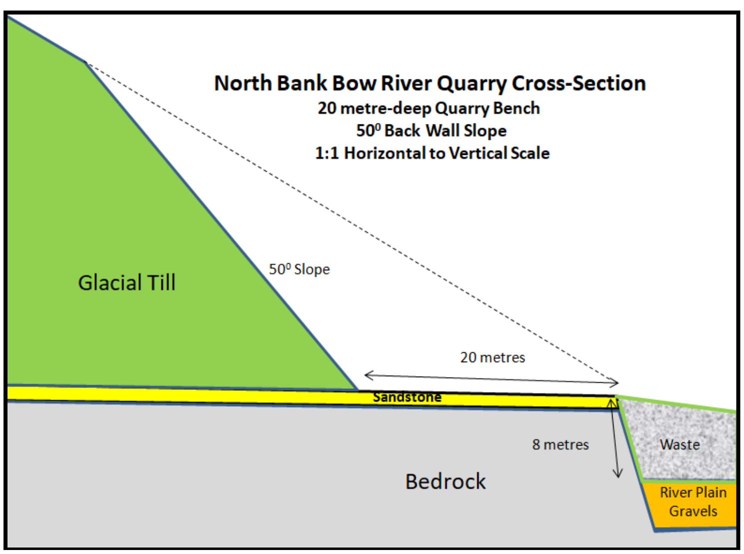
1880s & 1890s Sandstone Quarry Locations
North Bank of Bow River, Calgary
Candidate Sites based on 1944-2021 Geotechnical Borehole Data
August 2022

1889 North Hill Bluff

Angus McCrae, his powerful arms crossed on his chest, gazes to the south from where he stands on the edge of a rock platform 25 feet up the bluff slope. It is mid-morning into what will be a blazing hot day and the mosquitoes are driving him crazy as they rise in swarms from the sloughs below. Cattle browse on the lush grass of the flats under the shade of a large cottonwood tree. Directly cross the river, the Eau Claire Lumber Mill is quiet today, as they are busy battening everything down in case the raging mud-brown river keeps rising and breaches its banks. Further south, a C.P.R. steam engine chuffs along unseen except for the trailing smoke plume, hidden behind the two storey buildings along Stephen's Avenue.

Angus is part of a four-man crew working on a ledge 20 feet deep and 75 feet long carved into the steep bluff slopes. A crashing thunderstorm yesterday chased them off the bluff and into a makeshift wooden shelter in the trees at the bluff base. The rains caused the back wall of the quarry to slide, spilling a clay slurry onto the cut bench. To start the day, they had to shovel and wheel barrow a foot of mud before they could resume work on the stone. After clearing the mud, the boy on the crew was sent up the bluff to repair the ditches used to divert water away from the cut bench.



Angus calls for the boy to fetch a bucket of water from the spring located below the sand cliff near the top on the bluff slope. It is sweet water and it takes only a few minutes to fill a bucket. In addition to quenching thirst, the water is needed to cool the steel drill bits and lubricate the sandstone on which Angus has been hand drilling a line of holes in the sandstone bed. Angus's cousin John is working a few *feet away on a parallel hole set. A few sledge hammer blows onto a wedge will cleanly spit the stone. This stone is easy to work compared to the granite of the Scottish quarries they were both apprenticed-on. The yellow sandstone has no natural grain, it will split easily in any direction desired - freestone, Sunnyside Freestone.*

A homesteader had worked the site a few years ago, opening a narrow bench along 20 feet of the outcrop. The previous winter, when labour was easier to hire and bluff slides infrequent, Angus's crew cleared the large bench they were standing-on. First, the steep bluff slopes above the bedrock outcrop were cleared of brush and trees. Then, the clay was dug-out by hand and shoveled down slope, spilling over the edge of the bedrock to form a large fan cone. A surprise in the excavation was the abrupt disappearance of bedrock to the west of the initial cut. Fortunately, there was good quality sandstone continuity to the east. The final stage was to remove three feet of waste bedrock with wedges, sledge hammers and crowbars to expose the underlying sandstone. The plan next winter is to extend the bench a further 20 feet into the slope and also further east by 100 feet.

The quarry crew has two similar size sandstone blocks, 2 feet x 4 feet x 2 feet, ready for loading by the wagon team. Each block will be hoisted up using the horses and the block & tackle mounted on a large wooden tripod and then swung onto the wagon bed. Just the weight of these two blocks alone comprises a full load for the two-Clydesdale wagon team. They will be hauled to the courthouse building site using the trail beside the river and then over the Bow Marsh Bridge (assuming the rising river hasn't taken-out the bridge).

Several stone masons from Angus's home town are working at the courthouse building site, chipping the rough quarry blocks with hammer and chisels into flat sides and mortaring the new blocks into the slowly rising walls. For this building, they use the full size range of stone blocks as they come out of the quarry. The outside facing sandstone block face is left rough; to save money it is said.

1880s & 1890s Sandstone Quarry Locations
North Bank of Bow River, Calgary
Candidate Sites based on 1944-2021 Geotechnical Borehole Data

Table of Contents

List of Figures

List of Tables

1.0 Introduction

Researchers have been unable to find any maps, photos, or documents to precisely locate the sandstone quarries known to have operated in the 1880s & 1890s across the Bow River from the settlement of Calgary. Public domain geology data derived from geotechnical boreholes utilized in this study provide insights to the most likely quarry locations. Conversely, the data also reveals locations where there could not have been quarries; this includes the traditional referenced 4th St. N.W. site for the McHugh Quarry and the Sunnyside Freestone Quarry.

The historical information available on the north bank quarries is summarized in section two of this document. Matching the historical data to the geological data is not straightforward. There is a minimal amount of legal documentation available; sometimes a mention of a quarry in the local newspaper is the only reference to go by. The Sunnyside Freestone Quarry is the one quarry where more information is available, including historic photos of buildings built with its sandstone.

The third section describes the geology setting, including the expected thicknesses and areal extent of the sandstone beds. This information provides the potential dimensions of any quarry site. Two short segments of bedrock outcrop along the escarpment base are described with accompanying photos. A conceptual 1880s north bank of the Bow River quarry operation is presented based on the geology and knowing the tools available at the time - this exercise is also useful for considering how the morphology of the escarpment slope today may preserve signs of a quarry operation from 130 years ago. The Present Day morphology of three of the candidate quarry sites in interpreted as being consistent with abandoned quarries.

The key part of this study is a description of how the geotechnical borehole data along the escarpment rim can be used to project the thickness of bedrock at outcrop along the north edge of the Bow River flood plain. Some of the boreholes terminated once they reached bedrock, but others penetrated several metres, encountering mostly claystone, but sometimes a sandstone bed. If the sandstone bed is near the top of the bedrock section, this flags a candidate quarry site at the offsetting outcrop from the borehole. In two cases, the candidate quarry sites are linked to the historical record and today's slope morphology to identify specific quarries locations. In another case, a strong candidate based on geology and slope morphology does not have an historical record of operations.

A summary is provided in section four, outlining the key findings, what has yet to be determined and where future historical and geological research could be directed. One geology project being considered by the University of Calgary for further research is outlined.

To understand the sandstone quarry geology, all aspects of the local geology needed to be reviewed. This includes the flood plain fluvial geology, glacial lake & till deposits, escarpment slope slides and the extent of a north-south erosional channel in the bedrock cutting beneath Rosedale & Sunnyside. Each of these different geological elements are summarized in the Appendices.

Thanks to the many people who assisted me with this project: Kristine & Carol at City Archives, Eva at Historical City Land Titles, Heather at Provincial Archives, Norma at Alberta Genealogical Society, Peter Hews a fellow Rosedale geologist, and Terry Poulton of Natural Resources Canada. Special thanks to Charlie Lund of Hillhurst Sunnyside Community Association for forwarding recent borehole data from

Green Line L.R.T. & Flood Mitigation Projects and local historian Alan Zakrison for historical information on quarries.

The plan is to make this document available to the local community associations for posting on their websites to supplement their local history postings. Also, the intent is to provide a summary of the local geology as a framework reference for community issues like slope failures and flooding. Any corrections or suggestions are welcome; I can be contacted at the email address below. As new historical or geology data becomes available, my plan is to update the document and repost.

David Paterson
(sdpater@shaw.ca)
August 2022

2.0 Historical Record of the North Bank Bow River Quarries

As part of the historical background research, the Calgary Library fonds, maps & books, the Glenbow online archive, the Provincial online archive and the City Land Titles were searched for information. The Glenbow archive at the University of Calgary was closed for in-person searches because of Covid-19, so there may be non-digital documents of interest not yet sourced. The information below is a compilation of work done by others; much of it available using a keyword search on the internet. It is possible that in the future historical family papers and business records may provide further details on the quarries. Details such as years open, workforce, operation issues, profitability, quarry size & location, and arrangements with land title owner.

As early as 1885, the CPR was quarrying sandstone where Edworthy Park is today and shipping blocks to Regina for construction of government buildings. "Calgary is booming" according to an August, 1886 Calgary Herald article - "there were seven homes & businesses under construction where material is specified, four are building with brick and three with stone." Construction in sandstone and brick accelerated after a fire later that year destroyed 70 buildings in the commercial centre of town. Government buildings were then required to be make of stone or brick.

The early sandstone buildings in Calgary were built from quarries located close to town: along the Elbow River at Scotsman's Hill and at the Butlin Quarry on his Britannia homestead. On the north side of the Bow River, the Orr Quarry below East Crescent Heights was operational from 1886 -1890 according to a Glenbow map (Appendix E). Of these early quarries, the Butlin Quarry seems to have been the most significant commercial operation, as he was advertising freestone in the Calgary Herald as early as February, 1886.

Within a few years, there were three additional sandstone quarries and a shale (claystone) quarry on the north bank of the Bow River opposite Calgary. Skilled stoneworkers, many from Scotland with a long history of stone working arrived in the city to apply their trade. By 1890, over half of the city's skilled trades were stonecutters or masons (Heritage Calgary brochure).

Calgary grew very slowly between 1886 and 1897, then with the opening of prairie homesteads to Eastern European immigrants in 1897, there was an economic boom in the North West Territories. The population of Calgary would increase fourteen-fold by 1913. New sources of sandstone and claystone were needed. The Oliver Brother's Quarry on the map below is located where Crowchild Trail runs today and was first operational in the 1880s. Brickburn, where Edworthy Park is today, and Glenbow, near Cochrane, became the principal quarries as they had the advantage of large outcrops and proximity to the railway line.

Building with bricks was cheaper than sandstone. The claystone outcropping with the sandstone was the raw material for making the bricks after crushing and grinding. The first brickworks was located opposite the Mission District on the east side of the Elbow River. It was owned by J.F. Peel with claystone excavation and a kiln on site. He started operation in August, 1886 with bricks shipped west for C.P.R. construction and for the rebuilding of Vancouver in brick after fire destroyed Gastown in June, 1886. The Mission brickyards, with a new owner, was still operating in 1897 when the economic boom began in Calgary.

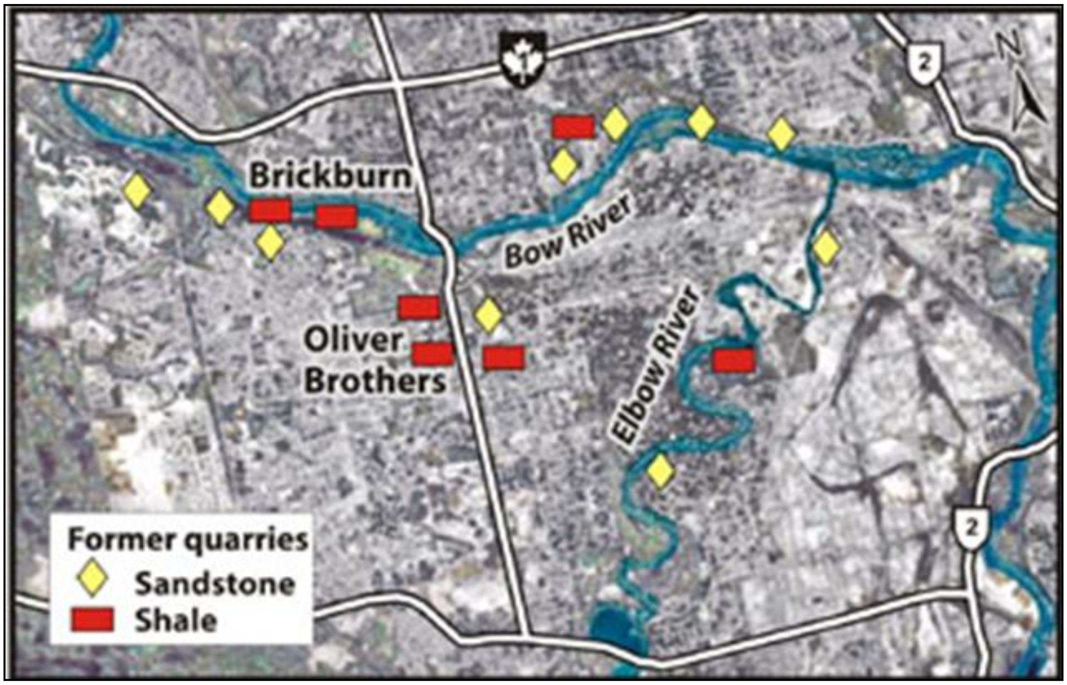


Figure 1. *Map of former quarry locations in Calgary (GSEC Network).*

There are three maps available that show the location of the quarries in the Calgary area. The GSEC version above is used as the reference for the discussion that follows. The other two maps are included in Appendix E. There are inconsistencies between the maps, including locations and names. The Sunnyside Freestone Quarry is common to all three maps.

2.1 Dominion Legal Survey

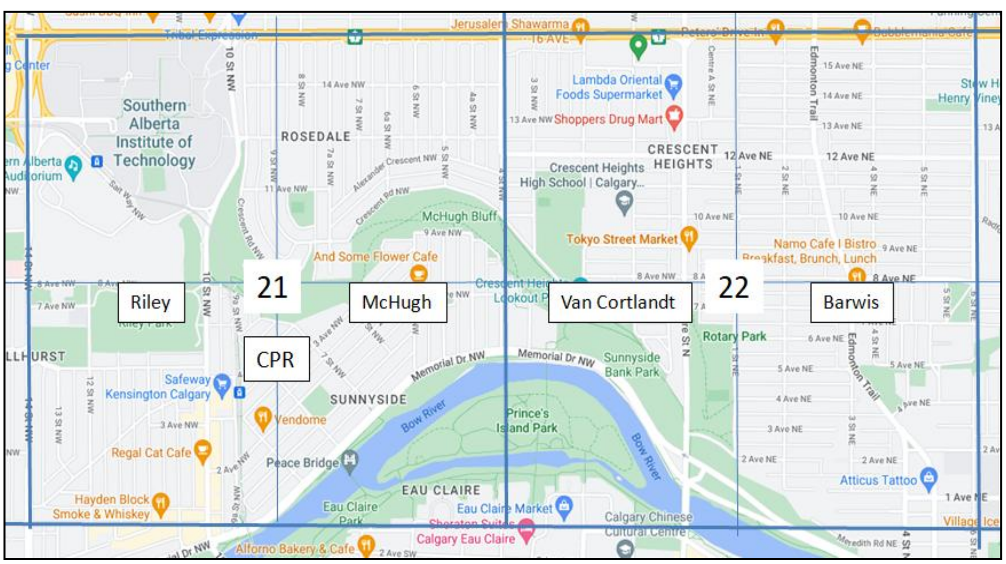


Figure 2. *Modern map with overlay of Township Grid showing the initial 1883 homesteaders' (McHugh, Van Cortlandt, and Barwis) partial quarter sections north of the river. McHugh lost his claim for title in Section 21 as it was reserved for the C.P.R. Riley bought the west half of section 21 in 1904.*

In 1883, there were 119 surveyors in the field striving to keep ahead of the advancing C.P.R. tracks that arrived in Calgary in August of that year. The government needed a map based on a legal survey in place before homesteading could begin. The first surveying west of the 5th Meridian (~ Barlow Trail) took place that year with a strip two townships deep and four wide, 12 miles x 24 miles, along the railway right-of-way. Most of this corridor was already leased by the Cochrane Ranch: the eastern boundary was Range Line 2 W5M, just 2 miles to the east of the Sunnyside area (by 1883, the Cochrane Ranch was a sheep ranch north of the Bow and a horse ranch south of the Bow as the cattle had been wiped-out by harsh winters the previous two years).

Those men who claimed homesteads on the north side of the Bow River likely were not interested in prime agricultural lands, they were there because they wanted to be close to the Calgary settlement. They were "businessmen" first, and they recognized the growth potential that Calgary offered. McHugh for example, secured timber leases, was a construction contractor for the C.P.R. and later owned a ranch. If there was the potential for sandstone quarrying on their land they would have been very active in developing the resource.

Claiming homesteads, as they did, east of the Cochrane Ranch grazing lease did not avoid land issues. A grazing lease was given in 1882 to the N.W.M.P. that extended 2 miles north of the river and included section 15 south of the river. The section 15 lease was later relinquished to the C.P.R. when they threatened to move their railway station further west from the existing small settlement at the junction of the Elbow and Bow Rivers. The odd numbered sections in a 24 mile corridor each side of the railway were reserved for ownership by the C.P.R. In Calgary, they exercised their option not only on section 15, but also on section 21, which McHugh had claimed. The grazing lease north of the river must have been relinquished at the same time, as homestead claims were filed in 1883. James Barwis, a N.W.M.P. member stationed at Calgary, claimed his quarter section on the Morley Trail north of the river where the N.W.M.P. grazing lease was previously located.

McHugh never received his land title. The survey of township 24 was completed the first week of August 1883. The surveyors dug mounds with a labeled post at the NE corner of each section within the township. For section 21 (Rosedale & Sunnyside), there would have been a marker at what is now the S.W. corner of 16th Ave. & 4th St. N.W.

McHugh was 32 years old when he left Ottawa with farm implements, a wagon and Clydesdales to travel via railway as far as Swift Current, the end of the C.P.R. line. From there, he drove his team to Calgary and in May, 1883 took a ferry across the Bow River to settle on the north bank. He built a shack and broke 20 acres of ground. The surveyors arrived at the end of July, 1883. He would have known then that his homestead was in section 21 and very likely he was aware that it was land reserved for the C.P.R.

Land title records of the original homestead grants and the subsequent changes of ownership were retrieved, but they do not reference any quarries. Van Cortlandt received title to his quarter section in 1889, referencing an 1886 legal survey, though his claim was dubious as he wasn't really a farmer and he was forced to negotiate with the government and purchase part of the acreage claim. Barwis received his land title in 1886.

2.2 Mineral Leases

The Provincial Archives were searched for Mineral Lease Records, the archivist's email summary of the search results was " *Our Surface Mineral Lease records do not go back as far as the date range you have provided. I searched the Mineral Application and Disposition Registers from that era and found reference to McCallum, Van Cortlandt and Riley, but no associated files.*" The ledger for Twp. 24, Rge. 1 W5M only has entries beginning in May, 1889 (see Appendix E) with none of the five quarries on the GSEC map listed. In 1883, the mineral title rights and surface rights both went to the homesteader. The homesteader could file his initial quarter section claim in 1884 when the official map for Twp. 24 was published (see Appendix E). To be awarded the land title ,the homesteader had to build a dwelling, live in it for at least six months per year, and clear & farm the land. After three years he could apply for the land title. Ira James Barwis received his land title in 1886 with no exclusion of mineral rights.

In 1887 the government changed the rules and retained mineral rights for the Crown when issuing new land titles. The exception to this rule is the C.P.R. sections, where mineral rights were retained by the C.P.R. and by those later purchasing lands from the C.P.R. The Ezra Riley land title for the W1/2 of section 21 does not have the "mineral rights reserved for the Crown" caveat that Van Cortland has on his SW 1/4 of section 22 title. Van Cortlandt did not receive his land title until 1889 and this document has mineral rights reserved for the Crown. Hence, the three parcels of land with historical quarries are each treated differently in respect to surface rights with mineral rights.

