

# **PS Modelling Sealing Potential within the Palaeozoic Sequence in the Fitzroy Trough, Canning Basin, Western Australia\***

**Julian Strand<sup>1</sup>, Cedric Griffiths<sup>1</sup>, and Laurent Langhi<sup>1</sup>**

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## **Abstract**

The Fitzroy Trough/Gregory Sub-basin system contains significant Palaeozoic sediments, studies suggest these are sediments are between 10 km and 12 km thick. The sub-basin contains sequences varying from the classic Frasnian reef complexes today exposed in the Kimberly to the thick Permo-Carboniferous glacial Grant Group. The units of the trough underwent a significant Mesozoic basin inversion event, the Fitzroy Transpression, resulting in the formation of anticlinal structures and locally significant erosion. Historically, exploration drilling within the Fitzroy Trough has targeted these anticlinal structures.

As part of a review of the Canning Basin, fault-seal potential has been estimated for the later Palaeozoic sequence in the NW of the basin. This study focused upon identifying localities where the sequence will be prone to fault-seal given suitable reservoir geometry. The application for this study is for hydrocarbon exploration, but CO<sub>2</sub> sequestration potential have accelerated impetus for the revaluation with the planning of the James Price Point (JPP) LNG facility, to service northern NW Shelf gas production.

The initial study analysed sequences directly from well data, which given the sparse data, there are only 65 wells within 200 km of JPP, limited the effectiveness of the modelling to the immediate vicinity of the wells. Additionally most of the wells are located on the trough's flanks rather than depocentres. Exploration targeting of anticlines has resulted in further under representation of the later parts of the sequence, due to significant, but localised, erosion on anticlinal crests, commonly including the significant top sealing, Noonkanbah Formation. Prior to identifying suitable, fault-bound structures, identification of shale-rich, top-seal and fault-seal prone sequences is required.

As such, the next stage goal of the project has been to produce a large-scale (1,000 x 250km) sedimentological model of the Fitzroy

Trough/Gregory Sub-basin. These sub-basins forming the northern flank of the Canning Basin have a similar tectonic history from the early Devonian to the Jurassic, which is not necessarily common to the rest of the basin. The stratigraphic forward modelling draws together data existing sedimentological models and the well data from the first phase. The output of the modelling will be used for additional estimates regarding seal potential and to provide a framework for hydrocarbon migration modelling studies.

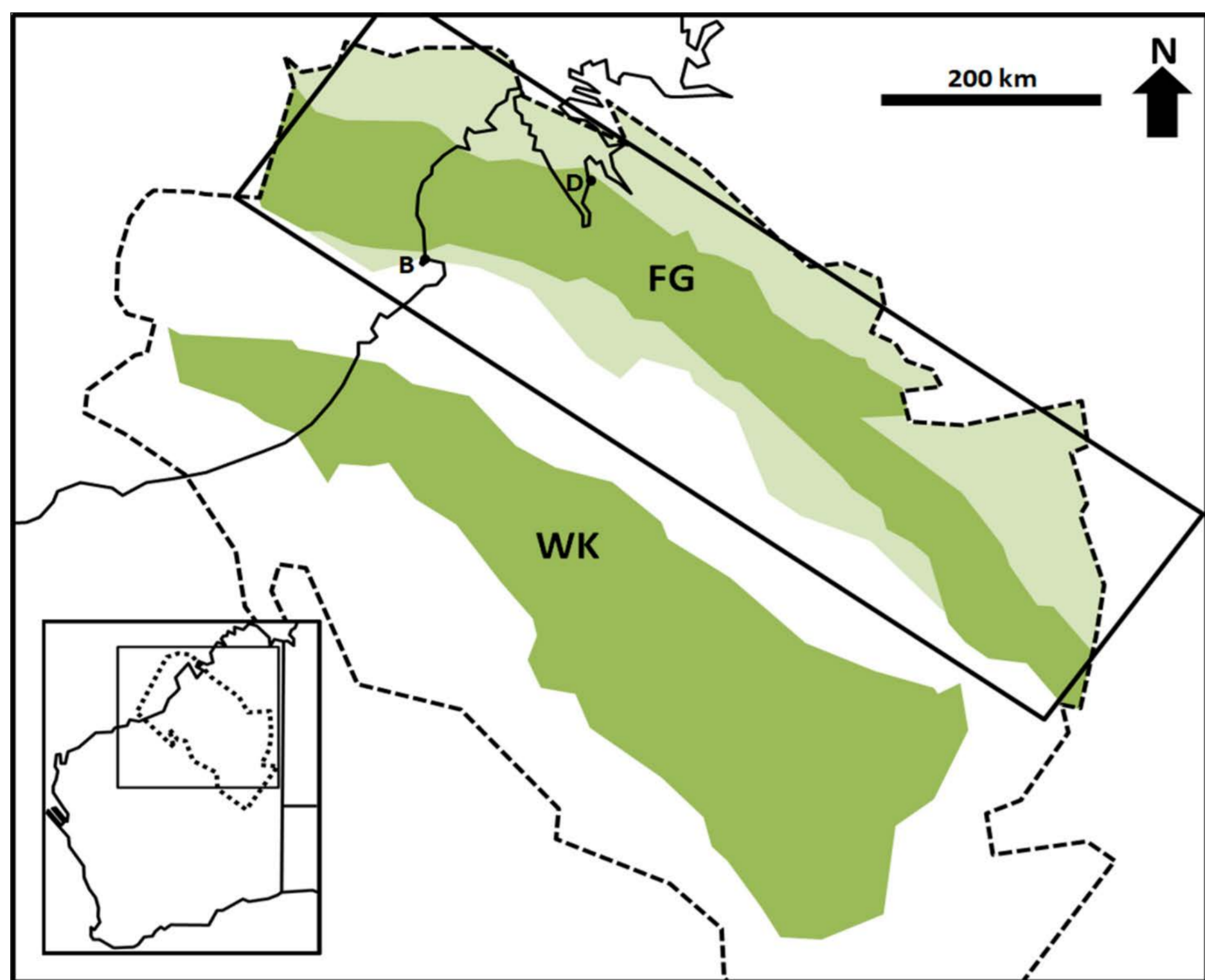
# Modelling sealing potential within the Palaeozoic Sequence in the Fitzroy Trough, Canning Basin, Western Australia [1]

