

# **Stratigraphic Forward Modelling for Investigating Hidden Reservoir Geometries and Connectivity: Springbok Formation (Surat Basin, Queensland)\***

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Search and Discovery Article #51202 (2015)

Posted December 14, 2015

\*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015, AAPG/SEG © 2015.

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## **Abstract**

Stratigraphic Forward Modelling can be used to predict reservoir architectures, in order to understand the potential for hydraulic connectivity between formations. This study focuses on a virtual reconstruction of the Springbok Formation (Late Jurassic) in the Surat Basin for investigation of geobody architecture in areas of low well and seismic coverage.

## **Introduction**

Interest in basin fill mechanisms for the Surat Basin has grown in response to significant onshore gas development. After a long history of conventional gas exploration, the eastern Surat Basin has developed as an active regional exploration target for Coal Seam Gas, hosting large gas reserves (Scott et al., 2007; Hamilton et al., 2012, 2014). The Surat Basin is characterised by sedimentary successions with a high level of geometric complexity. The difficulty in correlating coal seams and groups of seams from the eastern to the western flanks of the Surat Basin leads to uncertainty in the depositional model that is required to determine reservoir architectures. Stratigraphic Forward Modelling (SFM) can provide insight to probabilistic grain size distributions in areas with little well or seismic data. With adequate constraints on paleo climate, sedimentary sources, and pattern of accommodation space within the basin, SFM is able to predict the sequence stratigraphy with reasonable resolution from marginal to depocentre areas.

This work shows some preliminary results of a virtual reconstruction of the Springbok Formation, which was deposited during the early Late Jurassic (Oxfordian) within the Surat Basin (Queensland). This formation is ascribed in the literature to an extensive fluvio-alluvial system, which is conformably overlaid by the alluvio-coastal system of the Westbourne Formation (Kimmeridgian-Tithonian). The Springbok Formation has variable fluid flow characteristics ranging from that of an aquifer to that of an aquitard. Even the poor outcrop expression brings uncertainties to internal architectures and sediment dispersal. The key-feature of the Springbok Formation is the basal unconformity, which in places incises the Walloon Coal Measures on the eastern and western margins of the basin. The stratigraphic relationship between the Walloon and Springbok strata in the western and the central part of the basin has not been well documented (Hoffmann et al., 2009), until recent work by Sliwa as part of a basin wide study by the Office of Groundwater Impact Assessment (OGIA, unpublished). Investigating the nature of the unconformity can be useful for the prediction of reservoir connectivity of the Springbok and potential for poor well production in the underlying coal seams.

### **Geological Setting and Methods**

The Surat Basin is located in the eastern margin of Australia, across the boundary between Queensland and New South Wales. It covers 300,000 km<sup>2</sup> and is joined with Eromanga and Clarence-Moreton basins across intervening basement ridges. It was generally described as an intracratonic sag basin in which deposition was influenced by a constant subsidence, but recent geodynamic modelling suggested three main subsidence periods during the basin history. Although the Surat Basin does not have a complex tectonic history, it has persistent structural highs, such as the Roma Shelf on the west and the Burunga-Moonie-Goondiwindi fault system in the east.

LECODE (Landscape Evolution Climate Ocean and Dynamic Earth) is a new geomorphic and stratigraphic forward modelling code capable of simulating sedimentary processes in 3D through geological time (Salles and Duclaux, 2014). The forward model has to be fed by the conceptual model, which is constrained by the collection of geological data, such as background data, hydrological and sediment parameters and rainfall and uplift rates; they can be easily collected by well data or inferred by analogue study case. To better calibrate these parameters is necessary a wide and reliable dataset of constraining. The model could be very sensitive to the variation of parameters inferred by analogue modeling. In this case, the validation has a key role in the modelling, which can be satisfied by a constant checking in loop process between the forward model and the conceptual to complete them synchronously. The result will provide high-resolution stratigraphic records, sediment dispersion and clastic sedimentary system evolution (Bianchi et al., 2015).

