SERIES

Heritage Stone 9. Tyndall Stone, Canada's First Global Heritage Stone Resource: Geology, Paleontology, Ichnology and Architecture

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SUMMARY

Tyndall Stone is a distinctively mottled and strikingly fossiliferous dolomitic limestone that has been widely used for over a century in Canada, especially in the Prairie Provinces. It comprises 6–8 m within the lower part of the 43 m thick Selkirk Member of the Red River Formation, of Late Ordovician (Katian) age. It has been quarried exclusively at Garson, Manitoba, 37 km northeast of Winnipeg, since about 1895, and for the past half-century extraction has been carried out solely by Gillis Quarries Ltd. The upper beds tend to be more buff-coloured than the grey lower beds, as a result of groundwater weathering. Tyndall Stone, mostly with a smooth or sawn finish, has been put to a wide variety of uses, including exterior and interior cladding with coursed and random ashlar, and window casements and doorways. Split face finish and random ashlar using varicoloured blocks split along stylolites have become popular for commercial and residential buildings, respectively. Tyndall Stone lends itself to carving as well, being used in columns, coats of arms and sculptures. Many prominent buildings have been constructed using Tyndall Stone, including the provincial legislative buildings of Saskatchewan and Manitoba, the interior of the Centre Block of the House of Commons in Ottawa, courthouses, land titles buildings, post offices and other public buildings, along with train stations, banks, churches, department stores, museums, office buildings and university buildings. These exhibit a variety of architectural styles, from Beaux Arts to Art Deco, Châteauesque to Brutalist. The Canadian Museum of History and the Canadian Museum for Human Rights are two notable Expressionist buildings.

The lower Selkirk Member is massive and consists of bioturbated, bioclastic wackestone to packstone, rich in crinoid ossicles. It was deposited in a low-energy marine environment within the photic zone, on the present-day eastern side of the shallow Williston Basin, which was part of the vast equatorial epicontinental sea that covered much of Laurentia at the time. Scattered thin bioclastic grainstone lenses record episodic, higher energy events. Tyndall Stone is spectacularly fossiliferous, and slabs bearing fossils have become increasingly popular. The most common macrofossils are receptaculitids, followed by corals, stromatoporoid sponges, nautiloid cephalopods, and gastropods. The relative abundance of the macrofossils varies stratigraphically, suggesting that subtle environmental changes took place over time.

The distinctive mottles — 'tapestry' in the trade — have been regarded as dolomitized burrows assigned to *Thalassinoides* and long thought to have been networks of galleries likely made by arthropods. In detail, however, the bioclastic muddy sediment underwent a protracted history of bioturbation, and the large burrows were mostly horizontal backfilled features that were never empty. They can be assigned to *Planolites*. The matrix and the sediment filling them were overprinted by several generations of smaller tubular burrows mostly referrable to *Palaeophycus* due to their distinctive laminated wall linings. Dolomite replaced the interiors of the larger burrows as well as smaller burrows and surrounding matrix during burial, which is why the mottling is so variable in shape.

RÉSUMÉ

Tyndall Stone est un calcaire dolomitique distinctement marbré et remarquablement fossilifère qui a été largement utilisé

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pendant plus d'un siècle au Canada, en particulier dans les provinces des Prairies. Ce calcaire s'étend sur 6 à 8 m dans la partie inférieure du membre de Selkirk de la formation de Red River, d'une épaisseur de 43 m et d'âge Ordovicien supérieur (Katien). Il est exploité exclusivement à Garson (Manitoba), à 37 km au nord-est de Winnipeg, depuis environ 1895 et, depuis un demi-siècle, l'extraction est assurée exclusivement par Gillis Quarries Ltd. En raison de l'altération par les eaux souterraines, les couches supérieures ont tendance à être brun clair alors que les couches inférieures sont grises. Le calcaire Tyndall Stone, dont la finition est le plus souvent adoucie ou sciée, a été utilisé à des fins très diverses, notamment pour le revêtement extérieur et intérieur avec des pierres de taille à assises irrégulières, ainsi que pour les encadrements de fenêtres et les embrasures de portes. Le fini éclaté et la pierre de taille de dimension aléatoire utilisant des blocs polychromes fendus le long de stylolites sont devenus populaires pour les bâtiments commerciaux et résidentiels, respectivement. Tyndall Stone se prête également à la taille de colonnes et à la réalisation d'armoiries et de sculptures. De nombreux bâtiments importants ont été construits en Tyndall Stone, notamment les édifices législatifs provinciaux de la Saskatchewan et du Manitoba, l'intérieur de l'édifice du Centre de la Chambre des communes à Ottawa, des palais de justice, des bureaux de titres fonciers, des bureaux de poste et d'autres édifices publics, ainsi que des gares, des banques, des églises, des grands magasins, des musées, des immeubles de bureaux et des bâtiments universitaires. Ces bâtiments présentent une grande variété de styles architecturaux, des Beaux-Arts à l'Art déco, en passant par le style Château et le Brutalisme. Le Musée canadien de l'histoire et le Musée canadien pour les droits de la personne sont deux bâtiments expressionnistes remarquables.

Le membre inférieur de Selkirk est massif et se compose de roche sédimentaire carbonatée wackestone à packstone bioturbée et bioclastique, riche en ossicules de crinoïdes. Il s'est déposé dans un environnement marin à faible énergie dans la zone photique, sur l'actuel versant oriental du bassin de Williston peu profond, qui faisait partie de la vaste mer épicontinentale équatoriale couvrant la majeure partie de la Laurentia à l'époque. De minces lentilles éparses de grès bioclastique témoignent d'événements épisodiques à haute énergie. Tyndall Stone est spectaculairement fossilifère et les dalles contenant des fossiles sont de plus en plus populaires. Les macrofossiles les plus courants sont les réceptaculitides, suivis des coraux, des éponges stromatoporoïdes, des céphalopodes nautiloïdes et des gastéropodes. L'abondance relative des macrofossiles varie en fonction de la stratigraphie, ce qui suggère que des changements environnementaux subtils ont eu lieu au fil du temps.

Les marbrures distinctives – appelées "tapisserie" dans le commerce – ont été perçues comme des terriers dolomitisés attribués aux *Thalassinoides* et longtemps considérées comme des réseaux de galeries vraisemblablement creusés par des arthropodes. Dans le détail, cependant, le sédiment vaseux bioclastique a subi une longue histoire de bioturbation, et les grands terriers étaient principalement des éléments horizontaux remblayés qui n'étaient jamais vides. Ils peuvent être attribués à des *Planolites*. La matrice et les sédiments qui les remplissent sont surchargés par plusieurs générations de terriers tubulaires plus petits, principalement attribuables à des *Palaeophycus* en raison de leurs revêtements muraux stratifiés distinctifs. La dolomite a remplacé l'intérieur des plus grands terriers ainsi que des plus petits terriers et la matrice environnante pendant l'enfouissement, ce qui explique la forme variable de la marbrure.

INTRODUCTION

Tyndall Stone is a highly fossiliferous dolomitic limestone quarried northeast of Winnipeg, in southern Manitoba. It is arguably Canada's best recognized building stone, thanks to its unique composition and appearance, and widespread use in prominent buildings across the country. Its distinctive 'tapestry' is due to a striking colour mottling that is not exhibited by other building stones in Canada, and indeed elsewhere in the world. Tyndall Stone is a trade name that has been in use since the early 1900s, soon after numerous quarries were opened in the village of Garson beginning in 1895, because it was shipped by rail from nearby Tyndall. The name is now trademarked by Gillis Quarries Ltd., which is the sole remaining quarry operator.

Tyndall Stone belongs to the Selkirk Member of the Upper Ordovician (Katian) Red River Formation. It was deposited on the northeastern side of the Williston Basin, part of a shallow, tropical epicontinental sea that covered most of North America some 450 million years ago. It has been studied in detail owing to its conspicuously fossiliferous nature and the distinctive diagenetic dolomitization that was related to burrows made by infaunal invertebrates.

Stone from the Selkirk Member that is similar to Tyndall Stone was first used for masonry purposes in the construction of Lower Fort Garry, near Selkirk, which began in 1832. Subsequently, Tyndall Stone was used extensively in western Canada, notably for the Saskatchewan and Manitoba legislative buildings, completed in 1912 and 1920, respectively (Fig. 1A, B), but also in many other government buildings such as courthouses, town and city halls, and post offices, as well as banks, department stores, train stations, hotels and so forth in a variety of architectural styles. It was used to spectacular effect in the interior of the rotunda of Confederation Hall in the House of Commons, Ottawa, completed in 1922 (Fig. 2A–D). In recent decades, its use has expanded to other commercial buildings, museums, hospitals, universities and churches, as well as in residential applications, both exterior and interior. Tyndall Stone has been used for several public buildings in the USA and for Canada House (Kanada Haus) in Berlin, which houses the Embassy of Canada to Germany, completed in 2005. Upon our nomination, Tyndall Stone was formally designated as a Global Heritage Stone Resource by the International Union of the Geological Sciences in November 2022.

This paper aims to bridge geology and architecture. It reviews the geological attributes and use of the Tyndall Stone and explores in detail the nature and origin of the mottling and the burrow fabrics that were overprinted by dolomitization during burial diagenesis.

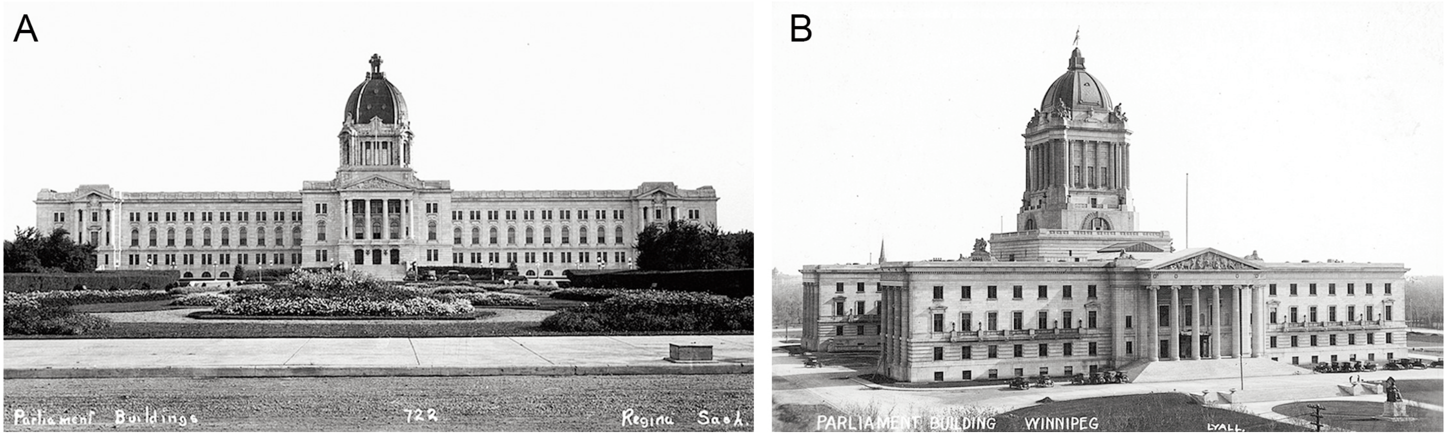


Figure 1. A. Saskatchewan Legislative Building, Regina, from a postcard of unknown origin, ca. 1925. B. Manitoba Legislative Building, Winnipeg, from a postcard by Lyall Commercial Photo Co. Ltd., ca. 1925. Images credit: PC013073 and PC013424, respectively, Prairie Postcards Collection, courtesy of Peel's Prairie Provinces (peel.library.ualberta.ca), a digital archive of University of Alberta Libraries.

BUILDING STONES

Heritage Stones

Building stone has long been the purview of quarry workers, architects, masons, tilers and interior designers, especially in North America, but in recent years there has developed increased recognition amongst geoscientists and the lay public that building stones and dimension stones are noteworthy components of both historical and modern constructions, and that they have considerable cultural, historical, archaeological, educational and scientific significance. Some stones, such as the Carrara Marble of Tuscany, have been extracted for thousands of years. For certain stratigraphic units, whose quarries have been exhausted, existing dimension stones represent a critical geological and historical record. The desire to enhance recognition of the importance of building stones led to the establishment of the Heritage Stone Subcommission of the International Commission on Geoheritage of the International Union of Geological Sciences (Pereira and Page 2017; Kaur 2022). The focus of the companion Heritage Sites and Collections Subcommission is on 'geodiversity', especially via the designation of key 'geosites'. The task of the Heritage Stone Subcommission is to encourage nominations for formal designation as Global Heritage Stone Resources.

To date, 22 stones belonging to a wide range of lithologies have been formally recognized, such as Carrara Marble (Primavori 2015), Tennessee Marble from the United States (Byerly and Knowles 2017), Larvikite from Norway (Heldal et al. 2014) and Makrana Marble from India (Garg et al. 2019), the last having been used to build the Taj Mahal. In turn, there has been media coverage of heritage stone recognition, for example, the Makrana Marble. Many others have been documented and await formal nomination and approval (e.g. Hannibal et al. 2020). We submitted a formal nomination of Tyndall Stone for heritage status in July 2022 and the proposal was ratified by the Executive Committee of the International Union of Geological Sciences in October 2022. It is the first and only Canadian stone to be nominated and receive this recognition.

Building Stone in Canada

Canada, being a comparatively young country and originally heavily forested in proximity to sites of early colonization, does not have a long tradition of building with stone, and Indigenous groups in southern Canada did not employ it for permanent structures before the arrival of Europeans. Some of the earliest stone buildings include a number of windmills, houses, towers, mills and forts in Quebec City and in the Montreal area, from the late 1600s and early 1700s. Notre-Dame de Québec church in Quebec City dates from 1647, and a stone chapel was built in Montreal in 1675. The early 1700s saw construction of the Fortress of Louisbourg in Nova Scotia and the striking Prince of Wales Fort on the shore of Hudson Bay by Churchill, Manitoba. With population growth in the 1800s, stone was used more frequently, especially in expanding urban areas like Montreal, Kingston, Ottawa and Hamilton, where there was ready access to nearby strata, mostly Middle Ordovician limestone units in eastern Ontario and adjacent Quebec, and Silurian dolostone and sandstone beds in the Niagara region (for examples of different building stone use, visit https://raisethehammer.org/authors/197/gerard_v_middleton). As the means of transportation evolved, stones were imported from further afield.

The situation was somewhat different after Canada became a dominion in 1867 and Manitoba joined the Canadian Confederation in 1870, followed later by the Northwest Territories, which included the areas that would become the provinces of Saskatchewan and Alberta. Aided by the completion of the Canadian Pacific Railway in 1885, the late 1800s saw a large influx of settlers arriving on the Prairies, and the corresponding growth of several cities, especially Winnipeg, Manitoba, which in 1911 was the third largest city by population in Canada. Like southern Ontario and Quebec, but unlike many other places on the Prairies, suitable building stone was at hand near Winnipeg, primarily Upper Ordovician dolostone and dolomitic limestone belonging to the Selkirk Member of the Red River Formation. This stone, quarried along the Red River north of Winnipeg at Saint Andrews and East Selkirk, was first

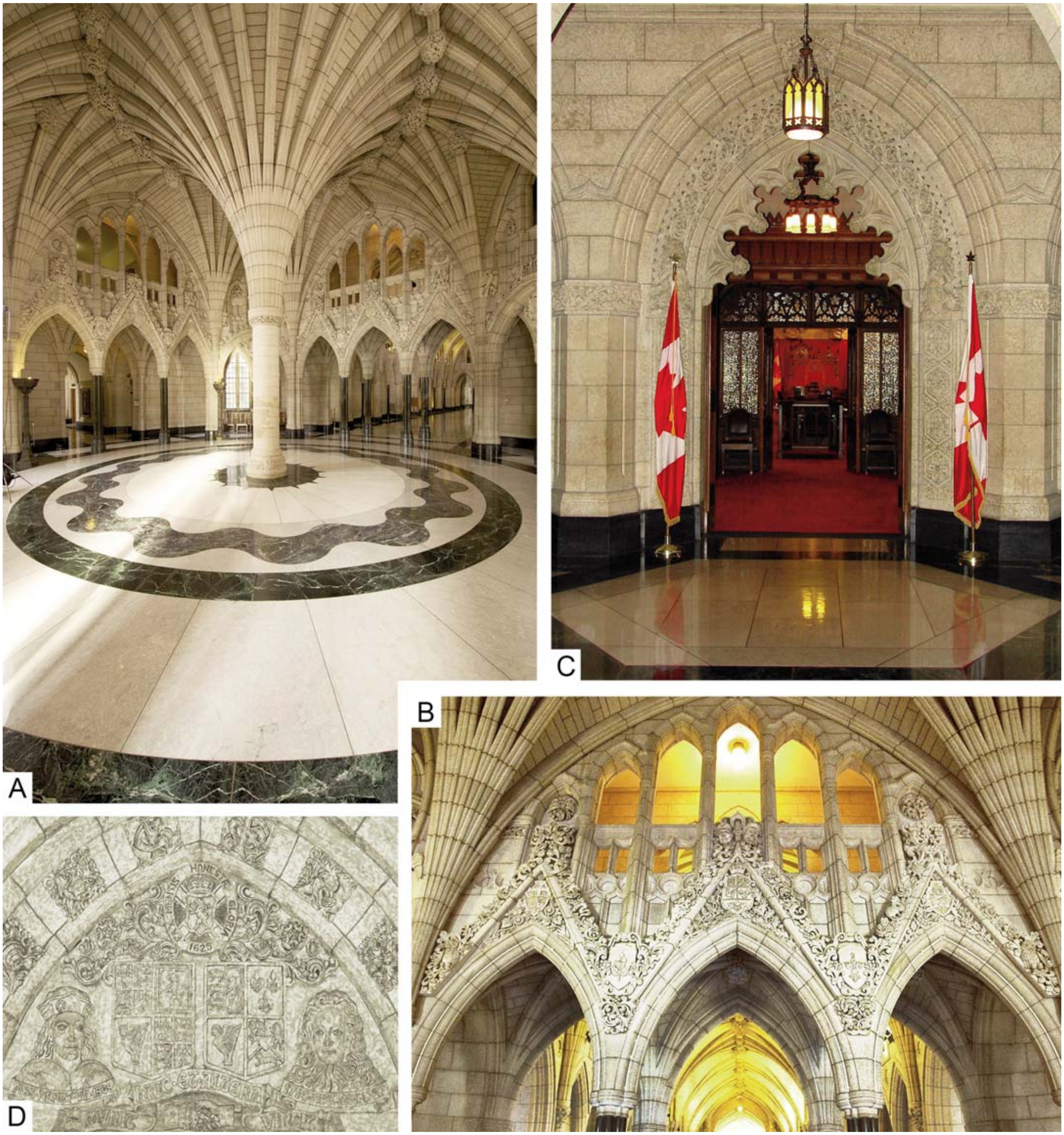


Figure 2. Elaborately carved Tyndall Stone used in Centre Block, House of Commons, Parliament Hill, Ottawa. A. The rotunda of Confederation Hall, the formal entrance to the Centre Block. It consists of a central fluted column, high-vaulted ceiling, arches, coats of arms of each province and territory, and various vegetal symbols. The floor consists of polished Missisquoi Marble from Philipsburg, Quebec, and serpentinites from Roxbury, Vermont and Tinos, Greece. The wavy pattern symbolizes the importance of water to Canada. Image credit: Canada Public Services and Procurement Canada (https://www.tpsgc-pwgsc.gc.ca/citeparlementaire-parliamentaryprecinct/decouvrez-discover/centre-eng.html). B. Detail of the Gothic arches and tympana in the rotunda above the entrance to the Hall of Honour. The two carved heads at the central gable apex show a miner (left) and a lumberjack (right) above the escutcheon of Canada. The left gable springer has an escutcheon with a trillium representing Ontario and the right one shows a fleur-de-lis representing Quebec. Image credit: Wikimedia Commons, Concierge. 2C (https://commons.wikimedia.org/wiki/File:Ottawa_-_Parliament_Hill_-_Centre_Block_10.JPG). C. Entrance to the Senate Chamber showing the carved arch and tympanum. Image credit: Canada Public Services and Procurement Canada (https://www.tpsgc-pwgsc.gc.ca/citeparlementaire-parliamentaryprecinct/decouvrez-discover/centre-eng.html). D. Tympanum at the Government Entrance to the House of Commons Chamber, showing figureheads of Henry VII (left) and George I (right) with escutcheons bearing the coats of arms of the two English kings. Image credit: courtesy of William Stewart.

