The Liard Basin Manetoe Dolomite: A New Look at a Frontier Deep Gas Play

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INTRODUCTION

Recent discoveries in 1999 of large gas reserves in the Manetoe Dolomite within the Liard Basin (Fig. 1) has led to a strong resurgence in exploration interest for this region. The recent discoveries at the P-66A, the K-29 and the M-25 wells, all occur within the Manetoe Dolomite, a product of diagenetic hydrothermal dolomitization of limestones of the Nahanni and Headless formations in the Liard region (Fig. 2). These recent discoveries at the Ranger P66A well and at the Chevron K-29 and M-25 wells with their very high initial absolute open flow (AOF) rates bear strong similarities to the early discovery wells at the Beaver River, Pointed Mountain and Kotaneelee Gas Fields. In all these older fields high initial production rates were followed by rapid decline and water invasion of the reservoirs.

FACTORS CONTROLLING WATER INFLUX

Davidson and Snowdon (1978) attributed this water invasion to an influx of water into a “two-porosity” gas reservoir system in which vuggy carbonates contain numerous vertical and horizontal fractures. Core from the Beaver River Gas Field contains numerous fractures. Production of gas from the more open fracture system was accompanied by water influx from the underlying Middle Devonian confined high pressure aquifer system that sealed gas in less well-connected vuggy Nahanni carbonates.

The rapidity of this differential water influx is due primarily two factors. First is the pressure drive of the water influx. The water pressure at the gas-water contacts (Fig. 3) in these gas fields is a function of the difference in elevation between the Middle Devonian aquifer potentiometric surface and the elevations at the gas-water contacts themselves. Figure 3 shows that this difference in elevations is greatest (about 13400 feet) at the Beaver River and Kotaneelee gas fields and somewhat less (about 12100 feet) at the Pointed Mountain field. The Nahanni top at the Chevron et al. Liard K-29 well is at an elevation of 6756 feet subsea. If a gas column similar to that at Pointed Mountain exists at the K-29 well then the gas-water contact is at about 8200 feet subsea (Fig. 3). The elevation of the aquifer potentiometric surface at K-29 is about 1000 feet (Ward, 1994) for a difference in elevation with respect to the gas-water contact of about 9200 feet, or considerably less than at the older fields. This is favourable for a longer production period at K-29.

The second factor that determines the rapidity of water influx into a gas field is the porosity-permeability distribution of the reservoir. Porosity and permeability distributions are functions of overall rock lithology, which is the result of its sedimentary and diagenetic history and also of the frequency, orientation and size of contained fractures.

FACTORS INFLUENCING POROSITY-PERMEABILITY IN CORES

Several cores from the Pointed Mountain, Kotaneelee fields and from the Chevron et al Liard M-25 well, a step-out well near the K-29 discovery well, will be compared to illustrate the evolution of porosity and permeability in these gas reservoirs. The Manetoe Dolomite is a post-lithification replacement of low-porosity open marine shelf lime mudstones and wackestones of the Nahanni Formation (Morrow and Potter, 1998). Porous stromatoporoidal patch reefs occur at the top of dolomitized Nahanni in some gas fields (Fig. 4). Zones of tightly cemented dolomitized mosaic and rubble breccia occur infrequently. Cores display evidence of at least one solution excavation event that either postdate or were contemporaneous with, emplacement of the Manetoe Dolomite. Solution cavities formed during this event may have been contemporaneous with Manetoe hydrothermal dolomitization and may in fact be a hydrothermal karst event. Similar geopetal fabrics have been observed in surface exposures of the Manetoe Dolomite. There, fossil hydrothermal Manetoe Dolomite masses several kilometres broad are encased within non-porous Nahanni-Headless limestone. This suggests that solution-excavation of these limestones was contemporaneous with dolomitization.

Movement of hydrocarbons into Manetoe Dolomite reservoirs postdates Manetoe hydrothermal dolomitization. Reservoir bitumens that completely occlude pre-bitumen macroporosity of the Manetoe Dolomite, particularly in the Kotaneelee E-37 well, may represent the products of the thermal cracking of oil to gas in pre-existing oil pools.

The present day porosities of the Manetoe Dolomite and Nahanni limestone in cores from the gas fields are consistent with depth-dependent burial porosity loss accompanied by occlusion of porosity by mineral cements (calcite and quartz) and bitumen. Additional porosity loss may have occurred from more time-dependent processes such as stylotization. Permeability, particularly vertical permeability, has been enhanced by dolomitization, except possibly in cases where pre-dolomitization porosity and permeability was high. Late stage fracture porosity is not pervasive, and, in most cores, is not present, unlike cores of the Beaver River Gas Field (Davidson and Snowdon, 1978).

Davidson, D.A. and Snowdon, D.M. 1978. Beaver River Middle Devonian carbonate: Performance review of a high-relief fractured gas reservoir with water influx; Journal of Petroleum Technology, p. 1673-1678.

