The Setting

- West side of Lake Winnipegosis near Duck Bay (***Figure 1***).

Winnipegosis Formation (***Figure 2***) outcrops on the shoreline.

- Karsted Silurian Interlake Group dolomite is present below a major unconformity and the overlying argillaceous Devonian Ashern Formation (***Figure 2***).
- Up-dip of vertical faults in the Precambrian basement along the eastern margin of the Superior Boundary Zone (SBZ), shown in ***Figure 1***.

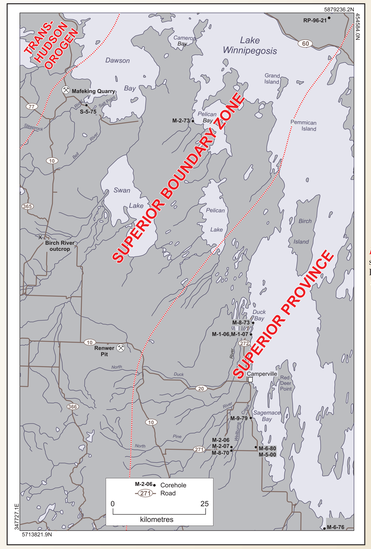

Figure 1: West-central Manitoba study area, showing locations of stratigraphic coreholes, Duck Bay, Pemmican Island, Mafeking Quarry and Birch River outcrop.

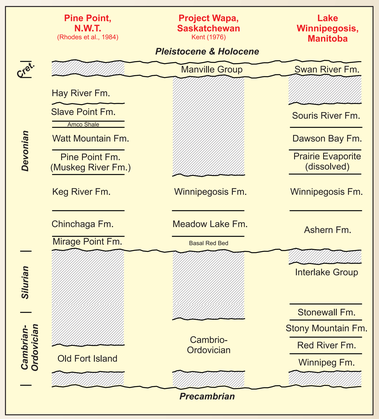

Figure 2: Comparative stratigraphy of Pine Point, N.W.T.; Project WAPA, Saskatchewan; and Lake Winnipegosis in west-central Manitoba (Modified from Rhodes et al., 1984; Kent, 1976, 1996).

The Evidence

M-1-07 Drillcore

In early August, 2007, Manitoba Geological Survey (MGS) stratigraphic corehole M-1-07 was drilled south of the community of Duck Bay (***Figure 1***). The hole was drilled by Doug Berk and his crew, near the south end of a dormant aggregate quarry, opened in Winnipegosis Formation (***Figure 2***).

Figure 3: (a) Doug Berk and his crew (Michael Ostry to his right and Ryan Sharpe to his left) recovering drillcore at M-1-07 drillsite, south of Duck Bay; (b) Doug recovering the core barrel with core from M-1-07.

Examination of core from hole M-1-07 reveals contrasting textures. Above the argillaceous Ashern Formation, the core shows typical buff Winnipegosis Formation dolomite (***Figure 4a***). In contrast, the core below a major unconformity and the Ashern indicates that several of the upper Interlake Group beds have been distinctly altered (***Figures 4b to d***). Some of the alteration consists of abundant dark grey and white mottles with blue-green argillic veinlets, as shown in Figures 4b and 4c. This alteration may be geothermal, or possibly is indicative of hydrothermal dolomite (HTD). In places, the beds are vuggy, very soft and contain very fine grained black sulphides.

Figure 4: Stratigraphic drillcore from M-1-07 (a) Devonian Winnipegosis Formation (buff) overlying Ashern Formation (red) that overlies altered Silurian Interlake Group (orangey-grey and cream-coloured). (b) Altered Silurian Interlake Group (dark grey with green argillic veinlets), separated by buff porcellaneous dolomite. (c) Downward continuation of Figure 4b; altered Silurian Interlake Group becoming less altered dolomite downward (light grey and cream-coloured layered mottles). (d) Downward continuation of Figure 4c, to bottom of hole; slightly altered Silurian Interlake Group dolomite becoming more altered downward (dark grey and cream-coloured mottles), overlying shale marker bed (grayish green) that overlies porcellaneous dolomite (buff) with thin sulphide-healed fractures.

