3D GEOLOGICAL MAPPING IN MANITOBA – MOVING FORWARD

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1. INTRODUCTION

For almost two decades, the Manitoba Geological Survey (MGS) has been producing and working with 3D geological maps and data, stimulated by demand for groundwater and hydrocarbons, as well as a desire to broaden our knowledge of the subsurface. In doing so, the MGS has spent a considerable amount of time creating a workable infrastructure for data collection, integration and output as it relates to 3D modelling. To date, the MGS has successfully modelled over 600 000 square kilometres representing over 50 geological units. Currently, the MGS is working to complete a 3D geological model of the Phanerozoic succession in southern Manitoba, south of latitude 55°N. This model is based on waterwell, oil and stratigraphic drillhole databases, as well as bathymetric and seismic data and surface datasets such as surficial geology (Keller, et.al. 2009).

The MGS employs a modelling methodology that consists of a series of cross-sections representing a 5 km wide east-west transect across the model area. The sections contain all available data within 2.5 km either side of the line of the section; this includes a topographic profile, a Phanerozoic unit distribution map, a 'strip' of the surficial geology map representing the 5km swath, as well as drillhole location and distribution maps. The uninterpreted sections are digitally created, printed and then hand interpreted by a geologist. The data included on the sections aid the geologist in visualizing the 3D distribution of data, thus allowing an appropriate cross-section to be drawn at the midline. The interpretation is then captured as a series of points representing unit 'tops'. The points are recorded at a 5 km east-west interval along the section, and then imported and modelled. A slight modification to this methodology is being used for the current southern Manitoba model in that sections from all previous MGS 3D models have been concatenated, reinterpreted collectively and digitized. These digitized sections are directly imported into our 3D modelling software as a set of 134 sections or 'vertical maps' (Fig. 1, 2). The MGS uses the term 'vertical map' in order to bring added emphasis to our determination to integrate the methods of plan-view mapping and 3D subsurface modelling in our work.

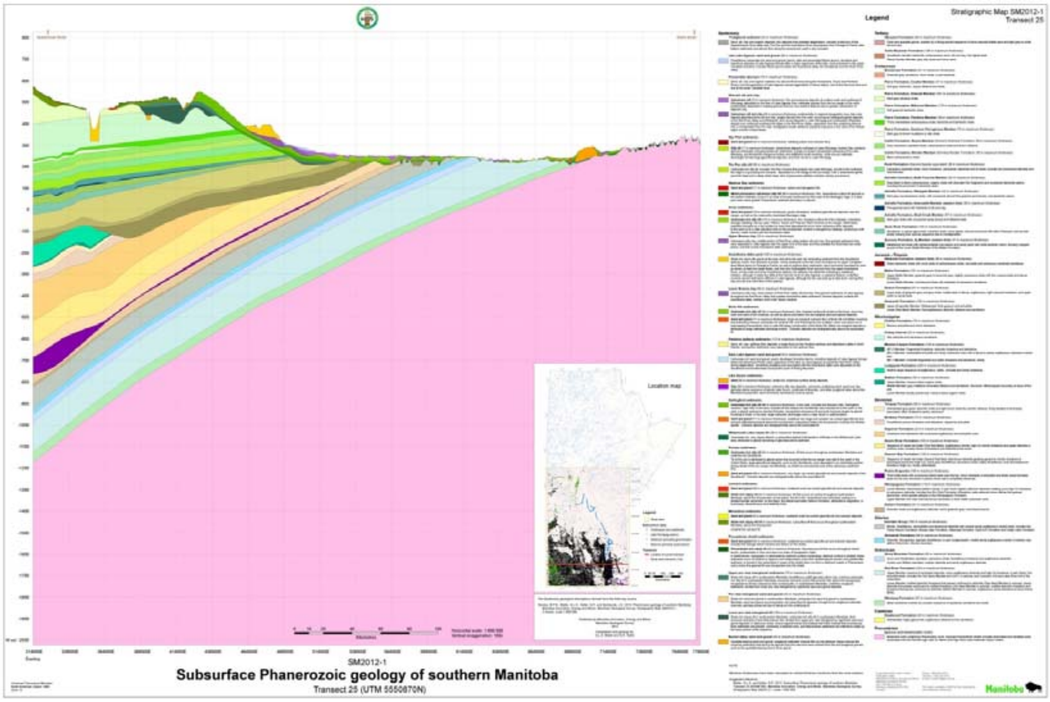

Figure 1: Transects 25 represented as vertical map (Matile and Keller, 2012).

Figure 2: Simplified 3D model vertical map legend.

2. SOUTHERN MANITOBA MODEL CONSTRUCTION

The MGS cross-section methodology is covered in detail in Keller et al. (2009). As discussed above, it was decided that southern Manitoba, as a whole, should not be modelled in increments as was done in previous projects; instead, all previously completed models were combined into one large southern Manitoba model south of 55°N. This methodology allowed us to compensate for subtle nomenclature differences from area to area and to resolve some modelling issues resulting from rock formation edges along escarpments plotting in 3D at elevations other than the projected trend of that particular formation.