From 1883 to 1887, any minerals exploited such as sandstone quarries would either be by the homesteader himself, or by someone who had a business arrangement with the homesteader. After 1887, a Crown mineral lease would be necessary for the Van Cortlandt acreage, but not for the C.P.R. or Barwis acreage. The Sunnyside Freestone Quarry is on Van Cortlandt acreage and operated after 1887, but any Crown mineral lease that might have existed has been lost or destroyed.

The historical information for the quarries on the GSEC map, from east to west, follow.

2.3 SE-22-24-1 W5M

The SE-22-24-1 W5M was homesteaded by James Barwis in 1883 when he was 30 years old. He had joined the N.W.M.P. in 1877 and finished his service in 1886 as a sergeant with E Troop at Fort Calgary. After discharge he worked for I.G. Baker in Calgary and farmed & ranched, eventually settling in Innisfail.

A map published by the Glenbow (Appendix E) states that Wesley Orr quarried sandstone in what is now the Bridgeland area below East Crescent Heights from 1886 - 1890. He also is listed as operating the quarry at the base of Scotsman's Hill during the same period. Orr arrived in Calgary in 1883. He was a businessman buying property for land development and was the editor and manager of the Calgary Herald. He was Calgary's mayor for 3 years beginning in 1894. It is doubtful if Orr actually worked at the quarry attributed to him. He likely had sufficient capital of his own combined with investors' capital to lease the sandstone mineral rights from the land owner, Barwis, and hire experienced stone masons to work the quarry. The Dewdney Bridge (where Reconciliation Bridge is now) was newly built in 1885, so there was a means of transporting the stone across the river to the Calgary settlement.

***Figure 3**. The Ashdown Block on Stephen's Avenue. Built in 1891 from sandstone taken from Orr's north bank quarry below East Crescent Heights.*

Two maps in Appendix E refer to a Barwis quarry. One representing 1905 Calgary (drafted in 2004) shows a Barwis Quarry immediately west of where Centre Street bridge was constructed in 1916. This is on land owned by Van Cortlandt. The second map has a Barwis Quarry operating in 1896, the location near Centre Street, but indeterminate for the precise location. The 1896 date for the Barwis Quarry is the more reasonable date, as by 1905 the large quarries west of Calgary were supplying most of the sandstone. The Barwis Quarry was likely abandoned by 1905, but served as a landmark to justify being put on the map.

Perhaps in ~1896, Barwis opened a new cut bench near the original 1886 Orr Quarry, re-opening it at a time when the demand for sandstone picked-up. It is possible that exploration further west identified additional sandstone beds and that an arrangement was made with Van Cortlandt for access. A Crown mineral lease would be required for the Van Cortlandt land, but there is no record of one. The mineral rights were held by the owner of the Barwis lands, so it seems more likely the quarry was on Barwis land and has been plotted incorrectly on the 1905 map.

Bedrock outcrop, borehole data, and hillside morphology help identify the potential site of a quarry in the SE-22-24-1 W5M.

2.4 SW-22-24-1 W5M

Similar to Orr/Barwis, historical references are made to two quarries on this quarter section. In addition, the 1884 McHugh quarry may have been on this quarter section as the geotechnical borehole data does not support a quarry west of 4th St. N.W. near the McHugh homestead (this is discussed further under SE-21-24-1 W5M).

The Sunnyside Freestone Quarry, discussed separately below, was located on the Van Cortland quarter section. Van Cortlandt may have operated a second sandstone quarry himsef, as referenced in a Calgary Herald article below, after Sunnyside Freestone Quarry ceased operations. Or, perhaps given the 1897 date, the locals referred to the old quarry site by the name of the current landowner, Van Cortlandt.

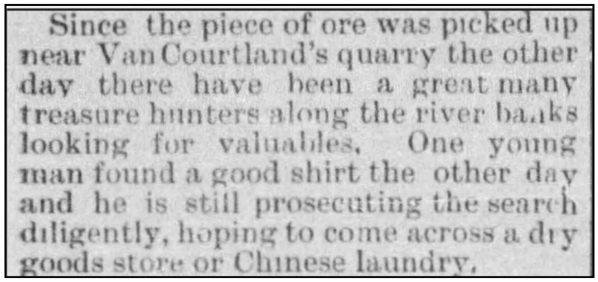

Since the piece of ore was picked up near Van Courtland's quarry the other day there have been a great many treasure hunters along the river banks looking for valuables. One young man found a good shirt the other day and he is still prosecuting the search diligently, hoping to come across a dry goods store or Chinese laundry.

Figure 4. *May, 1897 Calgary Herald story referencing Van Cortlandt's Quarry with some editorial sarcasm added.*

The geotechnical borehole data discussed in the next section indicates that the Sunnyside Freestone Quarry was located on the Van Cortland quarter section east of 4th St. N.W. A mineral lease with the Crown could have been held by either Van Cortlandt or by McCallum. Some form of business arrangement would have been needed between Van Cortlandt and John McCallum, the quarry operator, for access.

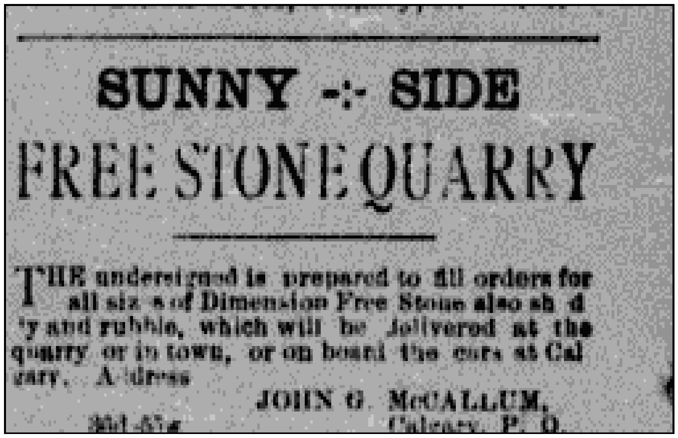
Van Cortlandt seems to have been quite the entrepreneur, taking out mineral leases on his land for whatever resource was in demand, likely with the idea of using other people's money to develop the mineral. In 1895, he had a mineral lease to extract coal, though nothing would have come of that as the seams are too thin. More significantly, in 1908 he took out a clay lease. The claystone may have been quarried to supply the Kempling Brothers Brick Works in Bridgeland, operational at that time - this possibility is discussed further below.

There is no bedrock outcrop exposure present day on this quarter section. Borehole data shows that bedrock would have outcropped along the base of the escarpment from the eastern boundary almost to the western boundary. Sandstone is present in the escarpment geotechnical boreholes. Hillside morphology clues to quarry sites have been obliterated over much of the slope, but at one site there are slope alterations consistent with an old quarry.

2.4.1 Sunnyside Freestone Quarry

The "freestone" in the quarry name is a rock property attribute. By definition, freestone is a thick-bedded, even-textured, fine grained rock (usually sandstone) that breaks freely and can be cut and dressed with equal ease in any direction without splitting.

The Sunnyside Freestone Quarry was operated by John McCallum. He was working the Sunnyside Quarry from at least 1888. His ads in the Calgary Herald ran from June 1889 to at least December 1890 (no online archives available for 1891 & 1892). Sandstone from the quarry was used in the construction of a commercial building in 1892. There were no ads in the Calgary Herald in 1893. It is uncertain when the quarry finished operations. As an individual, he was listed in the Henderson Business Directory in 1894.


SUNNY -:- SIDE

FREE STONE QUARRY

THE undersigned is prepared to fill orders for all siz s of Dimension Free Stone also sh d y and rubble, which will be delivered at the quarry or in town, or on board the cars at Cal ary. Address

JOHN G. McCALLUM,
Calgary, P. O.

Figure 5. *Sunnyside Freestone Quarry 1889 Calgary Herald ad for sandstone blocks and "shoddy" & rubble. Shoddy is loose stone used for construction.*

McCallum was in Calgary by 1885 at the latest, as he was the contractor that year for building the Calgary Town Hall. In 1888, he won a contract for a school construction. He was a city councilor in 1888. He operated a number of quarries, including taking over an Orr quarry along the Elbow River at the base of Scotsman's Hill. He had a mineral lease in 1889 for a quarry in the Sunalta area. Calgary's first courthouse was built with sandstone extracted from John McCallum's Sunnyside Freestone Quarry. McCallum was principally a builder and the quarries were likely a side-operation to secure a supply of building stone at a reasonable cost and in a timely manner so as to be competitive on tenders.

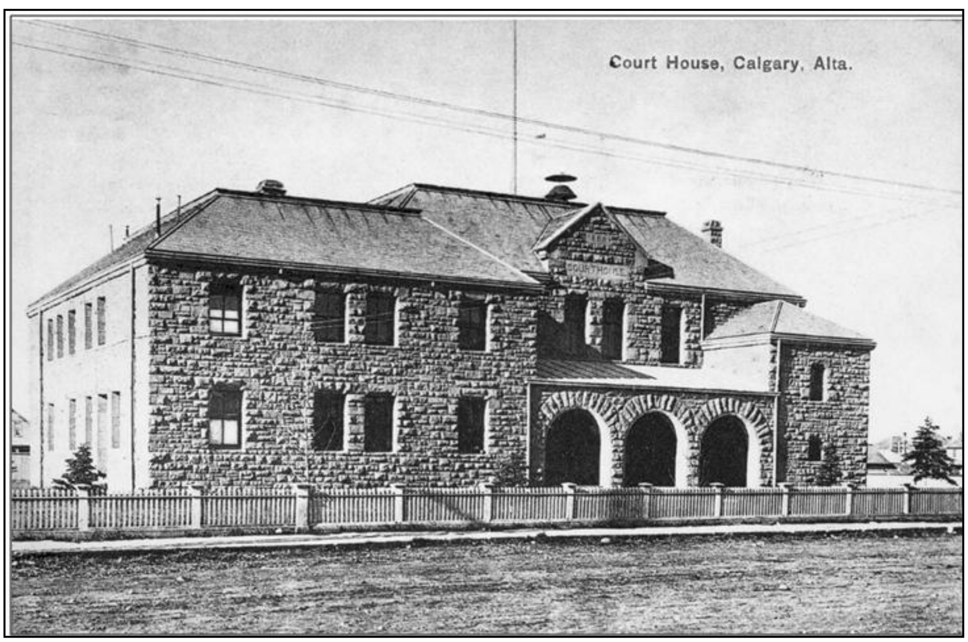


Figure 6. *Courthouse, Calgary, Alberta, (1908), (CU183007), by Unknown. Courtesy of Libraries and Cultural Resources Digital Collections, University of Calgary. Calgary's first courthouse, located on 4th St. S.W. between 5th & 6th Avenues, was built from 1888 -1890. It was demolished in 1958. It was constructed by John McCallum using rough cut sandstone blocks from his Sunnyside Freestone Quarry operation.*

John McCallum was awarded the contract with the federal government in November, 1888 to build the court house in Calgary for the North West Territories government. He won the competition with the low bid of $38,000. Over the winter of 1888/89 he cut stone from the Sunnyside Freestone Quarry and dug the court house foundations. The sandstone blocks may have been skidded across the frozen Bow River in winter, or perhaps transported via the Bow Marsh Bridge in Sunnyside that opened in 1887. Photos of other building sites from this period show the sandstone blocks were hauled to the construction site and were finished by masons at the building site into the desired size. He started building the courthouse in the Spring of 1889 and finished in 1890. The stone blocks were rough cut and varied between 1 to 2 feet in thickness. The use of unfinished stone was likely due to the Civics Works department in Regina facing budget constraints rather than due to a shortage of skilled stone masons in Calgary. The mortar was a mixture of sand and lime, the lime manufactured and shipped from a lime works near Banff. The rough exterior finish suited Calgary's frontier town image.

The court house dimensions were 91 ft. x 57 ft. x 27 ft. Assuming 2 ft.-thick walls, and a sandstone bed at the quarry that was 2 ft. in thickness, then a quarry bench cut that was 25 ft. deep, would need 320 ft. of quarry face excavated - for scale, the distance between 3rd St. N.W. and 4th St. N.W.

In addition to the court house, a Calgary Herald Oct., 1890 article reports that Sunnyside Freestone was one of the quarries supplying sandstone to the Hudson's Bay building under construction at Centre St. and 8th Ave. S.W. This two-storey building was opened for business in 1891 and unlike the original court house, it still stands. Other early buildings that may have used Sunnyside Freestone sandstone, though McCallum was not the builder, include the Alberta Hotel (1888), where the source of the sandstone is not reported. The Bank of Montreal (1889) and Lougheed House (1891) were built with sandstone from the Butlin Quarry. A detailed search of public, business, and private sandstone buildings from this era would likely reveal further examples of Sunnyside Freestone used in the construction. The library and Glenbow do not have any fonds for McCallum as they do for most other prominent people from this era. Knowledge of what other buildings he constructed would be a place to start the research.

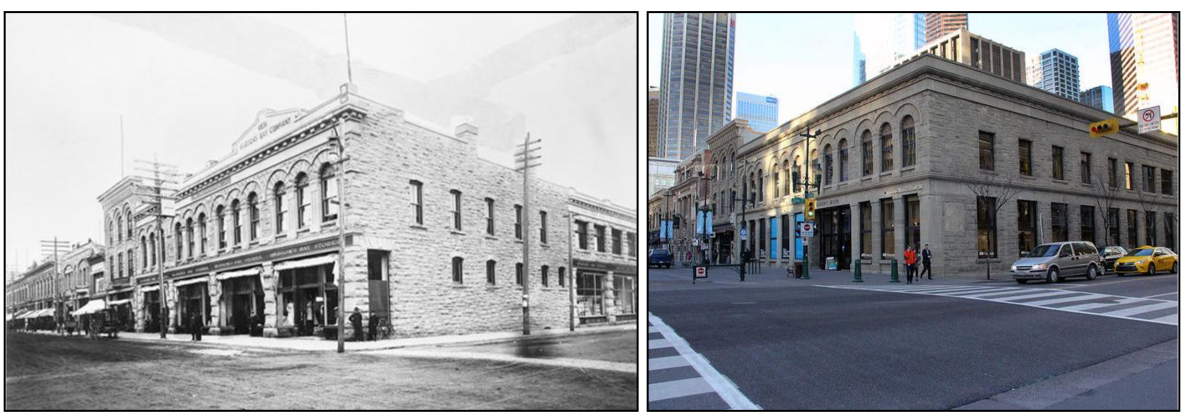


Figure 7. *"Hudson's Bay Company Store, Calgary, Alberta", (ca.1903), (CU11054951) by Unknown. Courtesy of Libraries and Cultural Resources Digital Collections, University of Calgary. 1892-built Hudson's Bay Store at the corner of Centre St. and 8th Ave. S.W. The more recent photo shows the building was later modified on the 8th Ave. S.W. side.*

It is unlikely that any sandstone from Sunnyside Freestone Quarry, or any other north bank Bow River quarry, was used in the building of the nineteen sandstone schools in Calgary. North bank quarries were likely either depleted or could not deliver the volume of stone needed. The first sandstone school was built in 1894 and the last, Balmoral School at 2nd St. N.W and 16th Ave., in 1914.

Figure 8. *Hillhurst School. Built in 1912, it was one of the last of the sandstone schools to be built. The sandstone blocks are of uniform size in comparison to the 1890 courthouse.*

2.5 SE-21-24-1 W5M

In historical accounts, Felix McHugh operated a quarry sited near his dwelling, at 4th St. N.W. His homestead quarter section was located west of 4th St. N.W. His dwelling is shown on the 1884 survey map (Appendix E) as just west of 4th St. N.W. Alternatively, a Glenbow map (see Appendix E) shows a McHugh quarry located near 9A St. N.W, though perhaps this map was never intended to show a precise location.

If McHugh was quarrying near his homestead dwelling then it was a quarry not on his land. The geotechnical borehole data indicates bedrock did not outcrop until at least 100 metres further to the east. He would have known his land boundaries, so perhaps he had an arrangement with Van Cortlandt to quarry. Perhaps he worked the outcrop for sandstone and may have been doing this for a couple of years during the title dispute with the C.P.R. His quarry was likely only of cottage industry scale, enough to extract rough hewn blocks for the foundations of his farm buildings; there were closer quarry sites to the settled part of Calgary to supply stone for sale.

The 9A St. N.W. candidate quarry site, also located on SE-21-24-1 W5M, is supported by bedrock exposure, by the 2022 excavation pit for the storm sewer tunnel at 10th St. N.W., borehole data, and hillside morphology. The only historical reference for a quarry at this site is the McHugh Quarry on the Glenbow Map.

2.6 W1/2-21-24-1 W5M

The base of the escarpment in the west half of section 21 is at the border between the SW & NW 1/4 sections. The land where the westernmost quarries are shown on the GSEC map was C.P.R. land until 1890 when it was sold to the Calgary Medicine Hat Land Company. A London-based speculator, Heath, purchased the land in 1904. The west half was flipped to Ezra Riley in 1904. According to the map, a shale (claystone) and sandstone quarry were located on the W 1/2 of section 21. It is most likely any quarry on this land was active in the 1880s or 1890s, as after that time the large quarries to the west of Calgary were opened. Any operator would have needed a lease from the C.P.R. or Calgary Medicine Hat Land Company.

Other than the GSEC map, there doesn't appear to be any other references to quarrying on this quarter section. Perhaps, like the suggestion for McHugh, there was a limited quantity of sandstone and the material extracted was used for foundation on the local farm buildings. Similarly, quarrying claystone and making bricks on site may have been a cottage scale operation, quite within the capabilities of the homesteaders who were jacks of all trades.

There is no bedrock outcrop today at this location that is found at the base of SAIT hill. Borehole data supports the possibility of thin bedrock outcrop, but can't confirm a thickness of 8-10 metres as found at 9A St. N.W. and further east at the escarpment base.

2.7 Claystone Quarries

Brickworks were usually located at the site of claystone outcrops that had a nearby water supply. The claystone was crushed and mixed with water to form the clay, formed with molds, and then fired in a kiln on site to make bricks. The Peel Brickworks, opposite Mission, was the principal brickworks in early Calgary, commencing operation in 1886. According to Manson in "Bricks in Alberta", a new brickyard in Calgary started-up every Spring for 25 years. If so, only a few are documented.

There may have been other claystone quarries in addition to the Riley Park Quarry on the north bank of the Bow. There was a brickworks operated by the Kempling Brothers just off Edmonton Trail in Bridgeland from 1906 to 1910. In a business directory, one brother listed his profession as a brick maker and the other as a stone mason; it is likely they operated the complete process from quarry site to brick sales.

There was a clay mineral lease taken-out in 1908 for the east portion of the Barwis quarter section. Quarries, without defining what mineral, are mentioned in Bridgeland behind the De Waal Building on 4th St. N.W. These may have been claystone quarries or gravel quarries. The borehole control is not available to map bedrock depths in this area of the escarpment.

A clay mineral lease was also taken-out by Van Cortlandt in 1908 for his quarter section just to the west of the brick yard. Perhaps, for the Van Cortlandt land, the claystone was quarried where the sandstone located at the top of the outcrop had first been quarried two decades earlier. This would seem to make sense as the overlying glacial sediments would have been removed and the bedrock exposed as a cut bench. Below is a tantalizing photo taken in 1908 from McHugh Bluff looking east. The McArthur, Steinbrechar and Paterson homes, located on 1st St. N.W. near Crescent Rd. are located on the skyline. Using a Present Day satellite image and lining-up the McArthur Bridge and Scotsman's Hill in the distance shows the photo was taken at Crescent Road and 5th St. N.W. The building complex at the base of the escarpment in the mid-distance is intriguing and appears to be industrial in nature. The hillside above the buildings has a horizontal bench cut and there is a large base of slope sediment fan cone spilling-out onto the flat ground, suggesting waste shed from higher up the slope.

