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Trusted environmental and geological information – stratigraphic frameworks for resource and hydrogeological assessments

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SUMMARY

The Australian Government's Trusted Environmental and Geological Information (TEGI) program is a collaboration between Geoscience Australia and the CSIRO that aims to provide access to baseline geological and environmental data and information for strategically important geological basins. The initial geological focus is on the north Bowen, Galilee, Cooper, Adavale, and their overlying basins. This paper presents seven stratigraphic frameworks from these basin regions that underpin groundwater, environmental and resource assessments, identify intervals of resource potential, and can assist in management of associated risks to groundwater resources and other environmental assets. The construction of stratigraphic frameworks for this program builds upon existing lithostratigraphic schemes to capture the current state of knowledge. The frameworks incorporate play divisions for resource and hydrogeological assessments. A total of 33 play intervals are defined for the north Bowen, Galilee, Cooper, Adavale, and their overlying basins, using chronostratigraphic principles. Where possible, unconformities and flooding surfaces are used to define the lower and upper limits of plays. Data availability and temporal resolution are considered in capturing significant changes in gross depositional environments. The results from this work enable the consistent assessment of shared play intervals between basins, and also highlight uncertainties in the age and correlation of lithostratigraphic units, notably in the Galilee and north Bowen Basins.

Key words: Adavale, north Bowen, Cooper, Galilee, Stratigraphy

INTRODUCTION

The Australian Government's Trusted Environmental and Geological Information (TEGI) program aims to provide access to baseline geological and environmental data and information for strategically important geological basins. The initial geological focus is on the north Bowen, Galilee, Cooper, Adavale, and their overlying basins including the Eromanga, Lake Eyre and other Cenozoic basins (Figure 1). Outputs from the program include regional resource and associated environmental assessments underpinned by transparent, trusted baseline geological and environmental data. To systematically undertake these assessments in space and time, a common regional chronostratigraphic framework is required. Despite a wealth of new stratigraphic data becoming available to assist basin-wide correlations, lithostratigraphic principles are still applied to correlate strata in the study area. However, lithostratigraphic boundaries are time-transgressive and are of limited value in reconstructing the temporal evolution of basin fills (Wainman *et al.*, 2020). Defining play intervals that link different geological unit nomenclatures and their associated chronostratigraphic surfaces is therefore necessary to ensure reliable regional correlations, thereby reducing resource assessment uncertainty (Bradshaw *et al.,* 2022).

This paper discusses the construction of seven interlinked stratigraphic frameworks that define 33 play intervals across the study area. The stratigraphic frameworks and the definition of play intervals are based on a detailed literature review, and analysis of publically available geological data (e.g., from well completion reports and stratigraphic databases). An example of a stratigraphic framework from the Adavale Basin and an example of an assessed play from the Adavale Basin resource assessment are presented.

STRATIGRAPHIC FRAMEWORKS

Stratigraphic frameworks for the TEGI Program were developed using a systematic approach to collate relevant stratigraphic information, starting with the most recent datasets before analysing older ones. Existing lithostratigraphic nomenclature at the formation and/or group rank, with unit age and bounding stratigraphic surfaces were captured. Other relevant datasets captured include geochronology, sequence stratigraphy, biostratigraphy (using the scheme of Price, 1997), and juxtapositions in depositional environments between underlying and overlying units. Where required, data and stratigraphic nomenclature were cross-checked with information stored on state and federal databases (e.g. South Australian Petroleum Exploration and Production System (PEPS; Government of South Australia, 2022)), including well completion reports and well logs. Examples of datasets used include geochronological information from the Galilee Basin (Phillips *et al.,* 2018), biostratigraphic data from the Eromanga Basin (Hannaford *et al.*, 2022), and sequence stratigraphic work undertaken on the Rewan Group in the north Bowen Basin (Grech and Dyson, 1997). In many instances, the age of lithostratigraphic units is uncertain, with data only available in a graphical format. In some cases, the original documentation was unusable or unavailable (e.g. for the Boonderoo beds of the Galilee Basin).

