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3D MODELLING AND DATA EXPLORATION OF THE PURCELL – SULLIVAN SEDEX MINERAL SYSTEM, SOUTHEASTERN BRITISH COLUMBIA

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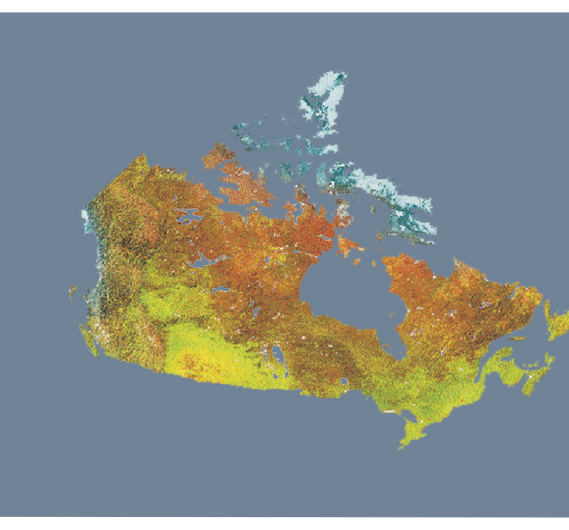
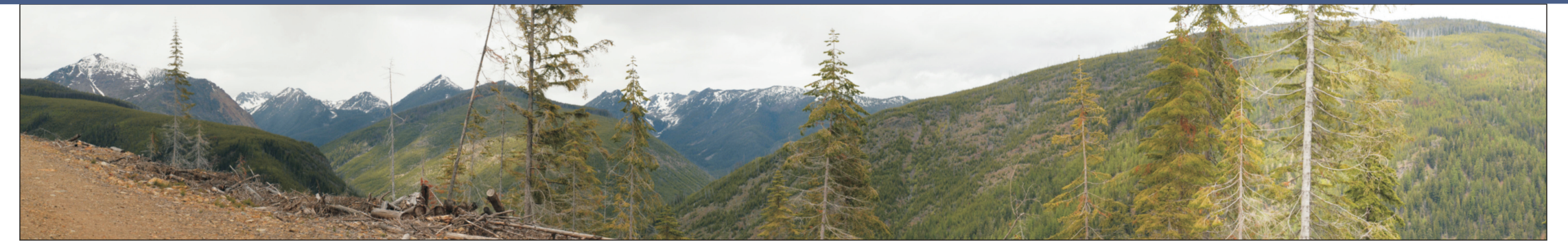
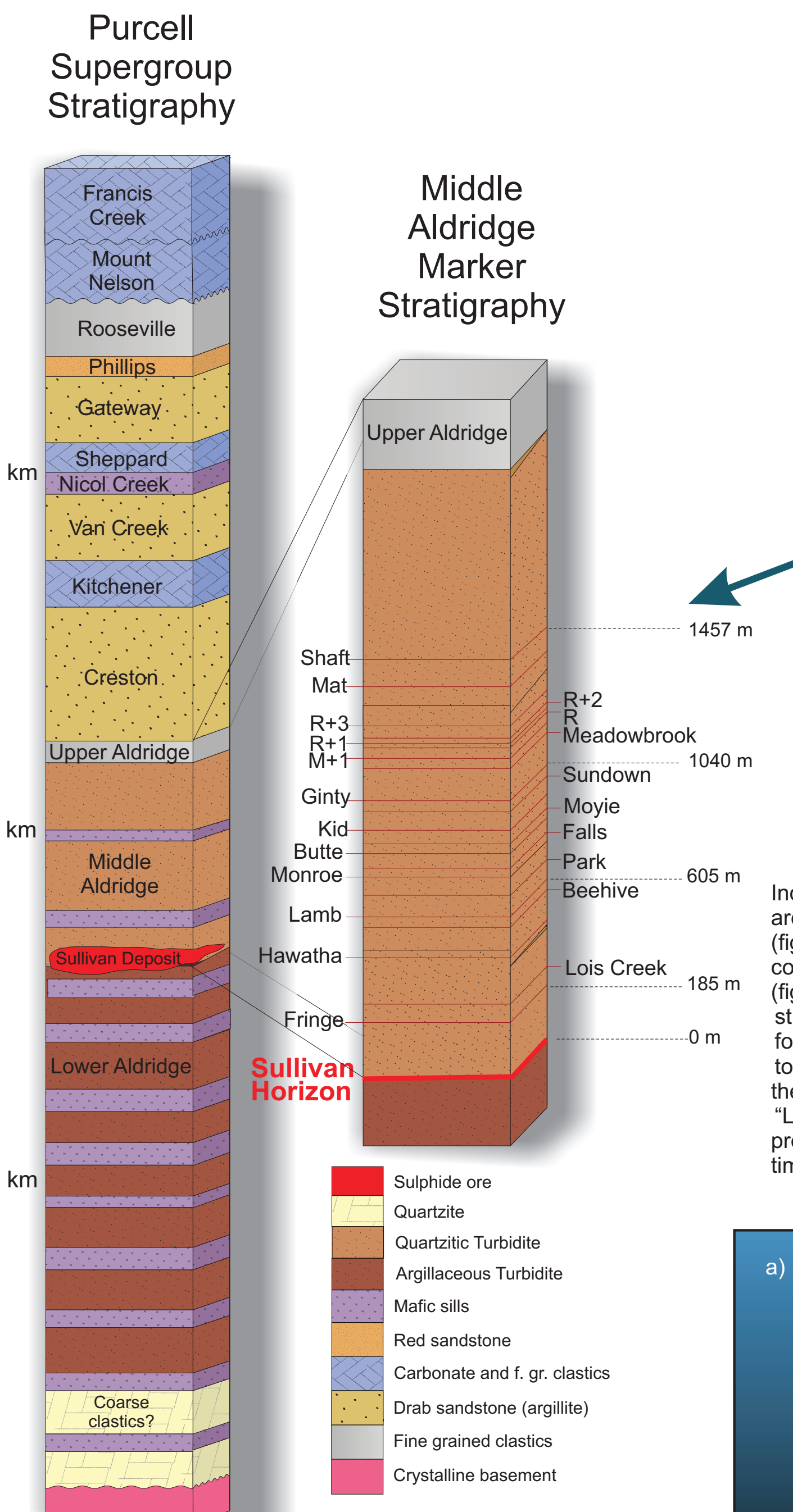




Abstract

Regional scale 3D modelling is important in enhancing our geological understanding of the subsurface to explore for mineral deposits at greater depths. The challenge is to upscale information available in densely drilled mine sites to regional 3D models in sparsely drilled environments. We present innovative methods used for regional-scale 3D geological modelling of the world class Pb-Zn SEDEX system in the Purcell Anticlinorium in B.C., developed through the Geological Survey of Canada's Targeted Geoscience (TGI4) program. We demonstrate how integration of geological map, drill hole and geophysical data is levered in a 3D environment to support interpretation of the entire ore system, thereby increasing the potential for deep discovery.



after A.S. Hagen, G.D. Delaney (personal communication, 1983) and D. Pighin, (personal communication, 2008) in Brown et al. 2011.

