Structural Modelling for Minerals and Mining

Analysis of the role of structures in controlling mineralization or deposit shape and stability is often neglected; however, it can have a large impact on successful exploration strategy or resource recovery, and is essential for safe mine operation. This becomes even more important now that shallow, easy to find deposits are becoming rarer. The future lies in locating and developing deposits that are deeply buried or blind. Finding deposits that are masked at the surface requires integration of a wide range of data types and techniques. At the stage of mine planning, structures (faults and fractures) are equally important to understand, because incomplete or incorrect understanding can result in decisions being made that have negative economic impact, or have potentially fatal consequences.

Exploration for deeply buried or blind deposits can be improved and costs reduced by properly understanding the structural system, for example the fault network, the shape of the faults, the strain (and fractures) associated with the faulting and the evolution of structures through time. Mining techniques, such as block caving, can be better prepared for by improved understanding of the fracture distribution and the likelihood of structures to fail under defined stresses. In this short feature we present two examples where structural geology modelling techniques, built-in to the Move™ software suite, are used to improve success in mineral exploration (Example 1) and reduce risk in mine planning (Example 2).

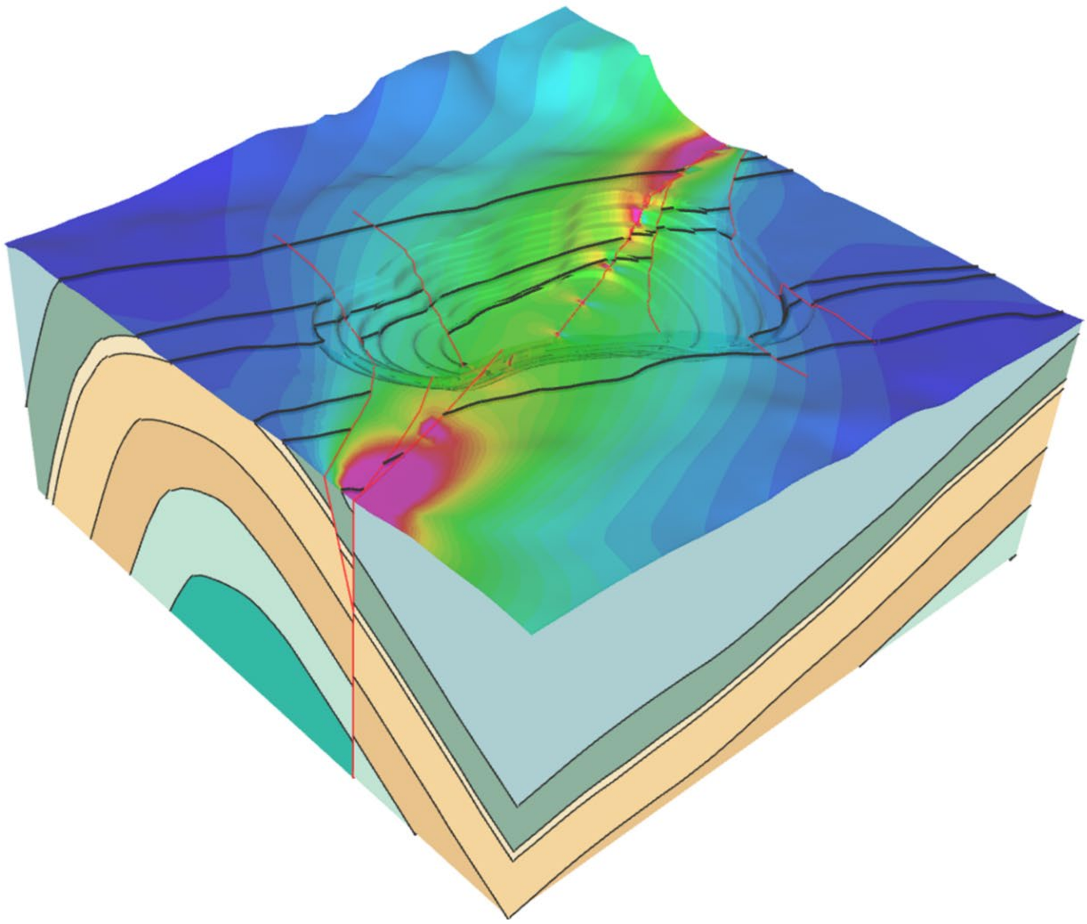

Figure 1. A 3D model in Move – geological model built and DEM colour mapped for strain associated with faulting. As discussed in this feature, this type of analysis can be important in mineral exploration and mine planning.