Figure 9. *"View of Bow River Looking East, Calgary, Alberta", (ca. 1908), (PB-12-39), by Unknown. Courtesy of Glenbow Archives, University of Calgary. Photo looking east taken from Crescent Road and 5th St. N.W. McArthur Bridge, where Centre St. Bridge is currently located, is visible in the distance. A complex of eight buildings is visible in the mid-distance at the base of the escarpment slope.*

Figure 10. *A zoom-in of figure 9 photo of buildings located at base of slope with a horizontal bench cut further up the slope. Further east, beyond the first trees, there is another light-coloured debris slope that may indicate quarrying above.*

The 1908-photo building complex plots as being at a base of slope site north of the Sunnyside Housing Co-op at 3rd St. N.W. A base of slope fan cone visible in the 1908 photo appears to be present today, cut by the diagonal walking path. A few years after the 1908 photo, the City tramline was running right by this spot, as it climbed-up the hill to Crescent Road, using the high angle walking path visible in the satellite image.

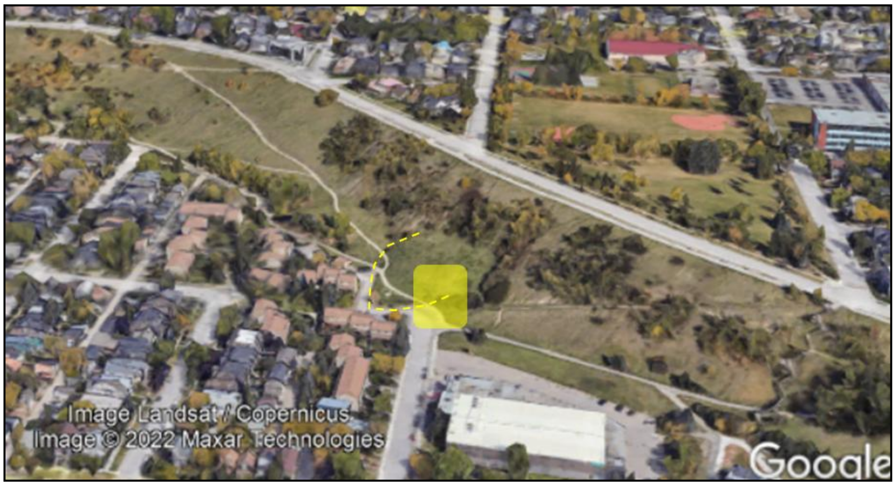


Figure 11*. Yellow rectangle is calculated location of building complex in 1908 photo posted on a Present Day satellite image. It plots at 3rd St. N.W. behind the Housing Co-op. The dashed line is a base of slope fan cone, crossed by the walking path, that may be the same feature that is present in the 1908 photo.*

What was the nature of the building in the 1908 photo? Sandstone quarrying had likely finished fifteen years earlier. Perhaps some of the buildings are from that era. One possibility is that claystone was being quarried using the abandoned sandstone quarry benches, crushed on site and transported the short distance to Bridgeland and the Kempling brick factory. If not associated with claystone operations, then they are likely buildings associated with the sandstone quarry initially and then taken over for a residence & farm; some land seems to be planted as a garden in the photo. Business records or personal journals, if available, should be able to confirm if quarrying actually occurred on this clay mineral lease.

3.0 Local Geology Setting

The regional geology framework taken from published papers (see references) that can be applied to the fluvial plain communities of Hillhurst/Sunnyside and the escarpment communities of Rosedale/Crescent Heights includes: the bedrock sandstones, the overlying glacial sediments, and the more recent river plain sediments. The glacial sediment geology and the recent river plain sediment geology are included as appendices.

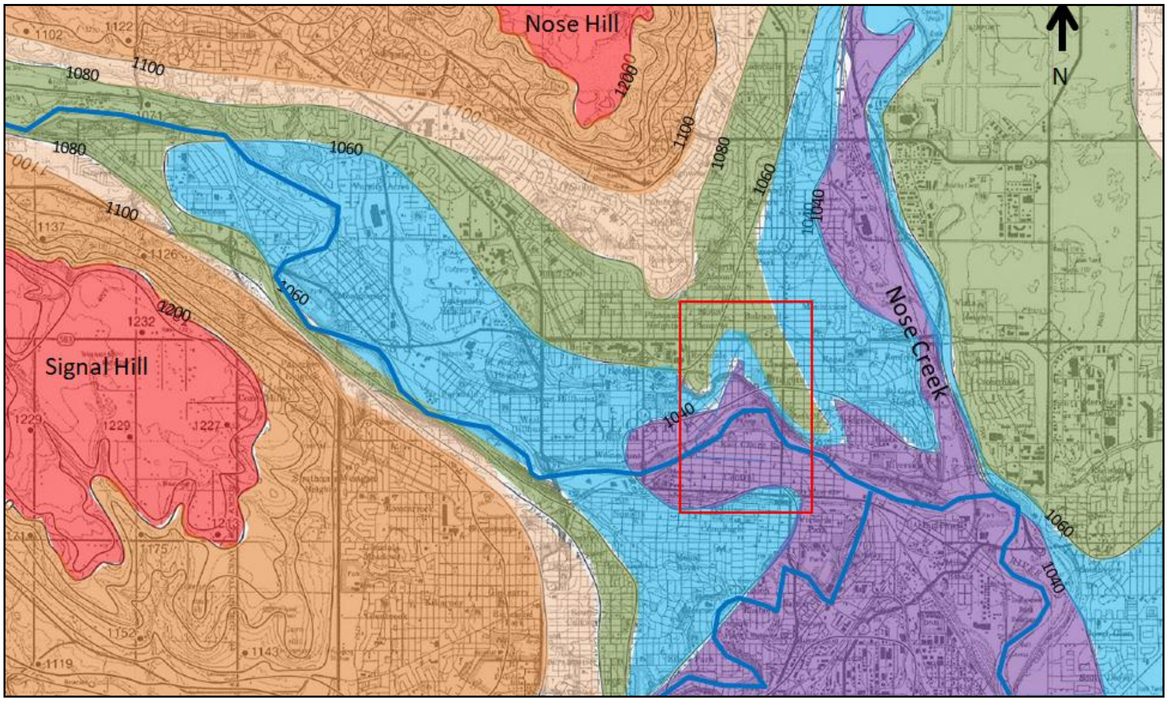


Figure 12. *Bedrock Topography Map of Calgary (modified from Moran, 1986). Depth contours are in metres above sea level. The red rectangle is the area with borehole data mapped in more detail.*

The regional bedrock topography map above shows the Bow Valley as a fairly flat-bottomed bedrock topographic low running between the glacial carved flanks of the Signal Hill and Nose Hill topographic highs. The Bow River valley between the two topographic highs and to the west existed prior to the most recent glacial episodes (25,000 - 12,000 years Before Present (B.P.)). In contrast, Nose Creek valley and the north end of the Elbow River valley are recent glacial features (12,000 years B.P.), created by meltwater channels of retreating glaciers. The abrupt turn to the south of the Bow River where it meets Nose Creek is a feature of the most recent glacial period. Prior to this, the Bow River valley continued on a course to the ESE.

Figure 13 is a geological cross-section oriented south to north from Mount Royal to SAIT. There are four boreholes that reached bedrock shown on the cross-section. The modern river has cut-down and removed 30-40 metres of glacial tills and lake sediments in the valley. These sediments are preserved in the communities of Rosedale and Crescent Heights. There has not been significant downward erosion of bedrock. The cross-section shows glacial sediments exposed on the valley flanks with 6-12 metres of flood plain gravels and clays in the valley bottom. In places on the valley flanks where the modern river eroded sufficiently far north to reach the pre-glacial valley flanks (not shown) then bedrock would outcrop as a 10 metre high cliff above the river plain. It is this outcrop that was the site of the north bank Bow River quarries.

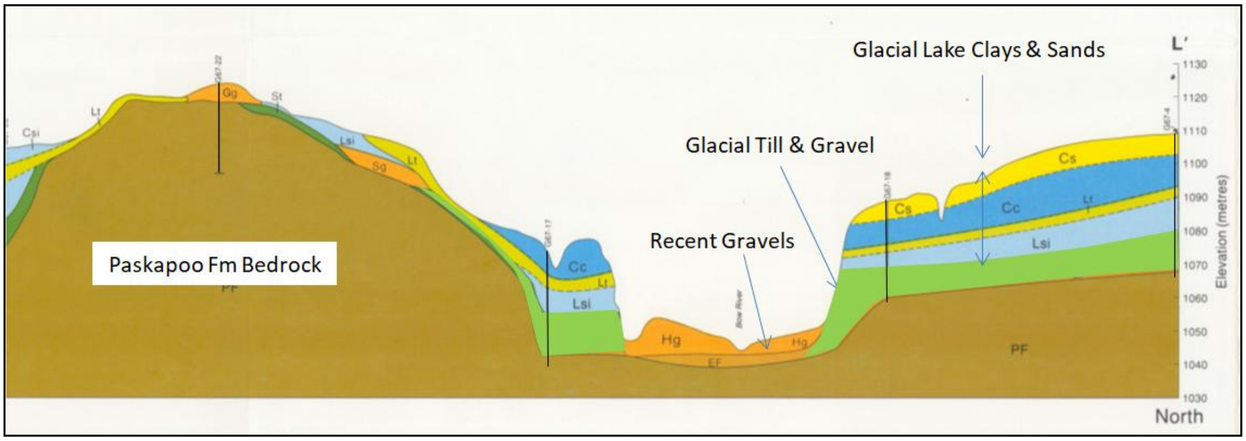


Figure 13. *Modified from Moran, 1986. A geological cross-section from Mount Royal to SAIT & then N.W. showing 30-40 metres of glacial lake & till sediments overlying bedrock north of the Bow River. Within the river valley there are 6-12 metre-thick alluvial gravels deposits.*

3.1 Paskapoo Sandstone

The Paskapoo Formation forms the bedrock in the Calgary area, outcropping on the flanks of the river valleys. It was deposited ~ 58 million years B.P. in a subsiding basin as the Rocky Mountains rose to the west. Approximately 500 metres of the formation was subsequently eroded in the Calgary area, exposing the Lacombe member at outcrop. Sediments consist of flood plain clays & silts and river channel sandstone. The Lacombe member is characterized by thin sandstone beds in a dominantly claystone and siltstone section with minor coal.

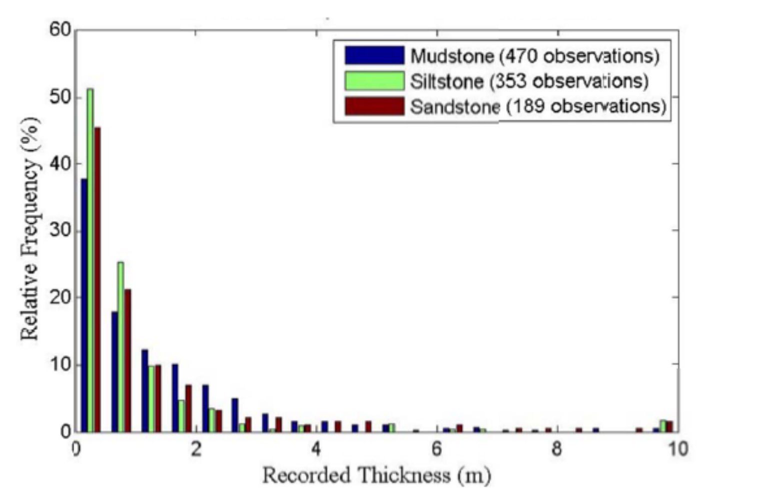


Figure 4-14: Distribution of rock type layer thickness observations in core logs from project sites throughout the city.

Figure 14. *From Crockford, A. 2012, showing Paskapoo bed thickness encountered in geotechnical boreholes in Calgary. Sandstone bed thicknesses greater than 2 metres are rare.*

The sandstones are randomly located fluvial channels encased in fine grained overbank deposits. A 1916 provincial government compilation of Calgary quarries showed the Oliver & Brickburn quarries (see Appendix E) had beds 3 - 6 metres in thickness, but the other five active quarries at that time had beds of 1 metre thickness with thin overburden. Quarry dimensions at that time were commonly 8 metres high and 50 metres in length (Crocq, 2010).

Bedding planes are near horizontal in the Paskapoo Formation. Vertical cross-jointing is prevalent, especially along river banks were sediment load has been removed. A recent modeling study of Paskapoo aquifers estimated that individual sandstone beds would be on average 75 metres in width and a maximum of 200 metres in length (Mathews, 2011).

The sandstone bed dimensions from these studies can be used to estimate the range of dimensions in a quarry. Bed thickness would have been known at the outcrop and continuity of a sandstone bed along the cliff face would establish the potential length of a quarry. Depositional setting indicates the sandstone beds are oriented approximately east-west for the long axis of the sandstone body. Where the Sunnyside Freestone Quarry was located, the escarpment is at a 30^0 angle to the east-west depositional orientation, reducing the maximum length of exposure from 200 metres to 150 metres.

The bed continuity into the hillside would have been unknown until the glacial sediment cover was removed. It is likely that test trenches were excavated to establish continuity to the north, beneath the glacial sediment cover. Erosion northward from the river removed on average one-half the original width of the sandstone body.

- Maximum Case (no erosion at cliff face) - 2 metre or greater thickness (10% of beds), 75 metres in width, and 150 metres in length (oriented east-west).
- Median Preserved Case (50% river erosion) - 1 metre thickness, 37 metres in width (50% eroded), and 75 metres in length.

The geotechnical borehole data indicates that north bank of Bow River sandstone beds are 0.5 - 1.0 metre in thickness. A bed width of greater than 20 metres likely would involve too much overburden excavation to be fully exploited (see section 3.3). A 50 - 75 metre sandstone bed length was likely.

3.2 Bedrock Outcrop

There is one good outcrop of bedrock in the study area and one spotty outcrop segment that is supplemented by bedrock exposure in a 2022 excavation.

At the base of the escarpment below 2nd - 3rd St. N.E. there is bedrock outcrop. It is the best location between 14th St. N.W. and Edmonton Trail where bedrock can be observed in outcrop today. Approximately 10 metres vertically above the Memorial Drive grass verge, where the slope changes from steep below to moderate above, there are bands of bedrock outcrop along a 150 metre-long exposure. The bedrock exposed is less than 1 metre-thick and the beds are near horizontal. The slope below the thin outcrop band is covered with sloughed glacial sediments from higher up the bluff. The glacial sediment contact with bedrock was not observed, but would not be difficult to reveal with a bit of excavation.

The location of the bedrock outcrop is shown by the dashed line on the satellite image below. Exposure occurs in patches along the steepest portion of the bluff amongst the bushes, trees and grass. Further west, within the rectangular box on the satellite image, the slope has been altered and is characterized by a series of bowls in the basal glacial sediments. Bedrock is not exposed. The slope bowls may indicate places where there was quarrying and overburden needed to be removed in order to expose the bedrock further into the hill. Further west yet, there are grass slopes associated with Centre Street bridge engineering with no trace of the original topography remaining.

Figure 15. *Satellite photo of East Crescent Heights Escarpment. The dashed line shows where a band of bedrock is exposed about 10 metres vertically above the base of slope. The white rectangle encloses an area of slope modification, perhaps indicative of excavation of a quarry bench.*

Grey claystone and thinly laminated siltstone are found at the eastern portion of the outcrop band, as shown in the photos below. The bedrock is heavily weathered, crumbling when picked-up.

Figure 16. *Outcrop at the east end of the bedrock exposure. Grey, finely laminated claystone and a laminated crumbling, brown siltstone.*

Figure 17*. Photo of slope angle change. The white line marks where bedrock is found at outcrop with glacial sediments above. The angle of the slope lessens above this line.*

Blocks of sandstone are found in places at the base of the slope. They may have been displaced from further up the hill; perhaps even due to quarrying operations. One small band of sandstone was found at outcrop near the west end of the exposure as shown in the photo below. It exhibits the characteristic yellow colour of the Paskapoo Sandstone. Immediately above this outcrop the slope has been excavated and is a bowl shape. Perhaps there was quarrying here and the bowl is due to glacial sediment overburden removal.

Figure 18*. Photo of yellow, blocky sandstone at west end of outcrop band. Sandstone bed is about 0.2 metres thick.*

The insights provided by the East Crescent Heights base escarpment bedrock outcrop that may be applicable to the outcrops further west that the homesteaders would have seen are:

- Only a thin interval of bedrock is exposed on the slope and this at the slope break at near top of bedrock. If this exposure was a thick sandstone bed, it would attract the attention of locals looking for quarrying prospects.

- The lower section of bedrock is covered by sloughs from the overlying glacial sediments. An exception to this may have been a case where the river channel was active at the base of the bluff, exposing more bedrock section, by undermining and removing the sloughed sediments.
- The slope is heavily vegetated both at the outcrop and above the outcrop.

3.3 10th St. N.W. Upper Plateau Storm Water Diversion Tunnel Excavation & Outcrop

Figure 19. *Excavation pit photo at base of 10th St. N.W. hill for the upper plateau storm water diversion tunnel. The very bottom of photo on left shows pit walls of yellow coloured sandstone below grey coloured claystone. Photo on right shows yellow sandstone rubble lifted out of pit. Thanks to Theo, site supervisor, for photos.*

Geotechnical boreholes drilled below the L.R.T. tracks for the upper plateau storm water diversion along 10th St. N.W. indicate top bedrock is ~8 metres above the Sunnyside ground level and that sandstone is present near the top of the bedrock (section 3.4 below). The excavation pit for the tunnel entry was opened in June, 2022 and during a walk-by, yellow coloured sandstone blocks were noticed in the mound of material dug out of the pit. The site foreman was kind enough to take a photo of the pit when requested.

Figure 20*. Two of the several small sandstone/siltstone outcrops at ~1059 metres a.s.l. elevation found between 9A St. N.W. and 7th St. N.W. Left photo courtesy of Peter Hews.*

East of the tunnel excavation, along the ~1059 metres a.s.l. elevation contour (±1 metre) between 7th St. N.W. and the candidate 9A St. N.W. quarry site (section 3.2), five small outcrops of sandstone/siltstone are found on the steep slope. Finding five such exposures along a 125 metre long slope segment at the same elevation as the top bedrock elevation in the nearby escarpment boreholes indicates these are valid near top bedrock outcrops and not construction blocks displaced from above. The easternmost bedrock exposure is 50 metres east of the path that climbs from Sunnyside to 7A St. N.W. in Rosedale.

3.4 Conceptual 1880s Quarry Setting

The slope profile of the escarpment when the 1880s quarries were in operation can be inferred from the steep areas of the escarpment today. These slope angles are consistent with 1930s & 1940s engineering reports analysing the McHugh Bluff slope failures prior to slope angle reduction modifications. The top of the escarpment has slopes up to 40 degrees, decreasing to 30 degrees near the base. The top of bedrock is 8-10 metres above the river flood plain gravels. In locations with recent active river channels at the base of slope, the bedrock would have been exposed and formed a cliff. In other places, bedrock would have been covered-up by slide debris. Today, the bedrock outcrop, except for the two outcrop segments described, is covered-up by material from higher-up the slope pushed-down to reduce slope angles and prevent slides.

