Quantifying uncertainty on interpreted cross-sections: How to visualise uncertainty by zones and levels?

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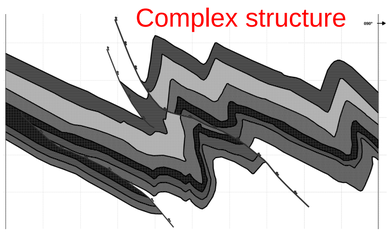
The Premise

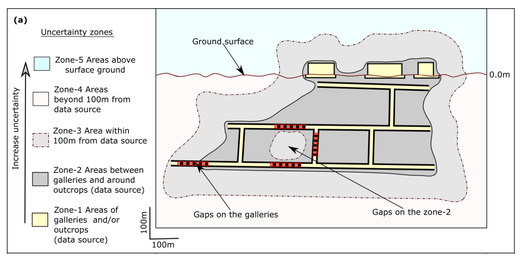
How can we represent risk and uncertainty in subsurface structural interpretation?



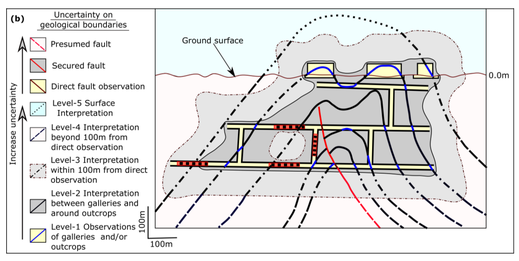
- Fold and fold-thrust structures have a complex structural history that is hard to unravel from limited data and 'accurate' interpretations are compounded by uncertainties inherent in subsurface structural interpretation – **but can high-resolution data help?**

- Here we show that high-resolution coalmine data provide an excellent opportunity to illustrate and quantify uncertainty using subsurface cross-sections of folds and fold-thrust geometries.

Visualize uncertainty by zone and levels



Schematic mode



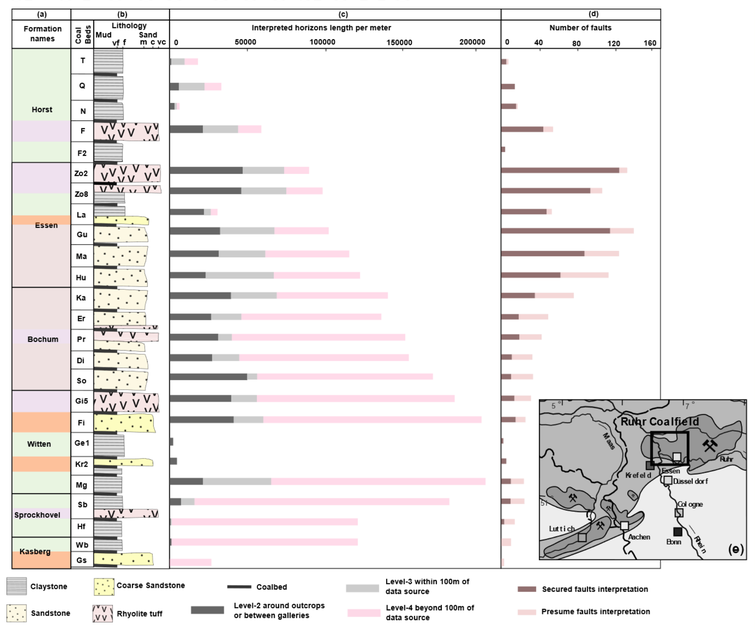
- Five uncertainty zones created by measuring the distance from outcrops, galleries and boreholes.
- Schematic representation of geology with the definition of uncertainty by levels.

Analysing published cross-sections

- Five zones have been used to display uncertainty in regional cross-section interpretations of late Carboniferous multi-layered stratigraphy through the Ruhr basin, coal measures of Germany.

- Location map and stratigraphic column with interpreted horizons length to charting variations in sample beds units and the faults that contained in Ruhr coalfield.

- The zones and levels approach can be plotted on interpreted horizons length from the coalbeds and the number of faults to illustrate the uncertainty.

