Australian Government
Geoscience Australia
AUSGEO news
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in brief

A new method to map areas of hard seabed

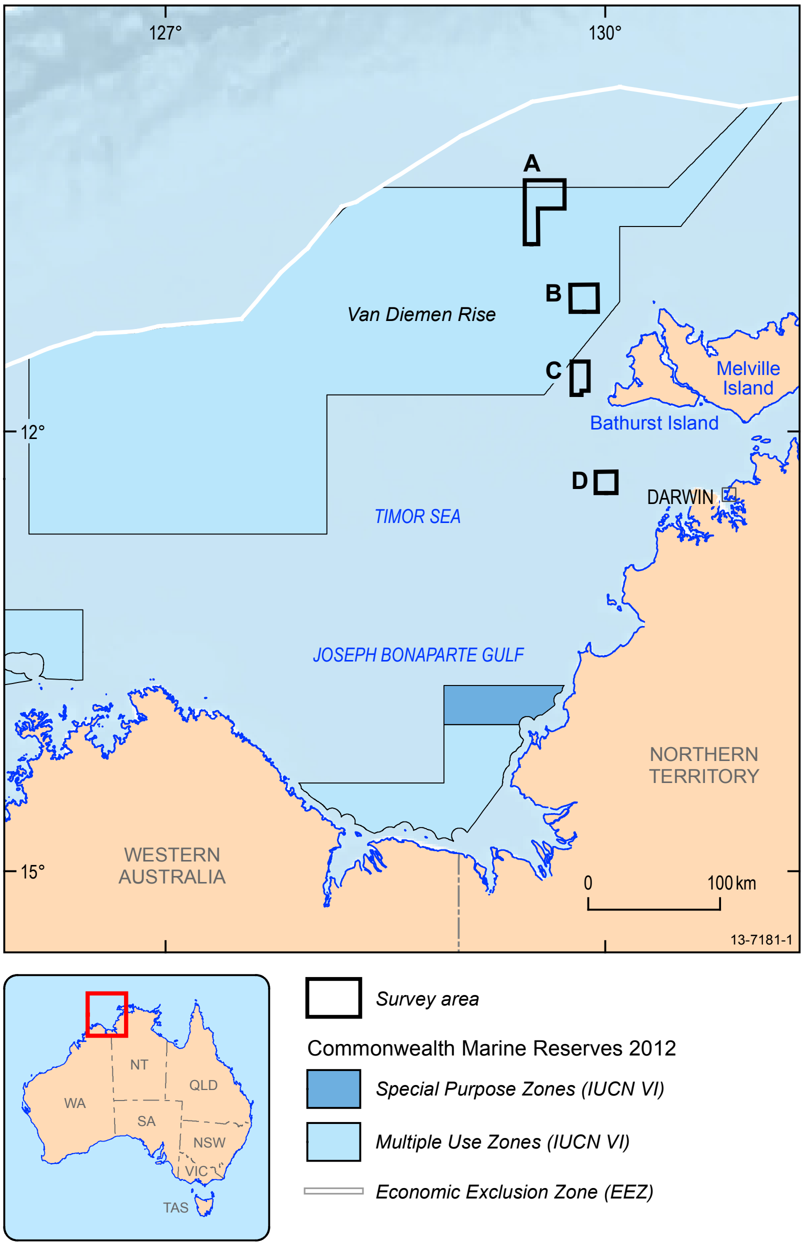

Figure 1: Map of the study area with Commonwealth Marine Reserves and Geoscience Australia survey areas indicated (A-D).

Background

A defining characteristic of the seabed is its hardness or mobility. For marine ecosystems, hard seabed provides the solid substrate needed to support benthic communities, often forming hotspots of biodiversity such as coral and sponge gardens. For the offshore resource and energy industry, knowledge of the distribution of hard versus soft seabed is important for planning infrastructure such as pipelines and wells. Knowledge about hard and soft seabed is important also for managing risk posed by geo-hazards such as migrating sand waves or mass movement on steep banks. Maps which delineate areas of hard and soft seabed are a key product therefore to informed management and use of Australia's vast marine jurisdiction.

As part of the Australian Government's Offshore Energy Security Program (2007–11) and its National CO2 Infrastructure Plan (2011–15), Geoscience Australia has been developing integrated seabed mapping methods to better map and predict seabed hardness using acoustic data (multibeam sonar) integrated with information from biological and physical samples. These samples, which include video observations, provide direct insight into the composition of the seabed, but their number and distribution are usually limited. In contrast, multibeam sonar mapping of the seabed provides full coverage data at high spatial resolution (decimetre). These data are processed to provide bathymetric maps and maps showing the intensity of the acoustic signal return, which is referred to as backscatter. It is this backscatter information that Geoscience Australia has been using to develop new methods for mapping areas of hard and soft seabed.

The Timor Sea and Joseph Bonaparte Gulf off northern Australia include extensive areas of hard seabed comprising carbonate banks and shoals which are complex in their spatial distribution, having rocky banks separated by valleys and plains (Przeslawski, 2011). The region is a significant area for both resource exploration and environmental conservation, with petroleum exploration blocks overlapping Commonwealth of Australia Marine Reserves (Multiple Use Zones therein). Adding to this complexity, an area of the outer Joseph Bonaparte Gulf has been identified as a potential site for the geological storage of carbon dioxide (the Petrel Sub-basin) (Figure 1). The relevance and the need for baseline marine environmental information to support the management of these diverse activities across this region have never been greater.

Seabed prediction methodology

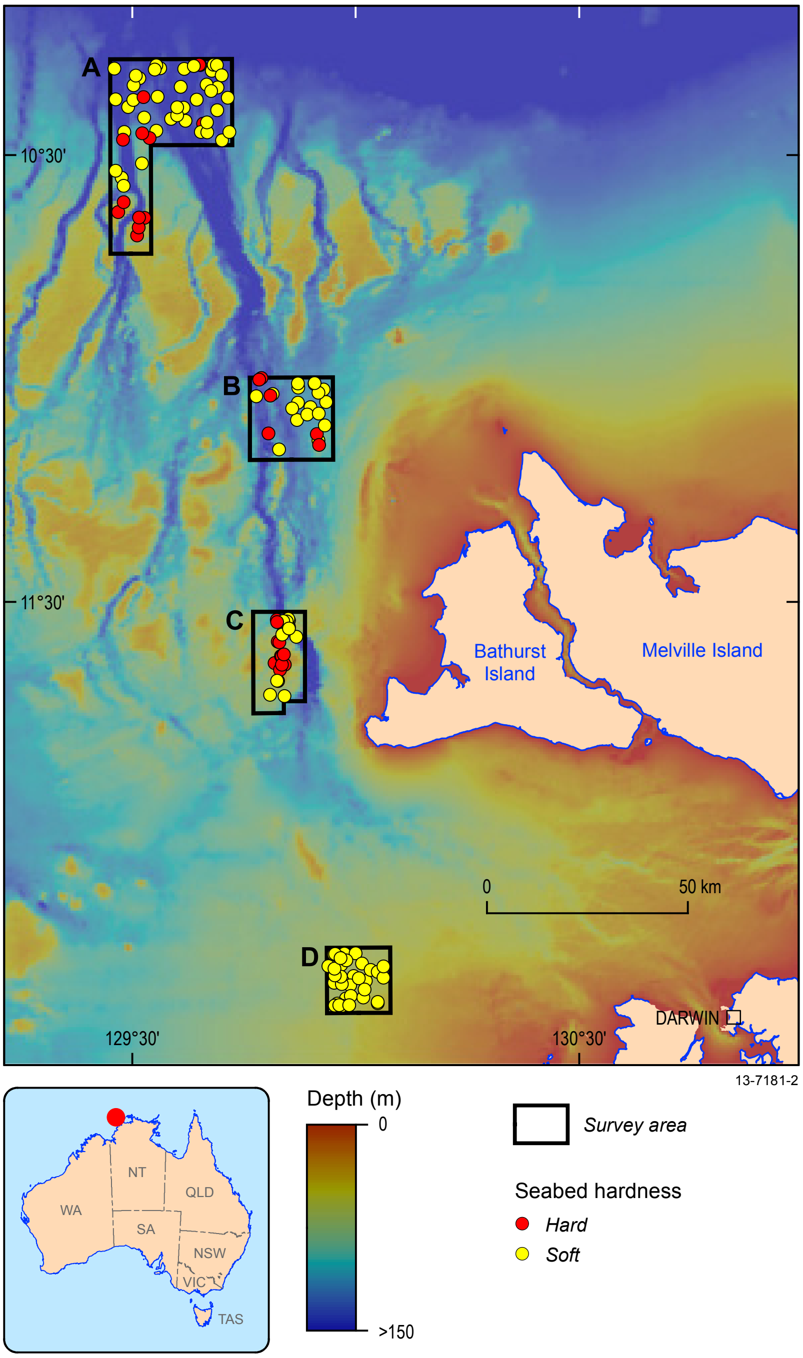

Figure 2: Bathymetry map of Van Diemen Rise (Joseph Bonaparte Gulf) showing Geoscience Australia survey areas (A-D) and point samples of seabed hardness observed from underwater video.

