The Thermal History of the Bowen - Gunnedah - Sydney Basins

by

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INTRODUCTION

The Bowen - Gunnedah - Sydney Basins formed a contiguous depositional system during the Permian, which now extends in a 50 to 100km wide strip from 21° S to 35° S. It is generally considered to have been accumulated in a back arc setting, with active subduction occurring some distance to the east. (Murray,1982) Although the thickness and type of sedimentation varies markedly during the accumulation of the Permian sequence, a common feature is the presence of coal seams, particularly in the Late Permian, when coal measures were found over the whole area. The basins all lie on the boundary between Palaeozoic deposits of the Lachlan Fold Belt (and equivalent aged units) to the west, and the New England Fold Belt to the east, which is characterised by extensive Permian and Triassic igneous rocks.

The area of Permian sediments and volcanics is subdivided into numerous subbasins, troughs, structural highs, ridges, and shelves (Hammond, 1987; Tadroz, 1982; Lohe and McLennan, 1991). Morphotectonic and structural units have been identified on the basis of basement characteristics and the structural deformation style present in the Permian. These morphotectonic units generally have distinctive thermal histories based on variations in subsidence, heat flow and intrusives, and structural history.

The thermal maturity of the Late Permian coal measures has been compiled in Figure 1, using published data (Beeston, 1986; Diessel, 1975; Middleton, 1983; Exon, 1974: Shiboaka *et al.,* 1973), as this stratigraphic horizon is widespread, and considerable information available.

From north to south, subdivisions of the basins considered are: north Bowen Basin, central Bowen Basin, southern Bowen Basin and beneath the Surat Basin, Gunnedah Basin, north Sydney Basin (Hunter Valley) and the central/southern Sydney Basin. The eastern boundary is delineated by major thrusts which impinge onto the basins in different ways along the margin. Maximum sediment accumulation has usually occurred in north - south oriented troughs along this eastern margin. West of these troughs are structural highs (platforms, shelves, ridges) which have been tectonically less active. In places these more stable platforms have been cut by north - south grabens (Denison Trough, Gilgandra Trough) which were formed as early Permian rift basins within a more stable basement platform. The grabens are overlain by late early Permian platform sediments.

Thermal maturity zones as indicated by vitrinite reflectance and in some areas by fisson track studies (Marshallsea, 1988) and geochemistry (Bai *et al.*, 1990, Eadington et *al.*, 1991) Along the western margin extending from central Bowen Basin to the northern Sydney Basin (Hunter Valley) the vitrinite reflectance ranges from 0.5 to 0.1. Sediments are laid down on stable platforms or over early Permian rift sequences, and are relatively undisturbed tectonically. The thermal history has been controlled by burial by sediments of the Permo-Triassic Bowen - Gunnedah - Sydney basins only.

MAJOR STRUCTURAL SUBDIVISIONS OF THE BASIN

Northern Bowen Basin

The area north of Peak Downs which takes in the Nebo Synclinorium has a distinctive thermal overprint associated with early Cretaceous igneous intrusions. The centre of this event is just north of the main Bowen to Clermont highway, on the eastern side of the basin, where vitrinite reflectance as high as 3.4 (K. O'Reilly, pers. comm.) is found.

The Central Bowen Basin

The eastern edge of the basin in this area is complex structurally, with large thrust sheets displacing basin sediments and basement westwards over the deepest part of the Permian basin. Vitrinite reflectance are up to 2.6 in this area, but the rank distribution patterns are clearly associated with the thrusting. The ranks are comparable to those expected in the Mimosa syncline directly to the south, but the timing of the maximum temperature has not yet been determined. Stratigraphic considerations favour the maximum rank to have been generated here in the middle to late Triassic, during development of the thrust sheets. To the west on the stable blocks of the Comet Ridge, the vitrinite reflectance quickly drops to levels which could have been generated by the Permo-Triassic sequence of the Bowen Basin alone. In the east 1-2 km of erosion is required to match predicted and observed maturity. (Mallett *et al.*, 1991)

Southern Bowen Basin, and extension under the Surat Basin

Here, burial by Mesozoic basins have raised the rank of coals to their highest levels in the Jurassic. In the Mimosa syncline and its extension south to the border region the Late Permian coal measures at the deepest sections of the Mimosa Syncline have not been tested, but analyses based on boreholes in the flanks of the syncline and depths projections from seismic traverses, suggest that vitrinite reflectance could reach levels up to 2.6.

