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Discussion

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Discussion on 'Fault seal modelling – the influence of fluid properties on fault sealing capacity in hydrocarbon and CO_2 systems', *Petroleum Geoscience*, 2020, https://doi.org/10.1144/petgeo2019-126

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This discussion responds to the recent paper by Karolyté *et al.* (2020), in which strategies for the application of the shale gouge ratio (SGR) algorithm to fault seals in CO_2 sequestration are discussed and outlined.

The authors propose that the observed hydrocarbon columns in the Katnook field in South Australia and the Boggy Creek field in Victoria are supported by fault rock seal. Fault rock seal (membrane seal) is thought to arise from a contiguous, fine-grained fault core, forming a capillary barrier for two non-miscible fluids (Yielding *et al.* 1997). The authors use the inferred hydrocarbon columns and pressures to calibrate and constrain the use of interfacial tension (IFT) and contact angle (CA) data for use in capillary seal calculations to forecast CO_2 accumulations.

The authors have not supplied the basic geologic data to support their work, and we question the author's conclusion that fault-rock seal is active in these two fields.

Using the data provided in the paper, we were unable to create Allan maps. The maps provided in figure 2 do not show contours thus we were unable to:

- tie the maps to the wells
- use the maps to assess fault geometry and displacement consistency
- check the Allan Maps that are presented.

Whilst well data have been used, the lack of comprehensive referencing of the data sources make it difficult to:

- define a stratigraphy
- review gas water contacts (GWC)
- define flow units
- assess VClay for an SGR calculation.

It should be noted that well completion reports and well logs are freely available from the respective state geologic surveys. However, the 3D models that were used to define the fault geometry are not publically available, nor adequately documented in the paper. Despite the lack of data we were able to make some preliminary inferences.

Katnook Field

The Ladbroke Grove growth fault appears to have *c.* 500 m of throw at the reservoir top. As the reservoir (Pretty Hill) and the top seal (Crayfish Group) are very thick, there will be a reservoir-reservoir juxtaposition across the Ladbroke Grove fault (figure 2c). The author's conclusion that the gas column of 31 m is supported by fault membrane seal is not the only explanation. The vertical seismic resolution is commonly 20–40 m and when convolved with picking uncertainty a significant systematic error is to be expected. In the absence of data and stochastic modelling of the fault geometry (Murray *et al.* 2019) it is suggested that the GWC could be controlled by a juxtaposition leak point rather than membrane seal. We also draw attention to the study by Boult *et al.* (2004), which states that the Katnook field is filled to structural spill (table 1 in Boult *et al.* 2004). These two points draw into question the validity of the author's figure 7 and the 'first-to-leak-point' analysis.

To support the author's assertions an annotated map that unequivocally ties to the well data and regional fluid contact data is required. Further a quantitative analysis of fault and displacement geometries are needed (Barnett *et al.* 1987).

There are three additional fault dependent fields in the vicinity of Katnook (Boult *et al.* 2004). It would be expected that statements regarding fault seal for Katnook should consider consistency across all four fields.

Boggy Creek Field

As with Katnook, the Boggy Creek analysis does not include a structure contour map with posted contours. Neither does it provide stratigraphic/ well log data. We were unable to:

- check the mapped GWC
- calculate throw profiles for the Boggy Creek or Buttress faults
- create Allan maps to determine cross fault juxtaposition.

The authors show the reservoir (Waarre Formation) juxtaposed against the Eumeralla Formation across the Buttress fault, and inferred that fault rock seal supports a 51 m gas column.

A review of the log data from Boggy Creek-1 shows a 60 m penetration of the Eumeralla (Fig. 1). Thus the available log data covers the interval where the authors concluded that a membrane fault seal is active.

The gamma ray for both the Eumeralla Formation and the Belfast Formation (topseal) are similar, and relatively uniform. Also of significance are the deep and shallow laterolog data. In the Eumeralla Formation these are coincident, thus showing no drilling

