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ADDITIVITY, METALLURGICAL RECOVERY and GRADE
After a paper by P Carrasco (Codelco, Chile), JP Chilè and S Seguret (Centre for Geostatistics, Mines ParisTech, France)

Let Q and T stand for the metal and ore tonnages, and Z for grade and H, C and T be descriptors for head, concentrate and tail, for instance T_H is the tonnage fed to the plant, T_C and T_T the concentrate and tail tonnages.

A copper deposit

Across the deposit, 1,112 core samples have undergone laboratory process tests resulting in Z_H, Z_C, Z_T and metallurgical recovery R = Q_C / Q_H data at each sample location. Z_H is an additive variable but Z_C, Z_T and R are not. Note that the (in situ) “recovered” grade writes Z_R = R x Z_H and is additive.

The “weight” recovery r = T_C / T_H = (Z_H - Z_T) / (Z_C - Z_T) is such that R = r x Z_C / Z_H. Finally, the authors stress that Z_H, Z_R and r are the additive variables relevant to the estimation of metallurgical recovery.

The paper examines any differences that may exist between 2 estimation procedures for R mean - 1) averaging point-support core R’s directly and 2) dividing the average of Z_R by the average of Z_H - both globally over the deposit and at the block scale within a restricted area of the deposit.

Data analysis

Well-structured direct and cross-variograms of Z_H, Z_R and r are modelled, and scatter diagrams plotted. The (Z_H, Z_R) correlation is very strong (0.995) and the (Z_R < Z_H) pattern very consistent.

Global recovery

- At the scale of the deposit, the difference between biased and correct estimators of the mean recovery is regarded as material.
- Additivity matters!
- Individual large areas show a similar pattern.

<table>
<thead>
<tr>
<th>Area</th>
<th># core samples</th>
<th>Mean Cu%</th>
<th>Average of recoveries (biased)</th>
<th>Ratio of averages (correct)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1</td>
<td>671</td>
<td>0.91</td>
<td>88.8%</td>
<td>89.3%</td>
</tr>
<tr>
<td>Area 2</td>
<td>394</td>
<td>1.16</td>
<td>88.9%</td>
<td>89.8%</td>
</tr>
<tr>
<td>Area 3</td>
<td>47</td>
<td>2.22</td>
<td>86.3%</td>
<td>86.9%</td>
</tr>
</tbody>
</table>

Local recovery

The restricted area (200m x 200m x 50m) is divided up into 500 blocks V_j (20m x 20m x 10m), each block being discretised in 500 nodes. Twenty conditional cosimulations of - Z_H, Z_R and r - are calculated at each node. For each cosimulation, 2 procedures are applied to determine the R(V_j) block recovery:

Additive procedure: Z_R(V_j) and Z_H(V_j) are calculated by averaging the point values in the block, R(V_j) being the ratio of these 2 quantities.

Non-additive procedure: at each node, point recoveries are calculated (R = Z_R / Z_H) and R(V_j) is obtained by averaging 500 point recoveries.

Surprisingly, over the 500 blocks and whatever the cosimulation, the two procedures deliver results showing no significant differences. Additivity appears to be irrelevant!

These results are consistent with the Z_H and Z_R geostatistical features of the deposit.

Note that additivity does not matter when Z_H is constant. This is nearly the case here: the small dispersion variance $\sigma^2(0 / V)$ supports that $Z_H$ does not vary much at the block scale.

Likewise, when $Z_R(x) / Z_H(x)$ is constant, the two procedures are again equivalent. As evidenced by the scatterplot $Z_R / Z_H$ and the 0.995 coefficient of correlation, the conditional variance of $Z_R / Z_H$ is small for any given $Z_H$, as $Z_H$ exhibits little variability at the block scale, $Z_R / Z_H$ is approximately constant.

At the deposit scale, $Z_H$ and $Z_R / Z_H$ vary more significantly and then additivity becomes critically important. The authors conclude with further comments on poor vs. best-practice R-estimation.