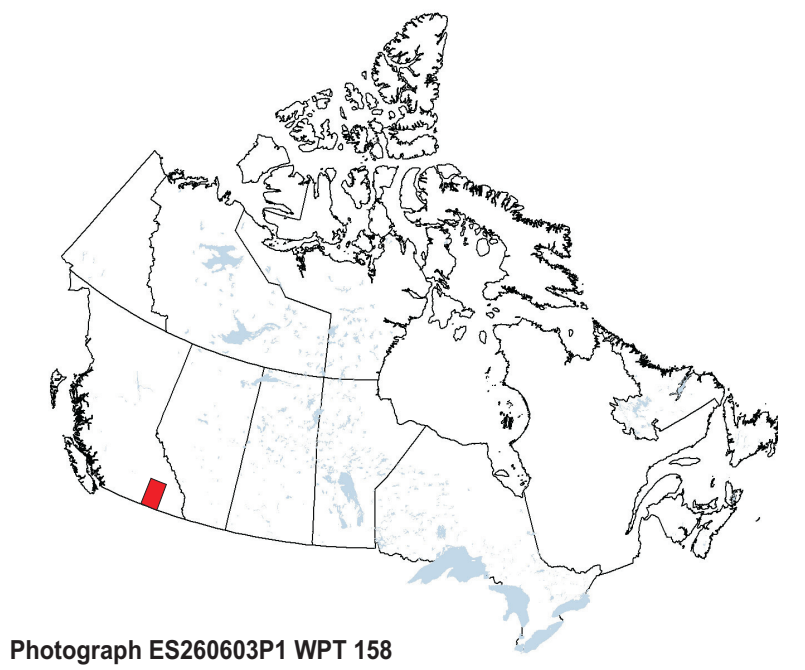


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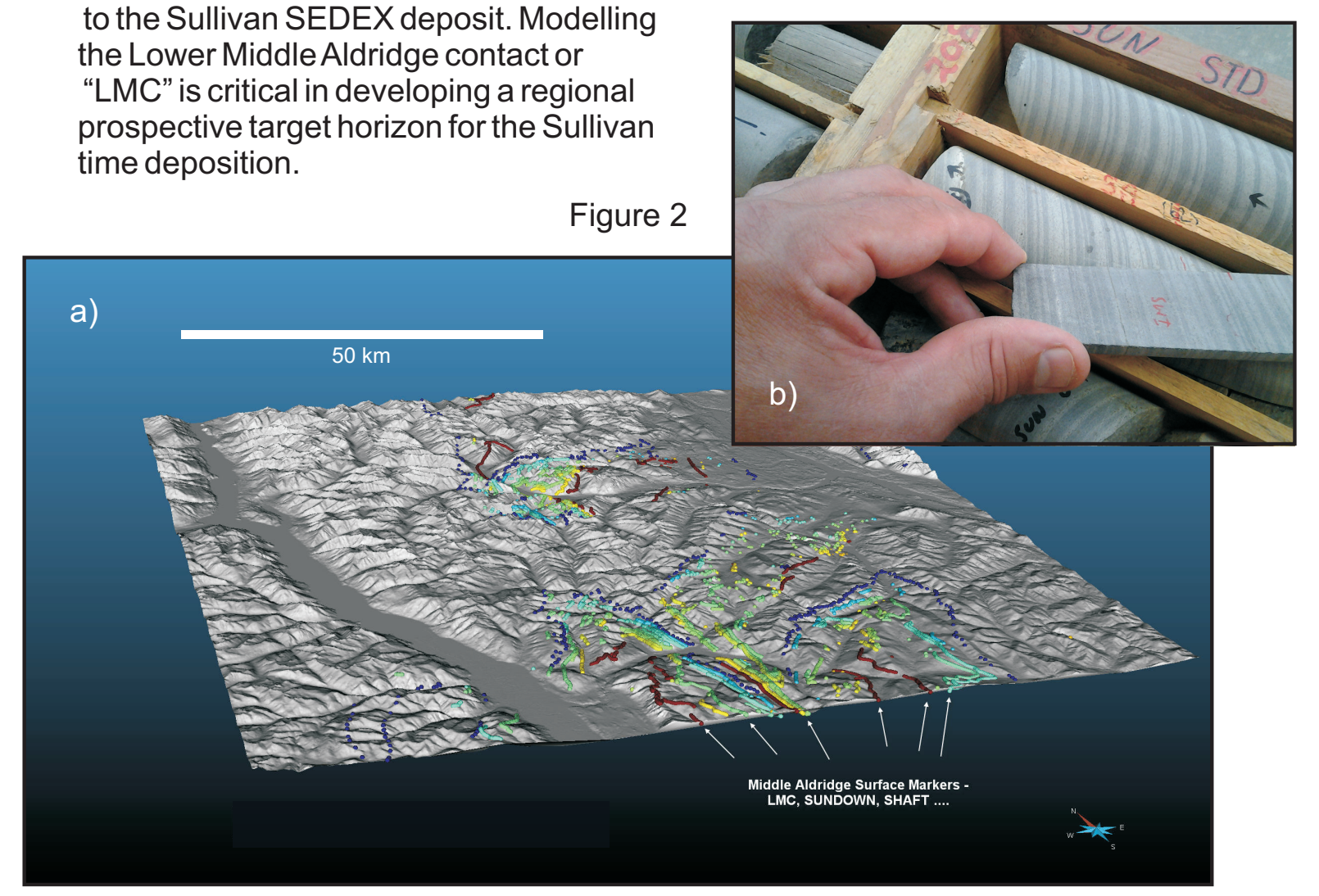
Figure 1 - Thick graded sandstone of the Middle Aldridge Formation. Cleavage, S1 refracts through bedding. Mount Fisher region.

Stratigraphic Correlation

Individual 'marker beds' characteristic of the Middle Aldridge Formation are used to correlate stratigraphic position throughout the Purcell basin (figure 1 above). Local expertise is required to determine these constraints which are used as 3D input into the modelling process (figure 2 a &b below). These will facilitate internal stratigraphic thickness determinations for the Middle Aldridge Formation host to the Sullivan SEDEX deposit. Modelling the Lower Middle Aldridge contact or "LMC" is critical in developing a regional prospective target horizon for the Sullivan time deposition.

