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Kinematic reconstruction of the Hastings Block, Southern New England Orogen, Australia

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SUMMARY

This research project uses 3D geological modeling software to build a 3D structural surface model of the Permo-Carboniferous rocks in the northern Hastings Block (NHB). The model is being built using comprehensive strike and dip structural data and a digital elevation model. It is designed to unravel a comprehensively mapped, complexly folded, extensively faulted geological sequence where there are no well-log data. The new 3D model will enable testing of the validity of existing tectonic models, which will assist in constraining the relative timing of fault development, testing fault emplacement of the block, and verification of the number and orientation of folding events in the NHB.

Fault-block analysis has highlighted shortcomings with the existing geological map of the NHB. Fault movement history shows early movement south of the NHB and later initial movement around the northern and northeastern margins of the NHB. Fault movement termination was probably during the Hunter-Bowen Orogeny after folding of the NHB. Preliminary 2D restoration indicated the NHB was compressed (folded) and then extensively faulted.

Key words: 3D geological modelling, NHB, Fault analysis

INTRODUCTION

The Northern Hastings Block, Southern New England Orogen (SNEO), is dominated by an open, ~ 40 x 30 km NW-trending dome with the dominant fold axis plunging gently northwest. It has been extensively faulted and rotated into its present position.

This research project uses 3D geological modeling software to build a 3D structural surface model of the Permo-Carboniferous rocks in the northern Hastings Block (NHB) (Lennox *et al.*, 1999) (Figure 1). The model is being built using comprehensive strike and dip structural data and a digital elevation model. It is designed to unravel a comprehensively mapped, complexly folded, extensively faulted geological sequence where there are no well-log data. It is believed that this new workflow will be widely applicable in the oil, gas, mining, and groundwater sectors.

Several tectonic models have been proposed to explain the structural and tectonic development of the Hastings Block which is outboard of similar Carboniferous fore-arc basin sequences in the Tamworth Belt, Australia. Mechanisms of development include emplacement either by faulting with or without rotation (Cawood and Leitch, 1985; Schmidt *et al.* 1994), or rotation during folding of the southern section of the Tamworth Belt (Cawood *et al.* 2011, Rosenbaum *et al.* 2012; Korsch and Harrington, 1987). The new 3D model will enable testing of the validity of these existing tectonic models. It will assist in constraining the relative timing of fault development, testing fault emplacement of the block, and verification of the number and orientation of folding events in the NHB.

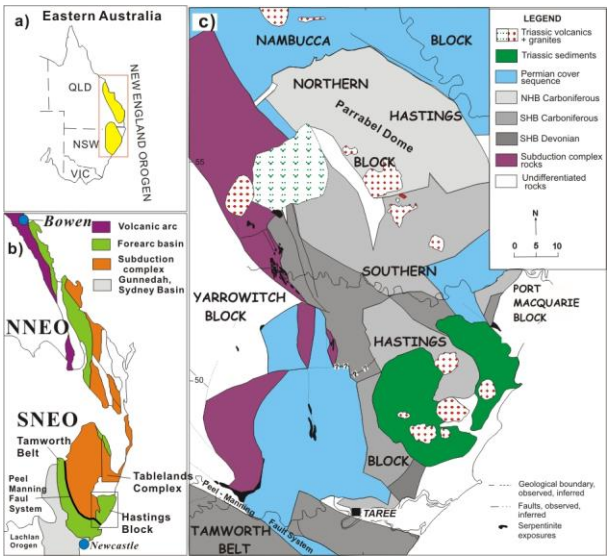

Figure 1. Location and tectonic setting of the Hastings Block (from Cawood et al. 2011 and Glen et al. 2012): (a) within eastern Australia, (b) within the southern New England Orogen (NNEO – Northern New England Orogen; SNEO - Southern New England Orogen). (c) major tectonic units and faults within and adjacent to the Hastings Block.

