The Bedrock Geology of the Grand River Basin

To the casual observer a traverse of the Grand River basin will not readily reveal many rock outcrops since the region is mantled with varying thicknesses of sediments deposited by the last ice or laid down following ice retreat. However, for those more familiar with the basin there are limited outcrops in stream beds and river banks and in a few places the bedrock can form some substantial and outstanding physiographic features. Perhaps the most spectacular is the Elora Gorge in the reach of the Grand between Elora and West Montrose. But there are other outcrops along the Grand and its tributaries, notably at Rockwood on the Eramosa River, at Cruickston near the confluence of the Speed and the Grand, in the eastern part of the watershed near Rockton and also in the Erie shore at Rock Point (cover image and Figure 3). Fortunately we do have a reasonable idea of the extent and types rocks that are found in the “subcrop” — that is underneath the glacial deposits — because of numerous wells that have intersected the bedrock surface.

These have been drilled mainly for water in the northern and central sections of the watershed and also oil and gas (the latter more successfully) in the south. There are over 20,000 wells that penetrate the bedrock surface within the watershed, with some 1,080 wells put down for petroleum exploration. A number of the latter have been drilled to more than one kilometer and many of them penetrate the Precambrian “basement”, the subsurface continuation of the Canadian Shield into southern Ontario.

Most of the strata between the glacial deposits and the basement rocks are near flat-lying, undeformed, sedimentary sequences of limestones, dolostones, shales and sandstones. These were originally laid down in the shallow marine inland seas of the Paleozoic Era from about 500 to 400 million years ago. The rocks dip very gently toward the west and are draped over a structural uplift known as the Algonquin Arch that trends NE – SW across the watershed centred between Elora and Waterloo (Figure 4). On either side of the Arch rock sequences of the Paleozoic thicken and this is a reflection of deposition in basins toward the west in the Michigan Basin and to the southeast in the Appalachian Basin.

The Precambrian rocks under the Basin (Basement Rocks).

About 223 deep boreholes within the watershed encounter the Precambrian crystalline rocks at depths that vary from about 700m to 1100m. The basement rocks are distinctly different from the strata above. Firstly, they are extremely ancient, and radiometric dates suggest that most belong in the time frame from 1.8 to 1.25 billion years. Secondly, they are metamorphic and igneous rocks that can be seen at the surface today in the vicinity of Honey Harbour and the eastern shore of Georgian Bay hundreds of kilometers to the north. The igneous rocks originally formed fiery intrusions in the cores of old mountain ranges that existed in this region well over a billion years ago. These deeply buried rocks are granites that have been recovered from cores in many parts of the watershed. The metamorphic rocks usually were former sediments (limestones and sandstones) that were heated stressed and altered by tectonic movements. These rocks are recovered from cores as marbles, quartzites and gneisses.

Because these deeply buried Precambrian rocks are effectively hidden beneath the glacial sediments and the Paleozoic strata geoscientists use other techniques such as gravity and aeromagnetic measurements to prepare maps of the different rock patterns, or domains, beneath the Grand basin. Five different domains are represented in the Precambrian rocks beneath the Grand River basin. These are from north to south the Alliston, Huron, Waterloo,
Cambridge, and Fishhog domains. Figure 5 shows the approximate boundaries of these domains and their age in millions of years. The few borehole samples recovered from these Precambrian rocks combined with estimated structural trends and other geophysical information have been used to indirectly identify the rock types in their domains. For example, granitic rocks seem most representative of the Alliston and Waterloo domains, and these are also areas with high magnetic readings that indicate relatively dense concentrations of magnetic or iron bearing rocks in the basement rocks. Metamorphosed sands, quartzites and gneisses largely comprise the Huron domain whilst marbles and other meta-sedimentary rocks characterize the Cambridge domain. The Fishog domain is represented by a distinctive aeromagnetic signature and the rocks that dominate this region are highly magnetic igneous rocks composed largely of quartz – mica – diorites.

**The Precambrian/Cambrian boundary**

The boundary between the Precambrian and the younger, overlying Paleozoic sedimentary rocks represents an unconformity or “time gap” that is over 450 million years. This is a far longer time than from the latest Paleozoic rocks in the basin to the present; — some 400 million years. Most boreholes drilled to the Precambrian surface grind and break the rocks as they go down, resulting in washed “chips” that are recovered at the surface. However, a number are “continuous cores” that bring long plugs of rock to the surface and these show the nature of the contact between the Precambrian and the Upper Cambrian beds. In some areas the Precambrian surface is heavily weathered with substantial mineral alteration indicating groundwater flow along the contact. In other areas the break is quite sharp with relatively unweathered rock below.

**The Paleozoic Rocks under the Basin**

About 1 km of Paleozoic rocks underlie the southern part of the Grand River basin and these thin to the north and west, with about 850m at Brantford, 700m at Kitchener, and 650m at Arthur near the north end of the watershed. A borehole (Figure 6) put down near Kitchener provides a typical cross-section through most of the strata in the subcrop of the central part of the Grand watershed.

