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Abstract

Late Triassic Prospectivity Insights from Automated Pre-interpretation Surfaces, Carnarvon Basin

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Summary
The Carnarvon Basin of the Australian Northwest Shelf is a world class gas province with joint venture groups investing billions of dollars on the creation of LNG infrastructure to produce these resources. Over the last twenty years more than 100,000 km2 of 3D seismic has been collected, providing the seismic interpreter with 100's of terabytes of post-stack data. Recently proposed facies models for the Triassic Mungaroo and Brigadier Formation reservoirs (Payenberg et al. 2013 and Adamson et al. 2013) are a synthesis of detailed contributions from countless geoscientists over a period of many years.

Since the authors do not have access to the large pool of skilled professionals or the resources of major oil companies, a new alternative approach was adopted to complete the study. A fully automated pre-interpretation processing technique was applied to the open file 3D seismic data from the Carnarvon Basin creating spatial databases of virtually every peak and trough surface in all of the 3D seismic volumes. Queries to these databases with respect to play elements such as structure, reservoir, seal and DHI's of several major gas fields enabled rapid integration and validation with the proposed geological facies models. With so many surfaces available for integration with the facies models, new detail was revealed about complex faulting, fluid contacts and reservoir forms. Moreover, many of these surfaces highlight reservoir detail such as differential compaction, channel and sand body distribution, brine versus gas saturation as well as insights into seal distribution and competency. In addition to validating many aspects of the recently proposed models, the spatial database of surfaces revealed new insights about key elements of the late Triassic gas plays and identified additional prospectivity.

Geological Setting & Depositional Model
The North Carnarvon Basin lies predominantly offshore Western Australia. It covers about 500,000 km2 and contains up to 15 km of Phanerozoic sedimentary rocks (Baillie et al., 1994; Stagg & Colwell, 1994). The study area extends from the Rankin Trend across the Kangaroo Syncline to the central Exmouth Plateau and covers 30,000 km2. Water depths range from 200m to 2,000m (Figure 1).

The structural architecture and evolution of the study area is similar to the four stages described by McCormack and McClay (2013) for the Gorgon Platform which is the southern part of the Rankin Trend. In Stage 1, the Mungaroo and Brigadier Formations were deposited after a period of thermal sag and are assigned to the TR20 and TR30 Play Intervals (Marshall and Lang 2013). In Stage 2, rifting and extension from latest Triassic to late Jurassic resulted in a prominent NNE-SSW fault trend. Stage3, was a period of oblique extension from the late

Jurassic to early Cretaceous. Finally, in Stage 4, from the early Cretaceous to present-day the platform has been a passive margin and has subsided.

The Mungaroo environments of deposition vary from marine pro-delta in the western outboard area, to deltaic and coastal plain in the medial area, and fluvial in the eastern inboard region on the Rankin Trend (Adamson et al., 2013) (Figure 1). The Brigadier environments of deposition vary from offshore carbonate and reefal in the outboard and medial regions to fluvio-deltaic and fluvial inboard (Adamson et al., 2013 and Grain et al. 2013).

