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FIELD TRIP GUIDEBOOK

Field Trip Guidebook FT-B1 / Open File OF2013-5

Geology of the Manitoba Legislative Building

Jeff Young, Graham Young and William C. Brisbin

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Geology of the Manitoba Legislative Building

by Jeff Young, Graham Young and William C. Brisbin

Geological Association of Canada–Mineralogical Association of Canada Joint Annual Meeting, Winnipeg

May, 2013

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This guide, produced for the Geological Association of Canada–Mineralogical Association of Canada Winnipeg 2013 annual meeting, is largely derived from the Geoscience Canada article "Geology of the Manitoba Legislative Building" (Brisbin et al., 2005). The abstract from the Geoscience Canada article is on page iv and the rest of the article, with minor changes, has been reproduced on pages 1 to 15. The article is followed by a summary of field trip stops beginning on page 15.

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Acknowledgements

Geology of the Manitoba Legislative Building (Brisbin et al., 2005)

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SAFETY INFORMATION

General Information

The Geological Association of Canada (GAC) recognizes that its field trips may involve hazards to the leaders and participants. It is the policy of the GAC to provide for the safety of participants during field trips, and to take every precaution, reasonable in the circumstances, to ensure that field trips are run with due regard for the safety of leaders and participants. Field trip safety is a shared responsibility. The GAC has a responsibility to take all reasonable care to provide for the safety of the participants on its field trips. Participants have a responsibility to give careful attention to safety-related matters and to conduct themselves with due regard to the safety of themselves and others while on the field trips.

Field trip participants should be aware that any geological fieldwork, including field trips, can present significant safety hazards. Foreseeable hazards of a general nature include inclement weather, slips and falls on uneven terrain, falling or rolling rock, insect bites or stings, animal encounters and flying rock from hammering. **The provision and use of appropriate personal protective equipment (e.g., rain gear, sunscreen, insect repellent, safety glasses, work gloves and sturdy boots) is the responsibility of each participant.** Each field trip vehicle will be equipped with a moderate sized first-aid kit, and the lead vehicle will carry a larger, more comprehensive kit of the type used by the Manitoba Geological Survey for remote field parties.

Participants should be prepared for the possibility of inclement weather. In Manitoba, the weather in May is highly unpredictable. The average daily temperature in Winnipeg is 12°C, with record extremes of 37°C and -11°C. North-central Manitoba (Thompson) has an average daily temperature of 7°C, with record extremes of 33°C and -18°C (*Source:* Environment Canada). Consequently, participants should be prepared for a wide range of temperature and weather conditions, and should plan to dress in layers. A full rain suit and warm sweater are essential. Gloves and a warm hat could prove invaluable if it is cold and wet, and a sunhat and sunscreen might be just as essential in the heat and sun.

Above all, field trip participants are responsible for acting in a manner that is safe for themselves and their co-participants. This responsibility includes using personal protective equipment (PPE) when necessary or when recommended by the field trip leader, or upon personal identification of a hazard requiring PPE use. It also includes informing the field trip leaders of any matters of which they have knowledge that may affect their health and safety or that of co-participants. Field Trip participants should pay close attention to instructions from the trip leaders and GAC representatives at all field trip stops. Specific dangers and precautions will be reiterated at individual localities.

Specific Hazards

Some of the stops on this field trip may require short hikes, in some cases over rough, rocky, uneven or wet terrain. Participants should be in good physical condition and accustomed to exercise. Sturdy footwear that provides ankle support is strongly recommended. Some participants may find a hiking stick a useful aid in walking safely. Steep outcrop surfaces require special care, especially after rain. Access to bush outcrops may require traverses across muddy or boggy areas; in some cases it may be necessary to cross small streams or ditches. Field trip leaders are responsible for identifying such stops and making participants aware well in advance if waterproof footwear is required. Field trip leaders will also ensure that participants do not go into areas for which their footwear is inadequate for safety. In all cases, field trip participants must stay with the group.

Other field trip stops are located adjacent to roads, some of which may be prone to fast-moving traffic. At these stops, participants should pay careful attention to oncoming traffic, which may be distracted by the field trip group. Participants should exit vehicles on the shoulder-side of the road, stay off roads when examining or photographing outcrops, and exercise extreme caution in crossing roads.

Road cuts or rock quarries also present specific hazards, and participants MUST behave appropriately for the safety of all. Participants must be aware of the danger from falling debris and should stay well back from overhanging cliffs or steep faces. Participants must stay clear of abrupt drop-offs at all times, stay with the field trip group, and follow instructions from leaders.

Participants are asked to refrain from hammering rock. It represents a significant hazard to the individual and other participants, and is in most cases unnecessary. Many stops on this field trip include outcrop with unusual features that should be preserved for future visitors. If a genuine reason exists for collecting a sample, please inform the field trip leader, and then make sure it is done safely and with concern for others, ideally after the main group has departed the outcrop.

Subsequent sections of this guidebook contain the stop descriptions and outcrop information for the field trip. In addition to the general precautions and hazards noted above, the introductions for specific localities make note of any specific safety concerns. Field trip participants must read these cautions carefully and take appropriate precautions for their own safety and the safety of others.

Abstract

The Manitoba Legislative Building was designed by Frank Worthington Simon, assisted by Henry Boddington III, architects from Liverpool, England. The building style is neoclassical, incorporating Greek, Roman and Egyptian motifs and elements. Construction was completed early in 1920 and the building was dedicated July 15, 1920, on the fiftieth anniversary of the Province. The building is located in central Winnipeg, close to the north bank of the Assiniboine River and rests on 14 m of glacial Lake Agassiz clays over till and limestone bedrock. The mass of the building is supported by 421 concrete caissons that extend through the clays to indurated till or bedrock. Steel frames rest on the caissons and support bearing walls constructed of bricks manufactured from Manitoba shale and clay. Dimension stones decorate the bearing walls inside and outside, and the floors and stairways within. Each type of stone has its own decorative characteristics and each records geologic processes at different times in Earth history. The predominant dimension stone both outside and inside the building is Manitoba Tyndall Stone. Grey, pink, and red Tennessee marbles are from the southern Appalachians. Botticino marble was quarried in the foothills of the Alps in northern Italy. Ordovician black marble and Verde Antique are from the Vermont-New York region in the northern Appalachians. Missisquoi marble is from quarries in southern Québec near Philipsburg, and also represents a northern Appalachian source. Bedford limestone, used for most of the statuary, is from south-central Indiana. Butler granite from Ignace, Ontario, was used for steps and floor surfaces of all four porticos. Red marble breccia, used to decorate most fireplaces, may have come from northern France.

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The Manitoba Legislative Building is a distinctive Winnipeg landmark, visible from many places in this city. It is such a common sight that most Winnipeggers probably barely think of it, but it is a gem, both architecturally and geologically. The Legislative Building, located just north of the Assiniboine River, was opened in 1920. Its form and proportions are neoclassical, but it dates from an era when North American architecture was influenced by the exuberant sculptural decoration of the Beaux-Arts school: the building's abundant statuary mixes Canadian history with classical, Egyptian, and prairie mythology. The Legislative Building's integration of geological materials is as eclectic as its mixture of motifs.

Since the Legislative Building rests on glacial Lake Agassiz clays, its mass is held up by caissons that extend down to bedrock. Brick bearing walls are supported by a steel structure that rests on the caissons. Construction started in 1913, but was hampered by World War I, financial problems and problems with defective caissons; the official opening did not take place until seven years later. The construction story provides a unique case history into the geologic controls on foundation design.

The building's surfaces combine expanses of cut Manitoba Tyndall Stone with a carefully-selected suite of imported dimension stones: pink and red Tennessee marble, cream-coloured Italian Botticino marble, Ordovician Vermont black marble, Neoarchean Butler Granite from northwest Ontario, Indiana Bedford limestone, Vermont Verde Antique marble, Québec Missisquoi marble, and a red marble breccia of unknown provenance. Through the combined skills of architects, stonemasons, and sculptors, these stones have been blended into a remarkably coherent structure.

This is one of the best places in Winnipeg to observe the Late Ordovician Tyndall Stone. On the exterior of the Legislative Building, nearly a century of weathering has optimally revealed the stone's famous burrow mottles and immense diversity of macrofossils, evidence of its deposition as sediment on an ancient tropical seafloor. The other building stones also tell interesting geological stories, from large batholiths stitching the Canadian shield together at collision zones, to a serpentine marble formed in the crust of the ancient Iapetus Ocean, to a wave-washed warm seafloor in the Mississippian of central North America, to a limestone formed in a Jurassic basin in northern Italy.

The Legislative Building is a short distance from the Winnipeg Convention Centre where the conference is being held, a location that permits a walking fieldtrip during the conference. This half-day trip will focus on the unique geological characteristics of the different types of dimension stone, the processes recorded in their formation, and the paleoenvironmental conditions under which the rocks formed. We will also discuss the history of the building, its construction and foundation conditions.

We will depart from the main entrance of the Convention Centre and walk to the Legislative Building. Most of the field trip will involve touring inside the building, but we will spend some time outside (dependent on weather).

Introduction to the geology of the Manitoba Legislative Building (Brisbin et al., 2005)

The geology of the Manitoba Legislative Building encompasses the subsurface geological conditions of its site, and the source and characteristics of the dimension stones and of other geological materials used in its construction.

The first Legislative Building was opened in 1871. This humble, roughhewn log building was destroyed by fire on December 3, 1873. A second, architecturally-designed Legislative Building was completed in 1884. It served the legislative requirements of Manitoba for a short time only. Rapid growth of the province in the early 1900s led to the need for a much larger building. Consequently, in 1911, plans for the third, and current, Legislative Building were set in motion.

A history of the design competition, site selection, planning, financing, political controversy, and construction of Manitoba's third Legislative Building is in the remarkable book Symbol in Stone (Baker, 1986). The following are some highlights.

A competition for the design of the building was won by the team of Frank Worthington Simon, assisted by Henry Boddington III, architects from Liverpool, England. The site selected in Winnipeg is near the Assiniboine River, immediately east of the Osborne Street Bridge (Figure 1). The building is neoclassical, incorporating Greek, Roman and Egyptian motifs and elements. Bodnar (1979, p.136) described it as "exhibiting a graceful simplified quality, Beaux-Arts in its arrangement of masses and spaces, but more complex in its treatment of plan and dome." The plan of the building is in the form of an H. The mass of the building is supported by concrete caissons that extend to indurated till or bedrock. Structural brick piers faced with dimension stone comprise the exterior walls, and structural brick piers faced with dimension stone or plaster, are used for the interior walls. Floors are concrete, covered by dimension stone or terrazzo.

Construction began in 1913. The general contract for construction was awarded to Thomas Kelly and Sons in July 1913. In January 1915, after a delay caused by the start of World War I, a review revealed financial and contractual improprieties, and the Kelly contract was terminated. Furthermore, problems with defective caissons delayed construction.

It was not until the end of 1916 that new tenders were called to complete the construction. The new general contractor was J. McDiarmid and Company. Figures 2 and 3 show the different stages of construction.

By February 1920, the new Legislative Building was completed. It was dedicated July 15, 1920, on the fiftieth anniversary of the province. Figure 4 is a current view of the front of the building.

At completion, a list of costs was issued by the Manitoba Department of Public Works (Table 1, Anonymous, 1921). Baker (1986), with the benefit of an historical review, estimated the cost as $9,379,000, not including interest on the debt after the dedication and opening.

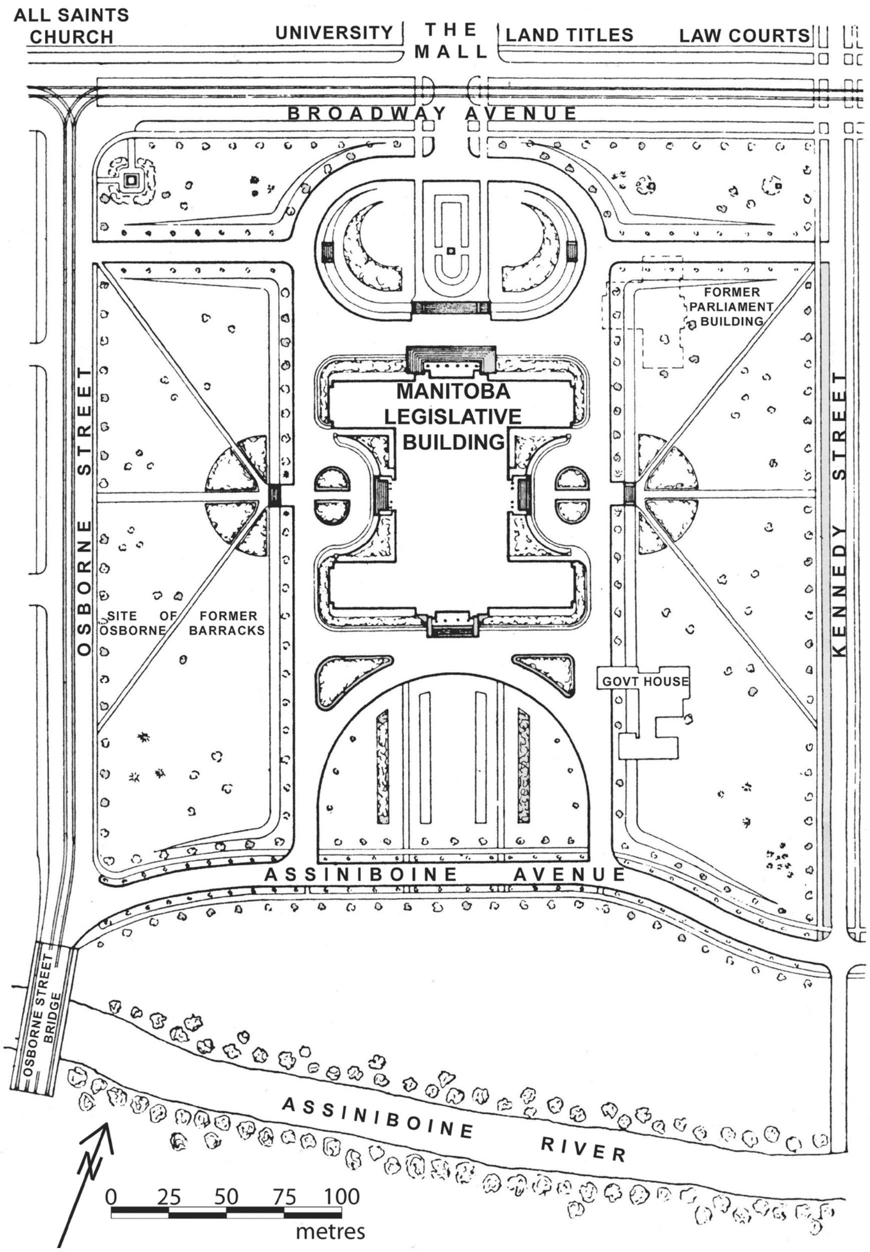

Figure 1: *Plan of the Manitoba Legislative Building and the surrounding area. Modified from Leslie (1925).*

