Compressional evolution of the PNG margin from an orogenic transect from Juha to the Sepik

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SUMMARY

A crustal-scale, fully restored section across the PNG orogenic belt reveals the Oligocene to Recent compressional deformation of the margin. The northern end of the section comprises the Landslip Metamorphics, an accreted continental terrane, separated from the main part of the Fold Belt by the Jurassic April Ultramafics and Om Metamorphics, interleaved with Eocene volcanics which together constitute an accretionary prism. Existing maps show that the suture is overlain by distal Miocene sediments indicating Oligocene docking and probable compression prior to Early Miocene subsidence. The latter is consistent with Early Miocene extension in PNG and the emplacement of metamorphic core complexes in the Sepik area, but is also related to dynamic topography causing subsidence of the whole northern margin of Australia. Neogene compression commenced around 12 Ma with ~70km shortening in the Om terrane and ~38km shortening in the Fold Belt. Existing thermochronology data indicate shortening of ~12mm/year from 12-4 Ma, but only 2.5mm/year from 4-0 Ma, consistent with a change in structural style in the Fold Belt from thrust to more ductile, fold-dominated deformation. The model also requires substantial thickening of the continental crust beneath the Muller Ranges, here represented by 'basement' underthrusting. Gravity modelling indicates the presence of sedimentary graben up to 10 km deep beneath the Fold Belt, which were strongly inverted, such as beneath the Lavani Valley. A key issue is when this inversion occurred, in the Oligocene or Pliocene, as this has a significant influence on the timing of hydrocarbon generation and migration.

Key words; PNG, tectonics, balanced cross section

INTRODUCTION

The island of New Guinea straddles a complex zone of microplates between the Indo-Australian and Pacific plates (Pigram & Davies, 1987). It has broadly been divided into a northern zone of accreted terranes, a central Mobile Belt comprising igneous, metamorphic, distal sedimentary rocks and ophiolites, and a southern Fold Belt and Platform which were the northern margin of the Australian continent prior to Tertiary arc-continent collision (Dow 1977; Hill & Hall 2003). A key issue is the timing and nature of terrane accretion relative to the main period of orogenesis. It is well known that the main compression in the Mobile Belt and Fold Belt occurred in the Late Miocene to Pliocene as Middle to Late Miocene carbonates and volcanogenic sediments are deformed. Furthermore, apatite fission track data record Late Miocene to Pliocene cooling due to uplift and erosion (Hill & Raza 1999). However, ophiolite accretion is thought to have occurred in the Eocene to Oligocene, either along the New Guinea margin or remotely in a terrane that subsequently accreted to New Guinea in the Miocene (Davies & Jaques 1984; Pigram & Davies 1987; Baldwin et al 2012).

This study focuses on an area of western Papua New Guinea (Figure 1) previously mapped by Davies (1983) and Davies & Hutchison (1982) with considerable recent work due to gas and mineral exploration (eg. Hanani et al, 2016; Crowhurst et al 1997). A regional transect has been constructed across the Fold Belt, the Om sediments and Metamorphics, the April Ultramafics and the Landslip Terrane (Figure 1). The Fold Belt comprises deformed Jurassic to Miocene shelfal sediments on Triassic granitic basement and continental crust. A key issue is the relatively small amount of shortening recorded to create structures with many kms of relief. The Om Belt comprises thick and highly deformed distal Cretaceous and Jurassic sediments that are metamorphosed in the north. The timing of deformation is poorly constrained. The April Ultramafics comprise interleaved thrust slivers of Jurassic ophiolite and Eocene volcanogenic sediments (Davies & Hutchison, 1984) in part thrusted over and into the northern Om Belt. This represents the closing suture of an old ocean (Zahirovic et al 2015). A key observation on the maps of Davies (1983) and Davies & Hutchison (1982) is that distal deep water Miocene muds and marls appear to overly the interleaved Eocene volcanics, Jurassic ophiolites of the April Ultramafics and perhaps the northern Om Beds. This suggests that the terrane had sutured, but was still submarine in the Early Miocene. The Landslip Terrane to the north comprises continental crust on the southern margin of the Sepik Terrane that collided with New Guinea. Extensive isotopic and thermochronological analysis of this area by Crowhurst et al (1996, 2004) shows Late Miocene uplift, erosion and cooling due to orogenesis, but also weak evidence of an Oligocene cooling event, similar to that found along strike by Hill & Raza (1999) and Page (1976).

