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# A STRUCTURAL SYNTHESIS OF THE SYDNEY BASIN – WORKING TOWARDS IMPROVING GEOLOGICAL CONFIDENCE AND PRODUCTIVITY

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*ABSTRACT:* In a globally competitive environment, coal mining operations are continually focusing on improving longwall mine production and productivity levels, and at the same time enhancing safety practices. Commonly operators look to reduce costs and increase development rates by looking to improve equipment performance, change work practices and reduce unplanned downtime. This can be achieved in part by complementary assessments into potentially disruptive geological and geotechnical issues such as faults, intrusives and poor strata conditions, using advanced geological exploration and imaging techniques, in conjunction with their existing site-based geological knowledge. However, the location of, and controls on, local structural risk issues are not always well understood. Geometric patterns of small and local scale structures typically are a reflection of structures that are developed at regional scales. Developing an understanding of regional structure can enhance the insight into local mining risks. Regional structures are important in controlling basin initiation, depositional centres, fold and fault development, fault reactivation, and the loci for volcanic and intrusive activity.

## INTRODUCTION

A structurally-based basin-scale study was undertaken for the Sydney Basin and the eastern part of the Gunnedah Basin and was principally designed to provide a GIS-based regional structural framework as the basis for more detailed assessments of structural risk issues for coal resources. This study was undertaken by a team of consultants with the support of a number of coal mining companies and the NSW Dept. of Mineral Resources (DMR). The structural framework was developed by integrating a wide variety of geological and geophysical information, gathered from not only the public domain but also using confidential and high resolution data offered by supporting companies. Use of the GIS database facilitated the interrogation of a range of geological parameters such as intrusive, fault trend relationships and/or regional to local fault patterns and regional stress data.

A structural model that includes 4D interpretation of the Basins as well as a series of maps which highlight the known and interpreted regional basement geology and structural features has been developed. Using this information, regional-scale structural corridors and domains can be identified and ranked according to a range of regional risk parameters, such as the relative nature and/or abundance of basement structural features, basement geology, depth to basement, and the distribution of intra basin intrusives. The interpretation forms a base onto which more detailed information can be added and analysed in a regional context.

Importantly, this study provides a data platform as well as offering participating companies the ability to interrogate a more integrated and comprehensive dataset of the entire Sydney Basin for their own long term planning and risk analysis. By improving recognition of structural patterns in the Basin both regionally and locally, an understanding of the relationship between basement features (structure, composition, depth) and known structural risk can help reduce geological uncertainty and therefore be more effective in managing

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structural risk. The Springvale and Angus Place operators are a case in point, where an improved regional understanding of influences relating to local/operational-scale anomalies was the first stage in a structural review and risk analysis study that has assisted in improved operational efficiency for these longwall mines (Knight and Teasdale 2001).

## BACKGROUND

Coal mining operations are continually focusing on improving productivity levels in a range of areas. One of the critical areas is the geology. Geological issues include coal quality, changes in seam thickness, seam splitting and identifying or resolving potentially disruptive geological and geotechnical issues such as faults and intrusives. From a company's competitive perspective, a reduction in geological uncertainty should lead to improved mining decisions, and commensurate productivity and cost-related benefits over time. Industry-supported integrated regional-scale studies which aim to deliver practical outcomes can also help provide positive impacts on the overall competitiveness of the region (Woodfull, Munroe and Hanna, 2003).

To help resolve the potentially disruptive geological and geotechnical issues such as faults, intrusives and poor strata conditions, coal mining operations use forward structural interpretation (i.e., ahead of mine planning and development). Forward structural interpretation studies and the structural framework and models that develop from this work, can be derived from a range of geological data sources including geological mapping (surface and seam), drill hole information and the interpretation of remotely sensed data (SRK, 2004, Woodfull, Munroe and Hanna, 2003). The location of, and controls on, local structural risk issues are not always well understood. Geometric patterns of small and local scale structures typically are a reflection of structures that are developed at regional scales.

More detailed interpretations and structural models developed from these studies typically result from the integration of a combination of geological field data (drill hole, mapping) and potential field data such as airborne and seismic surveys. While potential field data may be used as assessment tools for near surface to at-the-seam mining risk issues, these data sets (mainly magnetics and gravity) can also provide a window to the basement. Once calibrated to geology, this data provides information that allows the development of a predictive structural model based on basement composition and structure.