Figure 2: *June 1917; an observer on the southeast wing of the Legislative Building overlooks the east grounds of the building site (Archives of Manitoba, Foote Collection 82). A brick bearing wall with Tyndall Stone facing occurs behind the observer. Blocks of Tyndall Stone are stacked in a staging area below. The old Manitoba parliament building is located on the left side of the photograph adjacent to the northeast wing. The Fort Garry Hotel is the tall building in the distance.*

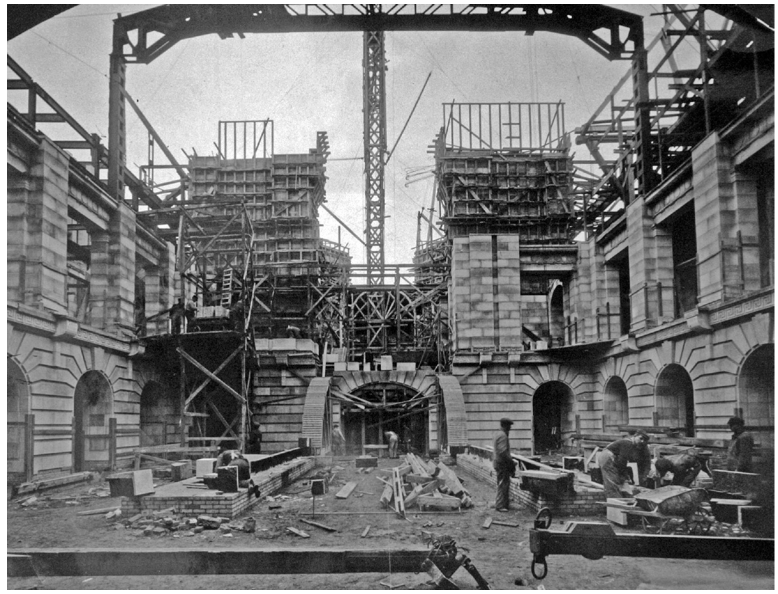

Figure 3: *1916; the Grand Staircase area on the main floor. (Archives of Manitoba, Foote Collection 78). Workers lay brick and steel supports to prepare the base of the Grand Staircase for its railings, addition of the Tyndall Stone facing and placement of the two bronze bison that flank the staircase (see Figure 8a).*

Figure 4: *The Manitoba Legislative Building viewed from the north in spring 2005. Visitors are greeted at the front entrance by six Ionic columns capped with a pediment symbolizing Canada. A sculpture of Queen Victoria, seen on the front lawn of the building, is one of many sculptures on the grounds. The refurbished Golden Boy atop the building symbolizes Manitoba's eternal youth and progress. Government House, the residence of the Lieutenant-Governor of Manitoba, is located on the left side of the photograph.*

Table 1: Lists of costs of the Manitoba Legislative Building (source: Anonymous, 1921).

Building Site	$200,000.00
Building construction	$4,476,466.76
Prime cost items	$371,810.63
Electric work	$157,172.72
Plumbing, heating, ventilating	$219,551.29
Repairing defective work	$296,023.59
Fair wage claims	$16,710.39
Tunnel construction	$56,378.52
Quantity survey	$45,502.00
Engineering and inspection	$114,866.44
Furniture and furnishings	$150,000.00
Vault equipment and fittings	$100,000.00
Decorations	$60,000.00
Grounds	$400,000.00
Architects fees	$250,000.00
Interest during construction	$1,141,383.00
TOTAL	$8,075,865.59

Site foundation conditions

Excavation of the foundation

On July 21, 1913, two steam shovels began excavating the sub-basement at the site of the new Legislative Building. Excavation took 31 days, although seven days were lost because of rain and equipment breakdowns. After five days of excavation, the design plans were modified by, 1) moving the site of the Legislative Building 13 m southward toward the Assiniboine River and away from the main access artery, Broadway Avenue, and 2) raising the terrace adjacent to the building by 0.6 m, and the building by 0.3 m, thus reducing the depth of excavation from 2.5 m to 1.5 m (Manitoba Royal Commission, 1915). Raising the building added an additional 0.3 m of cut stone along the perimeter of the building. During excavation about 16,000 m^3 of soil were removed. Some of the excavated soil was probably used to add a raised terrace adjacent to the Legislative Building.

Foundation conditions

The stratigraphy underlying the Legislative Building was documented in logs from eight test holes sunk in 1912 and 1913 (Archives of Manitoba, GR 3085 G8106, Item 176), logs acquired during caisson excavation (Archives of Manitoba, GR 3085 G8100, Item 6; GR 3085 G8107, Item 549) and logs acquired during later examination of selected caissons (Archives of Manitoba, GR 3085 G8105, Item 121; GR 3085 G8105, Item 122; GR 3085 G8106, Item 196; GR 1609 G8014, File 3 Item 2). This later examination was in response to cracks that developed in the floors and walls of the Legislative Building during construction, particularly along the north outside wall under both wings and the north portico. These logs revealed a stratigraphy consisting of bedrock, commonly overlain by indurated till and unconsolidated boulder clay, overlain by grey and yellow clay and capped by a thin black loam.

The bedrock underlying the Legislative Building consists of carbonate rocks of the lower part of the Fort Garry Member of the Red River Formation (Baracos and Kingerski, 1998). The depth to bedrock is 14 to 15 m from the top of the horizontal steel frame resting on the caissons (i.e., grillage), except under the north part of the building where it occurs at 14 to 20 m (Figure 5). Bedrock relief in the northeast wing and under the north portico defines abrupt depressions that drop up to several metres (Archives of Manitoba, GR 3085 G8106, Item 196; GR

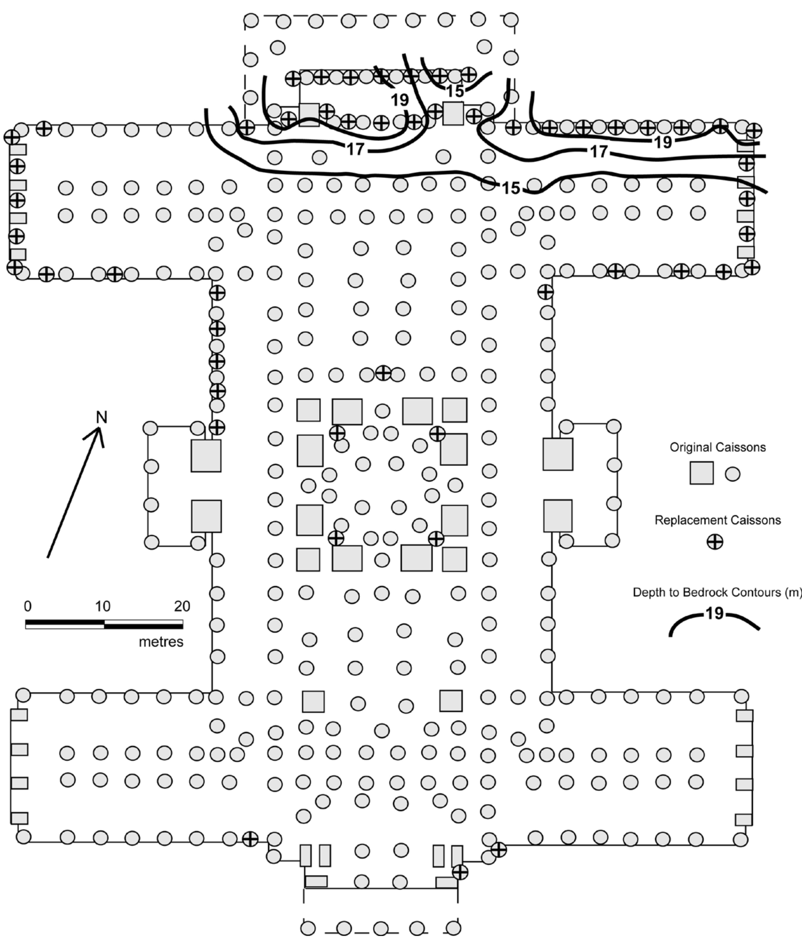

Figure 5: *Plan and location of caissons, Manitoba Legislative Building (Archives of Manitoba, GR3085 G8107, Item 545). The Legislative Building rests on 421 caissons, 369 of which are original caissons, and 52 of which replaced original caissons of poor quality. Caissons on this figure are to scale. The building is outlined by a thin solid line, except under the stairways at the north and south entrances, where the outline is dashed. The depth to the bedrock surface, measured from the top of the steel grillage that rests on the caissons, has been contoured using a contour interval of 2 m. Depth values under the southern portico of the building are between 14 and 15 m; consequently no contours are shown. Beneath the north entrance, contour lines have not been extended under the stairways because the depths to bedrock are poorly constrained.*

1609 G8014, File 3 Item 2). These depressions in the bedrock surface are consistent with paleokarst features underlying Winnipeg (Baracos and Kingerski, 1998).

Unconsolidated boulder clay or indurated till typically overlies carbonate bedrock (Archives of Manitoba, GR 3085 G8100, Item 6; GR 3085 G8105, Item 121) and is probably equivalent to till described by Baracos and Kingerski (1998). Boulder clay underlies most of the Legislative Building, but is absent in the southwest corner of the building whereas the indurated till occurs under the wings of the building, including the northeast wing, but is typically absent under the dome and central part of the building (Archives of Manitoba, GR 3085 G8100, Item 6). Where boulder clay and indurated till occur in the same section, the indurated till underlies the boulder clay. Under the northeast wing of the building where depressions occur in the bedrock surface, several metres of silt occur between the bedrock and indurated till (Archives of Manitoba, GR 3085 G8107, Item 549).

The boulder clay is overlain by unconsolidated grey clay, generally overlain by thinner yellow clay, which thins to the southwest. The yellow clay also occurs as a discontinuous lens within the grey clay (Archives of Manitoba, GR 3085 G8106, Item 176). The grey and yellow clays probably correspond to Agassiz units 1 and 3, respectively (Teller, 1976).

Excavation of caissons

In November 1912, Provincial Architect V.W. Horwood suggested a change in foundation design from piles to caissons (Table 2) because of problems with other engineered projects in the Winnipeg area that used piles. The change was implemented in August 1913. Excavation to bedrock of the original 369 caissons (Figure 5) was started in late August and completed in February1914 (Archives of Manitoba, GR 3085 G8100, Item 6). Under the northeast corner of the building, a caisson intersected up to 3 m of indurated till, but continued excavation never encountered bedrock (Archives of Manitoba, GR3085 G8105, Item 125). To ensure adequate bearing capacity of the indurated till, it was tested once in September 1913 (Figure 6) and again in October 1913. From this testing, recommendations were adopted that allowed caissons to be taken to indurated till. Recommendations also stated that the indurated till was to be drilled to determine its thickness and the depth to bedrock.

Caissons were dug by hand and the spoil removed in buckets to an overhead railway, which took the clay to carts for disposal. Caisson walls were supported during excavation by wood cribbing held in place by iron rings and bolts (Figure 6). Cribbing in one caisson failed, causing deformation of the walls in five adjacent caisson excavations (Archives of Manitoba, GR3085 G8104, Item 53).

Seepage into caisson excavations from the underlying carbonate aquifer was a common problem. The potentiometric surface of this aquifer underlying much of Winnipeg is currently above the bedrock surface (Render, 1970), and may have been higher at the time of construction. Evidence suggests that most caissons contained some water, and several contained excessive amounts of water when the concrete pour took place (Archives of Manitoba GR1609 G8014 File 5; GR1609 G8014 File 3 Item 2).

Following the beginning of construction of the first level, cracks appeared in some floors and walls suggesting that some caissons were of poor quality, possibly reflecting seepage or that some were installed improperly and had not reached bedrock or indurated till (Archives of Manitoba, GR 3085 G8102, Item 43). An additional 52 caissons were installed (Figure 5) to replace poor quality caissons, and to repair and underpin caissons that did not reach supporting material (Archives of Manitoba, GR 1609 G8014, File 3 Item 1).

Dimension stone

Dimension stones used in the Legislative Building are from Canada, the United States and Italy (Table 3). The order presented is based on the volume of each stone used in the Legislative Building, from greatest to least. Technical properties of dimension stones are presented in Table 4. Figures 7 through 10 show the different dimension stones in the Legislative Building.

Tyndall Stone

Introduction

Tyndall Stone is a grey to buff, mottled, fossiliferous, dolomitic limestone that is quarried at Garson, Manitoba, 37 km northeast of Winnipeg. It belongs to the Late Ordovician (Maysvillian–Richmondian; Elias, 1991) Selkirk Member of the Red River Formation [the Maysvillian and Richmondian are now included in the internationally-recognized Katian Stage]. This stone gives many parts of the Legislative Building its characteristic appearance and is used for exterior walls, columns, bases of pediments, bases of statuary, and the fountain in the south grounds. In the interior it can be seen in walls, columns, the main stairway and gallery balustrades, and some sculptured forms (Figures 7e, 8a).

Table 2: Descriptions of caissons used in the Manitoba Legislative Building.