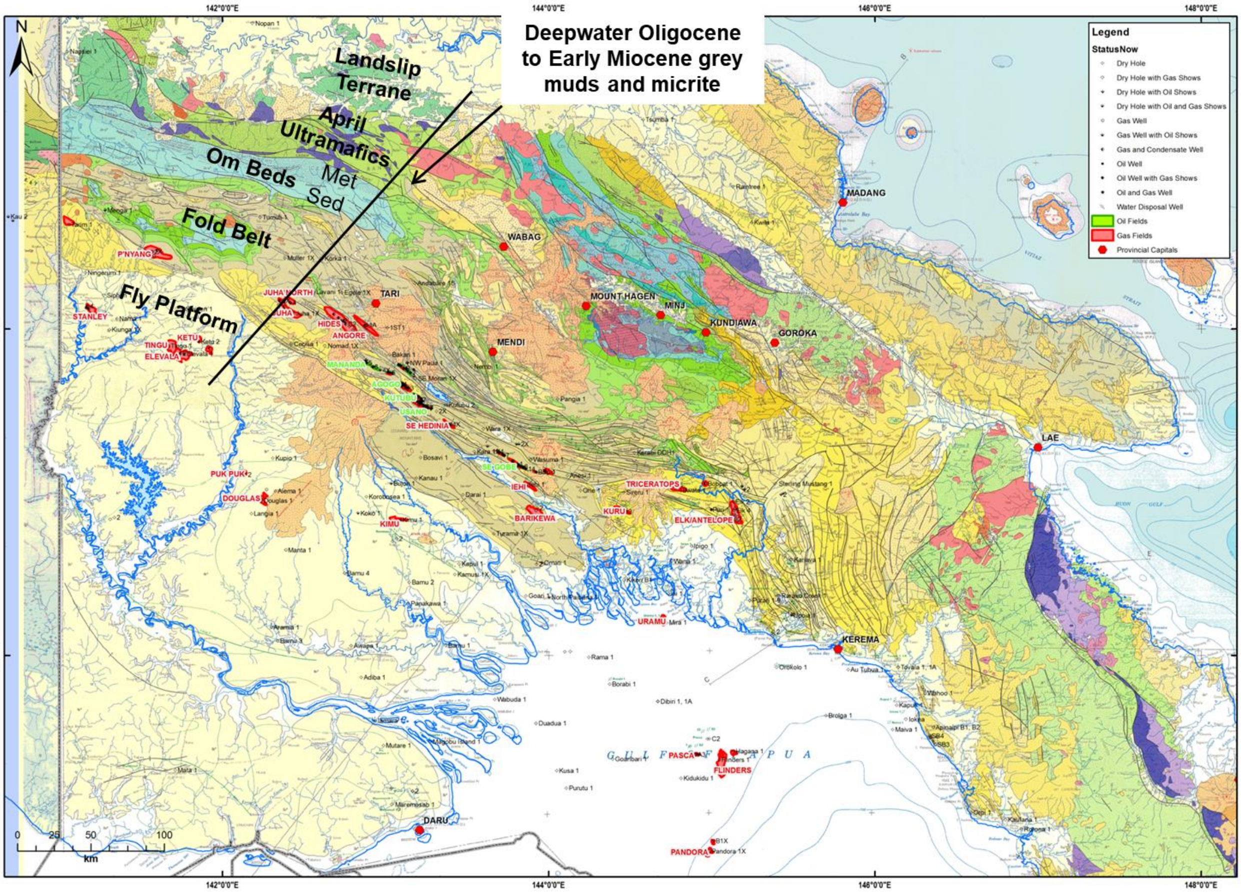

Figure 1 Location map of the regional transect in PNG, shown on the published regional PNG geology map.

METHOD

A regional transect was constructed across the Fold Belt and Om beds by Mahoney (2015) and extended in this study to pass across the April Ultramafics and Landslip Terrane. The section included all the data from the maps of Davies (1983) and Davies & Hutchison (1982) as well as all available industry seismic, well and dip data, mainly in the Fold Belt. The section was balanced and restored in Move^{TM} using standard geometrical techniques. To restore the northern area a model for the pre-compression architecture of the margin was required so a regional section from the coast to oceanic crust across the Otway Basin was used (Palmowski et al 2004). Once the section was incrementally restored back to its inferred Early Miocene geometry, it was forward modelled, but this time using full crustal thicknesses to show crustal thickening and related isostatic uplift. The timing of the fault propagation, deformation and uplift was strongly constrained by fission track and U/Th/He thermochronology.

RESULTS AND CONCLUSIONS

It is inferred that in the Early Tertiary, the Sepik Terrane was distant from New Guinea and separated by oceanic crust that was consumed along a subduction zone dipping to the north beneath the terrane (Zahirovic et al 2015). This gave rise to Eocene arc volcanics that became interleaved with ophiolite slivers in an accretionary prism. This terrane sutured to the New Guinea margin in the Late Eocene to Oligocene, perhaps with uplift and erosion giving rise to nebulous Oligocene cooling ages (Page 1976, Crowhurst et al 1996, Hill and Raza 1999). At that time the subduction zone switched to a more northerly location, both towards the north along the Melanesian arc and towards the south beneath the New Guinea margin. In the Early Miocene, the margin was again put into extension as suggested by metamorphic core complexes in the Sepik-Landmark terrane (Crowhurst et al 1996, 2004), leading to regional subsidence. During the Miocene thick carbonates and distal muds and marls were deposited in the south with arc-related volcanics in the north above the subduction zone. Towards the end of the Middle Miocene the Melanesian arc accreted to New Guinea above a foundering double subduction zone (eg Pegler et al 1995) causing the onset of orogenesis.