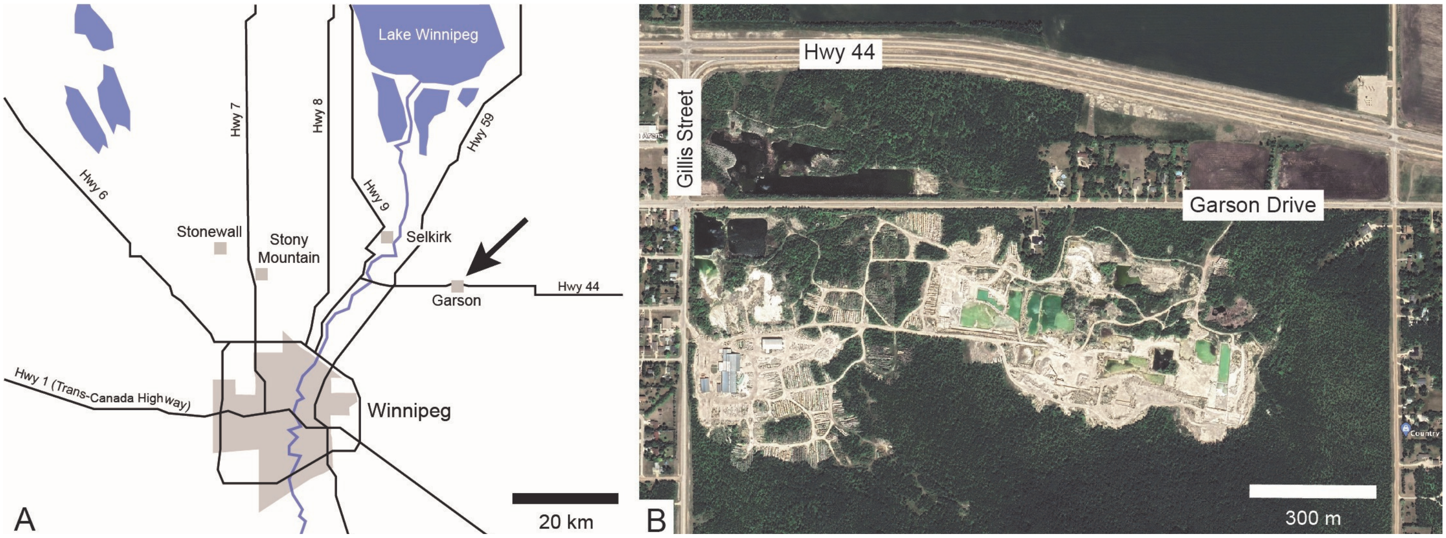


Figure 3. A. Map of the Winnipeg area of southern Manitoba, showing selected highways, the Red River and the southern end of Lake Winnipeg, the city of Selkirk, and the villages of Stonewall, Stony Mountain, and Garson (arrowed), where the Gillis Quarry is located. B. Google Earth view of Gillis Quarry in Garson.

used for the walls of Lower Fort Garry in the 1840s. It was later used as blocks for foundations in Winnipeg and elsewhere, and as finished stone in structures such as the Stony Mountain Penitentiary (1877) and Holy Trinity Church, Winnipeg (1884). By contrast, overlying dolostone units from the Stony Mountain and Stonewall formations were used for some foundations and walls (Young et al. 2008), but this was limited due to the difficulty of shaping these tough stones. As public and commercial building increased in the 1890s, the Tyndall Stone quarries at Garson were opened. Stone from the Selkirk Member, and Tyndall Stone in particular, was used in numerous other buildings especially as exterior cladding, and often carved for ornamentation.

Relatively few other Canadian limestone and dolostone units have been extracted for similar purposes. Light grey Missisquoi Marble was quarried during the first half of the 20th century at Philipsburg, Quebec, by Lake Champlain. It belongs to the Strites Pond Formation of late Cambrian age (Salad Hersi et al. 2002). It has been used for cladding, but it takes a good polish so it was mostly used as an indoor dimension stone, including in the Centre Block of the House of Commons, and several provincial legislature buildings (Lawrence 2001; Burwash et al. 2002; Ledoux and Jacob 2003; Brisbin et al. 2005). The light grey to buff Adair limestone (actually dolostone) and the strikingly laminated, grey to brown Eramosa Formation are two Silurian dolostone units extracted from southern Bruce Peninsula, Ontario.

TYNDALL STONE EXTRACTION

Quarry Location

Tyndall Stone proper was first quarried at the village of Garson in about 1895. Garson is the only place where the distinctive stone is extracted, and it has been quarried there for over a century (Fig. 3A, B). At the end of the 1800s it was known as Garson stone, from the name of the person who opened the first quarry and whose name lent itself to the village. It was also called Manitoba limestone, Manitoba Tapestry limestone and Winnipeg limestone. In the early days the stone was transported on spur lines using small steam locomotives to the village of Tyndall, about 2 km east of the quarries, where there was a freight depot on the Canadian Pacific Railway. Thus, it became better known as 'Tyndall Stone', i.e. stone shipped from Tyndall (https://www.tyndallstone.com). Tyndall Stone was extracted from several adjacent quarries owned by a number of companies in the early years (Goudge 1933, fig. 7), but most notably since 1925 by family-owned Gillis Quarries Ltd., which was incorporated in 1922. Gillis Quarries Ltd. has been the exclusive producer since 1969. Exposures of equivalent strata to the north, beyond Grand Rapids and The Pas and into adjacent east-central Saskatchewan (Nicolas et al. 2010), while containing similar fossils and burrows, lack the visually contrasting mottling against a limestone matrix because they are fully dolomitized. These rocks are utilized only for aggregate.

Quarry Operation

Tyndall Stone is extracted using standard methods for stratified limestone (Fig. 4A–D). The stone is cut vertically, using either an eight-foot (2.44 m) diameter saw or a nine-foot (2.74 m) long belt saw mounted on one hundred-foot (30.5 m) tracks. It is then split into 6–8 tonne blocks using a jackhammer and wedges inserted by hand parallel to bedding; the blocks are then moved using front-end loaders. Gillis Quarries Ltd. operates a large finishing plant with an area of about 4000 m^2. Stone is processed along advanced cutting lines that feature three primary saws and three gantry saw/line stations, four saw/profiler stations, as well as a tile line and lathe, allowing it to be cut into a variety of sizes, shapes and finishes (Fig. 4E, F) as specified by the architects (https://www.tyndallstone.com). These finished pieces are delivered to the customer and no further fabrication is required. Even though Tyndall Stone is extracted from just a single, privately owned and operated quarry, the property is large and the Selkirk Member is widely distributed in the Garson area. Thus, there

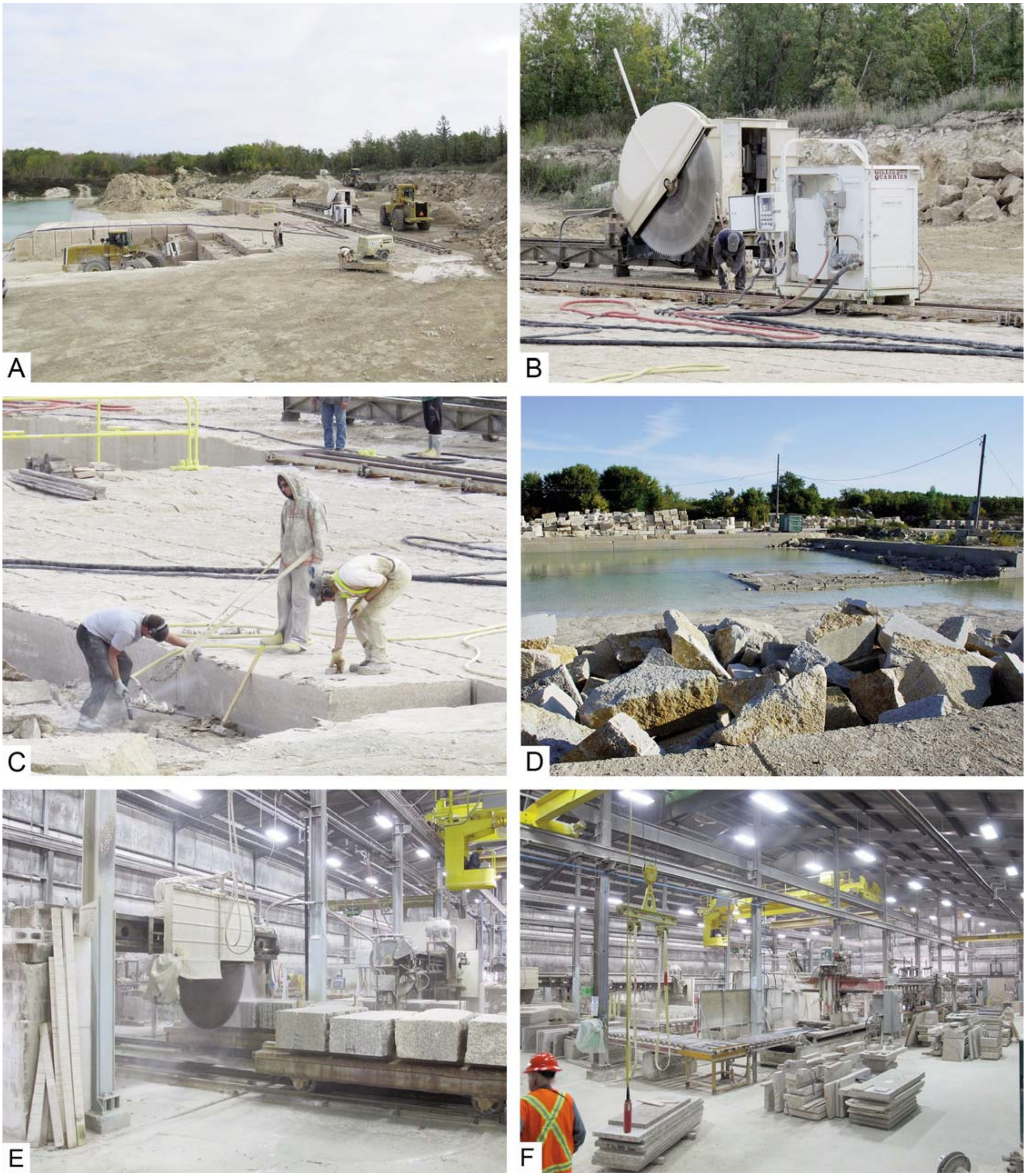


Figure 4. Gillis Quarry in operation at Garson. A. Extracting blocks from the middle zone. B. Circular saw and belt saw (white box) on movable tracks. C. Jackhammering cut blocks so that they split apart along stylolitic horizons. D. Flooded lower zone with stacked blocks behind; blocks are aged prior to cutting into slabs. E. Sawing blocks into slabs in the finishing plant. F. Various sawn slabs and pieces prepared according to customer specifications.

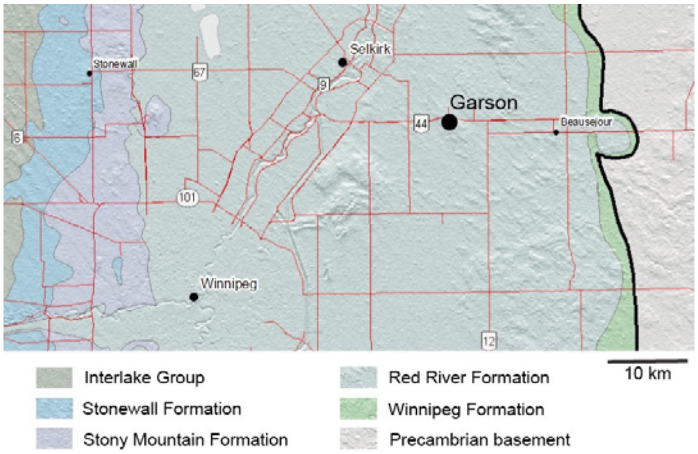


Figure 5. Geological map of the Winnipeg area, southern Manitoba. Adapted from Nicolas et al. (2010).

is no prospect of stone supplies running out in the foreseeable future.

TYNDALL STONE GEOLOGY

Stratigraphy

The Upper Ordovician to lower Silurian succession cropping out in west-central to southeastern Manitoba consists of nearly flat-lying limestone and dolostone beds dipping imperceptibly to the west (Fig. 5). These strata originated as carbonate sediment deposited on the eastern side of the Williston Basin, a shallow epeiric (epicontinental) sea in the centre of Laurentia, the early Paleozoic North American craton (Fig. 6A, B). Tyndall Stone is formally part of the Selkirk Member of the Red River Formation (Fig. 7). In the early 20th century before modern stratigraphic nomenclature was established, it was called the Upper Mottled Limestone (Dowling 1900). Tyndall Stone occurs within the lower half of the 43 m thick member; the lowest horizon in the Garson quarries is about 10 m above

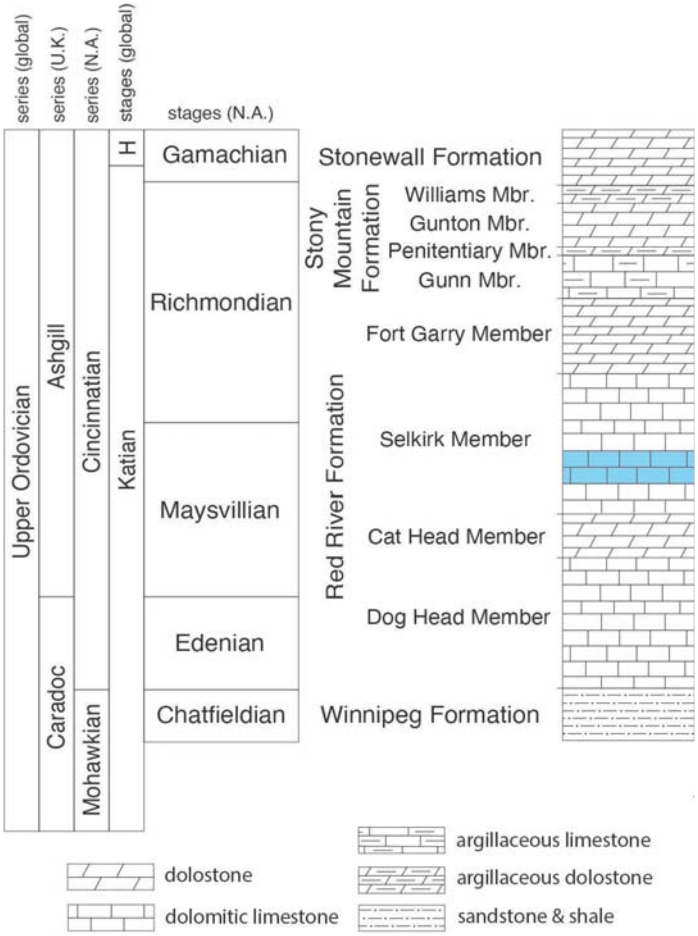


Figure 7. Stratigraphic framework of the Tyndall Stone (Selkirk Member of the Red River Formation) in the Williston Basin, southern Manitoba. The interval from which Tyndall Stone is extracted is highlighted. Adapted from Elias et al. (2013, fig. 6).

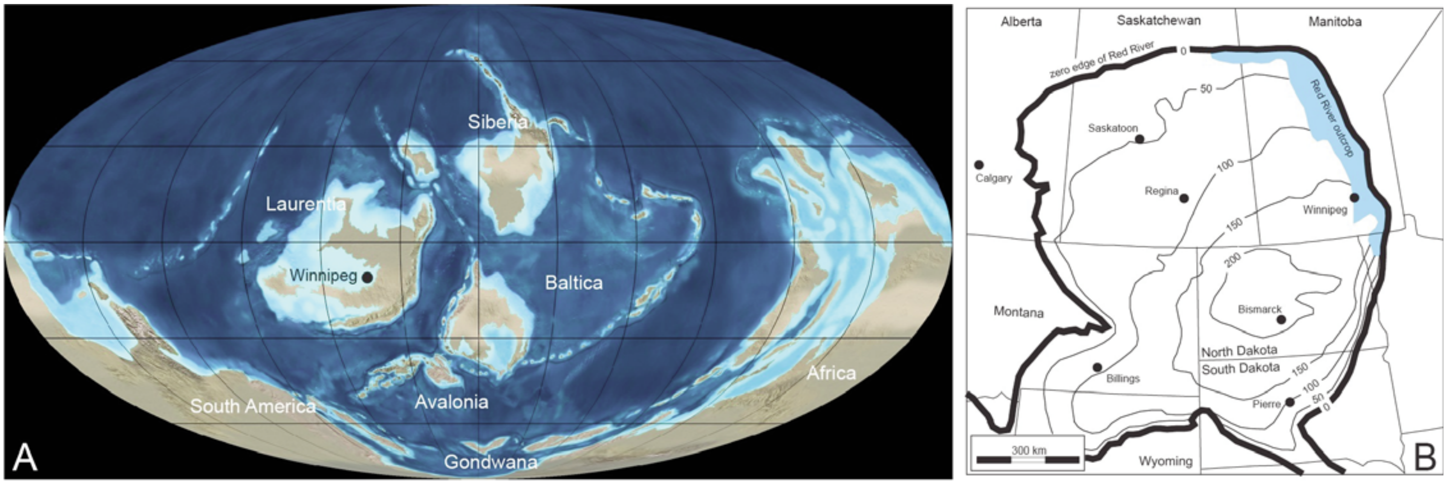


Figure 6. Global and regional context of Upper Ordovician strata in central North America. A. Paleogeography of Laurentia and other cratons with shallow epicontinental seas shown in light blue, and the location of Winnipeg, Manitoba. Map courtesy of R. Blakey and DeepTimeMaps™, Colorado Plateau Geosystems Inc. B. Isopach map of the Red River Formation in the Williston Basin. From Pratt and Haidl (2008), based on sources cited therein (see also El Taki and Pratt 2012, fig. 4A). Contour interval is 50 m.

the top of the underlying Cat Head Member (Goudge 1944; Cowan 1971; Young et al. 2008). In terms of North American Late Ordovician chronostratigraphy, the Selkirk Member is Maysvillian to early Richmondian (~ 450 Ma) in the Cincinnatian Series (Young et al. 2008), which is equivalent to the middle part the global Katian Stage. The Red River Formation correlates with the Surprise Creek Formation of the upper part of the Bad Cache Rapids Group across the Severn Arch in the Hudson Bay Basin (Jin et al. 1997; Lavoie et al. 2022). Tropical, shallow-water conditions were present across much of Laurentia at this time and correlative strata are widely distributed, from west Texas and New Mexico to the Arctic Islands and northwest Greenland (e.g. Sweet and Bergström 1984; Holland and Patzkowsky 2009; Jin et al. 2012, 2013; Cocks and Torsvik 2021). The invertebrate biota defines the Red River–Stony Mountain Faunal Province due to its similarity over the whole region, which contrasts with that of parts of eastern North America (Elias 1981, 1991; Young et al. 2008). Broadly similar limestone units of Middle and Late Ordovician age were deposited in other areas of the world, notably in the Baltic Basin, exposed in southern Sweden, southern Finland, Estonia and the St. Petersburg area of western Russia (e.g. Nestor et al. 2007). These strata bear some similarity to fabrics present in the Upper Ordovician units in Manitoba.

