Estimating the amount of uplift during Canning Basin tectonic events using well logs

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SUMMARY

The on-shore Canning Basin, located in northern Western Australia, has a long and complex depositional and tectonic history spanning almost the entire Phanerozoic. The succession includes several regional unconformities and estimating the amount of uplift with which they are associated can provide important constraints on the geohistory of the basin.

Estimation of uplift based on analysis of sonic slowness- and density-depth data is a well-established method but has mostly been applied to Mesozoic basins which have experienced relatively little deformation. Application of the method to the Canning Basin requires careful definition of the 'reference curves', with particular attention paid to the geological context of the reference well locations, and the use of a combination of density and slowness data.

Initial results, from the Permian Noonkanbah Formation have produced results which are consistent with the known history of the Canning Basin. The map apparent uplift suggests only a few hundred meters of uplift has occurred and the dominant trend is parallel to the Fitzroy Trough, the main fault controlled depo-centre in the northeast of the basin.

Key words: Canning Basin, density log, sonic log, uplift.

INTRODUCTION

The on-shore Canning Basin is located in the north of Western Australia (Fig.1). The basin contains strata ranging in age from Early Ordovician to Early Cretaceous. A total sediment thickness of over 15 km is reported, concentrated in two NW trending depocentres. The northernmost of these is the Fitzroy Trough-Gregory Sub-basin complex, while the southernmost is the Willara Sub-basin - Kidson Sub-basin complex. At least eight tectonic phases have affected the area (Kennard et al., 1994), creating a very complicated history in terms of heat flow, structure, hydrocarbon generation/migration and timing.

Funded by the Western Australian |Government's Exploration Incentives Scheme the Centre for Petroleum Geoscience and CO2 Sequestration is working with CSIRO on an integrated geoscientific study of key system elements and events affecting the Canning Basin (Fig.1); relevant to exploration for energy resources and geo-sequestration of CO2. As part of this project all available downhole logs have been collated, offering the opportunity to assess the suitability of the Canning Basin for quantification of uplift associated with tectonic events using logs that measure porosity. Such estimates of apparent uplift data can be used in conjunction with fission-track and vitrinite reflectance data in geohistory modelling of the Canning Basin.

METHOD

The estimation of the amount of uplift using sonic logs has been successfully applied to Mesozoic and younger basins in Europe and on-shore Australia, see for example Hillis (1995). The technique is conceptually very simple (Fig.2). Slowness (interval transit time), as measured by the sonic log, is a measure of porosity, which is reduced as over burden pressure increases with depth of burial. Because compaction is irreversible the slowness data provides information about a unit's maximum depth of burial. Comparison with a reference (maximum burial) slowness-depth curve allows the determination of whether the unit is currently at its maximum depth or has been subsequently uplifted to a shallower depth. The amount of apparent uplift (E_A) is estimated from the difference between the observed and reference curves.

Crucial to the method is the definition of the reference curve. The most common approach involves determining average slowness and average depth for the same stratigraphic interval in all available wells. These data are plotted and points with the greatest slowness for a given burial depth are assumed to define the reference curve (Fig.2). At depths greater than a few hundred meters this curve is close to linear and the reference curve is defined by fitting a straight line to these data.

The method has been trialed on the Permian Noonkanbah Formation (Fig.3). This unit was chosen because it (i) is widespread across the basin, (ii) comprises a consistent lithotype so facies related slowness variations are unlikely, (iii) is mostly argillaceous, and therefore likely to experience significant compaction, (iv) was deposited relatively soon before the Fitzroy Transpression (Triassic) which is the last major tectonic event to affect the basin and hence is likely to record uplift only from this event.

Concerns about applicability of the method to the Canning Basin, its complex tectonic history, led to the following variants on the established methodology:

- The average slowness-average depth plot was used to identify wells which were potentially sources of the reference curve. The entire log datasets from these wells were combined and regression used to define the reference curve.
- The reference curve was only defined in the depth interval for which data were available, i.e. no extrapolation.
- The process was repeated using the bulk density (rhob) log (fewer available than sonics) to ensure the same wells were defining the reference points and estimates of uplift where correlated.
- The locations of the reference wells were compared with each other and all wells from which data were available to assess clustering of reference wells and geographic isolation from non-reference wells and that the geological setting of the reference wells was plausible as locations of minimum uplift.