With a focus on the carbonate banks of the Van Diemen Rise in Joseph Bonaparte Gulf, multibeam data from surveys completed by Geoscience Australia in 2009 and 2010 were used to test two independent approaches to identify areas of acoustically hard seabed. The initial interpretation of acoustic backscatter indicated that the shallow tops of the carbonate banks produce the highest backscatter return, i.e. they are acoustically hard. Terraces also show a strong acoustic return. In contrast, sediment deposits between the banks and terraces have the weakest acoustic returns. The potential for these relationships to be modelled and supported by quantitative analysis provided the impetus for this work.

The first method used was a two-stage, classification-based clustering method which used acoustic backscatter angular response curves to derive a substrate type map. The angular response curve represents the backscatter value in relation to the incidence angle, defined as the angle between the acoustic signal return from the seabed and the vertical axis of the vessel. The second method was a prediction-based classification using a machine learning method called random forest. This method was based on bathymetry, backscatter data and their derivatives, as well as underwater video and sediment data.

The two methods were applied to 140 sample sites which had underwater video characterisations of seabed type in the survey areas (Figure 2).

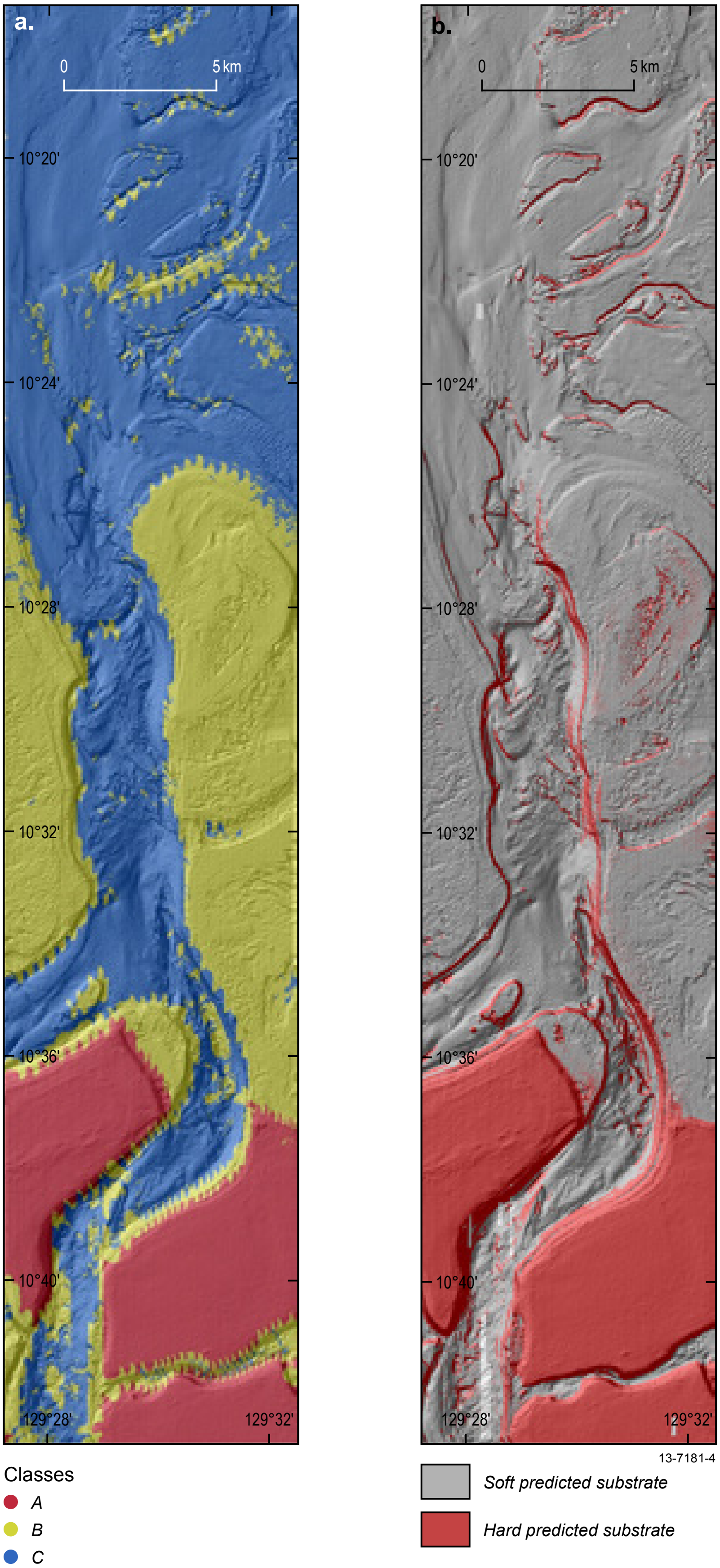

Figure 3: Map of seabed hardness for a section of survey Area A, based on results from (a) the two-stage classification approach (A – hard, B – mixed, C – soft) and (b) the prediction approach.

Results

The first classification approach generated three classes of substrate (hard, mixed and soft) that clearly associate with geomorphic features on the seabed (Figure 3a). Thus, carbonate banks are classed as hard, terraces with patchy sediment cover as mixed and valley floors as soft. When validated against underwater video, these classes yielded model accuracies of 78–87 percent. Video images also show distinctly different benthic biological communities associated with each substrate type. These included corals on the hard banks and burrows from sediment-dwelling organisms being a common feature of soft plains (Figure 4).

The prediction approach resulted in two categories of seabed substrate, hard and soft. Again, these showed a close association with geomorphic features. They also highlighted fine-scale features not represented in the first classification approach (Figure 3b). Thus, hard substrate was predicted for banks along the steep rocky edges of terraces and localised patches on terraces where sediment cover is thin to absent. Soft substrate was predicted for the valleys and the sediment-covered parts of terraces. These results were validated, yielding a model accuracy of 92 percent. The stronger performance of this approach is attributed to the inclusion of bathymetric and backscatter variables into the analysis. These data also contributed to the mapping of the fine-scale spatial patterns in seabed hardness.

in brief

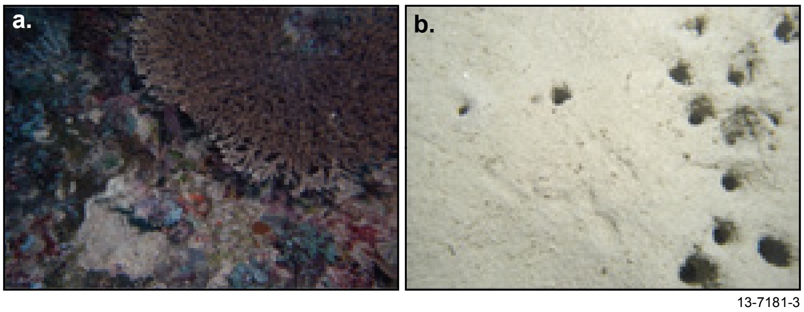

Figure 4: Examples of benthic biological communities identified from survey Area A: a) hard coral communities on a bank in 13 metres water depth; b) bioturbated sediments on a plain in 104 metres water depth.

Major products

The major products and key benefits from this study include:

- Spatially continuous maps of substrate hardness for surveyed areas of the Van Diemen Rise
- Two independent and robust methods for extracting new information from multibeam data

Key benefits

The success of the classification-based and prediction-based approaches developed in this study highlights:

- The utility of acoustic data for objectively classifying seabed substratum
- The power of visualisation to represent relationships between variables and guide sampling design, as used in the hierarchical clustering and machine learning techniques
- The value in integrating multiple datasets to maximise the information gained from seabed surveys, particularly for understanding spatial patterns of substrate types and their associated habitats.

Conclusion

This study represents the first documented application of acoustic backscatter response-derived products to predict and map seabed hardness, which resulted in high predictive accuracies being obtained. The two techniques developed by Geoscience Australia provide comparable results and can be used where intensive seabed sampling is not feasible. The clustering method is best used when a rapid assessment of seabed substrate type is required, using only backscatter angular response data. In contrast, the prediction method is better suited for applications which require an understanding of fine-scale patterns of seabed hardness. This would involve additional computational steps. Overall, these new techniques are a significant advance in Geoscience Australia's capacity to provide spatially continuous maps for priority areas of the national marine estate.

Further information

The results of this study have recently been published in a Geoscience Australia Record 2013/11 titled *Methodologies for seabed substrate characterisation using multibeam bathymetry, backscatter and video data: A case study from the carbonate banks of the Timor Sea, Northern Australia (Siwabessy, 2013)* and a book chapter titled *Predicting seabed hardness using random forest in R* (Li, 2013).

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in brief

Geoscience Australia's Open Day 2013

Sunday 18 August, Geoscience Australia burst to life playing host to Open Day 2013.

Figure 1: A crowd enjoying the exploding volcano.

More than 8000 future geologists and their families flocked to Geoscience Australia, setting a new record and rating it as a great success. The weather was extremely kind and Geoscience Australia shone. Staff were welcoming, enthusiastic and unstintingly helpful through a long day.

The feedback received has been overwhelmingly positive with many people indicating one of their favourites was the return visit by the roving Erth dinosaur. This year's prehistoric visitor, a juvenile T-rex (Tyrannosaurus rex), was a great hit with kids both big and small. Another crowd favourite was Questacon's liquid nitrogen exploding volcano..

Families explored and learnt about the amazing world of Geoscience Australia with over 500 Open Day passports being completed with stamps collected from all of the Open Day activities.

Visitors navigated the grounds using GPS to locate hidden treasure and took a walk through geological time. They discovered the science behind sediments and were invited to bring along a mystery rock from home for identification by a geologist.

