EA Karst – Is There a Magic Way to Model it?*

Huijun Hou[1], Brad Bailey[1], Sigurdur Jonsson[1], Darren Blazak[1], Bruce Taylor[1], and Glen Johnson[1]

Search and Discovery Article #51656 (2020)**
Posted May 4, 2020

*Adapted from extended abstract prepared in conjunction with poster presentation given at 2020 AAPG/EAGE 1st Petroleum Geoscience Conference & Exhibition, PNG's Oil and Gas Industry Maturing through Exploration, Development and Production, Port Moresby, Papua New Guinea, 25-27 February 2020
 DOI:10.1306/51656Hou2020

[1]Oil Search Ltd, Papua New Guinea (huijun.hou@oilsearch.com)

Abstract

Karstification plays an important role in the reservoir effectiveness of carbonate reservoirs. It is estimated that 38% of the world's oil and gas volumes in carbonates are associated with karst-affected features. Predicting the properties and distribution of karst formations is very challenging and commonly uses the integration of high-definition, 3D seismic data. Various techniques for karst modelling have been published but are generally field specific and not readily transferable to other carbonate reservoirs. This paper presents an innovative approach to karst modelling of the Antelope gas field in Papua New Guinea utilizing 2D seismic data, modern-day analogues, and appraisal well data.

Discussion

The Antelope gas field is located within the Eastern Foldbelt of the Papuan Basin, in Papua New Guinea. The field is situated in a sequence of isolated, Miocene, platform carbonates, interpreted to be related to structural relief generated during early stages of regional compression. Antelope is at the western end of what has been interpreted as an atoll-shaped reef build-up overlying a basal platform carbonate, with lagoonal facies located within the central low area of the atoll (Figure 1). A significant amount of dolomite is predicted – and observed on well penetrations – within the upper part of the reefs related to karst processes that enhance the reservoir quality. Karst units can be identified from well logs, core and drilling events, which can also be broadly linked to 2D seismic character. Given only moderate quality 2D seismic lines were acquired over Antelope, the main challenge was modelling the spatial distribution of the dolomite and karst-impacted reservoir.

An integrated workflow was created focusing on three steps for the karst modelling: defining the representative concept karst model to understand the karst distribution patterns; creating the input data needed for karst modelling to mimic the concept karst model; and, designing the karst modelling workflow and approach to realize the model and honor the field data.

A simultaneous dolomitization and multiple level overprinting Carbonate Island Karst Model (CIKM) (Figure 2) was defined based on the investigation of both modern and ancient analogues and crosschecked to the field seismic data. This model suggests confining extensive karsts to the reef front facies, with karst caverns most intense in reef facies, but less frequently penetrating the tighter lagoonal facies.

Karst channels also generally ran parallel to the reef front orientation, with finger-like extensions normal to the reef front and into the back reef forming hand-like shapes in map form. As previously mentioned, karst was broadly linked to 2D seismic character in Antelope. It was observed that transparent and chaotic seismic features indicated porous dolomite/limestone within the reef build-up and were often associated with karsts/reef collapse, and, continuous and strong reflectors indicated poor limestone/lagoon deposits with less karst influence. Such characters were used as the guidance to define the lateral outer boundary of karstification.

Three types of key input data were developed from the raw field data to implement the karst concept in the modelling process: depo-facies model, karst isopach maps and karst flow unit indicator. The 3D depo-facies model acted as the conditioning framework for karst distribution according to the relationships described above. Karst isopach maps were built from the analysis of well logs, seismic attributes, analogues, and the conceptual diagenetic model. These maps defined the karst envelopes controlling the lateral karst distribution and approximate karst proportion between wells. Karst flow unit indicators were reproduced from Morphic Rock Facies (MRF), an index curve produced from Resistivity Image logs, core data, other log data, and drilling events that were used to guide development of karst flow units. These controlled the near-wellbore karst distribution and the vertical karst proportions.

Three classes of flow units (High Flow Unit (HFU), Solution Enhanced Unit (SLE), and Non-Karst Unit (NKU)) were defined from well logs to skillfully characterize the karst features. And three sets of isopach (high case, middle case, and low case) were created to cover the karst uncertainty. These isopach maps and flow units were combined to build up the 3D karst network using the Truncation Gaussian Simulation (TGS) approach and conditioned by depo-facies, zones, and karst envelopes (Figure 3). Finally, the karst model was overprinted on the depo-facies model for populating with petrophysical properties such as porosity, permeability, and water saturation, before ready for dynamic simulation.

The 2-level karst drainage character (HFU and SLE) provided flexibility for dynamic simulation. The model was validated and tuned by utilizing the extensive well testing results, giving confidence in prediction of karst formations within the Antelope Field.

Selected References

Chung, E.K.Y., K.K. Ting, and O. AlJaaidi, 2011, Karst Modelling of a Miocene Carbonate Build-up in Central Luconia, SE Asia: Challenges in Seismic Characterization and Geological Model Building: International Petroleum Technology Conference, Bangkok, Thailand, 15-17 November 2011, IPTC 14539-MS, 6 p. doi.org/10.2523/IPTC-14539-MS

Fernandes-Ibanez, F., P.J. Moore, and G.D. Jones, 2019, Quantitative Assessment of Karst Pore Volume in Carbonate Reservoirs: American Association of Petroleum Geologists Bulletin, v. 103/5, p. 1111-1131.

