petroleum system involving mature source rock (kitchen area proximity), migration pathways, good carbonate rerservoirs, resilient seals, and good stratigraphic traps. This is supported with a working time sequence of hydrocarbon generation, migration, trapping, and subsequent preservation of the accumulation. Source rocks are organically rich shales and coals of the Eocene Ngimbang formation. Offshore discoveries include the Jenggolo, Bukit Tua, and Payang fields which are located at the Central Deep depression and Madura Sub-basin.

From an exploration standpoint the essential stratigraphic features are:

a. The Wonocolo carbonate platform, deeply incised with channels, which presents seismic imaging challenges for the deeper targets
b. The Kujung carbonates, which contain the pinnacle reefs that are the main reservoirs encountered to date.

c. The Ngimbang formation, in which the clastics have largely been untested. Less than 5% of all wells drilled to date have targeted this play

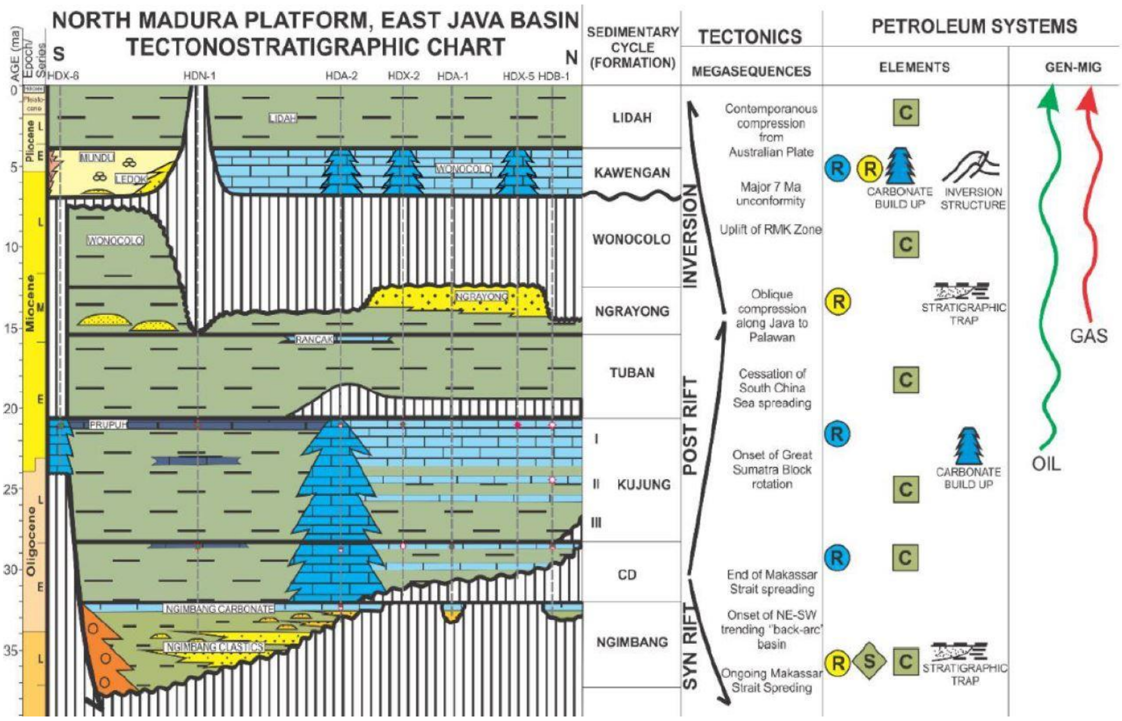

Figure 2. The stratigraphy of the East Java Sea Basin (after Nugraha et al., 2016).

Seismic acquisition and imaging

A multi-client 3D survey (MC3D) was acquired offshore Madura Island during 2017 in two parts. Area 1 covers 1950 sqkm and sits over the Central Deep depression; Area 2 is 650 sqkm over the Madura platform.

In order to mitigate against risks from dense fishing activity and the shipping channel out of the nearby port of Surabaya, a triple-source configuration was used in the acquisition to reduce the number of streamers deployed without compromising the efficiency of acquisition or the density of subsurface sampling. Broadband seismic data was achieved via dual-sensor recording (Carlson et al., 2007), resulting in improved resolution of events, deeper penetration of signal, and a step-change in improved interpretability.