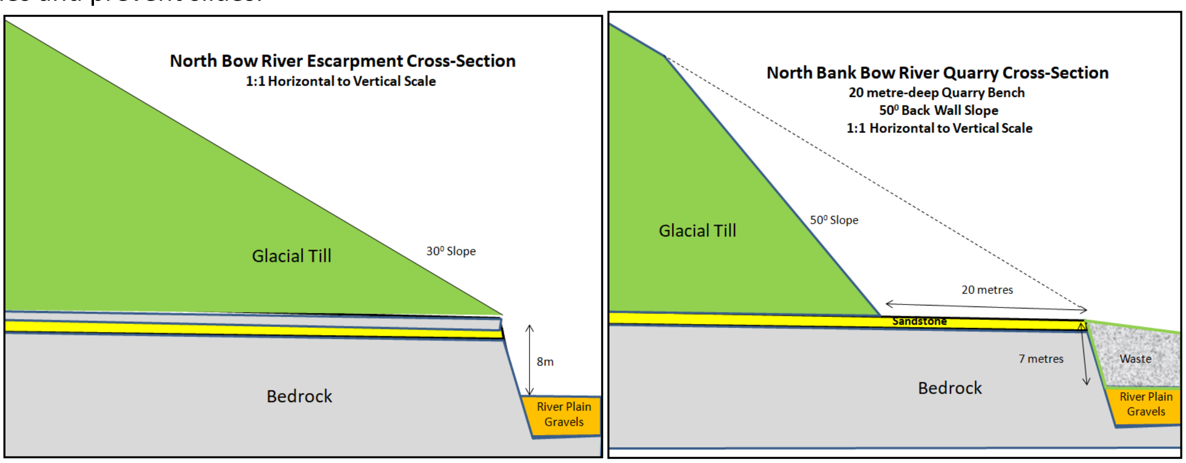


Figure 21. *Sketch of escarpment in 1880s before and after quarry operations. An 8 metre-thick bedrock section, including a 1m-thick sandstone unit, forms a cliff above the gravels of the Bow River flood plain. The overlying glacial sediments form a 30 degree slope. Image to right shows the case for a 20 metre-deep bench cut into the hill with glacial sediment cover dumped off of cliff face.*

In practical terms, the amount of a sandstone bed able to be exploited would have been limited by the effort needed to remove the overburden. The waste claystone and till would have been shoved off the bench and accumulated at the base of the outcrop. There must have been a limit on how far into the hill that the bench was evacuated. To cut back 10 metres into the hill would have created a 6 metre vertical face in the glacial till in the 30^{0} slope case. In the diagram above, a 20 metre bench case, a sloped back wall is assumed so as to avoid wall collapses every time it rained. Large volumes of waste would need to be dumped onto the river plain flats, with the toe of a debris fan located 40 metres or more beyond the original outcrop face. Only the thicker sandstone beds (2 - 3 metres) would have made this effort worthwhile.

The location of the historic bedrock cliff exposures along the Bow River flood plain are north of the Present Say base of slope. A 10 metre cliff face, even if not quarried because there was no sandstone, would be located 16 metres into the hill as it became covered by slide debris to an angle of repose of 30^0. Slope cross-sections made in 1932 (Appendix D) show this to be the case.

The ideal location of the sandstone bed within the outcrop would be near the top, sufficiently deep so as to be below the ~1 metre-thick weathered top bedrock zone and sufficiently high in the outcrop that large volumes of overlying claystone weren't required to be removed to get at the sandstone. A high quality sandstone bed at the base of the outcrop was not of much value because of the effort needed to remove the large volumes of overlying bedrock waste rock. Surprisingly, the borehole data discussed in the next section shows that many of the boreholes along the escarpment encountered sandstone in the optimum scenario - near the top of the bedrock section below a thin claystone weathered layer.

These first quarries would have been quarried by hand. Shovels, pick-axes and wheel barrows would have been used to remove the glacial sediment overburden. The top of the sandstone would be exposed by inserting horizontal wedges at the sandstone/claystone contact and using crowbars and sledge hammers to lever-off the claystone waste in large blocks. Hand augers would be used to create vertical holes in a straight line in the sandstone to the approximate size of the block desired. Wedges and sledge hammers would then be used to split the sandstone along these lines. The rough blocks would have been hauled away to the construction sites and finished by skilled masons on site.

In later years, blasting and steam powered machinery was used in the large quarries of west Calgary. It is unlikely this was the case for the north bank Bow River quarries of the 1880s & 1890s. Quarrymen from Scotland provided the labour - physical strength combined with skill and experience.

The footprint of the quarry likely changed very quickly after abandonment. The exposed glacial till face would have collapsed with the first heavy rains. And eventually the overlying glacial lake sediments further up slope would have slid down-slope and covered the quarry face and the waste material at the base. 130 years after abandonment, assuming no further modifications by man, an old quarry site may appear only as a minor break of slope 20 - 30 metres above the river plain ground level.

3.5 Geotechnical Borehole Data

There are a large number of public domain boreholes drilled along the north bank of the Bow River escarpment that penetrate bedrock. On the borehole data sheets, the bedrock depth and the lithology of the bedrock encountered is recorded. Some of these wells are located within 70 metres of the base of the escarpment Present Day (~50m to historical bedrock outcrop). The elevation of bedrock in the borehole establishes the maximum 1880s bedrock outcrop elevation and thus, the bedrock exposure above the river flood plain. Boreholes that encountered sandstone near the top of the bedrock section flag sites where sandstone may have been at outcrop and thus, candidate quarry sites.

The earliest top of escarpment geotechnical borehole data is from a 17-well drilling program in 1944 after a major slide on the slope (Appendix D). Only four of these wells reached bedrock, but this includes a well in the middle of Crescent Heights Park that establishes the presence of sandstone 500 metres further west than the modern borehole control. Projecting this well to the base of the escarpment at 3rd St. N.W. in Sunnyside is where the 1908 photo showed a bench cut on the slope above buildings.

Following another major slide in 1958 of the Sunnyside escarpment (see Appendix D), a total of 33 boreholes were drilled to bedrock in Rosedale and Mount Pleasant. The program was designed to map aquifers within the glacial sediments that overlie the bedrock that brought groundwater to the Sunnyside Slope. The concept was that once the aquifers were mapped, new wells would be drilled some distance back of the escarpment and equipped with pumps to prevent water reaching the slope. Below is an example of a borehole record - thickness and lithology of the different units encountered are described.

						PAGE	D 7	
RECORD_NUMBER	00951	U.T.M._ZONE	11	METHOD	DYNAMIC CONE	HAMMER		LB.
DATE_(MO/YR)	03/59	EASTING	704860	PURPOSE	TEST HOLE	DROP		IN.
LOC._PRECISION	164. 0 FT.	NORTHING	5660570	RELIABILITY	GOOD	SPOON_DIAM		IN.
REFERENCE	MT0312004	N.T.S._MAP_NO	8201A	SURFACE_ELEV	3529. 2 FT. ASL	BOTTOM_OF_HOLE	140. 0 FT.	

DEPTH	SOIL_TYPE	DESCRIPTION	ATTERBERG DEPTH	ATTERBERG P=L	ATTERBERG M=C	ATTERBERG L=L	PENETRATION DEPTH	PENETRATION BL/FT	WATER DEPTH
0. 0	FILL, ASPHALT, GRAVEL.	SURFACE, AGE POST-GLACIAL.							
2. 0	SILT, SAND.	BROWN, LACUSTRINE, STRATIFIED, AGE GLACIAL.	2. 0		18		2. 0	34	
30. 0	CLAY(13), SILT(47), SAND(40).	GREY, LACUSTRINE, STIFF, LAYERED, AGE GLACIAL.	30. 0		24		30. 0	24	
52. 0	SILT, SAND, CLAY.	BROWN, LACUSTRINE, STIFF, STRATIFIED, AGE GLACIAL.	52. 0	17	18	24	52. 0	64	
91. 0	SILT, SAND.	GREY, LACUSTRINE, DENSE, AGE GLACIAL.	91. 0		13		91. 0	80	
104. 0	TILL, CLAY(28), SILT(58), GRAVEL.	GREY, GLACIAL, HARD, AGE GLACIAL.					104. 0	132	
137. 0	BEDROCK, SHALE, SAND.	GREY, ALLUVIAL, AGE PALEOCENE.							

Figure 22*. 1959 Borehole Record #951 (6A St. N.W. & Crescent Road) showing 137 feet of glacial sediments above bedrock with the 3 feet of bedrock penetrated described as shale and sand. Top bedrock in this borehole is below the surface elevation of Sunnyside.*

The data from the wells was mapped and interpreted in a 1961 paper by Meyboom (see References). A real surprise was the discovery that beneath Rosedale there was a bedrock erosional topographic low of ~400m width with the deepest portion between 6A St. & 5th St. N.W. of 170 metres width and up to 40 metres below regional escarpment bedrock values. The bedrock topographic map from the paper is shown below. It is likely that this north-south feature is a glacial scour and meltwater channel from a continental glacier when it was retreating to the north. Which glacial episode it is associated with has not been studied. The significance for the bedrock mapping is that the channel area coloured in blue has bedrock topography values lower than the elevation of the Sunnyside flood plain. Bedrock outcrop could not be present at the base of the escarpment and hence, this area can be ruled out as a candidate for the old quarries. The 1961 paper was primarily addressing the 1958 and earlier slope failures. The author considered the bedrock channel to be a significant factor in the slides; others studies have disagreed. It is a topical issue given the 2021 slide on the east side of 7A St. N.W. Further slide history and analyses is included as Appendix D.

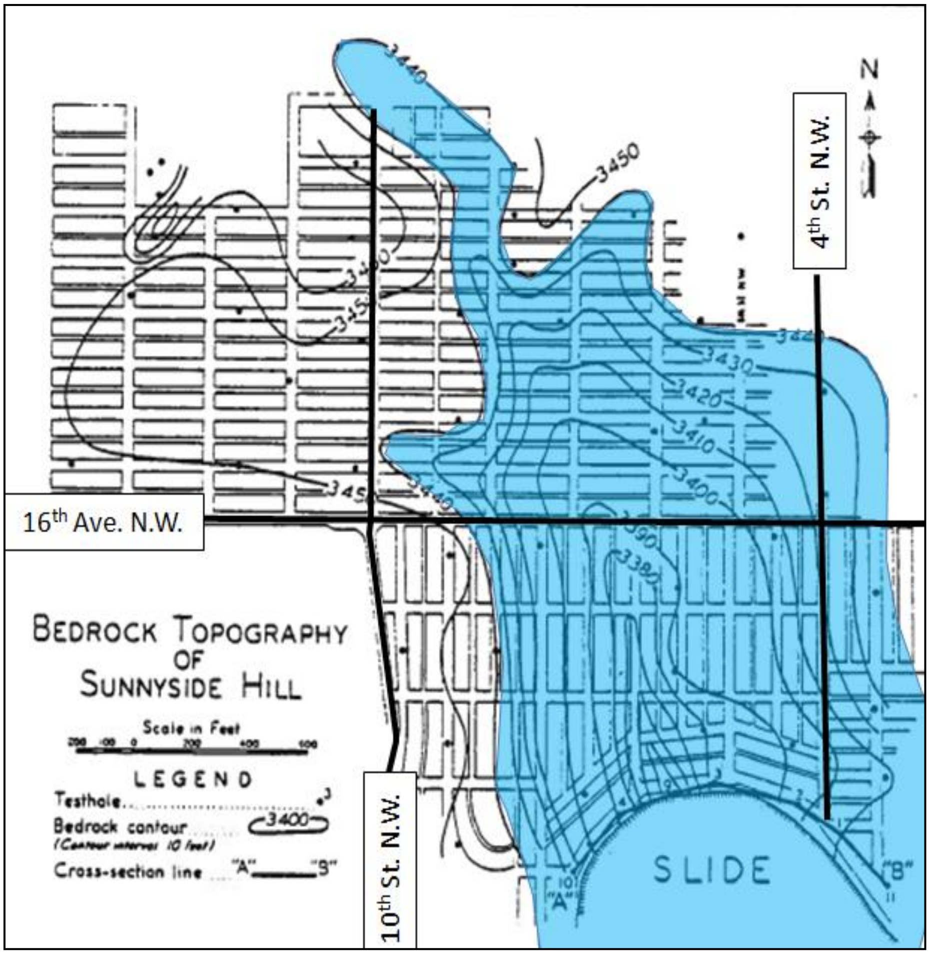


Figure 23. *Bedrock topography map beneath Rosedale and north as far as 24th Ave. N.W. in Mount Pleasant, from Meyboom, 1961. The blue shaded area is within a bedrock channel that, at base of the escarpment, has values structurally lower than the surface elevation of Sunnyside.*

The Rosedale bedrock topographic low is an interesting geology feature in its own right. There has been no further mapping published since the 1961 paper. A search of public domain borehole records reveals a continuation of this bedrock topographic low feature through Sunnyside to the Beltline. A map and discussion is included as Appendix C.

Hundreds of boreholes have been drilled to map the glacial geology of the Calgary region. Some of the wells are only 2 metres deep and drilled with a hand auger. The data was mapped to identify potential fresh water aquifers and commercial gravel deposits. The glacial geology is summarized in a 1986 paper by Moran. Several of these boreholes were drilled on the escarpment east of the 1959 boreholes and provide useful control for bedrock depths and lithology. This dataset was especially useful for mapping the bedrock channel continuation south of the Bow River.

The Alberta Water Well data set provided a few useful data points. Recent geotechnical drilling activity that has contributed borehole data along the escarpment includes the Centre Street Green Line L.R.T. boreholes and the Flood Mitigation boreholes near 10th St. N.W. These latter two datasets have more detailed lithology information for the bedrock and the overlying sediments than the vintage data.

The bedrock depths and lithology from the boreholes located along the escarpment were used to project bedrock outcrop at the base of the escarpment. Location and information from the boreholes is presented in section 3.6 that follows, where candidate quarry sites are discussed. In Figure 24, the blue colour indicates where top bedrock depth is below the elevation of the flood plain surface. The Sunnyside segment corresponds to the bedrock erosional feature shown in Figure 23.

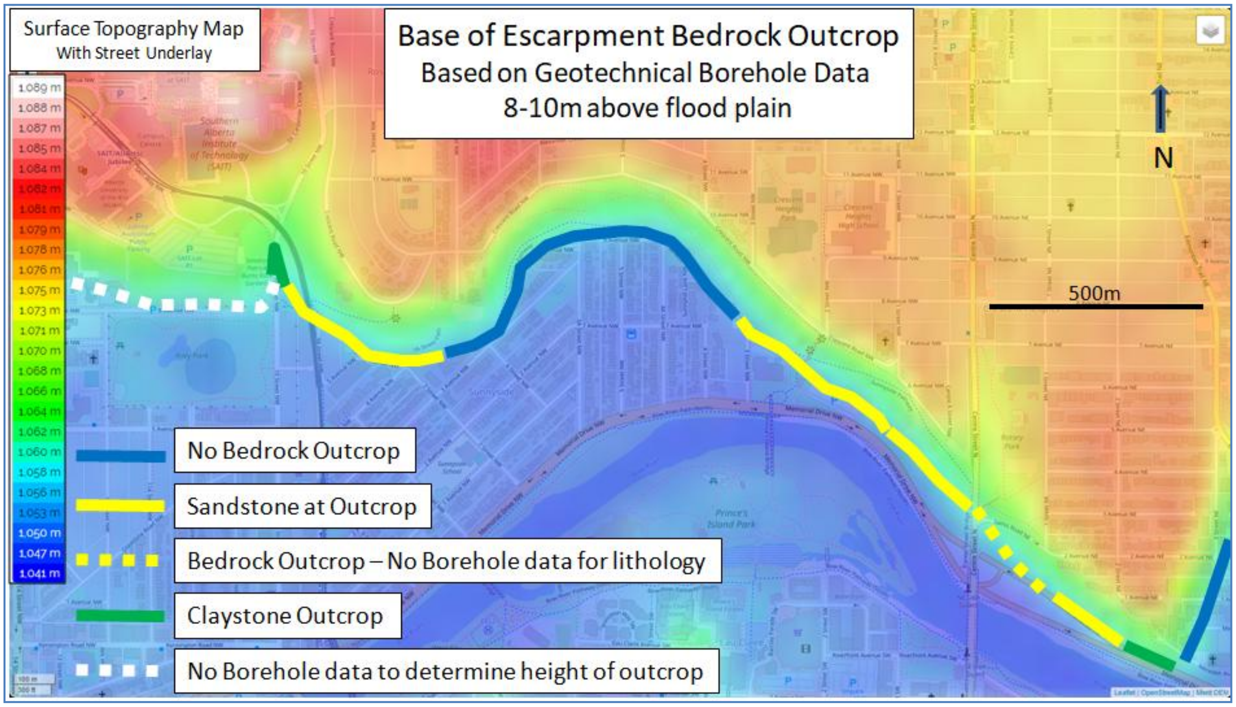


Figure 24. *Map of bedrock outcrop lithology at base of escarpment on north bank of Bow River based on geotechnical borehole data.*

The solid yellow colour indicates segments where sandstone was likely to have outcropped. The dashed yellow lines are segments where bedrock elevations of 8-10 metres above the flood plain are projected from boreholes, but there is insufficient bedrock penetration to determine if sandstone is present. The green lines are where claystone is projected to outcrop and sandstone is not present. The white dashed line, located between 10th St. N.W. and 14th St. N.W., has borehole control to project only a 2 metre-high bedrock outcrop. This outcrop may have been higher.

It is very unlikely that there was continuous quarrying along the yellow coloured segment, both solid and dashed combined. As discussed in section 3.1, the sandstone beds are predicted to be limited in size, only 50 - 75 metres in length. It is most likely there were a series of discrete quarry bench sites, of different lengths and excavation depths into the slope, the size depending on the continuity and quality of the sandstone bed.

3.6 Candidate Quarry Sites

The geotechnical borehole data is combined below with the historical data of Section Two and with slope morphology information to evaluate candidate quarry sites. Figures 24 & 25 show the geotechnical well control along the escarpment. The well numbers are shown along with the thickness of the sandstone bed encountered. The coloured segments at the base of the escarpment are the projected bedrock lithology at outcrop.

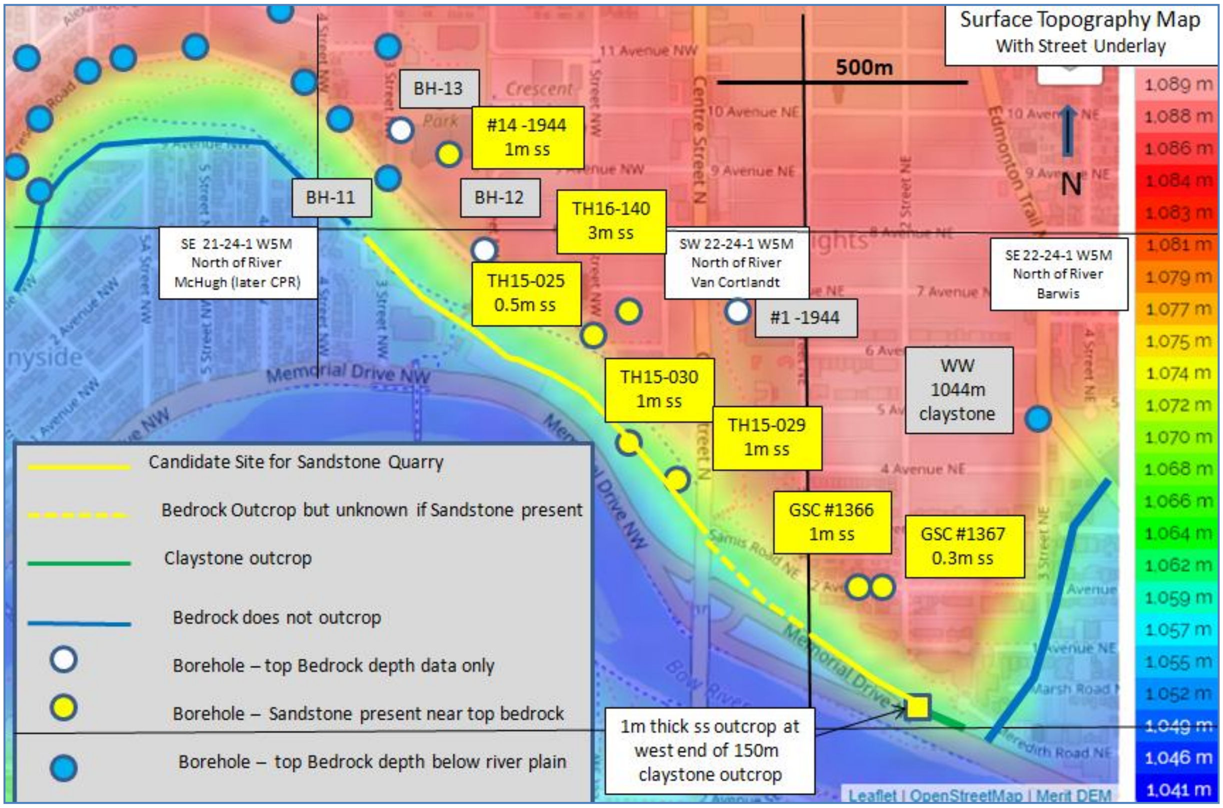


***Figure 25.** Geotechnical Borehole Data Map along the escarpment between 3rd St. N.E. and 7A St. N.W. overlain on surface topography map. The original homestead grants boundaries are highlighted.*

3.6.1 Orr Quarry

The historical data refers to an 1886-1890 quarry located in either Bridgeland or further west along the escarpment base. There is also reference to a Barwis Quarry. Barwis homesteaded the quarter section where the Orr quarry was located (see map above). Either it is two different names for the same quarry, or Barwis later worked the outcrop separately.