The nature of the altered core from hole M-1-07 in Figure 4 can be compared with known HTD found in corehole exploration programs carried out in Newfoundland and New York State (Deer Lake Oil & Gas Inc., 2007; Martin, 2006). Figures 5 and 6 show the typical HTD textures found in the Deer Lake Basin of Newfoundland and the Appalachian Basin of New York State, respectively.

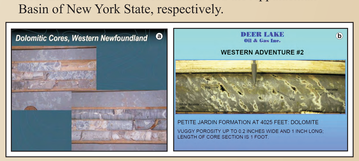

Figure 5: HTD core from western Newfoundland (Deer Lake Oil & Gas Inc., 2007; Martin, 2006).

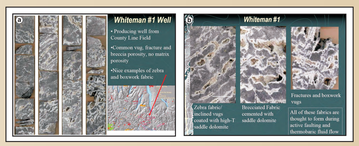

Figure 6: HTD core from New York State (Martin, 2006).

The nearest stratigraphic corehole to M-1-07 (which penetrated the same stratigraphic interval) was drilled in 1976 at Paradise Beach (M-6-76, as shown in ***Figure 1***) near the south end of Lake Winnipegosis, approximately 75 km to the southeast. Examination of the core from M-6-76 shows only the uppermost 3.1 m, below the Ashern Formation, is altered (***Figure 7***) over a 16.1 m interval (to bottom of hole); whereas the same interval in M-1-07 is almost completely altered. It should also be noted that corehole M-1-07 is approximately 40 km closer to the vertical faults in the Precambrian basement along the eastern margin of the SBZ (Macek et al., 2006).

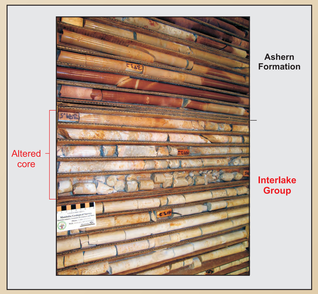

Figure 7: Stratigraphic drillcore from M-6-76. Devonian Ashern Formation (red and brown) overlying altered Silurian Interlake Group (orange, buff and dark grey) that overlies normal buff porcellaneous dolomite.
Note: depths, shown on wood blocks, are in feet.

The core from M-1-07 (***Figure 3***) has been split and half of the core crushed and sent for instrumental neutron activation analysis (INAA) and inductively couple plasma (ICP) analysis. Selected samples were also prepared as thin sections and forwarded to the Department of Geology at the University of Manitoba for petrographic examination. It is hoped, in the future, to carry out isotope, fluid inclusion and vitrinite reflectance studies in order to determine the temperature of dolomite formation compared to that of the surrounding country rock at the time of dolomitization. And, to reconstruct the maximum burial and geothermal gradient.

Hydrothermal indicators

West-central Manitoba

- Bezys et al. (1996) indicated the possible presence of Cretaceous volcanic vent within the SBZ in Cominco RP-96-21 (***Figure 1***). They stated that non-kimberlitic accretionary lapilli found, within the Swan River Formation (***Figure 2***) likely originated from a volcanic vent within or adjacent to the SBZ, not more than 20 km from the drillhole.
- The discovery of the mineral minrecordite in the drillcore of M-5-00 (***Figure 1***) by the Department of Geology, University of Manitoba (J. Young, pers. comm., 2007). Minrecordite is associated with a dolostone-hosted hydrothermal polymetallic ore deposit in Tsumeb, Namibia (University of Arizona, 2005).
- The identification of hydrothermally-altered conodonts by McCracken (1999) from argillaceous residue contained within chimney structures within the Mafeking Quarry (***Figure 1***). According to Fedikow et al. (2004), the chimney structures in Devonian carbonate host-rock, lined with siderite-rich rind and siliceous sinters, are interpreted to be paleo-brine discharge sites.
- Altered Marco Calarenite, contained within the Assiniboine Member of the Cretaceous Favel Formation, underlain by iron oxide-bearing shale, found along the Birch River (***Figure 1***) by Bamburak (1999).
- Mississippi Valley-type (MVT) mineralization found in coreholes (M-2-73, S-5-75, M-9-79, M-6-80 and M-5-00, shown in ***Figure 1***) drilled in the vicinity of the north basin of Lake Winnipegosis as reported by Gale and Conley (2000) and Bamburak (2006).