The basement of any basin provides the foundation onto which the sediments are deposited. The inherent composition and fabrics within the basement play a major role in the manner in which the crust deforms during major periods of extension or compression. Basement structures are important in controlling basin initiation, depositional centres, fold and fault development, fault reactivation, and the loci for volcanic and intrusive activity.

By improving our understanding of the relationship between regional-scale basement features (structure, composition, depth) and known local structural risk (such as recognised structural hazards at the mine), we can help to reduce some areas of geological uncertainty and, therefore, be more efficient and effective in managing risk at a range of scales.

## OBJECTIVES

The two main objectives of the study were to:

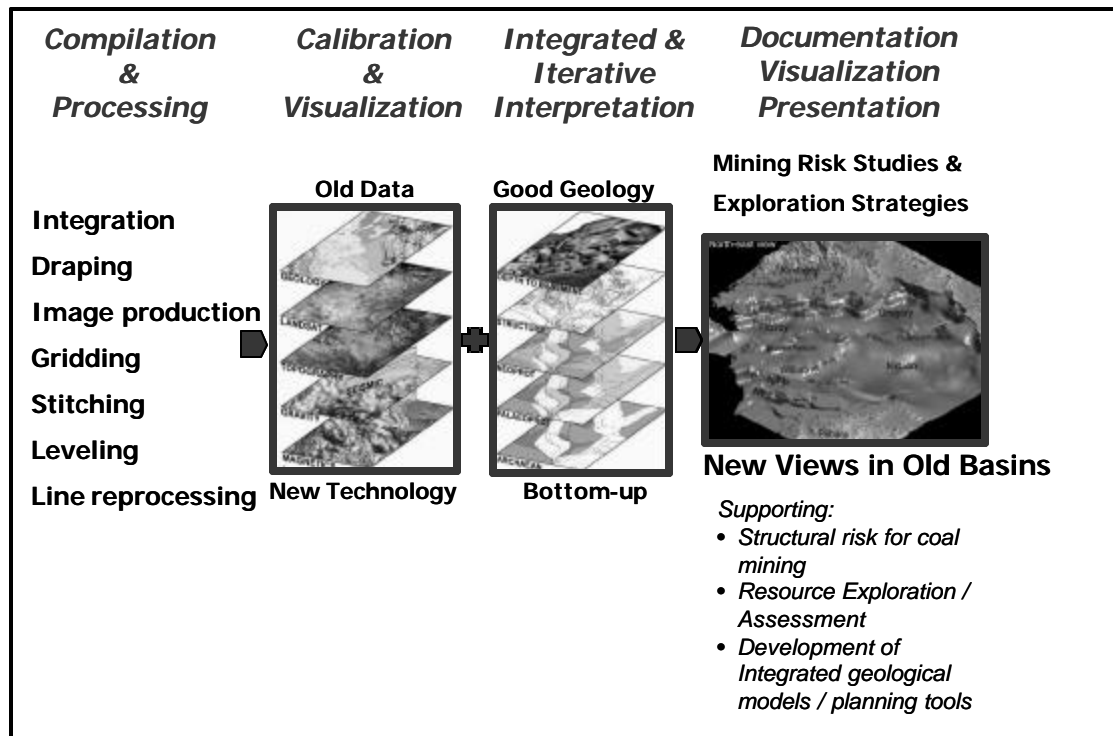
- provide GIS-based, integrated regional-scale geological data that is relevant to structural geology studies, principally in the area of structural risk management, whereby future short to longer term sub-regional to mine-scale studies can build on the results of this synthesis work, and
- improve the understanding of the basement geology and regional fault kinematics during basin development, through the interpretation, at regional scales (1:500 000 to 1:100 000 where practical), of the data sets and the development of a 4dimensional structural geological model for the Basin area.

Additionally, the study aims to assist the change from an empirical to a more analytical approach to structural risk management. Understanding why potentially disruptive or changing geological conditions occur, can be a powerful tool in improving predictive studies and helping to manage risk areas / issues, (SRK, 2004). The study results may also have broader application within one organization as the regional structural model and/or

integrated data sets should have practical benefits to broader natural resource and risk-based studies including gas exploration, mitigation and/or sequestration initiatives, groundwater and land use planning / environmental studies.