Referring to Figure 24 above, the east flank of the East Crescent Heights promontory is interpreted not to have bedrock outcrop at the base of the escarpment. This is based on a single well, a recent water well drilled to bedrock, located on the escarpment and coloured blue on the map. The top bedrock in this well is below the Bridgeland surface elevations.

The short green segment on the map is the claystone outcrop exposure that was described in section 3.2. There is a small sandstone outcrop highlighted on the map and that is used to mark the east end of a 250 metre segment that is the candidate for the quarry site. There are two wells located on 2nd Ave. N.E. that encountered sandstone up to 1 metre in thickness overtop of claystone.

***Figure 26**. Satellite Image of slope above projected sandstone outcrop. The slope has been extensively reworked with flat spots and bowls on slope above the top bedrock elevation. This is consistent with overburden removal in the building of a quarry bench back into the hill. The arrow shows the extent of the slope reworking.*

The arrow in Figure 26 highlights a stretch of alterations to the glacial sediments in the slope above a projected sandstone outcrop. Iron cable and poles were found at one slope break location. The east end of the arrow marks the start of the claystone outcrop segment. The west end marks the severe slope modifications that were part of the building of the Centre Street Bridge. The west end of the arrow is also, coincidently, the boundary of the Barwis land title.

3.6.2 Van Cortlandt Quarry?

The Sunnyside Freestone Quarry was located on the Van Cortland quarter section and Van Cortlandt may have operated a second sandstone quarry as referenced in the Calgary Herald article discussed earlier, or started an operation that was taken over by John McCallum and incorporated into the Sunnyside Freestone operations.

Referencing Figure 25, there is no borehole data available on the eastern portion of SW-22 from 1st St. N.E. to Centre Street. It is likely that bedrock outcropped at the base of the escarpment, but it is unknown if sandstone was present near the top of the outcrop. City maps show legacy boreholes in this area, likely drilled for Centre Street Bridge engineering studies, but a data request failed to turn-up the well data. The escarpment slopes in this segment are significantly altered from bridge construction, so there is no slope morphology detective work possible.

Figure 27. *"The Centre Street Bridge, Calgary, Alberta", (July 1915),(NA-2782-4), by Unknown. Courtesy of Glenbow Archives, University of Calgary. The slopes on both sides of Centre St. have been excavated, destroying any indications of old quarries at the base of the slope.*

3.6.3 Barwis Quarry?

The next segment from Centre Street to 1st St. N.W. has four boreholes that penetrated to bedrock, all with sandstone beds near the top and ranging in thickness from 0.5 metres to 1 metres. This segment is a strong candidate for a quarry at the base of the escarpment. The escarpment slopes in this segment are also heavily altered from bridge construction work and were also the site of a large landslide in 1932 (Appendix D). There is no possibility of slope morphology preservation from the 1880s or 1890s. This segment roughly aligns with a ~1905 restoration map (Appendix E) that has the Barwis quarry just to west of Centre Street. Why Barwis would be quarrying on Van Cortlandt land is not explained. This possibility was discussed in Section 2.

3.6.4 Sunnyside Freestone Quarry

The third segment, from 1st N.W. to 3rd St. N.W., has two boreholes on the escarpment rim that reached siltstone bedrock, but did not penetrate further to determine if sandstone was present. Well BH-11 on the map, located at 3rd St. N.W. and Crescent Road is the eastern edge of the bedrock erosional channel discussed in section 3.4. The other blue wells further west are also located in this bedrock topographic low feature. Well #14 from the 1944 Slide Drilling Program, located in Crescent Heights Park, did penetrate a 1 metre of sandstone beneath 1.2 metres of claystone and overlying 2.1 metres of shale. This well is offset 220 metres from the base of the escarpment, but it does demonstrate the presence of sandstone 500 metres further west that the recent boreholes just west of Centre Street. Well #14 is significant because it projects onto the escarpment base of slope at 3rd St. N.W. Sandstone bed expected dimensions suggest the sandstone bed in the borehole could not be continuous all the way to the base of the escarpment.

All of this segment is the candidate site for the Sunnyside Freestone Quarry. The westernmost portion of the escarpment slope along this segment has been altered. There are bowls and changes of slopes located above the 8 - 10 metre-high projected bedrock outcrop. These features are consistent with excavation of the glacial sediments in order to cut a bench back into the hill to extract a flat lying sandstone bed. There are two fan cones at a lower slope angle that spill onto the river plain. These may be the sediments removed above the bedrock and then shoveled off the quarry face, even acknowledging there has likely been sliding of the slope in the decades since.

Figure 28. *3rd St. N.W. Candidate Quarry Site. Photo looking east taken from path that climbs to the escarpment. The near level line of steep faced sediments overlies a lower angle slope that may be indicative of historical quarry benches. Slope fan appears to be in 1908 photo of site.*

What makes the slope alteration hypothesis compelling is the 1908 photo of McHugh Bluff shown previously in Figures 9 & 10. Those photos shows a bench cut into the slope and a number of buildings below. The quarry operated for at least three years (1888-1890), if not longer, indicating a significant volume of sandstone was removed. Perhaps quarrying began at the western end of the bedrock outcrop at ~3rd St. N.W. where some buildings were constructed and then proceeded east towards Centre Street, where borehole data indicates sandstone was present. The commercial sandstone beds were likely present in discrete 50 - 75 metre long segments over this distance with a series of quarries distributed along the base of the escarpment. Perhaps with the stone moved back to the original site at 3rd St. N.W. for finishing.

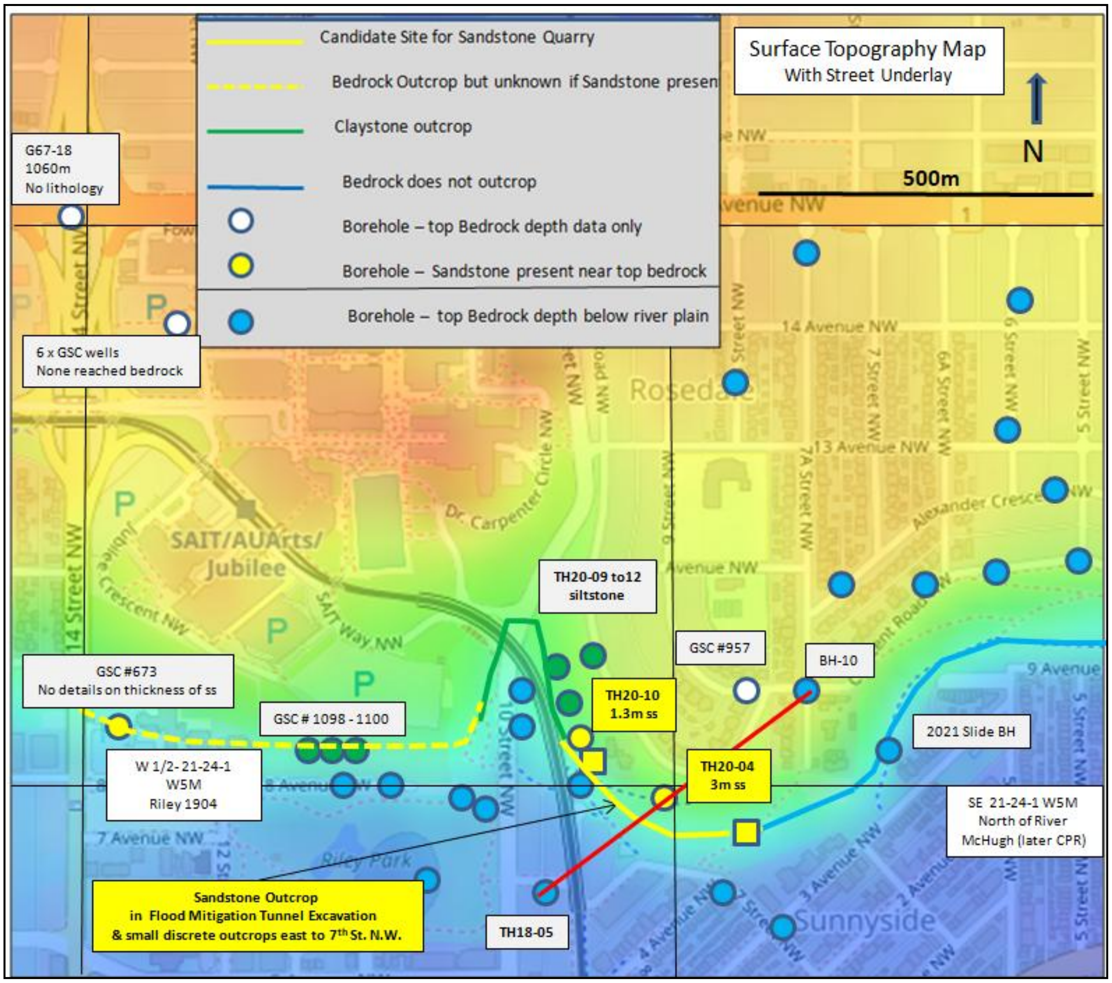


***Figure 29**. Geotechnical Borehole data map along escarpment from 5th St. N.W. to 14th St. N.W. overlain on surface topography map.*

Figure 29 shows the geotechnical borehole data control along the western segment of the escarpment. The blue coloured wells in the eastern portion of the map sheet show where there is a channel eroded into the bedrock to a depth below the Sunnyside surface elevation. A well drilled on the bike path beneath the 2021 slide on the east side of 7A St. N.W. also encountered eroded bedrock. The blue coloured wells on the Sunnyside flood plain have 6 - 8 metres of gravel covering bedrock.

3.6.5 9A St NW Candidate Site

The west side of the 7A St. N.W. promontory is a candidate quarry site from 4th Ave. N.W. to 10th St. N.W. A Glenbow map shows the McHugh quarry at this location (Appendix E), east of the Sunnyside Freestone Quarry, though this spotting is contrary to historical write-ups that have placed his quarry near 4th St. N.W. The excavation for the upper plateau flood mitigation tunnel (section 3.3) encountered sandstone. Two geotechnical boreholes encountered sandstone near the top of the bedrock section. There are five small (0.5 metre x 1 metre) sandstone exposures on the hill slope west of the 7A St. N.W bluff path at the depth of the borehole sandstone that are interpreted to be outcrop. The sandstone is not present in three wells further north along 10th St. N.W. located on the L.R.T. right-of-way.

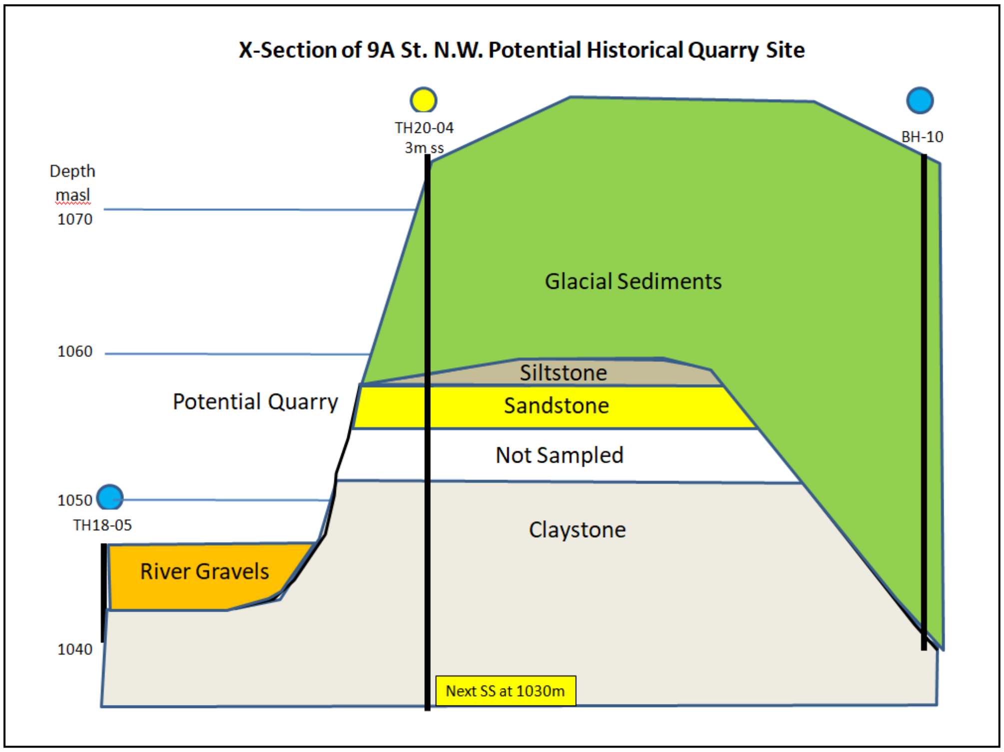


Figure 30. *A cross-section of the 9A St. N.W. candidate sandstone quarry site. The location of the cross-section is shown by the red line on Figure 29.*

Figure 30 above is a geological cross-section of the 9A St. N.W. candidate quarry site. River gravels overlie bedrock on the Bow River flood plain of Sunnyside. A cliff face of up to 10 metres height is shown with bedrock exposed, including a 3 metre-thick sandstone unit outcropping below a thin siltstone cap. Claystone is the most common bedrock unit. Glacial sediments that slumped down the hillside may have hidden the bedrock outcrop in places along the base of the escarpment. Glacial erosion followed by erosion of the Bow River created the abrupt change in bedrock elevation. The well, BH-10 is drilled on the escarpment rim, but the bedrock elevation is below the surface elevation in Sunnyside. This well is located on the western edge of the erosional bedrock channel that runs under the "crescent" in Crescent Road.

Figure 31 is a photo the hillside where a quarry site may have been located. There is a bowl in the hillside above where bedrock is projected to outcrop. The series of small bedrock outcrops are to the east of the bowl in the photo. There is a low angle fan cone below the bowl that runs to the base of the hill. These features are consistent with an old quarry site. There was a road, since converted to a path, running up the hill on the skyline. The glacial sediments excavated to build the road may have been dumped down the slope, so the slope alterations are not necessarily due to quarry operations.

Figure 31. *Photo of candidate 9A St. N.W. Quarry Site. Photo is looking north from path at base of hill towards depression in slope. The geotechnical borehole that encountered 3 metres of sandstone near the top of the bedrock was drilled along the pathway up the hill, approximately where the light pole is silhouetted on the horizon.*

3.5.6 Riley Park Sites

The GSEC map (Figure 1) indicates a sandstone quarry close to 14th St. N.W. and a shale quarry north of Riley Park. There doesn't seem to be any other historical references.

There are four wells drilled north of 8th Ave. N.W., a short distance up the slope, that encountered bedrock 1-3 metres above the flood plain elevation. The westernmost well indicated there was some sandstone encountered. The hillside slope in much gentler than the east side of 10th St. N.W. There is insufficient borehole control to determine if the hillside slope is indicative of a lower angle bedrock slope as well. The closest well control with a high topographic bedrock value is at the intersection of 14th St. N.W. with 16th Ave. It is possible that fluvial and glacial erosion yielded a gradual slope on this segment of the escarpment. Old photos of the Riley properties show that the hill slope was gradual in those days as well.

If only 1 - 3 metres of bedrock is potentially exposed, this does not appear to be a great site for a claystone quarry. There would not be a large volume of rock to excavate without digging a pit. The indications of sandstone near 14th St. N.W. is viable because the critical criteria for sandstone was that it needed to be near the top of the bedrock section - if there is a sandstone bed of sufficient thickness there, if could have been quarried. In this area, because of the lower angle hillside slope there was a lower volume of overlying sediments to be removed to clear a bench back into the hillside.

4.0 Summary

Candidate Quarry Sites Data Summary					
Site	Name	Historical Details	Geology	Slope Morphology	Candidate
2nd - 1st St. N.E	1886 Orr (1896 Barwis?)	solid	outcrop & borehole sandstone projections	consistent with slope excavations	Very Likely
1st St. NE - Centre St.	1896 Barwis?	weak	outcrop projection; no contol if sandstone	no historical preservation of slope	Possible
Centre St. - 1st St. N.W.	1896 Cortlandt or Barwis?	weak	borehole sandstone projections	no historical preservation of slope	Very Likely
3rd St. N.W.	1883/84 McHugh	fair	same site as Sunnyside Freestone Quarry	too small an operation	Possible
1st St. N.W. - 3rd St. N.W.	1888-1892 Sunnyside Freestone	good	borehole sandstone projection	consistent with slope excavations	Very Likely
4th Ave. N.W. -10th St. N.W.	?	weak	outcrop & borehole sandstone projections	consistent with slope excavations	Very Likely
10th St. N.W. -14th St. N.W.	?	weak	thin outcrop projection; possible sandstone	no evidence	Possible

Table 1*. A summary of the data supporting historical sandstone quarry sites along the north bank of the Bow River.*

In Table 1 above, the historical, geology, and slope morphology data are listed for the candidate sandstone quarry sites discussed. There are four sites identified that were very likely sandstone quarries in the 1880s & 1890s. Strongest weighting is given to the geology and historical data. The slope morphology data is consistent with slope alteration for a quarry in three cases. The Orr and Sunnyside Freestone Quarry locations are narrowed down to segments shown on Figure 28. Very likely there were multiple 50 - 75 metre-long excavation benches within each segment.

The candidate quarry site between 4th Ave. N.W. to 10th St. N.W. has no historical references. It seems unlikely this is where McHugh quarried some sandstone, but it is possible. The geology data indicates this is a good candidate site for a sandstone quarry.

The locations of the Barwis, Van Cortlandt, McHugh, and Riley Park quarries are unknown; there are several possibilities for each name:

- In 1896, Barwis may have re-opened the 1886 Orr quarry, with a deeper bench cut into the hillside or a new bench cut further west. Maybe the Barwis quarry operations extended to Van Cortlandt land west of 1st St. N.E., having begun on his own land, but there is no Crown mineral lease evidence if this is the case.
- Van Cortlandt may have operated a sandstone quarry on his land located west of 1st St. N.E. Or maybe, the 1897 newspaper article reference is to the abandoned Sunnyside Freestone Quarry, but instead using the name of the land owner as a colloquial reference.
- The McHugh story is that he quarried sandstone near his homestead cabin located just west of 4th St. N.W. If he opened-up a rock face near here, the geology indicated that it would have been on Van Cortlandt land to the east, not on his own homestead claim. This is possible if there was an understanding with Van Cortlandt. Perhaps it was a winter project to provide farm building foundation material.
- The story of the sandstone quarry and the claystone quarry between 10th St. N.W. and 14th St. N.W. shown on the GSEC map have not been progressed by this study. The geology data indicate the bedrock outcrop exposure may have much lower relief along this segment.