Tyndall Stone is dolomitic limestone. Dolomite is secondary, having replaced limestone during burial. Most of it is concentrated in and around burrows; this gives the rock its characteristic mottled appearance. The relative proportion of dolomite to calcite is therefore variable. According to Goudge (1933, 1944), chemically it is 83.21–89.26% $CaCO_3$ and 9.43–14.91% $MgCO_3$. According to Parks (1916), the light-coloured matrix averages 94% calcite and the darker coloured mottles average 71% $CaCO_3$, the rest being $MgCO_3$. Silica makes up 1.5% in both. There is a slight increase in iron oxide and clay in the burrows. The former could be due to a small amount of pyrite or iron enrichment in the dolomite, or both; it may also reflect contamination from iron-bearing groundwaters. The cream to light-buff colour of much of the Tyndall Stone is likely due to the effects of groundwater flow during Quaternary interglacial episodes, which affected the surface deposits by oxidizing trace amounts of iron in both the matrix and the dolomitic mottles. Some beds, particularly those lower in the quarries, retain a greyish colouration.

Lithology

Tyndall Stone is a massive dolomitic limestone; a pseudo-bedding is locally imparted by horizontal stylolites. It is an abundantly fossiliferous, bioclastic packstone and locally wackestone (in Dunham terminology). Intraclasts are rare, confined to the bases of some grainstone lenses. Stylo-bedding surfaces exposed by splitting and removal of overlying rock are lumpy due to the differences between the limestone matrix and the dolomite and may show the scattered areal distribution of robust fossils such as large stromatoporoid demosponges (Fig. 8A). Sawn quarry walls show that the stromatoporoids and colonial corals are typically concentrated at certain horizons (Fig. 8B) but other macrofossils seem to be more sporadically distributed (Fig. 8C–F), except where they have been collected together by redeposition during high-energy events (Fig. 8C, D).

In thin section, the matrix around the macrofossils is a biomicrite (in Folk terminology). Bioclasts, as whole and fragmented shells and skeletons of a wide range of sizes, occur in variable amounts and are surrounded by a microcrystalline calcite matrix (Fig. 9A–D). These small fossils are mostly not visible on rock surfaces and include a variety of taxonomic groups, such as crinoid ossicles, trepostome bryozoan skeletons, gastropods, brachiopods, dasycladalean calcareous algae, tetradiids, small solitary rugose corals and problematical skeletons of unknown but possible algal affinity. The variable orientation of the bioclasts within the matrix indicates that the sediment was mostly completely mixed due to bioturbation.

Some preferential alignment of nautiloid conchs and solitary rugose corals is apparent (Wong 2002), which suggests the presence of comparatively weak, west–east oscillatory currents. There is an upward increase in the presence of planar-laminated, normally graded, fossiliferous bioclastic grainstone lenses and remnants of lenses that escaped complete bioturbation (Fig. 8C, D), which have been interpreted as sediment deposited by occasional storms (Westrop and Ludvigsen 1983; Wong 2002). If so, this suggests a gentle shallowing such that the seafloor came within ambient storm wave base, or that storms became more frequent and/or stronger. Alternatively, if these record weak tsunami effects (cf. Pratt and Bordonaro 2007), then they may reflect episodic faulting, likely in the basin centre where syndepositional fault movements are recorded in overlying laminated facies by synsedimentary deformation structures (El Taki and Pratt 2012).

Paleontology

Fossils are commonly visible on sawn surfaces of Tyndall Stone. There is no comprehensive taxonomic listing, but the most complete one is in Young et al. (2008). Among the most conspicuous of the macrofossil biota are the molluscs. They include hyperstrophic gastropods belonging to *Maclurina* (Fig. 10A; also Fig. 11E) and turbinate gastropods probably belonging to *Hormotoma* (Fig. 10B). These are commonly preserved as shell moulds filled with dolomite microspar from replacement of microcrystalline calcite that records lime mud that infiltrated the cavities. Nautiloids are represented by a diverse assemblage that includes the straight-shelled actinocerid *Armenoceras* (Fig. 10B, E), straight-shelled endocerids possibly belonging to *Cameroceras* (Fig. 10C) and cyrtoconic nautiloids with curving conches such as the discosorid *Winnipegoceras* (Fig. 10D, F). Often the septa and conch walls have been either abraded or dissolved, or both, with partially preserved moulds filled with dolomitized microcrystalline calcite, and all the primary shell material that remains is the heavily calcified axial siphuncle. The segmented, beaded siphuncles of the actinocerids, whether exposed on glacially transported boulders or in the walls of buildings, are commonly misidentified by casual observers as vertebrate backbones. The dolomite that fills shell moulds points to dissolution of aragonite at and just under the sediment surface.

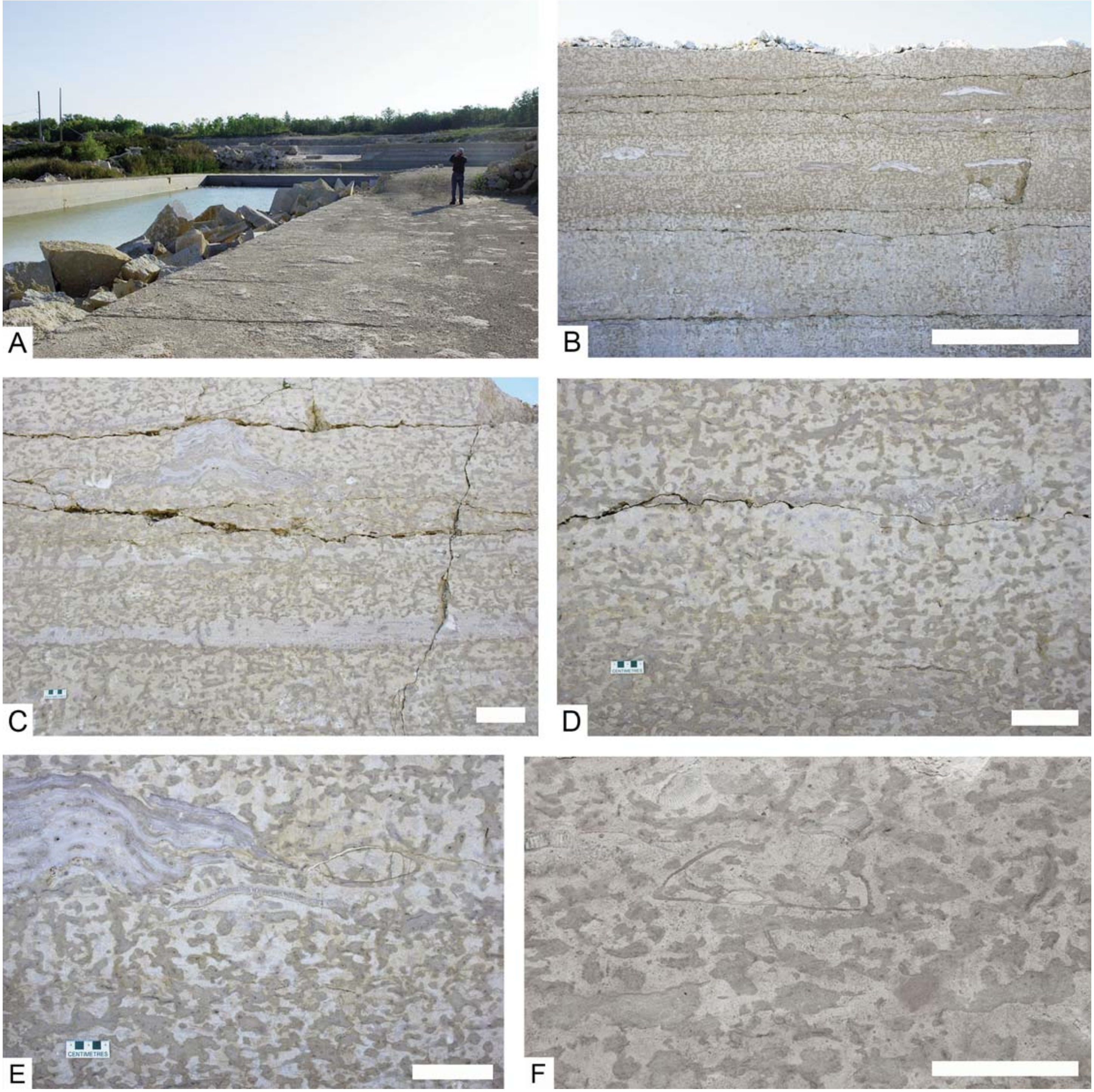


Figure 8. Exposures of Tyndall Stone in Gillis Quarry. A. Bedding plane with scattered domical stromatoporoids and colonial corals, partially flooded lower interval to the left, and upper interval in the background. Person for scale. B. Sawn wall in the upper interval with numerous stromatoporoids and colonial corals visible as thin lenses. Scale bar is 1 m. C. Sawn wall showing dolomite-mottled limestone with two thin layers of bioclastic grainstone (lighter coloured layers across and below middle; also Figure 15E), and cross-section of a high-relief domical stromatoporoid with intercalated sediment (upper left of centre). Scale bar is 10 cm. D. Sawn wall showing dolomite-mottled limestone, with burrowed grainstone (upper right). Scale bar is 10 cm. E. Sawn wall showing dolomite-mottled limestone with cross-sections of a receptaculitid (above centre), domical stromatoporoid (upper left), and a curving nautiloid (upper right). Scale bar is 10 cm. F. Sawn wall showing dolomite-mottled limestone and cross-section of large gastropod belonging to *Maclurina*. Scale bar is 10 cm.

Corals include horn-shaped solitary rugose corals, most of which belong to *Grewingkia* (Fig. 11A), colonial rugose corals belonging to *Crenulites* (Fig. 11C, D) and tabulate corals, which are colonial, belonging to the chain corals *Catenipora* (Fig. 10C) and *Manipora* (Fig. 11B), the honeycomb corals such as *Saffordophyllum,* and the common, domical *Calapoecia* (Fig. 11F). Dis-

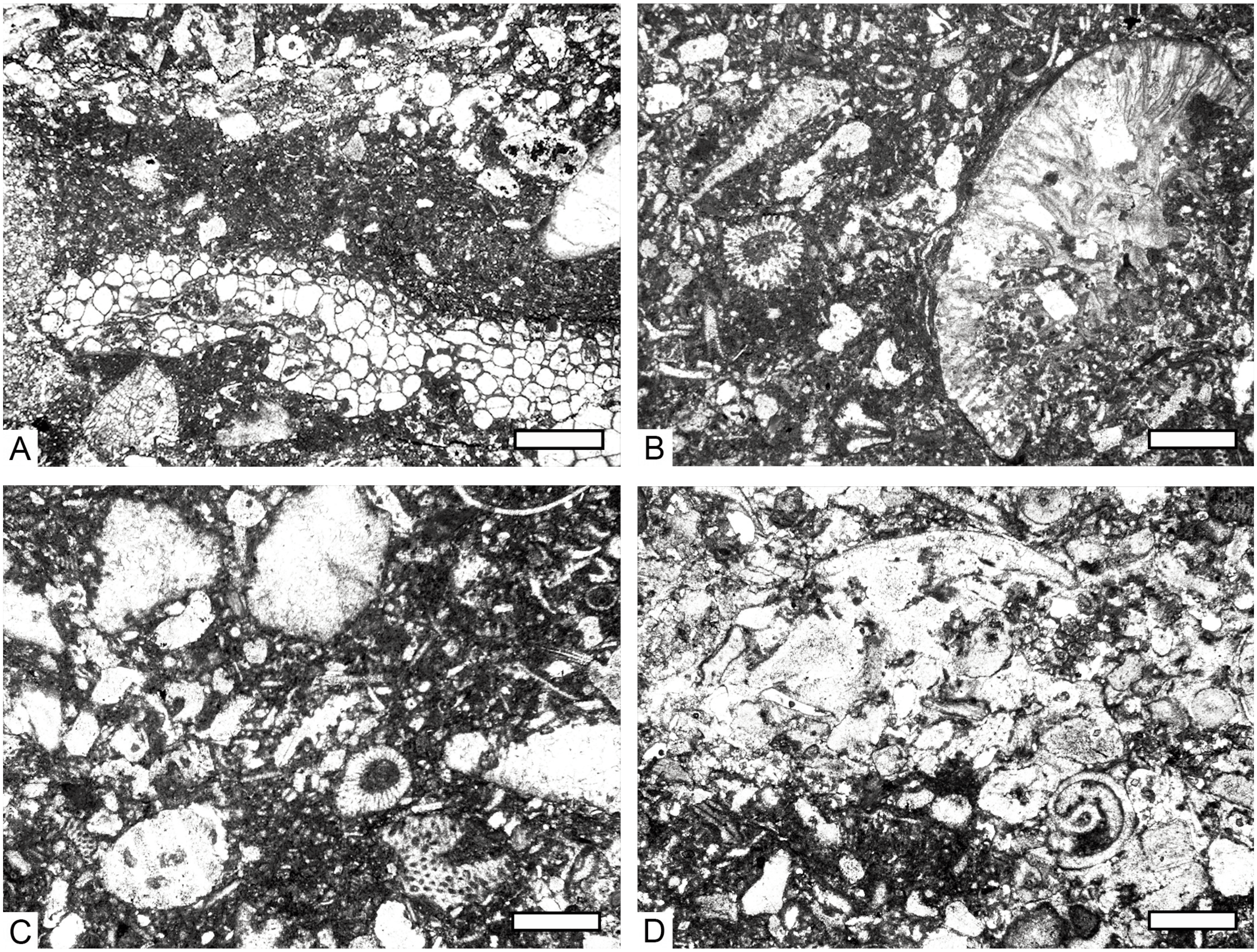


Figure 9. Thin section photomicrographs of biomicrite matrix of Tyndall Stone. Plane-polarized light, greyscale; oriented perpendicular to bedding. A. Possible calcareous alga (lower) overlain in turn by wackestone (middle) and packstone (upper) consisting mostly of crinoid ossicles plus lime mud, with a trepostome bryozoan (lower left). Scale bar is 2 mm. B. Wackestone to packstone matrix with abraded solitary rugose coral (right), dasycladalean green alga (centre left), and smaller bioclasts many of which are crinoid ossicles. Scale bar is 2 mm. C. Wackestone to packstone containing common crinoid ossicles, dasycladalean algae (lower right) and other bioclasts. Scale bar is 1 mm. D. Wackestone overlain by crinoidal packstone with a small gastropod (lower right) and abraded fragment of gastropod shell (upper centre). Scale bar is 1 mm.

tinctive on many Tyndall Stone surfaces are white laminar fossils with a dense microstructure that cannot be discerned even with a hand lens. These are the tabulate corals *Ellisites* and *Protrochiscolithus,* which were obligate encrusters, especially on stromatoporoids (Fig. 11E), but are difficult to distinguish on sawn surfaces. They often preferentially exhibit vertical borings termed *Trypanites,* which are absent in other shells and skeletons, apart from generally lesser numbers in solitary rugose corals and stromatoporoids (Elias 1980; Stewart et al. 2010).

Labechiid stromatoporoids are also common, forming tabular to dome-shaped masses of varying diameter and height, with internal growth lamination and ragged margins reflecting episodic lateral expansion and contraction (Figs. 8C, E, 11E). Siliceous sponges are rare.

Receptaculitids assigned to *Fisherites* are distinctive fossils in both plan and vertical views of Tyndall Stone (Fig. 12A–C). They are circular in plan view, but in vertical view are tabular to undulating to gently domical, and they may appear variable depending on the plane of horizontal section. Receptaculitids are composed of individual, interlocking skeletal elements termed meroms with a spiral orientation, which is why they have been called ‘sunflower corals’. Specimens with the meroms partially disaggregated are also observed. They are replaced mostly by blocky calcite which is suggestive of a primary aragonite composition, yet they do not appear to have been leached and infiltrated with lime mud like the molluscs. The affinity of receptaculitids is unknown but they are commonly regarded to have been a form of calcareous algae (Nitecki et al. 1999). This is supported by their absence in deeper water deposits in the Saskatchewan subsurface (Kendall 1976).

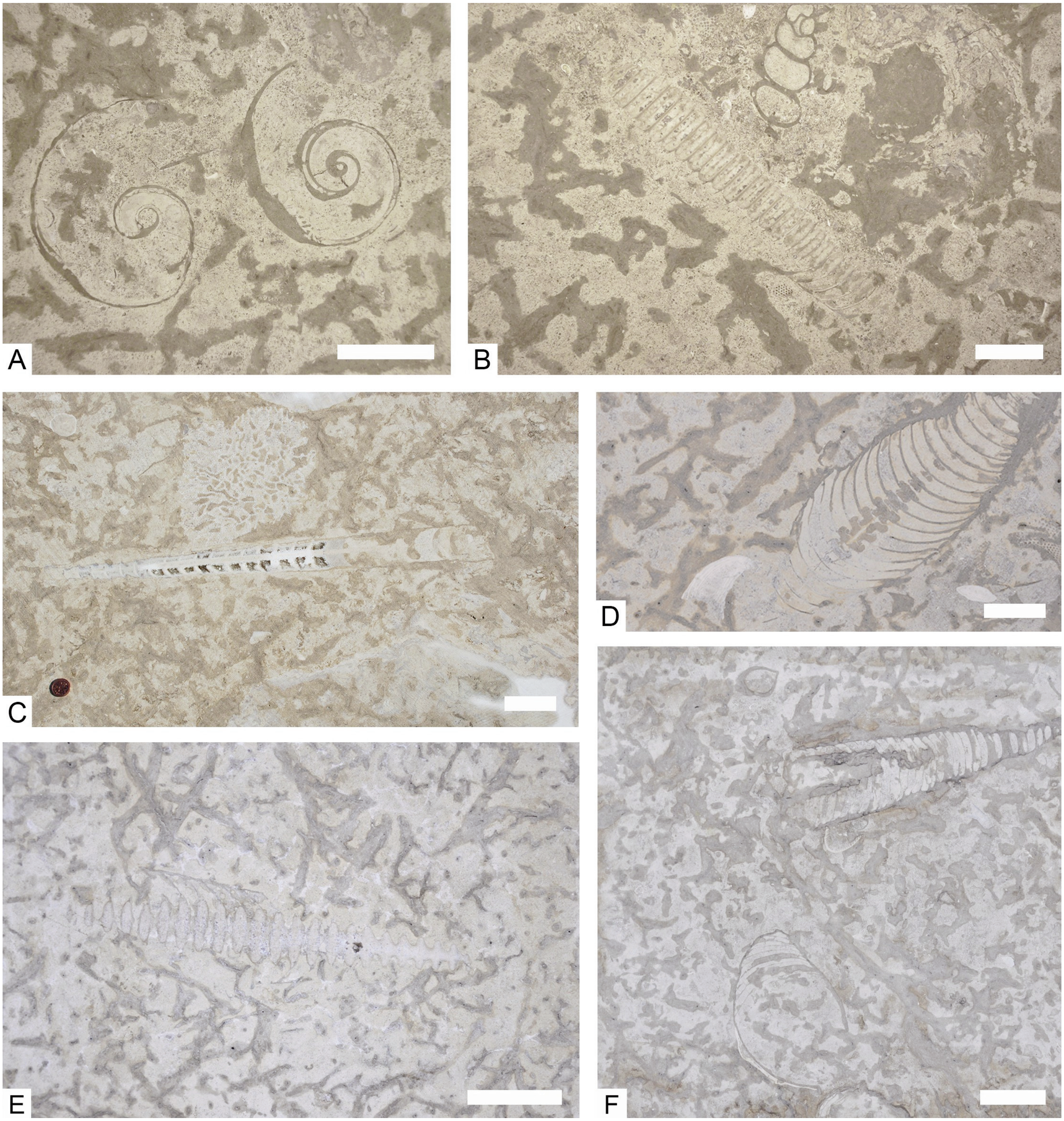


Figure 10. Fossil molluscs in Tyndall Stone, sawn parallel to bedding. Apart from calcitic siphuncles, shells were dissolved and the moulds are filled with dolomudstone. Scale bars are 5 cm. A. Two large hyperstrophic gastropods with a flattened base belonging to *Maclurina*. Polished, memorial wall to students who fell in the Second World War, Department of Geological Sciences, University of Saskatchewan. B. Large high-spired gastropod belonging to *Hormotoma* (upper centre) and part of actinoceratid nautiloid cephalopod, belonging to *Armenoceras*, preserving mostly the beaded siphuncle, with some septa (lower right). Same location as A. C. Endoceratid nautiloid (middle) preserving septa and siphuncle (left) but dissolved towards the aperture (right), with chain coral belonging to *Catenipora* (upper centre). Sawn surface, Gillis Quarry. D. Cyrtoconic nautiloid with dolomudstone-filled siphuncle, with rugose coral probably belonging to *Grewingkia* (lower left). Honed finish, exterior of TCU Financial Group building, Saskatoon. E. Siphuncle of actinoceratid nautiloid belonging to *Armenoceras*, preserving a few septa (left of centre). Honed finish, interior presentation wall, same location as D. F. Partially burrowed endoceratid nautiloid (upper centre) and possible cyrtoconic nautiloid (lower left) encrusted with a thin *Prototrochiscolithus* coral (white lamina). Same location as D.