Gines, A., J. Gines, and F. Gracia, 2013, Cave Development and Patterns of Cave and Cave Systems in the Eogenetic Coastal Karst of Southern Mallorca (Balearic Islands, Spain), *in* M. Lace and J. Mylroie (eds), Coastal Karst Landforms: Coastal Research Library, vol. 5, Springer, Dordrecht p. 245-260. doi:10.1007/978-94-007-5016-6_11

Jones, G.D., 2015, Flow-Based Effective Properties of Sub-Seismic Karst: SPE Middle East Oil & Gas show and Conference, Manama, Bahrain, 8-11 March 2015, SPE-172648-MS, 10 p. doi.org/10.2118/172648-MS

Mylroie, J.R., and J.E. Mylroie, 2007, Development of the Carbonate Island Karst Model: Journal of Cave and Karst Studies, v. 69/1, p. 79-75.

Neillo, V., L. Pauget, and C. Neumann, 2014, Integrated Workflow to Tackle Heterogeneous Karst Dominated Reservoirs: Kharyaga Example: Russian Oil and Gas Exploration and Production Technical Conference and Exhibition, Moscow, Russia, 14-16 October 2014, SPE-171204-MS, 13 p. doi.org/10.2118/171204-MS

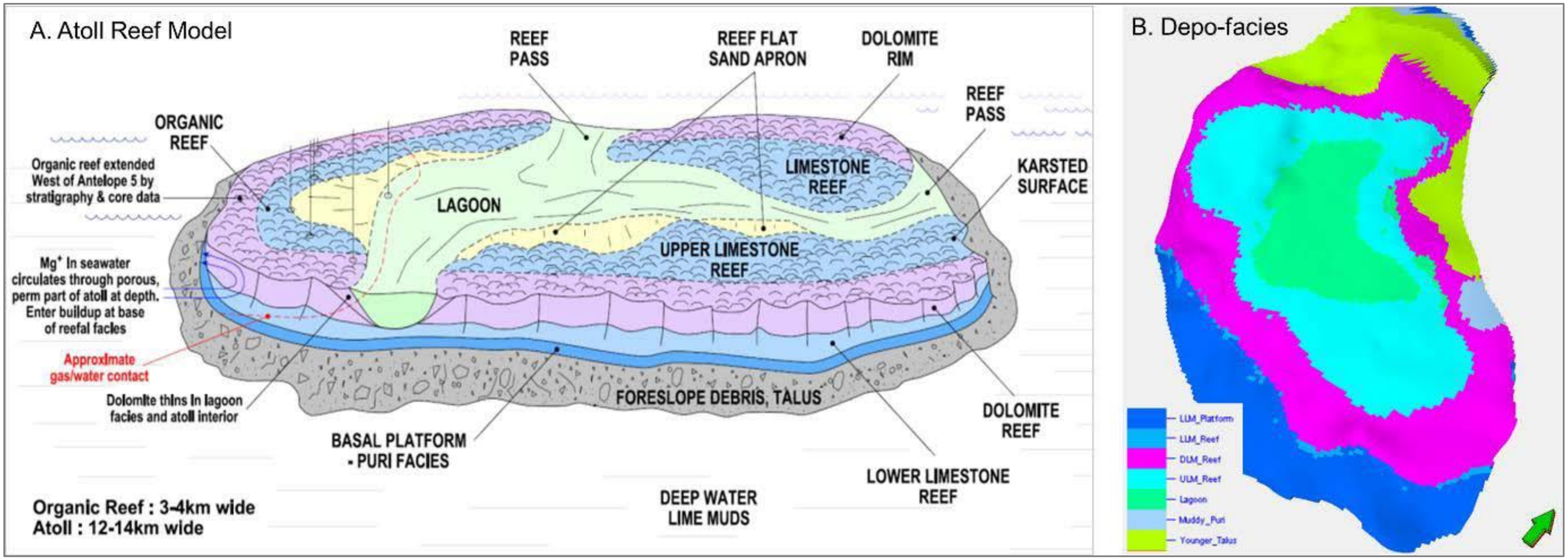

Figure 1. Antelope geological model - atoll-shaped reef build-up and the depo-facies.