Compression commenced around 12 Ma with ~70km shortening in the Om terrane and ~38km shortening in the Fold Belt. Existing thermochronology data indicate shortening of ~12mm/year from 12-4 Ma, but only 2.5mm/year from 4-0 Ma, consistent with a change in structural style in the Fold Belt from thrust to more ductile, fold-dominated deformation. The model also requires substantial thickening of the continental crust beneath the Muller Ranges, here represented by 'basement' underthrusting. Gravity modelling indicates the presence of sedimentary graben up to 10 km deep beneath the Fold Belt, which were strongly inverted, such as beneath the Lavani Valley. A key issue is when this inversion occurred, in the Oligocene or Pliocene, as this has a significant influence on the timing of hydrocarbon generation and migration.

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REFERENCES

Baldwin, S.L., Fitzgerald, P.G. & Webb, L.E., 2012. Tectonics of the New Guinea Region. Annual Review of Earth and Planetary Sciences 40, 495-520.

Crowhurst, P.V., Hill, K.C., Foster, D.A. & Bennett, A.P., 1996. Thermochronological and Geochemical Constraints on the Tectonic Evolution of Northern Papua New Guinea. in Hall, R. (ed) Tectonic Evolution of SE Asia. Geological Society of London Special Publication No. 106, 525-537.

Crowhurst, P.V., Maas, R., Hill, K.C., Foster, D.A. & Fanning, C.M., 2004. Isotopic constraints on crustal architecture and Permo-Triassic tectonics in New Guinea: possible links with eastern Australia. Australian Journal of Earth Science, v. 51, 107-122.

Crowhurst, P.V., Hill, K.C. & Foster, D.A., 1997. The structural and tectonic development of the Frieda River Mineral district, NW Papua New Guinea. In: Hancock, G.E. ed. Proceedings of the PNG Geology, Exploration and Mining Conference, 1997 Madang, pp. 51-60. Australian Institute of Mining and Metallurgy, Melbourne.

Davies, H.L., 1983, Wabag 1:250,000 geological map and explanatory notes, sheet SB/54-4. Department of Minerals and Energy, Papuan New Guinea.

Davies, H.L. & Hutchison, D.S., 1982. Ambunti 1:250,000 geological map and explanatory notes, sheet SB/54-4. Department of Minerals and Energy, Geological Survey of Papua New Guinea.

Davies, H.L. & Jaques, A.L., 1984. Emplacement of ophiolite on Papua New Guinea. In: GASS, I. G., LIPPARD, S. J. & SHELTON, A. W. eds. Ophiolites and Oceanic Lithosphere, pp. 341-349. Special Publication of the Geological Society of London, 14.

Dow, D.B., 1977, Geological synthesis of Papua New Guinea. Bureau of Mineral Resources, Geology and Geophysics Bulletin 201, 41 pp.

Hanani, A, Lennox, P. and Hill, K., 2016. The geology and structural style of the Juha gas field, Papua New Guinea. ASEG Extended Abstracts Vol 2016 No. 1, 25th International Conference and Exhibition – Interpreting the Past, Discovering the Future. 7 pages http://www.publish.csiro.au/nid/268/issue/8691.htm.

Hill, K.C. & Hall, R., 2003. Mesozoic-Cenozoic evolution of Australia's New Guinea margin in a west Pacific context. In: Hillis R.R. & Muller R.D. eds. Evolution and Dynamics of the Australian Plate, pp. 265-290. Geological Society of Australia Special Publication 22 and Geological Society of America Special Paper 372.

Hill, K.C. & Raza, A., 1999. Arc-continent collision in Papua Guinea: Constraints from fission track thermochronology. *Tectonics* 18, 950-966.

Mahoney, L. 2015. Regional scale structural modelling along a geological transect: insights from the NW Fold and Thrust Belt, PNG, - Extended Abstract, AAPG International Conference and Exhibition, Melbourne, Australia Sep 2015.

Page, R.W., 1976. Geochronology of igneous and metamorphic rocks in the New Guinea Highlands. Australian Bureau of Mineral Resources, Geology and Geophysics Bulletin 162, 117pp.

Palmowski, D., Hill, K.C. & Hoffman, N., 2004. Structural-Stratigraphic Styles and Evolution of the Offshore Otway Basin – A seismic-structural comparison between East and West. Eastern Australasian Basins Symposium II, 75-96.

Pegler, G., Das, S. & Woodhouse, J.H., 1995. A seismological study of the eastern New Guinea and the western Solomon Sea regions and its tectonic implications. Geophysical Journal International 122, 961-981.

Pigram, C.J. & Davies, H.L., 1987. Terranes and the accretion history of the New Guinea orogen. BMR Journal of Australian Geology and Geophysics 10, 193-212.

Zahirovic, S., Flament, N., Müller, R.D., Seton, M., Hill, K. & Gurnis, M., 2015; 3D plate tectonic reconstructions of New Guinea since the Triassic. - Extended Abstract, AAPG International Conference and Exhibition, Melbourne, Australia Sep 2015.