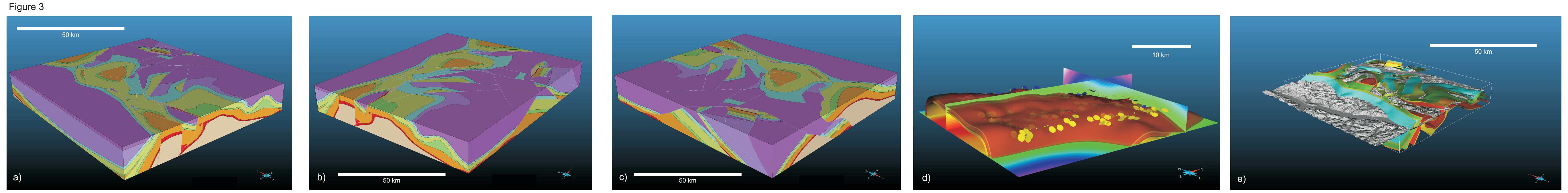
Figure 2



3D Models

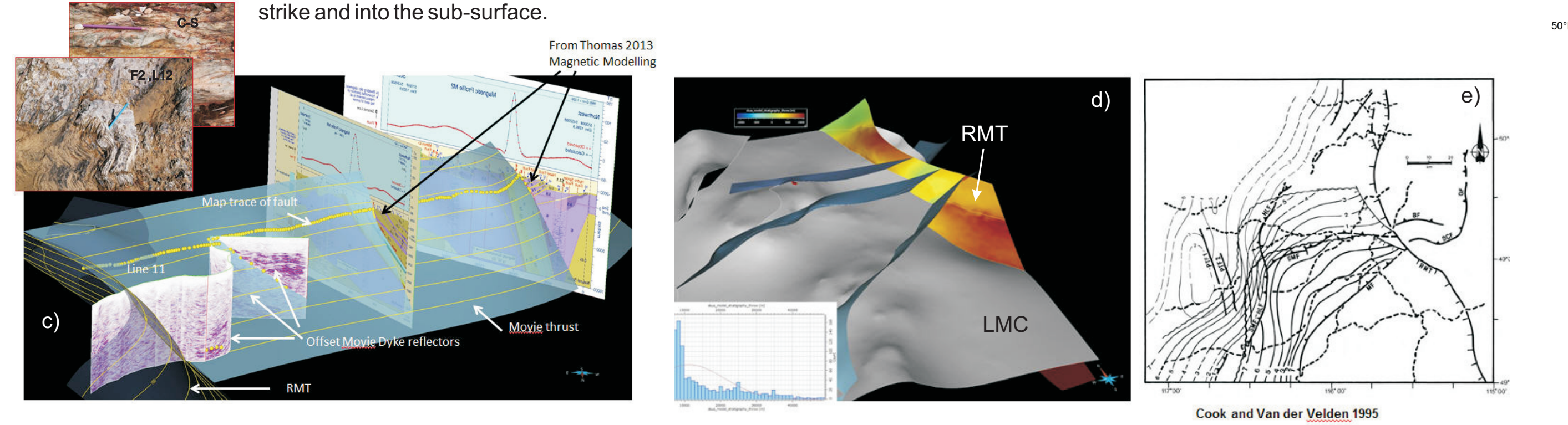
Research products (2D and 3D maps, data bases, Open File reports), have been derived from mine to regional scale digital models of the supracrustal units (Aldridge up to Kitchener formations) shown on the right. Perspective views of the volumetric model from the south-west (figure 3a) south-east (figure 3b) and the north-east (figure 3c). A multi-level example calculated using GRBF (see details in 3D Mathematical Modelling section and Hillier et al. 2014) from the Moyie block (figure 3d). Cover sequence faulted horizons (figure 3e) including Upper Aldridge, Creston, Kitchener and Nicol Creek formations.

Figure 3



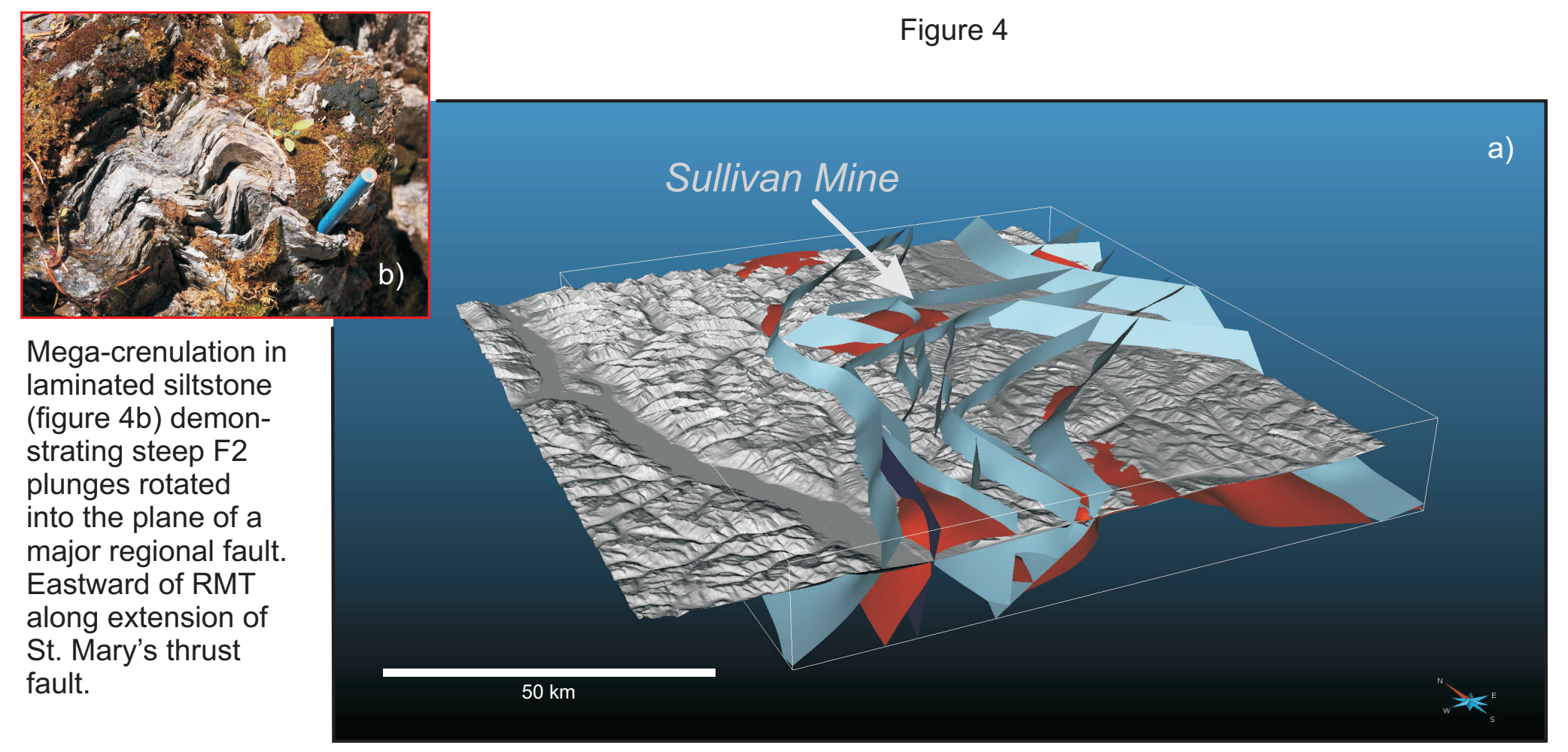
3D Fault Network Modelling

Fault network architecture is the first and most important structural feature to develop in the model. Input constraints for this include seismic, forward magnetics, field observations, drill data, map patterns and geomorphology. These are used as input to the General Radial Basis Function (GRBF) calculation for individual surfaces which through this process can be extended along strike and into the sub-surface.



