The 3D Digital Geological Model of the Latrobe Valley Coal Resource – benefits of building versatile models

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ABSTRACT

The 3D Digital Geological Model of the Latrobe Valley Coal Resource captures and safely archives 90 years of knowledge accumulated by the State Electricity Commission of Victoria and other workers that was previously accessible only as paper records. 9,086 bores have been modelled over a total area of 4,916 km^2, to include all onshore Gippsland Basin brown coal fields. Roofs and floors have been created for the sixteen thickest brown coal seams and splits off main parent seams. Seventeen coal quality parameters are incorporated into a block model.

The past few years have seen the purpose of the model changing. It is no longer a tool solely used to inform coal development opportunities, but is also used to inform coal mine rehabilitation. This paper highlights the relative strengths of explicit (data driven) versus implicit (significant amount of user input required) modelling based on the spatial coverage/resolution of the data. Also highlighted is the need for greater transparency in the strengths and uncertainties in 3D spatial models.

Keywords: Brown coal, resource model, Latrobe Valley, mine rehabilitation

1 INTRODUCTION

The 3D Digital Geological Model of the Latrobe Valley Coal Resource was developed for the State Government of Victoria in 2003 as a regional scale tool for supporting the management of the coal resource, matching coal to development opportunities and informing land use planning. Over time, the spatial extent of the model has been increased to cover more of the coal resource. This model helps stakeholders (Government, town planners, mining and exploration companies) make better informed decisions relating to coal resource development and future mine rehabilitation.

2 GEOLOGICAL SETTING

The 3D model covers the Latrobe Valley and Seaspray Depressions in the onshore part of the Gippsland Basin, which is one of the world's premier coal and petroleum basins (Figure 1). The Depressions are a late feature associated with Australia–Antarctic separation in the mid-Cretaceous (100 Ma). Rift fill sandstone of the Lower to Middle Cretaceous Strzelecki Group and Palaeozoic rock underlie and crop out around the Depressions. The South Gippsland highlands were initiated during shortening of these rocks in the Middle Cretaceous. Rifting that recommenced in the Late Cretaceous formed the Latrobe Valley and Seaspray Depressions.

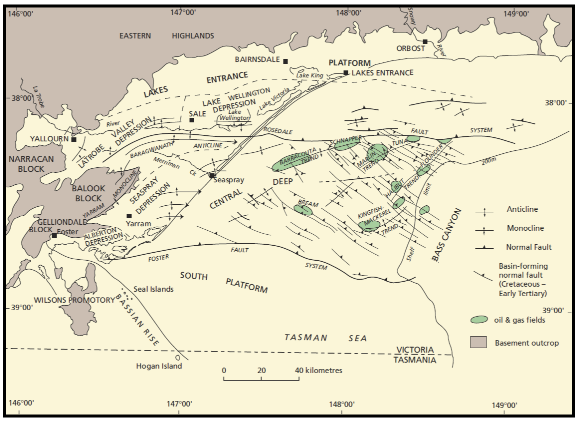

Figure 1. Gippsland Basin — tectonic setting and structure map. Also showing the main oil and gas fields offshore part of the basin. Modified from Abele et al. (1988).

Swamps that formed in this Depression were filled with organic material during the Oligocene to Miocene—the Traralgon, Morwell and Yallourn formations (Figure 2). The great thickness and uniformity of many of the coal seams over large areas is consistent with slow and steady rates of subsidence in the Depression.

Reactivated reverse faults in the underlying Strzelecki Group do not persist into the poorly consolidated Traralgon, Morwell and Yallourn formations but are expressed as monoclines and folds. Erosion of the Traralgon, Morwell and Yallourn formations was followed in the Plio–Pleistocene by deposition of a veneer of gravel, sand and clay—the Haunted Hill Formation (Gloe & Holdgate, 1991).

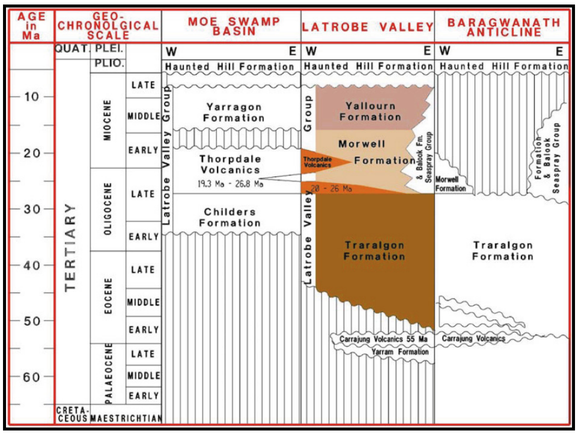

Figure 2. Stratigraphy of the Latrobe Valley Depression and neighbouring areas (after Abele et. al., 1988).