The Wonocolo carbonate platform in the ovderburden is deeply incised with wide, deep channels. These features result in large velocity contrasts (around 500 m/s) between the slow velocity channel fill, and the background high velocity carbonate (Figure 3). Pre-stack time migration (PreSTM) algorithms cannot suitably address such a large velocity contrast, resulting in aberrations in the imaging of the deeper data which manifest as erroneous sags in events beneath the channels. To address this challenge, pre-stack depth migration (PreSDM) can be applied to the data; however, in order for the PreSDM to perform correctly the input velocity model must exactly characterize the velocity contrast between each of the numerous channels and the surrounding incised carbonate platform. This is not a trivial task for conventional velocity model building, and FWI is required in order to resolve and capture velocity anomalies of such magnitude with the necessary temporal and spatial resolution. Figure 4 is an illustration of how the artificial sags introduced by the channel incisions in PreSTM can be addressed with PreSDM using a velocity model derived from FWI.

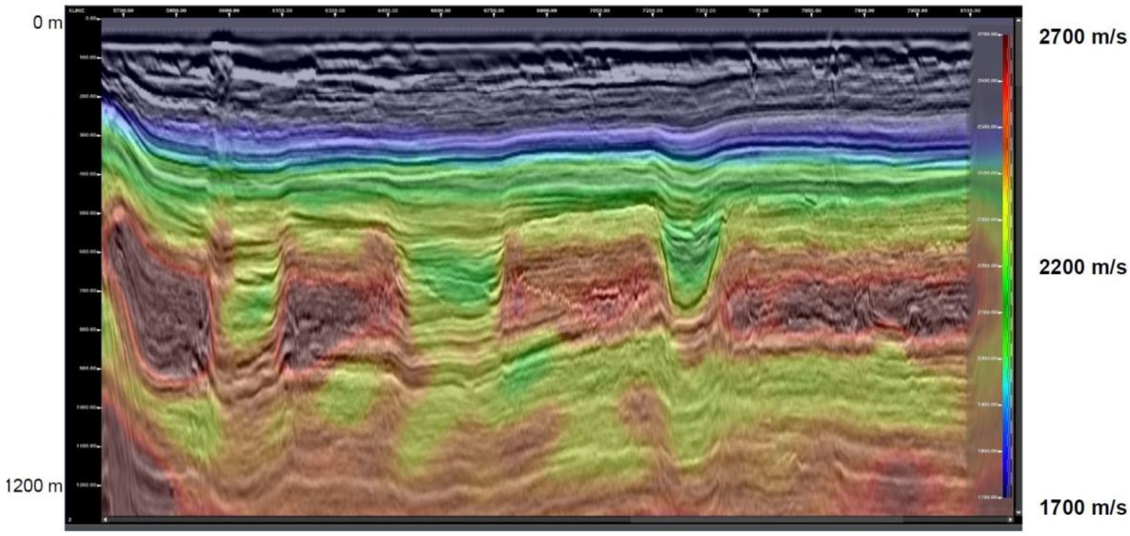

Figure 3. A section from the MC3D survey showing the channel incisions in the Wonocolo formation, and the associated velocity contrasts that result.

