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Geological maps and models: are we certain how uncertain they are?

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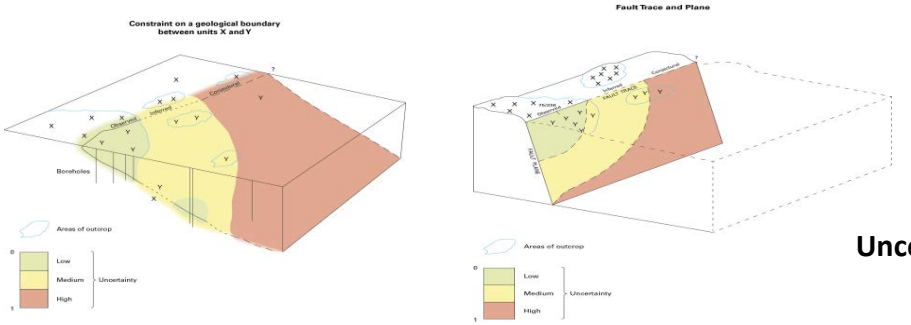
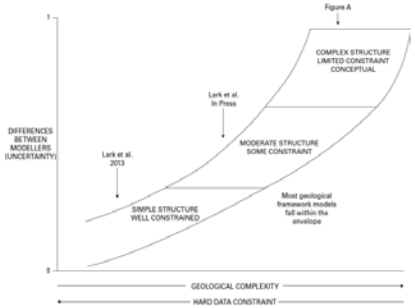
Uncertainty of geological lines in maps and models



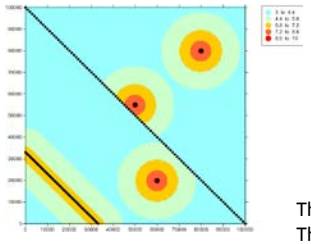
The main uncertainty concerned with any geological map or model is the accuracy of the geological boundaries. Traditionally by BGS these have been depicted on maps using three line styles that reflect the uncertainty of the boundary, e.g. observed, inferred, conjectural. Most geological maps focus mainly on the boundaries at the surface and have tended to neglect the subsurface expression (subcrops etc). Models could follow along similar lines with segments of subsurface geological boundaries (as digital node strings) tagged with levels of uncertainty.

Uncertainty due to differences of interpretation between geologists

In a recent study (Lark et al. 2013) five modellers used the GSI3D software package to construct a model in relatively simple Quaternary and unfaulted bedrock geology in East Anglia. GSI3D is one package that relies heavily on the modeller drawing the geology to link the controlling data (Kessler et al. 2009). The area modelled contained a good borehole dataset although its distribution was biased due to the reasons for the borehole drilling (e.g. linear routes, aggregate evaluation etc). The results showed a high degree of consistency between modellers, despite their very varied levels of modelling experience and familiarity with the area studied. This might well be expected from such a straightforward geological scenario. Studies of groups of modellers interpreting more complex geology are lacking at present. From a more theoretical standpoint, we might expect the differences in interpretation between modellers and hence uncertainty to become exponentially more significant with both increasing geological complexity and/or paucity of control data.

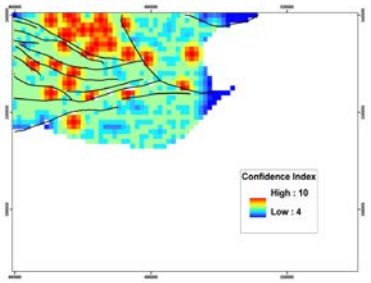


Development of a Confidence Index



The plot of the Confidence Index at left is for a simple hypothetical example. There are three boreholes (isolated black dots) and a line of seismic observations (bottom left corner). The region is also crossed by a fault, from the northwest to the southeast corner (broken black line). The colour code shows the Confidence Index at any location. The Confidence Index has a maximum value of 10 at any borehole with seismic lines showing a lower maximum value (7) as there is less confidence in the absolute depth and identity of the surface. The background value of the Confidence Index at a distance from any observation is 3, the Confidence Index decays from 10 to 3 with increasing distance from the nearest borehole. For the northeasterly borehole the Confidence Index decays to the background value over a distance of a little under 2000 m from the borehole. Faults truncate the zones of high confidence defaulting to the background value.

The values (0-10) for the Confidence Index were established by expert elicitation using a panel of experienced geologists. The geological consistency (predictability) of the individual surfaces was established using statistical methods. Hence simple unfaulted gently dipping surfaces enable hard data points to be extrapolated longer distances with confidence than those surfaces exhibiting faulting and folding. The plot to the right shows the Confidence Index plot for the top of the Dinantian sediments in the East Midlands of England (from Lark et al., In Press), white areas are where the surface is absent.



Key References

Kessler H., Mathers, S.J. and Sobisch. H.-G., 2009. The capture and dissemination of integrated 3D geospatial knowledge at the British Geological Survey using GSI3D software and methodology**.** ***Computers & Geosciences*** 35, 1311–1321.

Lark, R.M., Mathers, S.J., Thorpe, S., Arkley, S.L.B., Morgan, D.J. and Lawrence, D.J.D. 2013. A statistical assessment of the uncertainty in a 3-D geological framework model**.** ***Proceedings of the Geologists' Association***, 124, 946–958.

Lark, R.M., Mathers, S.J., Marchant, A. and Hulbert, A. In Press. An index to represent lateral variation of the confidence of experts in a 3-D geological model. ***Proceedings of the Geologists' Association.***