Other experiences included making maps, panning for gold, sieving for sapphires and tours of Geoscience Australia laboratories. Visitors also discovered how earthquakes are detected and became seafloor detectives. They experienced what it would be like in an Antarctic Field Camp and viewed planet Earth in 3D. There was something for everybody.

Geoscience Australia CEO, Dr Chris Pigram, said that enthusiasm of staff in sharing what they do with interested members of the community is undoubtedly one of the key factors that contributes to making the day the great success it has become.

"We look forward to welcoming the local community back next year," Dr Pigram said.

Alongside the physical presentations on the day, Open Day went national for the first time with an online presence taking the event beyond the confines of Geoscience Australia to the rest of Australia. Four science talks were streamed live online and remain available for viewing.

Related articles and websites

Geoscience Australia Open Day talks

ga.webcastcloud.com.au/Mediasite/Catalog/catalogs/openday2013 or www.ga.gov.au/education/public-events/open-day.html

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in brief

Radioisotopic calibration of Australian stratigraphy and biostratigraphy

The non-marine successions that dominate the Permian and Triassic strata of the eastern Australian coal basins pose a unique combination of stratigraphic challenges. Lithostratigraphic correlations are hampered, even over relatively short distances, by frequent and significant lateral variations in lithology, which render intra-basin correlation difficult and inter-basin correlations effectively impossible. Biostratigraphic correlations are complicated by the need to use a relatively low-resolution spore-pollen zonation based on endemic flora, and compromised by the extreme difficulty in rigorously correlating this zonation to The Geologic Time Scale 2012 (Gradstein et al., 2012), This is largely because the GTS 2012 was calibrated using fossils from marine successions in the northern hemisphere.

The recognition of tuffaceous felsic volcanic horizons within these non-marine successions has previously encouraged the use of isotopic techniques to establish stratigraphic control, principally via U Pb zircon dating using the Sensitive High Resolution Ion Micro Probe (SHRIMP; for example see Roberts et al. 1995, 1996). Such studies established useful regional frameworks, but the intrinsic limitations of secondary ion mass spectrometry limit the accuracy of U Pb SHRIMP zircon dates to about one per cent in the Phanerozoic Eon, which is generally insufficient for the purpose of refining biostratigraphic zonations.

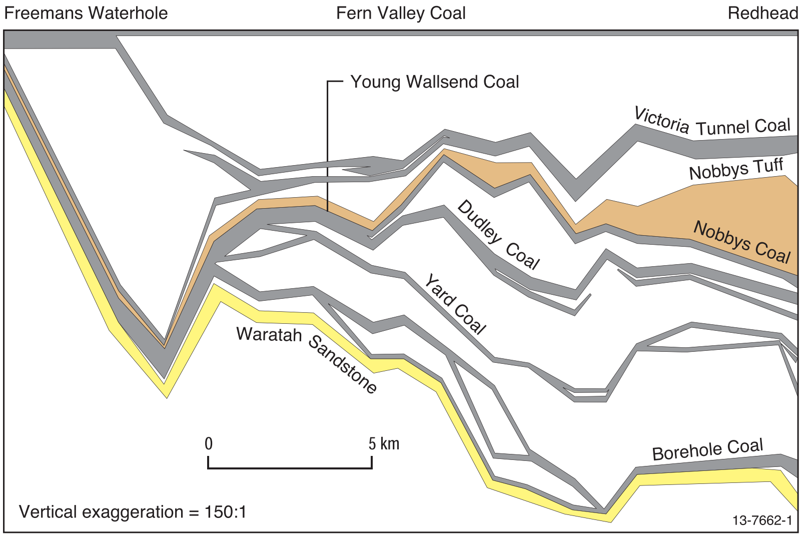

Figure 1: Cross-section of the lower part of the Newcastle Coal Measures from Freemans Waterhole to Redhead showing seam splitting in the coals in the Lambton Formation and lower Adamstown Formation, with the intervening Nobbys Tuff (modified from Hawley & Brunton 1995).

Since 2010, and in conjunction with an Australian Research Council Discovery Grant awarded to Ian Metcalfe (University of New England), Bob Nicoll (Australian National University and Geoscience Australia) and Yuri Amelin (Australian National University), Geoscience Australia has undertaken a program of U Pb dating of these tuff-hosted zircons using a recently developed method known as Chemical Abrasion-Isotope Dilution Thermal Ionisation Mass Spectrometry (CA IDTIMS; Mattinson 2005). This technique utilises a two-stage process to prepare the target zircons for analysis:

1. High-temperature annealing to repair minor defects in the zircon lattice.
2. Chemical abrasion using hot, concentrated and pressurised hydrofluoric acid.

This process has proven remarkably effective in isolating and leaching the domains of radiation-damaged zircon which, traditionally, have compromised the accuracy of conventional IDTIMS analyses. Improved sensitivity of modern mass spectrometers now permits the analysis of individual zircon crystals or fragments treated in this fashion and, in the absence of inherited zircon domains, a suite of several cogenetic zircons can yield a very precise and accurate crystallisation age, often with a 95 per cent confidence interval of ± 0.1 per cent or less. The analyses are conducted by Dr James Crowley (Isotope Geology Laboratory, Boise State University, Boise, Idaho, USA). A new CA-IDTIMS laboratory opened recently in the Research School of Earth Sciences at the Australian National University, under the direction of Dr Yuri Amelin, and some samples will be analysed at that facility.

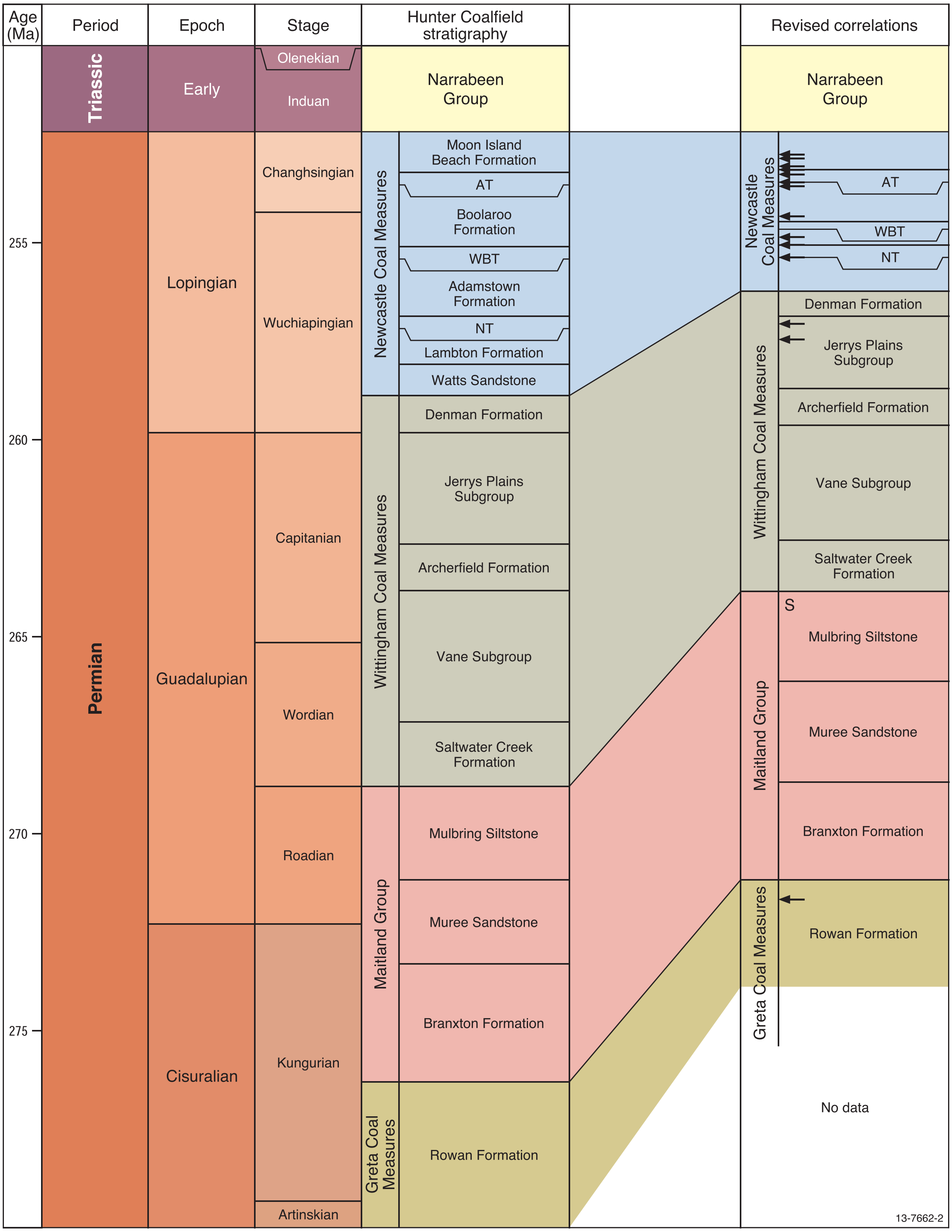

Figure 2: Revised correlation of the stratigraphy of the Hunter Coalfield based on CA IDTIMS dates (black arrows). Left: the standard chronostratigraphy of Gradstein et al. (2012). Centre: a recent correlation of the stratigraphy (Fielding et al. 2008). Right: a new correlation based on CA IDTIMS dating of tuffs in the succession. Abbreviations: NT = Nobbys Tuff, WBT = Warners Bay Tuff, AT = Awaba Tuff. The 'S' in the Mulbring Siltstone refers to a SHRIMP U Pb zircon date from Roberts et al. (1996).