Type	Number	Size (m)	Location
Rectangular	22	1.2 x 2.5	Mostly outside wall on wings, but also south portico
Square: small	8	2.8 x 2.8	Mostly under the dome, but also north portico and under the legislative chamber
Square: large	12	3.7’ x 3.7’	Mostly under the dome, but also east and west porticos
Circular	327	diameter: 1.8	Everywhere
Replacement / Repair / Underpinned - typically rectangular, although other types possible	52	up to 2.1 x 3.1	Mostly northeast wall and north portico, but also outside west wing, west outside wall, dome and locally in the south portico

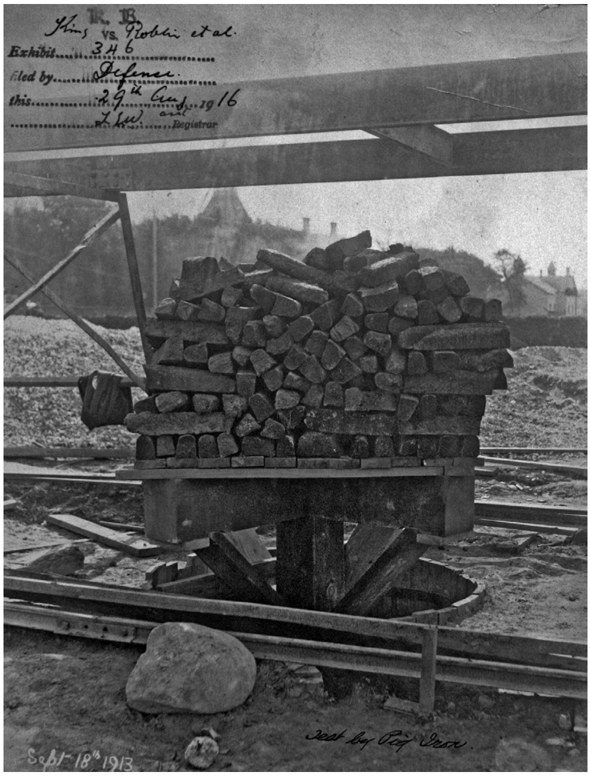

Figure 6: *Loaded platform for the bearing test on indurated till in the excavation for caisson 39, located adjacent the north portico along the northeast wing (Archives of Manitoba, GR3085 G8101, Item 28). The test was done using a progressively loaded platform, 1.68 m square, that was erected on a 3 x 3.6 m rectangular mast extending to indurated till (Archives of Manitoba, GR3085 G8100, Item 6). An initial 5 tons of pig iron was placed on the mast and 22 mm of settlement occurred after 3.5 hours. Another 10 tons of pig iron were added at intervals over the next 24 hours. A total of 26 mm of settlement was measured during the 44 hours of the test. Upon removal of the load 6 mm of rebound was measured. Wood cribbing and metal rings support the wall of the caisson excavation.*

Table 3: Dimension stones of the Manitoba Legislative Building.

Name of Stone	Source	Age	Principal use	Description
Tyndall Stone	Red River Formation, Selkirk Member, Garson, Manitoba	Late Ordovician	Exterior as facing on walls, columns, porticos. Interior on walls, columns, some carvings, balustrades	Mottled grey to buff, dolomitic limestone; macrofossils
Tennessee Marble	Holston Formation, Tennessee Valley, east Tennessee	Middle Ordovician	Interior on floors, stairways, columns, water fountains	Pink, red, or grey, crystalline limestone; stylolitic; micro-fossils
Botticino Marble	Corna Formation Brescia, Northern Italy	Early Jurassic	Interior, on Grand Staircase, benches doorways, balustrades	Cream to ivory coloured limestone; stylolitic; fossils
Ordovician Black Marble	Probably Crown Point Formation Isle la Motte, Vermont	Middle Ordovician	Interior on floors, walls, podiums in Legislative Chamber	Black carbonaceous limestone: micro-and macrofossils
Butler Granite	Indian Lake Batholith, Ignace, Ontario	~2700 Ma	Exterior entrances, as steps and landings	Grey, equi-granular granite; some gneissic portions
Bedford Limestone	Salem Formation, south central Indiana	Mississippian	Exterior and interior carvings	Tan, grey tan, limestone; bioclastic and oolitic; micro- and macrofossils
Verde Antique Marble	Missisquoi Formation, Green Mountains, Central Vermont	Ordovician	Interior, in decorative design on floors	Mixed (green, black, white), serpentinized ultramafic complexes
Missisquoi Marble	Strites Pond Formation, Philipsburg area, Southern Québec	Late Cambrian to Early Ordovician	Interior, on some upper level floors	Mottled light to med. grey, fine crystalline limestone; stromatolites
Marble Breccia	Unknown	unknown	Interior offices and meeting rooms, as fireplace trim	Mixed buff, rose and purplish-orange fragmental dolomites

Table 4: Physical properties of dimension stones of the Manitoba Legislative Building.

Name of Stone	Compressive Strength (MPa)	Density (Mg/m^3)	Water Content (%)	Reference
Tyndall Stone	52 to 70	2.5	2.5	Agricola-Mineralia, 1987
Tennessee Pink Marble	110	2.7	0.1	Tennessee Marble Co., 2004
Tennessee Red Marble	104	2.7	0.06	Tennessee Marble Co., 2004
Botticino Marble	116	2.7	0.17	Italithos, 2000
Ordovician Black Marble	95	2.7	0.2	Vermont Marble Co., pers. comm., 2004
Butler Granite	180	2.6	0.28	Ontario Geological Survey, pers. comm., 2004
Bedford Limestone	62	2.1 to 2.7	7.5	Indiana Limestone Inst., 2004
Verde Antique Marble	180	2.9	0.13	Tennessee Marble Co., 2004
Missisquoi Marble	140	2.7	0.06	Parks, 1914
Marble Breccia	No data	No data	No data	

Tyndall Stone has been quarried in the Garson area since 1895 (Coniglio, 1999). Similar stone was quarried since 1832 near Lower Fort Garry along the Red River. Tyndall Stone has been used extensively in Winnipeg building foundations, but the Legislative Building is probably its first large-scale application as dimension and decorative stone. Since that time it has been considered to be "…one of the best building stones in Canada…" (Parks, 1916, p. 35). The stone on the exterior of the Legislative Building bears this out; in the past 90+ years it has undergone differential weathering so that the mottles and fossils stand out (Figure 7c), but there has been little cracking or spalling. This is in contrast to the Bedford limestone, which has not withstood the climate so successfully (Figure 7b). Tyndall Stone, so named because it was shipped from Tyndall near Garson, can be seen in several other important buildings in Canada such as the Parliament Buildings in Ottawa, the Canadian Museum of Civilization in Gatineau, and the Empress Hotel in Victoria.

At the time the Legislative Building was being constructed, several companies were operating quarries in the Garson area. The stone came from what was then the Tyndall Quarries, within the large quarry pits toward the northeast corner of the current Gillis Quarries Ltd. site (50° 4.5′ N. Lat., 96° 41.8′ W. Long.). The Tyndall Quarries were operated by a syndicate of Winnipeg stone companies, using a range of tools including channellers, horse and steam derricks, jackhammers, and drills (Parks, 1916). A Canadian Pacific Railway spur line ran up to the working face of the quarry, facilitating transport of the quarried blocks. The Tyndall Stone in the Legislative Building was cut and prepared by the Winnipeg Stone Co. plant at 297 Gurney Ave., Winnipeg (Parks, 1916).

In the Garson area, stone is quarried from a relatively thin stratigraphic interval, about 6 to 8 m thick (Goudge, 1944; Lee and Elias, 2004). The upper beds tend to be more buff coloured than the grey stone occurring deeper in the quarries. This is considered to be related to weathering by groundwater (Goudge, 1944). The stone is massive, but the thickness of extracted blocks is limited by stylolites.

Stratigraphy and sedimentology

In the Garson–Selkirk area, the Selkirk Member is about 43 m thick; the Tyndall Stone quarries are within the lower half of the member (Cowan, 1971). The Selkirk Member is underlain by the more purely dolomitic Cat Head Member and overlain by the dolomitic Fort Garry Member (Cowan, 1971).

Most Tyndall Stone consists of dolomite-mottled, fossiliferous wackestone, which was deposited in a stable shelf environment. There are scattered bioclastic packstone and grainstone horizons, which commonly show fining upward (Wong, 2002); these represent deposition during brief storm events. The packstones and grainstones are generally laterally discontinuous, apparently because of bioturbation between storm events (Westrop and Ludvigsen, 1983). In the Legislative Building, these storm beds and lenses can be seen in the columns inside the front entrance portico, and in columns on the main floor around the Pool of the Black Star. Small chert nodules are rare.

Burrow mottling and diagenesis

The mottles that give Tyndall Stone its characteristic appearance (Figure 7c) are generally considered to be burrows made by organisms moving through the mud of a soft ancient seafloor (Kendall, 1977). The large burrows that form the mottles are assigned to the ichnogenus *Thalassinoides*; these were probably produced by arthropods (Kendall, 1977; Coniglio, 1999). Within these large burrows can be seen smaller burrows that have distinct outlines. These were made by organisms, possibly polychaete worms, which mined the original burrow fills for nutrients (Kendall, 1977).

The burrows are dolomitized, while the surrounding material is limestone. The surrounding sediment was partly lithified just below the seafloor surface, but burrows remained unlithified because their fill material had different porosity and permeability (Coniglio, 1999). It may have been at this time that the secondary burrowing took place (Coniglio, 1999). The burrow mottles became dolomitized later in the diagenetic process, as magnesium-rich fluids were able to pass through them, but not through the surrounding material (Kendall, 1977; Coniglio, 1999; Gingras et al., 2004). During diagenesis, most mollusc shell material was replaced with dolomicrite (Kendall, 1977).

Figure 7: *Building stones and their usage in the Manitoba Legislative Building. 7a) Exterior view of east side of the building; walls and plinth are Tyndall Stone, statue is Bedford limestone, and steps are Butler granite. 7b) Bedford limestone of exterior statue showing weathering relief and details of ooid and fossil grains. 7c) Tyndall Stone; detail of exterior stone showing differential weathering between pale buff limestone and darker dolostone burrow mottles; note abundant crinoid grains, particularly in the limestone. 7d) Butler granite, gneissic type. Slab is 1.22 m wide. 7e) Tyndall Stone alcove, second level interior hallway. Tyndall Stone in the walls is oriented parallel to original bedding, except in the keystones of the arch where the stone has been rotated so that bedding is in a radial position; baseboards are of Botticino marble. 7f) Drinking fountain carved from pink-red Tennessee marble shows the characteristic layer-parallel stylolites; the floor is of Tennessee marble and Ordovician black marble, and the baseboard is Botticino marble. 7g) Decorative use of marbles in the Rotunda at the top of the Grand Staircase. The carved balustrade encircling the opening to the Pool of the Black Star is Botticino marble; the floor includes grey-pink Tennessee marble, Ordovician black marble, and green Vermont Verde Antique marble. 7h) Marble floor on the main level of the Grand Staircase Hall is composed of pink and grey-pink shades of Tennessee marble, Ordovician black marble, and green Vermont Verde Antique marble.*

Figure 8: *(previous page) More building stones and their usage in the Manitoba Legislative Building. 8a) The Grand Staircase Hall; bison pedestals, arches, walls, gallery balustrades and sculptured forms on the ledge above the arches are Tyndall Stone; floors are of three different marbles (see Figure 7h); steps and carved railings of the Grand Staircase are Botticino marble. Cylindrical columns at the top of the staircase are Tennessee marble. Compare with Figure 3. 8b) Botticino marble; carved railing and steps on the Grand Staircase; 8c) Botticino marble; detail of stone, showing rounded oncolitic structures and dark brown stylolites. 8d) Red marble breccia; detail of stone, showing large clasts containing calcite veins, surrounded by deep red alteration rims and matrix. 8e) Red marble breccia, used as decorative trim on a fireplace in a meeting room. 8f) Ordovician black marble used for the steps and pedestals of the speaker's platform. A strip of light pink Tennessee marble is at the foot of the stairs. 8g) Missisquoi marble floor of an upper level corridor, showing grey-green mottled stromatolitic structures.*

Macrofossils

The most common Tyndall Stone macrofossils are receptaculitids, an extinct group of uncertain affinities, possibly calcareous green algae (Wong, 2002; Figures 9a, c). The second most abundant group is the solitary rugose corals (horn corals). Other common fossils include stromatoporoid sponges, colonial rugose and tabulate corals, brachiopods, bryozoans, gastropods, cephalopods, and trilobites (Figures 9b-e). The most abundant bioclasts in Tyndall Stone are sections of echinoderms. These can be readily observed on the outside of the Legislative Building, where grains are more visible as a result of weathering (Figure 7c). Complete echinoderms are very rare because their skeletons were readily broken up after death.

Many publications have dealt with various aspects of the Tyndall Stone biotas; perhaps most notable are a few monographs that have placed groups in a modern taxonomic context. These include publications about the rugose corals by Elias (1981), trilobites by Westrop and Ludvigsen (1983), and articulate brachiopods by Jin and Zhan (2001). A detailed paleoecologic study of the Tyndall Stone quarries was carried out by Wong (2002), who noted that fossil abundances vary with height in the quarry, suggesting that subtle environmental changes were taking place. Overall, macrofossils are more abundant in upper beds than in lower ones; relative abundances of receptaculitids and stromatoporoids increase, while those of cephalopods and horn corals decrease. Storm lenses become more common with height. Fossil counts on various parts of the Legislative Building's exterior suggest that stone from different levels in the quarry was selected for the various purposes (Table 5). Unusual fossils occur in a few places in the Legislative Building. Some of the stone in the east portico stair pedestals was quarried from a lens containing a greater density of brachiopods than the authors have seen in more recently quarried Tyndall Stone. The east portico contains two other notable fossils: a superb example of an unusual sponge occurs in one of the stair plinths (Figure 9d), and the largest fossil measured in the Legislative Building, a stromatoporoid 1.0 m wide and 30 cm high, occurs on one of the pillars. Many other beautiful fossils on both the interior and exterior of the Legislative Building show features such as annual growth banding (Figure 9e) and overgrowth relationships (Figure 9c).