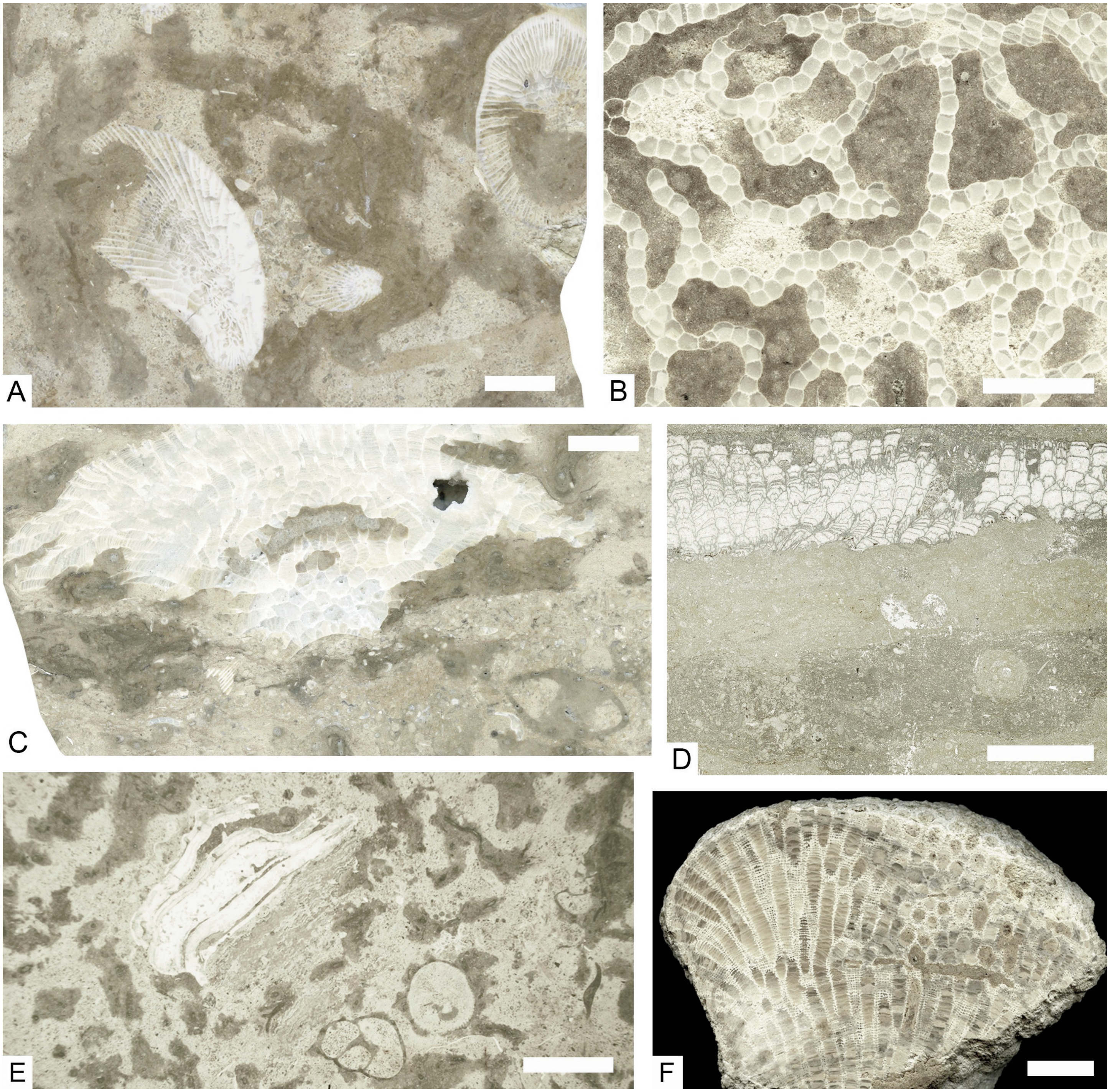


Figure 11. Corals in Tyndall Stone. All polished surfaces except D, which is a scanned, vertically oriented thin section. A, C, D = rugose corals; B, E, F = tabulate corals. A. Two large and one small solitary corals belonging to *Grewingkia*. Skeleton at left is perforated by numerous borings. Surface cut perpendicular to bedding. Scale bar is 2 cm. B. Close-up of chain coral belonging to *Manipora*. Surface cut parallel to bedding. Scale bar is 10 mm. C. Domical honeycomb coral belonging to *Crenulites*, with gastropod (lower right). Surface cut perpendicular to bedding. Scale bar is 2 cm. D. Bioclastic packstone with horizontal burrow conforming to *Planolites* (lower right) overlain in turn by wackestone and tabular honeycomb coral belonging to *Crenulites*. Vertical section. Scale bar is 2 mm. E. Stromatoporoid (indistinct laminae in centre) encrusted by several generations of dense, white-coloured skeletons belonging to tabulate corals *Protrochiscolithus* and/or *Ellisites*, with two gastropods probably belonging to *Hormotoma* (lower right). Surface sawn parallel to bedding. Second World War memorial wall. Scale bar is 5 cm. F. Tabulate coral belonging to *Calapoecia*. Surface cut vertical to bedding. Scale bar is 10 mm.

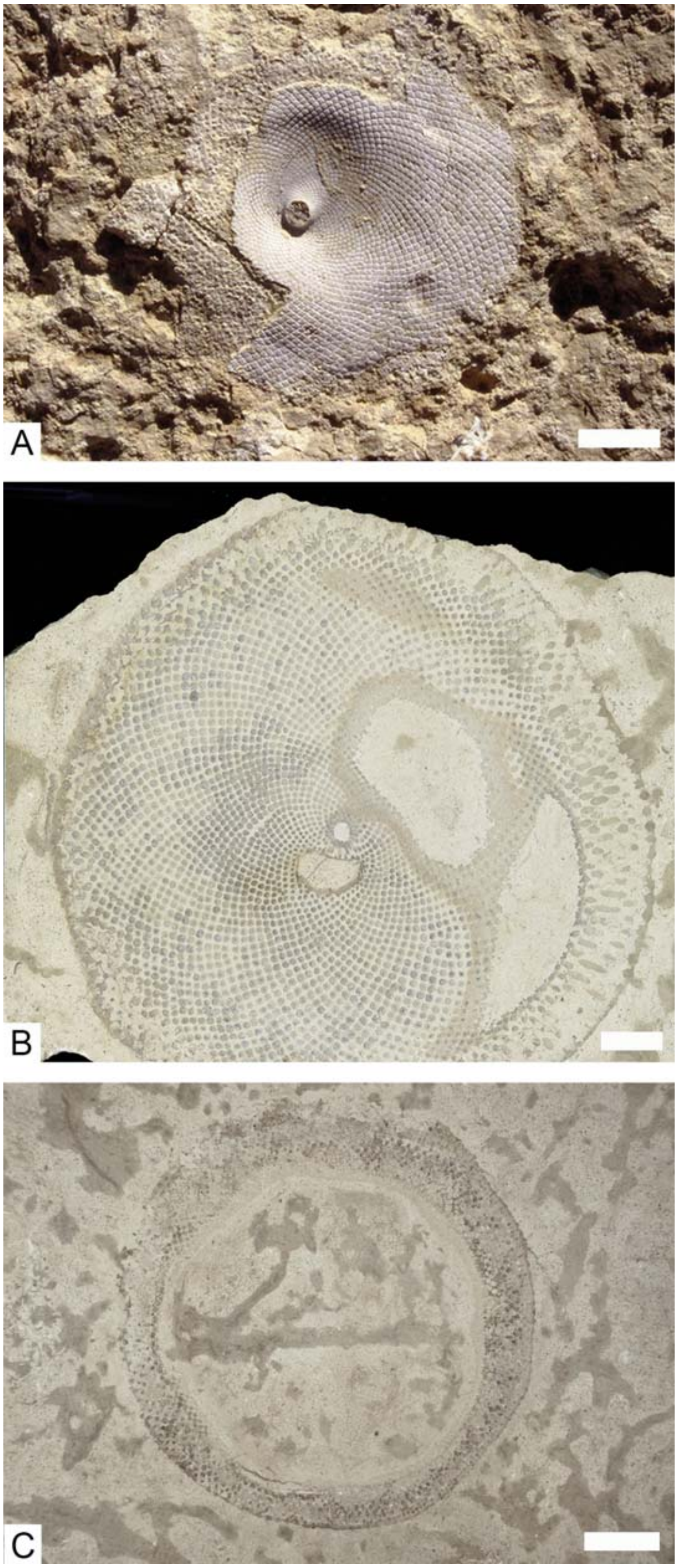


Figure 12. Plan views of tabular to gently domical receptaculitids belonging to *Fisherites*. A. Split surface at Gillis Quarry, Garson. Scale bar is 2 cm. B. Honed finish, surface sawn parallel to bedding. Scale bar is 2 cm. C. Polished, surface sawn parallel to bedding, Second World War memorial wall. Scale bar is 5 cm.

Paleoecology

Receptaculitids are the most common macrofossil type (Wong 2002; Brisbin et al. 2005; Young et al. 2008). Collectively the corals rival the receptaculitids in abundance, but in terms of individual groups the next most common fossil is solitary rugose corals. Cephalopods, stromatoporoids and gastropods are the next most common groups. Trilobites and brachiopods are present (Westrop and Ludvigsen 1983; Jin and Zhan 2001) but are difficult to identify on sawn surfaces. A striking feature of the biota is that many groups tend to be large in comparison with the same or related taxa in correlative strata elsewhere, such as in eastern Ontario (Young et al. 2008; Jin et al. 2012). The reason for this 'gigantism' is uncertain but may reflect abundant food resources at the base of the food chain, which was passed onto some of the higher trophic groups. Alternatively, some aspect of seawater temperature may have been conducive to enhanced growth rate or longevity. Stable environmental conditions also would have permitted organisms such as corals to grow to larger size, in comparison with environments with frequent disturbance of the seafloor.

In the Gillis Quarry, there is an overall upward increase in the abundance of stromatoporoids, receptaculitids, *Protrochiscolithus*, and colonial rugose corals, and increased abrasion of the solitary rugose corals, which suggests a gradual shallowing (Wong 2002). On the other hand, the relative abundances of solitary rugose corals and nautiloids decrease upward (Wong 2002). Other elements like tabulate corals show no obvious trends. Both *Maclurina* and *Hormotoma* appear to show an upward increase in size, whereas average nautiloid size remains more or less constant (Wong 2002). The relative proportion of tabular to domical coral and stromatoporoid growth forms is similar throughout (Wong 2002).

Near the base of the quarry section, more than half the solitary rugose coral skeletons are abraded, the proportion rising to more than 80 percent in the overlying strata. This interval shows a decrease in the number of stromatoporoids and receptaculitids, and the proportion of solitary rugose corals, and is thought to record a slight deepening (Wong 2002) and a small increase in sedimentation rate (Young et al. 2008). Other skeletons and shells, however, do not exhibit a similar degree of abrasion, although tabulate corals may also be broken and some actinocerid siphuncles are broken transversely. Breakage of small bioclasts is evident. It seems that physical reworking does not explain all these observations, and thus the cause is unclear.

The seafloor substrate was apparently soft, as indicated by the distribution of the skeletons of large benthic fossils, the abundance of lime mud and absence of evidence for distinct firmground or hardground surfaces. At the same time, it was somewhat consolidated, being able to support large skeletons, the visible burrows retained their shape, and moulds of dissolved molluscs did not collapse before they were infilled with lime mud. Shells and skeletons comprised the only hard substrates, and as a result they were encrusted by a variety of organisms (Young et al. 2008). Common examples included obligate encrusters such as the corals *Protrochiscolithus* and *Ellisites,* and also stromatoporoids, the coral *Calapoecia* and bryozoans. The occurrence of 'stacks', consisting of the skeletons of several different organisms that grew sequentially on top of one another, demonstrates that hard substrates were sporadically developed, and some of them were exposed on the seafloor for considerable lengths of time (Young et al. 2008). Many of these hard substrates also exhibit macroborings (Elias 1980; Stewart et al. 2010), a further indication of long-term exposure on the seafloor. Calcite cementation began under relatively shallow burial. This may have been below ~ 20 cm, as suggested by the vertical extent of burrows and the presence of intraclasts only in some grainstone lenses, eroded and redeposited during the stronger scouring events.

Combining the macrofossil biota with petrographic observations, the muddy seafloor had large quantities of small shells, skeletons and fragments mixed in, on which grew meadows of crinoids, representing the upper-tier suspension feeders. Lower-tier suspension feeders were tabulate corals, stromatoporoids, bryozoans, siliceous sponges, brachiopods, as well as *Maclurina* (Novack-Gottshall and Burton 2014). Rugose corals may have been microcarnivores. The trilobites were mobile detritus feeders and suspension feeders and/or scavengers. The turbinate gastropods were mobile deposit-feeders or herbivores. Delicate photosynthetic dasycladalean calcareous algae were rooted in the muddy sediment. Receptaculitids may have been sessile photosynthesizers. The nautiloids were likely nektobenthic predators. A variety of infaunal organisms burrowed the sediment. Undoubtedly there were soft-bodied animals and possibly green algae that are not preserved. An important point is that, despite the presence of common corals and stromatoporoids, and the propensity of some corals and stromatoporoids to encrust one another, there are no framework reefs or bioherms in the Tyndall Stone, or anywhere in the outcrop belt of the Red River Formation, although there are some small patch reefs at the top of the Selkirk Member equivalent in the Saskatchewan subsurface (Pratt and Haidl 2008).

Tyndall Stone's abundantly fossiliferous nature has inspired museum reconstructions of the paleoecological setting of the Late Ordovician tropical seafloor, such as the exhibit at the Manitoba Museum which blends the Selkirk Member and Stony Mountain Formation (Fig. 13A; Young et al. 2008, fig. 5). The display in the Stonewall Quarry Park, Stonewall (Fig. 13B, C) is supposed to reflect the biota in the Selkirk Member rather than the younger, less fossiliferous Stonewall Formation, which is the interval exposed in the quarry. Nevertheless, as is usual with such reconstructions, there is some artistic license taken, especially in the unrealistic crowding of the various biotic elements and the seafloor topography. In older dioramas receptaculitids were portrayed as globular (Fig. 13A), but a lower domical shape is more likely (Fig. 13C). Reconstructions in the USA are based on approximately correlative strata from the Cincinnati, Ohio area which consist of a different facies (e.g. https://www.priweb.org/blog-post/vanished-worlds; https://lsa.umich.edu/paleontology/resources/beyond-exhibits/life-through-the-ages.html), and that in the Redpath Museum, McGill University, Montreal, Quebec, reflects the Upper Ordovician of the Saint Lawrence Lowlands which also consists of different facies (https://www.mcgill.ca/redpath/article/ordovician-diorama).

TYNDALL STONE MOTTLING

Bioturbation

Description

The limestone exhibits brownish mottling due to the presence of dolomite that has incompletely replaced the original limestone. This unique and aesthetically desirable 'tapestry' of Tyndall Stone comes alive with its appearance on surfaces sawn parallel to bedding (Fig. 14A–D). From a distance the margins of the mottles appear sharp, but in detail they may be somewhat diffuse; in no case do they exhibit a distinct wall that comprises their margins. Locally the sharpness has been enhanced in vertical view by pressure solution and subhorizontal stylolite formation (Fig. 15A).

In horizontal view, the dolomitic mottles range from irregular to roughly circular and lobate patches, to elongate and seemingly branching to commonly crudely reticulate. Occasionally there are strikingly long, straight to curvilinear, sinuous features up to ~ 50 cm in length (Fig. 14C). Width of these domains is variable, up to ~ 4 cm wide. Where linear mottles are well defined, they are typically ~ 1–2 cm and occasionally up to 3 cm wide. In vertical view, the dolomitic domains are also variable in shape, from similarly circular to lobate to branching both vertically and horizontally (Fig. 15A–E).

Where grainstone lenses are interbedded, mottles are typically concentrated in the matrix just under them (Figs. 8C, 15E). Larger mottles intersect these lenses subvertically from the top, and they range from cylindrical to irregularly lenticular in shape and some penetrate the whole layer. Narrow, horizontally oriented, cylindrical mottles are also present.

The interiors of the mottles exhibit a swirly aspect imparted by various shades of brown and greyish brown; multiple generations of cross-cutting, cylindrical to tubular burrows can be discerned (Fig. 16A–F). These darker coloured, more distinctly defined curvilinear to irregularly sinuous burrows, are dominantly roughly horizontal (Fig. 16A–D) but also locally oblique and rarely vertically oriented (Figs. 15D, 16F). These burrows possess darker coloured linings. Their diameter is 5–13 mm. Many have a core 2–10 mm wide, cemented by dolomitic blocky microcrystalline calcite that is often leached leaving linear pores (burrow porosity); in some cases, there is geopetal dolomite on the bottoms of these pores. In addition, the dolomite that fills mollusc shell moulds commonly contains similar curvilinear burrows. Branching burrows 1 mm in width are locally preserved in the matrix inside nautiloids. Packstone-filled burrows that are not dolomitized are also locally visible in the limestone matrix.

