Resource classification in coal

It’s time to stop going around in circles
Why do we classify resources?

- Required for reporting resources in accordance with the requirements of the JORC code
- “to provide company executives and others making mining investment decisions concerning resources with a basis for assessing relative risk” (Stephanson and Stoker 2001)
- Best practice approach provides a transparent, comprehensive, justifiable and largely objective method of classification. (Yates and Hodson)

<table>
<thead>
<tr>
<th>Class</th>
<th>that part of a Mineral Resource for which:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a <strong>high level of confidence</strong>. The sampling locations are spaced closely enough to confirm geological and grade continuity.</td>
</tr>
<tr>
<td>Indicated</td>
<td>tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a <strong>reasonable level of confidence</strong>. The sampling locations are too widely or inappropriately spaced to confirm geological and/or grade continuity but are spaced closely enough for continuity to be assumed.</td>
</tr>
<tr>
<td>Inferred</td>
<td>tonnage, grade and mineral content can be estimated with a <strong>low level of confidence</strong>. It is inferred from geological evidence and assumed but not verified geological and/or grade continuity.</td>
</tr>
</tbody>
</table>
Process of resource classification

1. Assess the reliability of the data, and define a dataset to be used in resource estimation.
2. Build a map of underlying uncertainty in the estimate.
3. Rationalise this uncertainty to sensible zones of confidence.
4. Assess further geological features.

Points of Observation:
- Distances between points
- Remove spotted dogs
- Buffers around faults etc.
Circles around PoO (Aust Guidelines 2003)

- Point of observation: 95% linear recovery of ash sample analysis
- Distances from points of observation
- Remove spotted dogs

<table>
<thead>
<tr>
<th>Class</th>
<th>Distance between points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>500 m</td>
</tr>
<tr>
<td>Indicated</td>
<td>1000 m</td>
</tr>
<tr>
<td>Inferred</td>
<td>4000 m</td>
</tr>
</tbody>
</table>

Graphic: Example resource classification using Australian Guidelines 2003
Is it the best way?

- Simple
- Easy to apply
- Consistency between projects
- Transparent
- Confidence does decrease with increased distance from data
- It’s the way we’ve always done it
What are the distances based upon?

- QLD German Creek Coal Measures
- Southern coalfield underground projects
- Hunter Valley coal
Recommended spacings between boreholes of the 'Coal Guidelines' 1950 - 2013

- Measured
- Indicated
- Inferred

Recommended spacing between boreholes (km):
- 1950 - 1 Mile
- 1960 - 1 Mile
- 1970 - 1 Mile
- 1980 - 2 Miles
- 1990 - 4 Miles
- 2000 - 4 Miles
- 2010 - 4 Miles

mdgeology.com.au
The variogram is a model of the continuity of the geology.
Variogram

Raw Ash Variogram

- Nugget: 2.4
- Sill: 9.75
- Range: 3850 m
Range of the variogram

- Use the range of the variogram to calculate distances between PoO for resource classification

- Can be unreliable when a variogram is constructed using few data points, and if there is a high proportion of nugget variance compared to total variance.

<table>
<thead>
<tr>
<th>Class</th>
<th>Distance between points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>960 m</td>
</tr>
<tr>
<td>Indicated</td>
<td>1925 m</td>
</tr>
<tr>
<td>Inferred</td>
<td>3850 m</td>
</tr>
</tbody>
</table>
Global Estimation Variance

- More robust method of calculating distances
- Brings in an assessment of the geology
- Assesses support (volume)
- Made popular by Casely et al – presentations at Sydney Basin 2010, Bowen Basin 2009

<table>
<thead>
<tr>
<th>Class</th>
<th>Distance between points</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>800 m</td>
<td>10%</td>
</tr>
<tr>
<td>Indicated</td>
<td>2000 m</td>
<td>20%</td>
</tr>
<tr>
<td>Inferred</td>
<td>3100 m</td>
<td>35%</td>
</tr>
</tbody>
</table>
Comparison of distances

Drillhole spacing analysis

Measured

Recommended Distance (m)

0 200 400 600 800 1000 1200

South Walker Creek
Poitrel
Blackwater
Daunia

Indicated

Recommended Distance (m)

0 500 1000 1500 2000

South Walker Creek
Poitrel
Blackwater
Daunia

Inferred

Recommended Distance (m)

0 1000 2000 3000 4000 5000

South Walker Creek
Poitrel
Blackwater
Daunia

Rangal Coal Measures

Moranbah Coal Measures

Gregory Crinum
Crinum M Block

German Creek

After Bertoli et al 2012

Kriging Variance

- Provides a quantitative measure of uncertainty

- Kriging estimation uses:
  - distance between samples,
  - distance from block to samples,
  - model of spatial continuity (variogram)
  - the size of the block (support)

- Returns error associated with the estimate for each block in the estimate

- What error becomes meaningful?

Graphic: Example resource classification using Kriging Variance
Why circles?

- Draftsmen with compasses
- Assumption of same error around a point
- Variations on the Mickey Mouse shape for resource classification in coal is an image we are all very familiar
- Starting with a data point, and drawing circles around them.
Comparison of variance and Aust Guidelines

Legend
- Ash % ad
- Lease
- Ash 250m
- Ash 500m

Ash % ad
- Kriging variance
  - 4 - 5
  - 6 - 10
  - 11 - 15
  - 16 - 20
  - 21 - 25
  - 26 - 30
  - 31 - 35
  - 36 - 40
  - 41 - 45
  - 46 - 50
  - 51 - 55

Kriging variance and Australian Coal Guidelines 2003 Distances
Have things changed?

- Quantity of coal
- Type of deposit
- Market
- Capital Investment
- Technology
Are we there yet?

The questions of “ore” and “reserves” have been, and continue to be the subject of never ending examination in the metalliferous and coal industries, certainly since World War II, and no community has yet been able to claim that it has been given its final answer.

Ken Mosher 1973