Cook and Van der Velden 1995

Figure 4

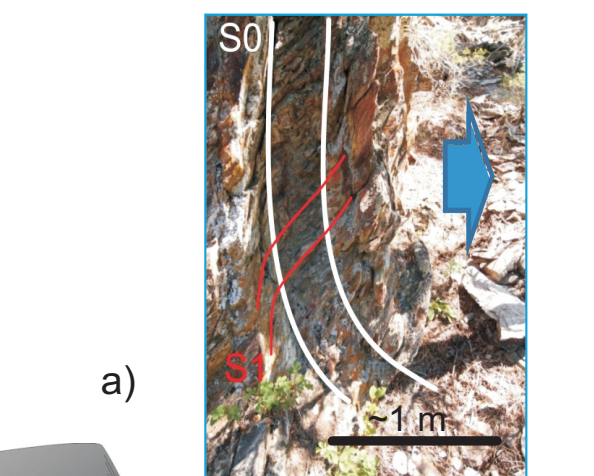


Mega-crenulation in laminated siltstone (figure 4b) demonstrating steep F2 plunges rotated into the plane of a major regional fault. Eastward of RMT along extension of St. Mary's thrust fault.

The new 3D fault network model (figure 4a) builds on previous models (figure 4e) in that it uses seismic constraints, but is now also based on dip estimations from historical cross sections constrained by drill holes (figure 4c) and a more objective estimation using the GRBF. Importantly the fault network can be re-calculated as new constraints are added, and with the horizon data, fault displacement vectors can be estimated (figure 4d) as well, for example on the Rocky Mountain Trench (RMT) above. This displacement field could in turn be used to constrain future fault restoration models throughout the region.

Structural Analysis & Modelling

Reconstruction of the regional structural architecture of the larger SEDEX system involves characterization of the local structural domains, separation of these domains in the horizon calculation process (GRBF) and an appreciation of the folding style which is needed during the interpretive process of the modelling workflow. Generally upright, shallow (5 - 25 degrees) north plunging, east vergent and occasional short eastward overturning of fold limbs are the common fold pattern (figure 5a). These patterns show up at local (figure 5b), mine (figure 5c) and regional scales (figure 5d).



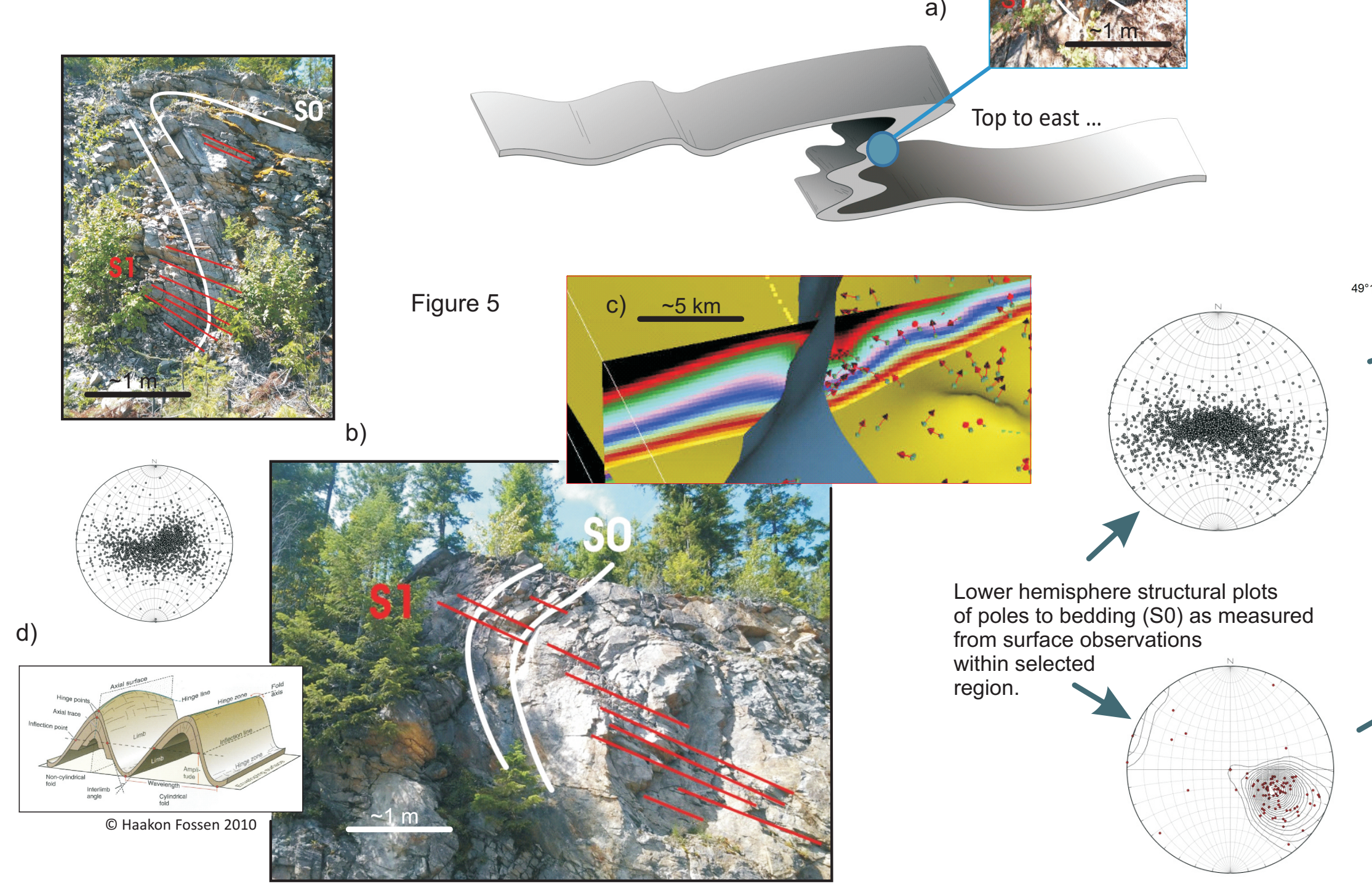
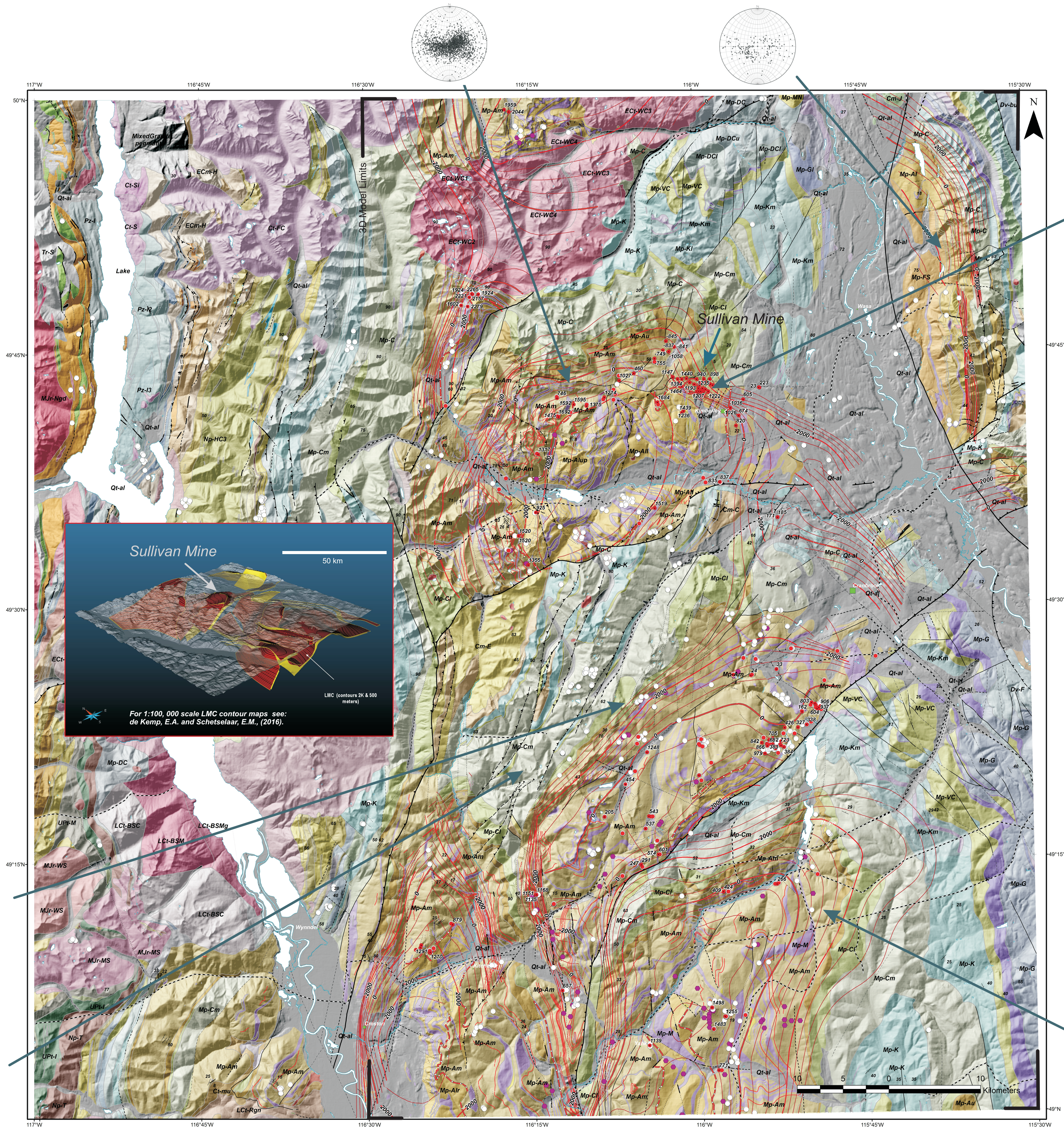
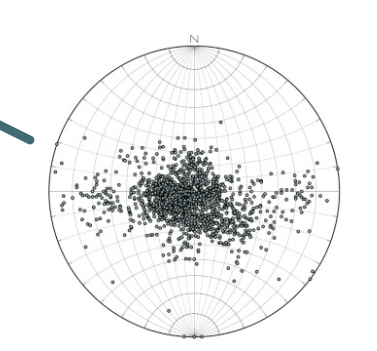