METHOD

Use geomodeling to restore the Northern Hastings Block where there are no well-log data. Build 3D models (backward and forward models) to test the existing tectonic models. The various steps are shown in the Figure 2.

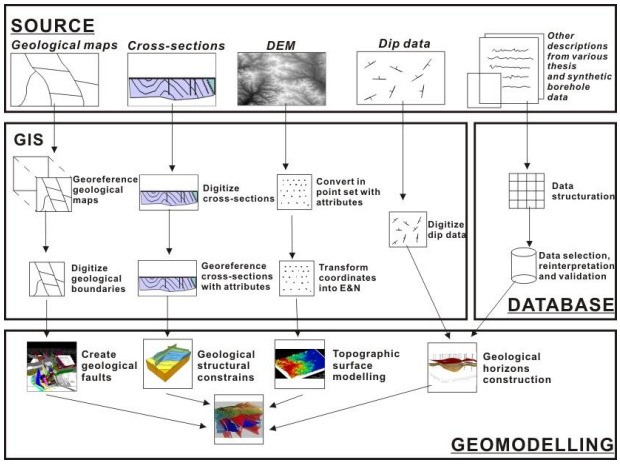

Figure 2. Methodology of the 3D structural geomodelling of Northern Hastings Block.

PRELIMINARY FAULT MODEL

This preliminary fault model was constructed using Leapfrog (www.leapfrog3d.com) and 3D MOVE (www.mve.com). At present all fault surfaces are assumed vertical (Figure 3). The inclination of the fault surfaces will be adjusted to be consistent with both the geological information available from field studies, the literature; and the need to balance geological processes over the region. Fault interrelationships, movement timing and orientions have been catalogued and analyzed to provide a preliminary fault history for use in 3D modelling.

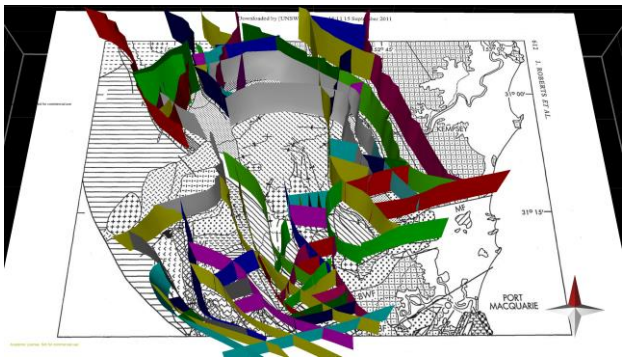

Figure 3. The preliminary 3D fault network model for the northern Hastings Block.

Preliminary conclusions from fault analysis are that faults in the blue box area between the northern and southern Hastings Block moved earlier than the faults around the margins of the northern HB in the red box (Figure 4).

FORMATIONS CONSTRUCTED

Horizons are being constructed within each individual fault-block using a combination of field mapping data and the consideration of the requirements of balanced geological sections. The horizons have been examined in each fault block to explain the folding (Figure 5).

Construction of horizons fault-block by fault-block has highlighted shortcomings with the existing geological map of the NHB (Roberts *et al*. 1995). These include the variability in the orientation of bedding within some fault blocks, between adjacent fault blocks, and around significant sections of the dome. This is clearly illustrated in the Birdwood Fault Block (Figure 5a), a fault-bounded block of Devonian-Carboniferous sequences on the SW limb of the dome that contains sequences facing northwest. In contrast, the surrounding rock sequences face northeast (Leitch E.C. pers.com. 2013) or possibly southwest (Roberts *et al.* 1995).