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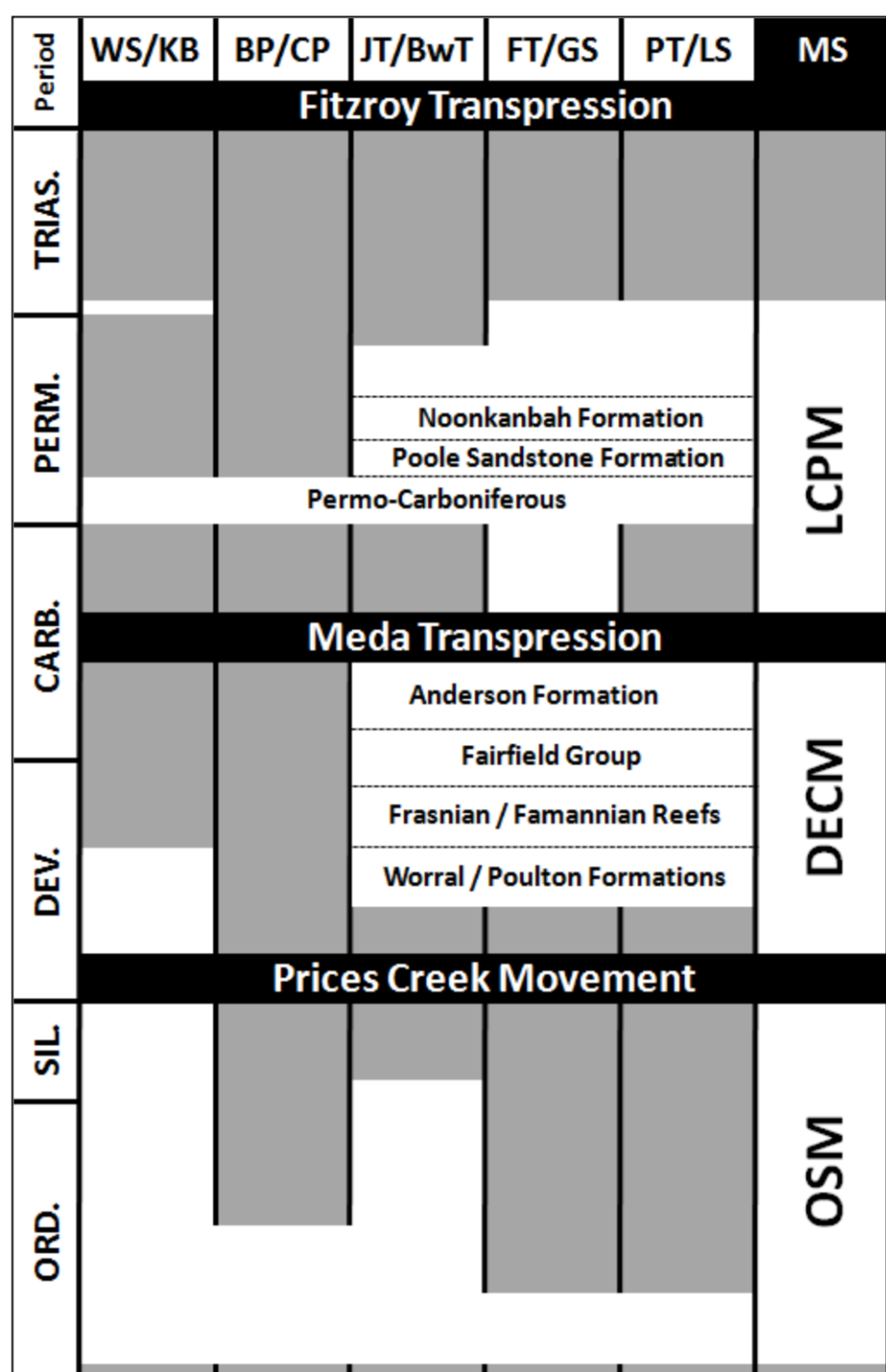
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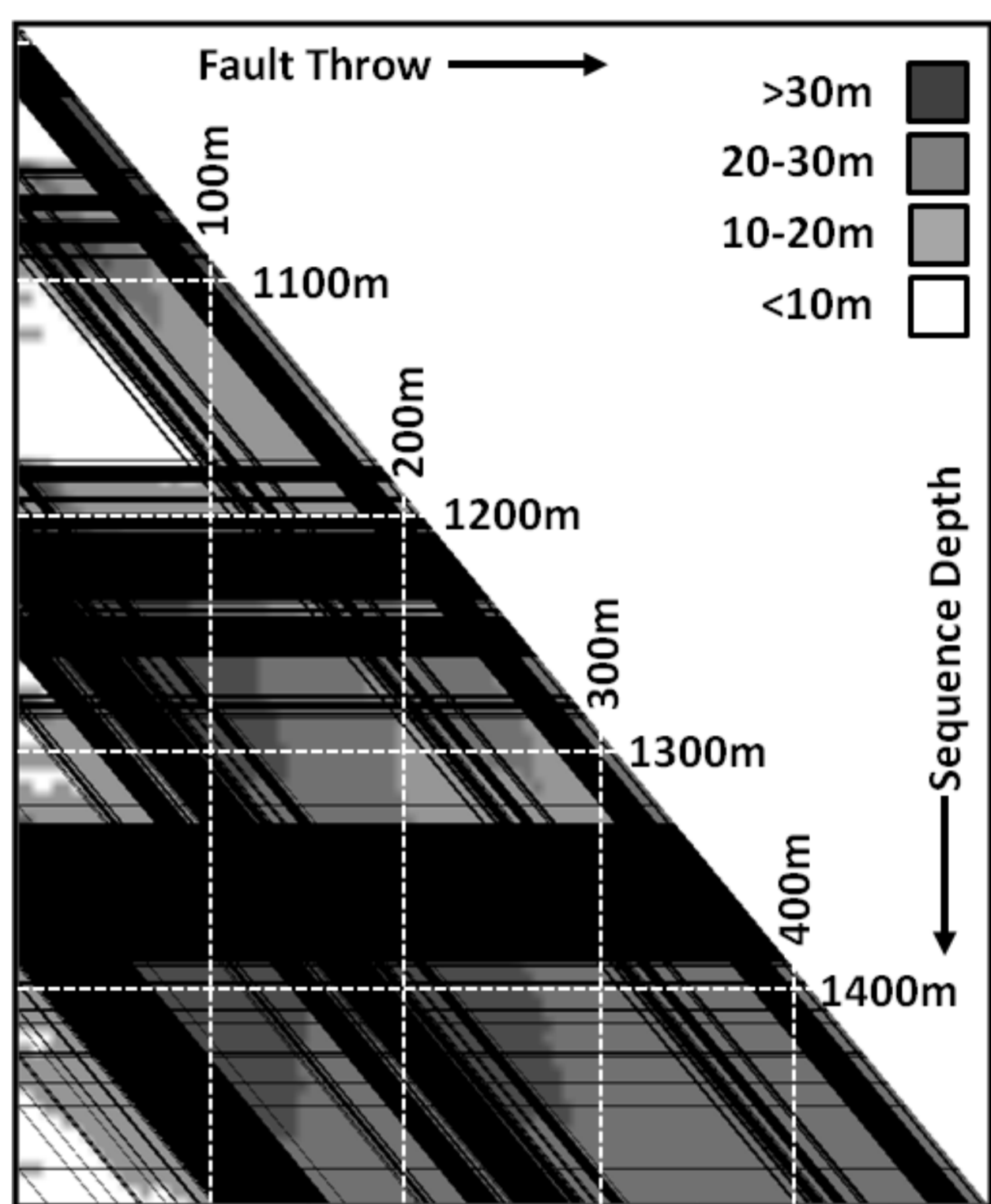
The Canning Basin in northern Western Australia is an extensive (500,000 km<sup>2</sup>), but underexplored Palaeozoic-Mesozoic sedimentary basin. The sub-basins are estimated to contain in excess of 12 km of Palaeozoic fill; however the deep sub-basins are further underrepresented by the well data which are concentrated on the flanks of the sub-basins. As part of a larger investigation of the resource potential of the Canning Basin, this stratigraphic forward modelling study draws together data existing sedimentological models and the well data from the earlier phases of the project to investigate the potential for predicting the sedimentary fill of the underexplored parts of the basin.