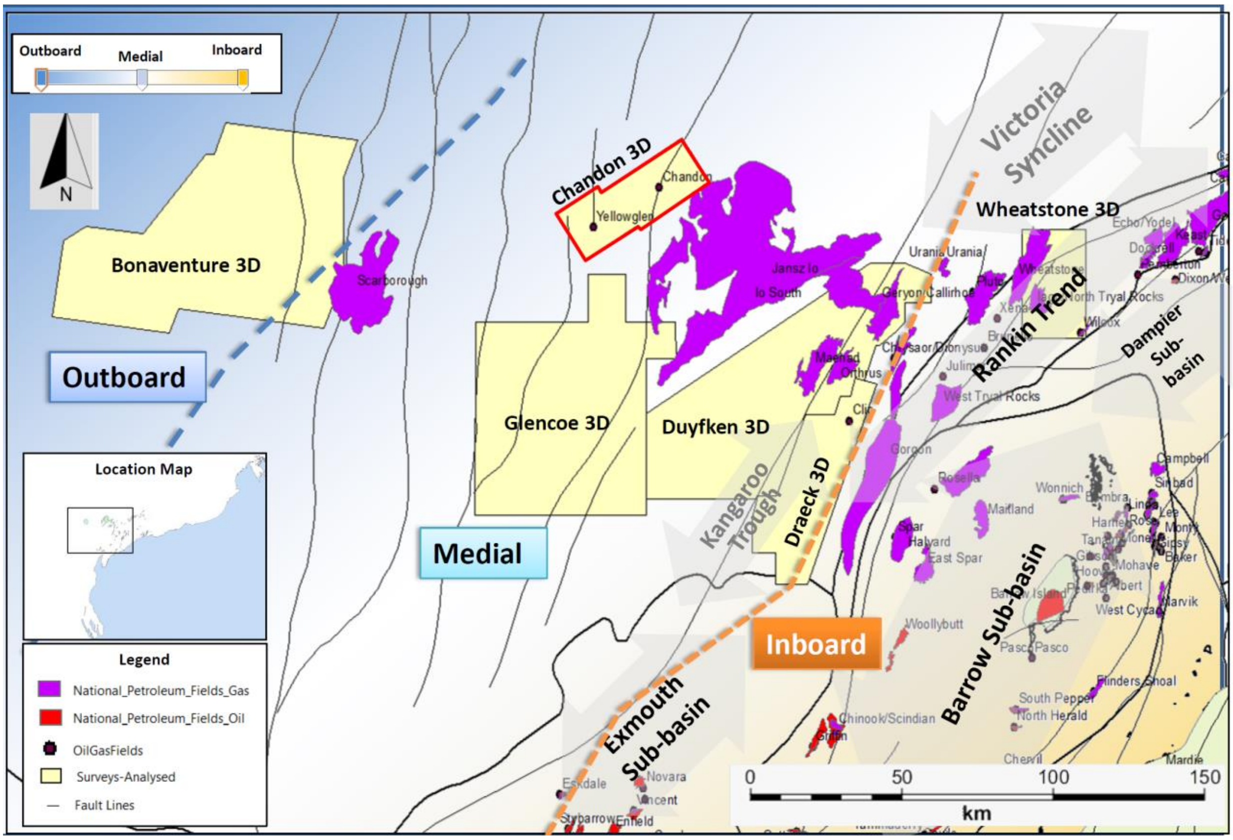

Figure 1: Northern Carnarvon Basin location map showing, gas fields, structural elements, open file 3D marine seismic surveys pre-interpretation data sets and late Triassic facies regions (Inboard, medial and outboard) after Adamson, 2013

Pre-interpretation Processing Concepts and Methodology

With the number, size and density of 3D seismic data coverage increasing dramatically over the last two decades, traditional methods of extracting surfaces can only examine relatively small portions of the available data. Consequently, there is a need to develop more automated analysis methods that can quickly and consistently process entire volumes to help ensure our geological models are developed based upon a review of all the data instead of only a small portion.

The pre-interpretation processing method applied in this study was inspired by mathematical techniques developed in the Human Genome Project (Dirstein & Fallon, 2011). Genetic algorithms are mathematical processes that use the principles of natural selection and biological evolution to determine the variability and size of a surface within a seismic 3D volume.

The processing algorithm initially segments every trace in the seismic volume into waveforms. From there, a waveform will only join with another waveform population if there is sufficient spatial genetic compatibility. The evolutionary process continues simultaneously throughout the volumes until virtually all populations of trough and peak surfaces have been identified and catalogued into a 3D visual database of uniquely named Geo-Populations™. Open file final full stack SEG-Y volumes were processed to produce pre-interpreted data bases of GeoPopulations using a computer workstation hardware with eight cores and 192 Gigabytes of memory.

The pre-interpreted 3D visual databases of GeoPopulations were then reviewed using a range of query criteria in the 3D viewer provided. Each GeoPopulation has associated attributes including two-way time (TWT), amplitude and fitness. The fitness attribute provides a measurement of the genetic relationship between any individual trace waveform to the common waveform (genotype) for the entire population. Variability observed on the fitness map draws the interpreter's attention to areas of changing reflector geometry. Review of these fitness changes and their morphology often reveals insights about changes in lithology, depositional facies, pore fluid, reflector geometry and the stability of boundary conditions. While many of the open file 3D seismic data volumes have been processed in this manner, one example is included in this abstract.