Geological transects representing a 5 km wide east-west swath containing all available geological data for that area, along with hand-drawn rock and Quaternary (sediment) units from previously completed regions, have been combined into 134 province-wide georeferenced vertical maps. Hand drawn transects from all previous modelling endeavours were scanned, georeferenced and combined, in ArcGIS, along with computer generated transects containing predicted stratigraphy points (PSP's) or virtual drillholes from the TGI Williston Basin project (TGI II working group 2009). The resulting province-wide transects were digitized and stored in an ArcGIS geodatabase as a series of attributed polygons. The digitized sections depict up to 41 rock formations and 35 sediment units (Fig. 2).

The MGS is considering several methodologies for completing the 3D model of the area. One option is to model using the cross-section polygons directly. This method introduces several complexities. The cross-sections were digitized with an X coordinate representing the UTM Easting along the line of the section and a Y coordinate representing the elevation with a 150x exaggeration. Because the UTM Northing is consistent and known for each cross-section, a simple calculation ($Z = Y/150$, Y = Northing of section, $X = X$) can be used to place the sections correctly in 3D (Fig. 3). Once the sections are loaded, they must be modelled; using this method, the imported units are represented by closed polygons (a top, base and sides). Coaxing the 3D software to create a 'correct' envelope using the closed polygons is a challenge that we are still struggling with. The Southern Manitoba model is the MGS' first attempt at using polygons in the modelling process. All previous models have been constructed from a regular grid of points (5km x 5km) representing unit tops, therefore, the second option is to model using points.

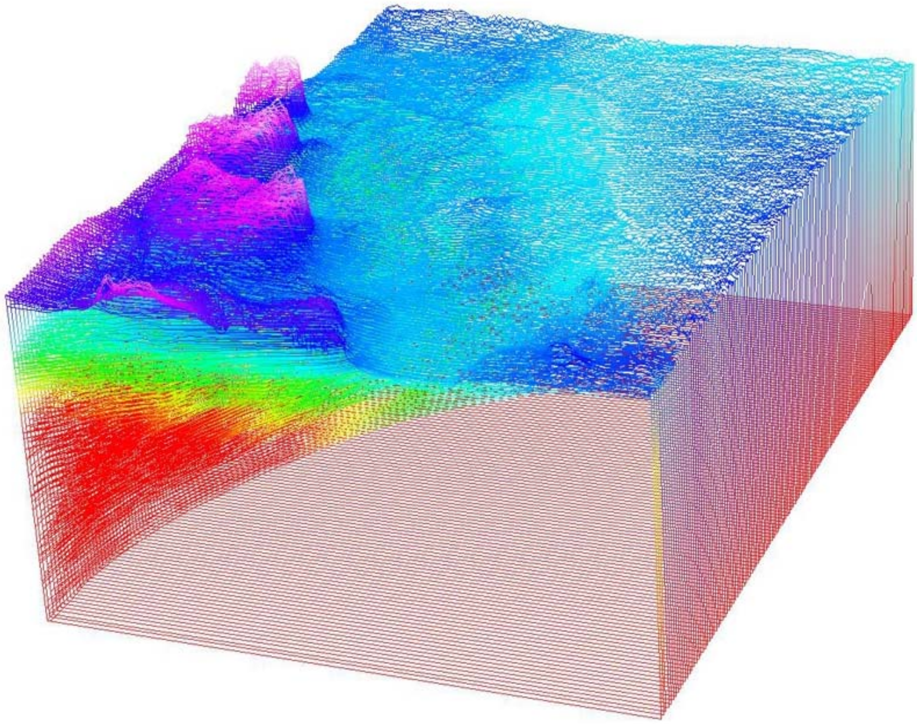

Figure 3: Cross-section polygons displayed in 3D space (150x exaggeration).

Typically, it is a fairly straightforward and simple matter to extract points from polygons in ArcGIS. In this case, it is a bit more of a complex issue. Only the points/nodes representing the top of the digitized unit are of interest. There must be a node at the beginning and terminus (unit edge) of each top as well as along the line. To manually extract these unit top points from 134 cross sections would be incredibly time consuming. To this end, we have written a custom Python script which examines each of the sections in the geodatabase. The script is written in such a manner that only the top polylines are extracted. Because we are not interested in the 'sides' of the polygons, the script also looks for nodes within the polyline that would create a segment along the line with an angle within 90° +/- a predetermined value (Fig. 4). The script then labels the nodes in the attribute table with a 'check' value enabling us to examine the flagged nodes and make a determination as to their validity. Once each section is complete, the nodes are extracted, en masse, and imported into our 3D software for modelling.