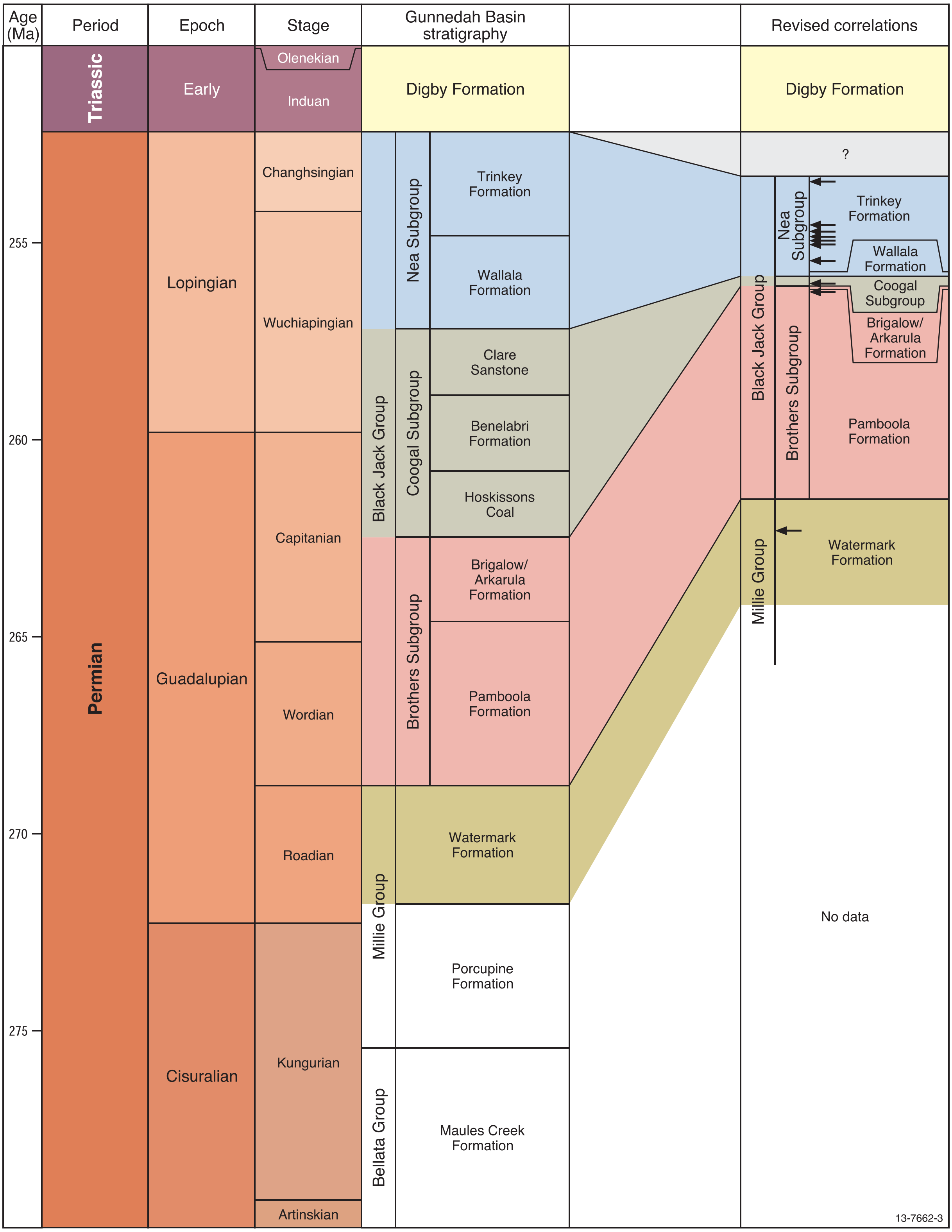

Figure 3: Revised correlation of the stratigraphy of the Gunnedah Basin based on CA IDTIMS dates (black arrows). Left: the standard chronostratigraphy of Gradstein et al. (2012). Centre: a recent correlation of the stratigraphy (Fielding et al. 2008). Right: a new correlation based on CA IDTIMS dating of tuffs in the succession.

in brief

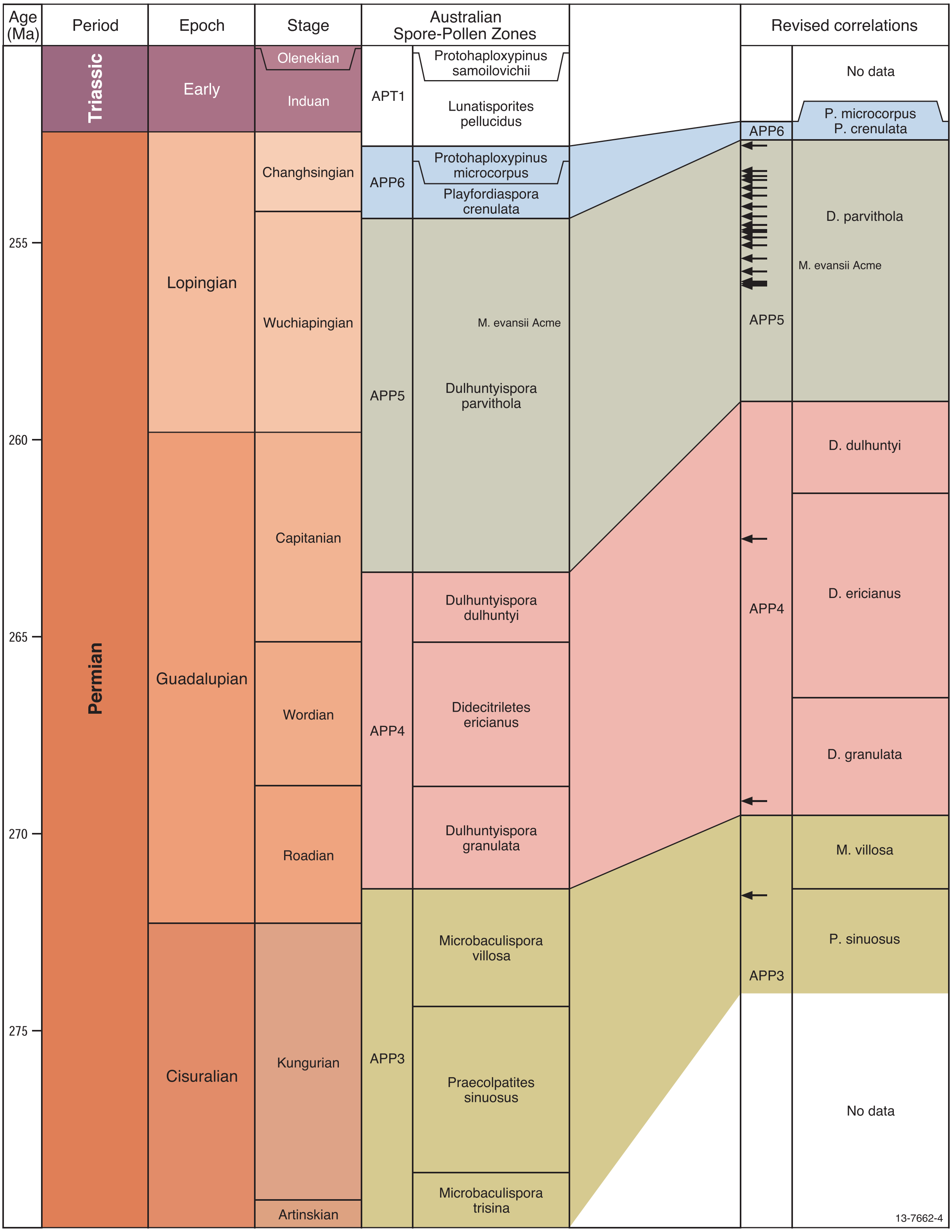

Figure 4: Revised calibration of the palynostratigraphic scheme for part of the Australian Permian based on CA IDTIMS dates (black arrows). Left: the standard chronostratigraphy of Gradstein et al. (2012). Centre: the most recent correlation based on Mantle et al. (2010) updated to The Geologic Time Scale 2012. Right: a new correlation based on CA IDTIMS dating of palynostratigraphically controlled tuffs.

Calibrating stratigraphy

The coal successions in the eastern Australian Permian are notoriously difficult to correlate lithologically, even over short distances, because of the marked lateral variation in lithology, which is characteristic of non-marine successions. Correlating lithologically between basins is therefore almost impossible. Figure 1 illustrates the degree of lateral variation in a section of the lower part of the Newcastle Coal Measures over a relatively short distance (about 25 kilometres) between Freemans Waterhole (about 30 kilometres west of Newcastle) and Redhead (about 10 kilometres south-southwest of Newcastle). Fortunately, there is a plethora of felsic ash-fall tuffs in the Permian-Triassic successions of eastern Australia and the precision of the U Pb zircon dates obtainable via CA IDTIMS allows these tuffs to be used effectively as time planes extending through one or more of the basins, facilitating broad correlations. Sampling was undertaken initially to:

- Demonstrate the usefulness of the CA IDTIMS technique across as broad a geographic spread of samples as possible
- Test the limits of the technique on suites of closely spaced samples from well constrained and carefully selected sections, such as the Fassifern Coal (Boolaroo Formation, northern Sydney Basin).