GeoPopulation Case Study

Chandon and Yellowglen: Triassic Fault Traps, TR30.1 TS

The Chandon and Yellowglen Gas Fields are Triassic footwall fault traps which dip to the east. The Mungaroo reservoir consists of amalgamated sands (TR27-28 fluvial and TR29 deltaic) that are sealed by the Brigadier (TR30.1 TS). The surface interpreted to be the TR30.1 reservoir was selected from more than 300+ surfaces available from the data base. The two-way-time and sub-waveform attribute maps of the surface are displayed (Figure 2). The complex faulting and structures within the graben are defined exceptionally well on the pre-interpretation surfaces (Figure 2 panel (a)). While the full waveform fitness map of the TR30.1 GeoPopulation was fairly featureless, the sub-waveform fitness map (Figure 2 panel (b)) highlights amalgamated channels within the reservoir at Chandon and also the extent of the gas water contact at Yellowglen. The sub-waveform fitness and time surfaces are co-rendered in panels (c) and (d) and sub-waveform strips are displayed on seismic sections through the wells in panels (e) and (f). The gas water fitness anomalies are clear on smaller structures within the graben to the west of Chandon and Yellowglen suggesting these are also gas accumulations. At Chandon there may be a fitness anomaly associated with the gas water contact but the feature is broader and therefore difficult to differentiate from the channel features. This case study from the medial region showed how co-rendering of TWT and sub-waveform analyses were used to map DHI's and reservoir trends.