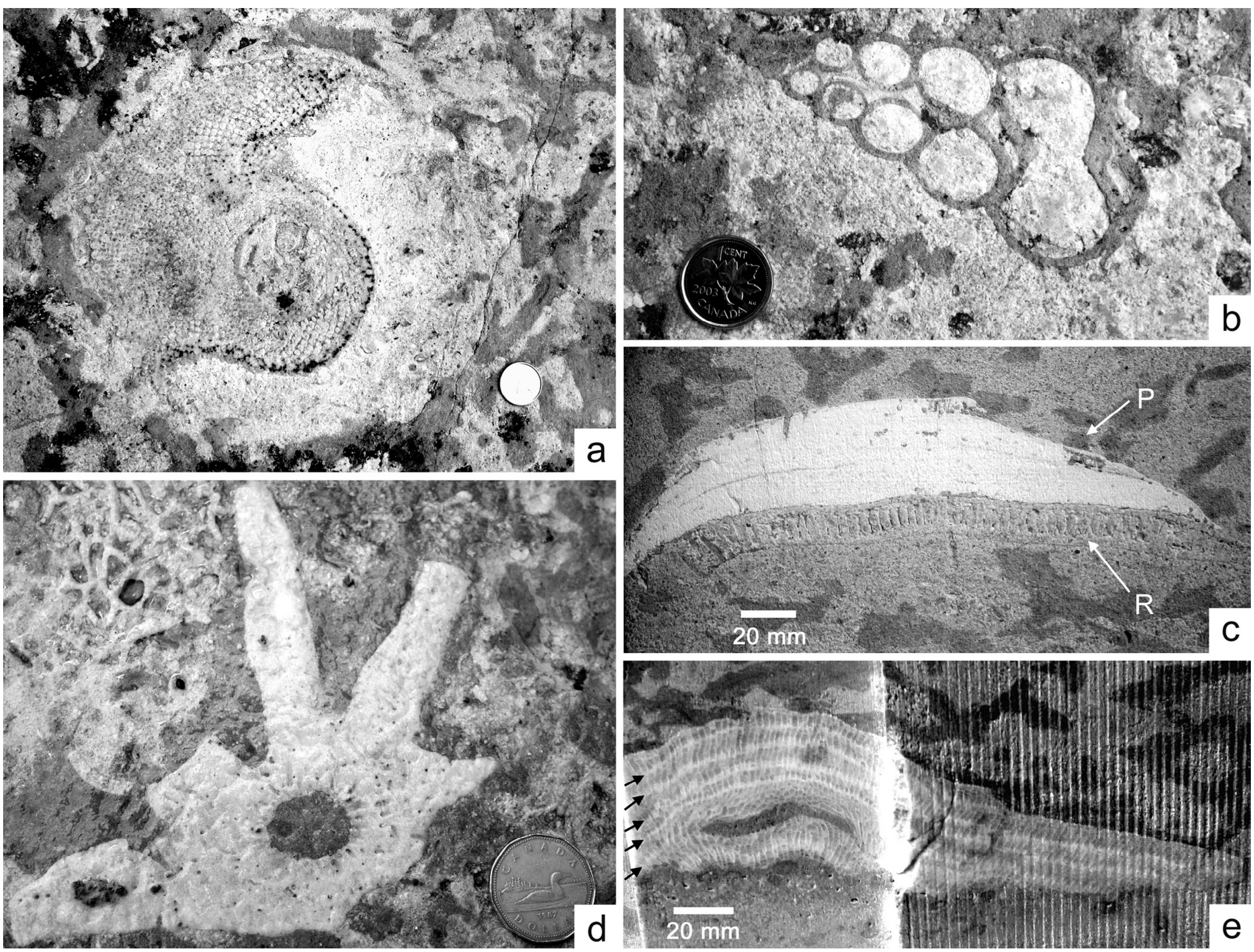

Figure 9: *Examples of the diverse fossils in Tyndall Stone at the Manitoba Legislative Building; a to d are on exterior surfaces; e is at the top of the Grand Staircase. 9a) Receptaculitid* Fisherites, *transverse section; coin diameter is 19 mm. 9b) High-spired gastropod (snail); coin diameter is 19 mm. 9c) Vertical section of receptaculitid (R) encrusted by tabulate coral* Protrochiscolithus *(P). 9d) Sponge (lower centre), with the chain tabulate coral* Manipora *(upper left); coin diameter is 26 mm. 9e) Vertical section through colony of the rugose coral* Crenulites, *showing distinct cyclic banding that probably represents annual growth bands (arrowed).*

Table 5: Relative abundance (% frequency) of fossils in Tyndall Stone on various exterior surfaces of the Manitoba Legislative Building. Crenulites is a cerioid colonial rugose coral genus, and Protrochiscolithus and Calapoecia are tabulate corals. "Other Fossils" include the colonial rugose coral Palaeophyllum, a non-stromatoporoid sponge, and Tetradium. The portico columns show high frequencies of receptaculitids and stromatoporoids and low frequencies of cephalopods and solitary Rugosa, suggesting that they came from beds near the top of the quarry. Walls above grade have lower frequencies of receptaculitids and stromatoporoids, and high frequencies of cephalopods and solitary Rugosa, indicating that their stone was derived from beds lower in the quarry. Results for foundation walls and stair plinths are more ambiguous.

	Foundation Walls	Stair Plinths	Walls (Above Grade)	Columns	Overall Rel. Abund.
Receptaculitids	41.3	23.4	28.6	43.7	32.3
Solitary Rugosa	22.2	16.8	21.2	14.6	18.4
Brachiopods	4.8	27.5	4.1	2.6	10.4
Cephalopods	11.1	6	10.1	9.3	8.9
Stromatoporoids	0	7.8	7.8	10.6	7.7
Crenulites	3.2	3.6	8.3	7.3	6.2
Gastropods	6.3	3.6	6	2.6	4.5
Chain Corals	3.2	4.2	2.8	2.6	3.2
Protrochiscolithus	1.6	0.6	4.6	2.6	2.7
Calapoecia	0	3.6	1.4	1.3	1.8
Bryozoans	0	1.2	2.3	2	1.7
Trilobites	6.3	1.2	1.8	0	1.7
Other Fossils	0	0.6	1	0.7	0.7
Total No. Counted	63	167	217	151	598

Paleogeographic and paleoenvironmental setting

The Red River Formation was deposited during, and after, a large Late Ordovician marine transgression. Much of North America can be assigned to a single "Red River – Stony Mountain" faunal province that extended from New Mexico to northwest Greenland (Elias,1981). Tyndall Stone from the Garson area was deposited along the northeastern flank of the Williston Basin (Elias, 1981). The Red River Formation thickens southward and westward, toward the deeper parts of the basin (Andrichuk,1959). Farther east and north, all Paleozoic sedimentary rocks have been stripped by erosion, exposing the Precambrian basement. As a result, it is not possible to determine the extent of Ordovician deposition, nor whether there was land in this region. The features of Tyndall Stone do not indicate proximity to land.

Paleogeographic reconstructions show that this part of North America was slightly south of the equator in the Late Ordovician (Scotese, 2004). The burrow-mottled carbonates and diverse fossil assemblage indicate that deposition took place in a warm inland sea, apparently with normal marine salinity (Westrop and Ludvigsen, 1983; Coniglio, 1999). The periodic storm beds, abundant calcareous algae, and possible algal nature of receptaculitids all indicate deposition in shallow water, below normal wave base but above storm wave base (Westrop and Ludvigsen, 1983; Coniglio, 1999).

Tennessee marble

Polished grey, pink, and red Tennessee marbles were used throughout the interior of the Legislative Building for room and hallway flooring (Figures 7g, h, 8a), for steps, risers and landings within enclosed stairwells, for stately cylindrical columns in the second floor Rotunda (Figure 8a), and for drinking fountains (Figure 7f) on most levels. This stone was used also in the building's public washrooms for partitions and walls. This stone came from the Middle Ordovician Holston Formation of the Chickamauga Group (R. Zurawski, Tennessee Division of Geology, pers. comm., 2004). The Holston beds outcrop in the Valley and Ridge fold and thrust belt of eastern Tennessee. The geology of these deposits is described by Gordon (1924). The stone has a fine- to medium-grained, crystalline texture that has been interpreted as diagenetic. The stone qualifies as a marble in the commercial sense only; it is actually a crystalline limestone that takes a good polish. Small crinoid fragments are embedded in many of the crystalline grains and can be seen in the Legislative Building. Otherwise, stone at the Tennessee quarry sites is reported to contain numerous macrofossils such as bryozoans, brachiopods, pelecypods and gastropods. These larger forms could not be recognized in the Legislative Building stone.

The Tennessee marble is characterized by well-developed stylolites having two orientations. Those parallel to bedding planes are predominant and those oblique to bedding are less common. The stylolites parallel to bedding are well demonstrated in three dimensions in the corridor drinking fountains (Figure 7f). Stairwell landings reveal unusual structures related to the intersections of the two orientations of stylolites. The origin of these features appears to have involved irregular dissolution and disturbance of bedding, but otherwise is considered problematic. The variation in colour of the Tennessee stone reflects variations in the amounts of iron oxide. Analyses in Gordon (1924) list ferric oxide (Fe_2O_3) contents in the grey stone (0.17%), pink stone (0.21%) and deep-red stone (0.46%). The Holston beds represent Middle Ordovician carbonate deposition on the North American passive margin of the Iapetus Ocean, an ocean ancestral to the Atlantic Ocean. Scotese (2004) indicates that this area was south of the equator at a latitude of approximately 35° during the Middle Ordovician. These beds were only marginally altered by the Taconic orogenic phase of Appalachian tectonic history (Middle Ordovician-Silurian), but underwent thin-skinned folding and thrusting at a later time during the Late Permian Alleghanian Orogeny (Hatcher, 1987).

Botticino marble

Cream- to ivory-coloured Botticino marble from Italy was used in the Legislative Building for the steps and carved railings of the impressive Grand Staircase (Figures 8a, b), for baseboards and benches in the main entry vestibule and other rooms, for the carved balustrade in the centre of the Rotunda (Figure 7g), for radiator ledges, for baseboards throughout the building (Figures 7e, f), and for smooth and carved olive-leaf trim around entrances to offices. This stone also serves as lamp footings in the Pool of the Black Star.

Botticino marble came from Lombardy Province in northern Italy just north of the Po Basin. The stone (also known formerly as Mazzano marble) was quarried close to the city of Brescia, in the foothills of the Southern Alps. It was quarried from selected carbonate beds within the Lower Jurassic, Sinemurian Stage, Corna Formation (Cassinis, 1968). The Corna beds underwent modest folding and thrusting during the early Miocene and these structures verge toward the south and southeast (Schmid, 2003).

The Corna Formation has been described as a fine-grained, compact, allochemical limestone having a veined texture (Italithos, 2004). It has not been metamorphosed and is a marble in the commercial sense only. It contains primary structures described as pseudo-oolites, and also an abundance of fossils including algal masses (oncolites). These features can be observed in the Legislative Building (Figure 8c). Also reported by Italithos (2004), but more difficult to find in the Legislative Building, are corals, crinoids, sponges, molluscs and forams. Botticino marble has brown stylolites parallel to the bedding (Figure 8c).

The Corna beds represent shallow marine carbonates, deposited on the eastern flank of the Lombardy Basin in northern Italy, as the basin was in the early stages of its development (Winterer and Bosellini, 1981). The Lombardy Basin represented early Jurassic continental extension that signified the oncoming separation and spreading of the Apulian Plate away from the Eurasian plate, leading to the development of the Ligurian Sea. Subsequent closure of the Ligurian Sea in the early Miocene carried these carbonates into contact with the Alpine orogenic front of the Eurasian Plate, resulting in retro-thrusting and folding (Schmid, 2003).

Ordovician black marble

Black marble was used in the Legislative Building for interior decorative purposes. It was used as floor paving bands and diamonds throughout the Legislative Building on the main and second floors (Figures 7g, h, 8a) and also in the Legislative Chamber at the bases of walls, and as ceremonial pedestals on both sides of the Speaker's platform (Figure 8f). This stone is a marble in the commercial sense only. Actually, it is a black, fine-grained limestone that takes an excellent polish and contrasts with the white macrofossils that are scattered throughout the stone or concentrated in layers; these are most obvious in the Legislative Chamber, but they can also be seen in the floors.

There is uncertainty about the source of this stone. It likely came from Isle La Motte in Lake Champlain, on the Vermont side of the border with New York. In this case the source quarry may have been one of five old quarries on the island that produced a stone called Champlain Black (M.J. Gale, Vermont Geological Survey, pers. comm., 2004). Champlain Black, the North American black marble most widely used in the first part of the twentieth century, was derived from the Crown Point Formation of the Middle Ordovician (Whiterockian) Chazy Group (Norton, 1993). The Crown Point Formation is mostly composed of muddy limestone to calcarenite, with local reefal facies (Oxley and Kay, 1959).

In the black marble, the most abundant fossils are crinoid stem segments, but there are also brachiopods, bryozoans, stromatoporoids, cephalopods, gastropods, and corals (Figure 10a-d). These are similar to forms found in the Crown Point Formation and other Chazyan units. The fossil assemblage includes stromatoporoids similar to the Crown Point Formation's *Labechia* and *Pachystylostroma* (Kapp and Stearn, 1975), and examples of the coral genus *Foerstephyllum* consistent with *F. wissleri* (Welby, 1961), which occurs in blue-black limestones of the Crown Point Formation in the Lake Champlain area. Nevertheless, the black marble in the Legislative Building apparently lacks the most characteristic Crown Point fossil, the gastropod *Maclurites magnus* (Oxley and Kay, 1959). Consequently the Legislative Building stone could have been derived from some other mid-Ordovician unit, but likely from the New York – Vermont area.

The Chazy Group was deposited on a passive North American continental margin as the Iapetus Ocean was undergoing closure. It represents a range of environments from storm-dominated shelf to sand shoals and tidal flats (Mehrtens and Selleck, 2002). The beds were deposited during or shortly after a period of block faulting (Mehrtens and Selleck, 2002), and were deformed into open folds during the Appalachian Taconic Orogeny.

Butler granite

Butler granite is a grey gneissic granite that was used for the steps and landings of the four exterior porticos of the Legislative Building (Figures 7a, d). The granite came from the Horne Quarry, near Ignace, Ontario, now known as the Butler Quarry, located in Bradshaw Township, District of Kenora, 7.7 km west of the town of Ignace on the north side of Highway 17, adjacent to the Canadian Pacific Railway right of way.