Additional historical data is needed to match the geology-defined candidate sites to the above names. The paper archives of the Glenbow stored at the University of Calgary have yet to be searched because of Covid-19 restrictions. T

An interesting by- product of the sandstone quarry research was the identification of the continuation of the Rosedale bedrock channel south through Sunnyside and all the way to the Beltline. The University of Calgary Geophysical Department may follow-up with some new research on this feature. In addition to the pure science aspects, there may be applications to Sunnyside slope failures, Sunnyside flooding, and to building foundation issues.

Another interesting outcome of the research is the possibility of north bank claystone quarries. Sandstone quarrying has been the focus of most historical research. Claystone quarrying for brick making has fewer references. Two claystone leases were opened on the north shore of the Bow River at a time a brickyard was operating in Bridgeland. More historical research is needed to determine from where the clay for the brick making was sourced. Perhaps this search will shed light on the story behind the buildings at the base of the escarpment located at 3rd St. N.W. in the 1908 photo (Figures 9 & 10).

5.0 References

Crocq, 2010, 2010. Building Stone in Alberta. ERCB, Alberta Geological Survey. Open File Report 2020-01.

Huck, B. and Whiteway, D., 1998. In Search of Ancient Alberta. Heartland Associates Inc.

Karrow, P. and White, O. (ed.), 1998. The Urban Geology of Canadian Cities: The Geological Association of Canada, Special Paper 43.

Manson, J., 1983. Bricks in Alberta. The Alberta Masonry Institute.

Mathews, V.A., 2011. Stochastic Modeling of the Paskapoo Formation. Unpublished master's thesis. University of Calgary, Calgary, AB.

Meyboom, P., 1961. Groundwater Resources of the City of Calgary and Vicinity. Alberta Research Council Bulletin 8.

Moran, S. R., 1986. Surficial Geology of the Calgary Urban Area. Alberta Research Council Bulletin 53.

Oetelarr, G.A., 2002. River of Change: a Model for the Development of Terraces Along the Bow River, Alberta. Geographie Physique of Quaternaire. Volume 56 (2-3), 155-169.

Poulton, T. et al, 2002. Geoscape Calgary. Geological Survey of Canada Miscellaneous Report 72.

Tharin, J. C., 1960. Glacial Geology of the Calgary Area; PhD Thesis, Urbana, III, 127 pages.

Wilson, M.C., 1963. Once Upon a River: Archeology and Geology of the Bow River Valley at Calgary, AB, Canada. National Museums of Canada, Archeological Survey of Canada, Ottawa, Paper 114. 464 pages.

Online Resources

https://www.calgary.ca/cs/cpb/projects-and-initiatives/historic-city-hall/sandstonequarries.html

https://www.heritagecalgary.ca/heritage-calgary-blog/trackingquarries

http://crescentheightsyyc.ca/chca/wp-content/uploads/2015/03/CHV-2012.06-June.pdf (McHugh)

City of Calgary, 2020. Sunnyside Flood Barrier - where we are today. Infoslides pdf.

https://www.bac-lac.gc.ca/eng/discover/land/land-grants-western-canada-1870-1930/Pages/search.aspx

https://www.calgary.ca/ca/city-clerks/archives/archives.html

https://calgarylibrary.ca/connect/calgary-story/

http://peel.library.ualberta.ca/newspapers/CWH/

https://digitalcollections.ucalgary.ca/

Appendix A
River Flood Plain Geology

In the Sunnyside/Hillhurst area, there are 5- 10 metres of fluvial sediments: cobbles, gravels, sands, and clays overlying bedrock, or in some locations overlying a thin glacial till section. Almost all of the fluvial sediment was deposited since the last glacial period ended ~12,000 years ago. There may be some thin pre-glacial fluvial gravels preserved in places, though this is very difficult to distinguish from the facies-equivalent post-glacial deposits. The fluvial sediments are spread across a flood plain that is 1 to 2 kms. in width, largely confined to the pre-glacial river valley.

As the mountain glacier retreated west up the Bow Valley, the river valley downstream of Calgary was blocked by a continental glacier ice dam. A large glacial lake formed behind the ice dam and fine grained sediments were deposited in the valley lake that extended from Mount Royal to Nose Hill (Appendix B). The glacial till and lake sediments are preserved in Rosedale/Crescent Heights as a 30 metre-thick section that forms the escarpment. When the short-lived ice dam was breached, the Bow River quickly cut down through the glacial sediments, removing them from the valley, and deposited fluvial sediments.

The Bow River renewal after the glacial retreat would have looked much like the Kicking Horse River does now near Field, B.C. - a wide braided river plain with multiple river channels. Subsequent climatic cycles created periods of river incision, alternating with periods of laterally thick fluvial sediment deposition. The lateral deposition periods are preserved today in Sunnyside/Hillhurst by two major terraces that marked the northern extent of the Bow River's fluvial plains: the 12,000 - 10,000 years B.P. (Before Present) T5 Terrace is found along the base of the SAIT hill extending east to 9A St. N.W. and west to Crowchild Trail. Upstream at Cochrane, this terrace is 60 metres above the current river floor. Downstream in Sunnyside/Hillhurst, the elevation differential is ~11 metres. Development activity has beveled the "step-up" to the T5 Terrace at its southern boundary in most places, though it is obvious where the boundary crosses the sports fields at Q.E. II School.

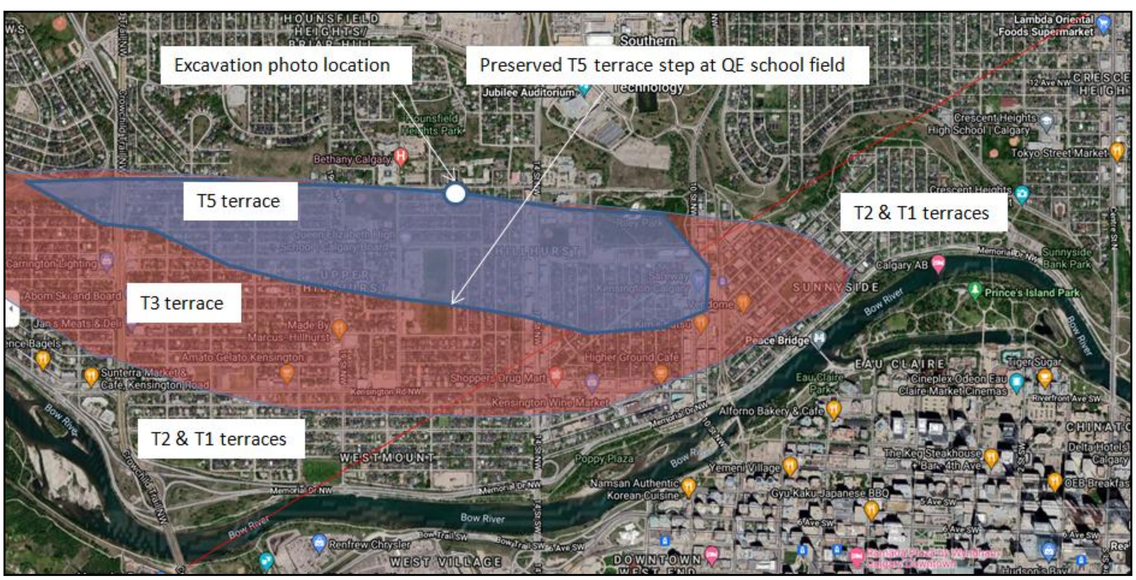


***Figure A1**. Satellite image of Sunnyside west to Parkdale with overlay showing the location of the T5 and T3 Terraces as shown in maps from Wilson, 1963. The T5 Terrace excavation photo location is highlighted.*

The 9,000 - 5,000 year B.P. T3 Terrace abuts the older T5 Terrace to the south and extends east to ~6th St. N.W. and west into Parkdale; its southern boundary is near Kensington Road. Mirror image T5 & T3 age terraces are found south of the Calgary downtown area. Younger and significantly lower elevation terraces, T2 & T1, are found south and east of the T3 Terrace in Sunnyside. Flooding in Sunnyside occurs to the east of the T3 terrace where the surface elevation is lower.

Figure A2. *A 2022 photo of a construction site located at 8th Ave. & 16th St. N.W., just south of the base of the escarpment. The cobbles and pebbles are river gravels associated with the T5 River Terrace. The shallow silty sand layer may be glacial lake sediments that were eroded from the adjacent escarpment.*

5,000 years B.P., there would not have been a "crescent" in the escarpment along McHugh Bluff. The escarpment would have extended in a straight line from 6th St. N.W. to Centre Street. The "crescent" in the escarpment and the creation of the river plain flats of east Sunnyside below it are relatively recent in age. The crescent shape of the base of McHugh Bluff escarpment is characteristic of a river "cut bank" where the main river channel is on the north side of the fluvial plain and laterally erosive. With time it cuts progressively to the north. The documentation of sloughs and avulsion channels in the recent flood mitigation studies of Sunnyside suggests there was active north bank erosion fairly recently in geological time.

The embayment of the Bow River plain below McHugh Bluff is coincident with the location of the bedrock channel underneath Rosedale and Sunnyside (Appendix C). Easier to erode glacial till, instead of bedrock, would have been exposed along the river cut bank when the active channel was at the northern edge of the flood plain. What is unexplained is why this progressive northward erosion only began after T3 Terrace deposition 5,000 years ago. Why wasn't the river deviated north earlier by an easy to erode north bank?

Dating the ages of the fluvial terraces and correlating one terrace to another upstream & downstream is a challenge for geologists. Charcoal and fossils are helpful. Precision dating is possible in places because of a tephra layer, created by ash spewing from Mount Mazama in Oregon 7,240 years B.P. It is preserved today at locations that were sloughs or ponds at the time of the eruption. It has been found in Sunnyside excavations as a white coloured layer about 8 cm. in thickness located within a metre of the base of the organic soil cover. It is found in excavations at the top of the escarpment, as well, overlying glacial sediments immediately below the organic surface layer.

Figure A3. *CGEN Website Photo. Mazama ash layer exposed along Fish Creek bank in Calgary.*

Short distances upstream and downstream of Sunnyside/Hillhurst, significant archeological sites have been found: the Mona Lisa site at 16th Ave. & 7th St. S.W., excavated in 1968, is a bison butchering site dated 8,050 years B.P. and at Point McKay, a camp site is dated to 4,680 years B.P. The Mona Lisa site findings are in T3 Terrace sediments, the southern side of the valley equivalents to sediments in Sunnyside/Hillhurst. The Bow River valley was a natural site for camps as it provided water, wood, shelter and access to big game. In winter, Sunnyside especially would have been a favoured site with its south facing valley walls a prime location for shelter. Wilson in his 1963 paper speculates that the places along the escarpment base where a river channel had undercut the bedrock and created an overhang would be a natural shelter exploited by ancient peoples. No archeological finds dating this far back have yet been reported in Sunnyside/Hillhurst.

Appendix B
Glacial Geology

Beginning ~25,000 years Before Present (B.P.), glaciers advanced and receded several times in the Calgary area - continental glaciers from the north and cordillera glaciers from the west. Till was deposited on bedrock by the Bow Valley Glacier as it advanced down the valley. The maximum glacial advance was 21,000 years B.P. Glacial till from these ice sheets is ubiquitous across the Calgary area and in Rosedale/Crescent Heights is up to 15 metres in thickness. In Sunnyside/Hillhurst glacial till is a few metres in thickness, or frequently has been eroded completely by river incision. The till is dark blue-grey in colour and contains large cobbles with low clay content. The till is primarily comprised of material scraped from the local bedrock, though sometimes cobbles from distant sources are present; granitic material from the Canadian Shield indicates a continental glacier source, whereas limestone cobbles indicate a mountain glacier source.

At the end of the last glacial cycle, about 17,000 years B.P., the Bow Valley mountain glacier began to retreat west, and at the same time a large glacial lake formed in the ancestral Bow River Valley due to the continental glacier blocking the valley south of Calgary. The lake extended all the way to Cochrane and was filled with clays and silts from the renewed Bow River and from run-off from the continental glacier to the north. The glacial ice dam was eventually breached, and the lake level dropped with successive breaches. Beginning no later than 11,400 years B.P., the Bow River started cutting a valley through the glacial lake sediments. Today the glacial lake sediments are preserved on the escarpment slope above Sunnyside/Hillhurst.

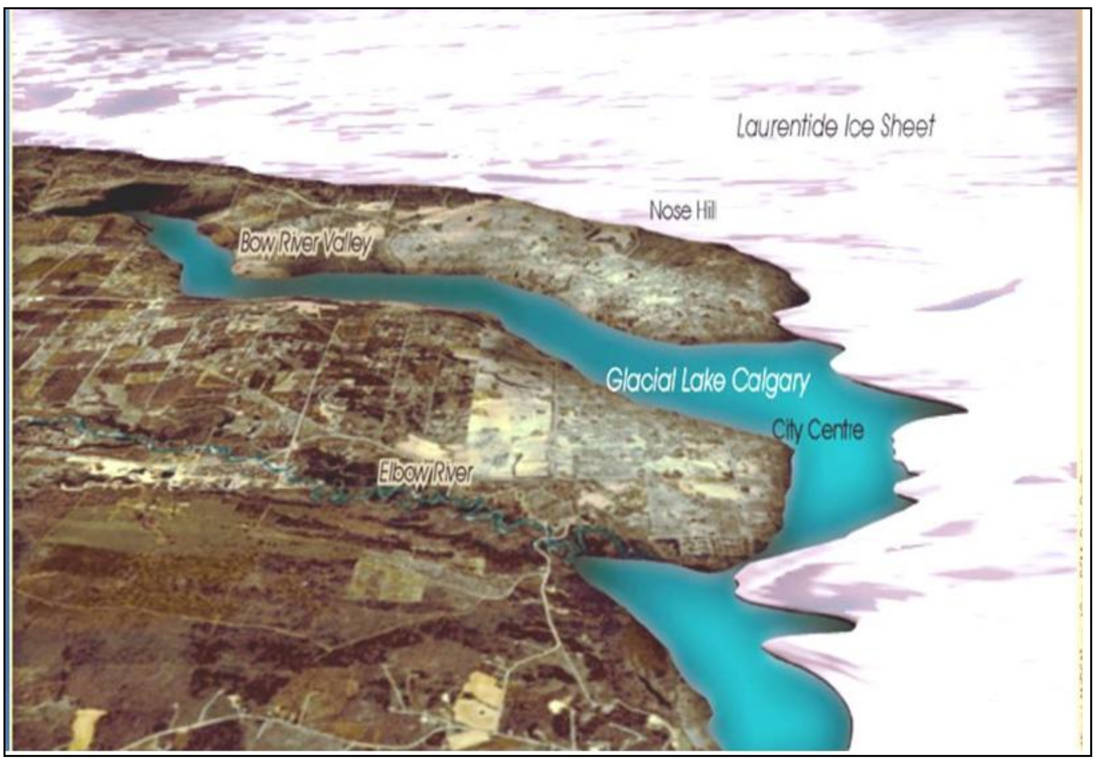


***Figure B1**. Glacial Lake Calgary was 100 kms. in length (GSEC Network).*

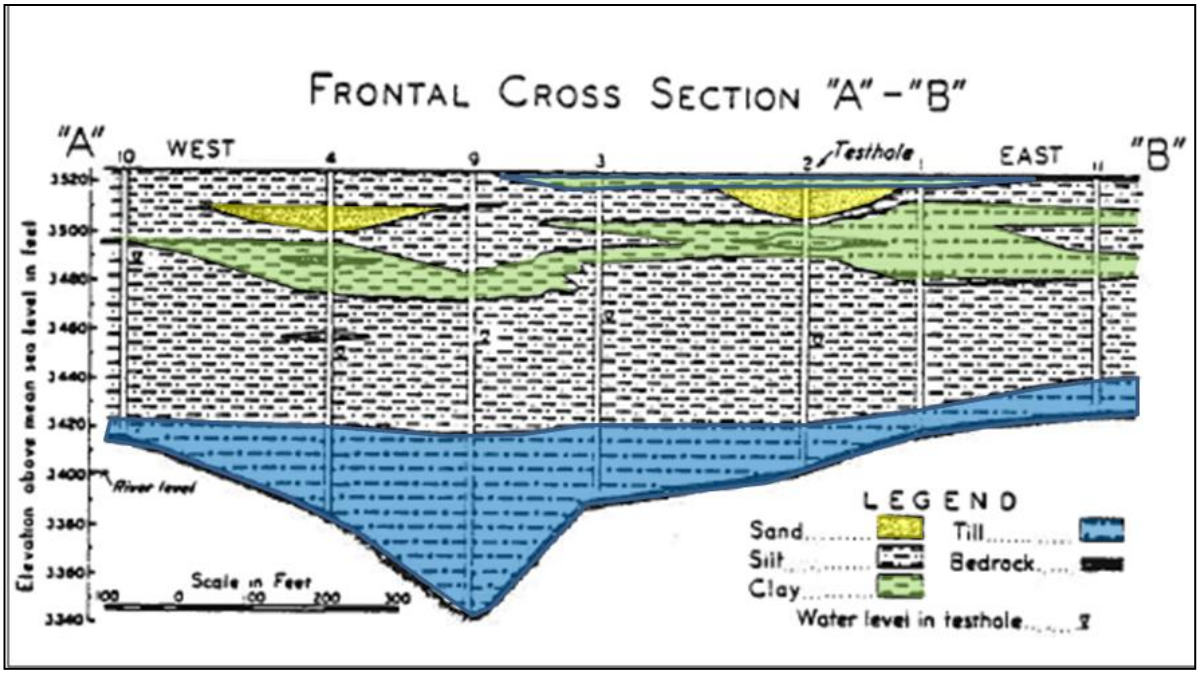


Figure B2. *A geological cross-section of glacial sediments correlated in geotechnical boreholes along Crescent Road in Rosedale. Glacial till is coloured blue and overlain by glacial lake sediments that are dominantly silts with some clay and sand layers. From Meyboom, 1961.*

The glacial lake sediments are up to 30 metres thick in the Rosedale boreholes shown in the cross-section above. These sediments are dominantly silts with thin clay layers in the upper third of the section. The silts and clays were likely deposited from suspension onto the lake floor, the Bow River having entered the lake much further upstream than Sunnyside/Rosedale. Sand units are not as common and are found at the top of the section; they may represent deposition into the lake from a meltwater stream coming from the continental glacier retreating to the north.

Figure B3*. Sandy glacial lake sediment in a 2022 house excavation at 6A St. N.W. and Alexander Crescent. No evidence of Mazama Ash in this photo.*

The geological cross-section shows an erosional low in the bedrock, filled with a thickened glacial till section. This feature is aligned north-south and may record a previous episode of continental glacial retreat with a meltwater channel that eroded into the bedrock. Analogous features are mapped along Silver Springs bluff exposures. Nose Creek valley is a large scale version of a major melt water channel during the final continental glacier retreat. This feature is discussed further in Appendix C.

The clays and silts tend to periodically fail and slide down the McHugh Bluff slope. Figure B2 above is from a hydrogeology paper examining the interaction between the water table and the glacial sediments in a large 1958 landslide. The history of the slides is discussed further in Appendix D.

Appendix C
Rosedale Bedrock Channel

The bedrock underneath Mount Pleasant and Rosedale is eroded into a north-south oriented topographic low. This feature was first described in 1961 by Meyboom in a paper based on geotechnical borehole data drilled after the 1958 slide on McHugh Bluff. His paper focused on explaining why the slide occurred and how the thick glacial sediments that filled the bedrock erosional feature may have contributed to the slide - this is discussed in Appendix D. There has been no follow-up over the intervening 61 years to mapping and interpreting the geology of this bedrock feature.