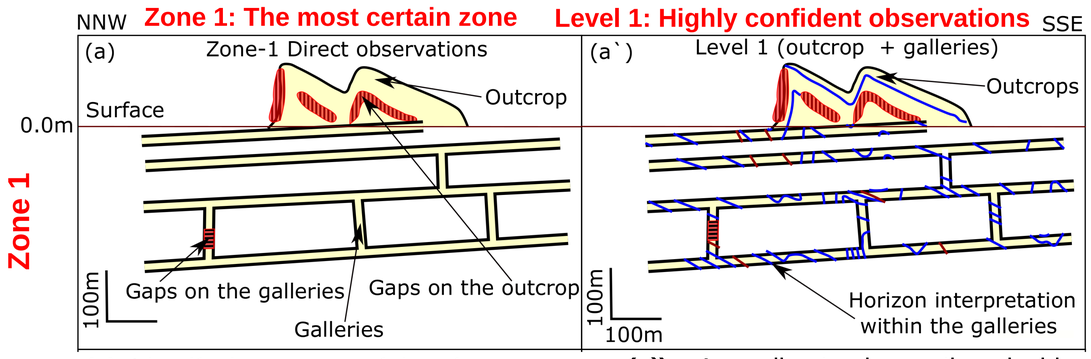


Application of workflow

Example of fold and fold-thrust structures interpreted from coalmines data, Ruhr basin, lower Rhine basin, Germany.

Increase Uncertainty

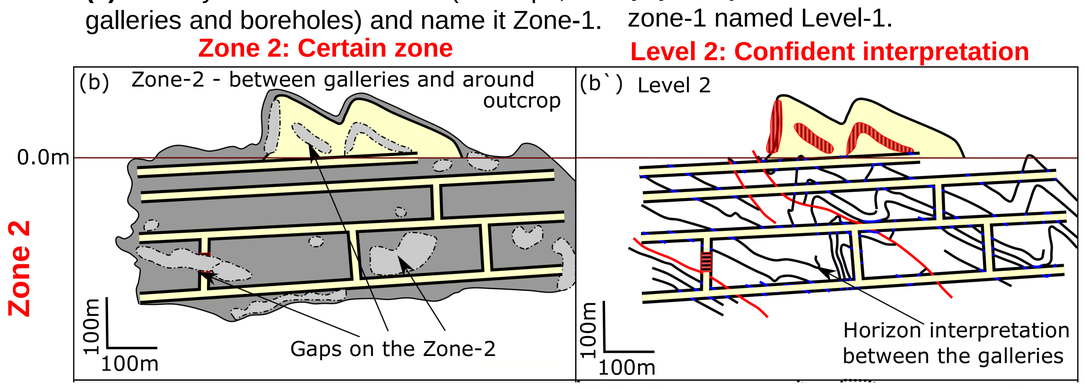
Zone 1: The most certain zone — **Level 1: Highly confident observations**



(a). Identify the sources of data (outcrops, galleries and boreholes) and name it Zone-1.

(a`). Any direct observation inside zone-1 named Level-1.

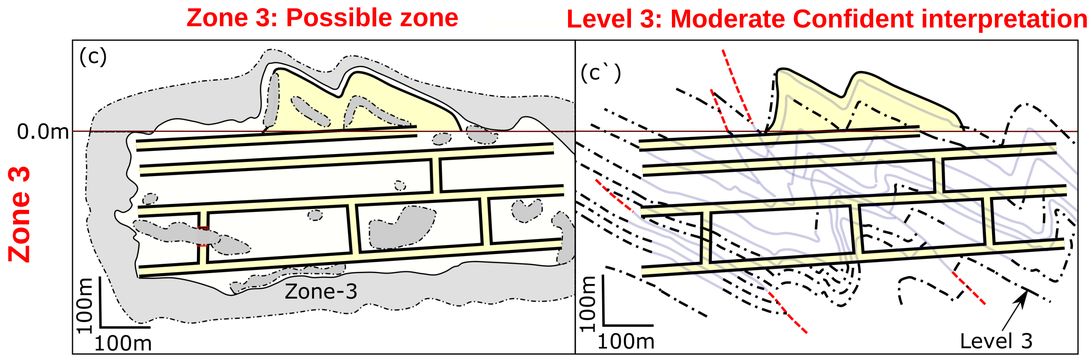
Zone 2: Certain zone — **Level 2: Confident interpretation**



(b). Calculate the distance between 2 sources of data where <100m is zone-2 .