Play intervals were defined by grouping stratigraphic units by the geological circumstances in which they were deposited and/or deformed. A compromise was required to balance data availability, completeness and temporal resolution to define gross depositional environments. This was important as sparse data in a basin may limit the number of plays recognised, leading to low-resolution resource and groundwater assessments. Large amounts of data may lead to a disproportionate number of plays being defined, adding excessive work to resource and groundwater assessments with negligible benefits to end users. Where possible, according to sequence stratigraphic and chronostratigraphic principles, the tops and bottom of plays were defined by unconformities (1 to 10 Ma timescales), flooding surfaces, regressive surfaces and their correlative conformities. As many units in the basins under investigation were deposited in non-marine environments, the expression of these stratigraphic surfaces can be uncertain (Shanley and McCabe, 1994). Instead, juxtaposition of depositional environments between stratigraphic units or the combination of reservoir-seal pairs have been used to define plays in a few instances.

Play nomenclature is based on lithostratigraphic names. An alternative would be to use a first and second stage divisions of numerical regional play intervals, as used by Marshall and Lang (2013) for the Northwest Shelf of Australia. However, such a scheme could (1) cause confusion or be little used by end users due to the historic use of lithostratigraphic terminology in the study area, and (2) cause users to link geological events in eastern Australian basins to those in the west (and vice versa), which evolved under different tectonic circumstances.

One hundred and forty five lithological units (formation status and higher) were recorded from the Early Devonian through to the present day, with their ages tied to the 2020 geological time scale (Gradstein *et al.*, 2020). Thirty-three plays (several being time-correlative) across seven stratigraphic frameworks were defined, streamlining the stratigraphic nomenclature applied. The stratigraphic frameworks (an example is shown in Figure 2 for the Adavale Basin) constructed for the TEGI Program synthesise information into easily understood figures and showcase three data themes: (1) stratigraphic, depositional and tectonic data for each basin; (2), plays and hydrostratigraphic intervals bound by key surfaces, and (3) potential resources associated with each play. Seven plays were defined for the Adavale Basin, six for the Cooper Basin, five for the Galilee Basin, five for the north Bowen Basin, nine for the Eromanga Basin and one encompassing play for the Lake Eyre and other Cenozoic basins. Examples of defined plays include the Givetian Cooladdi–Boree Play in the Adavale Basin (Figure 2), and the Roadian Collinsville Play in the north Bowen Basin. In some cases, hydrostratigraphic intervals do not mirror the play intervals due to two or more plays being defined as an aquifer, or where the hydrogeological status of several plays remains uncertain (e.g. the Adavale Aquifer of the Adavale Basin, Figure 2).

In basins with plentiful, geologically-sound datasets, defining plays was straight-forward. Examples include the plays of the Cooper Basin where the ages of key units are well established, with chronostratigraphic horizons adhering approximately to lithostratigraphic surfaces, including the transition from the Patchawarra Formation into the Murteree Shale (e.g. Kobelt, 2014). In contrast, in the north Bowen Basin stratigraphic inconsistencies are inherent, including the age and designation of units into either the Permian Blackwater and/or Back Creek groups (Hodgkinson and Grigorescu, 2020). The different structural elements of the north Bowen Basin (Draper, 2013), each have unique and complex depositional histories. This has led to the definition of many stratigraphic units in the basin with local and regional correlation beset by rapid facies change and endemic and/or rare biostratigraphic markers (Draper, 2013). Consequently, the designation of play intervals (e.g. the Upper Back Creek Play) is uncertain until new stratigraphic data become available. Similar issues are encountered in the Galilee Basin. All Cenozoic units, spanning the studied basins, are treated as a single play due to the sparsity of data to constrain their age. Additionally, the nature of stratigraphic contacts between Cenozoic units in many cases are uncertain.

PLAY BASED RESOURCE AND GROUNDWATER ASSESSMENTS

For each of the defined plays and hydrostratigraphic intervals, a full suite of resource and groundwater assessments were undertaken (see McAlpine *et al.,* 2022, Ferdinando *et al.*, 2022 and Hostetler *et al.,* 2022 for details). An example of a resource assessment workflow is described. The first step in these assessments is to interpret the presence and gross depositional environments of the strata for each play across the assessment area, typically based on evidence from exploration drillholes. Gross depositional environment interpretations and relevant well information (such as porosity and permeability) are then combined to infer the chance of each play element being valid (e.g. reservoir presence and reservoir effectiveness). The play element maps are then combined to derive a composite common segment map (at the play level). This firstly serves as a guide to the overall qualitative prospectivity of the basin, and secondly it assists in understanding potential impacts on environmental assets, as such water, in areas prospective for resource development (e.g. hydrocarbon extraction or carbon capture and storage), should development occur. An example of play element chance maps for the Eifelian to Givetian Lissoy–Bury Play of the Adavale Basin is shown in Figure 3.