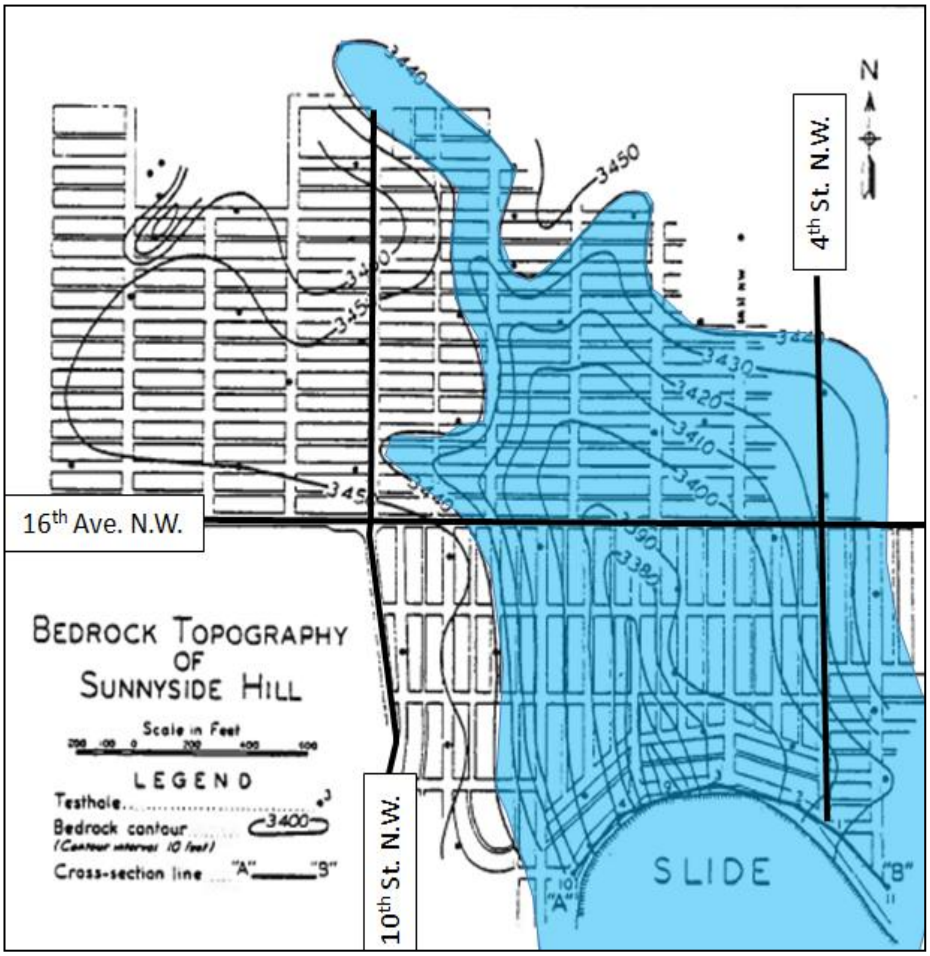


Figure C1. *Bedrock topography map of Mount Pleasant and Rosedale from Meyboom, 1961.*

The bedrock map above and x-sections below show a topographic low that is ~400m in width. It is asymmetric in x-section, having a gentler eastern margin. The deepest portion is ~175 metres in width and has depths up to 40 metres below regional bedrock depths. The deepest portion is intercepted by the closely spaced geotechnical boreholes drilled along Crescent Road. The borehole control north of Crescent Road is too sparse to determine how far north the narrow & deepest portion may extend.

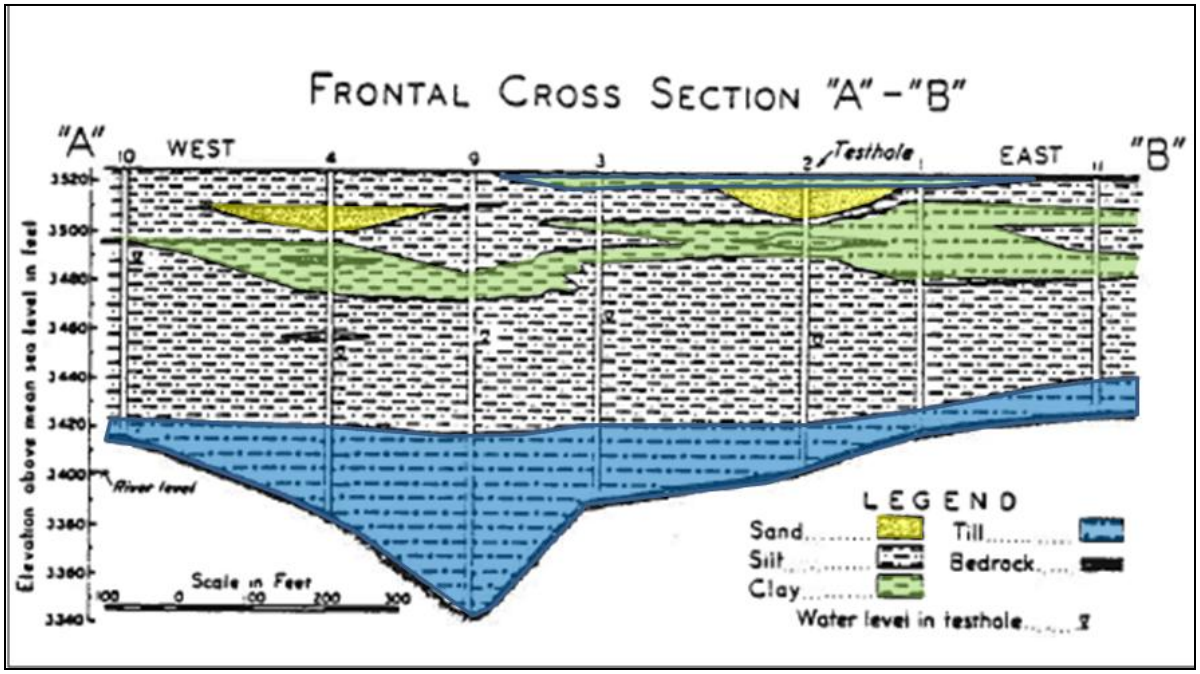


***Figure C2**. Geology Cross-Section A - B from Meyboom, 1961. See map above for location.*

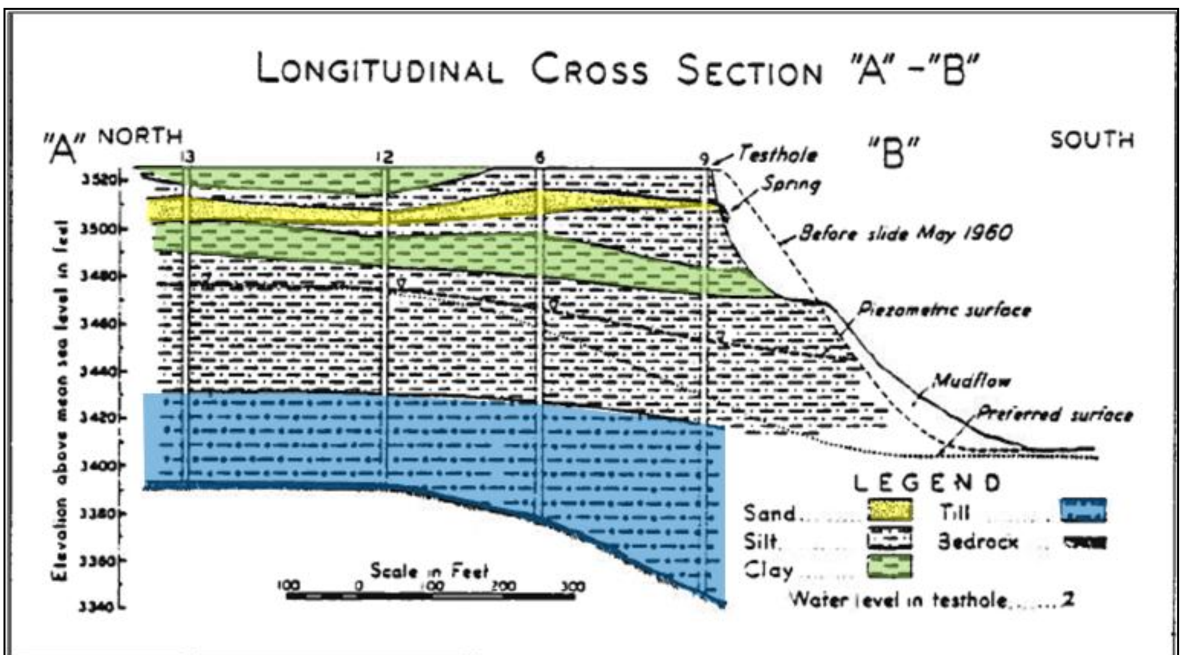


FIGURE 21. *Piezometric surface and longitudinal cross section of Sunnyside Hill slide, Calgary*

Figure C3. North-South Cross-Section from Meyboom, 1961.

Beneath Rosedale, there are ~30 metres of glacial lake sediments overlying 3 - 24 metres of glacial till; the till filling the topographic low in the bedrock. The glacial lake sediments are primarily silts with some clays and sandstones near the top of the section. The "till" label is better described as non-lacustrine sediments, i.e. glacial, but not lake sediments. The record below is from a borehole drilled to bedrock in the deepest portion of the topographic low and records 73 feet (22 metres) of till, silt, clay, and gravel below lacustrine sediments.

RECORD_NUMBER	00956	U_T_M._ZONE	11	METHOD	DYNAMIC CONE	HAMMER		LB
DATE_(MO/YR)	04/59	EASTING	704910	PURPOSE	TEST HOLE	DROP		IN.
LOC._PRECISION	164. 0 FT.	NORTHING	5660595	RELIABILITY	GOOD	SPOON_DIAM		IN.
REFERENCE	MT0312009	N_T_S._MAP_NO	8201A	SURFACE_ELEV	3526. 8 FT. ASL	BOTTOM_OF_HOLE	184. 0 FT.	PAGE A 8

DEPTH	SOIL_TYPE	DESCRIPTION	ATTERBERG DEPTH	ATTERBERG P_L	ATTERBERG M_C	ATTERBERG L_L	PENETRATION DEPTH	PENETRATION BL/FT	WATER DEPTH
0. 0	FILL, GRAVEL, ASPHALT.	SURFACE, AGE POST-GLACIAL.							
2. 0	SILT, CLAY, GRAVEL.	BROWN, LACUSTRINE, AGE GLACIAL.	2. 0		17				
15. 0	SILT, SAND, CLAY.	BROWN, LACUSTRINE, STRATIFIED, AGE GLACIAL.	15. 0		18				
43. 0	CLAY.	BROWN, LACUSTRINE, STIFF, AGE GLACIAL.	43. 0		22		43. 0	63	
52. 0	SILT, SAND.	BROWN, LACUSTRINE, DENSE, AGE GLACIAL.	52. 0		20		52. 0	123	
76. 0	SILT, SAND.	GREY, LACUSTRINE, STIFF, AGE GLACIAL.	76. 0	16	11	20	76. 0	91	
107. 0	TILL, SILT, CLAY, GRAVEL.	GREY, GLACIAL, HARD, AGE GLACIAL.	107. 0	13	6	22	107. 0	92	
180. 0	BEDROCK, SHALE, SAND.	GREY, ALLUVIAL, AGE PALEOCENE.							

Figure *C4*. *Borehole #956 (Crescent Road near 6A St. N.W.) lithology description.*

Interpreting the basal 22 metres as till suggests that the topographic low was carved by a glacier advancing from the north. It is reasonable that the broader 400 metre wide topographic feature may have been created by glacial erosion with initially till deposition, but the morphology of the narrow and deep central portion is more consistent with fluvial erosion. The lithology description of gravels in this interval also supports a fluvial contribution. One possible interpretation is that the erosional feature is a meltwater channel as the continental glacier retreated to the north at a time that the Bow Valley Cordilleran glacier had already retreated. The meltwater stream would have cut down through glacial till & bedrock and reworked this material into poorly sorted stream sediments.

Meltwater channels oriented north-south derived from a retreating continental glacier have been described from outcrops in Silver Springs area. But what age is the Rosedale bedrock channel? It is older than the base of the glacial lake sediments that overlie the "till" section; these are interpreted in the geology literature to have been deposited beginning 17,500 years B.P., when the Bow Valley glacier retreated and the continental glacier dammed the valley south of Calgary. If the meltwater channel is associated with this last de-glaciation window, it suggest a very short time interval between glacial retreat and lake sedimentation. Perhaps the channel is from one of the earlier continental glacier retreat episodes that have been documented. Detailed studies of borehole cuttings will be needed to determine the age and genesis of the bedrock erosional feature.

<u>Bedrock Channel Mapping South of Rosedale</u>

There has been no follow-up to mapping the southern continuation of the bedrock channel since Meyboom's 1961 paper. A search of public domain sites provided borehole data to extend mapping further south. The Alberta Geological Survey drilled hundreds of shallow wells in the Calgary area as part of their mapping projects of glacial sediments for aquifer and sand/gravel resource potential; a few of these wells were located in the area needed, but they did provide good regional coverage and established that there is relatively thin fluvial/glacial till section within the city limits. The search turned to building construction records and City engineering projects. This data was also consistent in showing about 6 metres of gravels overlying bedrock.

An in-person City archive search of the geotechnical borehole wells drilled in Prince's Island lagoon to determine bridge locations showed that for the length of the lagoon there was 6 metres of fluvial sediment cover over bedrock as expected, until the borehole at the western tip of the island drilled to 30 metres depth without reaching bedrock. Here was the southern continuation of the eastern edge of the Rosedale bedrock channel. Where was the channel in Sunnyside? A published cross-section (not shown here) along the 9A St. N.W. L.R.T. line showed the channel did not intersect this far west; the boreholes had encountered bedrock stepping-up in a series of shelves with 15 to 6 metres of gravel cover. Sunnyside data that does encounter the bedrock channel is listed at the end of this section; it is not yet in the public domain.

Soon after discovering the Prince's Island lagoon data, the map below was found online from City open source data. It is a map compiled by Stantec of bedrock depth from borehole data in the western part of downtown for evaluating L.R.T. route options. The sediment fill is not detailed in the report. The map is remarkably similar to Meyboom's Rosedale bedrock topography map: a narrow channel within a broader topographic low that is aligned north-south with bedrock elevations are up to 35 metres below regional values. The east side of the channel is steeper than the west, the opposite symmetry to the Rosedale channel. The Prince's Island lagoon well at the west end is directly north of Stantec's mapped channel.

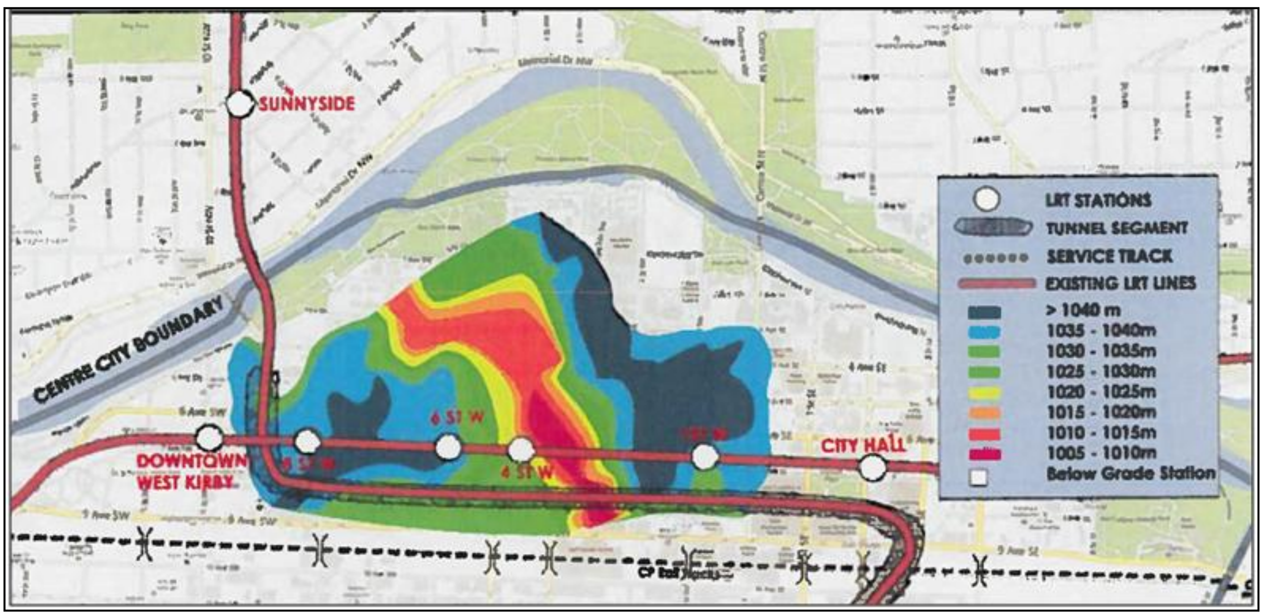


Figure C5*. 2014 Depth Map of Bedrock compiled by Stantec for City report on LRT location options.*

The chance finding of the Stantec map led to a more diligent search of City technical online reports. Key word searches like "geotechnical" or "borehole" produce hundreds of files that must be scrolled through in order to find something useful. The geological cross-section below is from another engineering report, this time from boreholes drilled along 2nd St. S.W., the proposed downtown route for the Green Line L.R.T. This cross-section is intercepting the bedrock channel at an oblique angle. It shows bedrock depths dropping 15 metres south of 7th Ave. S.W. - intercepting the orange coloured eastern side of the channel on the Stantec map (Figure C5). The sediment fill is mostly sand.

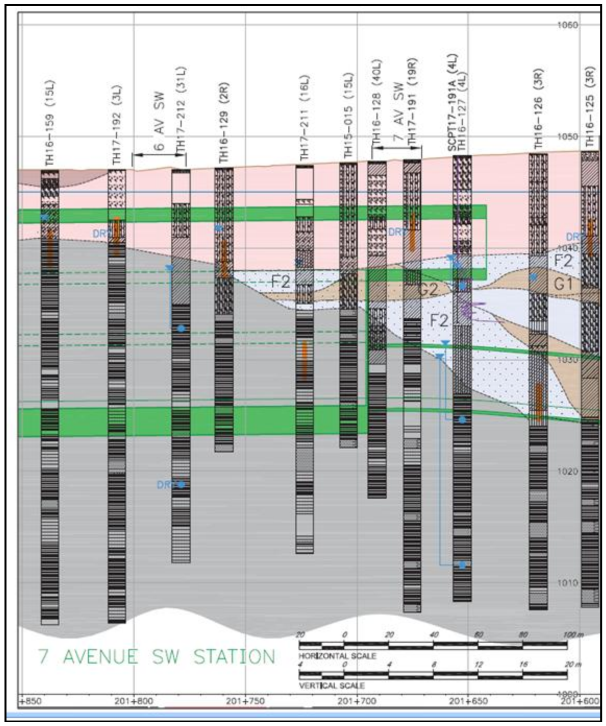


Figure C6. *A 2018 cross-section along 2nd St. S.W., a candidate Green Line L.R.T. Route, from City engineering report.*

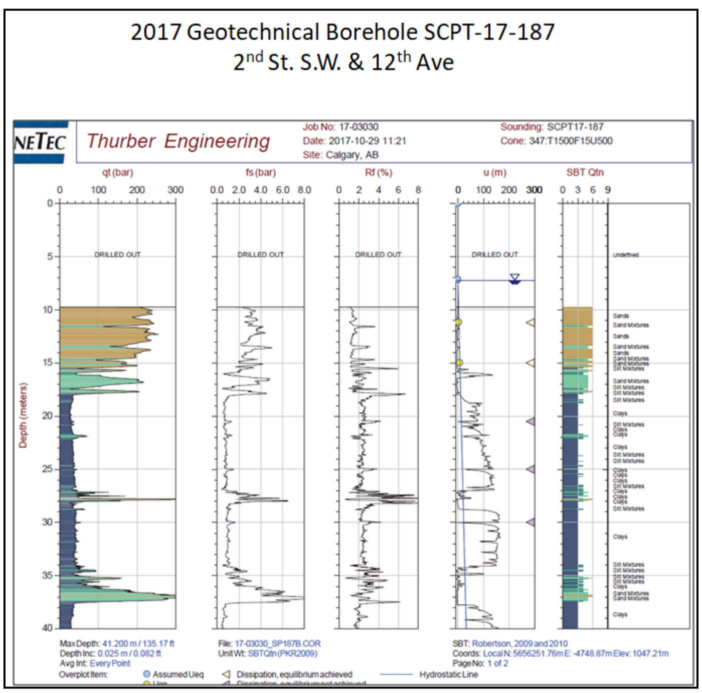


Figure C7. *Geotechnical Borehole from City data base drilled at 2nd St. S.W. and 12th Ave.*

South of the C.P.R. tracks a few additional borehole data points within the bedrock channel were added. The figure above shows the southernmost borehole found to have encountered the bedrock channel. It is located at 12th Ave. S.W. and 2nd St. It was drilled for the Green Line L.R.T. route assessment. It was drilled to 40 metres without encountering bedrock. The fill is mostly clay.