(b`). Any interpretation between galleries and around outcrops in range <100m.

Zone 3: Possible zone — **Level 3: Moderate Confident interpretation**

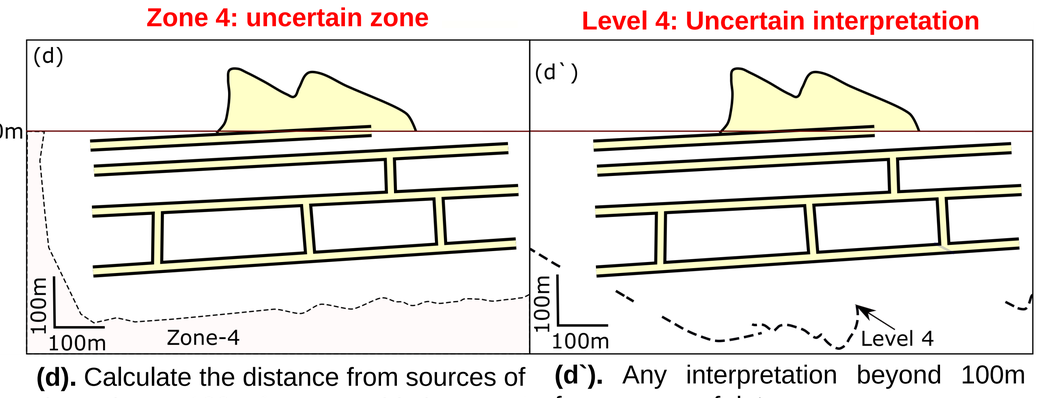


(c). Calculate the distance from sources of data where <100m from one side is zone-3.

(c`). Any interpretation within 100m from source of data.

Zone 1 — Zone 2 — Zone 3

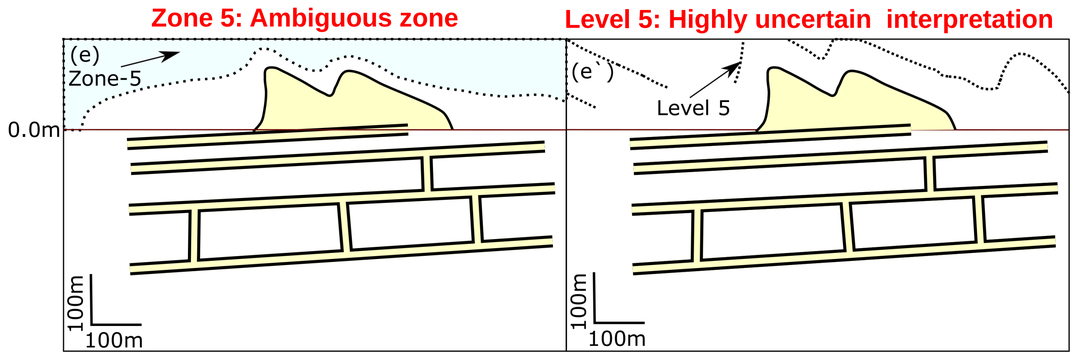
Zone 4: uncertain zone — **Level 4: Uncertain interpretation**



(d). Calculate the distance from sources of data where >100m from one side is zone-4.

(d`). Any interpretation beyond 100m from source of data.

