Integrated Exploration Information Management

Paper 20

3-D Visualization of Structural Field Data and Regional Sub-Surface Modelling for Mineral Exploration

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Before any in-depth regional exploration venture is undertaken it is essential that the explorationists involved begin to formulate, to some degree, a geometrical picture of the main geological features that will be under investigation. Ore bodies are by definition, three-dimensional geometrical objects that have formed with a specific orientation, shape, and position. Furthermore they are enclosed by more regional scale geologic objects that also have static geometrical controls that determine surface distribution, intersections at depth, and most importantly, geometries which could possibly influence or control the localized geometry and composition of the ore itself. It is imperative that every attempt, however speculative, be undertaken to increase the geologist's ability to rationalize key geological relationships by iterative attempts at 3-D visualization. Regional structural visualization is possible in many cases that have not been visualized to date. For regionally distributed (5–50 km) geological structures for which reasonable assumptions about the depth continuity can be made, such as pluton margins, regional shear zones, stratigraphic surfaces and brittle faults, it is possible to extrapolate existing data and visualize the result. The purpose of this iterative interpretation/visualization is not necessarily to come up with a unique or uncontested solution; it is in fact the opposite, to come up with several reasonable interpretations that could be tested by specific drilling, targeted field mapping or a follow-up geophysical survey.

Visualization of 3-D data sets typically requires expensive high-end software and hardware. This poster highlights the initial steps in the creation of what will hopefully become a tool-kit of 3-D spatial functions and viewing utilities based on readily-accessible programming tools (e.g., UNIX — awk, nawk scripting) and the emerging technologies associated with the Internet such as HyperText Markup Language (HTML) and Virtual Reality Modelling Language (VRML). Examples include linear projection of surfaces based on structural measurements and the projection of a number of drill holes based on down-hole deviations. A UNIX awk/nawk script performs the interpolation between the azimuth and dip measurements using component cosine directions. Visualization is via VRML as an Internet browser plug-in. The creation of the VRML version of the data is an option of the original script.

VRML is a descriptive language (Pesce, 1995) that is interpreted by the Internet browser in a manner similar to HTML. Both use the ASCII format. However where HTML produces static pages largely consisting of text, VRML creates a 3-D world. The user can interact with the objects within this world, viewing objects from different positions, rotating the objects and can even query these objects for additional data or move to a different VRML world. The VRML file consists of indexed list of vertices, a description of how these vertices are connected, as well as the material properties (colour, reflectivty, etc.) of the resulting objects. The object-oriented nature of VRML allows multiple copies of objects — for example, a Digital Elevation Model (DEM) or a surface based on magnetic response — to be easily duplicated and different properties applied. One example may show both the geology and an image of the magnetic response of the same region mapped onto two different versions, or instances, of the same object, namely the magnetic "topography" (Figure 3). Other VRML examples may use alternative methods of symbolizing surface structural measurements such as by orienting an ellipse according to the azimuth of the strike reading and tilting, and colouring the same ellipse according to the dip at the same site.

One particular visualization example from the layered troctolite, gabbro-anorthosite Kiglapait intrusion in Nain, Labrador, Canada (de Kemp *et al.,* 1997) is presented in Figures 1, 2, and 3. The geological assumptions made in this model were derived from the work of Tony Morse (1969), namely that the intrusion behaved as a contiguous magmatic system resulting from various crystallization stages in a continually fractionating magma. The pluton displays internal, igneous layering near the pluton phase boundaries, which in many cases reaches parallelism. Assumptions were that the lateral continuity observed from the map pattern along the troctolite unit continued at depth, and that the body was a lopolith-like structure as predicted by the regional trajectories of primary igneous layering. With this in mind an attempt was made to visualize the lower troctolite phase (Lower Zone) by integrating field observations of primary igneous layering and the surface traces of the mapped troctolite boundary. All field observations where digitized, spatially georeferenced and re-projected to the appropriate map projection for this region (UTM Zone 20 NAD27) in FIELDLOG (Brodaric, 1997).