Constructing a valid geological model from limited data to improve targeting and resource calculations in mineral exploration

Whether exploring for structurally controlled deposits (i.e. porphyry copper, epithermal gold) or deposits which are later offset by faults (i.e. stratabound base-metals and coal), results of structural modelling can be used to improve decision making.

Constrained model building and forward modelling techniques are commonly used in areas where data is limited or poor, to improve geological interpretations of the subsurface. The constraints used are the observed data and fundamental structural geological principles. In a workflow, these techniques are first applied to the available data in 2D and are based on the assumption that mass and area is preserved during deformation (Chamberlin 1910 etc.). The results of 2D structural modelling can then be used as an input for building a 3D geological model to inform drill hole planning and resource calculations.

Example 1

In the example presented here, a digital elevation model (DEM), mapped geological contacts, surface bedding measurements and information from sparse drill holes (contacts, dips) were available (Figure 2a). There was uncertainty in the interpretation of the folded beds and fault linkages and shapes (Figure 2b), which had impact on drill planning to intersect high grade mineralization zones. In order to improve our understanding of the geology, first a section was constructed across the area and nearby data was projected on to the section (Figure 2a). The surface contacts and projected dip measurements were then used to construct the shape of the shallow beds using the kink-band method (Suppe 1983) (Figure 2c). Fault and horizon contacts logged from drill core were constructed where possible, assuming parallel thickness of the horizons (Figure 2d). The shape of the faults at depth was predicted from the horizon shapes using fault construction techniques outlined in the Move Monthly Feature: Using Structural Validation and Balancing Tools. If other data was available, for example seismic reflection imaging, the results should be compared to this in order to check they are consistent.