**Figure 1:** The Canning Basin is systematically subdivided with a broadly northwest to southeast fabric. Northeastern and southwestern troughs (darker green) are separated by a central platform ridge. The northeastern trough (FG) is subdivided into the Fitzroy Trough and the Gregory Sub-basin. The southwestern trough (WK) is divided into the Willara Sub-basin and the Kidson Sub-basin. The more northerly Fitzroy Trough / Gregory Sub-basin system is the focus of this modelling. The area modelled is indicated by the black rectangle. The lighter green areas flanking the trough in the model area are those defined as being flanking terraces and shelves of the trough as defined in Hocking (1994). The locations of the towns of Broome (B) and Derby (D) are indicated.



**Figure 2:** Simplified stratigraphic column for the tectonic elements of the NW Canning Basin (modified from Kennard et al., 1994). The central columns indicate recorded sediments (white) or the absence of sediments (grey - whether by non-deposition or removal by erosion) for the tectonic elements indicated in Figure 1 and their relationship to the Palaeozoic megasequences defined in Kennard et al. (1994), the Late Carboniferous-Permian Megasequence (LCPM), the Devonian Early-Carboniferous Megasequence (DECM) and the Ordovician-Silurian Megasequence (OSM), these are indicated in the right megasequences column (MS). The units which dominate sedimentation in the Fitzroy Trough and for the main units of interest for this study are named.



**Figure 3:** This project is aimed at modelling possible sedimentary sequences in areas which are underrepresented by the sometimes very sparse well data. As part of a precursor study sequences from the known wells were modelled for fault seal potential. Here a triangle plot for the lower Late Carboniferous-Permian Megasequence in the Padilpa-1 well, which is theoretically faulted past itself. The potential fault surface properties can be calculated and the example shown here presents the CO<sub>2</sub> column height supported on sand against sand juxtapositions (Black lines plotted indicate the footwall and hangingwall shale). The lower Late Carboniferous-Permian Megasequence sequence illustrated here displays good sealing potential, especially where related to intra-Permo-Carboniferous Sequence shales, and significant columns are supported at relatively low throws (<50 m).

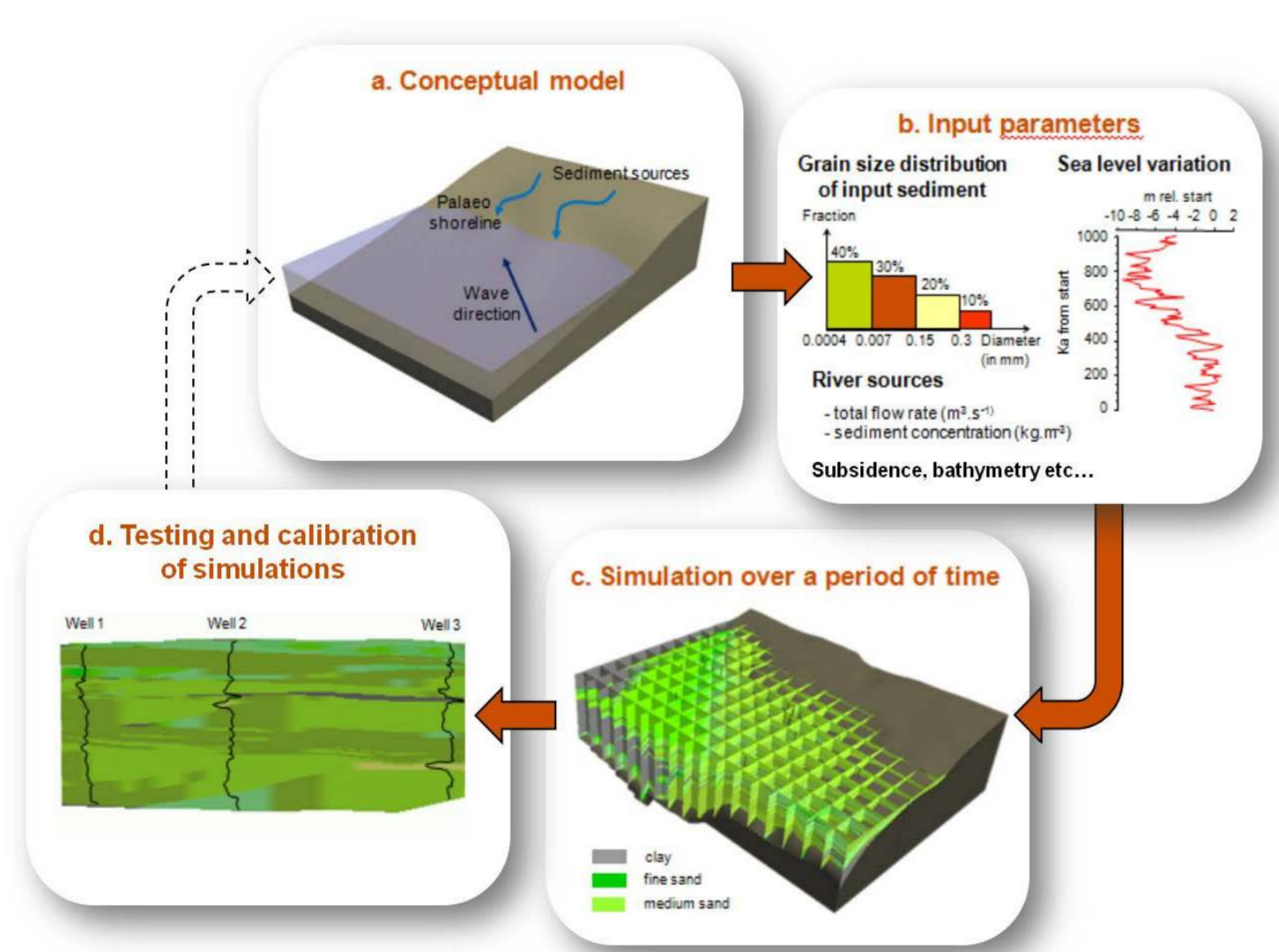
## Background

The Fitzroy Trough / Gregory Sub-basin system contains significant Palaeozoic sediments, studies suggest these are >10km; according to some estimates >12km thick. The sub-basin contains sequences varying from the classic Frasnian reef complexes today exposed in the Kimberly to the thick Permo-Carboniferous glacial Grant Group. The units of the trough underwent a significant Mesozoic basin inversion event, the Fitzroy Transpression, resulting in the formation of anticlinal structures and locally significant erosion. Historically exploration drilling within the Fitzroy Trough has targeted these anticlinal structures.