RESULTS

Figure 3 shows estimated uplift in the northern Canning Basin. The map of uplift suggests only a few hundred meters of uplift has occurred and the dominant trend is parallel to the Fitzroy Trough. Wells lying on the Pender Terrace were found to meet the criteria for defining the reference curve. This is consistent with the known nature of the Fitzroy Transpression, which involved reaction of NW-SE trending fault in the Fitzroy Trough in a dextral transpressive environment. However, the reference wells are located on the margins of the main area of deformation and so the apparent uplift may be under-estimated since it is not relative to an area unaffected by tectonic activity.

CONCLUSIONS

Estimating uplift from well logs is a well-established method in Mesozoic basins and has been applied to several moderately deformed basins in the northern hemisphere. Although the succession is older and the basin history complex, estimation of the amount of uplift in the Canning Basin using well log (sonic, bulk density) data appears feasible if data are carefully selected and interpreted. Data from the Permian Noonkanbah Formation are consistent with the known history of the basin and offer encouragement to apply the method to older units within the Canning Basin.

ACKNOWLEDGMENTS

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REFERENCES

Hillis, R.R., 1995. Regional Tertiary exhumation in and around the United Kingdom.In, Buchanan, J.G. and Buchanan, P.G. (eds), Basin inversion. Geological Society Special Publication 88, 167-190.

Kennard, J. M., Jackson, M. J., Romine, K. K., Shaw, R. D. and Southgate, P. N. 1994a. Depositional Sequences and Associated Petroleum Systems of the Canning Basin, W.A. *In:* Purcell, P. G. & Purcell, R. R. (eds.) The Sedimentary Basins of Western Australia, Proceedings West Australia Basin Symposium Perth.

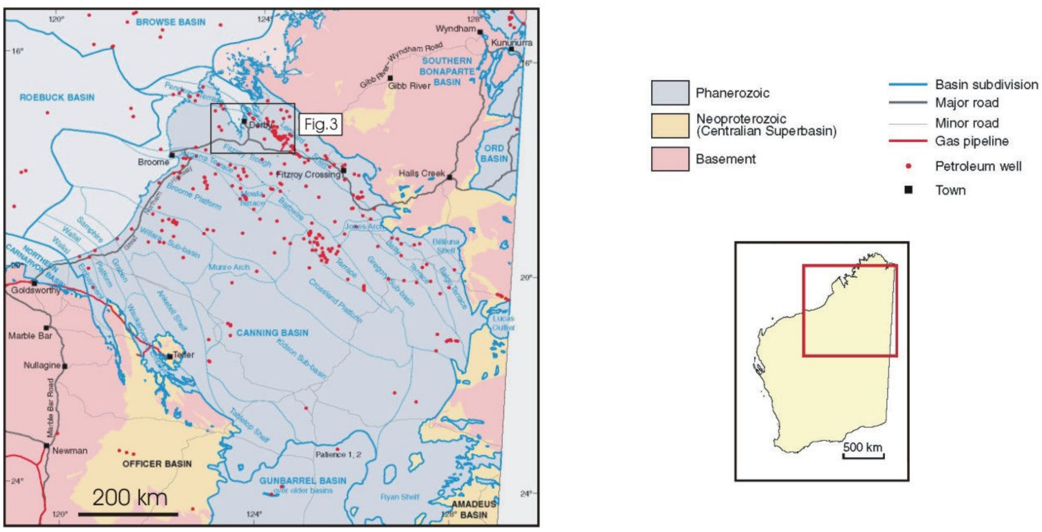

Figure 1. Map of the Canning Basin showing major structural elements and locations of wells. Modified from GSWA.