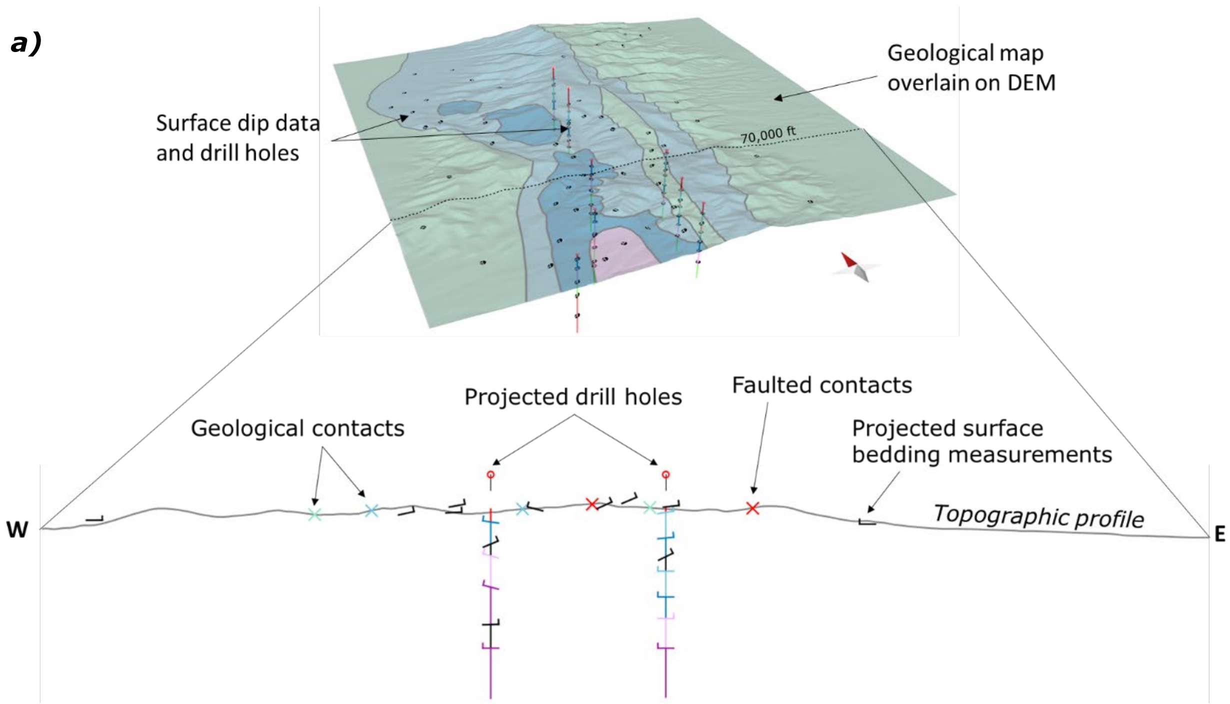

Figure 2. (Continued overleaf)