Initial sampling was fairly sparse, but preliminary dating indicates that the Nobbys Tuff in the northern part of the Sydney Basin in New South Wales is about the same age (c. 255 Ma) as a sample from near the base of the Trinkey Formation in the Gunnedah Basin and slightly older than the Huntley Claystone Member in the Bargo Claystone from the southern Sydney Basin. The Mannering Park Tuff Member of the Moon Island Beach Formation in the northern Sydney Basin is about the same age as a tuff in the Bulli Coal (c. 252.6 Ma) from the southern Sydney Basin which, in turn, is the same age as a tuff at the top of the Kaloola Member of the Bandanna Formation in the Bowen Basin in Queensland. In addition, preliminary dating suggests that the correlation of the stratigraphy to the GTS 2012 requires revision. For instance, in the Hunter Coalfield (northern Sydney Basin), the Rowan Formation (the uppermost unit in the Greta Coal Measures: Figure 2) has traditionally been considered early Kungurian in age. A CA IDTIMS date of c. 271 Ma from the upper part of this formation shows that it is instead probably early Roadian in age. Similarly, the top of the Wittingham Coal Measures was thought to be earliest Wuchiapingian, but an age in the latter half of the Wuchiapingian is more likely. Similar revisions to the correlation of the succession in the Gunnedah Basin (Figure 3) are required. In this basin, a CA IDTIMS date of c. 262 Ma indicates that the Watermark Formation is middle Capitanian in age, rather than Roadian, while a CA IDTIMS date of c. 256 Ma indicates that the top of the Brothers Subgroup is about middle Wuchiapingian, rather than middle Capitanian in age.

Calibrating biostratigraphy

The most effective technique for correlating non-marine Permian-Triassic successions uses the spore-pollen zonation for eastern Australia erected by Price (1997), and calibrated by Mantle et al. (2010). However, this palynostratigraphic zonation is fairly broad—only 13 zones are defined for the entire 46.7 million years of the Permian Period—and correlating this zonation to the global geological timescale is difficult at best. The reasons for this are twofold. Firstly, the Permian-Triassic segment of GTS 2012 (Gradstein et al., 2012) is based on marine fossils such as conodonts, ammonoids and fusulinid foraminifera, but conodonts and fusulinids have never been found in the eastern Australian successions, and ammonoids are rare. Secondly, the flora during the Permian and Triassic periods was largely endemic, occurring only in the circumpolar Gondwanan continents. As a result, correlation to the northern hemisphere is almost impossible, where every ratified Global Boundary Stratotype Section and Point is located. Consequently, the correlation of the Australian palynostratigraphic zonation with the global geological timescale is based on extremely limited evidence.

We have investigated the utility of U Pb zircon CA IDTIMS dating to this problem by pairing the sampling of tuffs in well constrained sections (several drillholes and one road cutting) with concomitant sampling for palynomorphs or, in some cases, sampling tuffs in sections where palynological control has previously been established. Initial dating has demonstrated that the correlation of the palynostratigraphic scheme to the global timescale requires recalibration, as shown in Figure 4. Palynostratigraphically controlled CA IDTIMS dates indicate that the top of the *Praecolpatites sinuosus* Zone is early Roadian rather than middle Kungurian in age, the top of the *Didecitriletes ericianus* Zone is much closer to the end of the Capitanian than the beginning, and the top of the *Dulhuntyispora parvithola* Zone is late Changhsingian, rather than late Wuchiapingian in age.

Future directions

Intermittent felsic volcanism has been a consistent feature of the geology of eastern Australia since the Cambrian Period. Now that the accuracy and precision of U Pb zircon dating has been improved via CA IDTIMS, there is considerable scope to refine the stratigraphic framework of sedimentary successions in that part of the continent, especially in areas where biostratigraphic control is either poor or not readily related to the global geological timescale. Specifically, we intend to:

1. Date all of the relatively thick tuffaceous units in the eastern Australian Permian-Triassic basins, in order to establish a refined temporal framework for the regional stratigraphy of these basins.
2. Continue the co-ordinated sampling of tuffs with that for palynomorphs to better recalibrate the Australian palynostratigraphic scheme for the Permian and Triassic periods.
3. Extend the same approach to the onshore Mesozoic basins in eastern Australia and the predominantly offshore basins in the western half of the continent.

Acknowledgements

We gratefully acknowledge support for this project from the following organisations (listed alphabetically): Australian National University, Australian Research Council, BHP Billiton, Boise State University, Centennial Coal, Geological Survey of New South Wales, Geological Survey of Queensland, Geological Survey of Western Australia, Muswellbrook Coal, Origin Energy, Peabody Energy, Santos, University of New England, University of Wollongong and Xstrata.

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in brief

Strengthening Natural Hazard Risk Assessment Capacity in Papua New Guinea

Papua New Guinea is a country at risk from a variety of natural hazards. In recent years, the country has been devastated by geological disasters including volcanic eruptions (for example Rabaul, 1994), tsunami (for example Aitape, 1998) and earthquakes (for example Wewak, 2002). In 2010, the Government of Papua New Guinea and Geoscience Australia established the Strengthening Natural Hazard Risk Assessment Capacity in Papua New Guinea project. This activity was supported by the Australian Agency for International Development (AusAID) and developed in collaboration with Government of Papua New Guinea technical agencies. It was designed to strengthen the technical capacity of Papua New Guinea agencies to develop natural hazard and exposure information and to integrate those elements for a pilot program in a Papua New Guinea province. The East New Britain Province on the Island of New Britain in northeastern Papua New Guinea was selected for the pilot project (Figure 1).

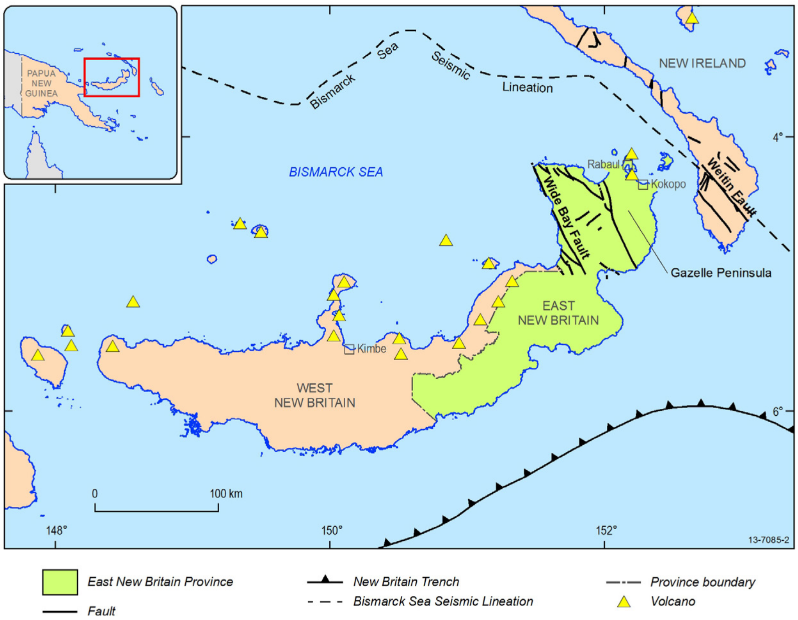

Figure 1: Geological features of East New Britain Province

East New Britain Province is regularly impacted by a range of natural hazard types including volcanic eruption, earthquakes and tsunami (Figure 2). Most of the 220 000 people in the province are concentrated in the northeast Gazelle Peninsula, within the urban areas of the two main towns, Kokopo and Rabaul, and in the peri-urban areas inland from the coast. Small settlements can be found along the north and south coasts and throughout the rugged inland areas where access by road is difficult.

Natural hazard and exposure information for East New Britain Province was developed jointly by staff from the Port Moresby Geophysical Observatory (PMGO), Rabaul Volcanological Observatory (RVO), the East New Britain Provincial Administration (ENBPA) and Geoscience Australia through a series of capacity building activities undertaken over a three year period (2010–2013). Probabilistic and deterministic hazard assessments of earthquake, tsunami and volcanic ash were undertaken across the province. The collation and value adding of fundamental spatial datasets to create a first iteration of exposure information for East New Britain Province was also achieved through the activity. Exposure information and modelled hazard output were integrated to provide an initial examination of which elements of the province (for example buildings, population, crops and roads) were most susceptible to impact within different time periods.

The pilot study concluded that, for the 100 year return period, it is likely that the province will be exposed to both localised and widespread tsunami, earthquake and volcanic hazards at a range of levels. This has important implication for short to mid-term disaster planning and preparedness. At the 1000 year return period it is likely that East New Britain Province will be exposed to even higher levels of impact from both localised and widespread tsunami, earthquake and volcanic hazards.

Figure 2: Volcanic ash hazard in East New Britain Province; Top—Eruption of Tavurvur volcano on 11 August 2013 (Photo: Courtesy of V. Miller—Geoscience Australia); Bottom—H. Ghasemi (Geoscience Australia) with children on a beach of volcanic ash on 11 August 2013 (Photo: Courtesy of V. Miller—Geoscience Australia).