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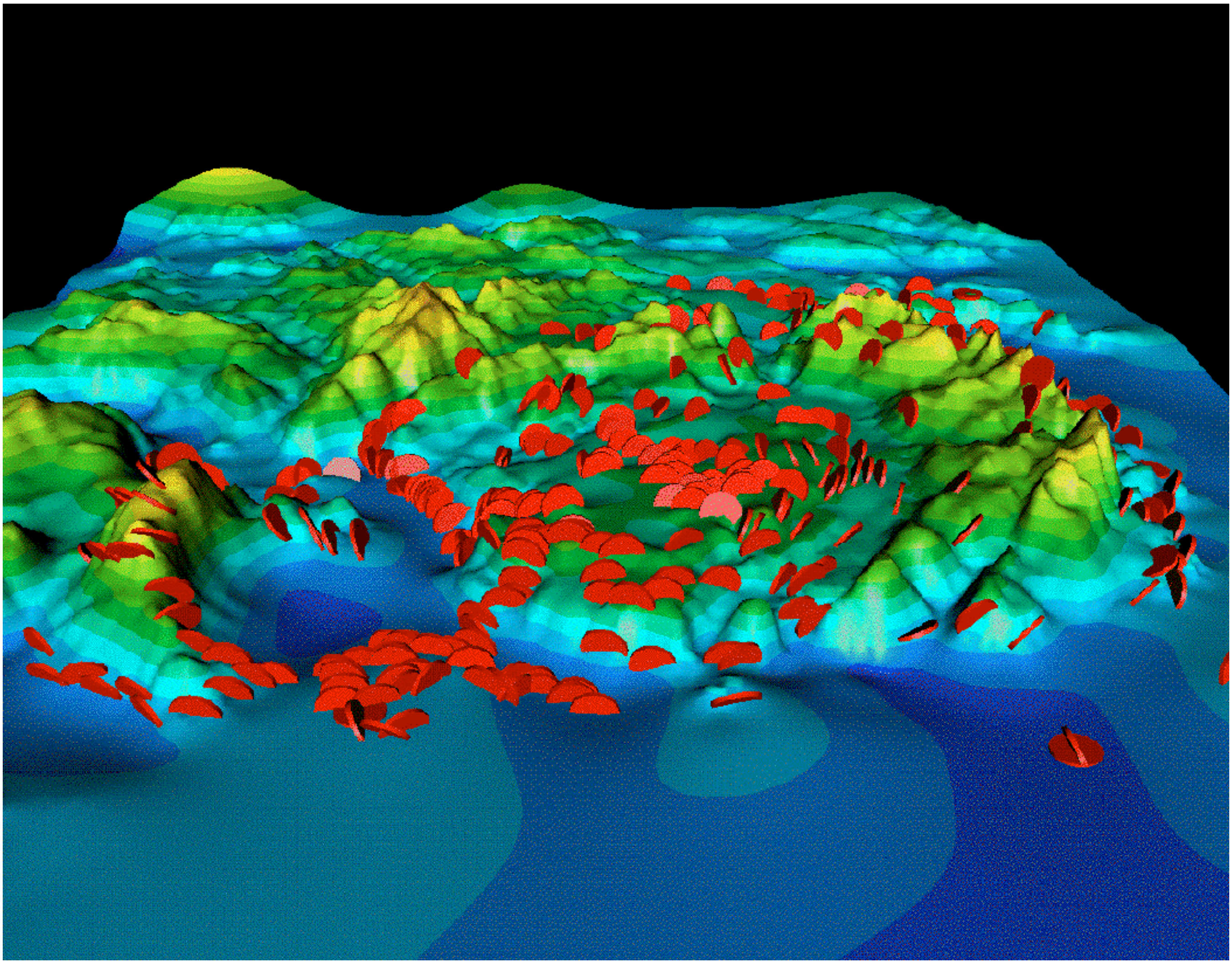

Figure 1: *3-D orientation regional primary igneous layering visualized as disks at surface of DEM, Kiglapait layered intrusion, Labrador, Canada.*

Then these data and the troctolite margin surface trace were corrected with respect to mean sea level in a 3-D modelling and visualization software package called EarthVision, using a digital elevation model exported from the Arc/Info GIS (Figure 1). Next, specific field observations of the strike and dip of primary igneous layering were conditionally assigned to local vertices of the feature train of the troctolite boundary, using a 500 m radius sphere cut off from the individual vertices. The lower intrusive contact and the upper zone contact of the troctolite X,Y, Z feature train was then densified along route and down-dip projected for 10 km using an interpolation routine that respects the field data (de Kemp, 1997). This process produced a depth-convergent constraint curtain from which 3-D control points could be inserted and interactively adjusted to form 3-D bézier lines (Farin, 1997). This process results in a series of smooth 3-D curve-lines, which become tangential at ground surface to the known field-observed geometry of the igneous layering. It is these smooth 3-D lines that form the construction feature lines for the entire model. Once a half dozen of these interpreted 3-D bézier feature lines were produced, surfaces representing the entire data set were generated using standard 3-D surface interpolation techniques. The interpolation step produces two surfaces, the upper and lower boundaries of the troctolite unit. These two geological surfaces combined with the regional DEM surface allows for the construction of a completely enclosed geologic volume of the Kiglapait Lower Zone troctolite body, which can be sliced to reveal internal geometries (Figure 2), examined for potential geologically interesting intersections or presented in a coherent 3-D perspective view.