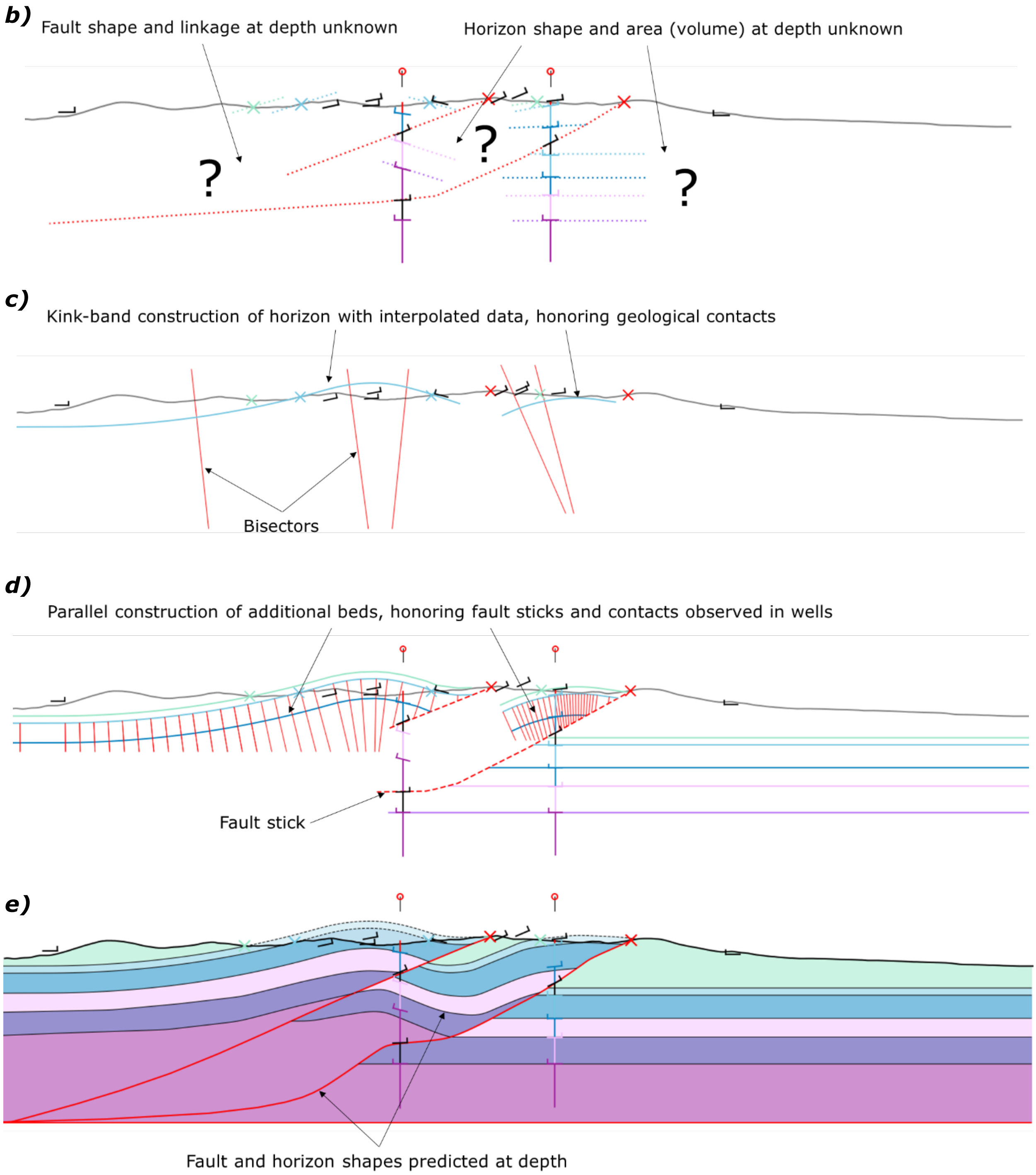

Figure 3. Workflow for creating a constrained geological model from limited data: a) Data available in 3D projected onto 2D section; b) Uncertainties highlighted in geological interpretation; c) Kink-band construction of light blue horizon; d) Parallel beds construction of other horizons; e) Fault and horizon geometries constrained at depth using constrained model building (forward modelling) techniques.

The results of this analysis reveals previously unrecognised fault and horizon shapes (Figure 2e). For exploration, the bends in the faults could be important as this is where high strain, fracturing and dilation are expected, which may focus fluid flow and be locations of mineralisation feeder zones. Constraining the shape of the horizons and, for example, in this case identifying structural repeats, is also key for mineral resource calculations and mine design.

Fracture modelling and stress assessment of structures to reduce risk in mine planning

As mentioned above, identifying strain associated with faulting can help to inform mineral exploration strategies. This is even more important at the mining stage. Understanding strain in the rock will reduce economic risk and make mining safer. Strain can be used as a direct indicator of fractures and, with the calculated values of strain from our structural models, we can predict fracture orientations and intensities. Further, we can assess the likelihood of different orientations of faults and fractures to fail or dilate under regional stresses. Using this geological approach we can improve our understanding of how the rocks might respond during mining.

Example 2

In this example we carry forward the dataset from Example 1. A 3D model was constructed from the validated geological sections and the strain associated with movement on the faults was calculated in 3D (Figure 3). Further details of this strain capture workflow are outlined in Move Monthly Features: Fracture Modelling Part 1 and Part 2. The results indicate that high strain areas are located where the hanging wall beds have moved through bends in the faults and ahead of propagating blind faults (Figure 3a). The strain results can be validated against hard data on the surface or, for example, fractures recorded from drill core. If the predicted data matches the observed data our analysis can be used to predict fracture orientations and intensities in areas with no data (Figure 3b). This should significantly reduce operational risk during extraction and increase mine safety.