3 MODELLING

3.1 Input Data

The 3D model is based primarily on borehole/drillhole data (Figure 3) collected and compiled into the Latrobe Valley Coal Bore Database (LVCBD) as part of the systematic resource evaluation by the State Electricity Commission of Victoria (SECV) to support coal development.

To infill gaps in deeply buried Traralgon seams within the Seaspray Depression, selected deeper petroleum wells with fair control on coal seams were modelled along with coal bores.

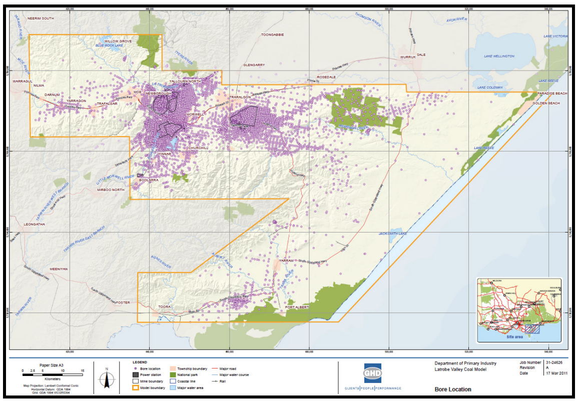

Figure 3. Borehole coverage of the model area

3.2 Methodology

The development of the coal model is undertaken using MineScape in two distinct steps.

i. A stratigraphic model of the geology developed; and
ii. Converting the stratigraphic model into a block model to define the distribution of coal attribute (quality) data.

The modelling methodology is described in detail by Jansen et al., 2003 and some of the key points are included here.

3.2.1 Stratigraphic Model

Roofs and floors have been generated for the sixteen thickest brown coal seams and splits (Figure 4 and Figure 5).

Formation	Seam / sub-seam / splits		Comment
Yallourn	Y	Y1	The splits Y+, Y3 and YP have been incorporated into the parent seam Y.
		Y2	
Morwell	M10		
	M1A	M1A1	The split M1A3 has been incorporated into the parent seam M1A.
		M1A2	
	M1B	M1B1	
		M1B2	
	M2	M2A	The M2C split (not shown) was not modelled. The split M2A1 has been incorporated into the parent split M2A.
		M2B	
Traralgon	TP		
	T1		The splits TRL and TRU have been incorporated into the parent seam T1.
	T2		

Figure 4. Modelled coal seams

The way that MineScape models these coal seams to produce the stratigraphic model is dictated by a set of “rules” which form a part of the schema. The schema controls all the modelling parameters that govern the way the structural model will be interpolated, such as stratigraphic relationship (conformable, nonconformable, transgressive…), seam splits, interpolation rules, limiting polygons, etc.

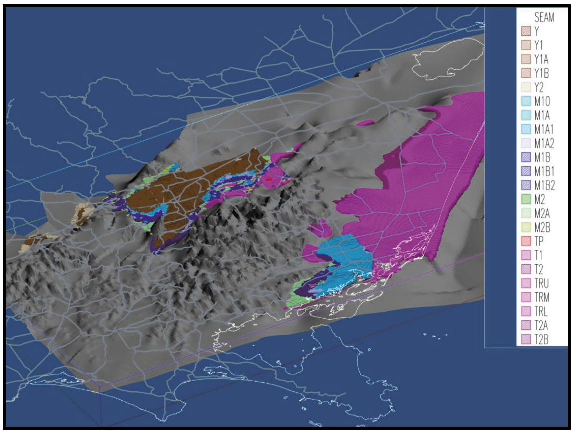

Figure 5. Latrobe Valley 3D coal model coloured by coal seam

3.2.1.1 Stratigraphic Model Validation

Roof and floor surface contours, and isopachs were generated for each coal seam and analysed visually. Anomalies in the data show up as bulls eyes and were reviewed and seaming updated where appropriate.

Modelled surfaces were also validated against hand drawn SECV isopachs for the Yallourn, Morwell 1B, Morwell M2 and Traralgon seams and splits. Ten regional cross sections were used to ensure consistency between the model and work of the SECV.

3.2.2 Block Model

Seventeen coal quality parameters have been incorporated into a block model. The block model was generated in MineScape using analysis from bores used in the stratigraphic model (Figure 6).