### APPROACH

The methodology used to develop a comprehensive structural model relies on the integration of all appropriate geophysical and geological information. Individual datasets alone can be ambiguous and when interpreted in isolation often produce poorly constrained results. Through integration, the model can be better constrained. Integration provides the means with which to calibrate each dataset to the other. Figure 1 presents an overview of the methodology. A more detailed discussion of the approach can be found in two related publications (SRK, 2004 and Woodfull, Munroe and Hanna, 2003).



**Fig 1 - Simplified pictorial flow chart showing the process followed in the development of the regional structural model for the Sydney Basin**

#### Data Sets and Regional Structural / Basin Model

More than a dozen geological and potential field data sets were compiled, processed and/or developed for this study. Table 1 aims to provide an overview of the key data sets and the series interpretive maps available for use as a result of this study.

As an example of how the various data sets were used, Figure 2 presents a simplified flow chart of the main data sets used in the development of the basement geology and structure interpretive maps, the modeled cross sections. Key interpretive information (basement geology, structural layers, regional geology) in conjunction with modeling results (e.g., cross sections, magnetic and gravity anomaly depth estimates) and critical data from selected data sets (e.g., drill hole, seismic data) were then used to develop the 4D regional structural / basin model shown at the bottom of Figure 2.

#### Benefits / Uses and Potential

One of the primary benefits of the study, and presently recognised by supporting organisations as a core strength of the project, is the collation and integration of a range of disparate data sets relevant to geology and

geotechnical risk studies (SRK, 2004). With the development of the GIS-based datasets, organisations and individuals can now more readily:

- place mining and exploration leases, or risk issues in a more regional context, and
- undertake iterative data analysis and assess their areas for data deficiencies / resolution issues as part of exploration and /or risk management planning.

Another important benefit of the study is the development of a 4-D structural / basin model. The development of this regional model does provide a:

- framework for ongoing detailed structural risk studies, or for re-evaluating risk issues, at a range of scales, and
- structural framework for coal companies to incorporate into their existing coal geology / resource models or to build district-scale coal resource models.

It should be noted that while the collation and integration work has been quite extensive, it does not necessarily represent all the geological or potential field data that could be included in the data sets, at this point in time. It is envisaged that the data sets and the 4-D structural / basin model will evolve over time. Furthermore, the structural model should benefit from improved calibration, via the inclusion of new data, such as higher resolution remotely sensed surveys and factual mine site data or feedback as the model begins to be used on-site.

However, while needing to keep in mind impacts on the coal seam, the study is regionally focused, therefore:

- The results of this study do not aim to be interpretive or predictive at the coal seam level.
- The project does aim to be predictive at a regional / district scale, particularly where there is a higher level of data quality and resolution.

## CONCLUSION

A 'Sydney Basin' regional structural synthesis study and basin model has been undertaken for a number of coal exploration and mining entities with interests in the Sydney Basin and the eastern part of the Gunnedah Basin. The study contains:

- a compilation of relevant data, processing (where appropriate) and integration of correlating data sets for a structural geological study,
- the provision of the data sets in a GIS (or equivalent) format,
- a number of interpretive data sets that have been generated from the initial data compilation,
- the development of a 4-D regional structural / basin model, using the compiled data set, and
- synthesis of the results of the study to understand the spatial distribution of observed geological features.

The starting point for the Basin study is the 'container', or basement, into which the Basin has been deposited, by the reactivation and activation of geologically controlled features. Pre-Basin geology and structure has had an important control on the geological development of the Basin. Syn-Basin and Post-Basin tectonics have also reactivated basement structures as well as activating intra-Basin features (SRK, 2004).

The data sets and accompanying regional structural / basin model developed for this study, provide coal exploration and mining companies with a more integrated geological framework for ongoing sub-regional to mine-scale geological risk based studies. The results of study can be immediately used to:

- More readily start to place their mining and exploration leases, or local risk issues in a more regional geological context,
- Broaden and quicken the process of iterative data analysis,
- Use the data sets as an aid during future exploration planning, such as for sub regional to local scale data acquisition programs, and / or
- Use the model as a platform for (or synthesis the structural components into existing) more detailed coal geology / resource models.