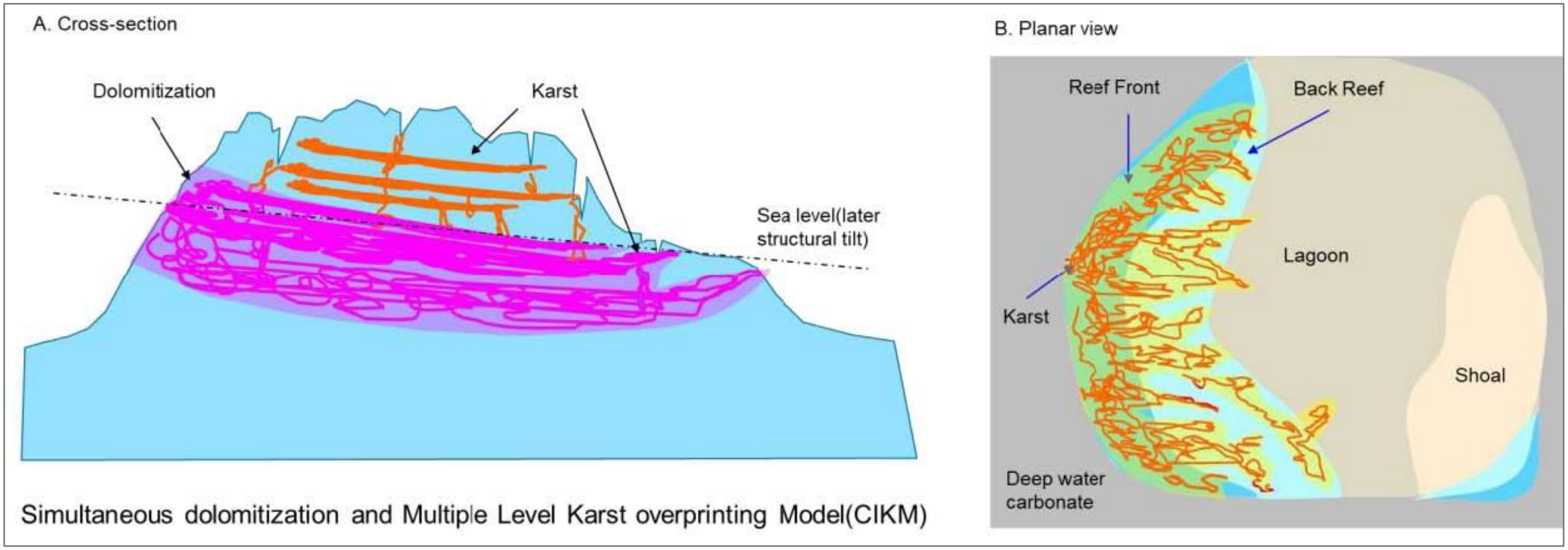

Figure 2. Simultaneous dolomitization and multiple level overprinting Carbonate Island Karst Model.

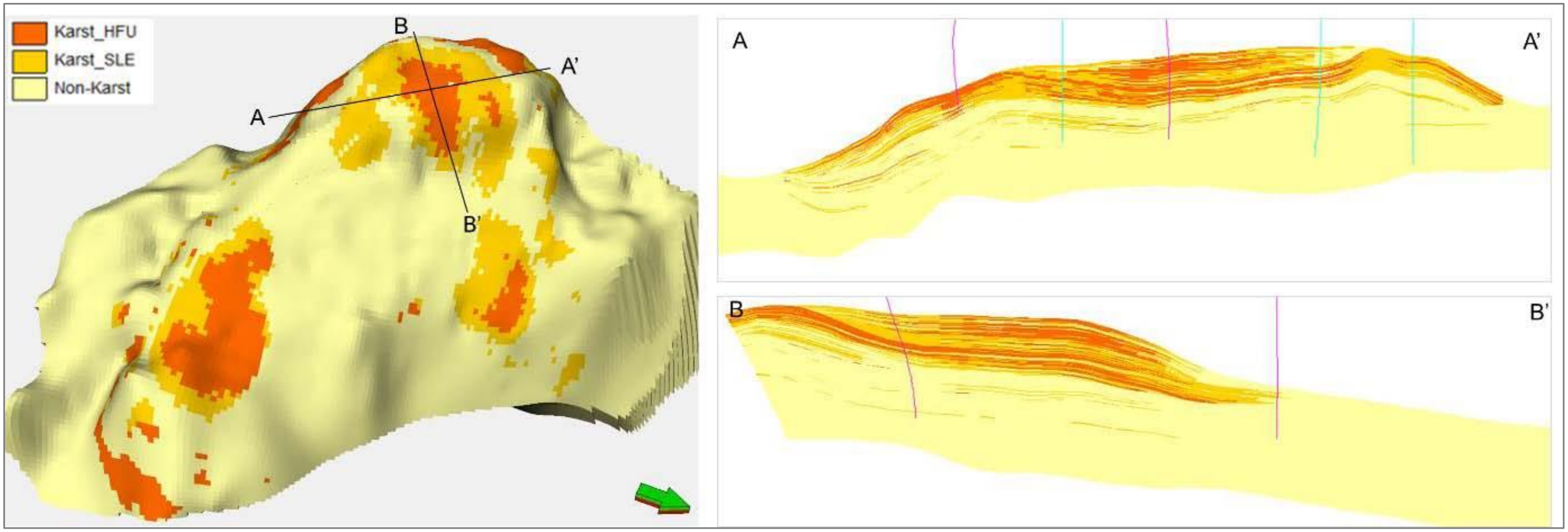

Figure 3. Antelope karst model and example cross-section display the 3D karst network.