In thin section, the mottles are seen to consist of brownish, variably dolomitized biomicrite in which bioclasts are still typically evident in the dolomicrite (Fig. 17A, B), although fewer in number than in the matrix; the larger, mostly robust particles like crinoid ossicles have escaped replacement (Fig. 17C). The interiors of the mottles typically show one or more horizontal burrows exhibiting the same features as those visible on sawn surfaces, that is, dolomitic calcite-cemented tunnels sur-

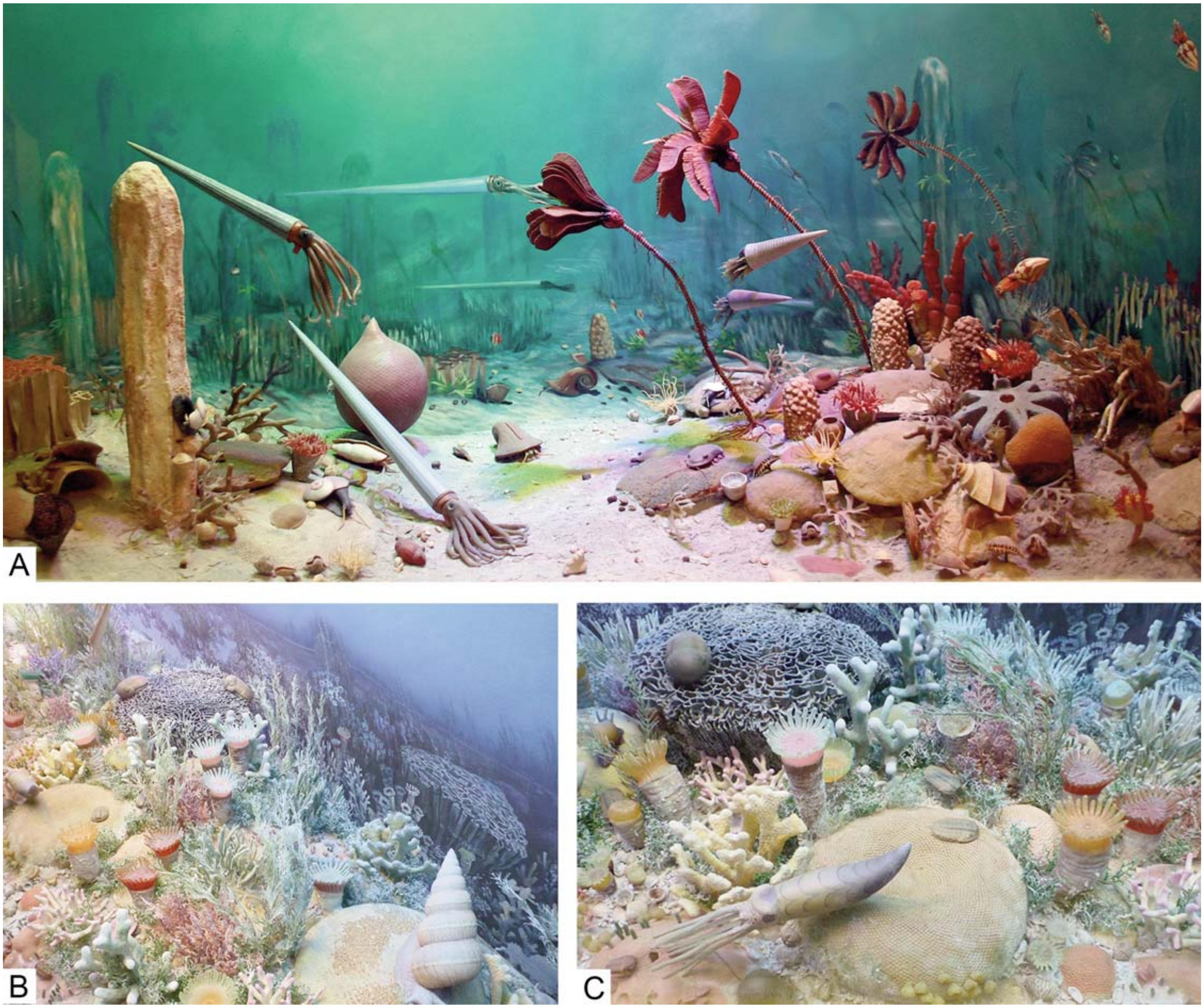


Figure 13. Museum dioramas showing reconstructions of the seafloor during deposition of Ordovician sedimentary rocks, including the Tyndall Stone (Selkirk Member). A. Manitoba Museum, Winnipeg, dating from the 1970s, composite of Ordovician biotas from Red River and Stony Mountain formations showing columnar aulacerid sponge, elongate orthocone nautiloids, globular receptaculitid, gastropods (snails) and other benthic invertebrates at left, and crinoids (sea lilies), short nautiloids, rugose and tabulate corals and other invertebrates at right. Copyright Manitoba Museum. B and C. Stonewall Quarry Park, Stonewall, dating from the early 2000s, showing rugose and tabulate corals including chain corals, domical receptaculitids, gastropods, trilobites, brachiopods and other invertebrates. These dioramas take some artistic license, such as crowding the organisms and exaggerating the seafloor topography in B and C. Used with permission from the Town of Stonewall Quarry Park Heritage Centre, 166 Main Street, Stonewall, Manitoba.

rounded by brownish, crudely concentric laminae and haloes. The margins of the dolomite mottles are not confined to these burrows and, rather, extend beyond them. Whereas the biomicrite matrix is clearly churned, in that bioclasts are variably oriented, in places straight to curvilinear burrows are recognizable. In cross-section some of these also have concentric linings and are filled with biomicrite in which the bioclasts range from variably to crudely concentrically oriented (Fig. 17D).

Comparable Facies

While the distinctive colouration and dolomitic mottling selectively overprinting limestone are unique to Garson, comparable burrow types are common to other Ordovician limestone and dolostone occurrences deposited in a similar low-energy, subtidal setting, including in equivalent dolostone beds of the Red River Formation nearby and far to the north on the northeastern side of the basin (Fig. 18A), and in broadly correlative limestone units in the Hudson Bay Basin across the Severn Arch (Fig. 18B). The former show well-defined, cross-cutting burrows that are 1–1.5 cm wide. More detailed fabrics are not visible, however, due to the complete dolomitization. The Gunton Member of the Stony Mountain Formation, which is

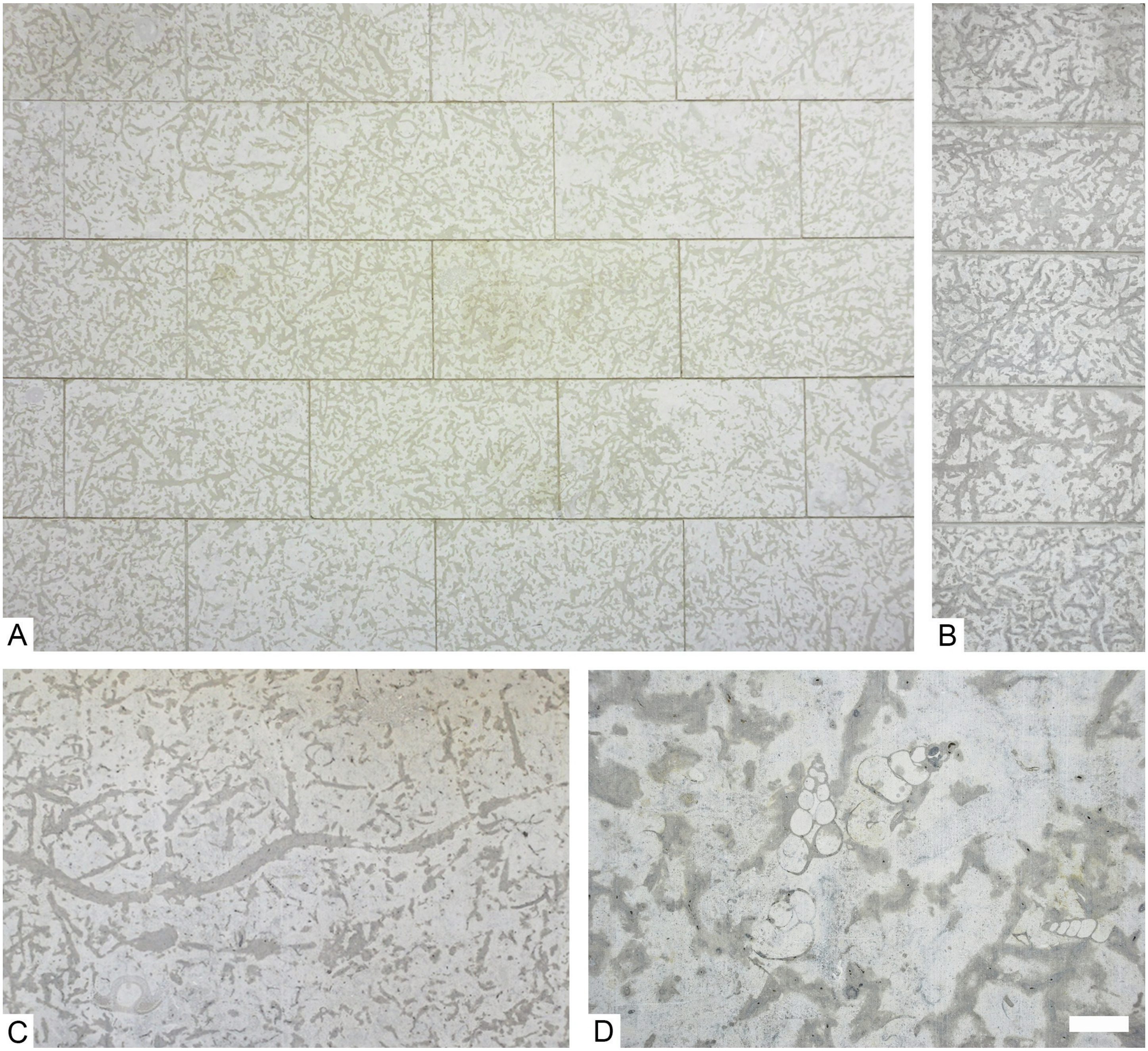


Figure 14. Walls sawn parallel to bedding with honed finish, showing the variation of shapes of dolomite mottling ('tapestry'). A. Exterior wall. Old bank building, Prince Albert, Saskatchewan. Slabs are 15 x 36 inches (~ 38 x 91 cm) in size. B. Exterior wall showing linear, elongate, irregular, branching, reticulate and circular shapes. Surfaces are 43 cm x 53 cm in size. Health Sciences Building, University of Saskatchewan. C. Interior wall with large sinuous mottle (across middle) overprinting curvilinear burrow. Mottle is 1 m in length. Health Sciences Building. D. Exterior wall showing relatively narrow mottles, with cluster (centre) of gastropods probably belonging to *Hormotoma*. Health Sciences Building. Scale bar is 3 cm.

younger than the Selkirk Member, also shows dense burrow patterns including long and reticulate features (Elias et al. 2013, fig. 29). In limestone of the Chasm Creek Formation of the Hudson Bay Basin, dolomite mottles are slightly narrower but well delineated, indicating a close morphological relationship with the original burrow fabrics (Fig. 18B). Besides some vertically oriented burrows, the networks may exhibit primary branching, unlike those in Tyndall Stone, suggesting a somewhat different behaviour, although this is not certain. Middle Ordovician limestone units of the Baltic Basin show comparable features but dolomitization of burrows is patchier, so only parts of burrows are replaced (Fig. 18C). Many younger fine-grained limestone beds deposited in low-energy subtidal conditions exhibit similar fabrics of backfilled branching and intersecting burrows (Fig. 18D).

Local iron staining in the Stony Mountain Formation, while in a different facies than the Selkirk Member, shows the bioturbation fabrics in striking detail, suggesting that burrowing in

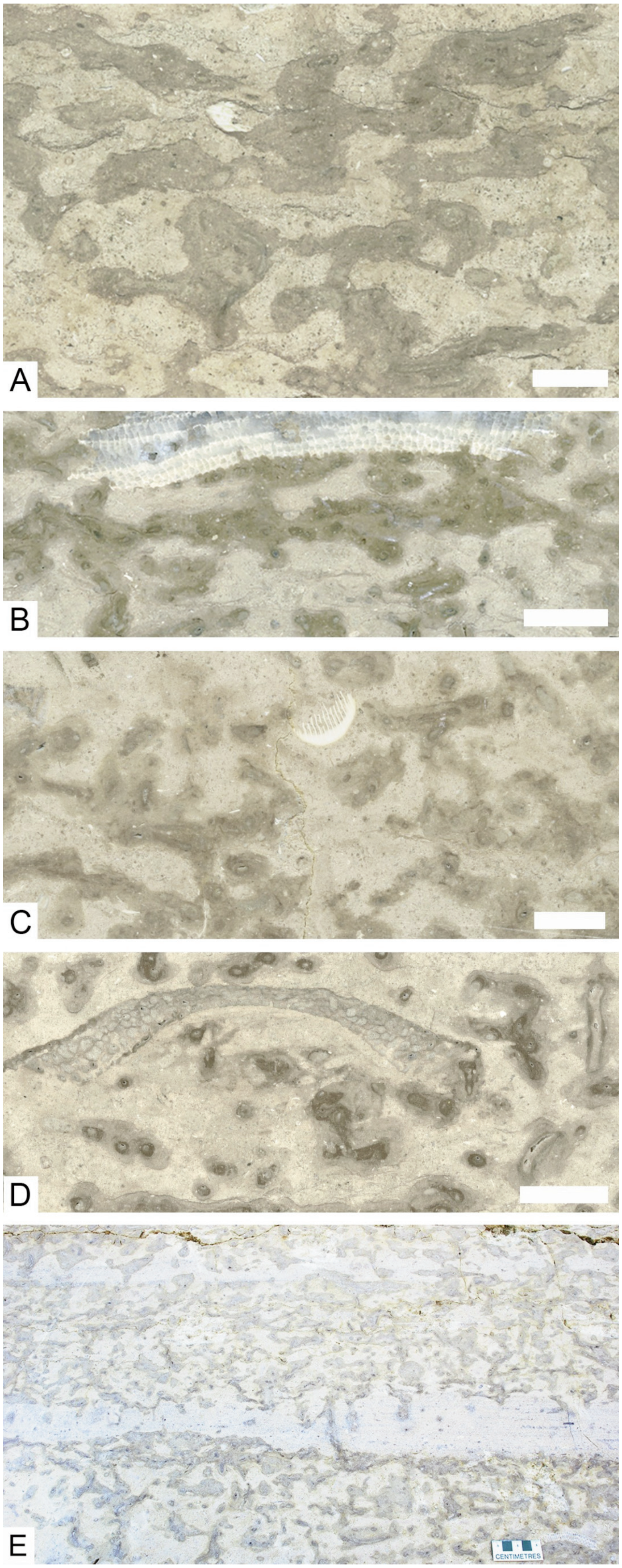


Figure 15. *(opposite)* Tyndall Stone cut perpendicular to bedding, showing details of dolomitic mottles (darker brown). A–D are polished surfaces; E is close-up of Gillis Quarry wall (shown in Figure 8C). A. Relatively large lobate mottles, with stylolites common near top. Scale bar is 3 cm. B. Elongate and variably shaped mottles, with some sharply abutting colonial rugose coral belonging to *Crenulites* (at top). Scale bar is 3 cm. C. Branching mottles with the edge of a solitary rugose coral calice possibly belonging to *Grewingkia* (upper centre). Scale bar is 3 cm. D. Small mottles including one with a vertical orientation (at right), with oblique cut through receptaculitid (also Figure 16F). Scale bar is 3 cm. E. Massive packstone with two lenticular, planar laminated grainstone beds that were burrowed from above. Lower bed shows mostly vertical and subvertical dolomitized burrows, ~ 1 cm wide. Upper bed is mostly burrowed away but exhibits some horizontal burrows (at left). Scale is in centimetres.

Tyndall Stone was likely much more complex than is readily apparent. Short curvilinear burrows with concentric linings, 0.2–0.3 cm in diameter, overprint the churned matrix which exhibits some narrower, seemingly mostly vertical burrows with curvilinear parts lacking linings (Fig. 19A, B). Some of these might be U-shaped. The lined burrows include many circular cross-sections as seen on surfaces cut parallel to bedding, and they only locally cross-cut each other. Brachiopod valves and trilobite sclerites are unoriented in the matrix. Larger burrows, 0.5 cm wide, have a lining and meniscate backfilling (Fig. 19B). Longer horizontal burrows 0.5–1 cm wide without linings are present and are cross-cut by many smaller burrows (Fig. 19C). Also present are indistinct horizontal burrows lacking walls but exhibiting a poorly defined meniscate backfilling. These are cross-cut by the smaller unlined and lined burrows.

Interpretation

Although they were initially regarded as plant and algal fossils and termed ‘fucoids’ (Wallace 1913) due to their vague resemblance to shoreline-inhabiting seaweed belonging to *Fucus* (which was a common view of such features at the time), it was later recognized that the mottles in Tyndall Stone reflected bioturbation by infaunal invertebrates, especially worms (Birse 1928). The apparent burrow networks were compared to gallery systems belonging to *Spongeliomorpha* (Kendall 1977), which in much younger rocks (and modern sediments) are ascribed to excavating crustaceans (e.g. Gibert and Ekdale 2010). Later, these kinds of burrows in Ordovician limestone were referred to *Thalassinoides,* which also consists of galleries (Sheehan and Schiefelbein 1984; Myrow 1995; Eltom and Goldstein 2023), and this identification has persisted for the mottles in Tyndall Stone and in subsurface equivalents and correlative units (Pak and Pemberton 2003; Cherns et al. 2006; Young et al. 2008; Jin et al. 2012, 2013). Sheehan and Schiefelbein (1984) suggested that these burrow systems reached a depth of one metre, although this is not apparent in the Gillis Quarry and in rock samples where the vertical expression seems to be no more than ~ 10 cm. The presence of trilobites associated with burrows led Cherns et al. (2006) to suggest that they had created the galleries which later became filled with biomicrite. No such relationship with dolomite mottles has been observed in Tyndall Stone.