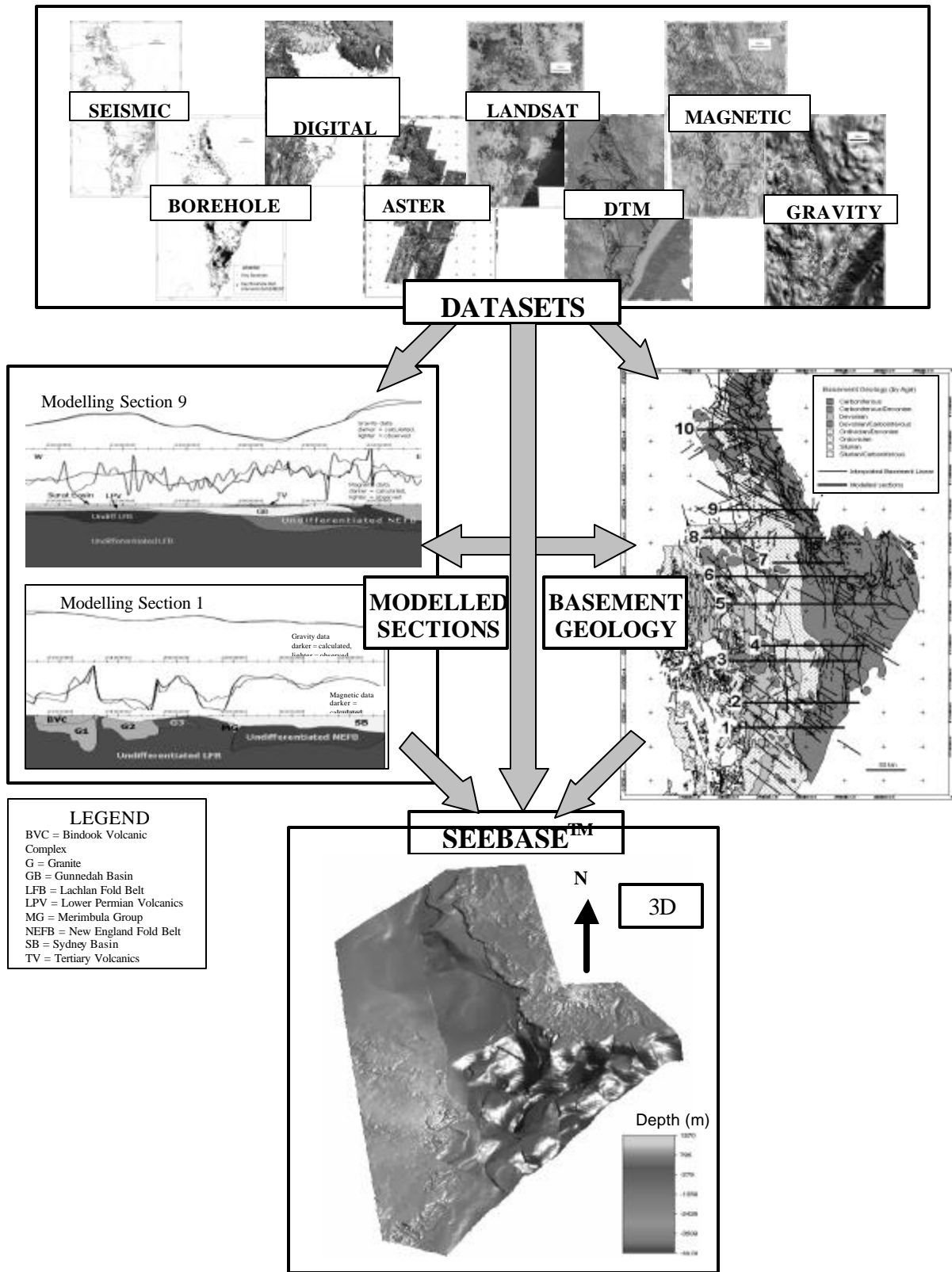
**Table 1 - Summary tables briefly highlighting and describing A) the key data sets compiled and developed for the study, B) the Time and Space Event History Chart and C) the interpretive maps developed for the study, based on the key datasets and Event History Chart.**

