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From two way time to depth and pressure for interpretation of seismic velocities offshore: Methodology and examples from the Wallaby Plateau on the West Australian margin

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ABSTRACT

The effect of water loading can account for sub-seafloor seismic P-wave velocity increases exceeding 1 km/s from shallow to deep water, but it is commonly ignored in offshore studies. Direct comparative analysis of interval velocity patterns between areas of significantly different water depths requires various water pressure related changes in velocity to be accounted for. This apparently simple task is not easy to implement in practical terms. One approach is to try to predict velocity increase at any given depth due to the pressure effect of water layer above, and then to reduce the observed interval velocity at that depth by subtraction of the predicted velocity increase. Interval velocities at different locations thus reduced can be compared and conclusions about rock lithology can subsequently be made. The application of water depth adjustments to seismic velocities, and the methods used to apply them, remain controversial. The presentation of velocity models as a function of pressure rather than two-way time, or depth, emerges as a possible solution.

Analysis of appropriately adjusted seismic interval velocities from Geoscience Australia's 2008/09 seismic survey GA 310 in conjunction with seismic reflection interpretation provides new insights into the geology of the Wallaby Plateau, offshore of Western Australia. Seismically distinctive divergent dipping reflector sequences (DDRS), identified in the area, are similar in seismic character to seaward dipping reflector sequences (SDRS) of inferred volcanic composition.

The water depth adjustment of seismic velocities analysed in our study reduces the distinction between SDRS, DDRS and sedimentary strata such that discrimination between volcanic and sedimentary strata in DDRS or SDRS is equivocal. A major uncertainty of this interpretation is caused by a lack of global reference velocity models of SDRS and DDRS.

1. Introduction

The Wallaby Plateau (Fig. 1) has been regarded as important to the understanding of the break-up of Western Australia and Greater India since the first description of its bathymetric characteristics. In 2008 a major portion of this submerged plateau was allocated to the Commonwealth of Australia under the United Nations Convention on the Law of the Sea. Despite the long history of study, the interpretation of the gross lithology of the Plateau remains largely speculative (Sayers et al., 2002).

This work is based on data from the 2008/09 seismic survey (GA 310) contracted by Geoscience Australia as part of the Offshore Energy Security Program to examine the geology of the southwest Australian margin, including the Wallaby Plateau. Five seismic lines were acquired across the Plateau using an 8 km long solid streamer and a 4290 in^3 airgun array with 106-fold recording.

Interpretation of these reflection profiles reveals seismically distinctive divergent dipping reflector sequences (DDRS). The DDRS are ~30–50 km wide and up to ~6–7.5 km thick, with generally smooth upper surfaces and concordant to on-lapping divergent internal reflectors (Fig. 2). These are similar to (1) seaward-dipping reflector sequences (SDRS) described beneath the Wallaby Saddle by Symonds et al. (1998); (2) correlative sequences on GA 310 lines (e.g., Fig. 3); and (3) SDRS on other volcanic margins globally (e.g., Planke et al., 2000).

Existing models for SDRS formation favour predominantly volcanic composition of these structures, with rift related volcanism assumed to fill accommodation space created in the process of rifting and with accumulation of 4–10 km thick tholeiitic basalts with minor tuffs and sediments over periods under 5 Ma (Planke et al., 2000; Symonds et al., 1998).

DDRS and SDRS have been interpreted in nine areas crossed by lines 59, 61 and 62 of survey GA 310. In this work we look at several representative examples and a similar style of analysis will be extended to other areas in the future.

This work is largely a discussion paper: the issue of using seismic interval velocities derived from stacking velocities to interpret rock

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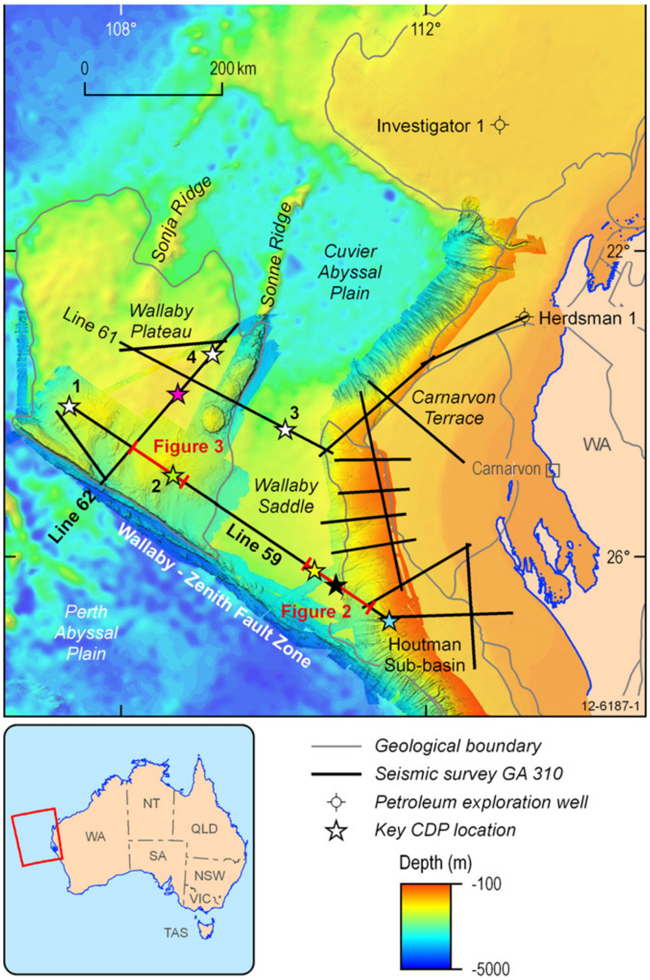