Kendall (1977) reconstructed the burrows as empty galleries made by arthropods that excavated before, during and

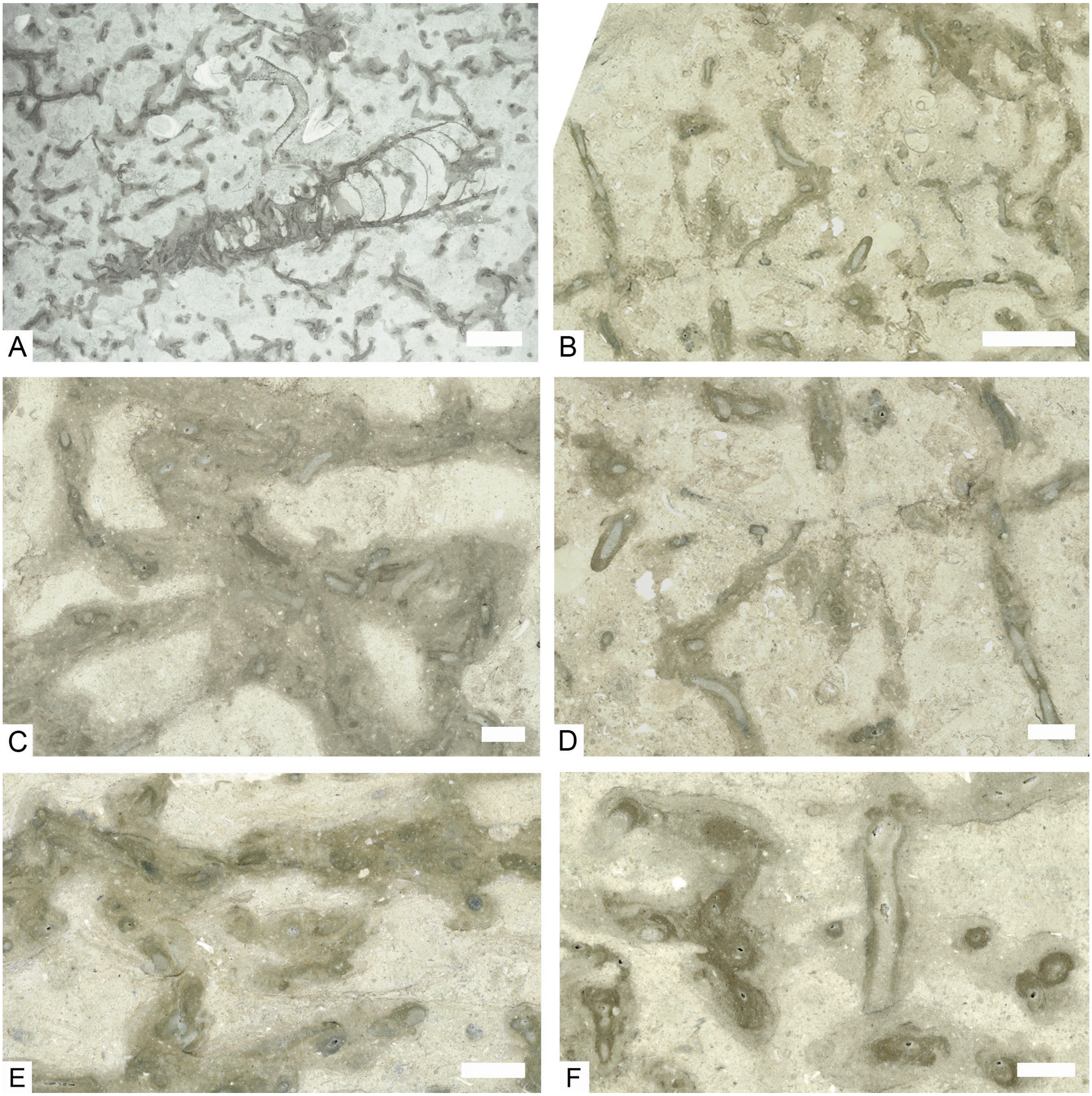


Figure 16. Close-up photographs showing details of dolomitic mottles (darker brown). A–D are surfaces sawn parallel to bedding; E and F are surfaces sawn perpendicular to bedding. A is honed finish; B–F are polished surfaces. A. Narrow linear and small circular mottles, densely cross-cutting each other around the posterior end of mould of orthoconic nautiloid (centre), with three solitary rugose corals probably belonging to *Grewingkia* and a receptaculitid (upper centre). Agriculture Building, University of Saskatchewan. Scale bar is 5 cm. B. Narrow, mostly linear mottles conforming to *Palaeophycus*, including some with calcite microspar-filled tubes, with gastropods (upper right of centre). Scale bar is 3 cm. C. Wide mottles with numerous burrows conforming to *Palaeophycus*. Scale bar is 2 cm. D. Narrow mottles with numerous burrows. Scale bar is 2 cm. E. Horizontally and vertically oriented mottles containing horizontally oriented burrows conforming to *Palaeophycus*. Close-up of left side of Figure 15B. Scale bar is 2 cm. F. Horizontally and vertically oriented mottles containing horizontally and vertically oriented burrows, the former corresponding to *Palaeophycus* and the latter to a vertically oriented *Palaeophycus* or possibly *Skolithos*. Close-up of right side of Figure 15D. Scale bar is 2 cm.

after sediment cementation, such that these burrows as well as aragonite shell moulds were filled after lithification and below the depth of active tunnelling, by lime mud that was then available to be burrowed by worms. The pervasive presence of

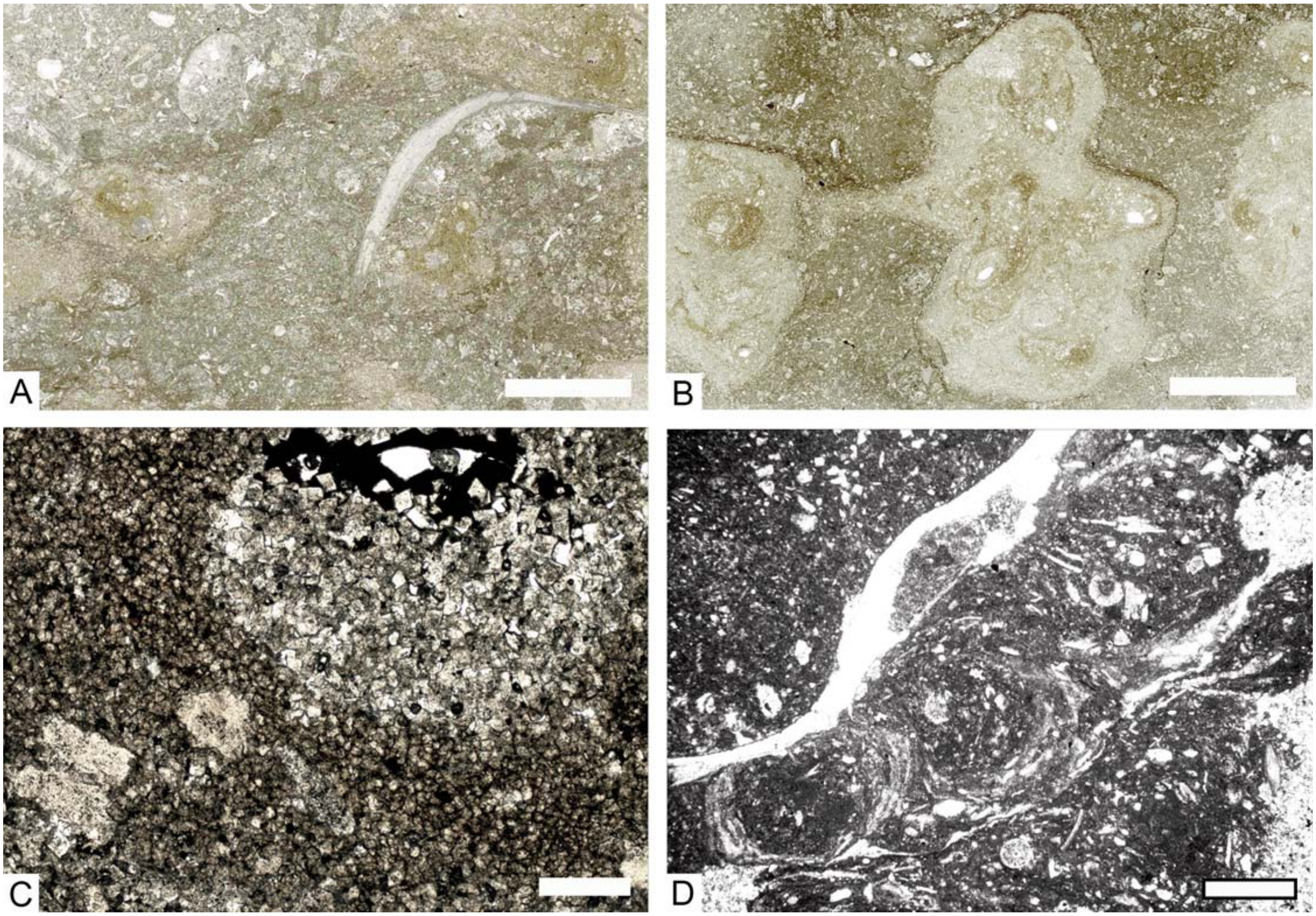


Figure 17. Petrographic detail of dolomitic mottles in biomicrite (packstone). Vertically oriented thin sections. A. Scanned image, including brachiopod shell (centre right), showing dolomitic, brown-stained linings and haloes of horizontal burrows. Natural colour. Scale bar is 10 mm. B. Scanned image showing interconnected, lobate dolomitic domains containing brown-stained horizontal burrows some of which show linings and haloes and calcite microspar-filled cores. Stylolites are present between the upper margins of the mottles and the matrix. Natural colour. Scale bar is 10 mm. C. Photomicrograph of part of a horizontal burrow showing central portion consisting of microcrystalline dolomite surrounded by brown-stained microcrystalline dolomite with finer crystal size containing scattered crinoid ossicles. The dolomite in the central portion shows geopetal structure overlain by opaque material collected inside pore after calcite dissolution. Plane-polarized light; natural colour. Scale bar is 1 mm. D. Photomicrograph of interior of nautiloid shell with horizontal, backfilled burrows with lining defined by crude concentric laminae. Plane-polarized light; greyscale. Scale bar is 2 mm.

large, empty galleries in lithifying sediment, however, is contradicted by the absence of sharp boundaries of the large burrows, their variable width, the presence of smaller burrows cross-cutting the margins of the mottles, and the sparse biomicrite filling large burrows. The multiple generations of smaller burrows in the biomicrite matrix and rarity of biomicrite intraclasts, present only in some grainstone lenses, also argue against excavation of cementing or cemented matrix. Some burrows in the correlative Yeoman Formation in the Saskatchewan subsurface (Kendall 1976, plate VIIIB; Pak and Pemberton 2003, figs. 11, 15) may be an exception to this. In these cases, it is possible that the matrix may have been lightly cemented, because the smaller burrows within do not penetrate the margins. These burrows may have been empty due to winnowing, before being infiltrated with lime mud. Washed-out burrows are present in the Gunn Member. There, the upper surface of some grainstone interbeds is a scoured surface showing grooves ~ 2 cm wide with smoothed margins. Comparable surfaces seem to be absent in Tyndall Stone. Moreover, it is difficult to envisage a complex system of interconnected, three-dimensional galleries continually being created by winnowing followed by filling due to sediment infiltration.

The small, millimetre-sized, curvilinear burrows in the biomicrite matrix and the dolomitic mottles mostly correspond to the ichnogenus *Palaeophycus* (Pak and Pemberton 2003). This taxon is distinguished from *Planolites* due to the lining of the burrow walls (Pemberton and Frey 1982; Keighley and Pickerill 1995). *Palaeophycus* appears to be common in lower Paleozoic limestone units, but in some cases the lining may instead be a diagenetic halo (Pak and Pemberton 2003; Pratt and Bordonaro 2007). Small, unlined, backfilled burrows correspon-

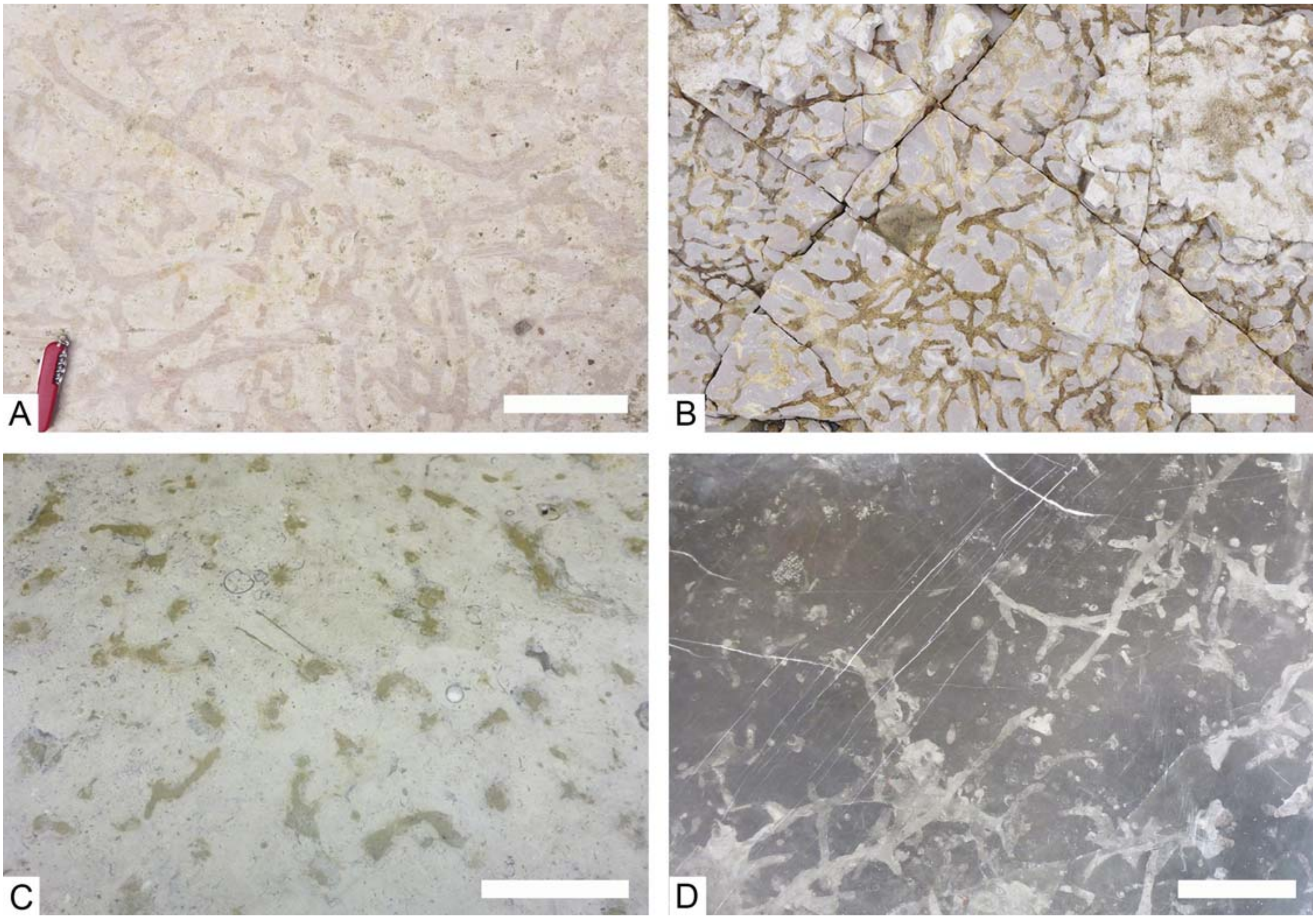


Figure 18. Comparable burrows in other limestones. A, B = Upper Ordovician; C = Middle Ordovician; D = mid-Cretaceous. A. Glacially polished, cream-coloured dolostone bedding plane showing well-defined large burrow networks. Red River Formation (undivided), Cranberry Portage quarry, 84 km north of The Pas, Manitoba. Scale bar is 10 cm. B. Limestone bedding surface with large burrow networks replaced by buff- to brown-coloured dolomite. Chasm Creek Formation, Churchill River Group, Churchill River, Churchill, Manitoba. This formation is correlative with the Stony Mountain Formation of southern Manitoba. Scale bar is 10 cm. C. Sawn block (capstone) of Reval, consisting of grey-coloured, bioclastic and fossiliferous packstone with portions of burrows replaced by brown-coloured dolomite. Tallinn, Estonia. Scale bar is 5 cm. D. Polished slab showing vertical and backfilled horizontal burrows. Hotel lobby floor, Mazatlán, Sinaloa (source is northeastern Mexico). Scale bar is 10 cm.

ding to *Planolites* are not prominent in the Tyndall Stone but are present in the correlative Yeoman Formation in the Saskatchewan subsurface (Pak and Pemberton 2003).

Pak and Pemberton (2003) identified a number of other ichnogenera in cores from the subsurface Yeoman Formation, including *Asterosoma*, *Rhizocorallium*, *Tricophycus*, *Skolithos* and *Chondrites*. However, *Asterosoma* is a radiating trace fossil and nothing resembling it is evident on horizontal surfaces of Tyndall Stone. *Rhizocorallium* consists of a looping horizontal burrow with curving spreiten in between, and it is also not apparent on horizontal surfaces. Burrows attributed to *Tricophycus* may be unusually wide mottles. Tyndall Stone exhibits rare vertical burrows that might be *Skolithos* but without a three-dimensional view it is also possible they are vertically oriented *Palaeophycus*. It is unlikely that they are *Arenicolites* as no U-shaped burrows have been identified in vertical section and pairs of circular burrow openings are not apparent on horizontal surfaces. Small branching burrows belonging to *Chondrites* are rare in Tyndall Stone. In the Stony Mountain Formation, Zheng et al. (2018) identified *Palaeophycus*, *Planolites*, *Nereites*, *Phycosiphon*, *Chondrites*, *Teichichnus*, *Rhizocorallium* and *Balanoglossites*. Parts of this unit exhibit a complex ichnofabric with seemingly abundant *Planolites* and small bioturbation features that are not readily discernible in Tyndall Stone.