<b>Datasets</b>	
<b>Airborne Magnetic</b>	Provide information on: <ul style="list-style-type: none"> <li>• Structure and composition of the magnetic basement</li> <li>• Exposed magnetic bodies such as igneous intrusions</li> </ul> Compilation of over 40 surveys from the public domain and higher resolution private company surveys <b>Area-based improvement in data coverage for the following coalfield areas: Hunter/Newcastle, 26%; Southern, 20%; Western, 10%; Gunnedah, 3%</b>
<b>Radiometric</b>	Sourced from recent public domain and a number of smaller private company surveys Provide information on regional structure at the surface
<b>Gravity</b>	Useful for <b>basin architecture, structure and geology</b>
<b>Digital Elevation Model (DEM)</b>	Surface expression of geology and structure The main sources were the NSW DMR 250m DTM grid (onshore) and the GA 2003 bathymetry and topography grid (offshore)
<b>Surface Geology</b>	Provide calibration for interpretation of DEM, gravity and magnetic data Provided by the NSW DMR as a 250K scale digital data set In addition, published 100K scale coalfield geology maps are included as scanned images. Digital data of structure and igneous bodies have been captured from the 100K scanned maps
<b>Satellite - Landsat 7 and ASTER</b>	Surface reflectance data is used for identifying surface geology and structure - reflected in outcrop, vegetation patterns or soil types Two satellite imagery data sets were compiled: <ul style="list-style-type: none"> <li>• <b>30 m pixel size</b> - Landsat 7 mosaic of bands 7 (Red), 4 (Green) and 2 (Blue) derived from the NASA Earth Science Enterprise coverage - MrSID (circa 1990)</li> <li>• <b>15 m pixel size</b> - ASTER mosaic (with near complete coverage for the Basins), for improved resolution over the</li> </ul>
<b>Published Seismic Data</b>	Provide regional constraints on the structural geometry of basement blocks and basins, and movement histories on major structures Selected published line profiles have been used to help constrain basement depth estimates for the regional structural
<b>Stratigraphic Drill Holes &amp; Petroleum</b>	<b>Calibration of basement depth and basement lithology</b> A key drill hole data set was developed to help constrain basement geology and depth estimates for the structural model
<b>Stress</b>	Compilation database incorporating data from the Australasian Stress Map Database and other independent stress measurements
<b>Mine Site Intrusion &amp; Structure Data Base</b>	Compilation map of <b>intrusion and structure data</b> mapped at the seam, from a number of companies, including sponsors
<b>Other Data</b>	<ul style="list-style-type: none"> <li>• Intrusion geochronology from a number of published sources</li> <li>• Earthquake epicentres from USGS global data base</li> <li>• Surface heat flow from Global Heat Flow data base (Pollack et al 1991)</li> <li>• Southern Coalfields structural compilation (ACIRL, 1989)</li> <li>• Current mine and lease boundaries</li> <li>• Cultural layers (state boundaries, towns, roads, national parks)</li> </ul>



<b>Outcomes &amp; Applications</b>	
<b>4-D regional Structural Model and Regional Basin model</b>	<b>Identifying regional geological risks and opportunities for future operations</b>
<b>Basement Geology and Structure</b>	Implications for structure and intrusion behaviour at the seam level
<b>Basin Architecture (SEEBASE™)</b>	3-D view of the base of the Permian and Triassic sequences which incorporate all information on geology, tectonics, palaeogeography, intrusions and structural risk
<b>Structural Interpretation</b>	Structural zones interpreted to have been active during key tectonic events Provides some indication of overprinting relationships, likely growth faults and later through going structures
<b>Regional Surface Lineament interpretation</b>	Interpreted structures / lineaments based on Landsat and DEM data sets; interpretive focus on coalfield areas
<b>Regional cross sections</b>	Iterative modeling of basement geology using gravity and magnetic profiles and relevant SEEBASE™ data
<b>Time and Space Event History Chart</b>	Compilation of key lithology, structure and deformation, tectonic and magmatic data for the Sydney and Gunnedah Basin areas over time, that highlights key kinematic events that have controlled the geological development of the areas, including the Basin geology and structure
<b>Bibliography</b>	A summary of useful technical publications / documents used in this study Has a bias toward structural geological, tectonic / kinematic, stress and / or intrusive-related papers

SEEBASE™: **S**tructurally **E**nhanced View of **E**conomic **B**asement.



**Fig 2 - Simplified flow chart showing the type of data sets that were used in the development A) the basement geology interpretive map and modeled cross sections, which formed a basis for B) the 4-D regional structural model**



Based on the results of this regional study, more detailed district-scale interpretive studies, (complemented with supplementary data set contributions and / or acquisition), can also be expected to provide a more comprehensive local data / model package for improving geological certainty and thereby a more effective performance in predicting and managing geological risk.

It is planned that at least one update to the data sets will occur over the next 12 months, prior to a general release of the study results, with the aim of including any new public domain data that becomes available and / or additional private sector data contributions, that will improve the quality of the data sets or allow improvement in the calibration of the regional structural / basin model.

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