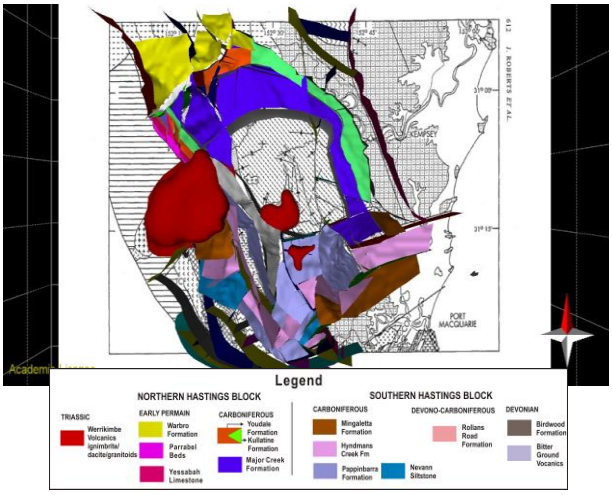

Figure 5. The 3D geological model of the northern Hastings Block showing selected geological horizons.

EMPLACEMENT OF THE BIRDWOOD FAULT BLOCK

Fault Block D was probably rotated 90° anti-clockwise from its original position if it is considered to have originally consisted of northerly-striking bedding younging to the east-northeast (Figure 6b & 6c).

Fault Block D was possibly transported into its current position by the transcurrent, sinistral movement between two bounding major faults (Pappinbarra Fault and Cowarral Fault) (Figure 6c). During this movement, the block rotated 90° anticlockwise as per the Crowell (1984) mechanism involving translation and 'porpoising'.

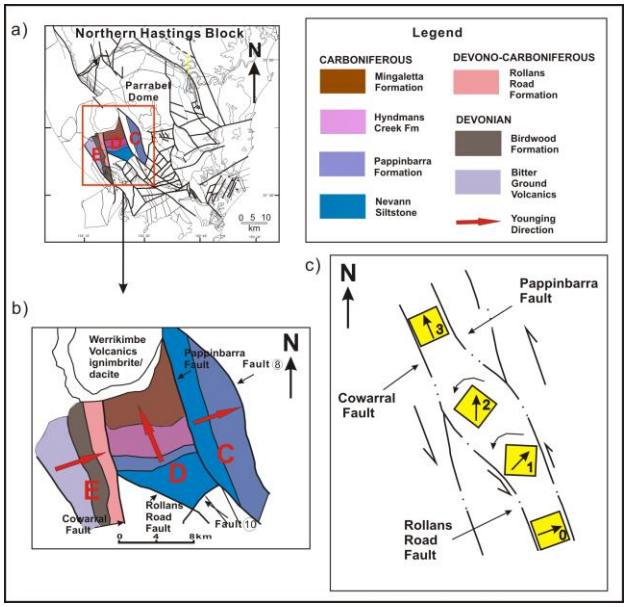

Figure 6. Location of the Birdwood Fault Block (Fault block D): (a) within Northern Hastings Block, (b) the surrounding rock sequences face east or west, whilst block D currently face north. (c) a possible model to explain how the Birdwood Fault Block experienced at least 90° rotation during it's emplacement (adapted from Crowell, 1984).

2D RESTORATION

Preliminary 2D restoration was conducted using 2D MOVE (www.mve.com) on the completed cross-sections in the Northern Hastings Block. It follows the principles of structural balance to create a model that is internally consistent and relies only on known assumptions (Figure 7).

Preliminary 2D restoration indicates the NHB was compressed (folded) firstly and then extensively faulted as found from field studies in which some folds are dissected by faults.

CONCLUSIONS

1. Fault block analysis shows that the existing geology map is partly incorrect.
2. The formation of some fault blocks can be explained using the Crowell (1984) fault model of block translation between two major bounding faults.
3. Fault movement history shows early movement south of the NHB and later initial movement around the northern and northeastern margins of the NHB. Fault movement termination was probably during the Hunter-Bowen Orogeny after folding of the NHB.
4. Preliminary 2D restoration indicated the NHB was compressed (folded) and then extensively faulted.

ACKNOWLEDGMENTS

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REFERENCES

Cawood P. A. & Leitch E. C., 1985, Accretion and dispersal tectonics of the southern New England Fold Belt, eastern Australia, Tectonostratigraphic Terranes of the Circum-Pacific Region, 1, 481-492.