Saskatchewan

- It should be noted that according to Campeau and Kissin (1988) and Kent (1999), HTD has been recognized in carbonate rock within the Meadow Lake Formation (equivalent to the Ashern Formation, shown in ***Figure 2***), in Saskatchewan, approximately 500 km northwest of M-1-2007. The HTD was found during Project Wapa (***Figure 2***) an extensive drilling program, carried out by Canadian Occidental Petroleum and Saskatchewan Mining and Development Corporation, 24 km south of La Ronge.
- Further, Christopher (1996) suggested that same hydrothermal fluids, which may have altered the carbonate rock within the Meadow Lake Formation (***Figure 2***), could have increased the grade of the coals in the Lower Cretaceous Manville Group in Saskatchewan to sub-bituminous grade.

The Implications

The possible recognition of hydrothermal dolomite (HTD), in a MGS corehole drilled near Duck Bay, would mark the first time that this lithology is present in Manitoba. This discovery, if confirmed, is of major significance because it would indicate that warm to hot saline fluids have flowed through the Paleozoic stratigraphic sequence in west-central Manitoba; and that they may have altered the country rock, and increased porosity and permeability.

Mississippi Valley-type mineralization

Pine Point

- According to Wright et al. (1994), karst development in the Pine Point area was related to basement re-activation that induced fracturing in the Devonian Pine Point Formation and Watt Mountain Formation dolomite (***Figure 2***) overlying the Great Slave Lake Shear Zone (and McDonald Fault).
- Deposition of most Pine Point orebodies occurred within a single interconnected paleokarst network within bedrock where metallic sulphides precipitated from chloride-rich brines (Rhodes et al., 1984).
- Krebs and Macqueen (1984) and Rhodes et al. (1984) noted that the Pine Point (***Figure 2***) MVT ore minerals are coeval with select phases of coarse HTD.
- Qing and Mountjoy (1992) noted that the coprecipitation of saddle dolomite and ore mineralization for the Pine Point deposit indicated a common hot parent fluid.

West-central Manitoba

Therefore, similarly karsted and leached limestone and dolomite in west-central Manitoba, also could be expected to host metallic mineralization, precipitated from brines, in fractures and voids (***Figure 8***). These processes may explain the Mississippi Valley-type (MVT) zinc-lead mineralization (***Figure 9***) found within Interlake Group (***Figure 2***), offshore of Pemmican Island in the north basin of Lake Winnipegosis

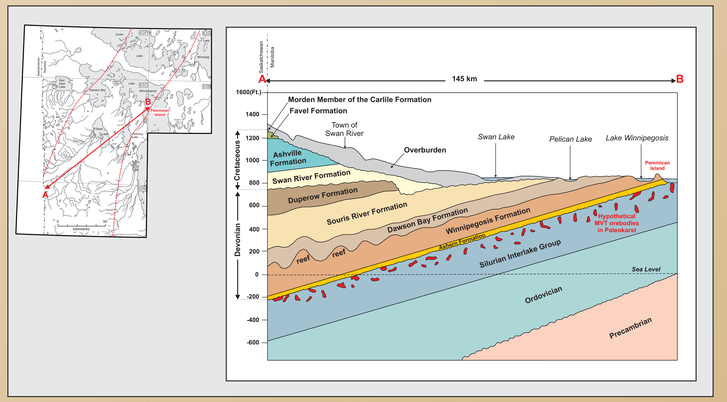

Figure 8: Cross-section across west-central Manitoba showing hypothetical MVT orebodies in Paleokarst.

Figure 9: Core from DDH Klyne No. 3, the Discovery Hole, drilled offshore of Pemmican Island in the north basin of Lake Winnipegosis, where a 6.5 m intersection averaging 0.61% Zn, was found in Silurian dolomite host rock. The intersection included a 15 cm interval grading 4.59% Zn, 0.41% Pb, 0.014% Cu, 10.4% Fe and 14.05% S.