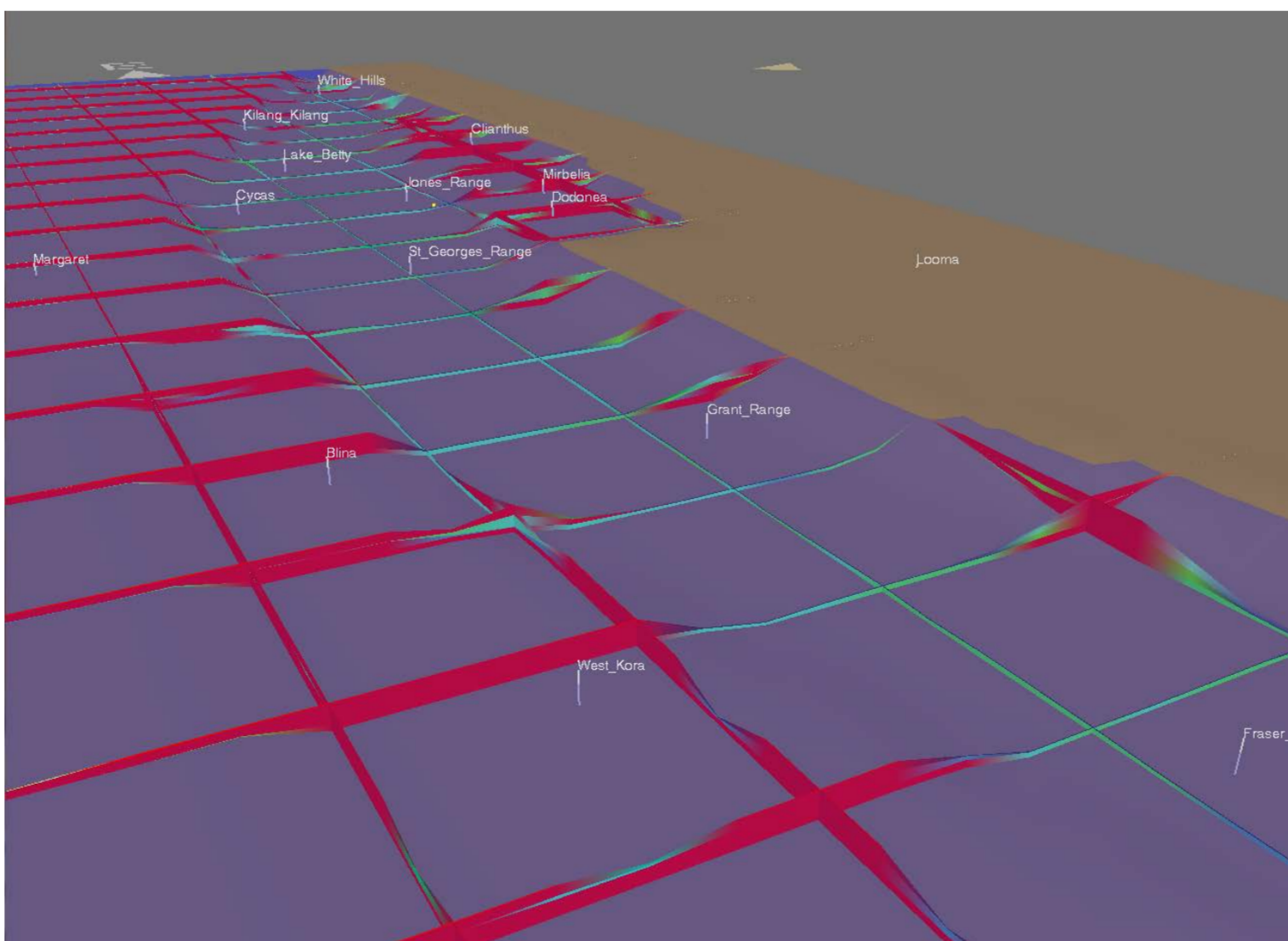
As part of a review of the Canning Basin, Fault-seal potential has been estimated for the later Palaeozoic sequence in the NW of the basin. This study focussed upon identifying localities where the sequence will be prone to fault-seal given suitable reservoir geometry. The application for this study is for hydrocarbon exploration, but CO<sub>2</sub> sequestration potential have accelerated impetus for the revaluation with the planning of the James Price Point (JPP) LNG facility, to service northern NW Shelf gas production.

The initial study analysed sequences directly from well data, which given the data sparsity, there are only 65 wells within 200km of JPP, limited the effectiveness of the modelling to the immediate vicinity of the wells. Additionally most of the wells are located on the trough's flanks rather than depocentres. Exploration targeting of anticlines has resulted in further under representation of the later parts of the sequence, due to significant, but localised, erosion on anticlinal crests, commonly including the significant top-sealing, Noonkanbah Formation. Prior to identifying suitable, fault-bound structures, identification of shale-rich, top-seal and fault-seal prone sequences is required.

As such the next stage goal of the project has been to produce a large-scale (900 x 300km) sedimentological model of the Fitzroy Trough / Gregory Sub-basin. These sub-basins forming the northern flank of the Canning Basin have a similar tectonic history from the early Devonian to the Jurassic which is not necessarily common to the rest of the basin. The stratigraphic forward modelling draws together data existing sedimentological models and the well data from the first phase. The output of the modelling will be used to additional estimates regarding seal potential and to provide a framework for hydrocarbon migration modelling studies.



**Figure 4:** Stratigraphic Forward Modelling has a four step iterative workflow. The simulation workflow is repeated while modifying the conceptual model and input parameters until appropriate convergence with available data is achieved.



**Figure 5:** The second series focussed on reproducing the Devonian carbonates. In these models sedimentary input / fluvial discharge input values were varied, in this case geographically to create the sedimentarily starved environment to enable carbonate growth and carbonate growth rules were iteratively modified to replicate the Late Devonian Reef systems. In these models the aggradational Frasnian reefs are indicated in red (10a) and progradational platform carbonates are blue (10b), silt is green, mud is purple and the brown shades indicate sandier facies. Black indicates organic rich units.