Both methodologies rely on a database of consistent unit 'edges' in order to properly model the strata, and have them 'seal' against the underlying unit. The MGS has an extensive digital database of unit edges which has been recently updated (Nicolas et al, 2010). This database of unit edges was consulted when creating the cross-sections, however some deviation was necessary in order to make 'sense' of the units when creating the vertical maps. This deviation was due to the increased availability of data when the sections were being produced. The existing unit edges must be manually modified to fit the sections in order to create the surface/solids in the 3D model. This is a tedious and time consuming process, however modelling cannot continue until this important step is complete.

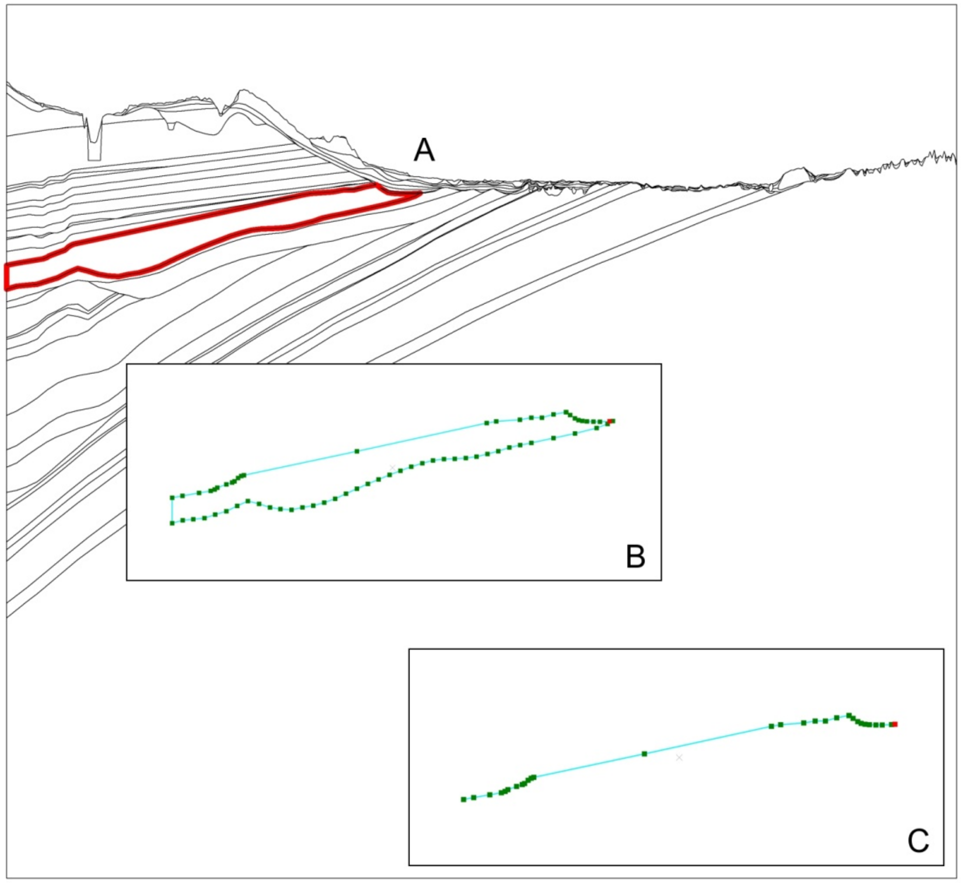

Figure 4: Effect of Python script on single unit within cross-section polygons. (A) Target polygon selected from cross-section (B) Target polygon converted from polygon to polyline (C) Nodes from 'top' surface of polyline captured.

Finally, a network of pre-glacial/Tertiary buried valley aquifers has been cut into the bedrock surface in southern Manitoba, but has yet to be systematically mapped in detail. We have recognized these channels on some of the cross-sections, but not consistently enough to map them with confidence; they are recognizable only when the channel is orthogonal to the cross-section. This presents a problem when modelling the units between sections. The MGS is experiencing a similar issue as it relates to surface water. In some cases, the channels represented on the cross-sections do not coincide with digital linework from the best available base maps. Again, it becomes difficult to model major rivers and streams between the 5km spaced sections.

3. FINAL THOUGHTS

Tremendous progress has been made in 3D mapping of southern Manitoba's Phanerozoic terrane; underlying the model is a basement map, depicting top of Precambrian. In order to produce hand-drawn cross-sections at a 5km resolution for the entire south – an area 450 x 650 km – required two decades of commitment toward this long-term objective. Huge strides were made in the first decade to carry out major drilling and geophysical campaigns, both onshore, and offshore in lakes that vary greatly in size (one of which is larger than Lake Ontario), and to assemble all data, especially drillhole databases and bathymetry. The second decade focused on model construction province-wide. Our current hurdle is to process the hand-drawn sections into satisfactory solids that will then be available for applications ranging from groundwater modelling and management to engineering design and industrial mineral planning. The following task will be to satisfactorily fill in the Phanerozoic terrane in the north, along Hudson Bay, resulting in province wide 3D mapping, into which areas of greater detail can then be nested as required.

4. REFERENCES

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