Cawood, P. A., Pisarevsky, S. A and Leitch, E. C., 2011, Unraveling the New England orocline, east Gondwana accretionary margin, Tectonics, 30, TC5002, doi:10.1029/2011TC002864.

Crowell, J.C., 1984, Notes to accompany lectures on tectonics, sedimentation and structural analysis of basins, Petroleum Exploration Society of Australia, 138-142.

Glen, R.A., Roberts, J., 2012, Formation of oroclines in the New England Orogen, Eastern Australia, J. Virtual Explor, 43 (Paper 3), http://dx.doi.org/10.3809/jvirtex.2012.00305.

Korsch, R. J. & Harrington, H. J., 1987, Oroclinal bending, fragmentation and deformation of terranes in the New England Orogen, eastern Australia, Terrane Accretion and Orogenic Belts, American Geophysical Union Geodynamic Series, 19, 129-140.

Lennox, P.G., Roberts, J. & Offler, R., 1999, Structural analysis of the Hastings Terrane. In Flood, P.G. ed. New England Orogen, Eastern Australia: Regional Geology, Tectonics and Metallogenesis 115-124.

Roberts, J.R., Leitch, E.C., Lennox, P.G. & Offler, R., 1995, Devonian - Carboniferous Stratigraphy of the Southern Hastings Block, eastern Australia, Australian Journal of Earth Sciences 42, 609-634.

Rosenbaum, G., Li, P. and Rubatto, D., 2012, The contorted New England Orogen (eastern Australia): new evidence from U–Pb geochronology of early Permian granitoids, Tectonics, 31, http://dx.doi.org/10.1029/2011tc002960 (TC1006).

Schmidt, P.W., Aubourg, C., Lennox, P.G. & Roberts, J., 1994, Palaeomagnetism and tectonic rotation of the Hastings Terrane, eastern Australia, Australian Journal of Earth Sciences, 41, 547-560.