The method outlined here is applicable to geological bodies that, for given structural domains, are behaving in a spatially continuous fashion. It is most applicable in situations in which orientation of specific structural elements, such as sedimentary bedding or igneous layering, is reflective of more regional scale boundaries. For example, a single primary bedding orientation in the midst of a layered turbidite sequence commonly approaches the orientation of the enclosing upper and lower bounding surface of the unit itself. However, this may not always be the case. For instance, a subareal deposit of regional extent may have local forset bedding orientations which could display up to 20° dip and 180°

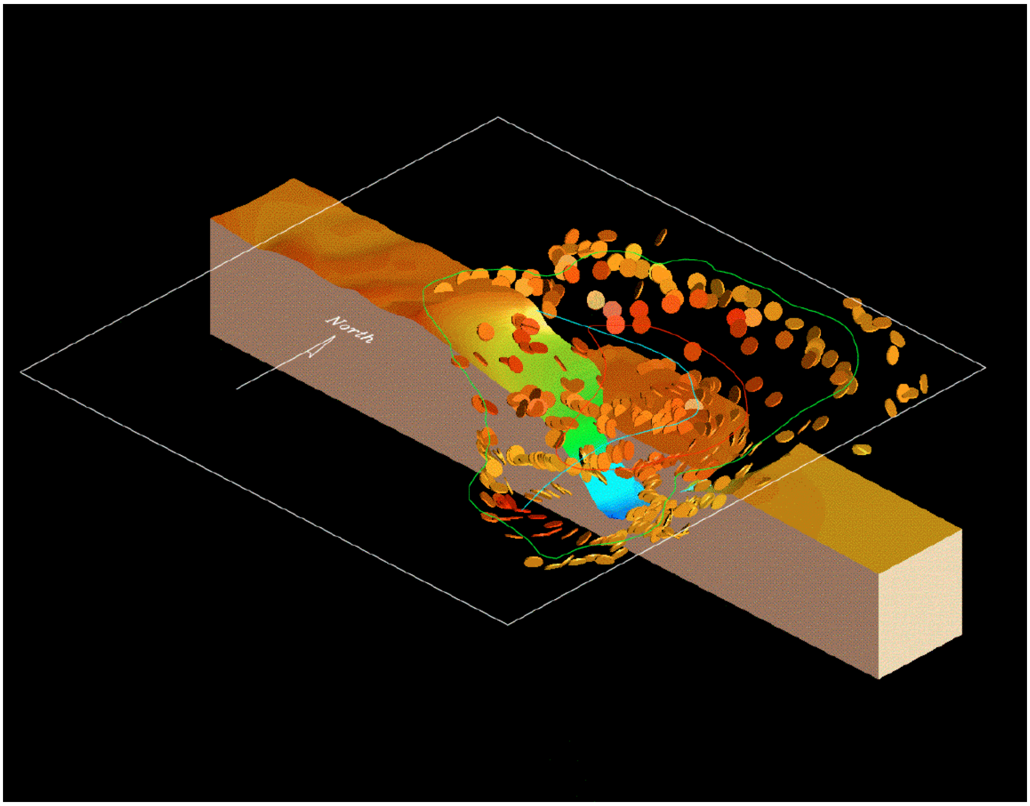

Figure 2: *Serial section of volumetric model of the Kiglapait intrusion with disk symbolization of regional igneous layering for geometric comparison. Note the overall convergence of dips towards the core of the structure.*