Morrow, D.W. and Potter, J. 1998. Internal stratigraphy, petrography and porosity development of the Manetoe Dolomite in the region of the Pointed Mountain and Kotaneelee Gas Fields; In Oil and Gas Pools of the Western Canada Sedimentary Basin (Ed. J.R. Hogg); Canadian Society of Petroleum Geologists, Special Publication S-51, p.137-161.

Ward, G.S. 1984: hydrodynamic Evaluation of the Devonian to Precambrian Formations Liard Arch, N.W.T. (5930'-6300'N, 12100'-12500'W); Ward Hydrodynamics Ltd., 89p.

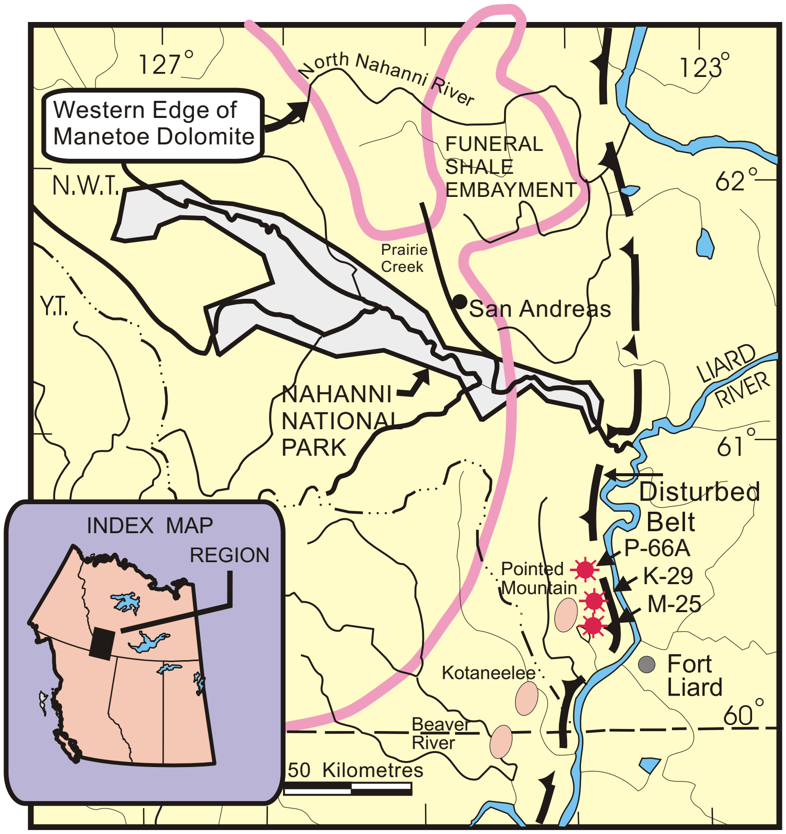

Figure 1. Location map showing the Beaver River, Kotaneelee and Pointed Mountain Gas Fields. Also shown are recent gas discoveries at the Ranger P-66A, the Chevron K-29 and the Chevron M-25 wells.

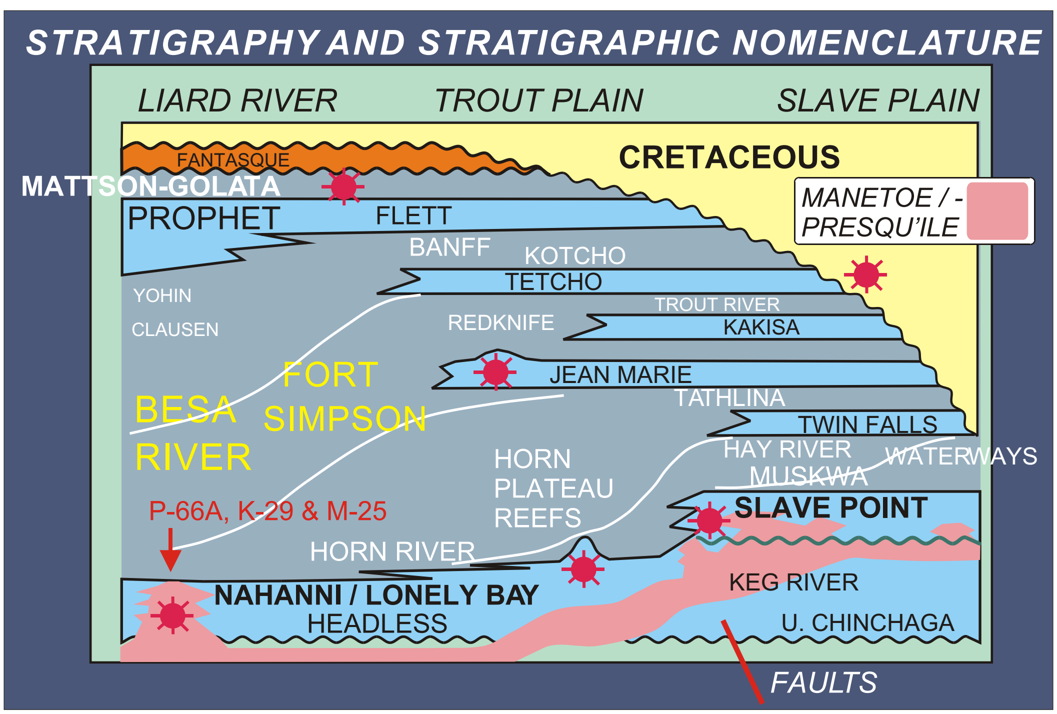

Figure 2. Stratigraphic chart of the Devonian to Cretaceous succession from the Liard region eastward across the southern interior plains. The recent discoveries at P-66A, K-29 and M-25 occur within the Manetoe Dolomite which has dolomitized limestones of the Nahanni and Headless formations.

