Diagenetic and burial history of Upper Carboniferous sandstone, Sydney Basin

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During its working life, the Phalen Colliery near New Waterford experienced natural gas outbursts from the Phalen Sandstone in the colliery roof. The sandstone is up to 30 m thick, with ~15 m of relief on its base, and was deposited from braided channels within a paleovalley. We studied the diagenetic history of this tight gas reservoir in the context of its basinal history, based on >200 core samples from the Phalen and Prince collieries and samples from elsewhere in the basin.

Sandstone porosity is secondary and ranges from 1 to 22%, average 7%, with 6% average for Phalen samples and 15% average for Prince samples. Permeability ranges from <0.01 to 42.5 md, average 0.8 md, with 0.2 md average for Phalen samples and 9.82 md average for Prince samples. Earliest diagenesis in soils and the shallow subsurface generated: reworked mud aggregates; nodules of calcite, siderite, chert and phosphate; grains of Al-rich glaucony; and pyrite cubes and framboids. Glaucony and abundant pyrite suggest local marine waters. At greater depth, euhedral overgrowths formed on quartz grains, and poikilotopic calcite cement occluded most primary porosity. "Floating" grain textures indicate that cementation predated much compaction.

Dissolution of perthitic K-feldspar at near-maximum burial depths generated most of the secondary porosity. Albite lamellae and veins ($An_{<5}$) in many perthitic grains may have formed by alteration within the parent intrusion (deuteric) or during deep burial. Skeletal feldspar grains contain ankerite rhombs, and tiny sphalerite, galena, barite, and siderite crystals. Chlorite at deeper stratigraphic levels probably formed during maximal burial. The Phalen Sandstone contains brine, with up to 176,000 mg/L salinity. The brine probably originated as residual, evaporative fluid during precipitation of Windsor salt, and entered the strata during deep burial.

In Prince Colliery sandstone at ~200-330 m below sea level, calcite cement and, probably, feldspar have been dissolved, resulting in virtual collapse of the rock framework. Many pores contain neoformed kaolinite, illite, quartz, and siderite, indicating that dissolution took place long before present. Dissolution reflects near-surface aggressive fluid — Prince formation fluid is low-salinity and Phalen sandstone at greater depth (~400-700 m) has not undergone dissolution. There is little indication that corrosive fluid from maturing coal and organic-rich shale created secondary porosity within the basin.

Apatite fission-track analysis suggests that burial temperatures exceeded 125°C — probably >160°C if much of the chlorite is diagenetic. Maximum burial depths were attained during the Permo-Triassic, when hydrocarbons probably entered the Phalen sandstone. Sydney Basin strata were at surface by the Early Cretaceous and within reach of aggressive surficial fluids thereafter.