A Geoscience Australia professional opinion entitled Integrating hazard and exposure for East New Britain was produced with Government of Papua New Guinea partners and documents the findings of the East New Britain Province study. The report details the development and integration of hazard and exposure information for the province and can be used by town planners and scientists as part of the decision making process associated with Disaster Risk Reduction (Contact H. Ghasemi for further information). The publication was launched on 9 August 2013 by the Government of Papua New Guinea and Geoscience Australia at a workshop entitled Using science to support decision makers which was held in Kokopo for community decision-makers from throughout Papua New Guinea who are engaged in Disaster Risk Reduction efforts (Figure 3).

To remain valid, risk analyses must be continuously updated and refined through the integration of changes in human geography, mitigation works, our understanding of historical hazard events for a region and lessons learned through observations of future natural hazard events. To that end, the Government of Papua New Guinea, AusAID and Geoscience Australia will work collaboratively to plan the forward program for natural hazard risk assessment in Papua New Guinea. The forward program will build on the work

Figure 3: Participants from across Papua New Guinea at the Using science to support decision makers workshop, co-led by the Government of Papua New Guinea and Geoscience Australia on 9 August 2013. (Photo: Courtesy of V. Miller—Geoscience Australia).

undertaken during the initial three year Strengthening Natural Hazard Risk Assessment Capacity in Papua New Guinea activity. The current program has entered into a transitional year which involves three main components:

- The development of a national earthquake hazard map for Papua New Guinea
- An assessment of landslide susceptibility along the Highlands Highway
- Scoping for the forward program scheduled to commencement in the 2014/2015 financial year.

For more information

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Time after Time: adapting to the Geological Time Scale 2012 (GTS 2012)

The evolution of the international geological time scale

A standardised and precise time scale is invaluable to geological research and crucial to meaningful correlation at local, regional and global scales for both researchers and industry. Modelling of petroleum system plays and ore-body generation, for example, both depend on accurate time scales to be usefully interpreted.

The geological time scale is one of the major achievements of geoscience. It has been developed by geologists over the past two centuries to describe and understand the Earth's history. Chronostratigraphic (relative-time) units, such as rock formations, biostratigraphic zones, (biozones; all the rocks characterised by a particular fossil or fossil assemblage) and magnetostratigraphy, are calibrated against a chronometric scale (an absolute age in years) to build the time scale. Absolute ages (years before the present) are usually measured using radioisotopic dating techniques. In the Cenozoic and Mesozoic absolute ages can be calibrated against high resolution orbital forcing events (astronomical cycles). Modern techniques and instruments are delivering increasingly accurate ages (with precision down to ± 0.1 per cent), and biozonation schemes are continually refined and standardised on a global basis. As such, constant updating of the geological time scale is required, making it a flexible, on-going project (figure 1).

Towards an Australian time scale

Prior to the 1990s there were numerous attempts to develop a standard global time scale, but none was completely satisfactory for application within Australia. As a consequence, during the 1990s Geoscience Australia's predecessor, the Australian Geological Survey Organisation, developed its own AGSO 1996 standard time scale (Young & Laurie 1996) which contained all current Australian biozonal schemes. After the release of the international Geologic Time Scale 2004 (GTS 2004; Gradstein et al., 2004) it was decided that this would replace AGSO 1996 as the standard time scale for use in Geoscience Australia products. The GTS 2004 has, in turn, been superseded by the Geologic Time Scale 2012 (GTS 2012; Gradstein et al, 2012). This Precambrian to Quaternary Period numerical scale (summarised in figure 2) has been collated during more than 30 years, by the International Commission on Stratigraphy and its 14 Subcommissions. This time scale, which was last assessed in 2012, is scheduled to be updated in 2016 and fully revised in 2020 (GTS 2020).

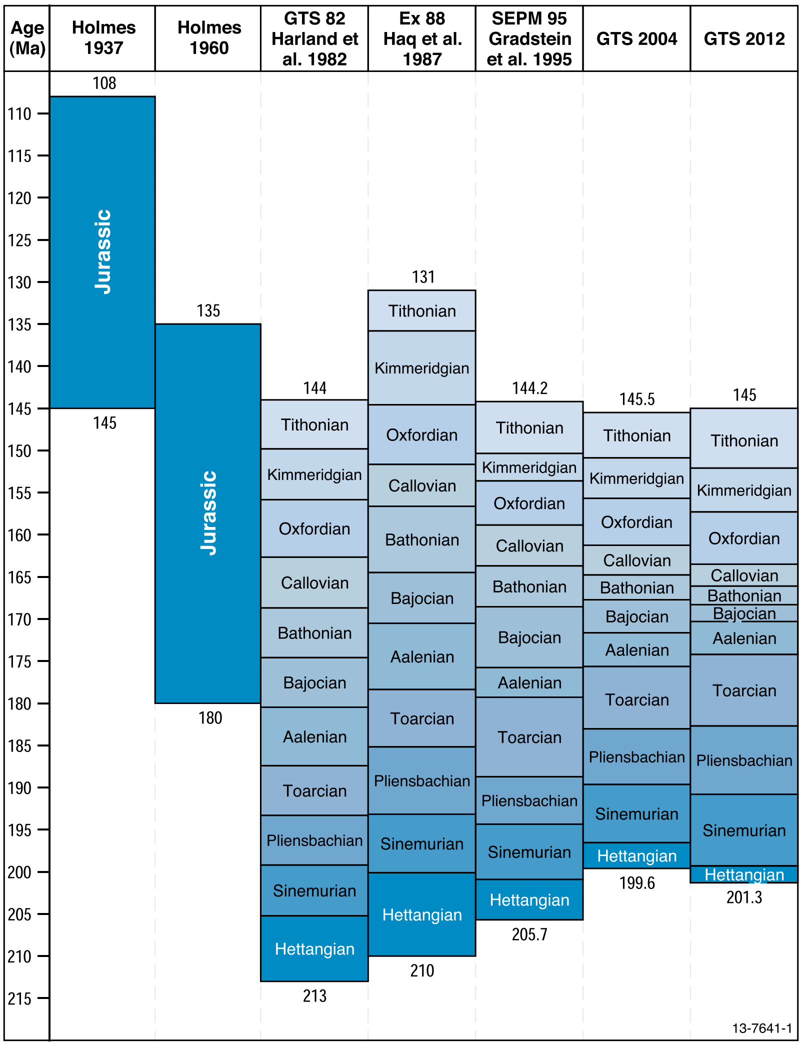

Figure 1: Illustration of the dramatic changes that have taken place with successive revisions of the geological time scale (based on Fig 1.10 in Gradstein et al 2012).

The GTS 2004 was mainly built around northern hemisphere datasets and, consequently, many of the biozones used in Australia were not included. These Australian biozones had been compiled and calibrated to the AGSO 1996 time scale, and, with the adoption of the GTS 2004, each biozone needed to be recalibrated. This process was detailed in an earlier AusGeo News article (Laurie et al 2008) and an Australian Petroleum Production and Exploration Association (APPEA) paper (Laurie et al 2009). It was a complex exercise because there was often no record of the reasoning, or of the data, to explain how the biozones were tied to the stages let alone the absolute ages. Furthermore, during the intervening period between the creation of AGSO 1996 and the adoption of GTS 2004, several of the local biozonal schemes were revised and needed to be updated in Geoscience Australia's databases.

With introduction of the GTS 2012, the biozones have been recalibrated once again. This has involved rescaling the biozones ties to the GTS 2012, as well as incorporating revisions to the schemes since the last update. Thanks to the earlier detailed work carried out calibrating and recording Australian biozones ties to the GTS 2004, the process of calibrating biozones has been a less laborious process this time around.

Calibrating biozones

A biozone is an interval of rock strata, which is defined on the basis of its included characteristic fossil species. As species survive for a relatively short period before extinction, if the same fossil is found in widely scattered rock units, it is most likely that those rock units were all laid down about the same time. In the petroleum exploration industry, biozones provide the primary time framework used in basin modelling, exploration and production.

Most biozonation schemes are based on the first and last appearance datums (essentially speciation and extinction events), or occasionally acme (abundance) events of fossil species. The first appearance datums are generally the most consistent and useful markers of a single point in time, because last appearances and acme events are more likely to vary with environmental influences.

A segment of the widely utilised HMP biozonal scheme (Helby, Morgan & Partridge 2004) is shown in figure 3. The zonation, based on the stratigraphic ranges of dinocysts (microplankton), is illustrated alongside the main bioevents (or datums) that define each zone. Figure 3a shows these zones as calibrated to the GTS 2004, while figure 3b shows the same zones recalibrated to the GTS 2012.

When calibrating the Australian biozones to the 2004 time scale, the aim was to capture the relationship of these bioevents to the time scale as a percentage of the time from base to top of a stage. For example, the base of the *Voodooia tabulata* Dinocyst Zone is set as the first appearance of the eponymous species, which is estimated to occur at 70 per cent from the base to the top of the Callovian (figure 3). There are more than 2500 biozones published in Australian biozonal schemes and capturing the relationships of these biozones to the stages required extensive literature searches and targeted revisions to achieve the required recalibration. This information is saved in the Timescales Database, which is a core lookup table for numerous databases across Geoscience Australia.

When the base age of the Callovian was updated in the GTS 2012, the *Voodooia tabulata* Dinocyst Zone automatically updated to a new numerical age because it is stored as a percentile of the Callovian stage. The process was not, however, so simple for all biozones. The base of the *Ternia balmei* zone (and FAD of *Wanaea digitata*) for instance, was calibrated to the GTS 2004 as 20 per cent up the Callovian (figure 3a). This zone has since been re-assessed based on correlation with European dinocysts (Riding et al. 2010), relocating its tie point to the base of the Callovian (figure 3b).