Petroleum

There is also the potential for the discovery of oil and gas reservoirs in Silurian and possibly older beds in southwestern Manitoba, due to the increased porosity and permeability that was induced by the hydrothermal fluids. Oil and gas migration may occurred simultaneously (or possibly later) with the movement of these hydrothermal, or succeeding fluids through the altered and karsted Silurian Interlake Group (and potentially within older formations, at depth), below the Devonian Ashern Formation argillaceous caprock (***Figure 8***). This was indicated by Porter and Fuller (1959), who were discussing the potential for locating producible petroleum reservoirs stated:
"The best exploration prospects in the Interlake group seem to be at the pre-Devonian unconformity, in areas where porous and permeable reef of shoal limestones have been truncated and sealed by post-Silurian - pre-Devonian weathering. Through the peripheral region of the basin, Interlake dips are shallow, and mineralizing solutions penetrated deeply into the exposed limestones, infilling the porosity to depths ranging up to 70 feet."
Therefore, the best potential for oil and gas traps would be within:

- Karst developed along vertical fractures and faults that were induced by basement reactivation along the trend of the SBZ (***Figure 1***), below the Ashern Formation argillaceous cap, or other tight units (aquitards).
- Karst developed below the Silurian unconformity at the top of the eroded Interlake Group, up dip of the SBZ (***Figure 1***), below the Ashern Formation argillaceous cap (***Figure 8***) or other tight units (aquitards).
- HTD aquifers with enhanced porosity and permeability, below the Ashern Formation argillaceous cap or other tight units (aquitards).

It is also may be of interest to note that according to Eaton (2004), Hydro-Québec committed $330 million, in 2002, to an oil and gas exploration program in eastern Québec focused on HTD and faulting.

Late-breaking News

Preliminary petrographic examination of thin sections from the core of M-1-07 by the Department of Geology at the University of Manitoba (pers. comm. 2007-10-29) has confirmed the presence of **saddle dolomite cement**. This confirms that, at a minimum, geothermal alteration has taken place below Duck Bay.
Therefore, the answer to the Question is:
Geothermally-altered Silurian dolomite is present beneath Duck Bay on Lake Winnipegosis! However, until isotope, fluid inclusion and vitrinite reflectance data is acquired and reconstruction of maximum burial and geothermal gradient work is carried out; the final conclusion, as to whether the alteration is hydrothermal, is still pending.

Definitions

Geothermal dolomite - According to Machel and Loonnee (2002), a mineral formed at or near the same temperature as the surrounding rocks (within 5-10 °C) should be called "geothermal".
Hydrodolomite - A mixture of hydromagnesite and calcite (AGI Glossary of Geology).
Hydromagnesite - A white, earthy mineral: Mg4(OH)2(CO3)3.3H2O. It occurs in small monoclinic crystals or in amorphous masses or chalky crusts (AGI Glossary of Geology).
Hydrothermal dolomite (HTD) - According to Machel and Lonnee (2002), a mineral should be called "hydrothermal" only if it can be demonstrated to have formed at a higher (by >5-10 °C) than ambient temperatures, regardless of fluid source or drive).
Saddle dolomite cement - White cement found in vugs and fractures in coarse-crystalline massive replacement dolomite. The cement shows rhombohedral to symmetrical saddle forms, with diagnostic sweeping extinction under cross-polarized light, and a dull red cathodoluminescence (or possibly, slightly deeper cores with lighter red rims) (Quing and Mountjoy, 1992). According to Machel and Lonnee (2002), saddle dolomite could be geothermal, in origin, and may not be hydrothermal. Its presence may only indicate a temperature of formation that is relatively high in the context of diagenetic studies.

Acknowledgements

A thank you is extended to Doug Berk and his crew for drilling and for preparing core samples for chemical analysis and thin section. Doug's interest in the drilling was especially welcomed, and since M-1-07 (***Figure 1***) and M-2-07 were the last two holes he drilled for the MGS before his retirement, I will miss his dedicated effort and his accomplishments.
Bonnie Lenton is gratefully acknowledged for preparing the figures for this poster.

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