Storey (1986) indicates that the rock is a massive, light grey to white, biotite granite (approximately 5% biotite). A very weak foliation trends north-northwest. There are no obvious knots or inclusions in the granite but there are rare

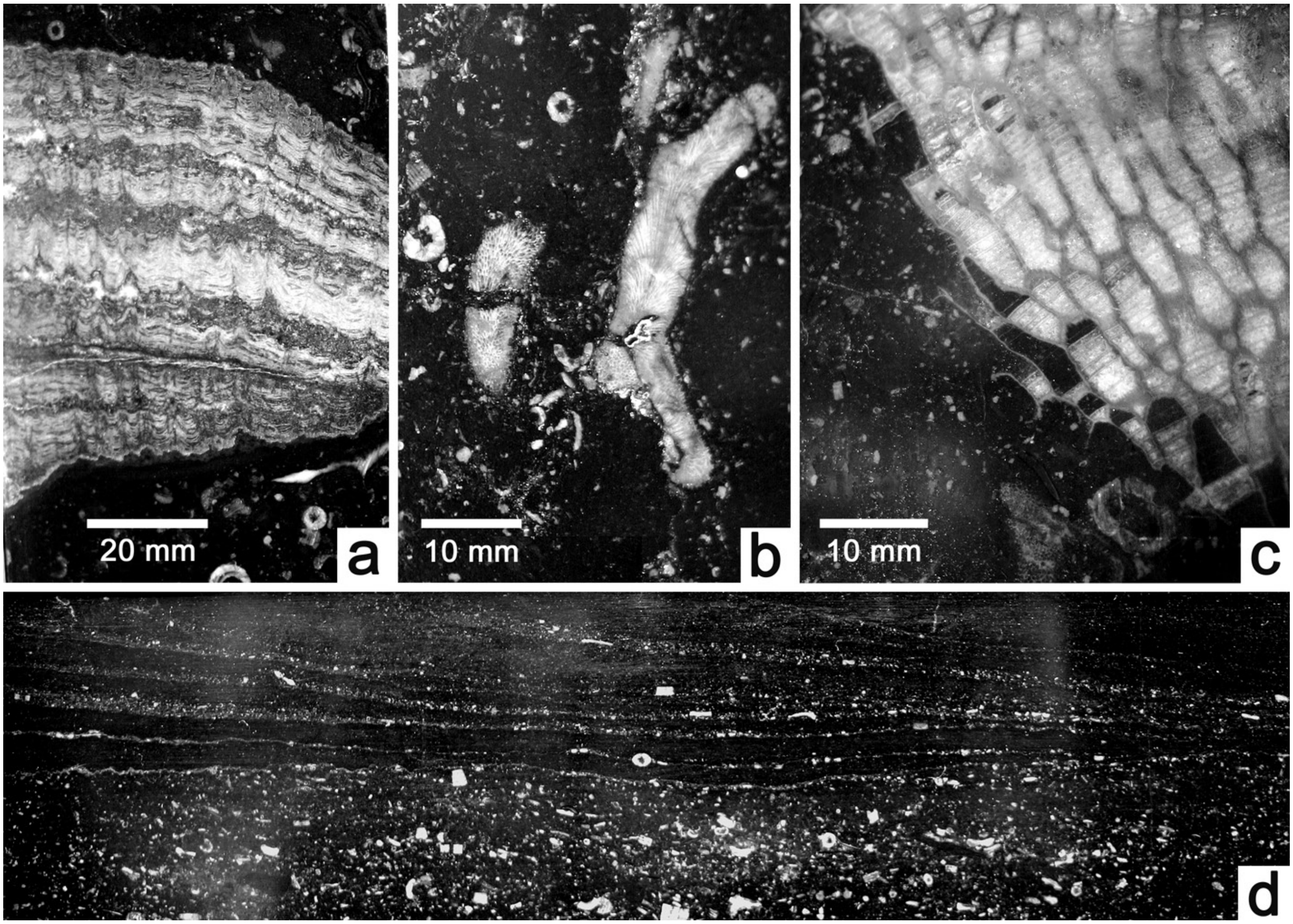

Figure 10: *Examples of fossils and structures in Ordovician black marble in the Legislative Chamber. 10a) Stromatoporoid sponge, vertical section. 10b) Branching bryozoans associated with echinoderm debris. 10c) Colonial coral* Foerstephyllum *sp., oblique vertical section. 10d) Vertical section of cross-laminated limestone, with abundant echinoderm (crinoid) debris.*

rusty-weathering spots on the weathered surface. The rock polishes well with no plucking of the biotite. The major joint set in the granite strikes Az110°, with minor sets at 045° and 070°. The stone on the Legislative Building porticos is characterized by local variations in composition and grain size resulting in a layered gneissosity, along with patches of pegmatite.

Mineral point count analysis identifies the predominant phase of this rock as a quartz monzonite. The mineralogy is 40% plagioclase (3% of which is myrmekitic), 29% quartz, 28% potassium feldspar (microcline and orthoclase), and 3% biotite, with trace magnetite and rare epidote and chlorite.

The Butler granite represents part of the Indian Lake batholith (Blackburn et al., 1991), one of many granitoid plutonic complexes that occur within the central Wabigoon subprovince, of the Superior province of the Canadian shield. Two U-Pb zircon crystallization ages for the batholith are both 2671 Ma (Tomlinson et al., 2004). These ages are the youngest within the central Wabigoon subprovince and suggest that the pluton may be a product of post-collision continental magma generation following earlier Archean continental plate growth as described by Blackburn (1980). The Butler granite represents the oldest dimension stone used in the Legislative Building.

Bedford limestone

Bedford limestone was used for most of the statuary of the Legislative Building (Figure 7a). Decades of weathering have developed some inter-granular relief on the surfaces of the exterior carved works (Figure 7b). The Bedford limestone now is formally known as Salem Limestone, but also simply as Indiana limestone. It was quarried in south-central Indiana, between Bloomington and Bedford. It has been used as a dimension stone for over 100 years because of its uniform texture and ease of working. It is fairly soft and can be shaped easily with carving tools.

The limestone is described as a cross-bedded calcarenite that is medium- to coarse-grained, tan, grey tan, and light grey, porous, and fairly well sorted. It occurs in exceptionally thick beds. Individual grains are mostly microfossils (including especially the foraminiferid *Globoendothyra baileyi*), macrofossil fragments, and whole diminutive forms of macrofossils. Coated grains and oolitic textures are also common (Indiana Geological Survey, 1997; Pinsak, 1957).

The stone was deposited in an epi-continental, warm-water, marine environment during Mississippian time. The fine-grained oolitic texture suggests that wave action and marine currents winnowed the fossil fragments to a uniform size

(Ketter, 2003). The Indiana Geological Survey (1997) classifies this stone as chemically pure, averaging 97% plus calcium carbonate and 1.2% calcium-magnesium carbonate.

Vermont Verde Antique marble

Vermont Verde Antique is a serpentine marble that has irregularly mixed green chlorite and intermediate to dark green serpentine, irregularly veined with white calcite. It was used for a variety of decorative purposes in the Legislative Building to provide artistic contrast with the lighter coloured Tennessee and Botticino marbles (Figures 7g, h). Examples include the patterned floors of the Grand Staircase hall, the Pool of the Black Star, the Rotunda, and the Manitoba Room on the second floor. Verde Antique was used also as fireplace trim in the Speaker's offices.

This marble came from one of several serpentinite bodies near the town of Roxbury, Vermont, where several quarries operated from 1853 through to the 1950s (M.J. Gale, Vermont Geological Survey, pers. comm. 2004). The serpentinite occurs as pods and lenses in the Missisquoi Formation, a metamorphic complex in Vermont assigned to the Lower Ordovician. Structurally, these rocks occur on the eastern limb of the Green Mountain anticlinorium.

The structural setting, composition, and pod-like form of the source serpentinite bodies have led to the interpretation that the original ultramafic material represents the pre-Taconic oceanic crust (possibly ophiolite) flooring the Iapetus Ocean. The bodies may represent dismembered, complexly sheared and metamorphosed material caught up in an accretionary wedge during the Appalachian Taconic Orogeny (Williams, 1984).

Missisquoi marble

Missisquoi marble (Figure 8g) was used as flooring in parts of the northern upper level corridors of the Legislative Building. The stone was described by Parks (1914) as having characteristic colour variations consisting of shades of light and dark grey, sometimes arranged in irregular patterns. The patterns were commonly described as ovoid in form, up to 20 cm across, and locally separated by green stylolites.

The Missisquoi marble comes from quarries at Philipsburg, Québec. The stone occurs in beds of the upper member of the Late Cambrian to Early Ordovician Strites Pond Formation (Salad Hersi et al., 2002). Salad Hersi and Lavoie (2001, p.8) indicate that one upper limestone lithofacies of the Strites Pond Formation is composed of crystalline limestone " … characterized by small, irregularly woven, light grey and medium grey patches of dense micrite, which gives a mottled appearance similar to clotted bioherms. Looking from the bedding surface, these bioherms form rounded, ellipsoidal, and irregular mounds with stylolitic boundaries". This description is consistent with the stone in the floors within the alcoves at the two ends of the upper-level north hall, which has the appearance of domical stromatolites that have been cut parallel to bedding (Figure 8g). Otherwise the Missisquoi marble used on the floors of the upper level is of the non-patterned, light grey type.

The attributes of the upper Strites Pond Formation suggest sedimentation in a subtidal to supratidal setting on the North American passive margin during the Late Cambrian to Early Ordovician; the formation was subsequently slightly deformed and metamorphosed to low-greenschist grade during the Taconic Orogeny (Salad Hersi et al., 2002).

Red marble breccia

This colourful stone was used exclusively as fireplace trim in meeting rooms and in most Ministers' offices (Figures 8d, e). Records show that the original stone specified for fireplace trim was black marble, and that a later cost-saving substitute was to have been one of several possibilities (Archives of Manitoba, GR1609 G8015, File 4, report on deductions and alterations), none of which was used.

Macroscopic examination of this red marble was restricted to properties that could be observed on polished faces around the fireplaces, because it was not possible to extract samples for microscopic or laboratory analysis. The rock is calcareous, and macroscopic structures and textures indicate a history of fragmentation followed by lithification. Most fragments are angular. Larger fragments are grey, buff, or rose and may contain white calcite veins, and commonly have darker red alteration rims. The matrix consists of smaller fragments or fine-grained material having an orange-rose to deep-red colour. No layering or stratification was discerned from the polished surfaces, and no preferred orientation of long dimensions of fragments was identified. The available evidence suggests the possibility of karst dissolution, collapse and brecciation, followed by lithification. As far as can be determined from textural evidence this stone may be a marble in name only.

No other relevant archival material has been located concerning the source of this stone. A recent search of commercial stone products has yielded one stone from Picardy Province in France, named Brèche St. Maximin, that is similar to the red marble breccia. Notwithstanding, the evidence is not compelling; consequently we use a generic name and acknowledge that the age, geological setting and origin of this stone are uncertain.

Other geological materials

Terrazzo

Terrazzo was used primarily for basement floors, reporters' gallery stairs, some corridor floors (within marble borders), and some stairwell landings. The terrazzo material was derived from crushing and sorting waste from the marble and limestone used in the building interior (excluding Tyndall Stone). The specifications for the terrazzo mix were to produce a floor surface showing 85% marble chips and 15% light coloured interstitial cement. The proportions of chips of individual marble types were specified as 10% Verde Antique, 10% dark Tennessee, and 80% combined light coloured marble chips (Archives of Manitoba, GR1609 G8015, File 4, report on marble work and terrazzo).

Construction aggregate

Bird's Hill, 10 km northeast of Winnipeg, was the source of almost all aggregate used in the construction of the Legislative Building (Archives of Manitoba, GR 1609 G8016, File 9). The first development of the Bird's Hill gravel and sand deposit took place in the 1890s, and production continues to this day. During construction of the Legislative Building, sand and gravel were transported to the city by train using a special spur line of either the Winnipeg Selkirk & Lake Winnipeg Railway Company, or the Canadian Pacific Railway.

The Bird's Hill deposit is an esker-delta complex approximately 15 km in length. It consists of coarse-grained, braided esker deposits near the western margin, changing to finer deltaic deposits to the east. It is surrounded by silt and clay deposits of glacial Lake Agassiz. Nielsen and Matile (1982) stated that the complex was formed at a retreating ice margin approximately12,000 years ago. Melt-water carried glacially-derived sediment from two ice margin crevasses into Lake Agassiz and produced the esker-delta complex. Subaqueous mass wasting, wave action from Lake Agassiz, and subaerial erosion modified the original distribution of material.

Brick clay

Approximately ten million bricks were used in the construction of the Legislative Building (Manitoba Royal Commission, 1915). They were used for construction of load bearing walls (piers) on all levels and usually were faced with dimension stone or plaster. Unadorned piers can be observed in service corridors and some storage rooms in the basement, and in service areas above the second floor. Brick piers also were constructed on higher levels to support the dome of the Legislative Building. Two types of brick were used, one buff coloured and the other red. They were manufactured from local materials by two Manitoba brick plants between 1913 and 1916.

Most of the bricks are buff coloured and came from the Stephens Brick Company in Portage la Prairie, Manitoba (Archives of Manitoba, GR1609 G8014, File 2). The source for the Stephens bricks was postglacial alluvial clay, yellow-grey in colour, that filled abandoned channels of the Assiniboine River near Portage la Prairie, Manitoba. The clay in the channels is 1.5 to 2.7 m thick and is overlain by approximately 0.5 m of soil (Bannatyne, 1970). The Stephens bricks were molded by the soft-mud press process, then dried for eight to ten days, after which they were fired to a buff or pale brown.

The red bricks came from a plant operated by the Leary-Alsip Brick Company in Roseisle, Manitoba. Archival material supporting this source was less definite; consequently X-ray analysis was conducted to confirm Leary-Alsip as the manufacturer. Leary-Alsip bricks contain quartz, microcline and muscovite in contrast with the Stephen bricks, which contain diopside and quartz. The source of the Leary-Alsip bricks was the Cretaceous Morden Shale (McNeil and Caldwell, 1981) that is dark and carbonaceous. The Morden Shale was quarried along the Pembina Hills part of the Manitoba Escarpment, from the banks of Roseisle Creek. After crushing and sieving the shale was formed into bricks by a dry press process. The bricks were fired to their typical red colour in a down-draft beehive kiln (Bannatyne, 1970). These bricks were admired by the architect, Frank W. Simon, for their superior strength (Archives of Manitoba, GR1609 G8014, File 2).The Leary kiln near Roseisle stands today.

Chemical analyses and temperature gradient tests relevant to the manufacturing of both types of brick are given by Bannatyne (1970).

Field trip stop locations

Stop 1: Introduction and history of the Manitoba Legislative Building

Location: Front lawn of Legislative Building / UTM 14U 0633183 5527365

This location offers an excellent view of the front and east sides of one of the most distinctive buildings in Winnipeg, Manitoba's third and current legislative building (Figure 11). The building sits partly on the former site of Osborne Barracks and just east of the second Manitoba Parliament Building (Figure 12). Government House, home of Manitoba's Lieutenant-Governor can been seen through the trees to the south. The building was designed by Liverpool architect Frank Worthington Simon, assisted by Henry Boddington III. It has a neoclassical design, incorporating Greek, Roman and Egyptian elements. Today, some suggest that many of these elements are related to the occult and Freemason culture.