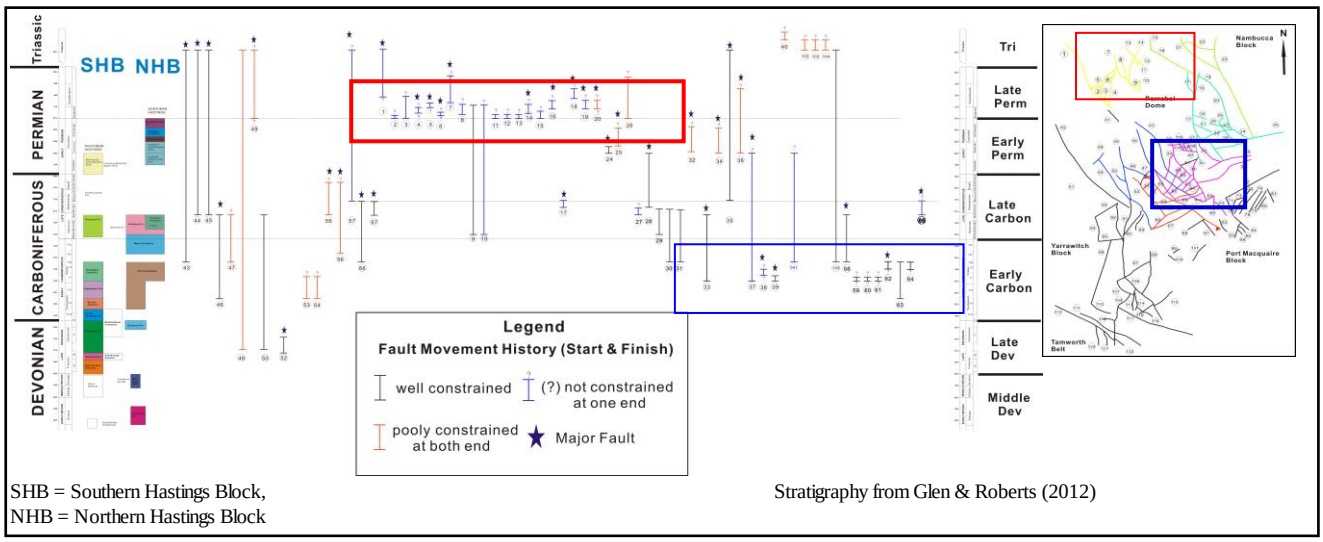

Figure 4. Fault analysis – criteria to time the movement on the faults from Bykerk-Kauffman(1989). Faults in the blue box area between the northern and southern Hastings Block moved earlier than the faults around the margins of the northern HB in the red box. The time scale and stratigraphic columns are from Glen & Roberts (2012).

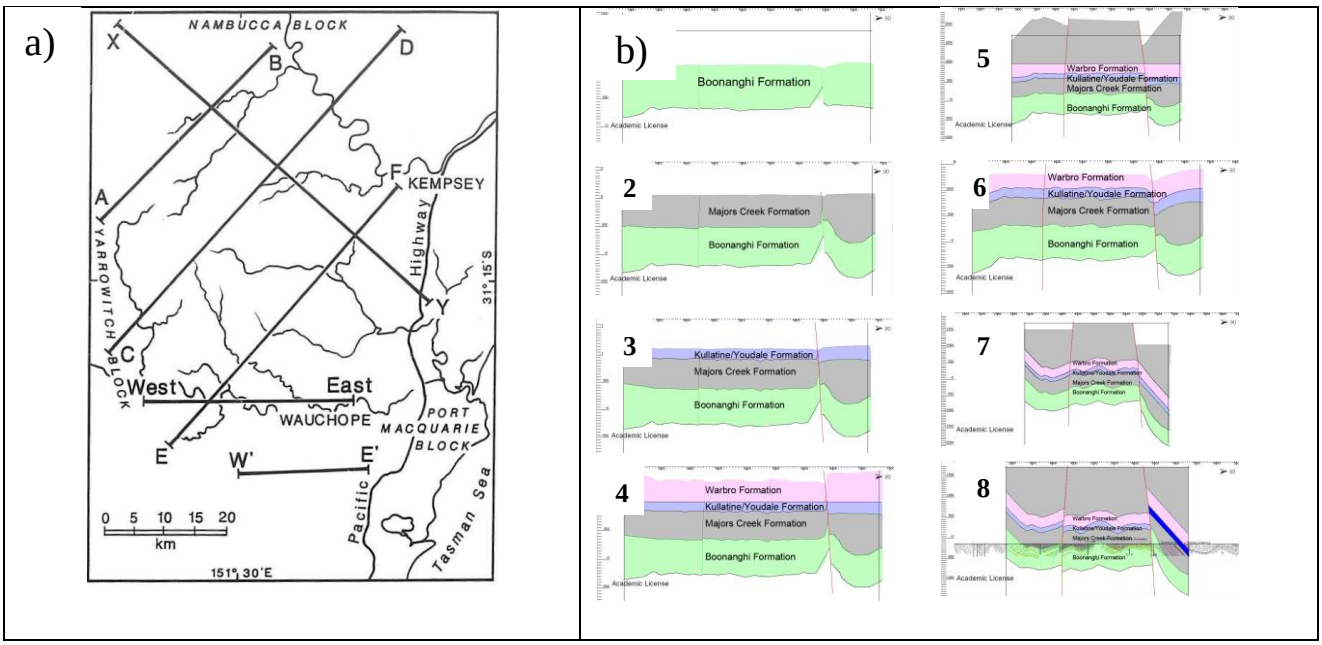

Figure 7. 2D restoration of one cross-section CD in the Northern Hastings Block. a) Location of the cross section CD in the NHB. b) 2Dresoration of CD indicates that the NHB was compressed (folded) firstly and then extensively faulted.