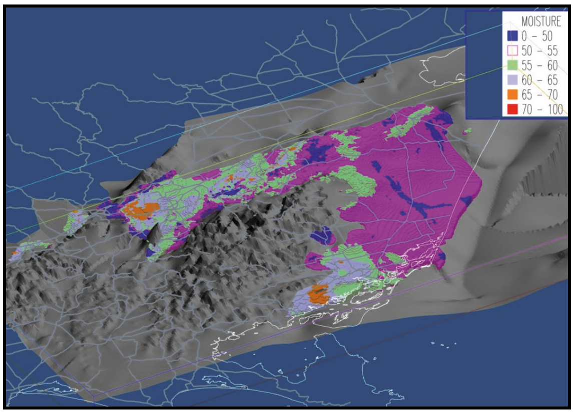

Figure 6. Latrobe Valley 3D coal model coloured by moisture (%)

3.2.2.1 Block Model Specification

The most basic block model parameter is the parent block size. This defines the maximum block size into which coal qualities will be interpolated. The parent cell size is 160 x 160 x 12 m (X, Y, Z). This size was selected to balance model resolution with performance. The 12 m vertical (Z) size was chosen to correspond to the maximum coal quality sample interval. The X and Y dimensions (160 m) were chosen to honour the borehole spacing and to balance model resolution with performance.

3.2.2.2 Block Model Interpolation Parameters

Three sets of interpolation parameters (Int_ash, Int_moist, Int_sodi) were used to interpolate coal qualities into blocks (Figure 7) and applied to qualities that behaved in similar ways. These are based on search distance (in metres), direction (defined by octants) and the inverse distance power.

Name	Search radii	Min octants	Min samples/oct	Max samples/oct	Inv dist power
Int_ash	5000	1	1	8	2
Int_moist	2500	3	1	8	1
Int_sodi	1500	3	1	8	2

Figure 7. Parameters used to interpolate coal qualities

3.3 Resource Calculation

As a validation process, the model was used to estimate coal resources and compared to previous resource estimates. It was found that there was good agreement between historical resource and modelled resource estimates. This is not surprising because both estimates employ the same methodology, with the MineScape model being a much more efficient means of estimation. Because resource estimates require average seam thicknesses from specific areas of interest, the model is capable of rapidly analysing hundreds or thousands of boreholes and their associated coal quality attributes.

3.4 Assumptions and Limitations

It is important to recognise that the confidence in modelled seams decreases with distance from bores. This includes confidence in seam presence or absence, seam roof, floor and thickness and seam quality. Seams need to be reviewed in the context of the bore data from which they are extrapolated. Bore densities across the model area range from metres to tens of kilometres. This is different for shallow and deep seams; with deeper seams only intersected by rarer deeper drilling.

The seam and quality interpolation parameters selected, to the extent that is possible, balance the need for resolution in areas with high bore densities (e.g., within mining tenements) and low bore densities (e.g., along the Ninety Mile Beach where Traralgon seams are deeply buried.

3.5 New uses for the model

The Latrobe Valley Coal model was originally created in 2003 and was last updated in 2011. Its original stated purpose was to "*to be used as a regional scale tool for supporting the management of the coal resource, matching coal to development opportunities and informing land use planning.*" While this fundamentally has not changed, the new "development opportunities" are constrained to fit within "*the future use of brown coal in a low emission context*" (Statement on Future Uses of Brown Coal, DJPR, 2017), and land use planning. This includes rehabilitation planning for the 3 coal mines in the Latrobe Valley involving:

- Simple calculations of pit volumes to determine water or material volumes
- Calculations of areas of exposed coal
- Overburden/lithology investigations
- Integration of LiDAR elevation data to analyse changes in landform
- Producing geological cross sections through the mine pits to inform batter stability modelling in other modelling software packages (Figure 8)

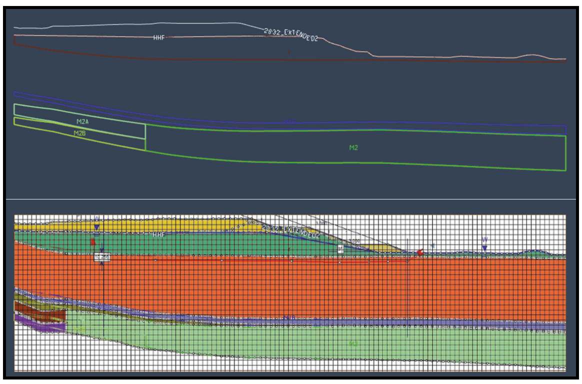

Figure 8. MineScape cross section (top image) through mine pit used as an input into geotechnical modelling software (bottom image)

3.6 Model Uncertainty

Although this is one of the best constrained 3D geological models of this scale, as for all models, there is still a degree of uncertainty as to its accuracy, especially in areas will low borehole density. It is important to consider where the uncertainty lies and how it is communicated and represented.