Gunnedah Basin

The rank of the Late Permian coal increases towards the east and the boundary thrusts, as generally occurs throughout the basins. The level of maturity is relatively low and comparable to sequences on the western edge of the central and southern Bowen Basin. (Middleton, 1983)

Northern Sydney Basin

Although the thickest sequence of Sydney Basin sediments have accumulated adjacent to the Hunter Thrust, the Late Permian coal measures have ranks typical of stable platforms along the western edge of the Permian Basins. Values increase slightly close to the thrust. Modelling of bores near the thrust show that very thick sequences have been eroded to derive present land surfaces (3 km), which is the largest erosion required anywhere in the basins (Middleton and Schmidt, 1982). This might be related to overthrusting and burial along the thrust system.

Central and Southern Sydney Basin

The Sydney Basin shows maximum ranks in the Late Permian centred around Sydney. Analyses of boreholes indicate that burial by 1-2 km of sediments which are now eroded, is required to match modelled reflectivity profiles with those observed. As these thicknesses are less than those required in the southern Hunter Valley, it suggests that the elevated thermal maturity is the result of higher heat flows centred on the coast around Sydney, rather than burial by a sedimentary sequence now eroded away. The Sydney Basin has been affected by the opening of the Tasman sea, with associated uplift and higher heat flows approximately 80-64 Ma B.P. (Shaw 1978). The present surface vitrinite reflectance maximum is close to, but displaced from the highest values in the Late Permian coal measures. Magnetic overprinting has been generated by the thermal event, but it has not been possible to discriminate the Early Jurassic and Middle Cretaceous pole positions, both of which are possible times for the heating (Schmidt, 1990).

There is a complex interaction of processes responsible for the thermal maturity now seen in the Bowen - Gunnedah - Sydney Basins which include basin subsidence and burial, tectonic thickening of overlying strata with thrusting, and localised heat flow increases. The relative effects of these mechanisms can usually be separated by modelling maturity profiles, but is the cases of potential tectonic burial, further evidence on relative timing of events is required to discriminate mechanisms.

References:

Beeston, J.W., 1986. Coal rank variation in the Bowen Basin, Queensland. **International Journal of Coal Geology, 6,** 163-179.

Bai, G.P., Hamilton, P.J., Eadington, P.J., & Keene, J., 1990. Isotopic and fluid inclusion studies of fluid flow history in the Narrabeen

Sandstone. **Proceedings 24th Newcastle Symposium on Advances in the study of the Sydney Basin, Newcastle, March 1990, Department of Geology, University of Newcastle, Publication No. 344.** 80-85.

Diessel, C.F.K., 1975. Coalification trends in the Sydney Basin, New South Wales. in: Campbell, K.S.W. (Ed.) **Gondwana Geology,** papers presented at the 3rd Gondwana Symposium, Canberra, 1973. ANU Press, Canberra. 295-309.

Eadington, P.J., Hamilton, P.J., & Bai, G.P., 1991. Fluid history analysis - A new concept for prospect evaluation. **APEA Journal 31,** 131-142.

Exon, N.F., 1974. The geological evolution of the southern Taroom Trough and the overlying Surat Basin. **APEA Journal 14,** 50-58.

Hammond, R.L. 1987: The Bowen Basin, Queensland Australia: an upper crustal extension model for its early history. 16th BMR Research Symposium, **Bureau of Mineral Resources Geology and Geophysics Record 1987/51,** 131-139.

Lohe, E., & McLennan, T.P.T., 1991. An overview of the structural fabric of the Sydney Basin and a comparison with the Bowen Basin. **Proceeding 25th Newcastle Symposium on Advances in the Study of the Sydney Basin, Newcastle, April 1991, Department of Geology, University of Newcastle, Publication No. 413,** 12-21.

Mallett, C.W., Russell, N.& McLennan, T.P.T., 1990. Thermal history of the Bowen Basin. **Bowen Basin Symposium, Mackay, September 1991,** Geological Society of Australia Inc., Queensland Division, Brisbane, 15-20.

Marshallsea, S.J., 1988. The thermal history of the Bowen Basin (Qld), an apatite fisson track study. PhD thesis, University of Melbourne, October 1988, 291pp (plus appendices).

Middleton, M.F., 1983. Coal rank trends in Eastern Australian Permian coal basins. **CSIRO Division of Fossil Fuels, Investigation Report 141,** North Ryde, Australia, 26pp plus tables, figures, maps.

Middleton, M.F. & Schmidt, P.W. 1982. Palaeothermometry of the Sydney Basin. **Journal Geophysical Research 87 (B7),** 5351-5357.