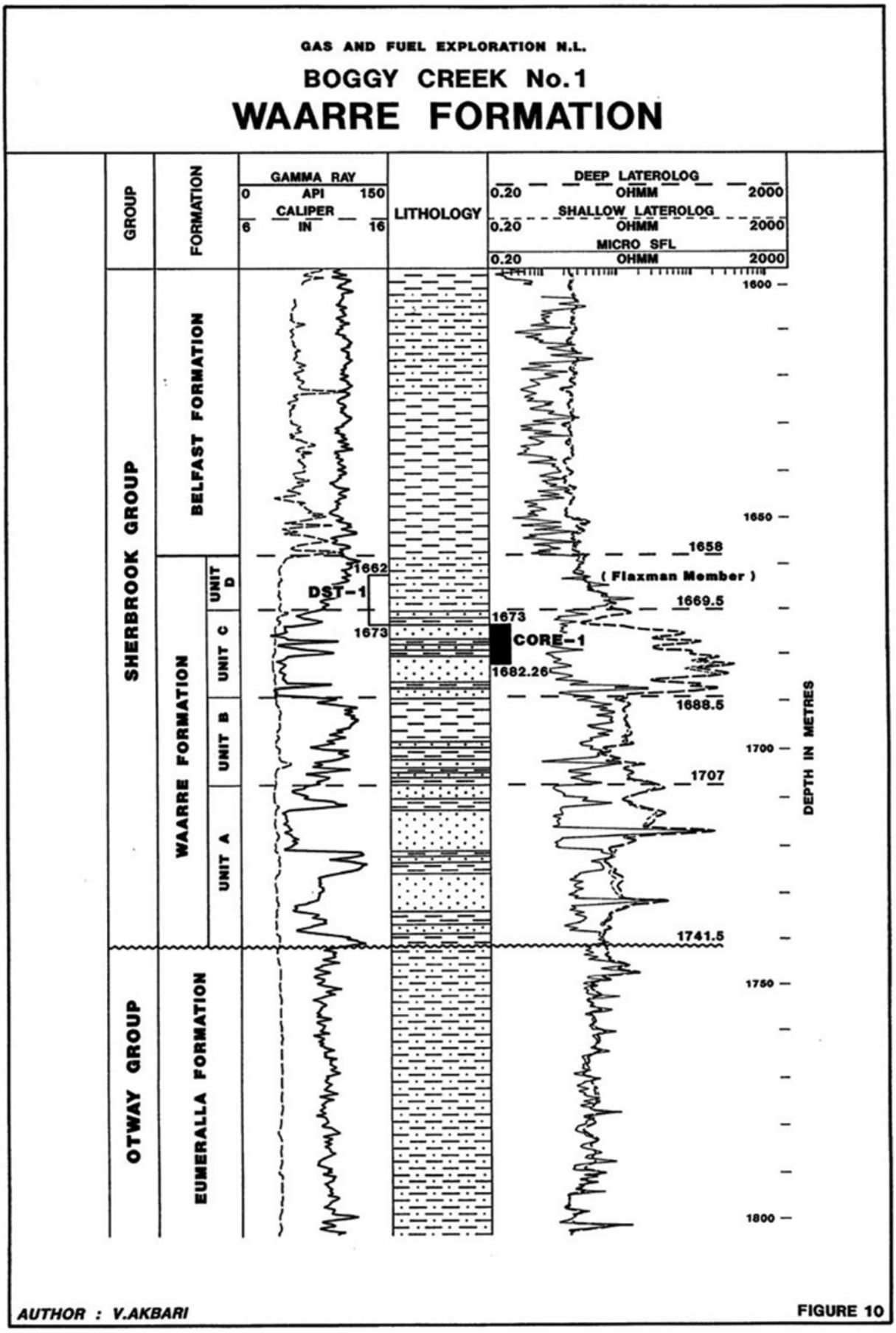

Fig. 1. Summary log from the Boggy Creek-1 well completion report. Note that the contrast in deep and shallow laterolog resistivity is minimal in the Eumeralla, consistent with very low permeability. We question the interpretation of the Eumeralla as a flow unit necessitating fault rock seal.

mud infiltration. This observation, in the absence of other data, leads us to consider the Eumeralla a seal facies.

To support the author's assertions properly annotated maps that unequivocally tie to the well data and regional fluid contact data are required. Consistent fault and displacement geometries should be illustrated. There are two other fault dependent fields in the vicinity of Boggy Creek; it would be expected that all the fields be considered. Finally an explanation as to why the Eumeralla should not be a seal and thus require fault rock seal to support a column should be provided.

Summary

Given the lack of maps and stratigraphic data we suggest that the authors have not presented a firm case for fault membrane seal. If membrane fault seal cannot be shown in these fields and the neighboring five fields, the foundation for the main body of work presented is in question, as are the conclusions (see for example the author's figure 8 and the surrounding discussion).

The authors should be commended for developing stochastic methodologies for capillary seal processes. However, we would encourage the use of similar methods to evaluate assumptions of fault membrane seal. Given uncertain data it is important to evaluate a range of solutions rather than the single possibility of fault rock seal. If fault rock seal is not occurring in these fields it is likely the authors have built on a single answer that is precisely wrong.

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Data availability statement The datasets generated during and/or analysed during the current study are available in the Geological Survey of Victoria repository (https://earthresources.vic.gov.au/geology-exploration/maps-reports-data).

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