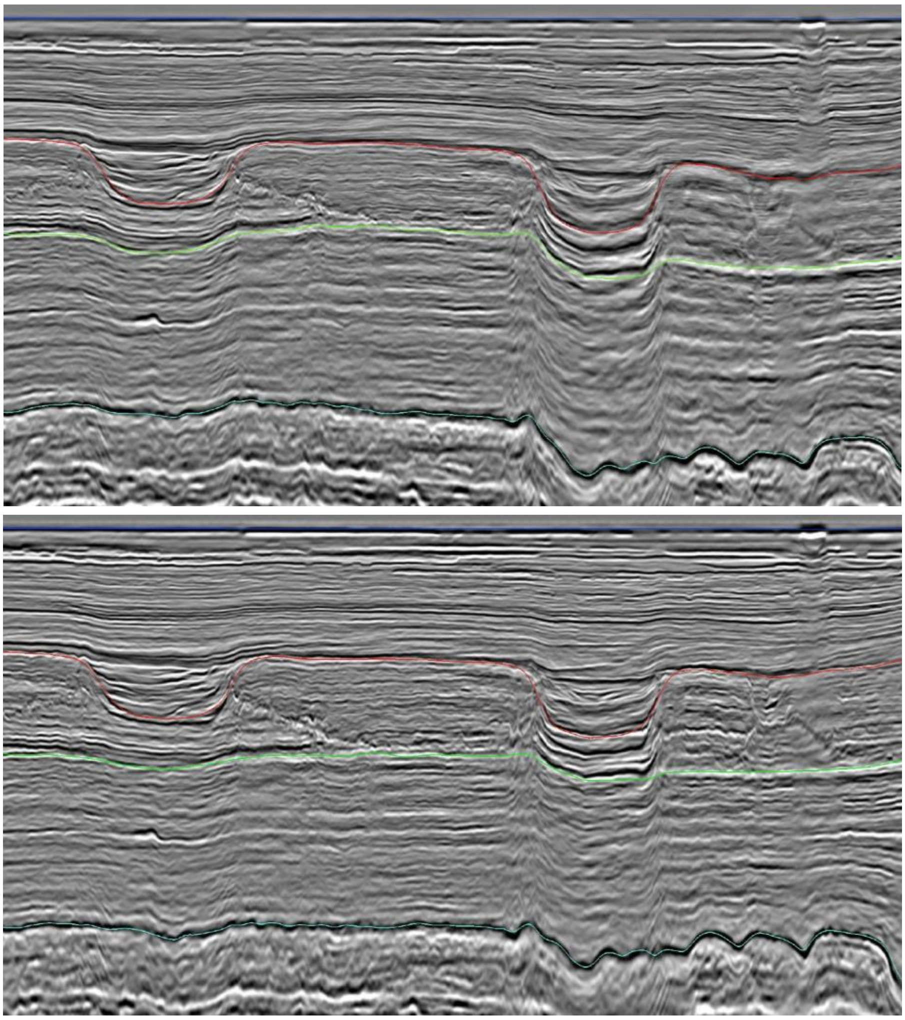

Figure 4. Top: PreSTM converted to depth, showing artificial sags in events beneath the channel incisions. Bottom: PreSDM with velocities derived from FWI. Interpreted horizons are: Water bottom (blue), Top Wonocolo carbonate (red), Base carbonate (green), and Kujung I (dark green).

Conclusions

Modern seismic technologies in acquisition and imaging are providing new insights into mature areas and can open up near field exploration and new plays. Figure 5 is representative of the existing legacy 2D data in the area, in which it is difficult to make out even where basement sits. Figure 6 is a section taken from the MC3D survey. Of course there is a host of technology improvements between the two, but the comparison is made simply to show the difference in quality and interpretability of the data which was previously available to the explorationist versus what is available now.

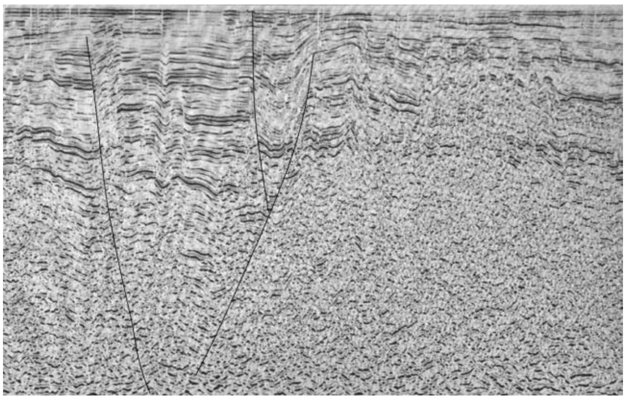

Figure 5. Section typical of legacy data. Deeper events are obscure and basement cannot be discerned.

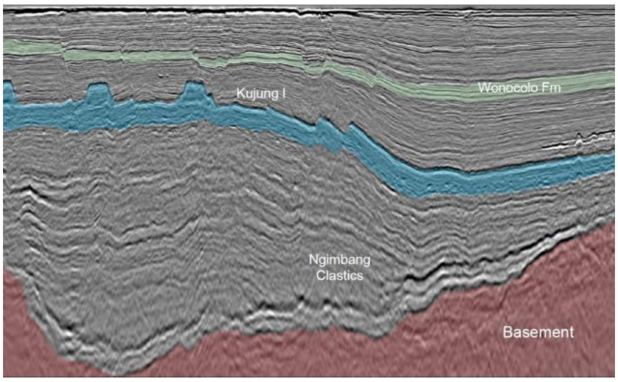

Figure 6. Section from new MC3D seismic data with major formations interpreted. The deeper Ngimbang formation and basement are well imaged.

References

Carlson, D., Long, A., Söllner, W., Tabti, H., Tenghamn, R. and Lunde, N. [2007] Increased resolution and penetration from a towed dual-sensor streamer. *First Break*, **25**(12), 71-77.

Nugraha, H., Darma I., and Darmawan, F. [2016] Ngimbang clastics play in the East Java Basin: New insight and concepts for North Madura Platform. *40th IPA Annual Convention & Exhibition*, Proceedings.

Ramos-Martinez, J., Crawley, S., Kelly, S. and Tsimelzon, B. [2011] Full-waveform inversion by pseudoanalytic extrapolation. *81st SEG Technical Program*, Expanded Abstracts, 2684–2688.

Ramos-Martinez, J., Crawley, S., Zou, Z., Valenciano, A. A., Qiu, L. and Chemingui, N. [2016] A robust gradient for high-resolution velocity model building. *76th SEG Technical Program*, Expanded Abstracts, 1258-1262.