### FOR FURTHER INFORMATION

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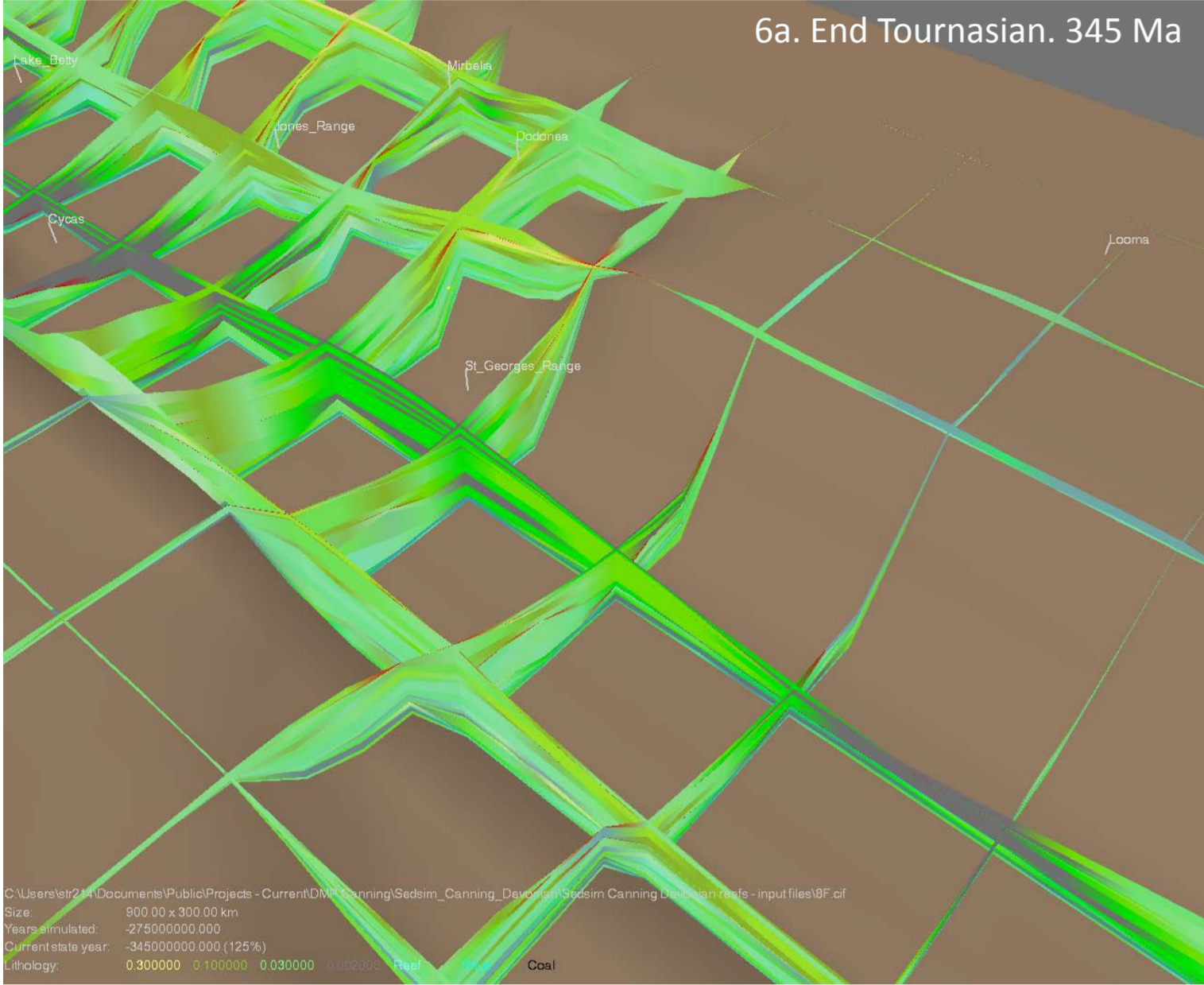
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