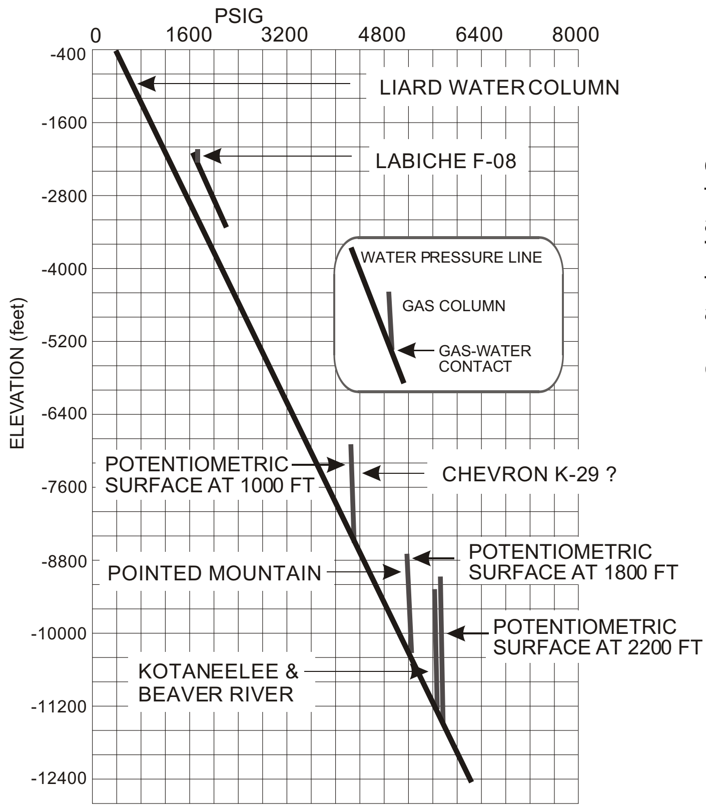

Figure 3. Pressure versus elevation graph of subsurface fluids in the Middle Devonian aquifer (after Ward, 1994). The potentiometric surface of this aquifer is over 2000 feet above sea level at Beaver River but is lower at the Chevron K-29 and M25 wells.

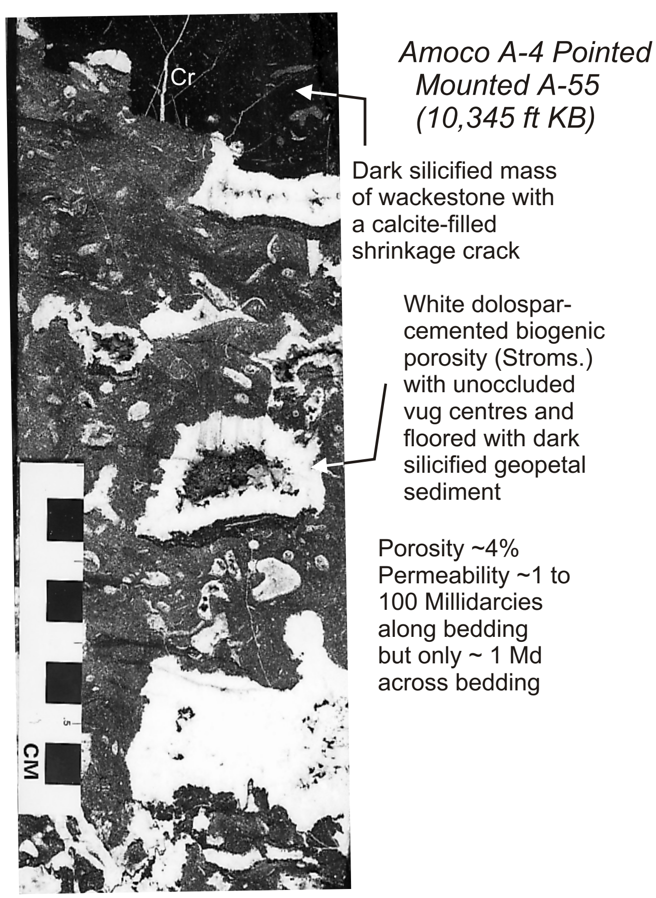

Figure 4. Very porous and permeable core from the Pointed Mountain Gas Field. This core is typical of the uppermost dolomitized Nahanni. Open fractures are less evident in the Pointed Mountain Gas Field than at the Beaver River Field. This core displays numerous silicified geopetals in biogenic macroporosity as well as larger irregular silicified masses of uncertain origin.