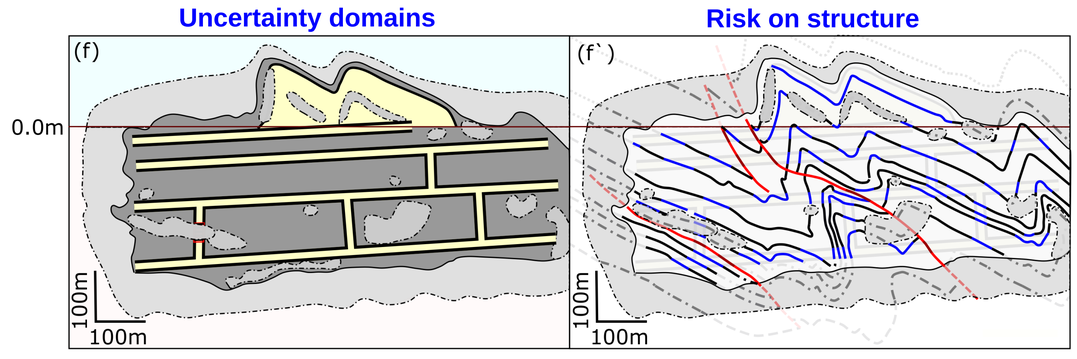
Zone 5: Ambiguous zone — **Level 5: Highly uncertain interpretation**



(e). The area above the earth's surface for eroded or covered geology. .

(e`). Any interpretation above the Earth's surface for eroded or covered geology.

Uncertainty domains — **Risk on structure**



(f) Show total uncertainty domains.

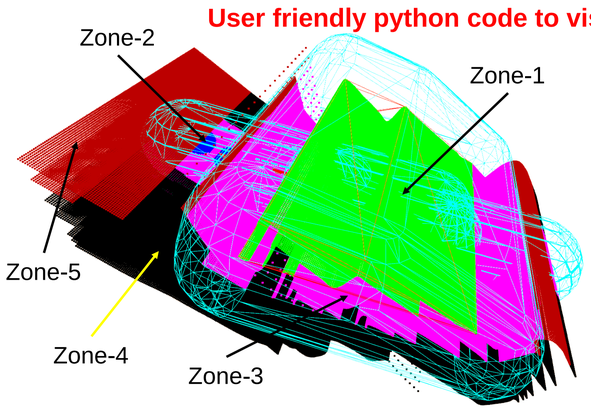
(f`). Risk on structure by overlaying uncertainty domains over uncertainty on geological boundaries.

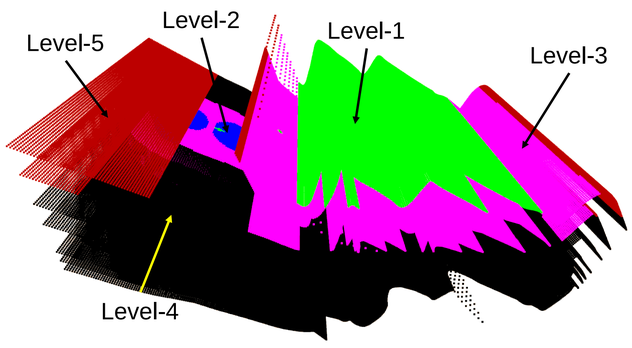
Zone 4 — Zone 5

Increase Uncertainty

Automotive uncertainty workflow

User friendly python code to visualized the uncertainty classification which will be available at https://github.com/ very soon.