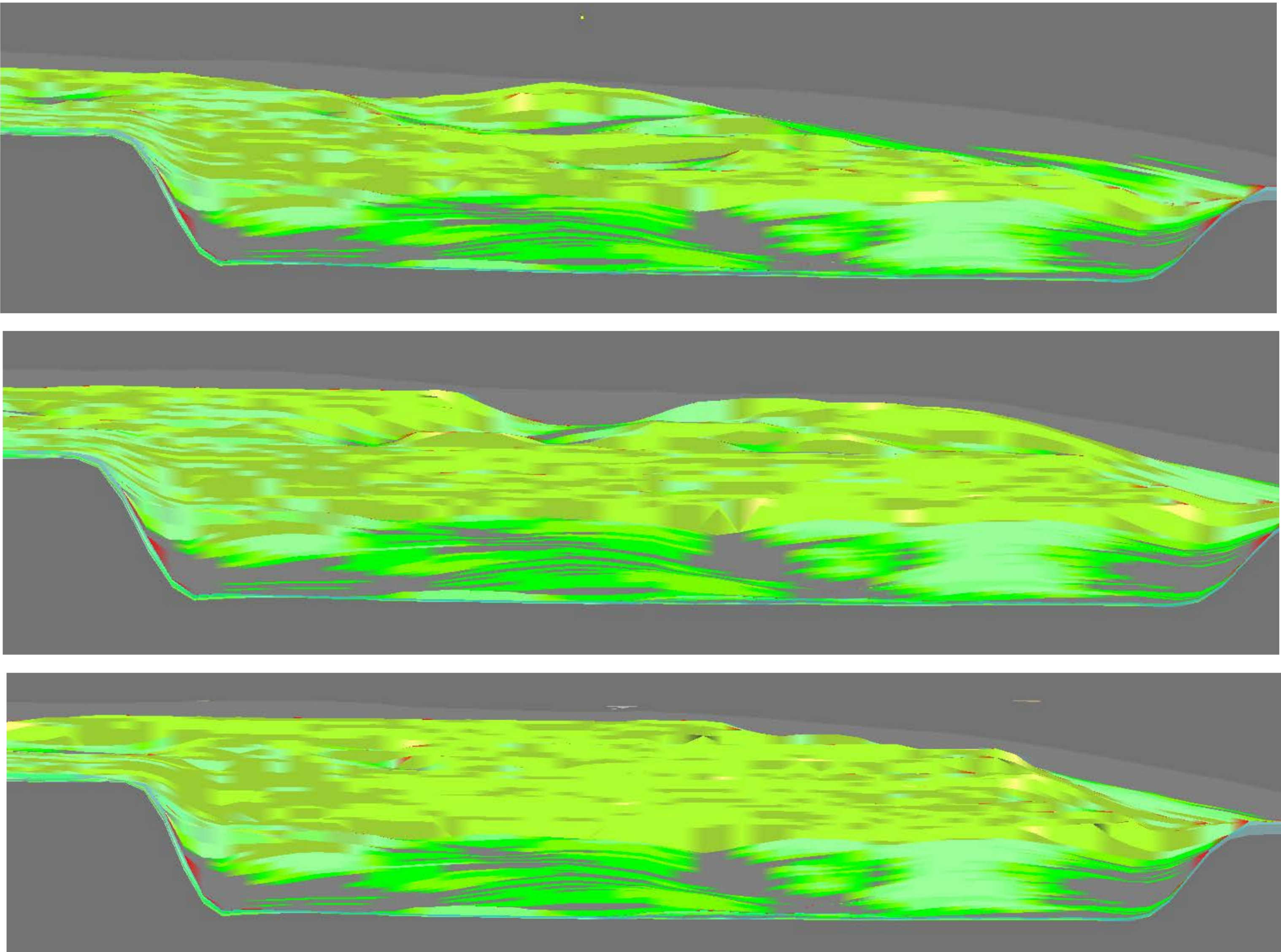
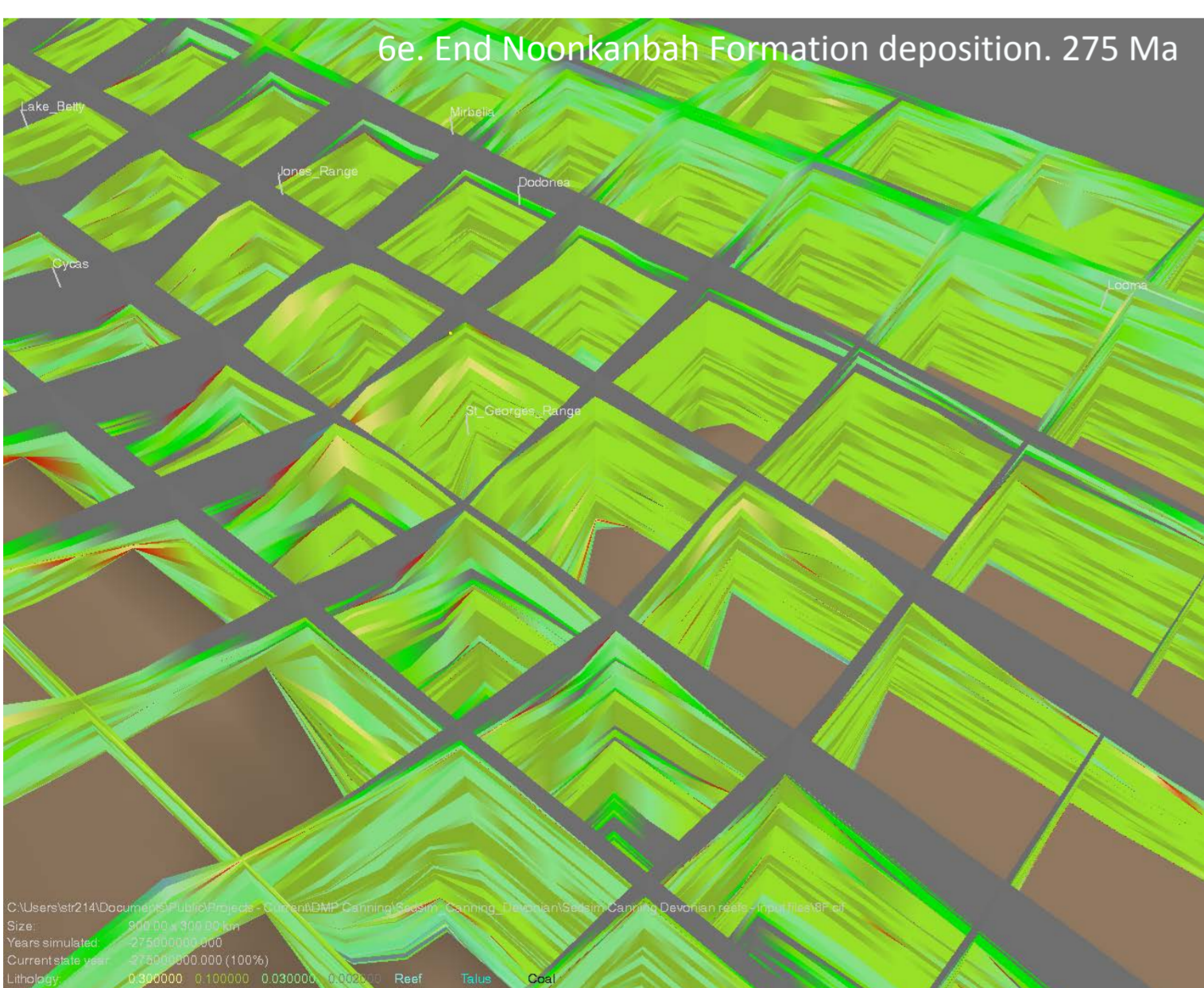
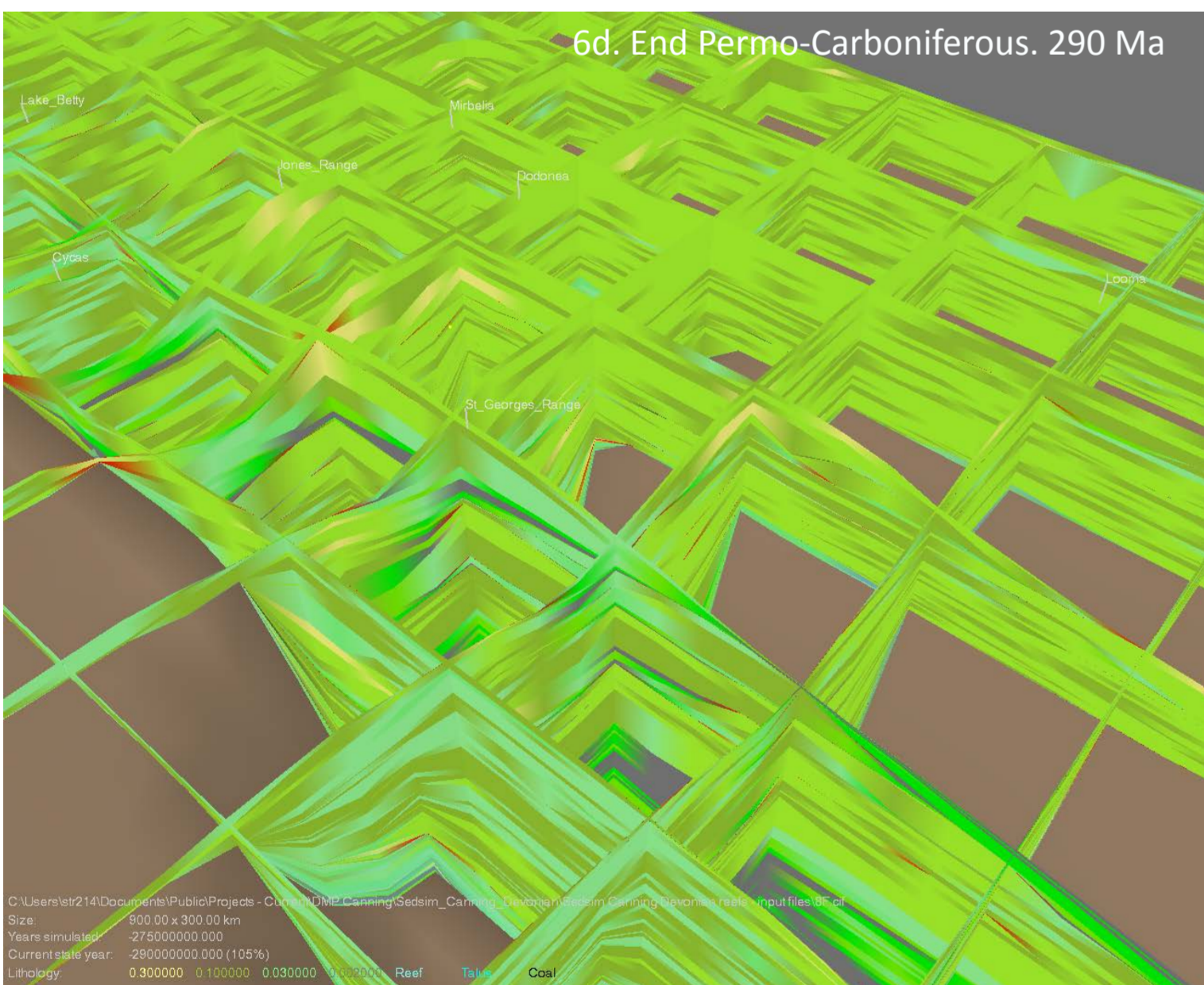
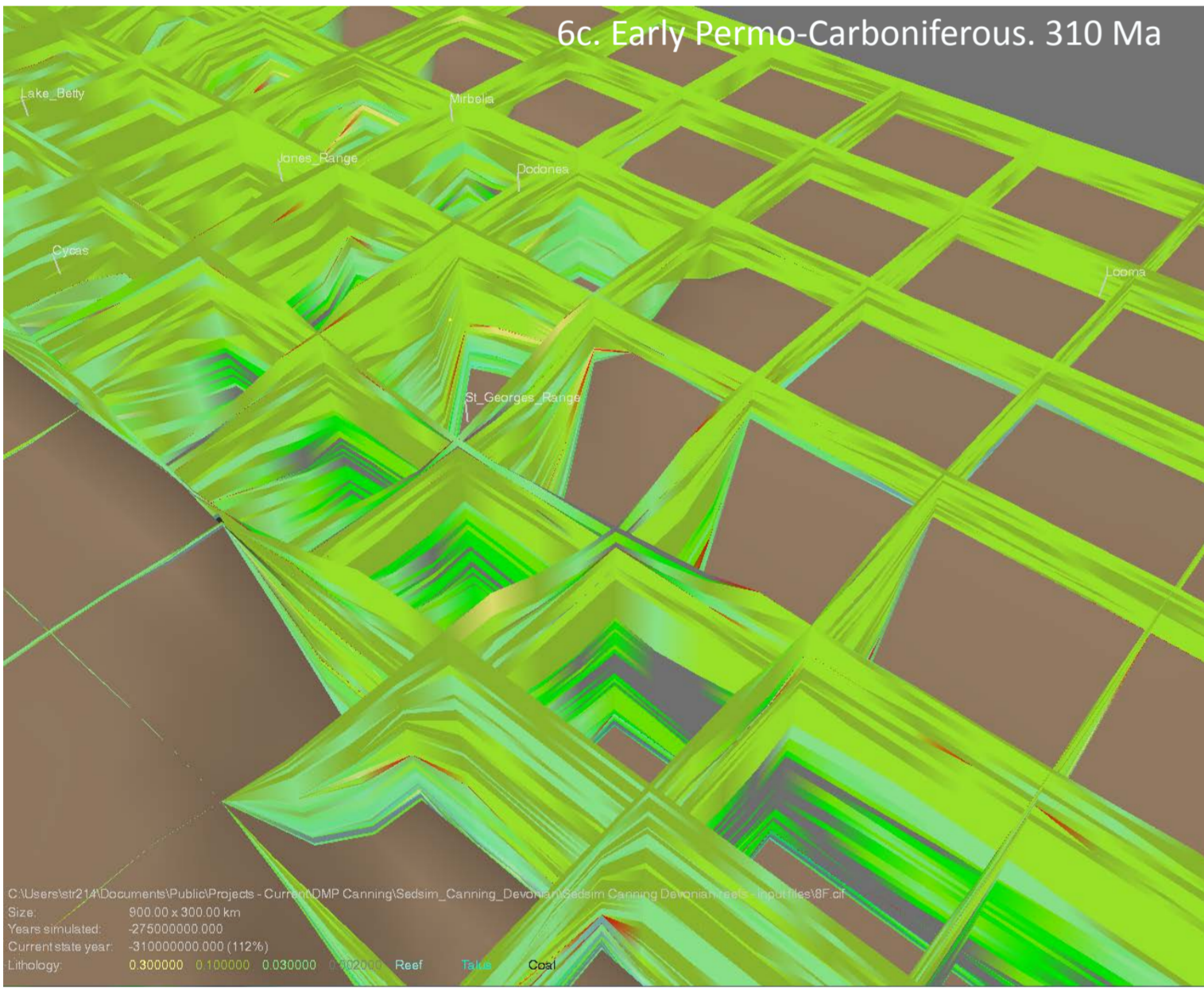