Re-assignments such as these mean that although the biozone calibrations to the GTS 2004 were easily and automatically rescaled to the GTS 2012, a thorough review of updated biozone correlations was still required. Indeed, radioisotopic dating studies being carried out by the timescales team at Geoscience Australia are recalibrating many Australian Spore-Pollen zones (see the accompanying AusGeo News article by Laurie et al.), the results of which are being incorporated into the GTS 2012 biozone calibrations.

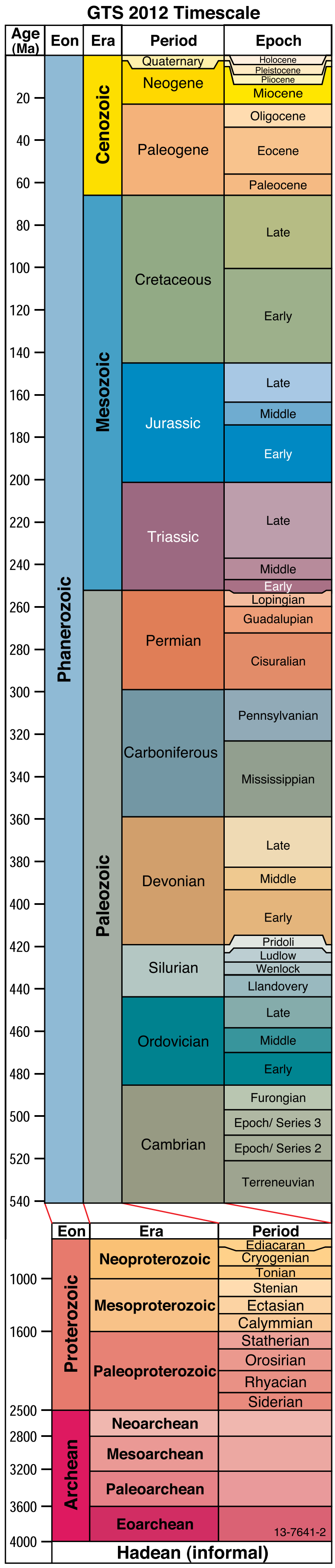

Figure 2: The Geological Time Scale 2012 (Gradstein et al 2012).

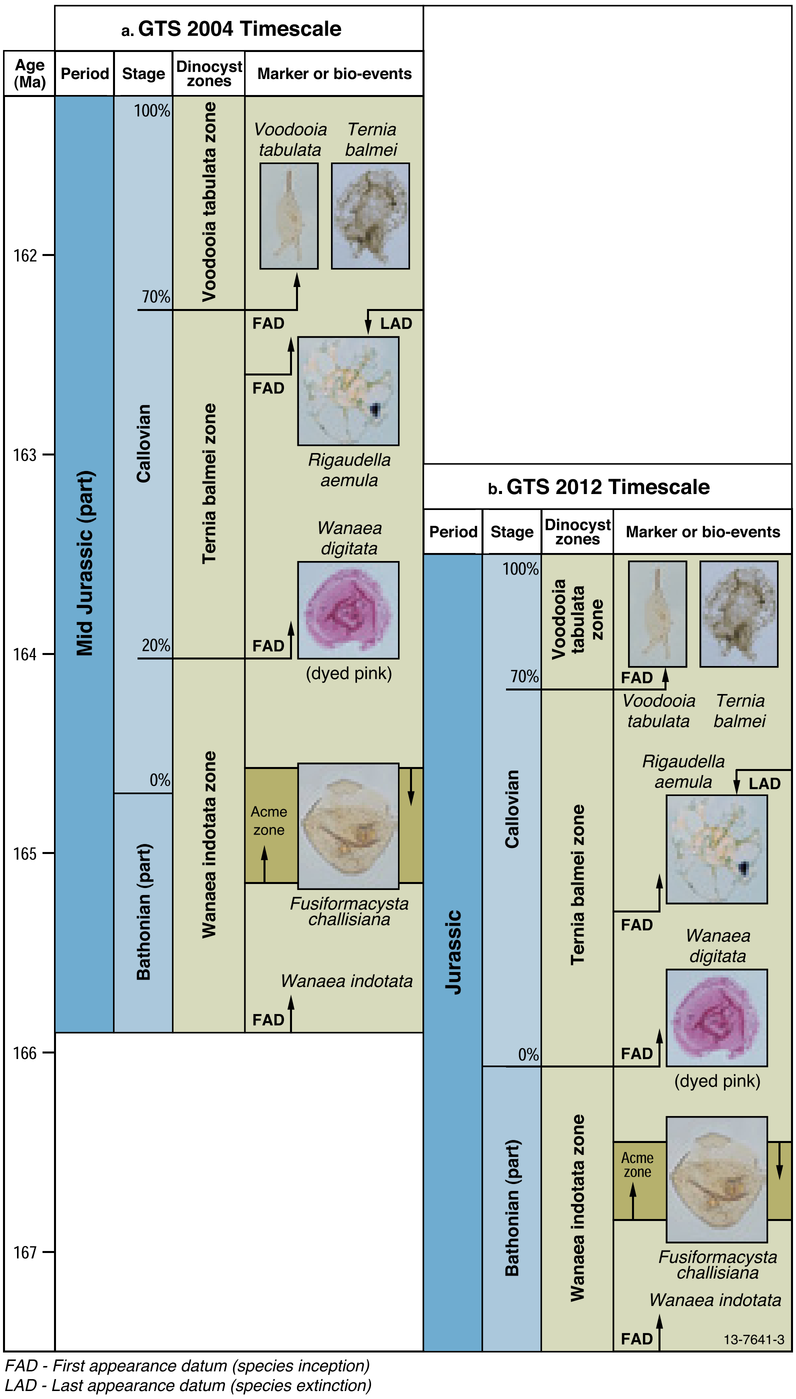

Figure 3: Comparison of the **a.**GTS 2004 and **b.**GTS 2012 Middle Jurassic portion of the Helby, Morgan and Partridge (2004) dinocyst biozonal scheme illustrated with formal marker events.

Creating time scales

TimeScale Creator is a software package developed by Adam Lugowski and Jim Ogg (Purdue University), which acts as a visualisation tool for the time scale data included in the GTS 2012. There are two versions of this software, one freely available and one commercial. The free version, TimeScale Creator 6.1 released in March 2013, contains a datapack comprising the divisions of the GTS 2012, magnetic polarity zones, biozones, oxygen- and carbon-isotope curves, sequences and sea-level curves, totalling more than 10 000 event-age entries and upwards of 200 stratigraphic columns. Any permutation of these biozonal and other schemes can be chosen and displayed against the selected portion of the time scale. It is an easy-to-use software package and primarily useful for quickly generating graphic displays of chronostratigraphic schemes against the GTS 2012.

The commercially available version. TimeScale Creator Pro, allows the user to generate their own datapack and to either add this to the standard version, or replace the standard datapack. In association with Professor Jim Ogg, Geoscience Australia has been able to develop an up-to-date datapack containing all current Australian biozonations so that time scales containing Australian data can be generated separately or in association with the assorted international schemes. This Australian datapack will be freely distributed at the 2014 APPEA Conference and Exhibition in Perth (6 to 9 April 2014) and will be available from Geoscience Australia's Biostratigraphy webpage and the TimeScale Creator website.

Stratigraphic data can also be inserted into TimeScale Creator Pro to allow it to generate stratigraphic columns calibrated against any biozonal schemes the user chooses. An example image generated by TimeScale

in brief

Creator showing the lithostratigraphy, basin phases, sea-level curve and relevant biozones for the Jurassic segment of the onshore Perth Basin is shown in figure 4. In collaboration with staff from some of the Australian State geological surveys, Geoscience Australia has been using TimeScale Creator Pro to generate up-to-date basin biozonation and stratigraphy charts. These are replacing charts drafted relative to the GTS 2004 and some drafted more than a decade ago using the AGSO 1996 time scale. To date, Geoscience Australia has compiled GTS 2012 stratigraphic charts for the Canning, Georgina, Gippsland, Northern Carnarvon, offshore northern Perth and onshore Perth basins. Others, such as the Browse, Bight, Bonaparte, and Otway basins are in the process of being converted from GTS 2004 to GTS 2012. These charts provide a relatively detailed stratigraphic overview of each basin and are available for download from Geoscience Australia.