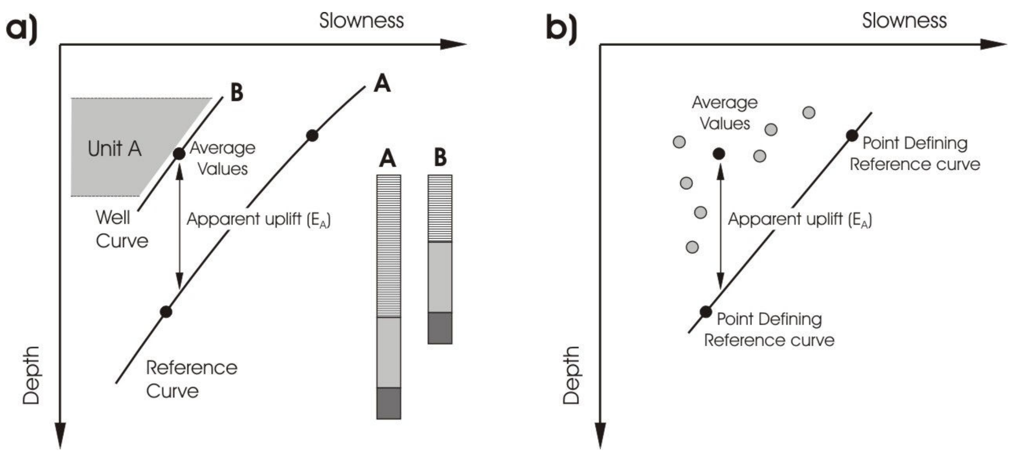

Figure 2. Idealised evolution of seismic slowness during maximum burial (A), subsequent exhumation (B). Apparent exhumation (E_A) is estimated from the displacement, along the depth axis of the sonic slowness/depth relationship of the exhumed sequence (B) from that of the normally compacted or reference, sequence (A). Modified from Hillis (1993).

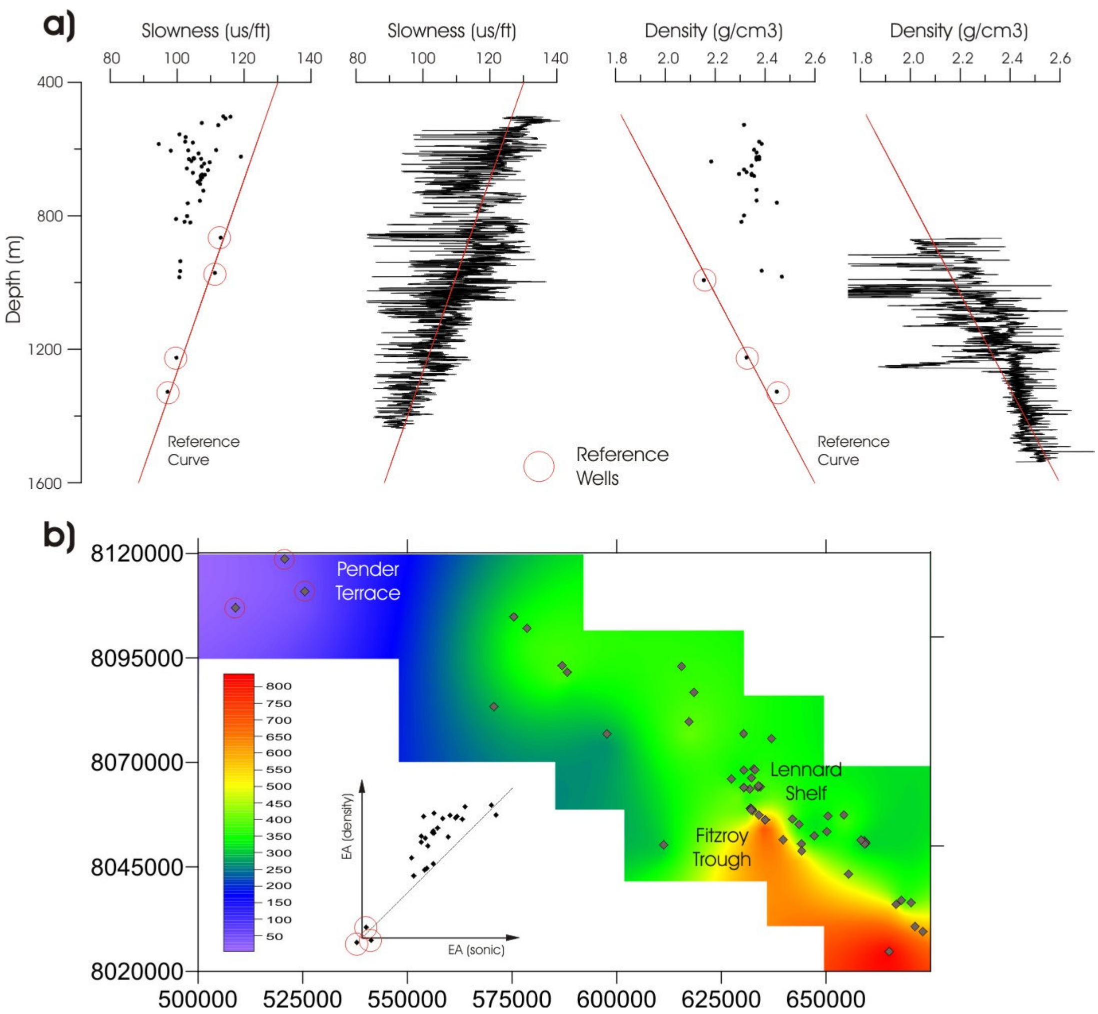

Figure 3. Estimation of tectonic uplift of the Noonkanbah Formation based on sonic and bulk density logs.See Figure 1 for location of map.