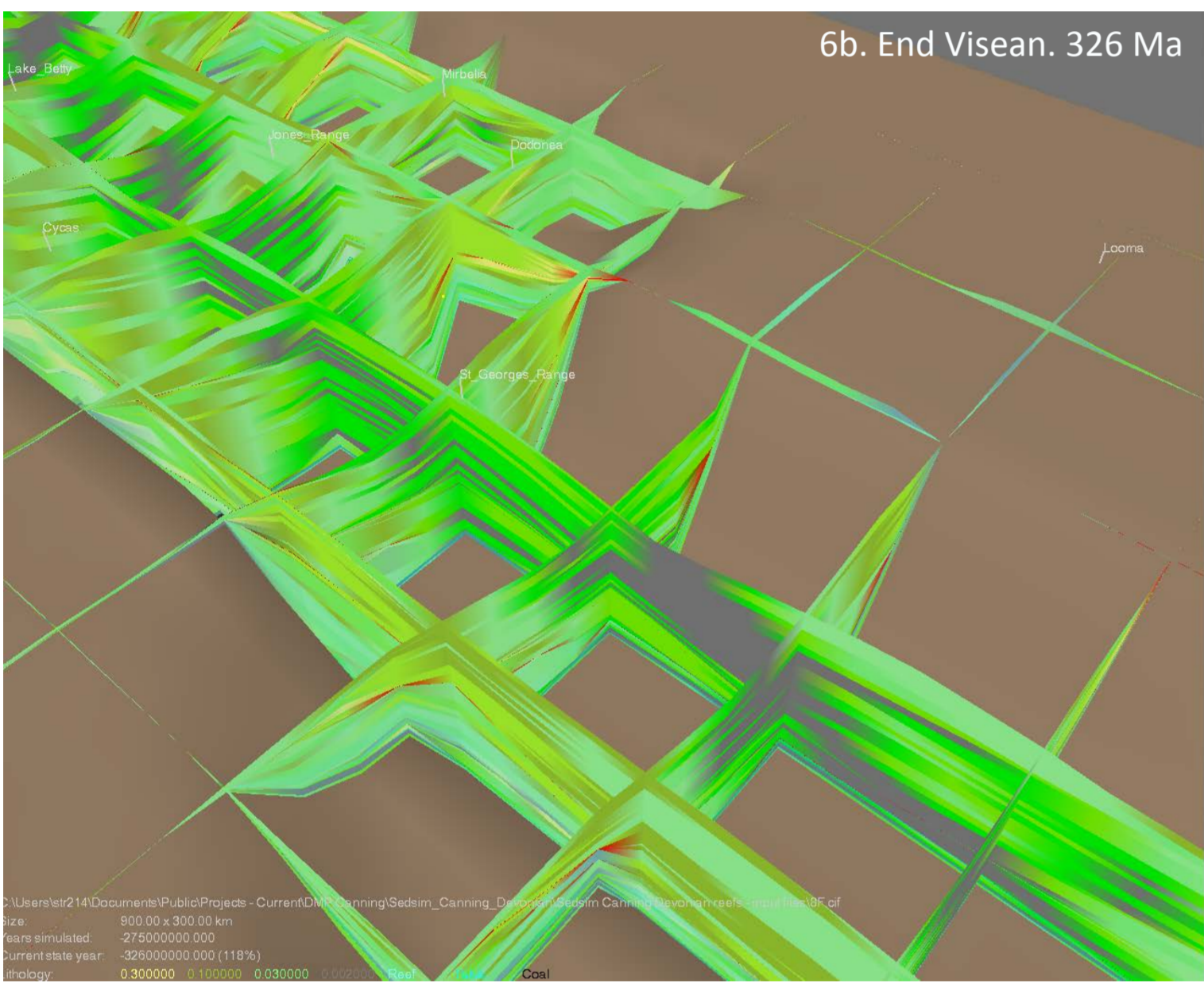
# Modelling sealing potential within the Palaeozoic Sequence in the Fitzroy Trough, Canning Basin, Western Australia [2]