Figure 11: *The Manitoba Legislative Building, viewed from the site of the northwest corner of the second Manitoba Parliament buildings, winter 2013.* Field trip Stop 1.

***Figure 12:** The second Manitoba Parliament Building viewed from the north-northeast in May 1917 (Archives of Manitoba, Foote Collection). Construction of the third, and current, Legislative Building is ongoing in the background*. Field trip Stop 1.

Construction of the Manitoba Legislative Building started almost 100 years ago with excavation of the site in July 1913. World War I and financial and contractual irregularities delayed construction and the building officially opened in July 1920. Originally tendered for almost $2.9 million, the final cost has been estimated at almost $9.4 million. The political scandal surrounding the cost and construction of the Legislative Building contributed to the downfall of the government of the day.

The Manitoba Legislative Building rests on glacial Lake Agassiz clays that overlie till and limestone bedrock. The building load is supported by 421 concrete caissons that extend through the clays to indurated till or bedrock. A steel frame rests on the caissons and supports brick bearing walls. Dimension stone from around North America and Europe covers the bearing walls. Tyndall Stone is the dominant dimension stone used on the outside of the building. Butler granite occurs as stairs at the entranceways and Bedford limestone is used for some of the statuary.

It took about one month to excavate the site. After five days of excavation, design plans were changed to move the building site 13 m southward and away from Broadway Avenue (Figure 13). The excavation depth was also changed from 2.5 m to 1.5 m and the adjacent terrace was raised 0.6 m. These changes were done to improve the grandeur of the building.

Stop 2: Introduction to the geology the Manitoba Legislative Building

Location: Main floor, Grand Staircase

The Manitoba Legislative Building uses dimension stone and other construction materials that span almost 2.7 Ga of Earth history (Figure 14). We will visit a number of locations inside and out to view these materials and discuss the engineering geology and construction of the building. At this stop we can see that the dominant building stone used inside the Legislative Building is Ordovician Tyndall Stone, which covers load-bearing brick walls and has also been used for intricate carvings on the walls (Figure 15). The floors and stairways consist largely of "marbles" of Ordovician age quarried in the Appalachians (Figure 16), except the Grand Staircase, which consists of Jurassic Italian Botticino marble.

***Figure 13:** View northward down Memorial Boulevard from the rooftop of the Manitoba Legislative Building in June, 2005. Broadway Avenue is the main east-west thoroughfare in front of the Legislative Building. The two sphinxes in the foreground are carved from Tyndall Stone, the dominant dimension stone used in the building. Note that gable in the centre of the image is made from bricks*. Field trip Stop 1.

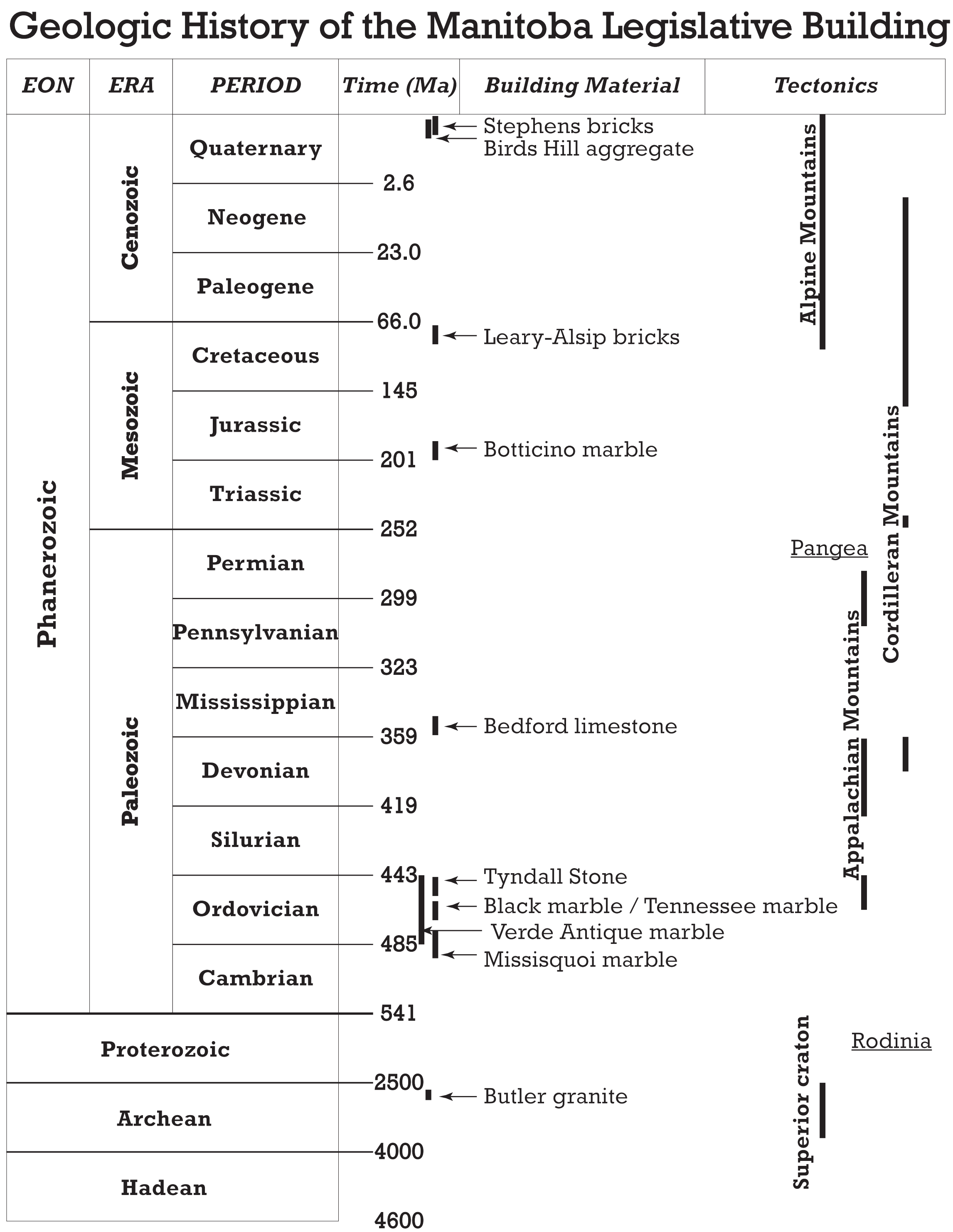

Figure 14: Geologic time scale showing the age of construction materials used in the Manitoba Legislative Building. Major orogenic events and timing of supercontinents are listed in the right-hand column. Field trip stop 2.

The oldest stone in the Legislative Building is the Neoarchean Butler granite, which is used outside at the four entranceways into the building. The remaining stones used in the building range in age from the Cambrian-Ordovician Missisquoi marble on the third floor to Jurassic Botticino marble on the Grand Staircase and elsewhere, and a red marble breccia of unknown age, which occurs in select committee rooms. The youngest materials in the building are the clays that were used to make bricks for the bearing walls, and the aggregate used for concrete. Like the Tyndall Stone, this material was obtained locally.

Stop 3: Engineering geology of the Manitoba Legislative Building

Location: Main floor, northwest wing, near rooms 106 and 118 (Figure 17)

Figure 15: View from the top of the Grand Staircase. Tyndall Stone is the dominant dimension stone used in the Legislative building. It is used on walls, arches, columns, gallery balustrades and sculptured forms. The floors at the bottom of the staircase are Tennessee marble, Ordovician black marble and green Verde Antique marble. The four caryatids on the top floor are carved from Bedford limestone. Field trip Stop 2.

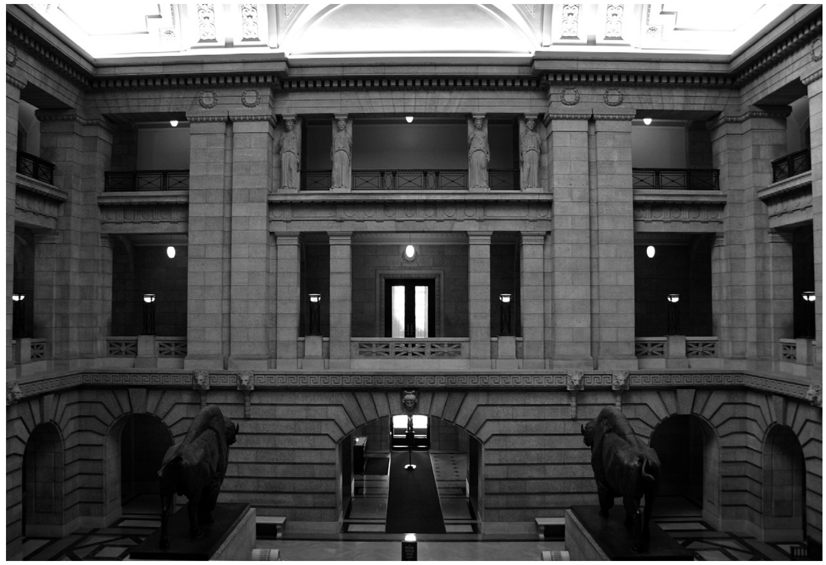

Figure 16: Marble floor on the main level of the Grand Staircase Hall. Floor tiles are pink and grey-pink Tennessee marble, Ordovician black marble, and green Verde Antique marble. The black marble and Verde Antique define the detail in the floor patterns. Tyndall Stone is used on the walls and as sculptured forms on the walls. Field trip Stop 2.

At this stop we will discuss the stratigraphy and groundwater conditions under the Legislative Building and their impact on engineering decisions. The stratigraphy underlying the Legislative Building consists of Ordovician bedrock, commonly overlain by a relatively thin layer of indurated till and unconsolidated boulder clay, overlain by a relatively thick layer of grey and yellow clay and capped by a thin black loam. Bedrock underlying the building is dolostone and dolomitic limestone of the Fort Garry Member of the Red River Formation. The depth to bedrock from the steel framework resting on top of the caissons is about 15 m, except in the northeast corner of the building where bedrock occurs at depths of more than 19 m (Figure 18).

The upper part of the Fort Garry Member, directly underlying the boulder clay or indurated till, contains the upper carbonate aquifer. The upper carbonate aquifer is a confined aquifer that is recharged through glacially derived sand and gravel deposits that occur near the margins of the Red River basin and in the Bird's Hill area. At the time of construction, Winnipeg's first city-owned water system pumped up to 10^7 gallons per day to fulfill public requirements (Render, 1970). Demand for groundwater dropped dramatically when the Lake of the Woods aqueduct was opened in 1919. By 1980, groundwater usage for industrial purposes and air conditioning had increased to levels similar to usage between 1913 and 1919 (Render, 1983). The potentiometric surface of this aquifer is currently above the bedrock surface, although seasonal usage of the groundwater can cause fluctuations of the potentiometric surface of up to 6 m (Render, 1970, 1983).

Stratigraphic and groundwater conditions under the Legislative Building led to the following construction decisions or conditions: (1) a change in foundation design from piles to caissons, (2) the use of indurated till as a load bearing substrate, (3) hand removal of spoil from the caissons and cribbing of caisson walls; and (4) seepage into caissons.

Stop 4: Botticino marble

Location: Grand Staircase

Jurassic Botticino marble is quarried in the Alps of northern Italy. The Grand Staircase contains the best and brightest exposures of Botticino Marble in the Legislative Building. The marble is an allochemical limestone that has a cream to ivory-coloured appearance, abundant oncolites, and distinctive bedding features (Figure 19). Oncolites are rounded ovoid centimetre-sized structures that have a concentric structure

Figure 17: *Northwest wing hallway on the main floor of the Manitoba Legislative Building. The north wall of the hallway is lined with photographs documenting the constuction and opening of the building. The photographs were taken by Lewis B. Foote, a professional photographer who recorded the development of Winnipeg on film in the first half of the twentieth century. The Foote photographic collections are held in the Archives of Manitoba.* Field trip Stop 3.

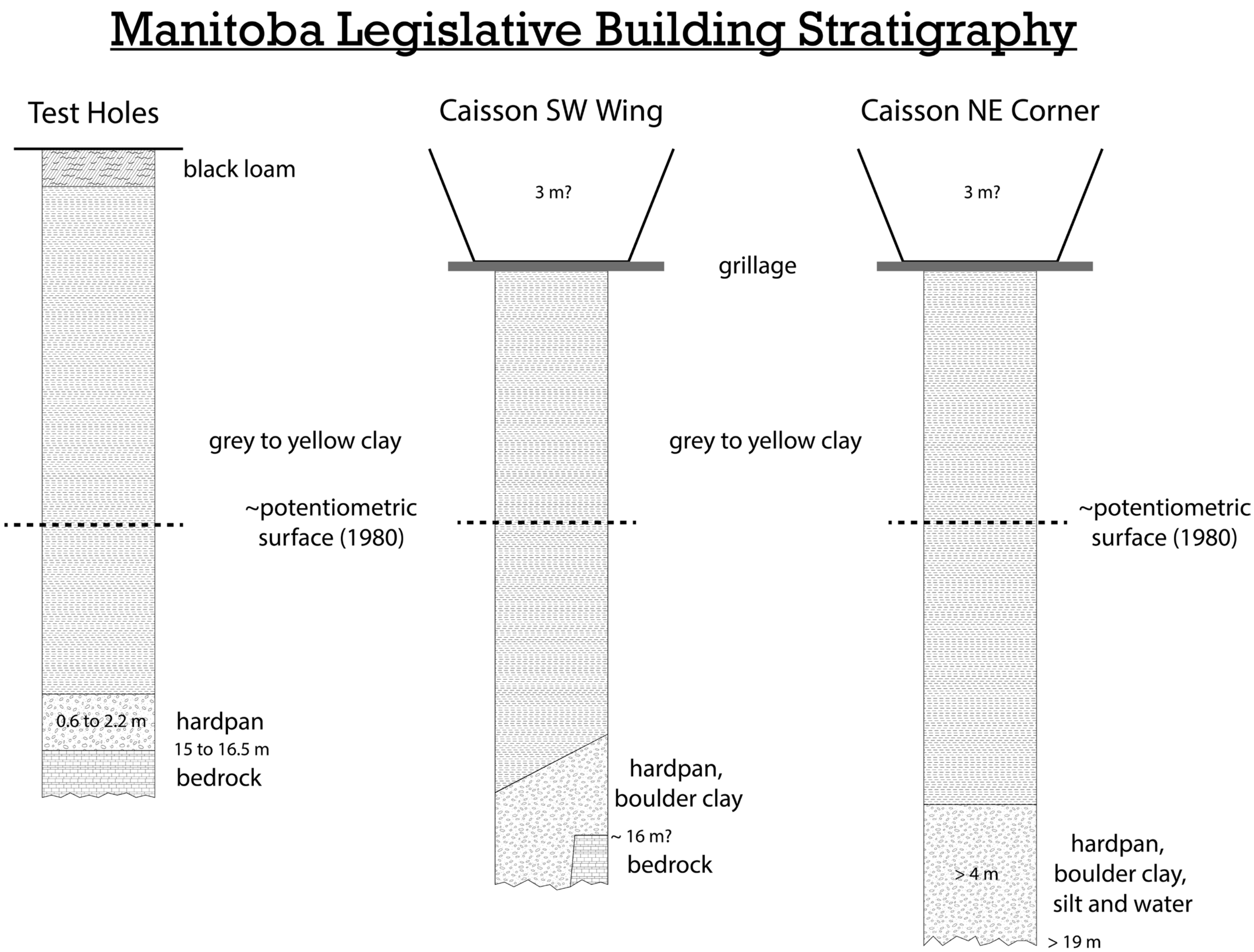

Figure 18: *The stratigraphy underlying the Legislative Building consists of bedrock, commonly overlain by a relatively thin layer of indurated till and unconsolidated boulder clay, overlain by a relatively thick layer of grey and yellow clay and capped by a thin black loam. Eight test holes bored in early 1913 indicated depths to bedrock of 15 to 16.5 m. A caisson under the southwest wing of the building encountered some bedrock, whereas a caisson in the northeast corner of the building did not encounter bedrock.* Field trip Stop 3.