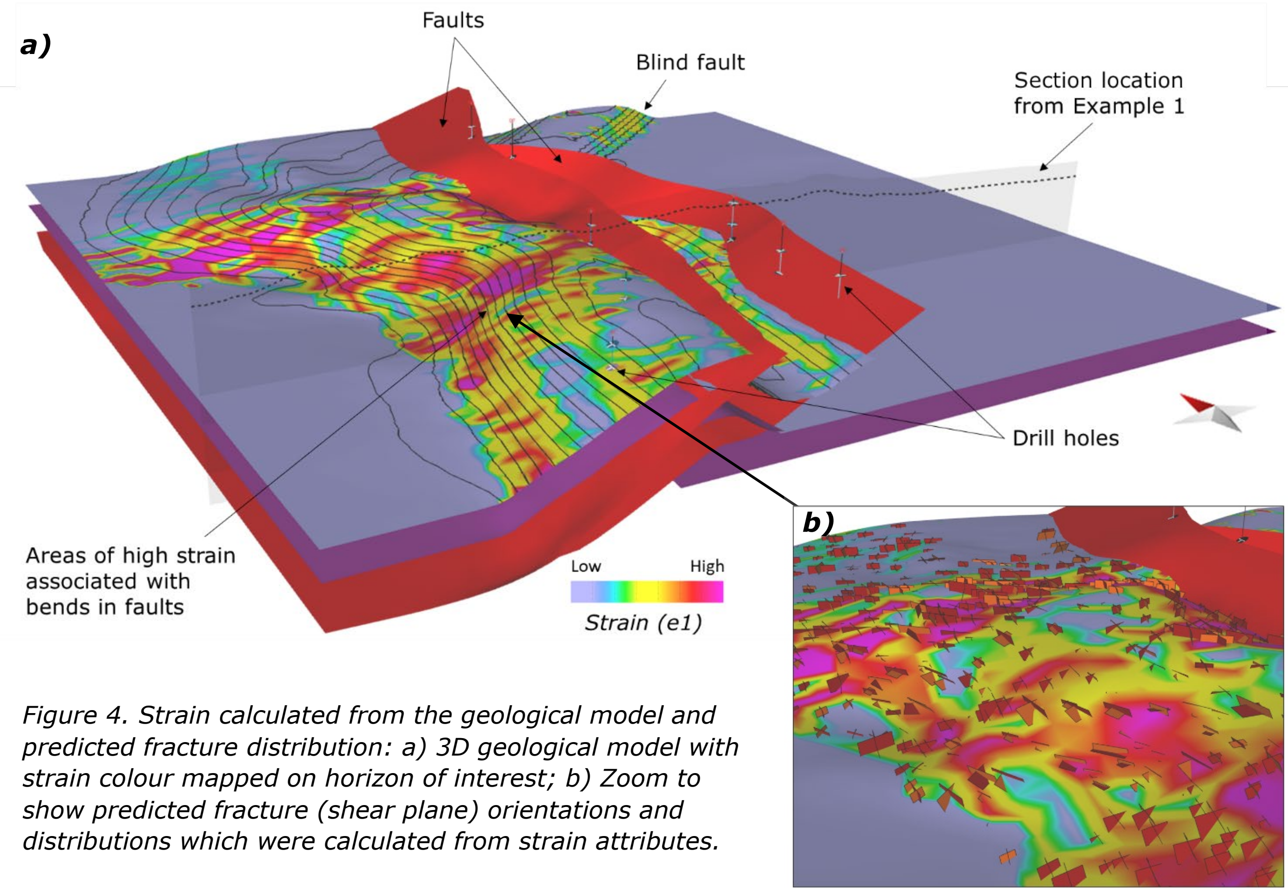

Figure 4. Strain calculated from the geological model and predicted fracture distribution: a) 3D geological model with strain colour mapped on horizon of interest; b) Zoom to show predicted fracture (shear plane) orientations and distributions which were calculated from strain attributes.

Conclusions

Here we have demonstrated some simple structural analysis techniques that can improve efficiency in exploration and reduce risk in mining. Using structural analysis techniques, such as constrained model building as illustrated in Example 1, we can improve our understanding of structural controls to streamline drilling strategies in order to improve success rates and minimize costs. At the mining stage, understanding the structural system, for example fracture distributions as illustrated in Example 2, is vital to better predict how the rock will fail during extraction and improve safety.

References

Chamberlin, R. T., 1910, The Appalachian folds of Central Pennsylvania: Journal of Geology Chicago, 18, p.228-251.

Suppe, J., 1983, Geometry and kinematics of fault-bend folding: American Journal of Science., v. 283, p. 684-721.

For those who want to further understand the capabilities of structural modelling applied to exploration and mining we are holding a technical meeting specifically for the mineral sector in Vancouver on the 12th March 2019 and you are invited to join us there.