The data path can be used to examine sources of uncertainty:

- The logging of the bore: where to start and stop sampling to pick up the roof and floor of the coal seam has implications for the recorded seam thickness. The transition into the coal is often gradual.
- Assigning of names to coal seams: is this determined by the position in the drillhole, the lithotype, or the palynology (plant spores)? All these things require a subjective interpretation.
- Correlation and interpolation? between boreholes: how is interpolation managed, especially between areas of low and high borehole density
- The interpretation of the geophysical log to correct the lithological log: If you have ever had the pleasure of working with geophysicists or even radiographers, you will realise that interpretations of the same image can be quite different depending on knowledge and experience.

Then there are the modelling assumptions. There are 11 pages of rules and assumptions described in the original document that was released with the 2003 coal model (Jansen et al, 2003, Appendix VII). These include:

- The reinterpretation of lithology and stratigraphic codes to provide consistency across the model area and between the datasets associated with the 3 different mining licences.
- The "filling" of gaps in the coal seams within the bore logs. The software requires that no seaming gaps exist between the top and bottom of a seam, therefore, this gap filing is essential for the model's operation.

Finally, there are the interpolation methods and grid resolution. Different coal qualities require different interpolations through the model space (Figure 7).

One way to do this in both two and three dimensions is to create buffers around data points which can be assigned a level of confidence (Figure 9). These might be based on:

- The distance to a borehole/between boreholes
- The distance to a borehole with coal quality analysis
- The distance to a borehole with downhole geophysics
- The distance to a borehole with palynology

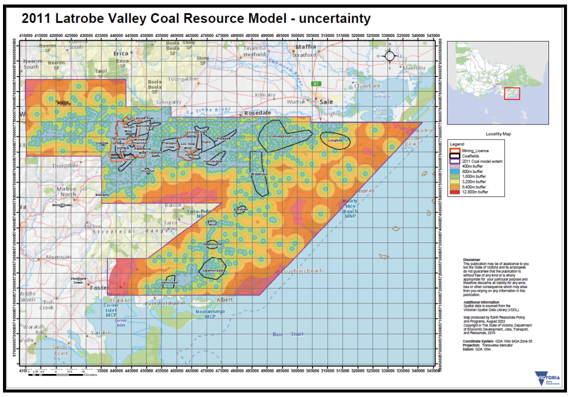

Figure 9. An example of a way model uncertainty could be illustrated

3.7 Model Outputs

The Latrobe Valley coal model is available as a "BASIC" package which gives an overview of the coal resource for the benefit of coal explorers, mine operators, proponents of new, low-emissions coal projects, the Government and land use planners that contains a metadata database, the borehole database and GIS layers for coal seam roofs, floors and isopachs. The other packages contain three-dimensional surface and block models of the coal resource in MineScape formats.

Outputs of the model are also available through GeoVic which is the Department's free online mapping application. GeoVic enables the user to build earth resource related maps, perform searches and access data using a huge range of data sources. These model outputs include coal seam depths to tops and bases as contours, seam thickness isopachs, coal seam quality contours and coal seam stripping ratios, amongst others. The example in Figure 10 shows the stripping ratio (coal to overburden) for the Yallourn coal seam.

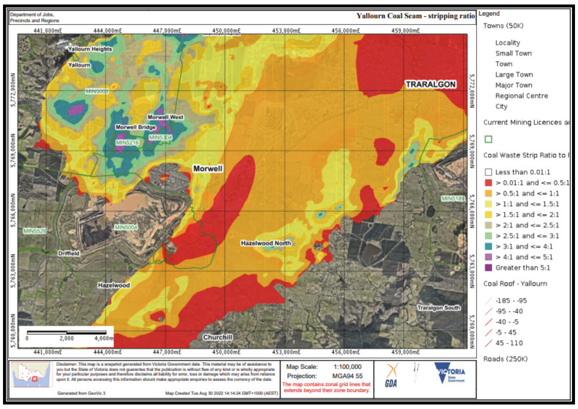

Figure 10. An example of an output from GeoVic

4 CONCLUSION

The Latrobe Valley Coal Resource model is a great example of how explicit and implicit modelling can be used to better define a resource and the challenges of finding the balance between the two approaches. The model was built from data collected over a 90 - year period. The data were recorded consistently and managed effectively, which has meant that a robust model can could be created. Although this model is so extremely well constrained by data (in places) it also highlights the need to be is clear that there is uncertainty in the model and understanding, quantifying and communicating this uncertainty is critical. This paper does not provide a solution, but encourages 3D modellers and model users to question the uncertainty of any model they are presented with, rather than accepting model results at face-value. Better outcomes are made possible by greater transparency in the strengths and uncertainties in 3D spatial models.

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