Knaust (2021, p. 18) identified the dolomitic mottles in Tyndall Stone as *Balanoglossites,* which are empty galleries associated with firmgrounds. However, no firmground surfaces were observed in the Selkirk Member and in correlative dolostones farther north. Other, more sharply defined burrow systems in Ordovician limestones have also been assigned to *Balanoglossites*, including those in correlative Upper Ordovician units in Laurentia that lack evidence of seafloor cementation. *Balanoglossites* was identified in the Stony Mountain Formation (Zheng et al. 2018). While that unit does have evidence for early lithification in some beds, such as intraclasts in grainstone, and corroded or encrusted erosion surfaces that may

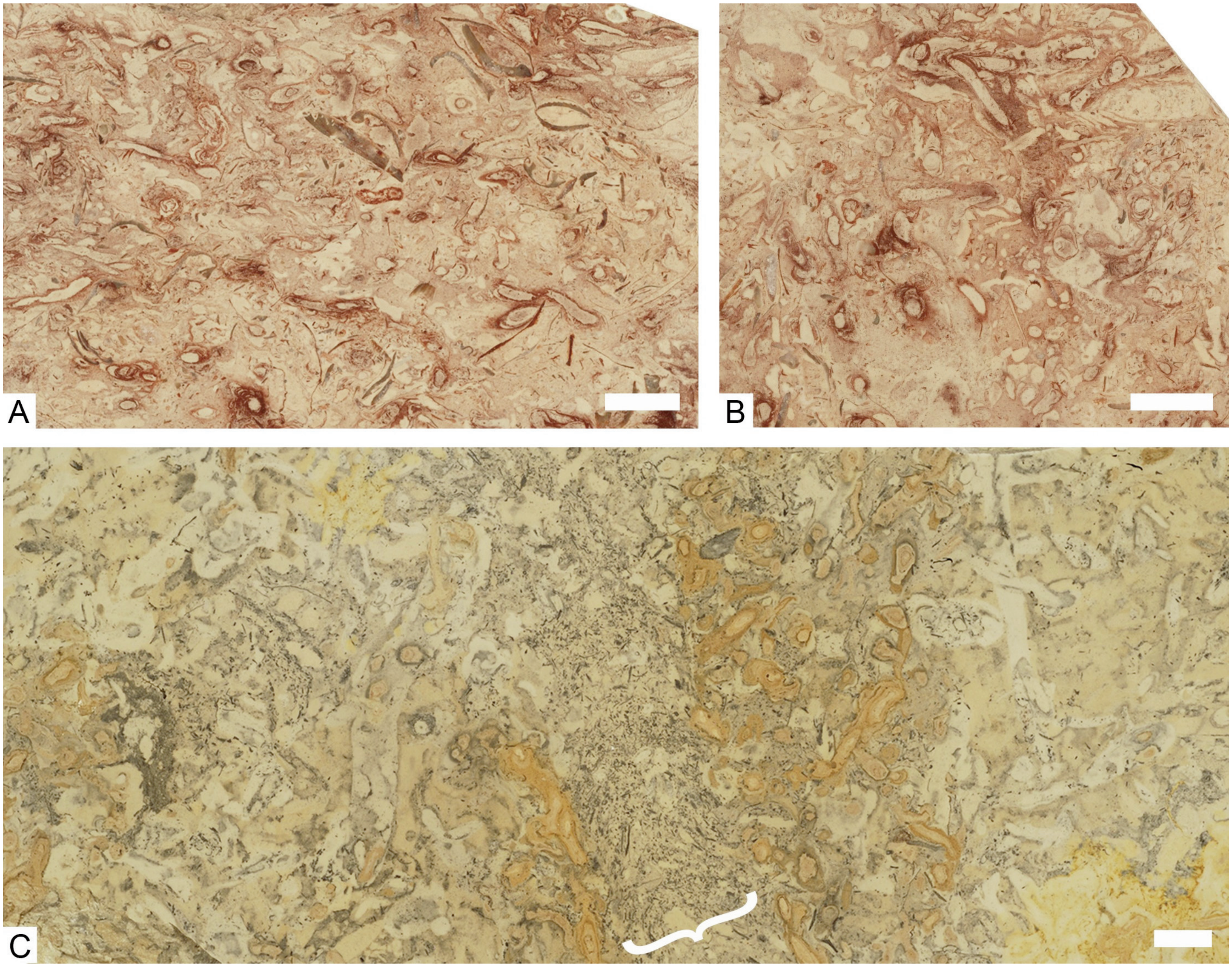


Figure 19. Comparable burrow fabrics in dolostone of the Stony Mountain Formation. A, B = Penitentiary Member, City of Winnipeg Quarry, Stony Mountain, Manitoba; C = Sturgeon Landing quarry, 56 km northwest of The Pas, Manitoba. Scale bars are 1 cm. A. Polished surface cut perpendicular to bedding, showing heavily bioturbated finely bioclastic carbonate mudstone overprinted by curvilinear burrows with linings conforming to *Palaeophycus*. The earlier bioturbation left a variegated appearance with locally discernible, short, narrow curvilinear burrows lacking linings, along with variably oriented brachiopod valves. B. Oblique and horizontal burrows with linings conforming to *Palaeophycus*, with wider burrow (upper right) exhibiting meniscate backfill. Polished surface cut parallel to bedding. C. Polished surface of buff-coloured dolostone sawn parallel to bedding showing wide, obliquely oriented, horizontal burrow (in middle) with meniscate backfill of micrite and tiny bioclasts (the width shown by white curly bracket), a narrower horizontal, mud-filled *Planolites* burrow (left of centre) that disturbs the part of the older portion of the larger burrow and is in turn cut by vertical burrows, and bioturbated matrix in which mud-filled *Planolites* burrows are discernible, with a final stage of backfilled *Palaeophycus* burrows with linings (mostly orange-coloured). *Planolites* burrows of the final stage do not penetrate the interior of the wide burrow, but the earlier generation of *Planolites* burrows disturbed the older portion of the large burrow (at top).

represent firm- or hardgrounds, the burrows appear to have been made before consolidation and erosion. Partially pyritized grooves ~ 1 cm wide on the surfaces were interpreted as tracks (Zheng et al. 2018), whereas similar grooves were named *Sulcolithos* by Knaust (2020) and interpreted as burrows or borings made on firmground and hardground surfaces. However, those in the Stony Mountain Formation represent relatively large burrows that were exhumed by the high-energy events that deposited the grainstone beds. Burrows attributed to *Balanoglossites* in the Stony Mountain Formation appear to be similar to the larger burrows in the Tyndall Stone and similarly have variable shapes. On the other hand, in dolomitic limestone of the Hudson Bay Basin, the larger burrows may be interconnected but it is unclear if they were ever empty gallery systems.

In Tyndall Stone, the variably well-defined, large curvilinear burrows containing biomicrite, oriented dominantly horizontally, were likely created by deposit-feeding worms ranging up to about 1 cm in diameter, that backfilled the burrows as they moved through the sediment. Examples of apparent branching represent mostly false branching due to crisscrossing burrows created by other worms active at the same time, as well as multiple generations of worms. The fact that the reworked sediment in the burrows is still a mixture of lime mud and bioclasts, although containing fewer of the larger grains such as crinoid ossicles, means that it does not strongly contrast texturally from the matrix. The large burrows and matrix were reburrowed by generations of smaller worms that produced *Palaeophycus*. Calcite microspar cement commonly fills an empty tube or the upper part of a tube with a geopetal micrite floor. Thus, the wide curvilinear and unlined burrows belong to neither *Thalassinoides* nor *Balanoglossites*, but can be assigned to *Planolites*, albeit a very large form.

As is typical for shallow-marine carbonate rocks in shelf and epicontinental seas, dolomitization is a diagenetic phenomenon that post-dated microcrystalline and blocky calcite cementation and took place during burial, followed locally by crystal size increase due to neomorphism (Zenger 1996a, b), rather than by near-surface biogeochemical reactions as proposed by Gingras et al. (2004). In Tyndall Stone, the brown dolomite is only crudely selective, in that it is a replacement of mostly microcrystalline calcite and small bioclasts in the larger burrows as well as *Palaeophycus* and some of the surrounding matrix. Thus, the mottles are not confined to discrete burrows, which is part of the reason why the mottles range so widely in size and shape. By contrast, in completely dolomitized carbonate rocks of the Red River Formation to the north, the outlines of the larger burrows are more distinct.

TYNDALL STONE IN ARCHITECTURE

Aesthetics and Uses

Tyndall Stone is rarely used as a polished dimension stone, with notable exceptions including the lobby floor and staircases of the Banff Springs Hotel, a feature wall in the former Royal Alberta Museum and the memorial wall in the Geology Building, University of Saskatchewan, commemorating the geology students who fell in the Second World War. For the latter two, slabs particularly rich in macrofossils were selected.

Tyndall Stone used for cladding on both interior and exterior walls is usually sawn parallel to bedding (Fig. 20A, B) and a smooth finish (rubbed or honed) is most common. In some cases the original sawn surface is retained. Other surfaces can be prepared. In older buildings, surfaces that were bush-hammered to give the stone a texture were popular for stone at eye level. Uniformity in hue is selected for individual projects. Because large, conspicuous fossils are variably present, slabs with numerous fossils were typically discarded in earlier years when they were deemed visually undesirable because they interrupted the appearance. In recent years, slabs with fossils have more often been used for cladding. The unique paleontological content is increasingly being recognized as worth showcasing in some situations. For example, two bank buildings, one in Saskatoon and the other in Regina, have feature walls using eye-catching fossiliferous slabs. In the foyer of the Manitoba Museum are two walls with the fossils labelled and interpreted.

Split face finish (broken perpendicular to bedding) is increasingly being used for exterior walls (Fig. 20C). Ashlar (wall consisting of dressed stone) utilizing blocks with rustic ranch finish (split parallel to bedding) typically has hues that are mixed for a mosaic effect (Fig. 20D). This is popular especially for houses and other residential buildings. Machine-shaped decorative elements like string courses, window casements, doorways and buttresses are used, especially in collegiate gothic buildings at the University of Saskatchewan (Fig. 20E). There, Berea Sandstone was used before the First World War, then Indiana Limestone was employed, but in recent decades Tyndall Stone has been used exclusively. Tyndall Stone is also now used for indoor flooring and besides large slabs (Fig. 20F), roughly one foot x two foot (297 mm x 500 mm) rectangular tiles are manufactured with a honed or polished finish, and thin veneer products have been recently introduced.

Tyndall Stone also lends itself to carving, although it is a much harder stone than Indiana Limestone and some stones popular in other countries. In earlier years, government buildings like provincial legislatures and courthouses were especially well decorated (Figs. 2A–D; 21A–C, F–H). Numerous public and commercial buildings have been adorned with carved scenes (Figs. 20A, 21E). Hand-carved elements are still occasionally produced (Fig. 21D). There are sculptors who have utilized large blocks of Tyndall Stone.

While Tyndall Stone is a particularly durable material, it is still a carbonate rock with a hardness much less than that of granite, and it is soluble in acidic water. In rare situations where the stone is under some stress, such as in exterior staircases, cracks may develop in stone that has been in place for many years (Fig. 22A). Gradual etching of surfaces close to the ground may occur due to rain splash and from salt spread on sidewalks during winter (Fig. 22B). In a few cases, receptaculitids have popped out of blocks or cladding due to water infiltration and freeze–thaw cycles (Fig. 22C). Rare chalky-textured chert has also been a problem in external walls of some older buildings due to differential weathering, but slabs exhibiting this impurity have long been avoided. In locations where there is excess moisture, surfaces may by stained somewhat by black fungal or microbial growth (Fig. 22C). Probably the most visible ‘damage’ is done by repairs such as patching with cement or using stone with a different size or hue (Fig. 22D). On the other hand, Tyndall Stone cladding has been recovered from some demolished buildings and re-used.

Geotechnical Specifications

Comparison of the physical properties needs to take into account that some measurements conform to American Society for Testing and Materials (ASTM) standards, while others are based on other testing procedures, not to mention difficulties in comparing European (EN) standards. This makes comparisons with European dimension stones difficult. Tyndall Stone has properties similar to those of many other fairly hard limestone and marble examples, such as Tennessee Marble (a bioclastic limestone) and Georgia Marble (a true marble), but it is less dense and has greater water absorption due to the presence of minor porosity (Table 1; Parks 1916; Goudge 1933). The porosity is probably related to leaching by groundwater. Tyndall Stone is slightly denser than Indiana Limestone, which is a softer stone that is easier to work.

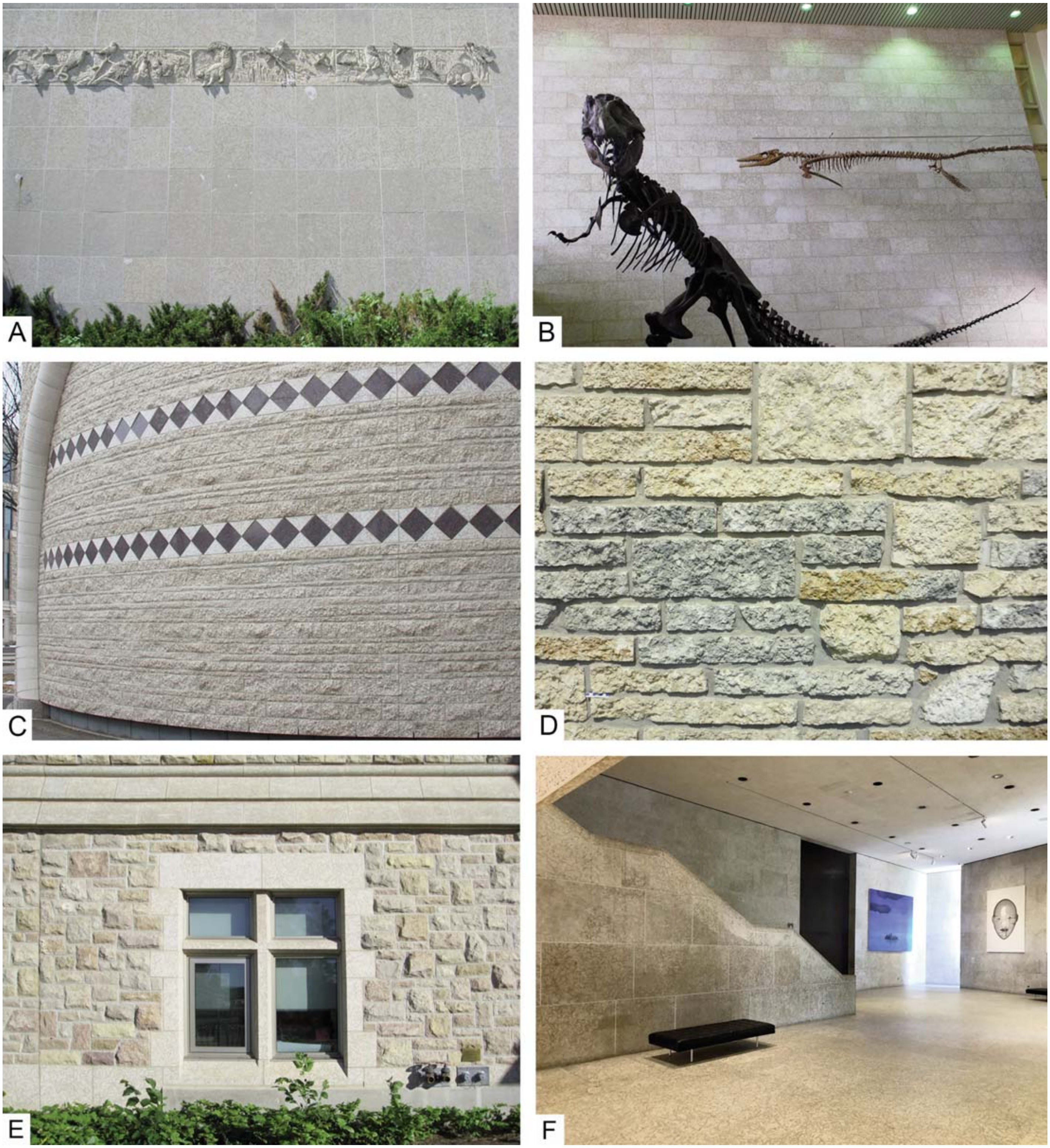


Figure 20. Examples of common Tyndall Stone usages and decorative elements. A. Exterior cladding consisting of coursed ashlar using square slabs with honed finish, with carved animals along top. Royal Saskatchewan Museum, Regina. B. Interior cladding consisting of coursed ashlar with rectangular slabs with honed finish. Natural Sciences Museum, University of Saskatchewan, with replicas of *Tyrannosaurus rex* and *Mosasaurus*. C. Exterior wall with coursed ashlar with split face finish (split perpendicular to bedding), with decorative courses of triangles with honed finish and red-coloured polished granite squares. Gordon Oakes Red Bear Student Centre, University of Saskatchewan. D. Exterior wall with random ashlar with different-coloured rustic ranch rock (rustic finish split along bedding-parallel stylolites). Condominium, Saskatoon. E. Exterior wall of random ashlar with rock-faced dolostone (fieldstone) and Tyndall Stone window surround and mullion, and stringcourses (bands at top and cladding along foundation). Health Sciences Building, University of Saskatchewan. F. Interior walls, floors and staircase faced with Tyndall Stone sawn parallel to bedding, Winnipeg Art Gallery, Winnipeg.

Figure 21. Examples of carved Tyndall stone. A. Fluted column with Ionic capital. Manitoba Legislative Building. B. Façade with pediment, various ornaments and coat of arms of the United Kingdom. Courthouse, Humboldt, Saskatchewan. C. Ornamental element with laurel wreath in honour of the arts and sciences. Carnegie Library, Winnipeg. D. Crest of the University of Saskatchewan. E. Sculpture of farm worker scything with grain elevators and rising sun behind. Bank of Montreal Building, Saskatoon (also Figure 29E). F. Ornament in the shape of tiers of leaves. Manitoba Legislative Building. G. Crest of the Province of Saskatchewan, courthouse, Battleford. H. Ornamental urn. Manitoba Legislative Building.

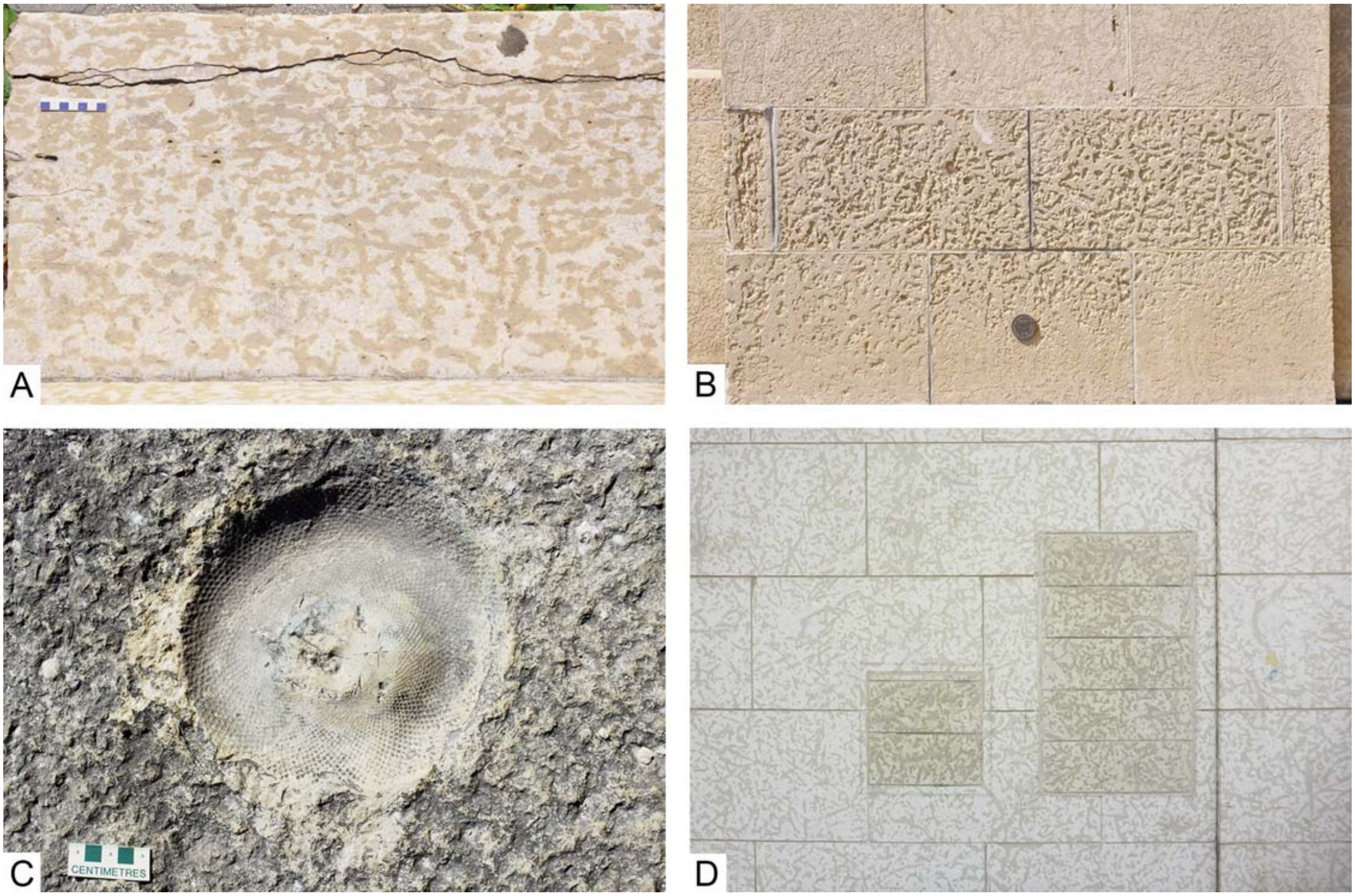


Figure 22. Examples of damage to Tyndall Stone. A. Looking down on plinth with vertically oriented cracks. Winnipeg. Scale in centimetres. B. Weathered bush-hammered foundation slabs, with Canadian Geodetic Survey levelling benchmark tablet (lower centre). Courthouse, Humboldt, Saskatchewan. Width of view approximately 1.5 m. C. Upper surface of stairway retaining wall block with concave mould of receptaculitid, which has popped out. Manitoba Legislative Building. Scale bar in centimetres. D. Cladding of old bank building with night depository drop box portals replaced with stone having different sizes and hue. Prince Albert, Saskatchewan. Width of view approximately 1.5 m.