## Parameters and Simulation

The model starts with the set up of background layers, as the reconstruction of a paleotopography and the substratum geology. The initial paleotopography has been assumed by considering the restored top surface of the Walloon Subgroup with thermal subsidence still ongoing; it has been recognised in more than 3000 wells across the basin. As substratum geology, a widespread clay- and silt-rich layer has been set up, in order to simulate the erodible lithology that constitute the top members of the Walloon Subgroup. Tectonic and climate controls have been applied as constant forcing to the sedimentation through time. In particular, the uplift/subsidence patterns have been considered as the difference between the actual top Walloon and the restored surface. The cause could be double: thermal subsidence or/and deformation for compaction. The simulation lasts 1 My with the setting of constant sediment supply given by three sources. They provide three streams with the same hydraulic and solid parameters (see [Table 1](#) for details of parameters). The modelled parameters have been chosen considering the similarity with bedforms and drainage size of the Bramaputra River modern depositional analogue in the segment near Assam. For strictly constraining the sedimentary facies and dispersal, available FMI and core analysis show the depositional setting to be an overall fluvial environment characterised by the gradual change from amalgamated to less amalgamated channels ([Figure 1C](#)). This evolution is clearly recognised by the presence of sandy channel scoured on sandy channels, which ascribe an amalgamated setting, whereas sandy channel plugged by mud and silt indicates less amalgamated channel setting. The lower amalgamated section of the Springbok Formation is characterised by the presence of channels filled by 10-m-thick frontal or lateral accretion features. The upper less-amalgamated section of the Springbok Formation displays 3-m-thick fining-upward sequences culminating in coal accumulation at the top. The sediment dispersal for the lower section has a main direction toward the S-SE ([Figure 1A](#)), whereas the upper section shows a radial pattern highlighting the presence of more sinuous channels, with a main direction towards S and E ([Figure 1B](#)).

## Results and Discussions

The model predicts sedimentation patterns in the depocentre and basin margins similar to models proposed by companies (e.g. QGC modelling on Springbok Formation, 2012; [Figure 2A](#)). Model results consist of (i) a basal coarse-sandy floor widespread across the basin, (ii) very-thick fine-sand deposits indicating periods of high-accommodation space, then (iii) a clay-rich layer which seals the system was deposited at the end of the period of high-accommodation space ([Figure 2B](#)). At the margin, a (iv) thin-layered coarse clean sandy wedge is predicted to be prograding toward the basin depocenter, representative of deposition during a period of low-accommodation space ([Figure 2C](#)).

The clay-rich layer, which behaves like a “sealing” layer for the reservoir, has economic relevance (Pohl, 2010). The Springbok Formation is no longer considered as a uniform aquifer, but has strong heterogeneity in the stratigraphy.

Due to the imposition of constant sediment supply and tectonic and climate controls, the sedimentation is driven by autogenic processes beyond any sea-level fluctuation. The model finds the equilibrium profile at the end of the overfilling of the system (Leeder, 2011), which corresponds to deposition of the clay-rich layer ([Figure 2B](#)). At that moment, the gradient is nullified by the overfilling and generates the retreat of the sediment sources. Since the subsidence is still on going (set as a constant in the model) a depositional gradient is eventually re-established. When the gradient is re-established, sources tend to then cannibalise the sediment of the overfilling phase (Ghinassi, 2005), resulting in a coarse-sandy prograding wedge ([Figure 2C](#)).

Several hypotheses of basin forming processes such as climatic changes and tectonics are associated with the Springbok Formation unconformity. Although the literature proposes that the Argoland rifting (NW of Australia) occurring at the time of Springbok deposition, it seems too far distant to trigger such an extended erosional event.

### **Conclusions**

Because of the hydrological laws built into the SFM it has the power to predict the basin stratigraphy. One of the strengths of the SFM is the prediction of reservoir or seal lithologies at location where there is little well or seismic control. Keeping allogenic processes constant during the sedimentation results in the models forecast of grain-size heterogeneities being driven by autogenic processes. This provides insights in how overfilling and cannibalisation can result in deposition of “self-sealing reservoirs” (reservoir sands capped with mud).

### **Acknowledgments**

We gratefully thank Queensland Gas Company (BG group), Santos, Origin, Arrow, Office of Groundwater Impact Assessment, Center for Coal Seam Gas (University of Queensland), Queensland Government, Dr. Renata Sliwa, Dr. Morteza Jami, Dr. Fengde Zhou and Daren Shields.

## Selected References

- Bianchi V., T. Salles, M. Ghinassi, P. Billi, E. Dallanave, and G. Duclaux, 2015, Tectonically driven deposition and landscape evolution of upland incised valleys: numerical modeling of the Pliocene-Pleistocene Ambra Valley: the Plio-Pleistocene Ambra Valley-fill succession (Tuscany, Italy): *Sedimentology*, v. 62/3, p. 897-927.
- Ghinassi, M., 2005, Tectonic driven evolution of a Pliocene Gilbert-type delta (Val d' Orcia Basin, southern Tuscany, Italy): *GeoActa*, v. 4, p. 105-122.
- Hamilton S.K., J.S. Esterle, and S.D. Golding, 2012, Geological interpretation of gas content trends, Walloon Subgroup, eastern Surat Basin, Queensland, Australia: *International Journal of Coal Geology*, v. 101, P. 21-35.
- Hamilton S.K., J.S. Esterle, and R. Sliwa, 2014, Stratigraphic and depositional framework of the Walloon Subgroup, eastern Surat Basin, Queensland: *Australian Journal of Earth Sciences*, v. 61/8, p. 1061-1080.
- Leeder, M.R., 2010, Tectonic sedimentology: sediment systems deciphering global to local tectonics: *Sedimentology*, v. 58, p. 2-56.
- Salles T., and G. Duclaux 2014, Combined hillslope and channel processes simulation applied to landscape and alluvial system modelling: *Earth Surface Processes and Landforms*, <http://dx.doi.org/10.1002/esp.3674>.
- Scott S., B. Anderson, P. Crosdale, J. Dingwall, and G. Leblang, 2007, Coal petrology and coal seam gas contents of the Walloon Subgroup — Surat Basin, Queensland, Australia: *International Journal of Coal Geology*, v. 70, p. 209-222.