Figure 5

Lower hemisphere structural plots of poles to bedding (S0) as measured from surface observations within selected region.





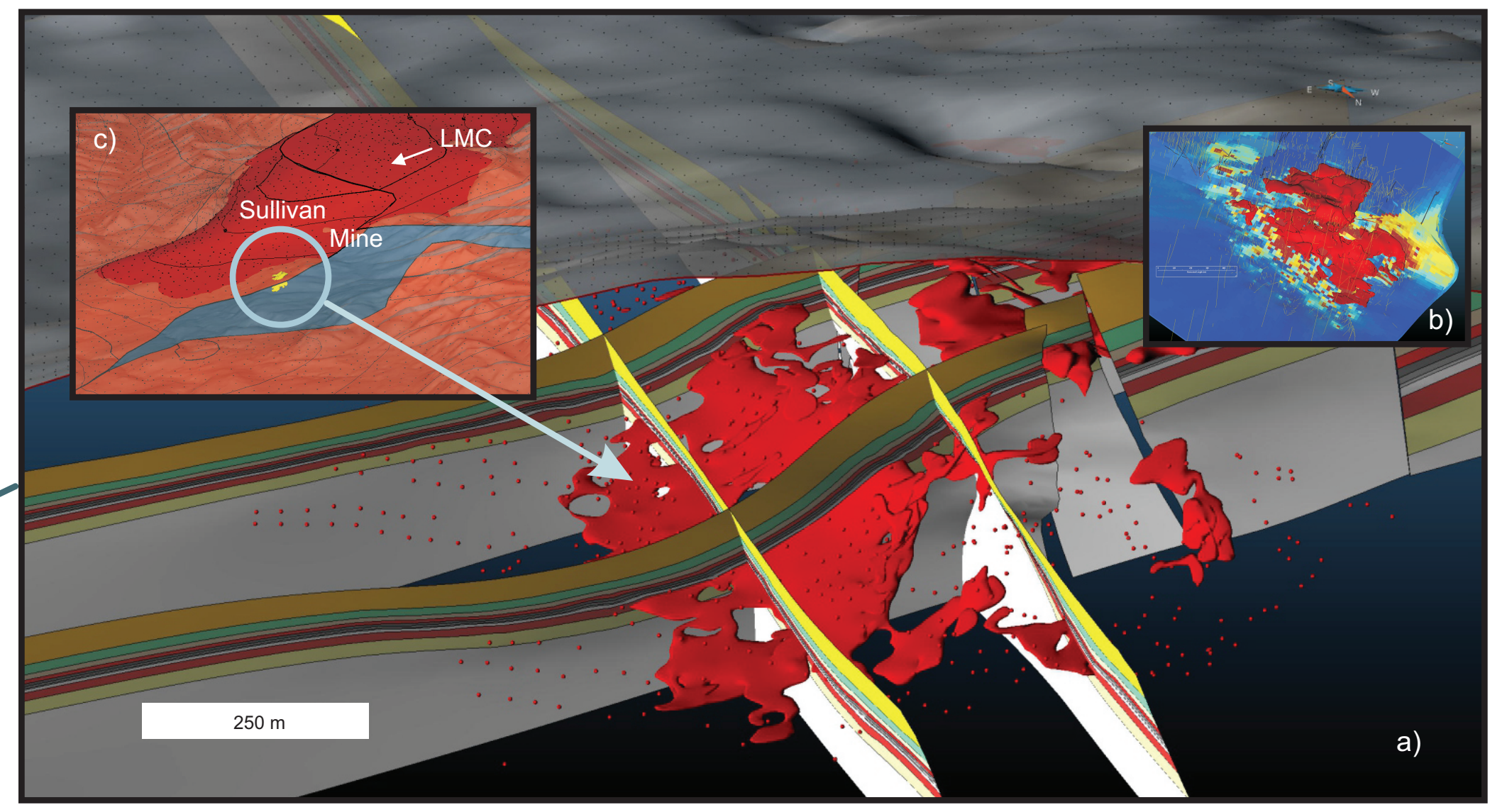


Figure 7

Figure 8

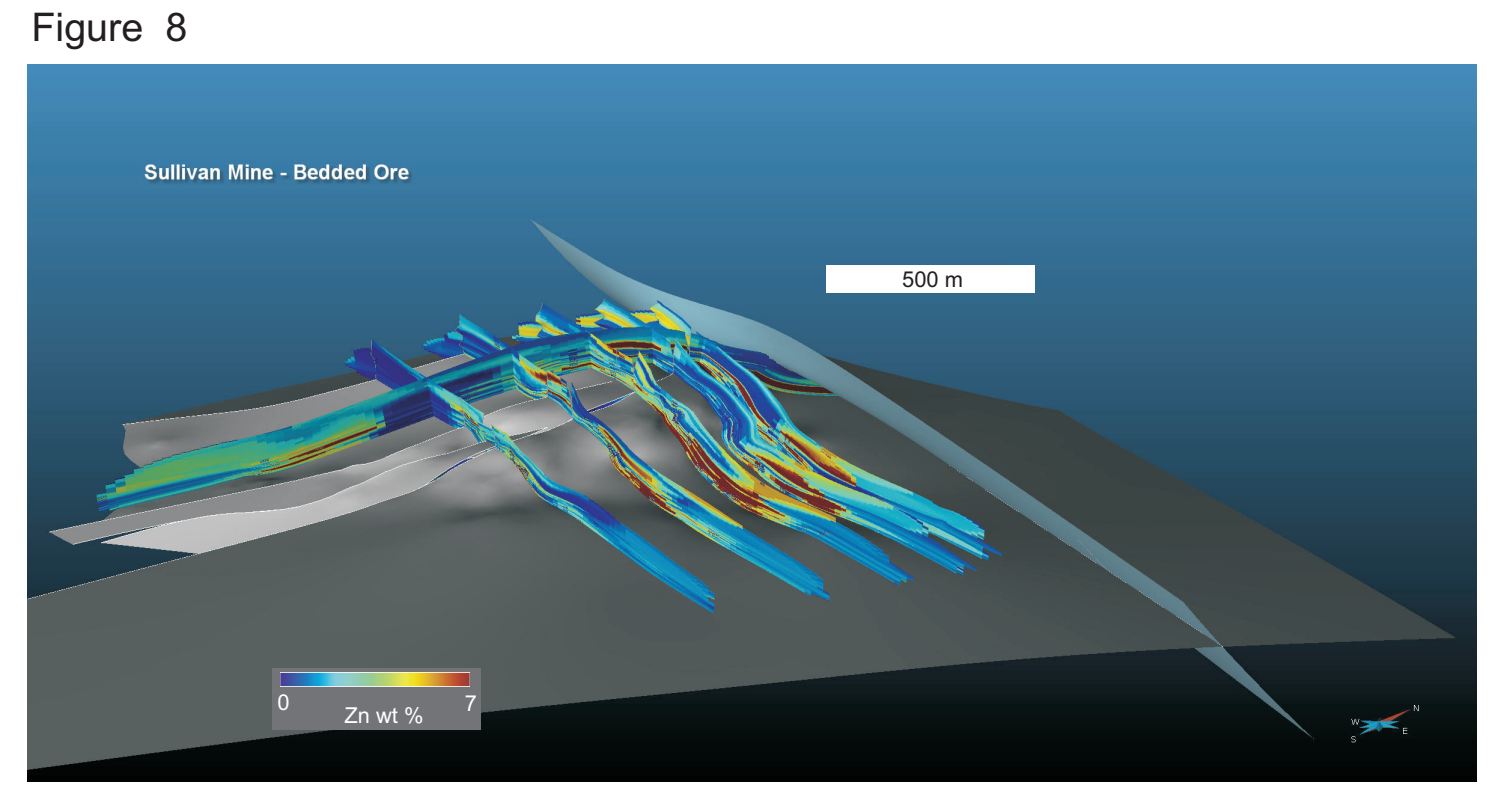
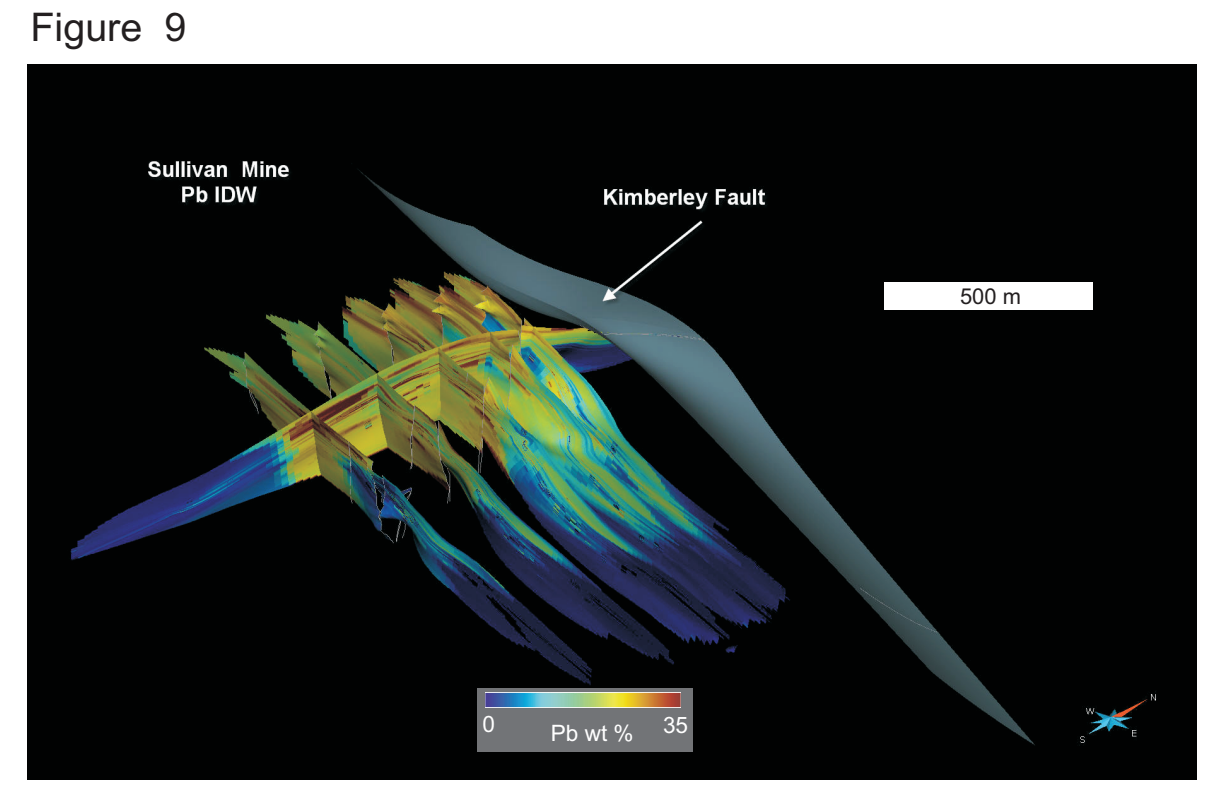