Table 1. Physical properties of Tyndall Stone, two other limestones and a marble for comparative purposes. ASTM test procedures are noted if recorded.

Property [test procedure]	Tyndall Stone	Indiana Limestone	Tennessee Marble	Georgia Marble
Specific gravity [C97]	2.44	2.1–2.75		
Density (weight) (kg/m^3)	2435 kg/m^3	2307 kg/m^3	2713 kg/m^3	2730 kg/m^3
Compressive strength – dry [ASTM C170]	62.8 MPa	minimum 27.6 MPa	105 MPa	68.1 MPa
Tensile strength		2.1–4.9 MPa		
Shear strength	7.3 MPa	6.2–12.4 MPa		
Transverse strength	9.2 MPa			
Flexural strength [ASTM C880]			17.9 MPa	10.4 MPa
Modulus of rupture – dry [ASTM C99]	9.9 MPa	minimum 4.8 MPa		10.1 MPa
Modulus of rupture – wet [ASTM C99]	5.2 MPa			
Absorption [ASTM C97]	3.49%	maximum 7.5%	0.06%	0.08%
Porosity	average 11.36%	about 5%		
Modulus of elasticity [ASTM C1352]	41.37 GPa	22.75–37.23 GPa		

Sources: Tyndall Stone – gillisquarries.com/about-us/properties (also Gillis Quarries Ltd. n.d., 2012); Indiana Limestone – ILI 2007; Tennessee Marble – tnmarble.com/specifications/; Georgia Marble – polycor.com/stone/marble/georgia-marble-white-georgia/.
Units for US stones changed to metric. ASTM = American Society for Testing and Materials (now ASTM International).

Figure 23. Examples of the range of buildings utilizing Tyndall Stone. A. City Hall (1914), Moose Jaw, Saskatchewan. Beaux Arts style. B. Bessborough Hotel (1932), Saskatoon. Châteauesque style. C. St. Andrew's Church (1912), Moose Jaw. Neo-Gothic style. D. Sturdy Stone Building (1977), Saskatoon. Brutalist style. E. Canadian Museum of History (1989), Gatineau (Ottawa). Expressionist style. Image credit: Wikimedia Commons, remundo (https://en.wikipedia.org/wiki/Canadian_Museum_of_History#/media/File:Canadian_Museum_of_History_(30397442792).jpg).

Examples of Buildings

In the early years, Tyndall Stone was used almost exclusively in the Prairie Provinces of western Canada. Besides the Saskatchewan and Manitoba legislative buildings, it has been used in many other government buildings such as courthouses, post offices, land titles buildings, and city and town halls, as well as banks, department stores, train stations, office buildings, schools, and hotels (Figs. 23–30). It was used to striking effect in the interior of the rotunda of Confederation Hall in the House of Commons, Ottawa (Fig. 2A–D). The stone was used sporadically across the rest of the country prior to the Second World War. In the middle 20th century, its use expanded

Figure 24. Older buildings using Tyndall Stone, Winnipeg. A. Law Courts (1916). Beaux Arts style. B. Land Titles Building (1904). Neo-classical style. C. Hudson's Bay Company Building (1926). Neo-classical style. D. Hamilton Building (1918). Chicago School style. E. Manitoba Power House (1915). F. Union Station (1911). Neo-classical style.

Figure 25. Examples of the range of building styles using Tyndall Stone, Winnipeg. A. Carnegie Library (1905). Neo-classical style. B. Civic Auditorium (1932). Art Deco style. C. Federal Building (1936). Classical Moderne style. D. Castle on the Seine (1986). Contemporary classical style.

to other commercial buildings, museums, art galleries, concert halls, hospitals, universities and churches, as well as residential uses both exterior and interior. Tyndall Stone has been used for several buildings in the USA and for Canada House (Kanada Haus), which is the Embassy of Canada to Germany, in Berlin. It was often used as an accent in buildings mainly constructed with red brick.

Architectural styles have varied over time as taste and construction methods evolved. Before the First World War, the most common were Neo-classical and Beaux Arts styles. A number of Art Deco-inspired buildings were constructed in the 1930s during the Depression. In the 1960s, Modernist style was commonly adopted for public buildings like museums and art galleries, as well as larger banks and other commercial

Figure 26. Newer buildings using Tyndall Stone, Winnipeg. A. Winnipeg City Hall, Susan A. Thompson Building (1963). Modernist style. B. Bank building, Main Street. Modernist style. C. Canada Life Building (1983). Modernist style. D. Canadian Museum for Human Rights (2014). Expressionist style.

buildings. Recent decades have seen a number of forays into Brutalist, Contemporary classical, Postmodern and Expressionist styles.

In addition to the iconic legislative buildings in Regina and Winnipeg, monumental buildings using Tyndall Stone that were constructed in the first decades of the 20th century are distinctive elements in the centres of these and other cities and towns. These buildings, constructed when the Prairie Provinces were growing rapidly in population prior to the Depression, have stood the test of time and are in good condition, lending a sense of permanence. To many they are aesthetically more pleasing compared to more commonplace brick, concrete or glass and steel buildings. In modern times, many of them have been repurposed. Cities and larger towns now have historical or heritage societies and, in collaboration with various levels of government, many of these buildings have been designated as heritage properties and are protected.

CONCLUSIONS

Tyndall Stone is an iconic building stone in Canada. It has been used since the beginning of the 20th century, especially in the Prairie Provinces. It is spectacularly fossiliferous, and slabs sawn parallel to bedding give an unparalleled snapshot of a tropical, shallow seafloor of Late Ordovician age. Conspicuous fossils include receptaculitids, corals, stromatoporoids, nautiloids and gastropods. What makes Tyndall Stone unique is especially the tapestry of brownish mottles composed of dolomite on the light grey to cream limestone background. These mottles represent dolomite replacement of burrows created by infaunal invertebrate animals, along with some of the adjacent matrix. Long thought to have originally been empty galleries and assigned to *Thalassinoides*, they were actually backfilled burrows likely made by large worms, and more reasonably assigned to *Planolites*. They are one component of several bioturbation phenomena, including churning of the bioclastic muddy sediment, and multiple generations of smaller burrows, most of which have linings on their margins and are referable to *Palaeophycus*, also made by worms.

Tyndall Stone is a versatile, durable stone that has been used in a variety of ways for many buildings, especially in the Prairie Provinces, including the legislative buildings of Manitoba and Saskatchewan, courthouses, land titles buildings, city and town halls, banks, stores, office buildings, train stations, hotels, schools, museums, universities and churches, as well as

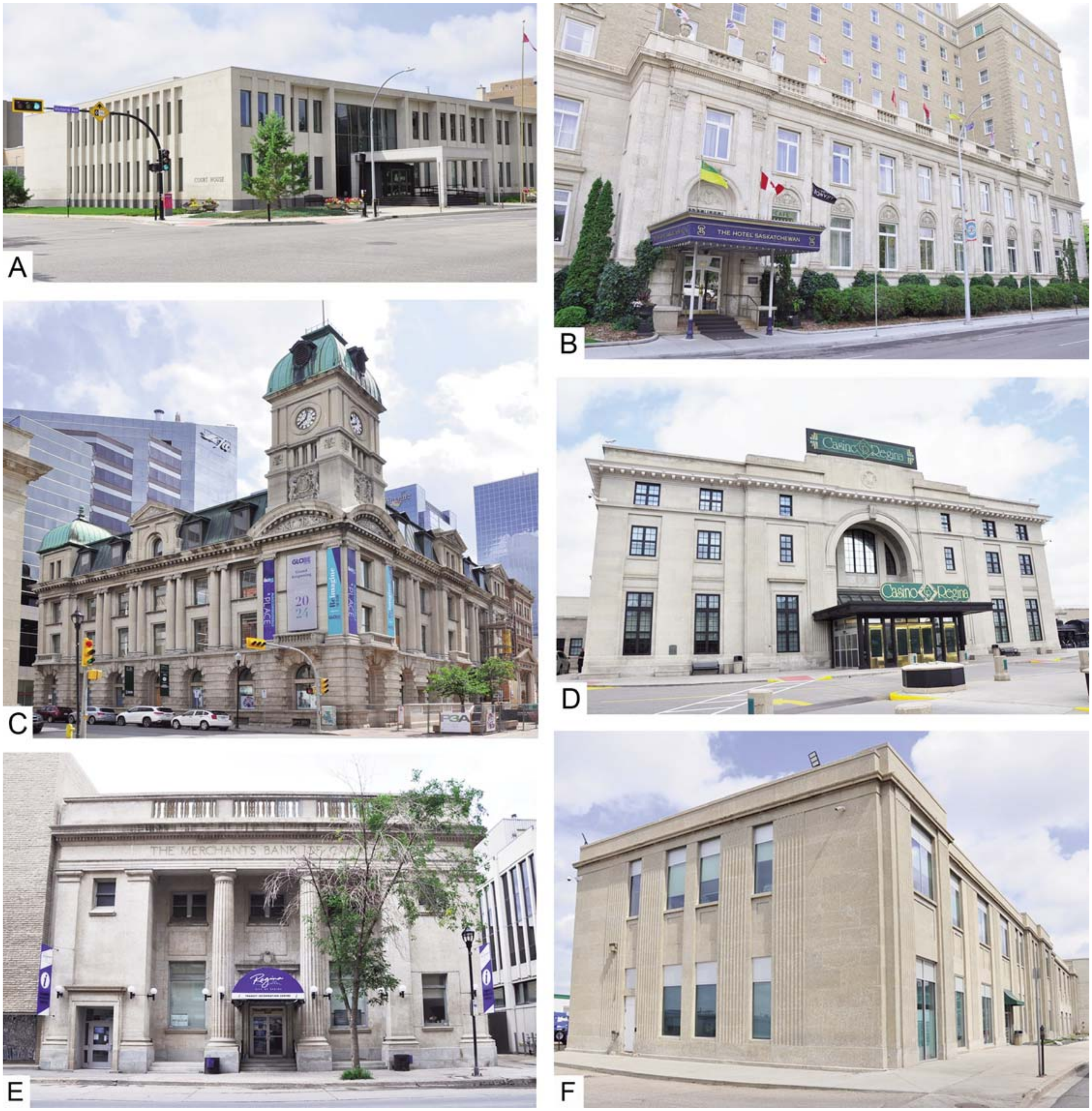


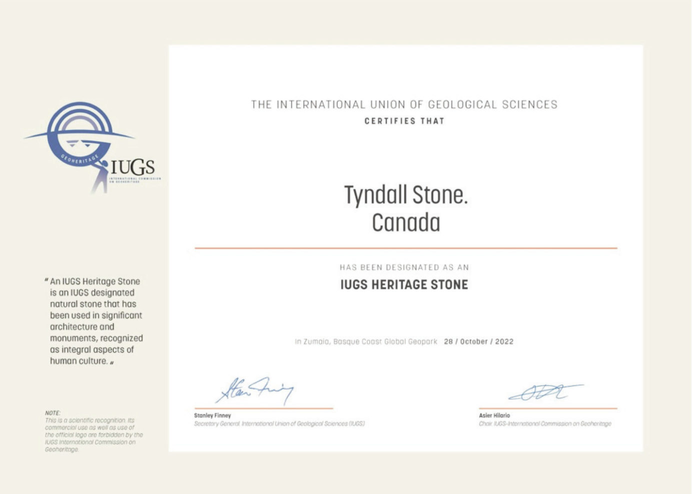
Figure 27. Examples of the range of building styles using Tyndall Stone, Regina. A. Courthouse (1961). Modernist style. B. Hotel Saskatchewan (1927). Neo-classical style. C. Post Office (1909). Beaux Arts style. D. Union Station (1911). Simplified Beaux Arts–Classical style. E. Merchants Bank (1911). Neo-classical style. F. CN/CP Telegraph Building (1932). Art Moderne style.

Figure 28. Examples of the range of building styles using Tyndall Stone, Regina. A. Darke Hall (1929). Neo-Gothic style. B. Imperial Bank of Canada Building (1912). Neo-Georgian style. C. Trust and Loan Company Building (1923). Neo-classical style. D. Motherwell Building (1956). Modernist style. E. Knox–Metropolitan United Church (1913). Norman and Gothic styles. F. Dominion Government Building (1936). Art Deco and Art Moderne styles. G. Use of sawn and split finishes on exterior wall. Commercial building (recent).

Figure 29. Examples of the range of building styles using Tyndall Stone, Saskatoon. A. Land Titles Building (1910). Neo-classical and neo-Romanesque. B. Eaton's Building (1928). Neo-Renaissance style. C. Spinks Addition to Chemistry Building, University of Saskatchewan (2003). Châteauesque style. D. Health Sciences Building (2014). Collegiate Gothic style. E. Bank of Montreal building (1955). Modernist style (also Figure 21E). F. Use of split face, sawn and rustic finishes on exterior wall, in random (lower) and coursed ashlar (upper). Irene and Leslie Dubé Centre for Mental Health, Saskatoon (2010).

Figure 30. Examples of courthouses using Tyndall Stone in combination with red brick. A. Humboldt, Saskatchewan (1916). Edwardian classical style. B. Minnedosa, Manitoba (1910). Queen Anne style. C. Dauphin, Manitoba (1917). Neo-classical style. D. Battleford, Saskatchewan (1909). Neo-Romanesque style.

residential buildings. Many architectural styles have been adopted, ranging from Beaux Arts to Brutalist, Neo-classical to Postmodern. Given its spectacular paleontological content, Tyndall Stone is also a unique educational tool and at hand in most Canadian cities. In October 2022 it was designated a Global Heritage Stone Resource by the International Union of the Geological Sciences Subcommission on Heritage Stones. This was ratified and as of late 2022, Tyndall Stone is an IUGS Heritage Stone, Canada's first (Fig. 31).



THE INTERNATIONAL UNION OF GEOLOGICAL SCIENCES
CERTIFIES THAT

Tyndall Stone.
Canada

HAS BEEN DESIGNATED AS AN
IUGS HERITAGE STONE

In Zumaia, Basque Coast Global Geopark 28 / October / 2022

Stanley Finney
Secretary General International Union of Geological Sciences (IUGS)

Asier Hilario
Chair IUGS-International Commission on Geoheritage

" An IUGS Heritage Stone is an IUGS designated natural stone that has been used in significant architecture and monuments, recognized as integral aspects of human culture. "

NOTE:
This is a scientific recognition. Its commercial use as well as use of the official logo are forbidden by the IUGS International Commission on Geoheritage.

Figure 31. Certificate from the International Union of Geological Sciences recognizing Tyndall Stone as a Heritage Stone.

ACKNOWLEDGEMENTS

Our collective fascination for Tyndall Stone goes back decades. We appreciate Ed Dobrzanski for his long interest in the Ordovician of southern Manitoba and Tyndall Stone in particular, and for his help and encouragement. GAY is grateful to Robert Elias for many years of collaborative research on the paleontology of the Tyndall Stone. BRP is grateful to Dolores Pereira for her encouragement of a nomination for recognition by the Heritage Stones Subcommission, and more recently Colin Sproat for collaborative effort on the Upper Ordovician of southern Manitoba. Special thanks to Donna Gillis for quarry access over many years, encouragement in the heritage stone nomination and for comments on quarry operations and products. Abigail Auld commented on historical and architectural aspects. We thank the Manitoba Museum and Stonewall Quarry Park for permission to illustrate dioramas, and Carlton

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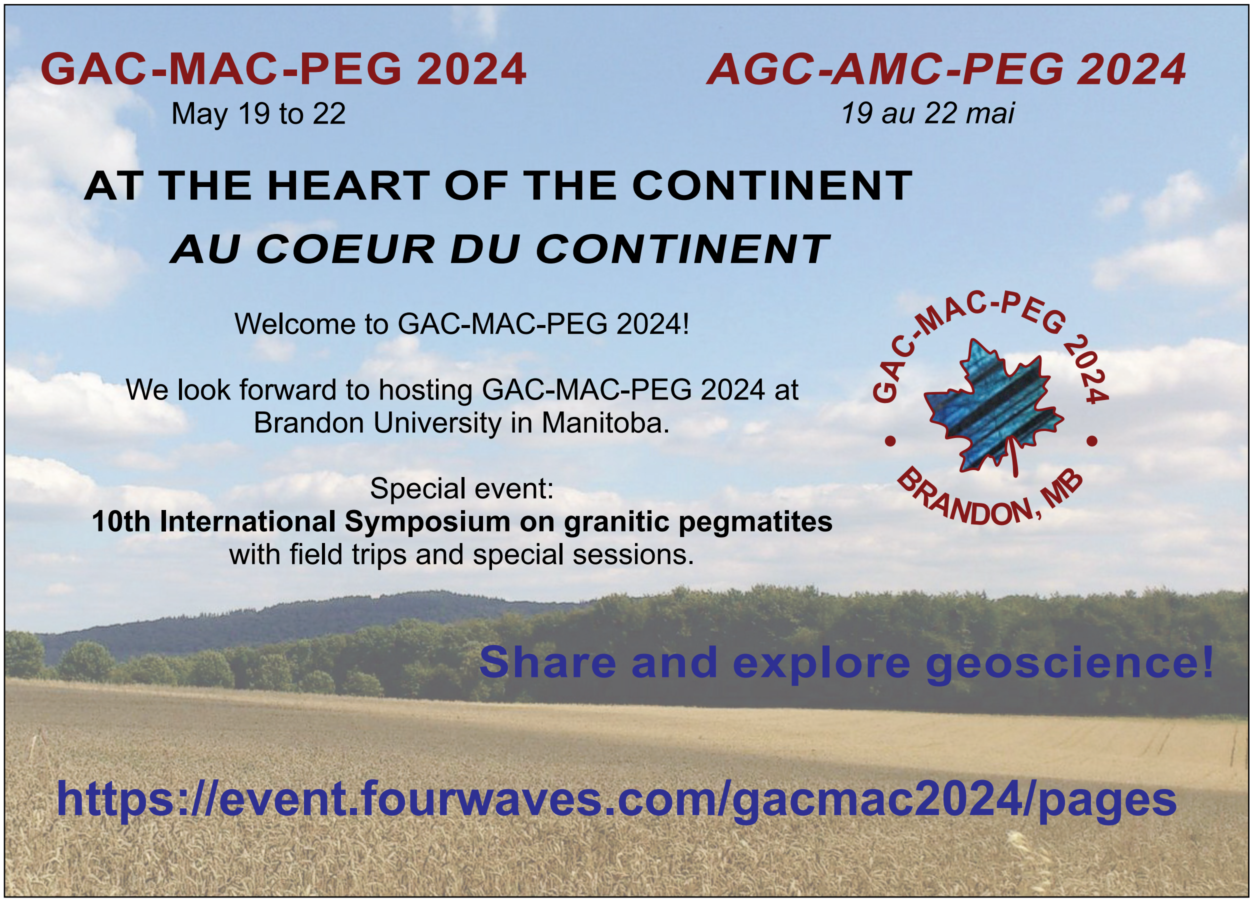

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