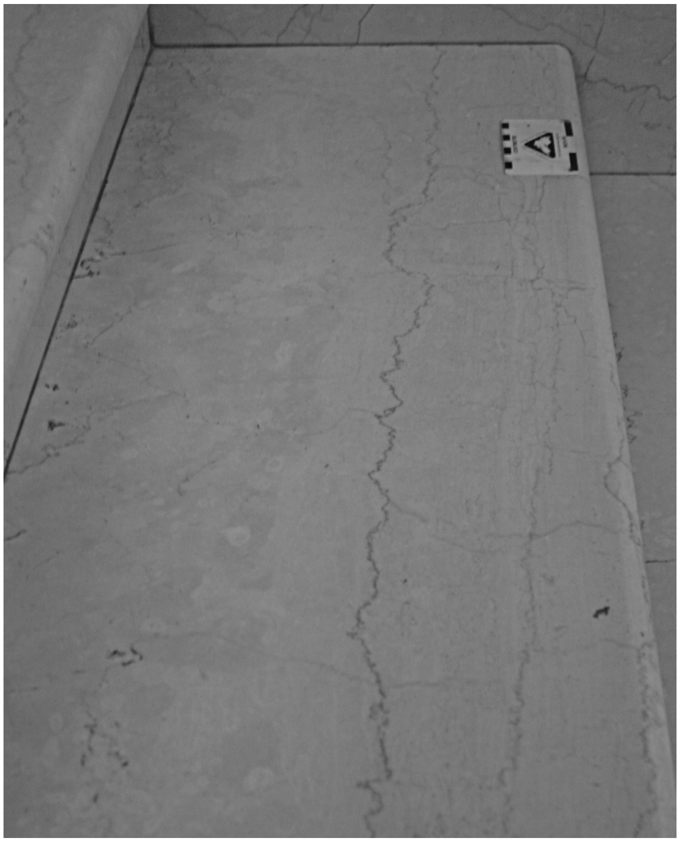

Figure 19: *Bedding in the Botticino marble is observed in some of the tread and railing tiles of the Grand Staircase. Bedding strikes from top to bottom of the image and parallel to the dark stylolite. Bedding is defined by variation in texture, including the abundance of oncolites, and colour.* Field trip stop 4.

internally (Figure 20). They are interpreted to represent algal masses. Bedding is defined by variations in the concentration of oncolites or grain size in the limestone, and bedding relationships are complex. Brown stylolites are commonly oriented parallel or subparallel to bedding orientations, although some stylolites are oblique to bedding.

Stop 5: Ordovician black marble

Location: Legislative Chamber (Figure 21)

Ordovician black marble occurs as a base wall trim along the outside of the chamber, but is best exposed on pedestals at the south end of chamber on both sides of the Speaker's chair (Figure 22).

Stop 6: Red marble breccia

Location: Room 255, Premier's Room West (alternative location: Room 254, Premier's Room East)

Red marble breccia in the Legislative Building is only used as fireplace trim in the Premier's rooms. There is little information about the stone other than from macroscopic examination of the fireplace.

Stop 7: Marbles of the Manitoba Legislative Building: Tennessee marble, Vermont Verde Antique marble, Ordovician black marble, Botticino marble and Tyndall Stone

Location: Rotunda at the top of the Grand Staircase (Figure 23)

The floor of the Rotunda area represents one of the best exposures for several of the marble types, including Tennessee marble, Ordovician black marble and Verde Antique marble. Marble tiles on the floor are set in a complex concentric and radial pattern that exploits the bedding and structural features of the rock (Figure 24). Botticino marble occurs as the carved balustrade encircling the opening to the Pool of the Black Star, and also as the moulding to the doors of the Legislative Chamber and trim at base of the walls. The walls and columns consist of Tyndall Stone.

Pink Tennessee marble is the dominant stone used in the floor of the Rotunda. It occurs largely as large rectangular tiles containing stylolites that are oriented tangential to the walls of the centre well, or as tiles in the radiating slices that contain stylolites oriented normal to the walls of the centre well. Adjacent the Rotunda, tiles have been oriented such that stylolite orientation varies from parallel to diagonal to tile length. In the

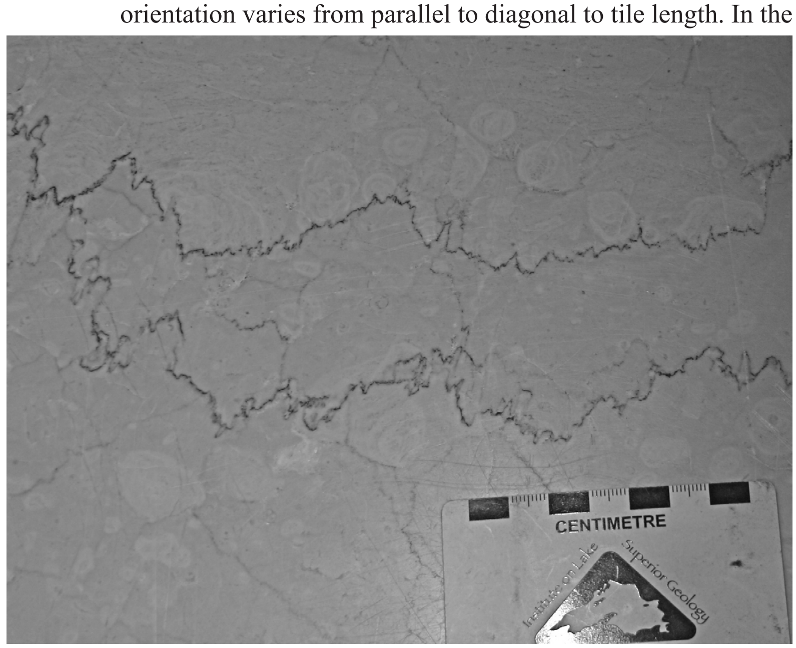

Figure 20: *Close-up of Botticino marble in a tread from the Grand Staircase. Dark stylolites crosscut the marble and define bedding orientation. The ovoid structures concentrated in the upper part of the image are considered to be oncolites. The oncolites have a concentric internal structure and are interpreted to be algal structures. Several oncolites are cross-cut by the upper stylolite in the image.* Field trip stop 4.

Figure 21: *Doors to the entrance of the Legislative Chamber are framed by Botticino marble, which occurs as the door moulding and at the base of the walls. Tyndall Stone occurs on the walls and as carved elements over the doorway. A thin strip of Ordovician black marble separates pink Tennessee marble in the floor tile in front of the doors*. Field trip stop 5.

adjacent hallway to the west, some tiles of the pink Tennessee marble display an intraformational breccia consisting of pink carbonate fragments in a lighter coloured matrix (Figure 25). Stylolites are observed in several of the breccia fragments. Red Tennessee marble occurs as smooth polished columns at the entranceways into the Rotunda. In these columns, stylolites are oriented vertically.

Ordovician Black Marble occurs as slender tiles that are laid in a circular and radiating pattern around the centre well. These tiles contain abundant echinoderm (crinoid) fragments, but cephalopods, brachiopods, bryozoans, stromatoporoids, gastropods, and corals may also be observed (Figure 26). In this area, as in many floor tiles, scratches from general wear and tear obscure the exposure.

Vermont Verde Antique marble is used as decorative floor tiles set in a band adjacent to the centre well, as diamond-like shaped tiles that increase in size away from the well, and in various geometric patterns set within the Pink Tennessee Marble. The Verde Antique is a serpentine marble containing chlorite, serpentine, and magnetite crosscut by a complex array of white calcite veins and vein sets. Some tiles display relatively wide, carbonate-bearing shear zones (Figure 27).

At this location, Tyndall Stone is used as wall tiles that have been cut and set in various orientations relative to bedding. In archways, bedding orientation is always perpendicular to the arch. Tyndall Stone is also used for intricate carvings at the tops of the columns, or in sculptures that decorate the walls. In some wall tiles there are distinctive bioclastic horizons, which are interpreted as storm lenses or layers.

Stop 8: Bedford limestone

Location: Third floor, north hallway overlooking the Grand Staircase

At this location we get a close-up view of the back and sides of the caryatids overlooking the Grand Staircase (Figure 28). The four caryatids are statues of female figures that act as architectural support columns. Each caryatid consists of a female figure facing the Grand Staircase, backed by a rectangular limestone block that further supports the overlying load. The statues were carved from grey-buff Bedford limestone that has a massive, concrete-like appearance. The limestone is relatively soft, making it ideal for carving. Although the exposure is good, the oolitic character of the limestone is difficult to see at

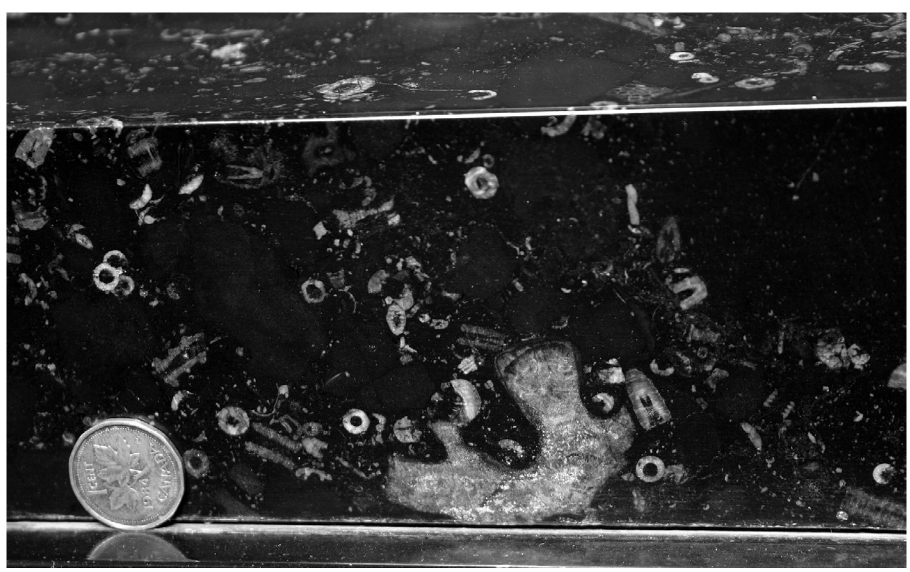

Figure 22: *Fossil-rich Ordovician black marble contains abundant echinoderm (crinoid) fragments (doughnut-shaped structures) and part of a bryozoan colony. Coin diameter is 19 mm.* Field trip stop 5.

Figure 23: The Rotunda at the entrance to the Legislative Chamber, at the top of the Grand Staircase, offers a dramatic exposure of dimension stone and its use. The walls are adorned with Tyndall Stone, which has been used on the walls and in intricate carvings such as the four columns in front of the outer wall of the Rotunda. Two smaller columns of red Tennessee marble flank the entrance to the Legislative Chamber. In front of these columns, the carved balustrade encircling the opening to the Pool of the Black Star is Botticino marble, as is the moulding to the doors of the Legislative Chamber and trim at base of the walls. Stone on the floor includes grey-pink Tennessee marble, Ordovician black marble, and green Vermont Verde Antique marble. These stones have been laid to highlight the circular nature of the room and a radiating pattern away from the centre well. Field Trip Stop 7.

Figure 24: Marble tiles in the Rotunda are set in a complex concentric and radiating pattern. The centre well on the left side of the image is walled by a balustrade of Botticino marble and bordered by Verde Antique and Ordovician black marble on the floor. The concentric pattern is defined by alternating bands of pink Tennessee marble (wider) and Ordovician black marble (narrower). The pink Tennessee marble contains tiles of Verde Antique set in various geometric shapes. Stylolites in the pink Tennessee marble are oriented tangential to the centre well. In the centre of the image, two narrow slices containing diamond-like tiles of Verde Antique radiate away from the centre well. The slices consist of two outer bands of Ordovician black marble that enclose diamond-like tiles of Verde Antique; tiles increase in size away from the centre well. The Verde Antique tiles are enclosed by pink Tennessee marble, which contains stylolites oriented perpendicular to the walls of the Rotunda. The walls are Tyndall Stone; Botticino marble occurs as floor skirting.

this location. We will be able to compare the Bedford limestone here with weathered Bedford limestone outside at Stop 12.

Stop 9: Missisquoi marble

Location: Third floor, northeast wing, rooms 309 to 311

Missisquoi marble only occurs in the northeast and northwest wings of the third floor of the Legislative Building (Figure 29). The stone is set as tiles along the north and south sides of the hallway and in the alcoves at the end of the hallway. Tiles along the sides of the hallway have an irregular mottled pattern defined by shades of light and medium grey limestone and small patches of white material. In the alcoves, light and medium grey limestone occurs in equant to ovoid structures bounded by an irregular network of dark grey limestone. The structures typically contain abundant white patches. The equant to ovoid structures probably represent domical stromatolites that have been cut parallel to bedding (Figure 8g).