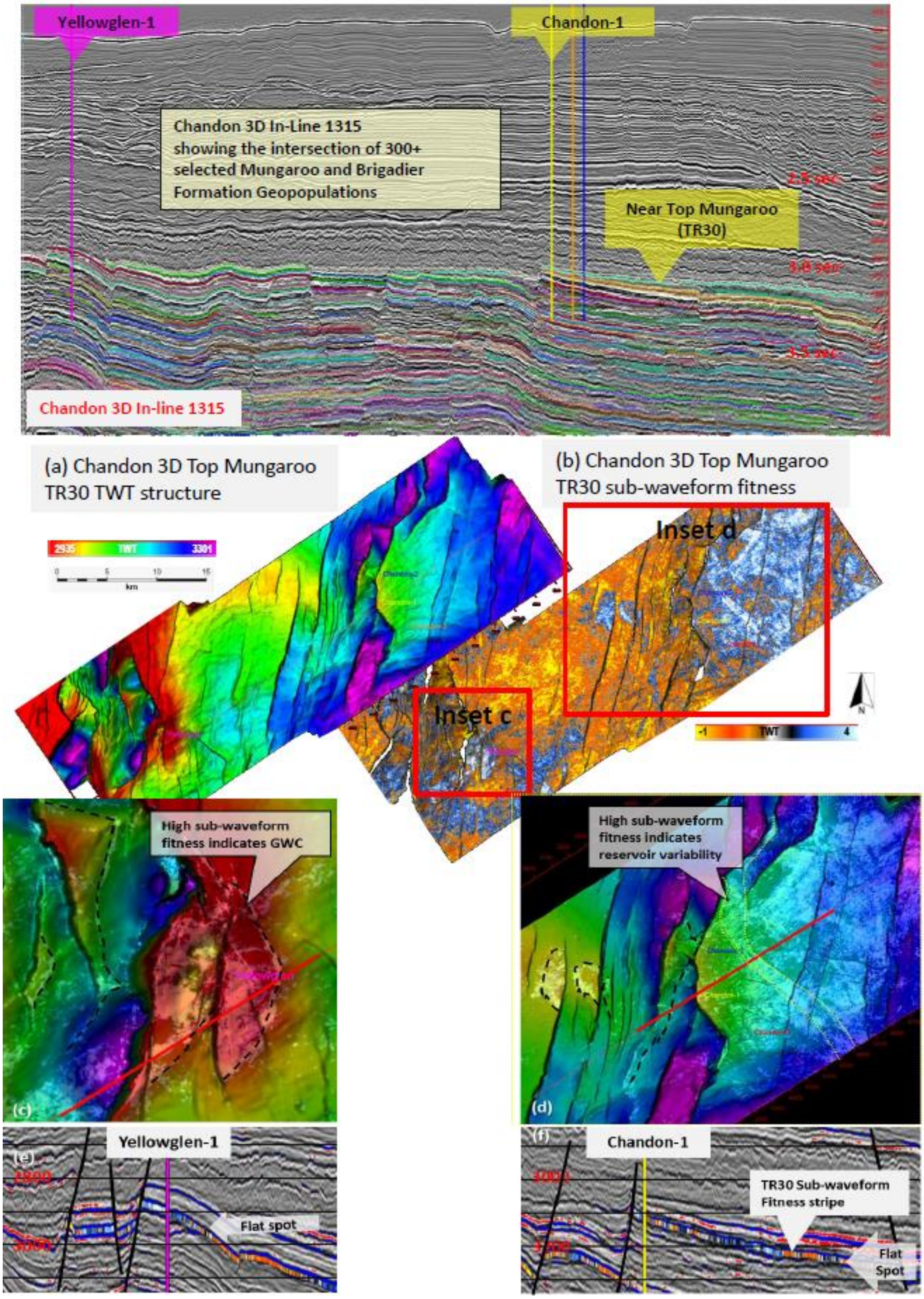

Figure 2: Chandon 3D, Medial facies region; Intersections of 300+ Mungaroo and Brigadier Formation geopopulations generated by pre-interpretation processing displayed on an arbitrary seismic line

(Chandon 3D) in panel (b) and in panel (c) the Top Mungaroo (TR30) two way time surface generated by selecting and merging several geopopulations

Conclusions

Once the database of pre-interpreted projects was built, the process of analysing and reviewing such a large area could be achieved in real time. Since all the surfaces were extracted using the same mathematical criteria applied to the entire volume, the geoscientist can spend more time thinking about the results. Moreover, this workflow is much more observation driven compared to a more traditional workflow and could easily be extended and applied to a wide variety of objectives such as; Fluid Flow Studies (Dirstein et al., 2013) and Geohazard Analysis (Dirstein et al., 2011).

Acknowledgements

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Biographies

Jim Dirstein studied Geology and Geophysics at the University of Toronto graduating in 1980. With more than thirty-five years of international experience in the oil industry including the last twenty-two years as the founder/director of Total Depth Pty Ltd. He is currently involved in petroleum exploration, Coal mining and airborne exploration projects which include aspects of prospect generation/appraisal/development, training, research and business development. Aside from his activities with Total Depth Jim has helped with the commercialization and application of several new technologies. Recently, this has included the refinement of a patent of a new airborne geophysical technique; Seisnetics patented processing algorithm and establishing Geoproxima Pty Ltd. Jim is a member of the ASEG and has current memberships with SEG, PESA, AAPG, SEPM and EAGE.

Alistair J. Stanley received his B.Sc. from Durham University in 2009, studying Natural Sciences where he majored in geology. Alistair is experienced in the oil industry having worked with both Pinemont Technologies on airborne exploration projects and Total Depth Pty Ltd. His work with Total Depth Pty Ltd has included the processing and interpretation of seismic data from a variety of sedimentary basins throughout Australia for both petroleum and coal exploration projects. He spends most of his time developing the pre-interpretation processing technology Seisnetics™ and GeoProxima™ having actively contributed to its application in both academic research projects and corporate workflows.

Cliff C. Ford studied Geology at the University of Western Australia gaining his BSc (Hons) in 1980 and Geophysics at the Western Australian Institute of Technology. He worked for WAPET, SANTOS and WMC Petroleum until 1997, as geologist, geophysicist and explorationist. Since then he has consulted as an Interpretation Geophysicist to the exploration industry. Cliff is a member of AAPG and PESA.