Figures and Tables

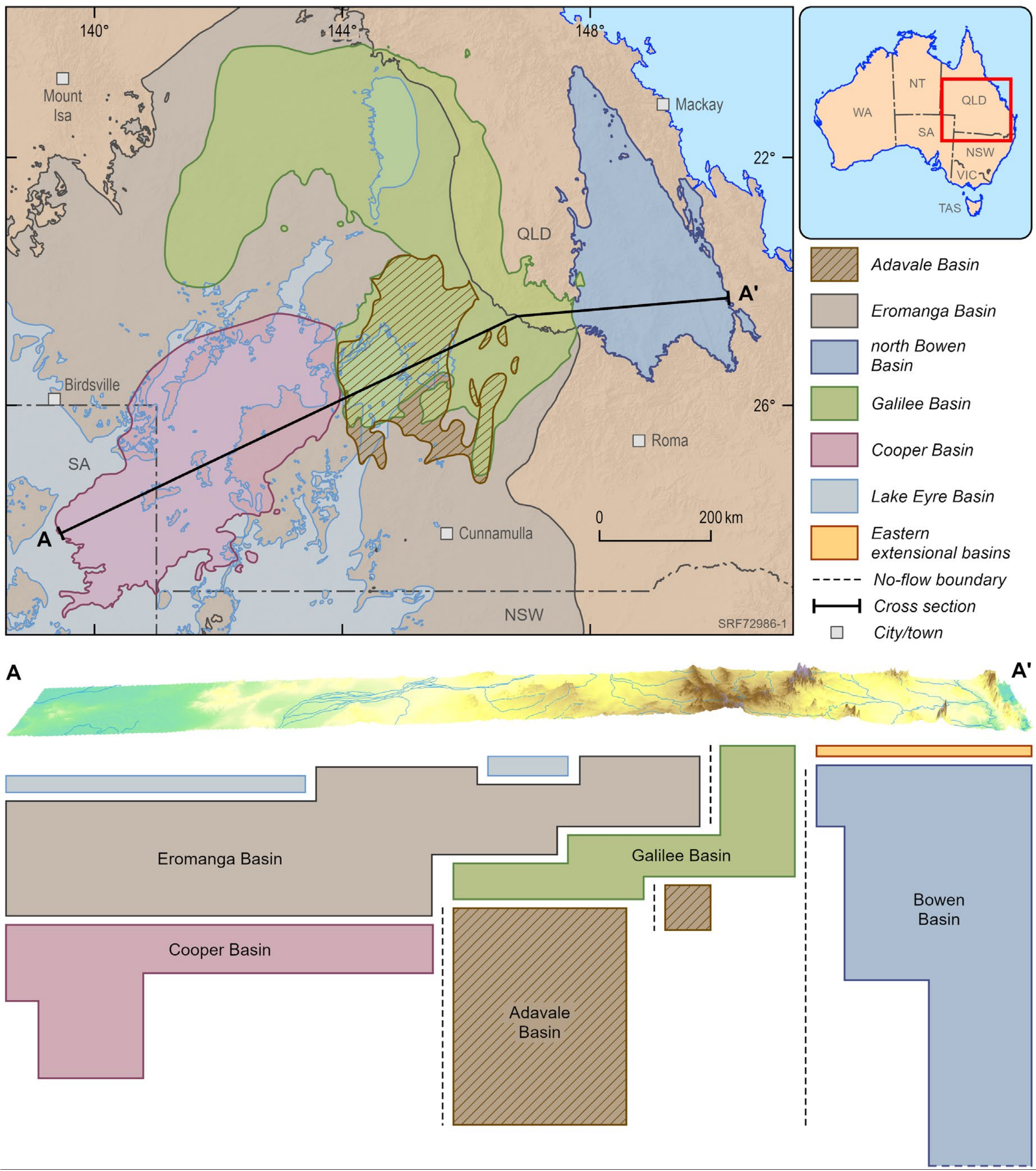

Figure 1. Locations of the TEGI geological basins for which stratigraphic frameworks will be delivered. The conceptual line for each basin is depicted along section line A-A'. *Note: no-flow boundaries refers to no groundwater connectivity between basins.*