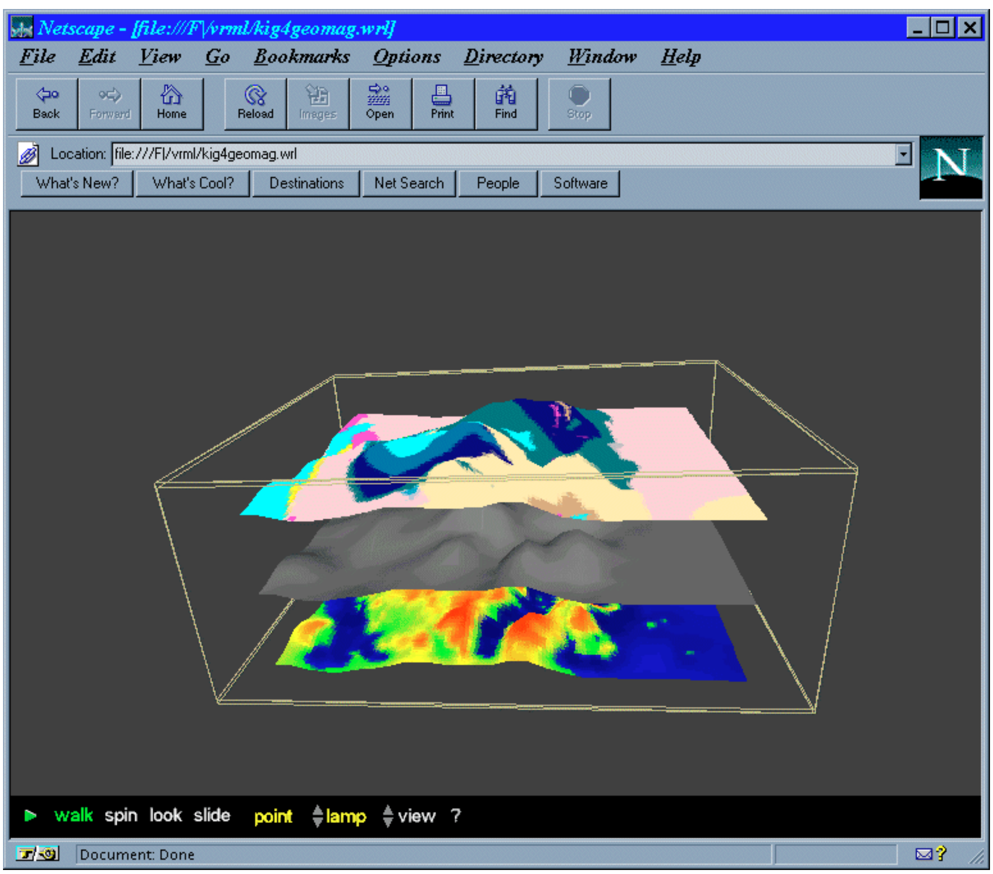

Figure 3: *A snap shot example of VRML display with geology and region total field magnetics draped over tl digital magnetic topography (DMT)*

strike variation along overlapping bounding surfaces. Geometric point observations of volcanic flow boundaries may be unrelated to the regional scale geometry of the paleotopographic surface which underlies these flows. Thus scale dependencies and the geological context of the specific surfaces to be visualized are important considerations. In addition, most geological objects at the map scale of 1:5000 to 1:250 000 are in fact not continuous, but are dissected and offset by later brittle or ductile tectonic breaks, or by truncating igneous or sedimentary boundary surfaces. For these situations, it is important to constrain the initial modelling of surfaces and geological volumes to within these discordant boundary surfaces. The collection of good geometrical field data, seismic interpretations or drill intersections for these superimposed surfaces is very important and should be undertaken first to limit what will become the reasonable extent of the detailed model.

This method could benefit from a more optimized technique for the assignment of regional structure measurements to specific geological feature traces. For example, 3-D geometric point observations could be run through a 3-D assignment operator, which has built-in spatial functions, that considers not only the distance to a specific set of observations but also the geological context of the feature being modelled. The depth trajectory and densification of geometric data points could also be made more dynamic by allowing users to more easily pick sub-surface grip points and adjust them accordingly, so as to be geometrically consistent with other constraining data sets, such as seismic, drilling or gravity data. These geological 3-D shaping tools need to evolve into truly interactive and user-friendly applications that the explorationists can use directly, so that several iterative attempts at a model can be produced without extensive preparatory data integration work. This will ultimately allow the interpreter to have a very powerful means of visualizing and presenting interpretations of the geology to colleagues, and from which specific geometrically defined targets could be selected for more detailed follow-up work.

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