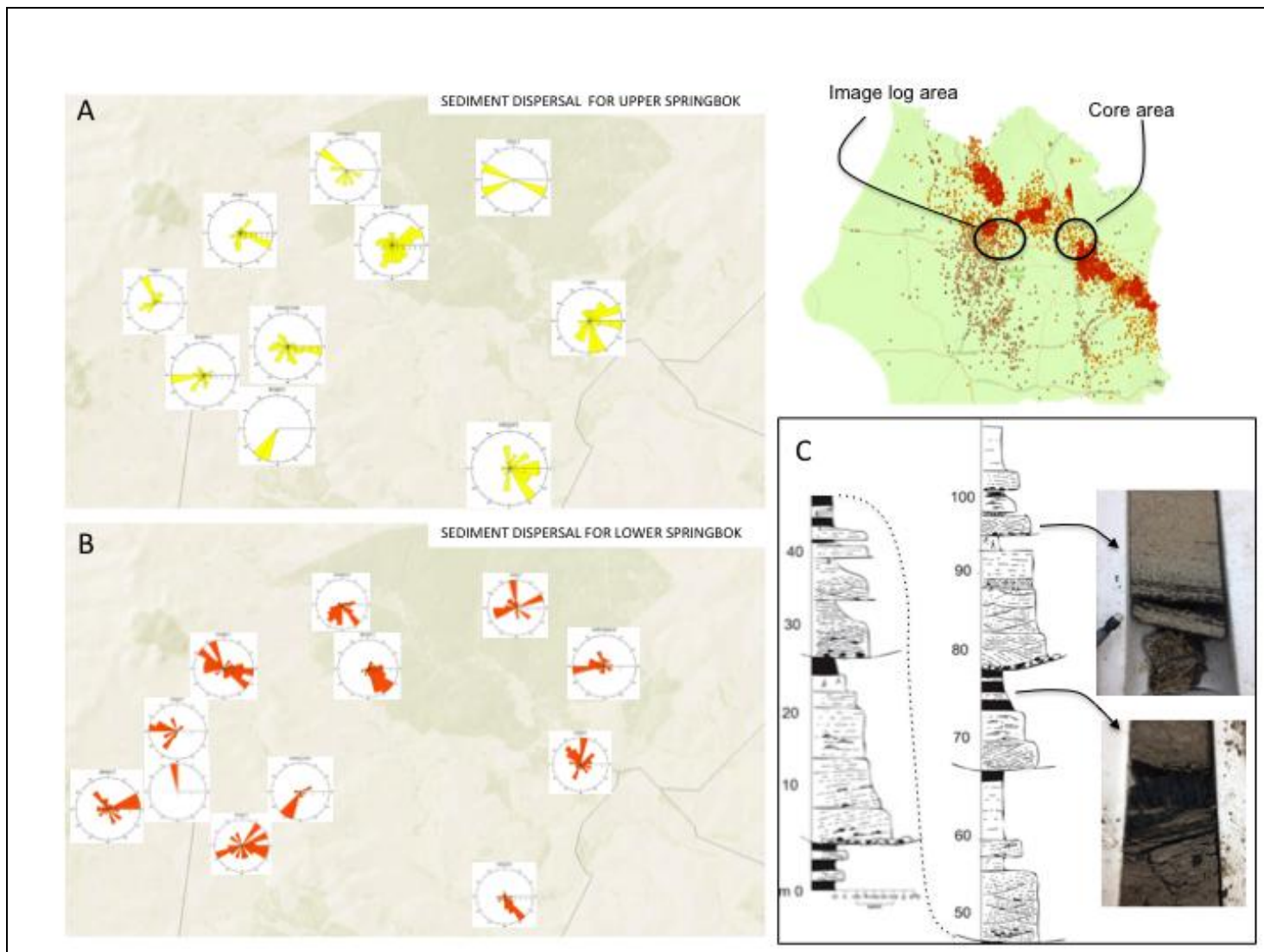


Figure 1. A) Sediment dispersal from image logs for upper Springbok, B) sediment dispersal for lower Springbok, C) core log and related photos. Inset located in the uppermost right-hand side.