Figure 9



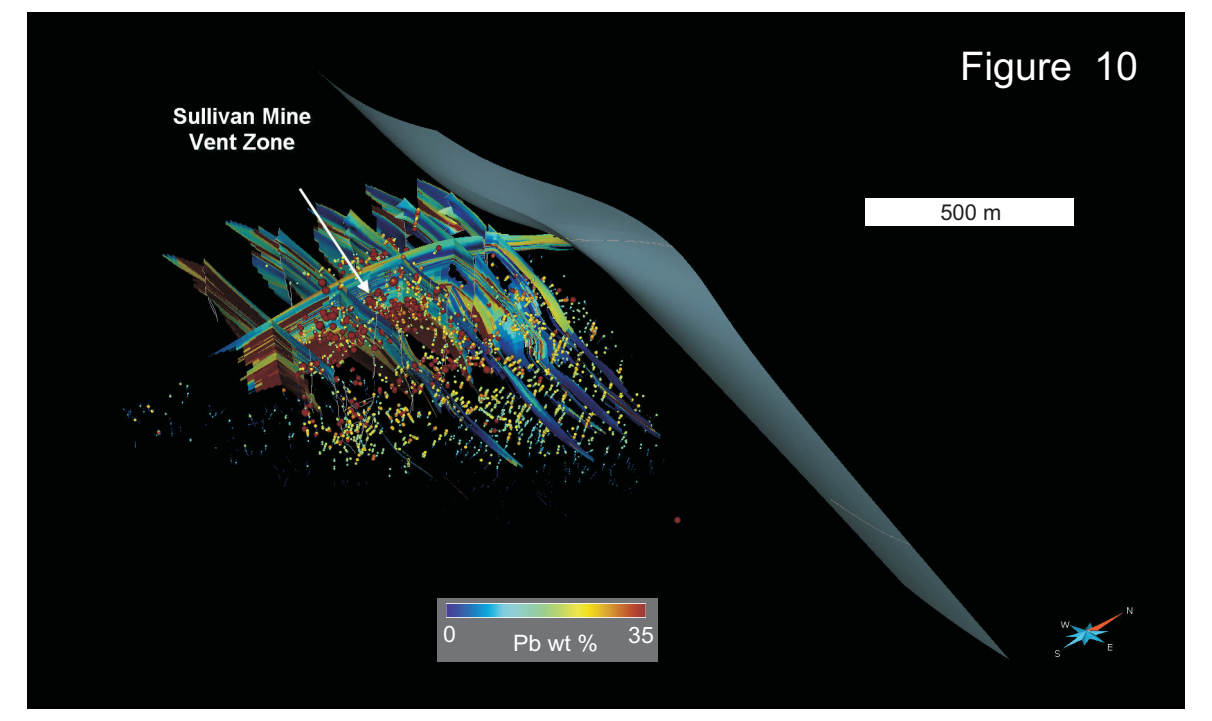
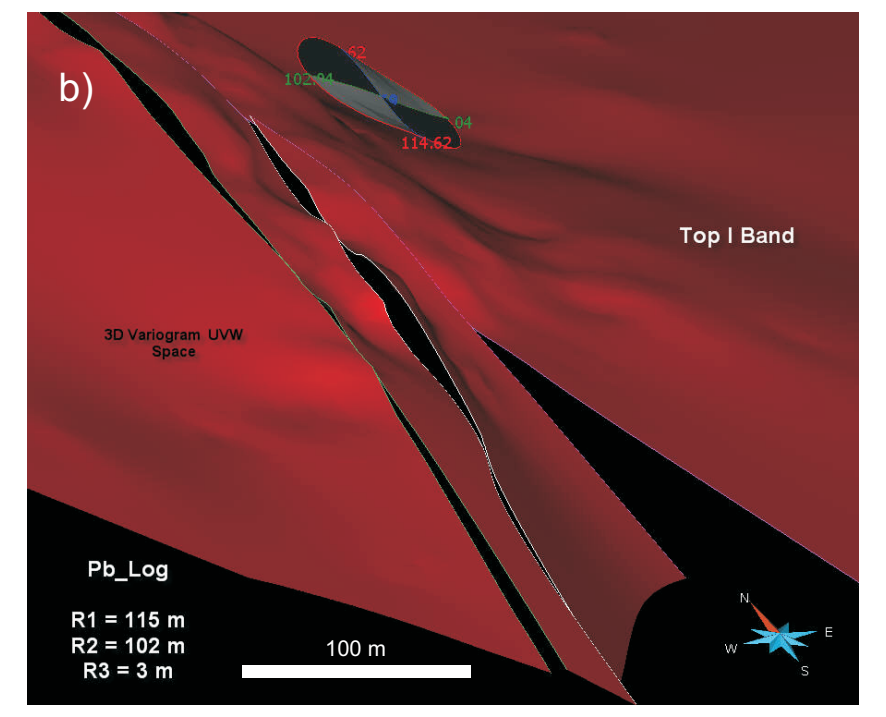


Figure 10

Metal Zonation and Mine Stratigraphic Modelling

Sullivan orebody and mine stratigraphy (figure 7a) with Pb zonation map (figure 7b) at the Main Band level (top markers as red points). Sullivan deposit (yellow body in figure 7c) at regional LMC contact. Arbitrary sections with Kimberley fault (light blue) and base of Main Band (gray) using a structural and stratigraphic GEOGRID. Interpolation using inverse distance weighted (IDW) log transformed data for Zn (figure 8) highlighting bedded ore, and Pb (figure 9) metal data concentrated near the vent zone (figure 10).

Metal assay data distribution from ~ 4,000 historical drill holes (figure 11a below). Faulted top of the I Band (red surface) with horizon based (UVT) variogram model (figure 11b) used for kriging in the Sullivan GEOGRID space. 3D variograms of Pb log transformed values for short (figure 11c) and long ranges (figure 11d).