Other stone used in the hallway includes Botticino marble as door mouldings and floor skirting, and Ordovician black marble that forms a border on the terrazzo tile in the centre of the hallway.

Stop 10: Tennessee marble and washroom break

Location: Basement, room 21, men's washroom

This stop will give us an opportunity for a washroom break as well as a chance to compare the red Tennessee marble to the pink Tennessee marble that we examined previously in the Rotunda. The red Tennessee marble is a fine- to medium-grained limestone that occurs on the walls and stalls (Figure 30). Like

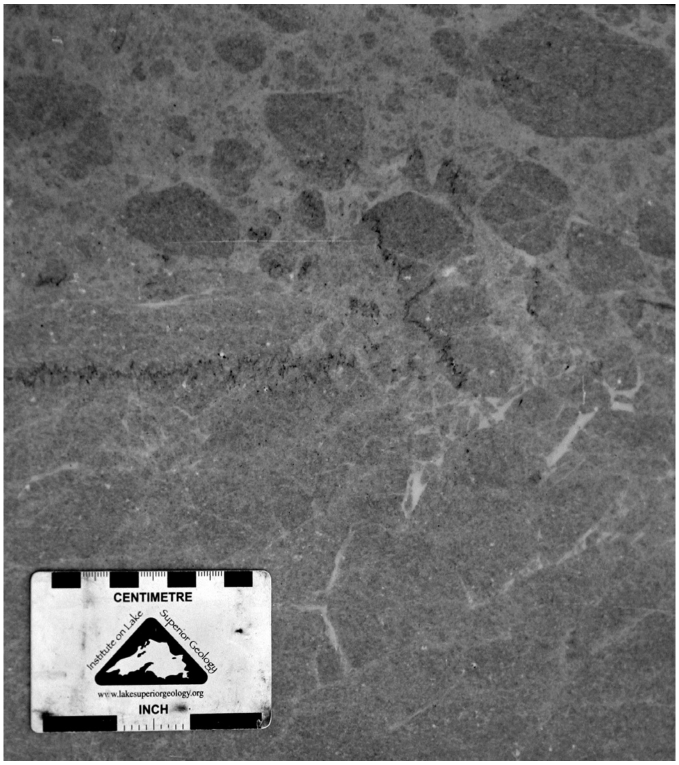

Figure 25: *Close-up of intraformational breccia in the Tennessee marble. Tiles of intraformational breccia occur in hallways adjacent the Rotunda area. Rounded to angular clasts of pink carbonate occur in a light pink to beige matrix. Veins of white carbonate and dark stylolites are truncated by the contact. Several breccia fragments contain stylolites that are truncated adjacent the matrix.* Field Trip Stop 7.

the pink Tennessee marble, the red Tennessee marble contains crinoid fragments and stylolites. Most stylolites are parallel to bedding, but on some walls the stylolites occur in two orientations. The intersection of these stylolites has involved irregular dissolution and appears to disturb bedding. Similar structures can be observed in the pink Tennessee marble in stairwell landings. The floor tile consists of terrazzo.

Stop 11: Butler granite and Tyndall Stone

Location: North portico / UTM 14U 0633101 5527478

The Butler granite occurs as steps and landings at all four exterior porticos of the Legislative Building. Typically the granite has a relatively uniform grey appearance with a random fabric, but at the north portico there are excellent examples of its gneissic character. The layered gneissosity is exemplified by variations in composition and grain size. Locally, there are patches or veins of pegmatite.

The Ionic columns resting on the granite landings are carved from Tyndall Stone. The Tyndall Stone has characteristic dark mottles considered to represent burrows made by organisms in carbonate mud. The burrows are dolomitized and the surrounding rock is limestone. The mineralogical difference between the two rock types leads to differential weathering on the ledges of the columns (Figure 31).

Stop 12: Tyndall Stone, Bedford limestone and Butler granite

Location: West portico / UTM 14U 0633097 5527430

The west portico offers excellent exposures of Tyndall Stone, Bedford limestone and Butler granite. Our attention at this stop is focused on the weathered condition of the Bedford limestone and the fossil types that occur in Tyndall Stone.

Two statues carved from Bedford limestone sit on Tyndall Stone pedestals flanking the west staircase. The statue on the north side of the stairway is Major General James Wolfe, who commanded the British troops at the Battle of the Plains of Abraham in September, 1759 (Figure 32). The statue on the south side of the staircase is Frederick Temple Blackwood, Earl of Dufferin and Governor General of Canada from 1872 to 1878. The Piccirilli Bros. of New York designed and carved both statues (Baker, 1986). Unlike the caryatids inside the Legislative Building, these statues have undergone significant weathering. The surfaces are strongly etched, highlighting the oolitic character of the stone (Figure 33).

The stair plinths, columns and walls display many of the common macrofossils found in Tyndall Stone. The most common macrofossils observed are receptaculitids, an extinct group

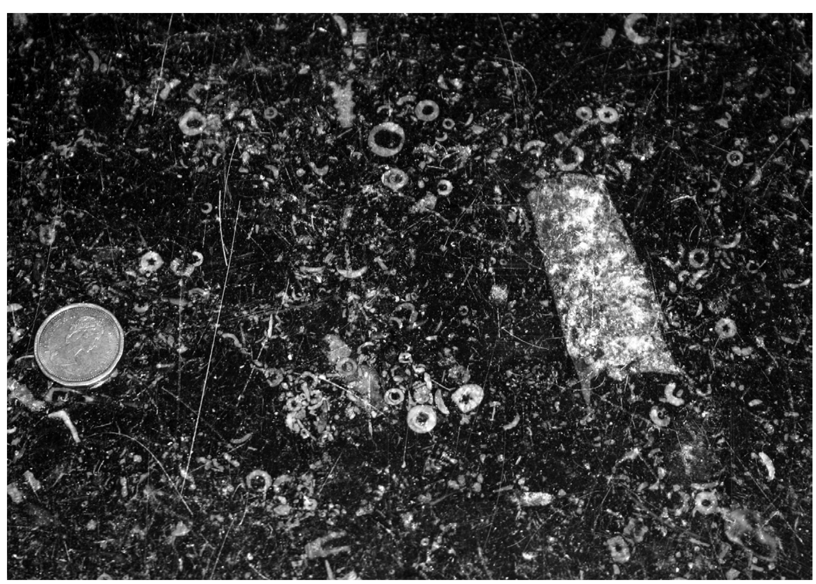

Figure 26: *Ordovician black marble in the floor of the Rotunda contains abundant echinoderm (crinoid) fragments and part of the shell of an orthoconic cephalopod. Coin diameter is 19 mm.* Field trip stop 7.

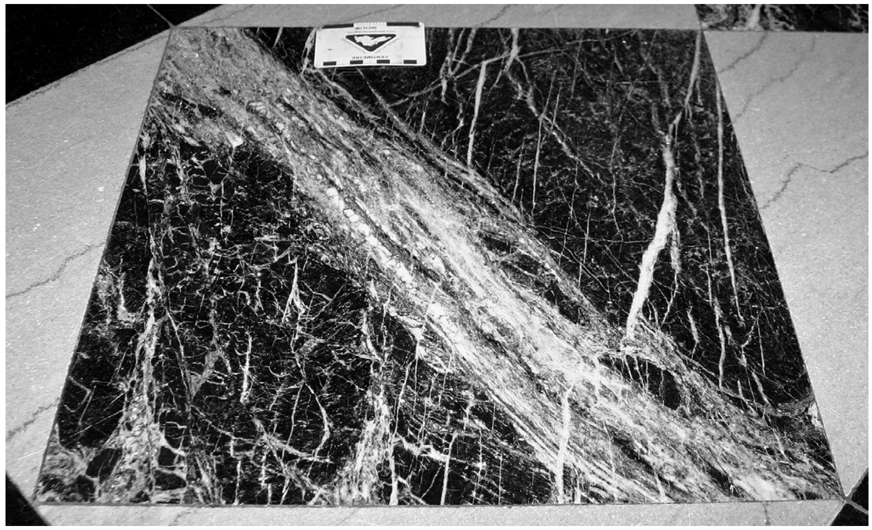

***Figure 27:** Green Vermont Verde Antique marble tile surrounded by pink Tennessee marble in the Rotunda. The tile displays numerous white veins and a relatively wide shear zone containing abundant carbonate. The veins occur in complex vein sets or as individual veins defined by different orientations. The age relationship between the veins and shear zone is problematic.* Field trip stop 7.

***Figure 28:** Profile view of caryatids in the north hallway on the third floor of the Legislative Building. The caryatids overlook the Grand Staircase. Each is carved from relatively soft Bedford limestone and backed by a smooth pillar of Bedford limestone. The statues have a concrete-like appearance that obscures their oolitic character*. Field trip stop 8.

***Figure 29:** Northeast wing hallway on the third floor of the Manitoba Legislative Building. Missisquoi marble occurs as floor tiles in the alcove at the end of the hallway, and as border tiles on the north and south sides of the hallway. Terrazzo forms square tiles in the rectangular inset extending down the centre of the hallway. The terrazzo is framed by Ordovician black marble. Botticino marble is used for the door mouldings*. Field trip stop 9.

***Figure 30:** Walls in the public washrooms are lined with red Tennessee marble. The marble displays many of the common features of the pink Tennessee marble that occurs in the Rotunda. Terrazzo forms the square floor tiles.* Field trip stop 10.

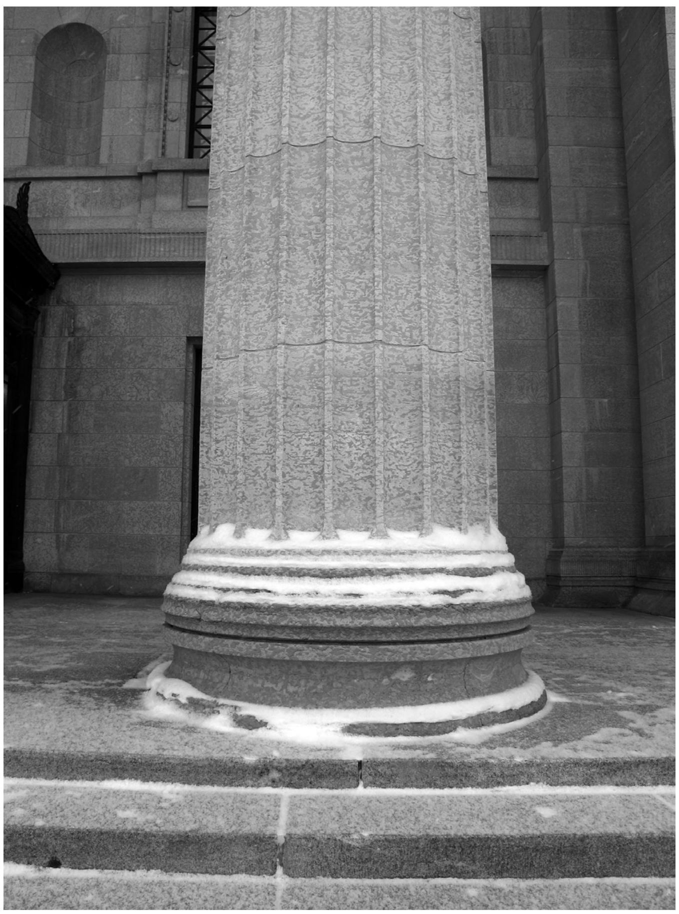

***Figure 31:** Tyndall Stone column on the north portico of the Legislative Building resting on Butler granite, winter 2012-2013. Snow has accumulated on the ledges near the base of the column. Close examination of these ledges shows differential weathering of the Tyndall Stone compared to the rest of the column. The calcite-rich part of the Tyndall Stone forms recessed areas adjacent to the dolomite-rich part.* Field trip stop 11.

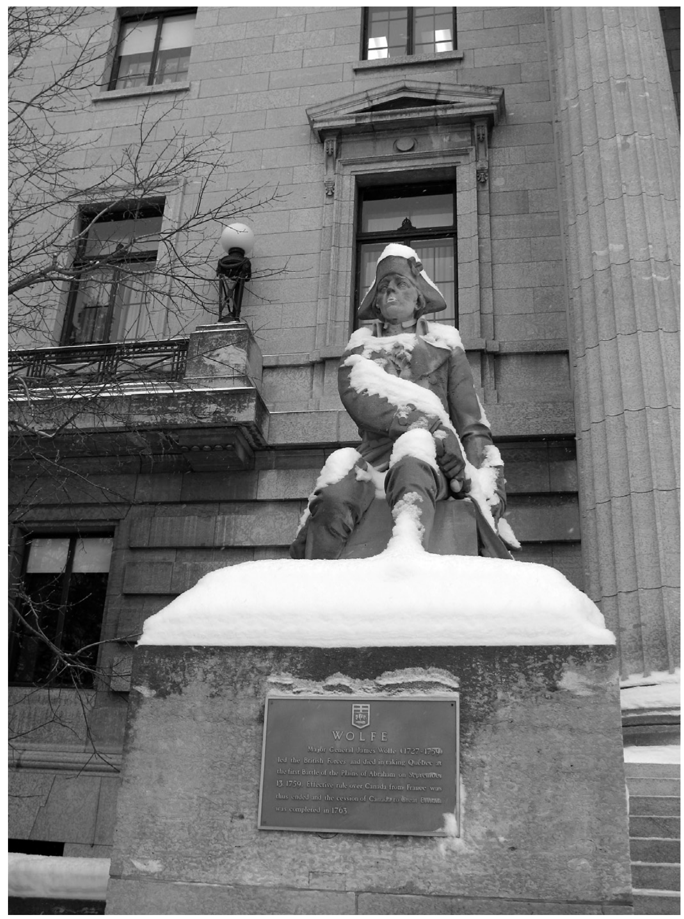

***Figure 32:** On the north side of the west portico, the statue of General Wolfe sits on a plinth of Tyndall Stone, winter 2012-2013. The statue is carved from Bedford limestone and the walls and column in the background are Tyndall Stone.* Field trip stop 12.

Figure 33: *On the south side of the west portico, the Earl of Dufferin statue is carved from Bedford limestone, winter 2012-2013. This detailed image shows the etched character of the Earl's face, due to differential weathering of the oolitic limestone.The walls and column behind the statue are Tyndall Stone.* Field trip stop 12.

of possibly calcareous green algae, but there are also solitary rugose corals (horn corals), stromatoporoid sponges, colonial rugose and tabulate corals, brachiopods, bryozoans, gastropods, and cephalopods. The most abundant bioclasts are echinoderms.

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