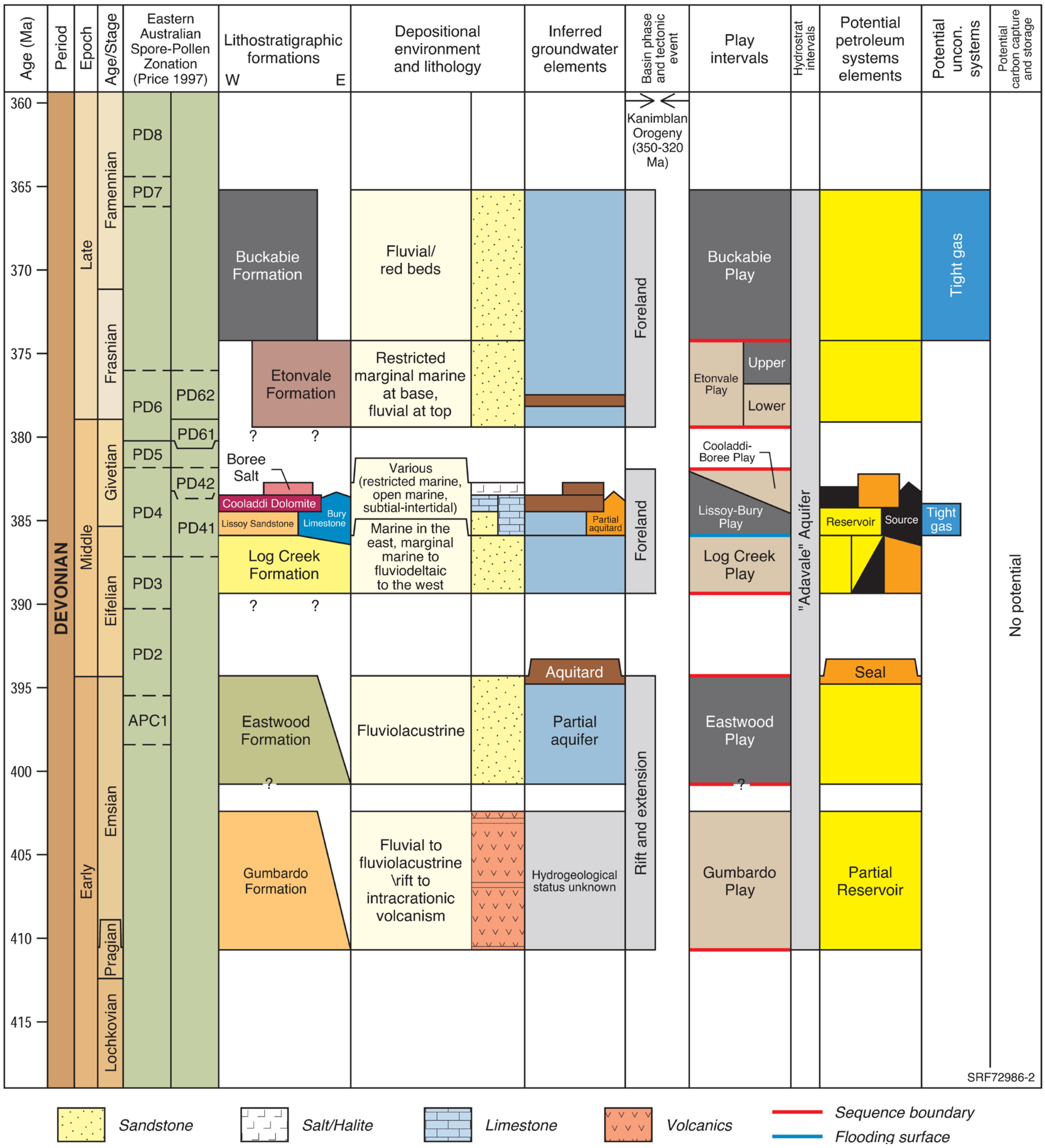

Figure 2. TEGI Stratigraphic Framework for the Adavale Basin. Geologic Time Scale after Gradstein et al., 2020).

