Abstract

The development of the Central Luconia carbonate build-ups were strongly influenced by the interplay between eustatic sea-level and basinal tectonics. The Alpha field addressed here is one of the seismically best imaged isolated carbonate platforms in Central Luconia and dendritic features, interpreted as karst, were found to be very prominent throughout the field. Karst is a diagenetic facies, an overprint in sub-aerially exposed carbonate bodies produced and controlled by dissolution and migration of calcium carbonate in meteoric waters. The exploration well in the Alpha field encountered total losses while drilling which was believed to be as a result of drilling into karst (common in Central Luconia carbonates). Some of the best features from Petrel, Landmark and Shell software packages have been integrated to generate an attribute volume for karst interpretation. Using Petrel Geobody, multiple 3D box probes with short time gate and optimum clipping value were used to extract the karst Geobodies. Using a short time gate box probe is crucial for CPU/memory performance and most importantly, to have better control on editing noise and non-karst signal later.

Karst has a big impact on well planning (problem with losses and completion length), the hydrocarbon volume in-place as karst provide substantial secondary porosity; and well management and development strategy (wells nearer to karst are more likely to water-out quicker). This study incorporated an integration of well data, seismic characterization and geological understanding of the field and near-by analogues in building a subsurface model for field development.

Geology

The Central Luconia Province is located in offshore NW Borneo. The province is delineated by two major strike-slip faults, the West Baram in the northeast and the Rajang line in the southwest (Figure 1). Seafloor spreading in the South China Basin during the Oligocene to middle Miocene resulted in formation of a horst graben system that which controlled distribution of subsequent reefal carbonate growth. At mid-late Miocene reefs developed preferably on horst blocks (Mohammad Yamin Ali & Abolins[1]). Two major factors controlling carbonate sedimentation in the Central Luconia province are the regional tectonics and eustatic sea level changes. Tectonics played a role in creating horst and graben structures which served as basement for the onset of carbonate deposition and exerted an influence on the size and shape of the build-ups (Ting et al[2]). The latter also dictated the type of the depositional facies and their distribution which governed the reservoir properties of the carbonate platform.
Field Background

The study area (Alpha field) is part of a chained build-ups located along the Bunga Pelaga High in the central part of the Central Luconia province. The massive carbonate platform measures some $6.6 \times 3.6$ km wide and has a trapezoidal shape with its long axis aligned in a W-E direction.

The Alpha field was discovered by well Alpha-1 based on vintage 2D seismic lines. The Alpha-1 encountered losses which are potentially the result of drilling into karst, a common problem in Central Luconia carbonates. The 3D seismic was then acquired for the appraisal & development of the field, which revealed an extensive network of dendritic features (karst). The appraisal well Alpha-2 was drilled based on the seismic characterization of karst (discontinuity of seismic reflector from semblance/variance cube, see
Figure 2) and successfully avoided the problem.

The wells confirmed the relative thin hydrocarbon column with 85% of the field having only 150ft column length. In order to put in place a field development plan such large field was essential to identify the facies their spatial distribution and overall reservoir property.
The karst has a big impact on future development well planning (problem with losses and completion length), field production (well likely to water-out quicker) and the volume in-place because karst provides substantial secondary porosity. Hence, there is a strong business case to map out the karst in details for the field development plan.

**Seismic Attribute & Interpretation**

The karst interpretation on 3D seismic data was carried out in Petrel but some of the best features from Landmark and Shell proprietary tool were incorporated into the workflow. First, the Landmark FK-Fan filter was applied the 3D seismic to enhance lateral seismic discontinuity and then followed by a Shell proprietary edge-preserving structural-oriented-filter for noise reduction. Next, Shell proprietary Sharp Semblance (similar to Petrel’s variance) algorithm is used to generate a seismic attribute volume.
Using Petrel Geobody, the karst was picked as 3D Geobodies that are extracted based on certain clipping value of Sharp Semblance attribute. The biggest challenge in karst interpretation is the separation of actual signal (karst) versus noise, not only laterally but also vertically as signal and noise may be connected & disconnected in 3D space. Besides that, Geobodies picking is a CPU/memory intensive work, especially when dealing with huge dataset. In order to overcome these issues, multiple 3D box probes with short time gate and optimum clipping value were used to extract the 3D karst bodies in sequence from top carbonate down to. Using a short time gate for the 3D box probe is crucial for CPU/memory performance and most importantly, doing so give better control on noise exclusion and make it easier to edit non-karst signal later. For example, the dendritic features (karst) and the patch reefs (non-karst) both have lateral seismic discontinuity that will be interpreted as the Geobodies. Hence, the patch reefs (circular features on the semblance) needed to be removed & excluded from the Geobodies (Figure 3).

Figure 3: Geobodies Extraction Before and After Edit/QC
In general, the karst had a more chaotic seismic signature (noise) that propagates deeper down, such as at around Alpha-1 area. The 2 intervals where losses were encountered at Alpha-1 matched with semblance signals that indicate possible penetration through the karst. On the contrary, the patch reefs show discontinuity at certain seismic loop at a very short time interval and usually are overlaying a continuous seismic reflector, such as at Alpha-2 area. Overall, the dendritic features (karst) show a consistent pattern as seen in Figure 3, and are concentrated at the centre of the field near Alpha-1. It is also important to acknowledge that there could be sub-seismic karst that could not be mapped out.
Finally, the interpreted Geobodies were outputted in points and are depth converted with base, low and high case velocity model in order to be modelled in the base, low and high case static models respectively.

**Static Modelling**

During the static modelling, the karst property (porosity) uncertainties are tested. It is important to test the impact of the facies on well management and development strategy. At the time of the study, Petrel2009 was the tool used for building the static model. The only method to import and incorporate these karst Geobodies into the static model is by converting it to point data and upscaling it. However, this method gave a ‘staircase’ look in terms of its distribution after upscaling. The issue is due to the karst being sampled in a regular interval in time but when converted to depth, the samples become irregular and the data points become too sparse as the model uses much finer sampling in thickness. This layered pattern of karst is an unrealistic model (Figure 5) and result in decrease vertical permeability due to thin bedded high permeability streak being combined with lower permeability reservoir. Nevertheless, the actual detailed depth converted points were used for well planning.
A second method (Figure 6) was using the seismic variance volume, resampled into the model grid resolution. Then, a calculator function was assigned to extract high attribute value from the variance cube as karst facies. The identified lagoonal patch reef areas are excluded to be assigned as karst facies by using polygons where no extraction is instructed at calculator function.

Cross checks between the two methods with the aforementioned method showed a lot of similarities in terms of distribution and geometry. Therefore the modelling method as shown in Figure 6 was used to model the karst facies in the static model.

Some of the nearby producing fields in Bunga Pelaga High require high porosity value in karst (up to 60% porosity) in order to achieve a history match. The well Alpha-1 encountered losses which are potentially a result of drilling in to karst indicate porous medium. For Alpha field porosity model, karst enhanced porosity of 40 % was assigned over the seismically mapped karst. Manda & Gross\cite{Manda2013} shows the modern fields like karstified Biscayne aquifer of South Florida yields porosity about 40%.
Lastly acoustic impedance volume from seismic is also used to constrain and test the uncertainty of the model; of which tends to result a lower average porosity (only 25%) than the above analogues. All the different interpretations of the karst property are modelled and tested to understand the behaviour of the field productivity.

Summary

The detailed interpretation of the karst is vital for the field development plan for Alpha field in terms of well placement to avoid drilling complications and to maximise hydrocarbon recovery. The different approaches in determining the karst property during the static modelling phase provided a better understanding of the uncertainties in the field productivity.

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Reference