The oldest beds overlying the Precambrian are thin (>2m) sandstones of Cambrian age. These thin from the southern part of the basin and pinch out north of Waterloo. Lower Ordovician strata are absent and the younger sequences commence with the Middle Ordovician Shadow Lake, Gull River, Cobocconk, Kirkfield, Sherman Fall and Cobourg Formations. These represent a continuous sequence of carbonates, calcareous mudstones and shales and non-calcareous shales. A number of these deeply buried beds form producing gas horizons at the southern end of the Grand Basin.

Overlying these are Upper Ordovician strata with bituminous Collingwood Shales and grey brown Blue Mountain mudstones. The latter are capped by beds with a striking colour difference, the red-maroon to purple and green Queenston Formation. The uppermost part of the Queenston forms the lower slopes of the Niagara Escarpment at Milton and these beds can be clearly seen in Figure 7. These fine-grained red beds were deposited in shallow inter-tidal flats under shallow marine conditions. The rock is utilized for brick making in several areas east of the Grand River watershed.
The upper lip of the Escarpment lies east of the Grand watershed and is capped by Lower Silurian limestones, dolostones and shales of the Cataract Group and Clinton Group. The dolostones of the Amabel (the caprock of the Escarpment at Milton) dip gently to the west and are then overlain by the Guelph Formation. The succeeding dolostones of the Guelph formation form much of the outcrop and hidden near surface rock in the eastern half of the Grand watershed. The scenic outcrops at Rockwood and at Elora and Cruickston, west of Cambridge, are formed in the Guelph Formation and were deposited in reefs and inter-reef areas in Middle Silurian time. These dolostones contain a few fossils since the dolomitisation process destroyed many of the more delicate forms. The rocks of the Guelph Formation were utilized locally for building stones and can be seen in many of the older buildings in Guelph and in different parts of Cambridge.

A small time break ensued before deposition of the overlying Upper Silurian Salina Formation occurred. Today the Salina is present beneath the glacial cover under most of the western part of the Grand River Basin. The Salina consists of evaporitic carbonates interbedded with commercial deposits of gypsum and salt. Gypsum was originally mined at Paris, Ontario, from near surface outcrops and underground at mines near Caledonia (Figure 8) and Hagersville. Just west of the watershed a third mine near Innerkip also mined gypsum, although this operation ceased in the 1990’s. Salt sequences in the Salina are mined or brine-pumped further west at Goderich and at Windsor. These evaporate sequences were deposited at times of alternating sea levels under arid conditions somewhat similar to that of the Oman – Red Sea - Ethiopia coast lines today. The Salina is overlain by dolostones of the Bass Islands/Bertie Formations and these represent the youngest Silurian strata.

The Devonian in the Grand River watershed is represented by a small area of grey sandstones of the Oriskany Formation and by limited areas of nodular cherts, limestones, and dolomites of the Bois Blank Formation. These are hidden beneath Quaternary sediments in the south and west side of the basin. The youngest rock sequence in the Grand basin is the Middle Devonian Amherstburg Formation. This can be seen in outcrop as limestone beds, rich in chert but with abundant fossils, at Rock Point just to the east of the mouth of the Grand at Port Maitland (Figures 1 and 9). Many of these fossils can be seen in living descendants in tropical and subtropical seas today (Figure 10). They remind us that this part of North America was in a near equatorial latitudinal position when these beds were deposited almost 400 million years ago. Continental drift, the closure of one ocean and the opening of the younger Atlantic has resulted in the more temperate positioning of southern Canada today.

Countless marine organisms that lived in the lower Paleozoic oceans died and were deeply covered by sediments. Through time they decomposed and organic compounds migrated through the rock units. Today we search for these as petroleum deposits and both oil and gas pools and fields have been found in the lower Grand Basin (Figure 11). Examples of less familiar organisms that helped to make up these deposits are shown in Figure 12.

References
Figure 4: General geology of SW Ontario showing main rock units, the Algonquin Arch and the respective basin areas west and southeast of the Arch.

Figure 5: The deeply buried Precambrian rocks under the Grand River basin follow a NNE-SSW trend that is a hidden extension of the Canadian Shield. (Modified from Carter and Easton 1990). The respective domain areas and their ages are given.
Figure 6: A borehole section that typifies the rock sequence at Kitchener, Ontario. The Precambrian granite can be seen at the base. Quaternary deposits are not illustrated.
**Figure 7:** Niagara Escarpment at Milton. This is west of Milton and is just east of the Grand River watershed. The regional dip is west (left).

**Figure 8:** A gypsum sequence in the Salina at Caledonia. This is in Georgia-Pacific’s mine (Cayuga #3) which is being decommissioned.

**Figure 9:** Middle Devonian rocks at Rock Point.

**Figure 10:** Composite coral, Rock Point.

**Figure 11:** Oil and Gas fields in the lower Grand basin. County boundaries and main settlements are marked and producing and older fields.

**Figure 12:** Bryozoan and mollusc remains in red calcareous shales of the Grimsby Formation (Upper Cataract Group) near Dundas.