Murray, C.G., 1983: Permian geology of Queensland. In, **Proc. Permian geology of Queensland Symposium, Geology Society Australia, Queensland Division, Brisbane.** 1-32.

Schmidt, P.W., 1990. An attempt to determine uplift of the Sydney Basin, New South Wales, Australia, from the palaeomagnetic signatures of dyke contacts from Kiana. in: Parker, Richmond & Tucker (Eds) **Mafic dykes and emplacement mechanisms.** Balkema, Rotterdam, 263-271.

Shaw, R.D. 1978. Seafloor spreading in the Tasman Sea: a Lord Howe Rise - eastern Australia reconstruction. **ASEG Bulletin 9,** 75-81.

Shiboaka, M., Bennett, A.J.R., & Gould, K.W. 1973. Diagenesis of organic matter and occurrence of hydrocarbons in some sedimentary basins. **APEA Journal 23(1),** 73-80.

Tadroz, N.Z. 1980. Structural subdivision of the Gunnedah Basin. **NSW Geological Survey Quarterly Notes 73,** 1-20.

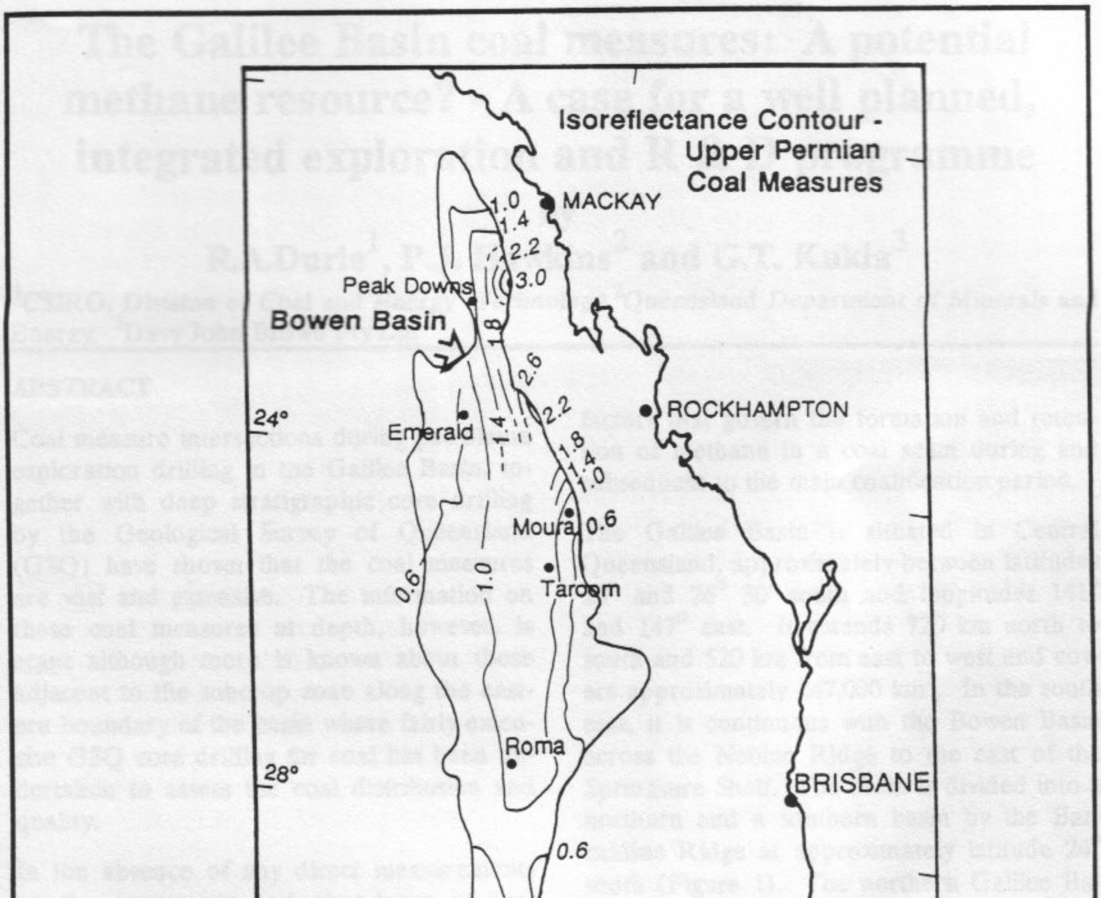

Figure 1. **Thermal maturity of the Late Permian coal measures in the Bowen-Gunnedah-Sydney Basins, indicated by vitrinite reflectance.**