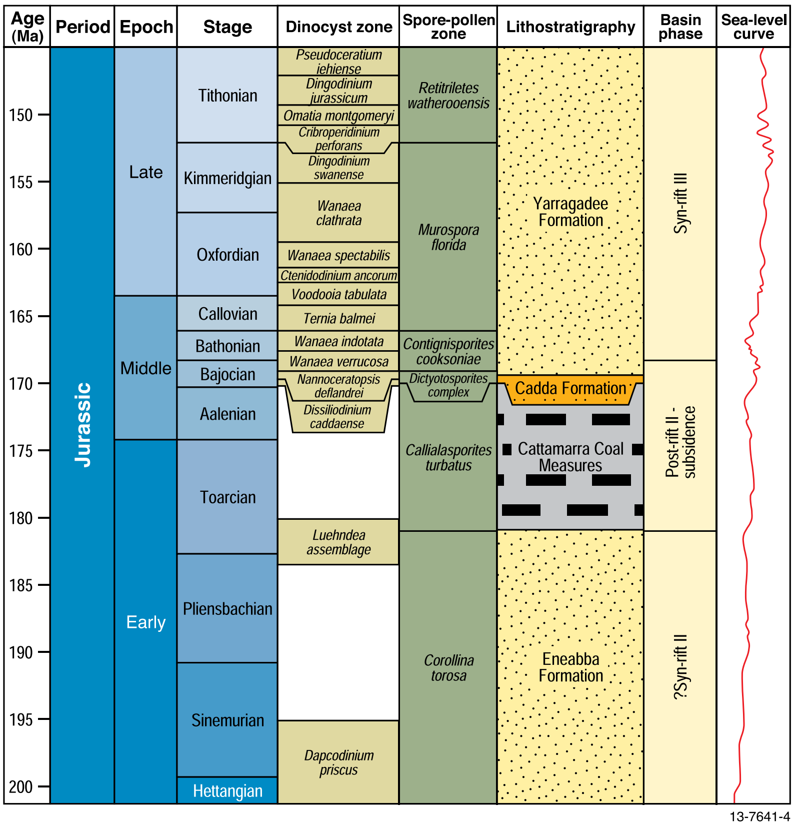

Figure 4: Sample output from Time Scale Creator software showing elements of the Onshore Perth Basin stratigraphy against the relevant biozonal schemes and the GTS 2012.

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Related articles and websites

Customising the Geological Timescale—*AusGeo News* 92, 2008.

www.ga.gov.au/ausgeonews/ausgeonews200812/timescale.jsp

Biostratigraphy Webpage—Geoscience Australia

www.ga.gov.au/energy/disciplines-techniques/biostratigraphy.html

Geoscience Australia's Basin Biozonation and Stratigraphy chart series

www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=76687

The Geologic Time Scale 2012 Chronostratigraphic Chart

https://engineering.purdue.edu/Stratigraphy/charts/chart.html

TimeScale Creator

https://engineering.purdue.edu/Stratigraphy/tscreator/index/index.php

For more information

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in brief

Palaeogeographic maps of the Early Cretaceous deltaic systems in the Vlaming Sub-basin to assess quality of the seal

Introduction

In 2011 as part of the National CO_2 Infrastructure Plan, Geoscience Australia started a three year project to provide new pre-competitive data and a more detailed assessment of the Vlaming Sub-basin prospectivity for the geological storage of CO_2. An initial assessment of this basin by Causebrook et al. (2006) identified the Gage Sandstone and South Perth Shale as the main reservoir-seal pair suitable for long-term storage of CO_2. The South Perth Shale is a thick (up to 900 meters) deltaic succession with highly variable lithologies. It was estimated that South Perth Shale is capable of holding a column height of CO_2 of 300 metres to 663 metres based on mercury injection capillary pressure (MICP) tests (Causebrook et al., 2006). Applying a sequence stratigraphic approach, this study defined the South Perth Supersequence as a second order supersequence and the distribution of pro-delta mudstone facies within the supersequence was mapped across the basin. These facies could provide an effective sub-regional seal in the area and are the focus of this study. Analysis of the spatial distribution and thickness of the effective seal is used for characterisation of the containment potential in the Vlaming Sub-basin CO_2 storage assessment.

Methods

The analysis of the Early Cretaceous South Perth Supersequence is based on the integration of 2D seismic interpretation, well log analysis and the new biostratigraphic data (Macphail, 2012). Palaeogeographic maps are based on mapping higher-order sequences within the South Perth Supersequence. Using seismic and well data the pro-delta facies was mapped as being distal to the slope break, the seismic data was then used to extrapolate the mudstone facies away from the wells.

Results

The South Perth Supersequence is interpreted to comprise two third order sequences: Sequence 1 (*G. mutabilis*) and Sequence 2 (*K. scrutillinium to B. jaegeri*).

Sequence 1 is sub-divided into a low stand systems tract (LST) and a high stand systems tract (HST). During Sequence 1, HST sediments from the south were transported down the two canyons located to the east and west of the Sugarloaf Arch; in the northern depocentre the sediment supply probably came from the trough located to the east of the Edwards Island Block (Figure 1a).

Across the entire sub-basin in Sequence 2, the prograding units of the Falling Stage Systems Tract (FSST) and LST were formed as a result of a forced regression. In the southern depocentre sediments coming from the southeast began to fill the depocentre to the north of the Harvey Ridge, while another deltaic system continued to build from around the Sugarloaf Arch. In the north the deltaic system of the FSST and LST continued to prograde southwards into the depocentre located to the east of the Edwards Island Block (Figures 1b and 1c). Falling relative sea level caused regression of the shoreline by approximately 18 kilometres in the north and 20 kilometres in the south.

During Sequence 2 Transgressive Systems Tract (TST), the southern deltas continued to build in the south, southwest and adjacent to the south-eastern margin of the basin. The northern deltas continued to build southward into the depocentre adjacent to the Edwards Island Block. The shelf break in both the north and south shows aggradation and minor basinward progradation. Rising relative sea level caused a transgression of the deltaic shallow marine shoreline by approximately 20 kilometres from the end of the LST to the top of the TST, both in the southern and northern parts of the sub-basin (Figure 1d).

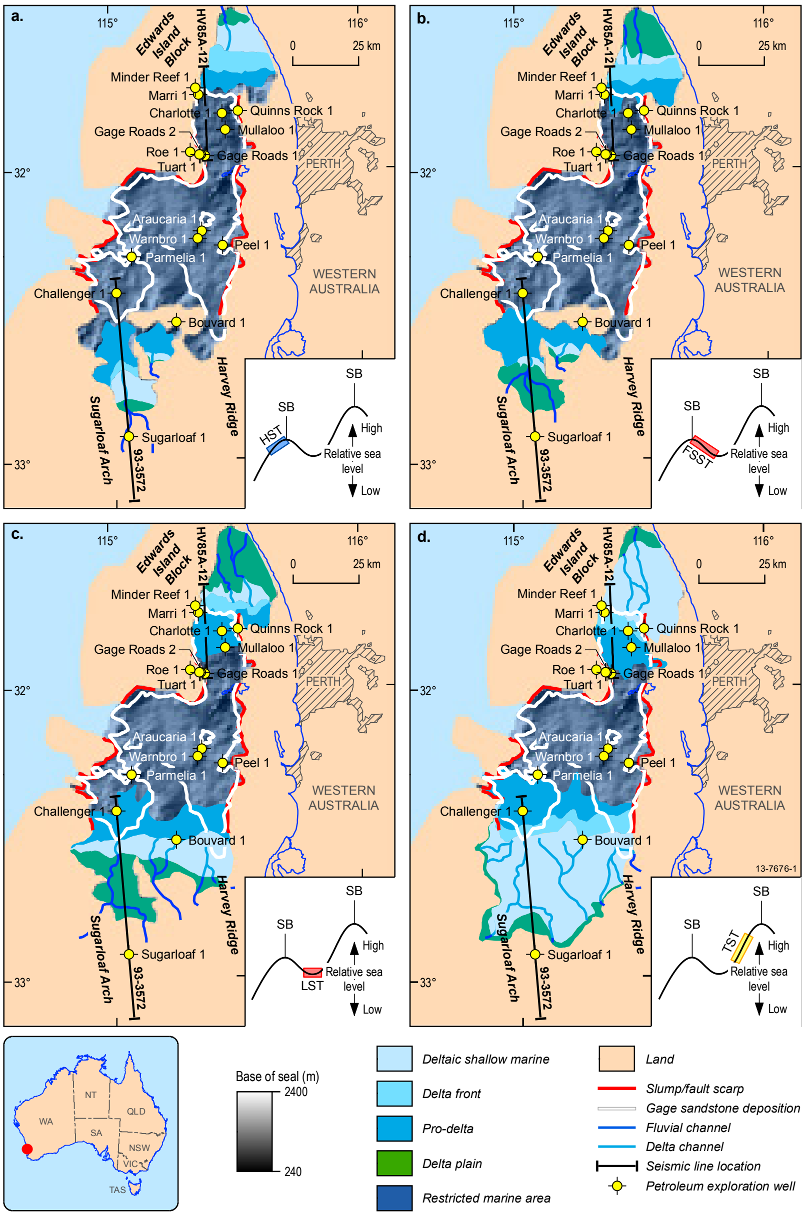

Figure 1a: Palaeogeographic map for the end of Sequence 1, highstand systems tract. **1b:** Palaeogeographic map for the end of Sequence 2, falling stage systems tract. **1c:** Palaeogeographic map for the end of Sequence 2, lowstand systems tract. **1d:** Palaeogeographic map for the end of Sequence 2, transgressive systems tract.

From the interpretation above, the pro-delta mudstone facies, mapped as the effective seal, was found to build out into the Vlaming Sub-basin during all phases of deposition and eventually cover almost the entire LST reservoir by the end of the Sequence 2 HST, thus creating a suitable reservoir-seal pair.

For more information

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Summary

- Sequence stratigraphic analysis of the South Perth Supersequence resulted in defining two third order sequences.
- Each of these sequences has been split up into several system tracts stages reflecting relative changes in the sea level and sediment supply.
- Palaeogeographic maps for these stages reveal a cycle of regression and transgression leading to filling in the palaeotopographic depression by the deltaic succession.
- The pro-delta facies at the base of this succession cover most of the Gage LST reservoir and with the known MICP results are likely to provide an adequate seal for the CO_2 storage in the Vlaming Sub-basin.

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