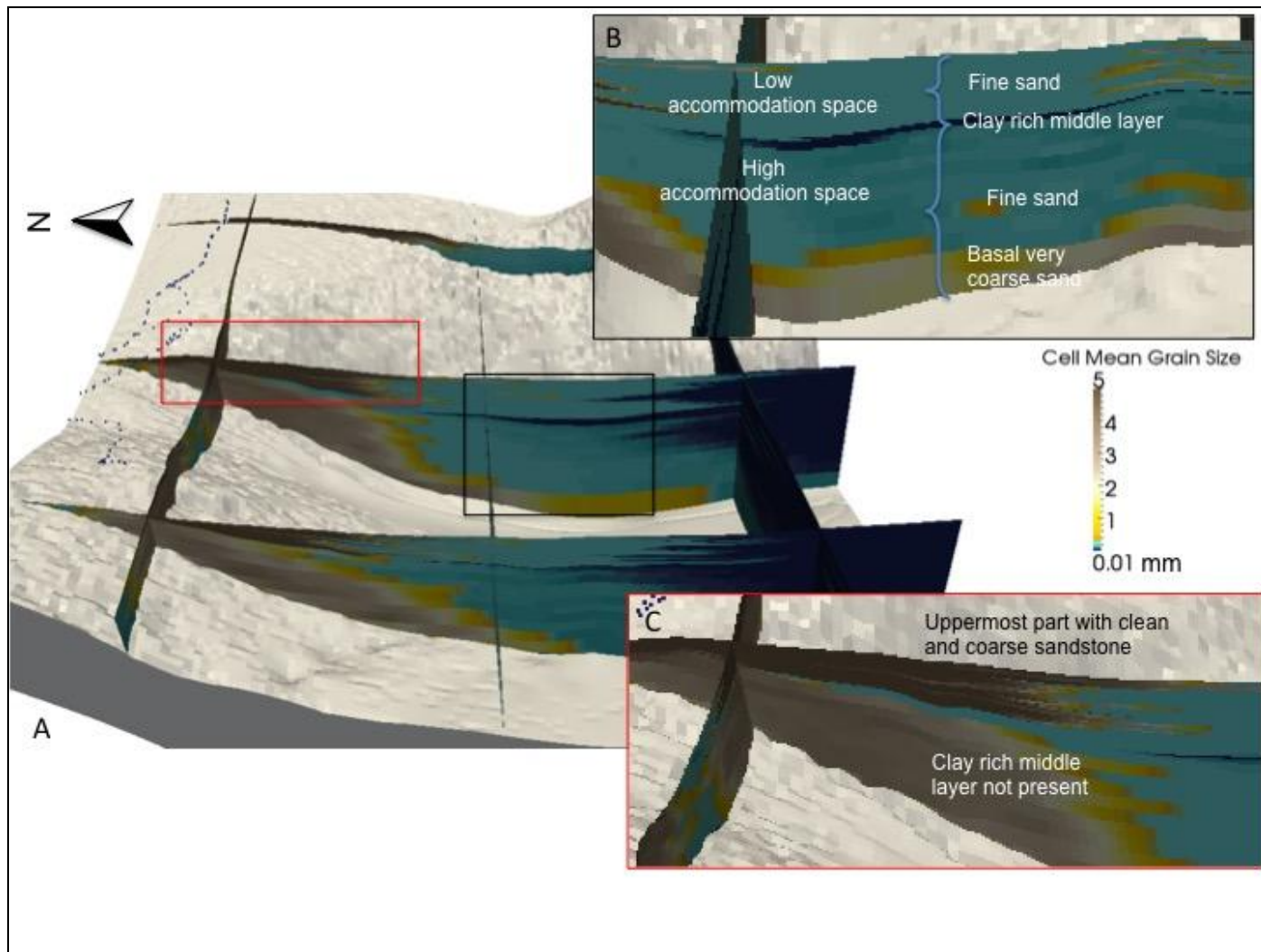


Figure 2. Screenshot of the Forward Stratigraphic Model in A. Details in B (depocentral areas) and C (marginal areas).

Parameters	Maximum WDischarge	Bedload discharge	Grain-size classes	Velocity	Flow type	Recurrence per annum	Min/Max Depth	Min/Max Width
Values	1000 m <sup>3</sup> /s	100 Mt/a	Coarse sand Medium sand Fine sand Clay	1 m/s	Laminar (openchannel)	75%	0.05/20 m	1/1000 m

Table 1. Hydraulic and solid parameters of sources.