Fig. 1. Study area and location of seismic sections. Background bathymetry is derived from satellite measurements (low resolution) and ship-board SWATH data (high resolution). Key CDP locations are discussed in the text and colour coded to sections and graphs in Figs. 10 and 11. Locations marked 1 to 4 correspond to SDRS/DDRS areas 1 to 4 represented by graphs in Fig. 14.

lithology is controversial and has been a topic of considerable debate over the years (e.g., Al-Chalabi, 1994; Sheriff and Geldart, 1995). There are also controversies in the approaches used to estimate compaction-related and true lithologically-related effects on seismic velocities, particularly in the offshore environment where just the variation of water depth from shallow to deep can result in compaction-related velocity increases exceeding 1 km/s. This study, based on combined analysis of seismic velocities and reflectivity patterns, provides new evidence of the rock types present on the Plateau, and casts some doubt on the predominantly volcanic composition of the DDRS/SDRS interpreted in the GA 310 data.

2. Geology summary

Early studies of the Wallaby Plateau assigned a variety of origins and characteristics: largely continental (Symonds and Cameron, 1977); a volcanic build-up formed on oceanic crust (Veevers and Cotterill, 1978); the result of convective partial melting following a ridge-crest jump in the Cuvier Abyssal Plain (Colwell et al., 1994); and part of a hot-spot trail involving the Bernier Platform and the Wallaby and Zenith Plateaus (Mihut and Müller, 1998). Later studies based largely on the seismic reflection characteristics and tectonic setting of the Wallaby Plateau (Sayers et al., 2002; Symonds et al., 1998) proposed that it is a composite feature cored by areas of extended continental crust that have been modified and blanketed by voluminous magmatism associated with breakup and transform development along its southern margin.

Rock lithology within geological structures imaged as DDRS/SDRS has a direct implication for petroleum prospectivity of the area. If these structures are made of predominantly volcanic material, then the prospectivity would be low. But if they are made of a mixture of sediments and volcanics, then the relative fraction of these components, their ages and their spatial distribution will complexly interplay, and only advanced subsidence and hydrocarbon maturation modelling will permit a sensible assessment of the resultant petroleum prospectivity.

3. Interpreting lithology from seismic interval velocities

3.1. Velocity processing and calculation of interval velocities

In this study we consider two types of interval velocities (V_{int}): (1) V_{int} calculated along vertical profiles through the crust at fixed locations, and (2) V_{int} calculated between certain horizons interpreted in the reflection seismic data and therefore characterising velocity variation along the line between a number of fixed locations. Interval velocities of the first type are discussed in Section 4, and those of the second type — in Section 5. The first type is more formal than the second because its calculation does not depend on subjective interpretation of seismic horizons, and is controlled by less subjective selection of certain coherent events in pre-stack data.

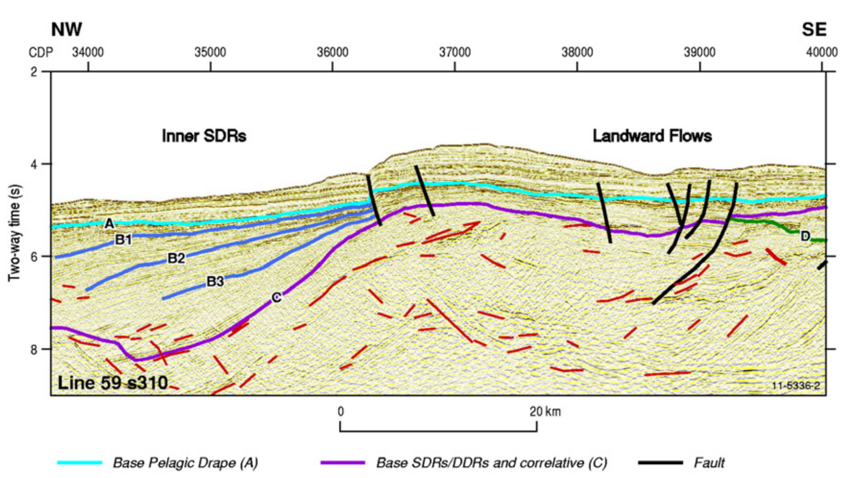

Fig. 2. Interpreted seismic section along line 59 of survey 310 illustrating divergent dipping reflector sequence (DDRS) on Wallaby Saddle. Line location shown in Fig. 1.