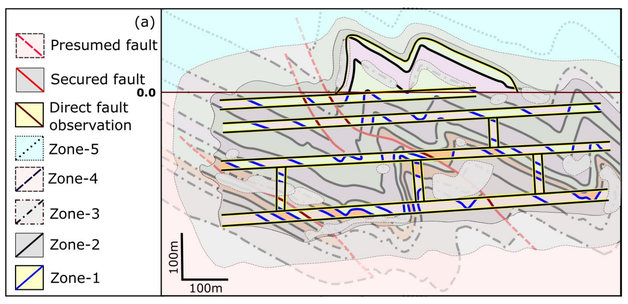


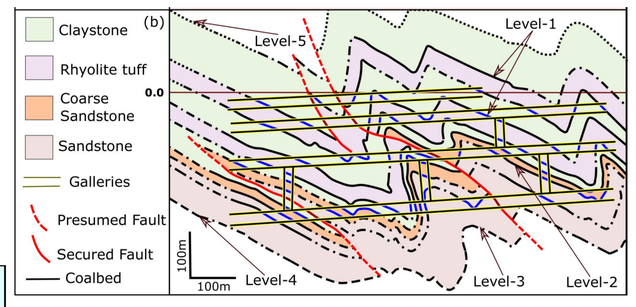
- Automatic uncertainty workflow using Python model. The zones generated by calculating the distance from outcrop and galleries - can be modified by users.
- Levels of uncertainty as an output result from the model to quantify and illustrate the risk of structural interpretation.

Final section

Message

- Final cross-section shows the classification workflow by illustrating uncertainty levels for horizons and faults interpretations and its associated uncertainty zones.





- Lithologies between coal seams and it interpreted horizons and faults classified into five levels of uncertainty.

Confident in subsurface interpretation illustrate by clear representations of geological boundaries and high uncertainty represented by fuzzy polygons.

- Five uncertainty zones to demonstrate uncertainty variations.

Conclusions

- Uncertainty classification workflow using zones and levels can help to quantify and visualise uncertainties in structural interpretation.
- The workflow can be used in a wide range of subsurface applications rather than coal mines such as oil and gas, carbon storage and thermal energy.
- These study also provide analysis and investigation of sample bias resulting from the amount or lack of raw data.
- Python programme has been created to automotive the uncertainty workflow.
- These provide a focus for further work in the AI area, hence geoscience fully understand and reduce risks for better decision making in the future.

References

- Andrews, B. J. et al., 2019. How do we see fractures? Quantifying subjective bias in fracture data collection. Solid Earth, European Geosciences Union, 10(1), p. 487–516.
- Bond, C. E., 2015. Uncertainty in structural interpretation: Lessons to be learnt. Journal of Structural Geology, 74(1), pp. 185 - 200.
- Bond, C. E., Johnson, G. & Ellis, J. F., 2015. Structural model creation: the impact of data type and creative space on geological reasoning and interpretation. Geological Society, London, Special Publications, 11(421), pp. 83-97.
- Drozdzewski, G., 1980. Ruhr Carboniferous Depth Tectonics Investigation Project, Westphalia Krefeld : Geological State Office North Rhine.
- Drozdzewski, G., 1983. Tectonics of the Ruhr District, illustrated by reflection seismic profiles In Seismic Expression of Structural Styles - a Picture and Work Atlas.. AAPG Studies in Geology, 1:7(15), pp. 134 - 341.
- Drozdzewski, G., 1993. The Ruhr coal basin (Germany)" structural evolution of an autochthonous foreland basin. International Journal of Coal Geology, 23(02), pp. 231-250.
- Giessen, F. W. et al., 1990. Geophysical imagery of geological structures along the central segment of the EGT. Crustal structure of the Rhenish Massif: results of deep seismic reflection lines DEKORP 2-North and 2-North-Q. Geologische Rundschau Journal, 79(3), pp. 523-566.
- Lark, R., Mathers, S., Marchant, A. & Hulbert, A., 2014. An index to represent lateral variation of the confidence of experts in a 3-D geological model.. Proceedings of the Geologists' Association, 3(125), pp. 267 - 278.
- Wellmann, J. F. & Regenauer-Lieb, K., 2012. Uncertainties Have a Meaning: Information Entropy as a Quality Measure for 3-D Geological Models. Tectonophysics, https://doi.org/10.1016/j.tecto.2011.05.001, 2012., 526-529(1), p. 207–216.
- Wilson, C. G. v., Bond, C. E. & Shipley, T. F., 2019. How can geologic decision-making under uncertainty be improved?. Solid Earth, European Geosciences Union (EGU), 2(10), pp. 1469 - 1488.
- Wrede, V., 2005. Thrusting in a folded regime: fold accommodation faults in the Ruhr basin, Germany. Journal of Structural Geology, 27(04), p. 789–803.