4. Guest Article

Geotechnical Data Obtained from Wireline Logs

A discussion on discontinuity, stress and strength data: identifying patterns in East Australian coalfields by ASIMS, Australia

To assist in building a geotechnical model, of particular use are the acoustic scanner and sonic velocity logs. Incorporating the acoustic scanner tool within the suite of geophysical logs used in any exploration program is a relatively inexpensive method of obtaining accurate discontinuity (joint) and stress orientation data; both of which are necessary for both open cut and underground mine planning and development. Whilst the sonic log can provide a very good estimate of the unconfined compressive strength (UCS) of the strata intersected in the drill hole. To demonstrate patterns, sites have been selected in the Southern (NSW), Hunter (NSW) and Bowen Basin (QLD) coalfields. The purpose is to discuss the extent of variation at a site, not to discuss absolute directions[i].

Discontinuities and the acoustic scanner log

With respect to discontinuities, emphasis should be on identifying meaningful data sets rather than on picking a large number of features. The reconciliation of the core itself and geologists' description of the core (lithology/geotechnical logs and core photographs) to the acoustic scanner image is an excellent method of assigning accurate orientations to significant discontinuities identified in the core by the site geologist. When using logs from non-core holes, care must be taken to remove noise from the data sets and only pick features with high confidence. In Australia, exploration programs utilise vertical holes. The impact of orientation bias tends to be reduced in vertical holes because:

1. from an underground perspective, most coal seams of interest dip at less than 10^o to 15^o
2. joints are dominantly normal to bedding
3. joint spacing in slightly deformed sedimentary rocks tends to be similar to the spacing of the dominant beds

Discontinuity patterns, eastern Australia: On a borehole to borehole basis, generally two major joint sets are identified with little to no rotation downhole. However greater variation exists laterally, emphasising the need to obtain widespread discontinuity data in order to understand the structural influences involved.

Stress measurements: borehole breakout in eastern Australia

Borehole **breakout** is the result of compressive failure in a borehole wall and appears as two caved zones 180^o apart. It has a distinct lemon shape in cross section on the travel time log of the acoustic scanner. The major principal stress is measured normal to the plane defined by the axis of the lemon. So far, we have not identified drilling induced fractures that are indicative of a tensile stress condition at the borehole wall.

Downhole stress variation: The World Stress Map (WSM) project suggests the highest quality breakout data has a standard deviation of less than 12^o. For the Hunter and Bowen Basin examples, stress directions are generally consistent downhole with a standard deviation of 12^o in the Hunter and 15^o in the Bowen Basin, indicating that the horizontal stress direction at these two sites is well defined.

Areal stress variation: The average stress orientation for the Hunter and Bowen Basin cases is very similar – the variability is relatively minor, although the standard deviation is higher. For the Southern coalfield site, variation extends across the project area. In both NSW sites, the strike of the major joint set was parallel to the direction of the major principal horizontal stress, while in the Bowen Basin site the strike of the major joint set was perpendicular to the direction of the major principal horizontal stress.

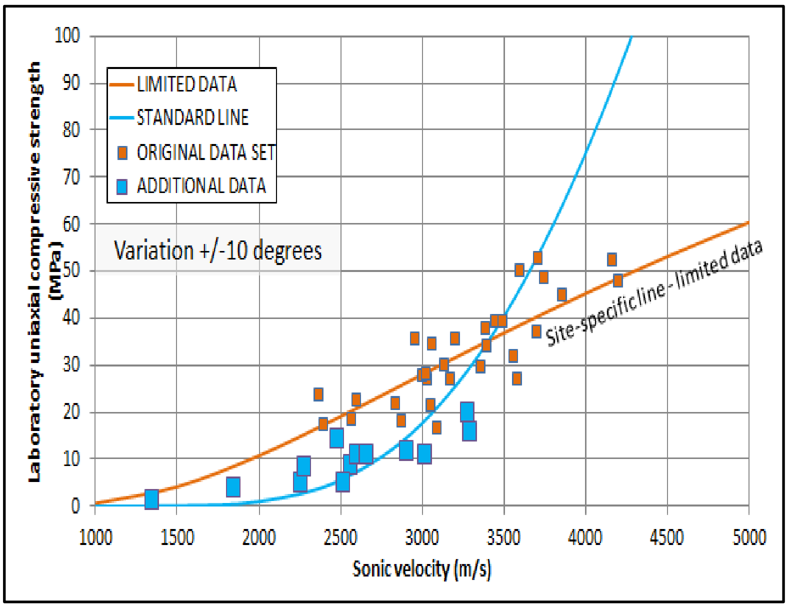
Estimating UCS using sonic logs: Australian coalfields

It is preferable to use a standard sonic velocity/strength regression line such as the one originally developed by BMA/Anglo in the Bowen Basin which has a particular focus on the lower strength rocks and is depicted by:

UCS (MPa) = $5785\, e^{(-17374/vel)}$

where vel = sonic velocity (m/s).

It is important to ensure the low strength rocks are not allowed to dry before testing, to avoid overestimation of rock strength. The method is unlikely to give an accuracy of better than +/-10 MPa at all strength ranges. This equation has wide applicability and has been used in Australian coalfields. It is recommended that rock strength tests are conducted to justify the continued use of this standard rather than to develop a site specific relationship. If developing a site specific line a few points of advice are offered.



Firstly the trend lines available in Excel are not adequate to fit over the full range of data. There is a need to assess the engineering application – for roof support design, accuracy at the low strength range is required; for rock cutting and blasting, accuracy over the high strength range is preferred.

In Australia, maps of the sonic-derived strength of the immediate roof and floor of target coal seams are now routinely produced for mine prefeasibility and feasibility studies. The density log is used to determine the average overburden density and from this an estimate of the pre-mining vertical stress can be obtained. Normalising the roof and floor strengths to the vertical stress provides key geotechnical indices to assess roof support and floor behaviour.

Of interest for longwall and pillar extraction mining methods is the possibility of massive overburden units which can be distant from the target seams and are often not cored during exploration to reduce costs. The presence of massive units may be identified from a uniform sonic velocity (suggesting no change in lithology) while the gamma log can be used to identify laterally persistent bedded units. Here the assumption is made that the bedded units contain the clay mineral illite and that the massive units have negligible illite. In coal measure rocks, illite is one of the very few minerals that contain potassium, the presence of which is identified by the gamma daughter product of the potassium to argon decay.

As a geotechnical aside, remember that a gamma log is not a 'clay' log because the other main clay minerals, kaolinite and montmorillonite, do not contain potassium. In some cases the neutron log is also used to assess massiveness and in this case the assumption is made that the massive unit has a low porosity and low clay content so that there is little hydrogen in the system. The neutron response in the thinly bedded units is assumed to be associated with hydration of any clay minerals.

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[1] Pell, S, Seedsman, R and Straub, K, 2014. *Geotechnical data from geophysical logs: stress, strength and joint patterns in NSW and QLD coalfields.* 14th Coal Operators Conference, University of Wollongong. Available on-line http://ro.uow.edu.au/cgi/viewcontent.cgi?article=2157&context=coal