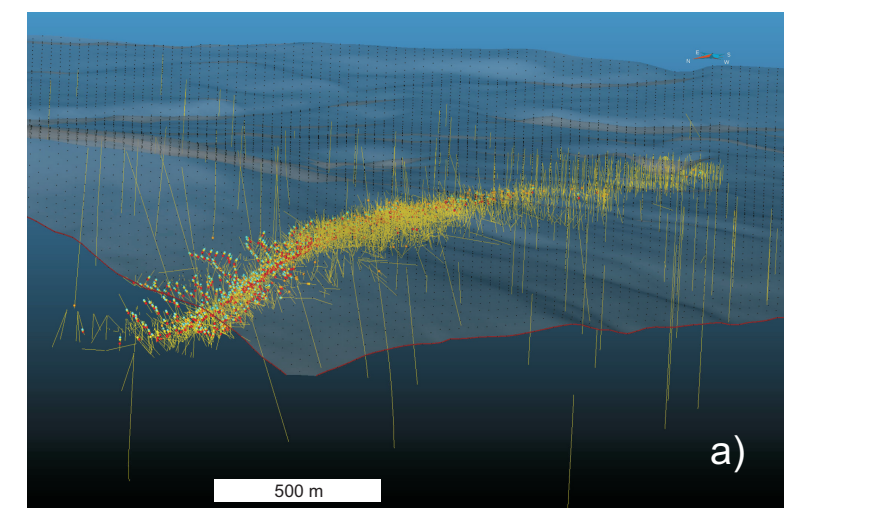
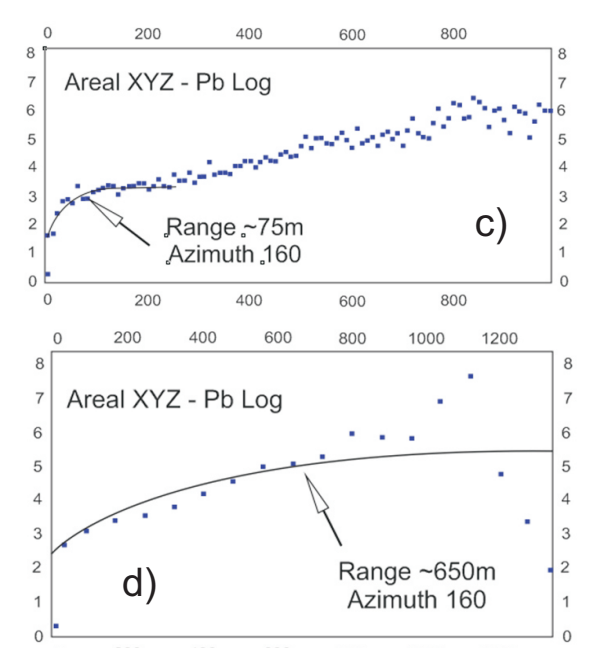


Figure 11



3D Mathematical Modelling

An innovative calculation engine was developed during the course of the Purcell 3D project based on an implicit estimation approach. The approach is now more widely used in 3D geological modelling but we extend and enhance the approach with what we call GRBF (General Radial Basis Function, see Hillier et al. (2015) for details). This new algorithm enhances the way sparse structural and geologic contact data can be modelled in 3D. This development allowed us to model faults and horizons (figure 3d and 3e above) which are traditionally better constrained in 3D geological modelling workflows using 3D seismic surveys. In the absence of these dense seismic data we needed to develop a method which could better interpolate and extend estimations into the subsurface, where there was very little hard constraints.

The GRBF method (figure 6a below) could prove useful in upscaling and integrating mine and regional data by making it easier to develop consistent models that use both dense and sparse data (figure 6b). Exploration strategies could benefit from this approach by undertaking 3D modelling exercises such as we show here, and with less risk, target for deeper ore , or better constrain conceptual geologic models (figure 6c) with deeper geologic holes based on the insight provided by the 3D model.

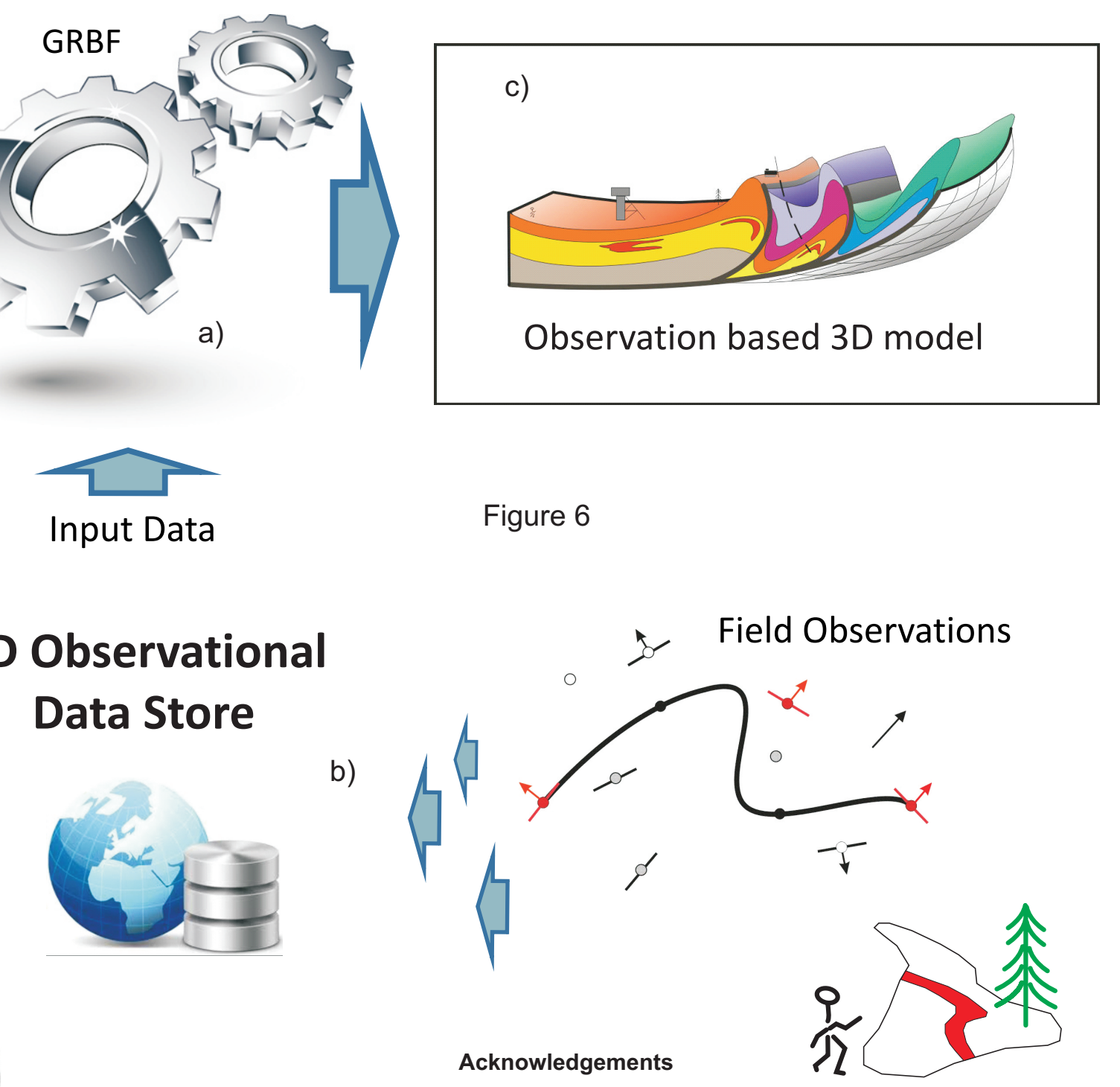


Figure 6

Metal Trend Analysis

Variogram analysis indicates strong horizon (principal spatial correlation ranges R1,R2 & R3 of 115, 102 and 3 metres respectively) anisotropy (figure 11d) within the bedded ore zone, as well as a subtle 160 degree trend (figures 11b & c) in metal content. This trend strongest for Pb and to a lesser extent other metals (Zn & Ag) indicated from the variograms a short ~ 75 metres trend and a much longer regional trend at ~ 650 metres. This trend matches well with the orientation defining the start of the bedded ore on the east side of the Sullivan deposit. This analysis supports the development of horizon controlled estimations in other prospective Middle Aldridge sediments at the 500 metre to 1 km ranges.

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