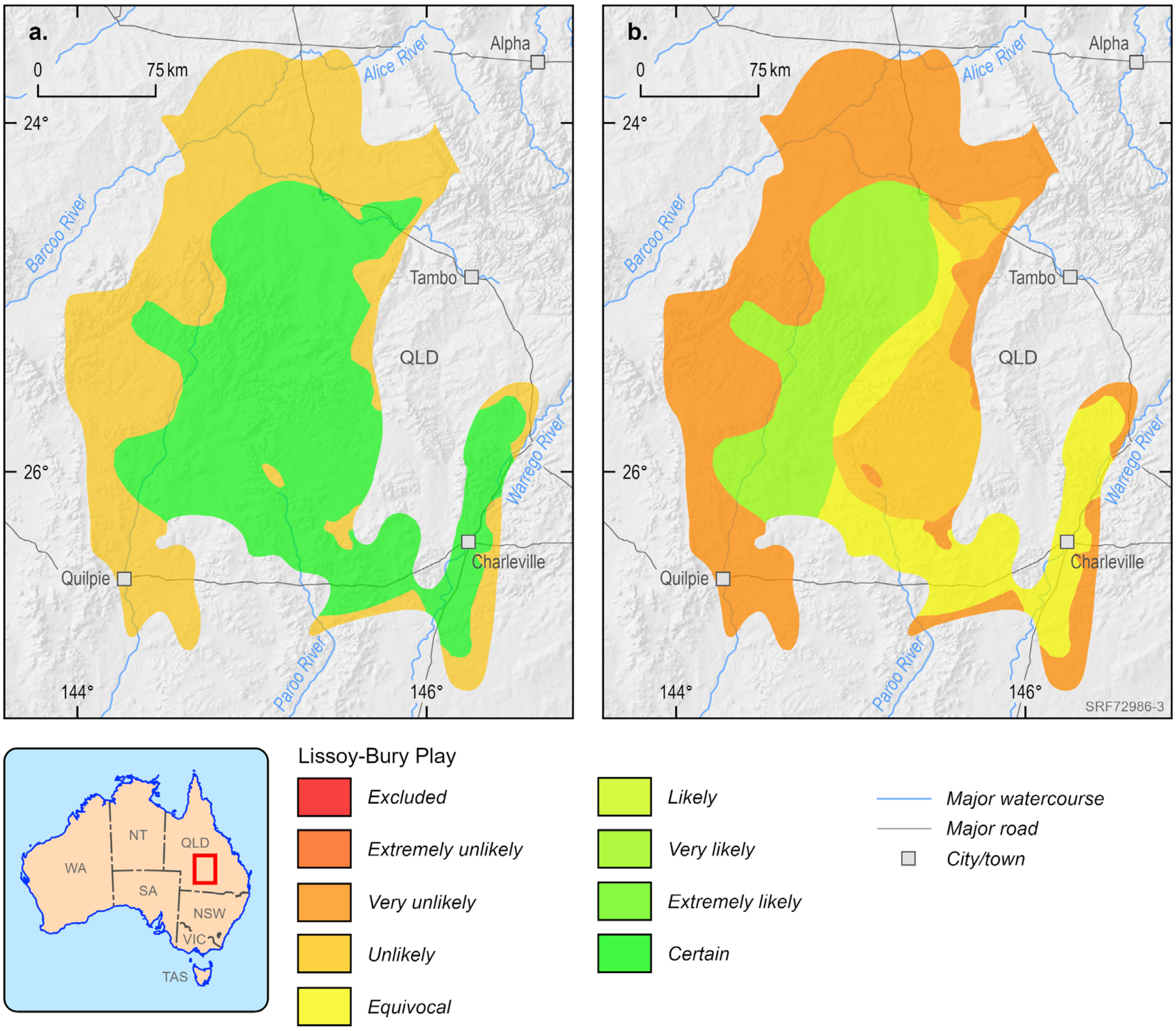

Figure 3. Play element chance of (a) reservoir presence and (b) reservoir effectiveness from the Lissoy-Bury Play (adapted from McAlpine *et al*., 2022).

CONCLUSIONS

Seven stratigraphic frameworks have been constructed for the north Bowen, Galilee, Cooper, Adavale, and their overlying basins that are being investigated as part of Geoscience Australia's TEGI program. An example from the Adavale Basin is presented above. Geological unit nomenclatures and their associated sequence stratigraphic surfaces are collated from literature reviews and publically available data to define 33 play intervals spanning the Early Devonian through to the present day. For any basin, striking a balance between data availability and the temporal resolution required to capture significant changes in gross depositional environments is critical in defining the appropriate number of plays required to conduct meaningful resource and groundwater assessments. While defining the plays in some basins (e.g. the Cooper Basin) is straight forward, uncertainties remain for other basins (e.g. the north Bowen and Galilee basins) due to data availability and data quality. The application of these frameworks and associated play intervals enables a systematic assessment of resources, groundwater and the associated environmental impacts should development occur in prospective areas.

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