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**Figure 6:** The build up of sedimentology throughout the later stages of model '8F' (360 – 275 Ma). The first image at 345 Ma illustrates the development of the Tournasian Fairfield Group, in particular the build up of silt and mud in the deep trough creating the Laurel Shale potential source. The pattern of sedimentation is largely continued into the Visean, with carbonate, mud, silty and coarser clastic deposition present, which replicates the varied nature of Anderson Formation deposition. Two images at 310 and 290 Ma illustrate the influx of fluvial material from the south, coarser clastic grains begin to dominate deposition, though lower net units are still common and even some carbonates occur. The final image is immediately post Noonkanbah formation deposition. This unit is dominantly mud dominated with siltier areas on the flanks of the trough. Noonkanbah Formation deposition is more problematic than the earlier sedimentation as the formation is the first which really has source points which are outside the trough model area.



**Figure 7:** Models in series '8' investigate the influence of localising discharge, hence sedimentary input. Upon observation natural discharge from source points into a given basin is generally dominated by flow from a restricted number of sources. The three cross-sections are aligned along the axis of the Fitzroy Trough / Gregory Sub-basin structure. The figure illustrates three realisations in which the Permo-Carboniferous Sequence was dominantly sourced via one, two or three fluvial systems. The same total volume of sediment enters the system in all three realisations. The impact on the shallow marine and fluvial environments in the trough is evident, especially when considering the accommodation space left for the later Noonkanbah formation to fill. The dominant factor is the size of the fluvial discharge carrying material into the depths of the trough, the single large fluvial system (model 8D) was more effective at producing a homogenous sedimentology in the deep trough, i.e. the single dominant source rather counter intuitively produced a more even sedimentary distribution in the trough axis as a result of the larger flow having more potential for carrying material into the deeper basin. Significantly this modelled homogeneity subsequently resulted in a more uniform Noonkanbah Formation thickness.

## Modelling Highlights

After an initial series of models to work out the bulk sedimentary volumes requires to fill the trough using the Sedsim sedimentary forward modelling software, a second series of models focussed on reproducing the Devonian carbonates (Fig. 5). Reef production is partly controlled by the tectonics interaction with the sea level, but led to the development for the Sedsim rules regarding carbonate generation throughout the whole modelled period. These were the first models where the sedimentary input / fluvial discharge input values were varied, in this case geographically to create the sedimentarily starved environment to enable carbonate growth.

The build up of sedimentology throughout the later stages of the model (360 – 275 Ma) is illustrated in figure 6. The first image at 345 Ma illustrates the development of the Visean Fairfield Group, in particular the build up of silt and mud in the deep trough creating the Laurel Shale potential source. The pattern of sedimentation is largely continued into the Tournasian, with carbonate, mud, silty and coarser clastic deposition present, which replicates the varied nature of Anderson Formation deposition. Two images at 310 and 290 Ma illustrate the influx of fluvial material from the south, coarser clastic grains begin to dominate deposition, though lower net units are still common and even some carbonates occur.

The final series of models investigated the influence of localising discharge, hence sedimentary input (Fig. 7). Upon observation natural discharge from source points into a given basin is generally dominated by flow from a restricted number of sources, this potentially might approach a power law distribution of discharge into basins, e.g. Gulf of Mexico, obviously dominated by the Mississippi, English Channel, dominated by the Seine. Figure 12 illustrates a series of cross-sections along the axis of the Fitzroy Trough / Gregory Sub-basin structure. The figure illustrates three realisations in which the Permo-Carboniferous Sequence was dominantly sourced via one, two or three fluvial systems.

## Key Conclusion

The sedimentary complexity of the Fitzroy Trough / Gregory Sub-basin structure has been modelled simply by varying a limited number of sedimentological input parameters. The sedimentological modelling has been fundamentally controlled by utilising a subsidence model determined from sedimentary thicknesses reported in wells around the trough. From this tectonic starting point the sedimentology of the trough is readily replicated, however the modelling also highlighted parameters controlling the location of and flow from specific source points as being one of the more significant factors to the internal distribution of facies.

### FOR FURTHER INFORMATION

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