The map below is a summary of all the borehole data accessed. The black dots are boreholes with thin regional fluvial gravel & clay (and sometimes a thin till layer) cover over bedrock. The yellow dots are boreholes with thick sediment cover over a topographic low bedrock. Data sources include:

- The blue polygon over Mount Pleasant and Rosedale is from Meyboom, 1961.
- The Stantec western downtown bedrock map outline is shown in a blue polygon.
- Three other blue polygons with dense well control use Alberta Geological Survey data, water well data, and building construction data.
- A blue line shows the geotechnical boreholes along the 2nd St. S.W. to Centre Street Green Line route. This data was also useful near Centre Street in identifying Paskapoo Formation sandstone penetrations and an offsetting candidate quarry site.
- A blue line shows boreholes along Memorial Drive for the Flood Barrier. This data was accessed via Sunnyside Community contacts. It has not been publically released. This data was the last to be accessed and as shown on the map, it intercepted the bedrock channel across the river from the western end of Prince's Island as expected.
- A blue line shows boreholes along 7th St. N.W. in Sunnyside that were drilled for the upper plateau water diversion tunnel. The boreholes on the east side of Sunnyside School intercepted the bedrock channel and thus define the location of the west side of the channel in Sunnyside.

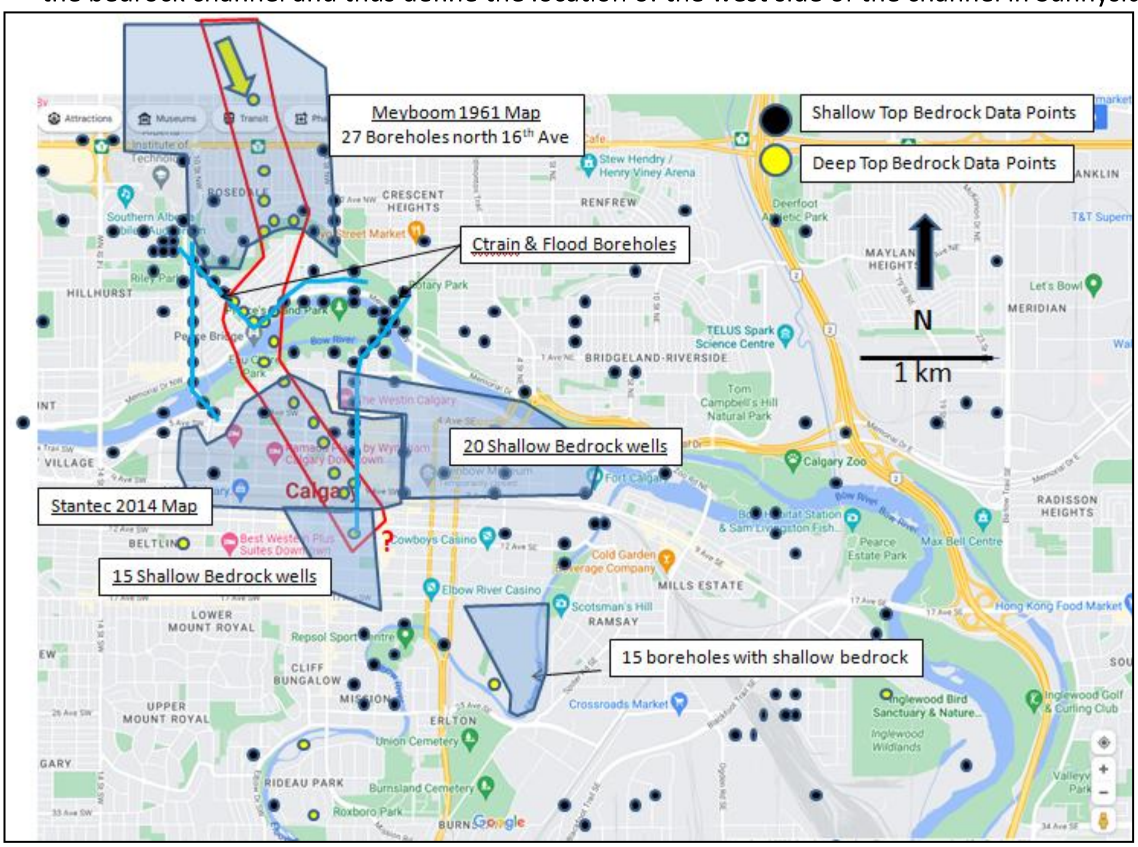


Figure C8. *Map of Bedrock Channel outlined in red polygon with borehole data locations.*

The bedrock channel outlined in the red polygon is mapped over a length of 3.5 kms., as far south as the Beltline District. Despite quite a few boreholes to the south and east it cannot be mapped further south than 12th Ave. S.W.

Future Studies

The Geophysical Department of the University of Calgary has been approached and is considering a research project to study the bedrock channel. Seismic and/or electrical profiles may be run to determine if the bedrock and sediment fill can be imaged. There is precedence, as a U. of C. study of the old creosol site west of 14th St. S.W. on the south bank of the Bow River was successful in imaging bedrock. If geophysical profiles tied to geotechnical borehole data prove successful in imaging the bedrock channel, then the technique could be used to extend the mapping further south where borehole data hasn't intercepted the bedrock channel. The project is ideal for a graduate student.

In addition to mapping, there are a lot of geology unknowns to be researched. Ideally, the age and genesis of the bedrock channel and the fill can be determined. Hopefully, some of the core and cuttings from recent City geotechnical boreholes are available for study.

The bedrock channel fill seems to vary considerably from borehole to borehole. Gravel and sandstone are present. There is a hydrogeology element to a possible study. Meyboom thought the channel fill contributed to the sliding on McHugh Bluff. The bedrock channel intercepts underground portions of the proposed Green Line route - there may be construction and aquifer issues. Future condo tower and commercial building development would benefit from a map showing if bedrock is shallow or deep.

A more local study could be conducted by Sunnyside Community themselves. It would be interesting to determine if homes and apartments within the projected bedrock channel path experience higher incidents of basement flooding at times of high water tables than those with shallow bedrock - this may indicate the channel fill is an active aquifer in comparison to the bedrock.

Appendix D
McHugh Bluff Slide History and Geology

Figure D1. *Slide History along McHugh Bluff 1932 -2021. Approximate locations superimposed onto a satellite image.*

The variables that lead to slope failures are slope angle, sediment type, and ground water. All of these have played a part in the three major slides along McHugh Bluff over the past 90 years. Other areas in Calgary with similar geology that have had slides include Parkhill (1948), Bridge Crescent (1961), Nose Creek (1965), Forest Lawn (1967), Home Road (1970), and Wildwood (pre-1970 to recent). There is not much that can be done about the geology, other than to ensure it is understood. City engineers' mitigation efforts have focused on reducing slope angles and installing drainage schemes to lower the water table. Loss of vegetation cover and overwatering yards can contribute to charging of shallow aquifers. However, the large scale slides on McHugh Bluff seem to be associated with failure in clay & silt sediments that are exposed mid-slope.

There are several types of slope failure: creep, piping where groundwater undermines a slope, debris flow, and mass slumping. Mass slumping is the most common and best explains the major slides on McHugh Bluff. Creep is evident today as shown by the photo below where the trees lean down slope. Piping beneath the shallow sandy layer, especially where associated with frost at the slope face, was common along the escarpment prior to the reduction of slope angle and gravelling of the surface. Frost activity year after year weakens the sediments on the portions of the slope face where steep slope angles are still present, such as along the east and south side of the 7A St. N.W. promontory. The trees and grasses on McHugh Bluff are important in preventing shallow slides, but vegetation has little effect in preventing the deep rooted slides of mass slumping.

***Figure D2**. 2021 Photo of Leaning Trees on McHugh Bluff - an example of soil creep.*

Engineering reports in City Archives document McHugh Bluff slope failure over the decades. These reports describe the physical extent of the slide with most of the report outlining potential mitigation efforts to prevent further sliding, especially focused on drainage of water. Below are brief summaries along with some sketches and photos of the major slides in chronological order.

1932 Slide West of Centre Street

Figure 27 in the main document shows extensive excavation of the escarpment slope undertaken in the construction of the Centre Street bridge in 1916. After the bridge was completed, a new Sunnyside tramway was cut across the slope in 1918, at a lower angle than the original route, to intercept Centre Street just north of the bridge. The slope west of Centre Street failed in 1932, both above and below the tramway. It seems likely that the construction activities may had indirectly led to the slope failure. The City engineers could not stabilize the slope and tram cars were stopped permanently on this route.

The general public was eager to help. One unsolicited letter to the mayor touted "Etheric Lines of Force" and major faulting to explain the slide with consulting services offered for a fee. The Crescent Heights residents were sure it was leaky City water mains that were leading to the slope failure. The City dutifully analysed the water and found it was natural ground water. Water saturated mud was sliding and could not be contained. A drainage tunnel was dug upslope. Wells drilled on top of the escarpment delivered a steady flow of water; one hit quicksand conditions. Four rock drains were constructed on the face of the slide, three of which flowed water at a steady rate. A quarried rock wall was constructed along the tramway's uphill side, but failed to hold further slides. The original slope of 1.5 to 1 (35^0) was graded to 2.5:1 (20^0), but there was still instability as the mud acted like a slow moving fluid.

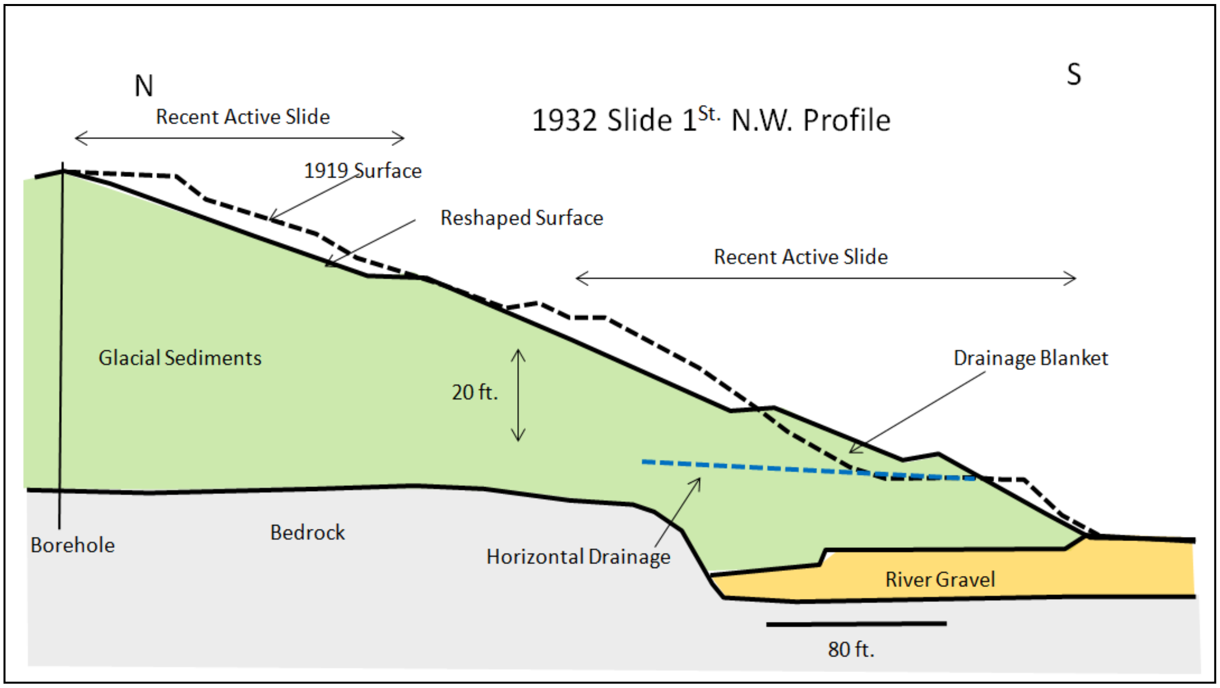
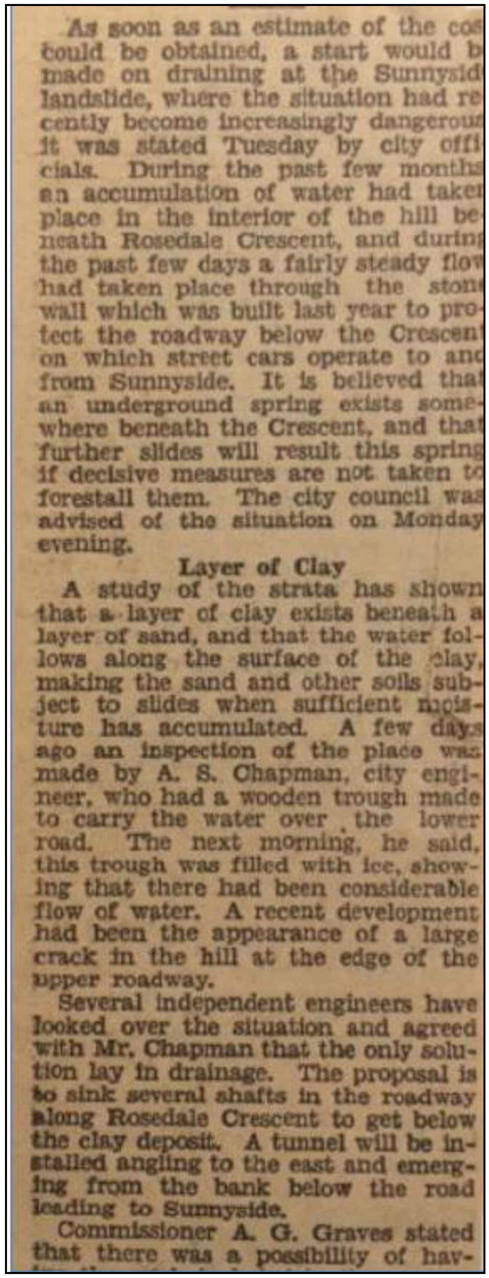


***Figure D3**. 1932 Slope Profile after slides at 1st St. N.W.*

The clay was determined to be bentonite, leading to a 40% swelling when water saturated. Bentonite is derived from volcanic ash. This is an interesting finding as there certainly could be Mazama Ash (see Appendix B) at the top of the glacial sediment section, but a layer of only a few cms. would be expected.

Figure D3 also illustrates why this area immediately west of Centre Street, a candidate quarry site, has no bedrock outcrop. A large wedge of glacial sediment has been built-up from upslope excavation work and slope slides to cover the original bedrock/river gravel outcrop. The slope sediments overstep what was once bedrock outcrop by160 ft. to the south. Escarpment borehole data suggest the buried bedrock step as a candidate historical sandstone quarry site.

The hypothesis outlined in the contemporary newspaper article below of water flow along a sand/clay layer leading to slides still holds today.



As soon as an estimate of the cos
could be obtained, a start would b
made on draining at the Sunnysid
landslide, where the situation had re
cently become increasingly dangerou
it was stated Tuesday by city offi
cials. During the past few months
an accumulation of water had take
place in the interior of the hill be
neath Rosedale Crescent, and durin
the past few days a fairly steady flo
had taken place through the ston
wall which was built last year to pro-
tect the roadway below the Crescen
on which street cars operate to an
from Sunnyside. It is believed tha
an underground spring exists some-
where beneath the Crescent, and tha
further slides will result this sprin
if decisive measures are not taken t
forestall them. The city council wa
advised of the situation on Monday
evening.

Layer of Clay

A study of the strata has shown
that a layer of clay exists beneath a
layer of sand, and that the water fol-
lows along the surface of the clay,
making the sand and other soils sub-
ject to slides when sufficient mois-
ture has accumulated. A few days
ago an inspection of the place was
made by A. S. Chapman, city engi-
neer, who had a wooden trough made
to carry the water over the lower
road. The next morning, he said,
this trough was filled with ice, show-
ing that there had been considerable
flow of water. A recent development
had been the appearance of a large
crack in the hill at the edge of the
upper roadway.

Several independent engineers have
looked over the situation and agreed
with Mr. Chapman that the only solu-
tion lay in drainage. The proposal is
to sink several shafts in the roadway
along Rosedale Crescent to get below
the clay deposit. A tunnel will be in-
stalled angling to the east and emerg-
ing from the bank below the road
leading to Sunnyside.

Commissioner A. G. Graves stated
that there was a possibility of hav-

***Figure D4**. A 1932 Calgary Herald Article on the slope failure.*

Longtime Bridgeland residents relate stories of houses along the base of the escarpment west as far as Centre Street that were removed in the 1930s because of slides on the East Crescent Heights slopes.

1944 -1948 Slides West of 5A St. N.W. to 4A St. N.W. (Sunnyside)

Second Section TORONTO, TUESDAY, AUGUST 10, 1948. Page 13

Mud Slides Halted, Threatened Houses Saved by Electrical Drainage

First Canadian experiment in the use of electrosmosis to prevent mud slides has been successfully carried out by Prof. R. M. Hardy, dean of engineering at the University of Alberta, working in area (circled at A) below Sunnyside Hill, Calgary. Mud slide forced 63 persons from their homes at (B) and there was another threatening slide at (C). Picture at right was taken from Point D in first picture. Germans used same system of electrically-forced drainage to build U-boat pens on the coast of Norway.

Figure D5. *Calgary made the second section front page of The Globe and Mail in August 1948. The photo caption announces the use of* electromosis *to try to dry the mud flow (first in Canada). It was not effective. Only three years after WW II, an analogy is made to U-boat pens in Norway to hook the reader.*

In 1944, there was a large slide from near the top of the slope depositing debris at the base of the slope, threatening houses located on the north side of 9th Ave. N.W. and the north end of 4A St. N.W. The City engineering mitigation strategy was first to see if they could prevent water getting to the slope. Seventeen wells were drilled to depths of 65 - 120 feet in Rosedale looking for aquifers, but most didn't encounter coarse sand. Coarse gravel was encountered at 65 feet in one hole. It was thought that the water bearing strata were "funnels" oriented N.-N.W. and up to 5 feet in thickness. These boreholes encountered water at 12 - 30 feet depths. Two pipe drains were installed where water flowed from springs on the face. The springs flowed up to 10 gallons/minute. The seepage was where sandy layers overlay impermeable clay sediments. Timber retaining walls were built at the toe of the slides to hold back mud flow. There were three to four years with additional sliding despite the fact drainage was installed from 4th to 7th St. N.W. The material at the toe of the slide acted as a mud flow in Spring, creeping forward at a rate of 1 foot in 24 hours.

On May 7th & 8th, 1948, a new slide occurred after a heavy rain. This was a westward extension of the earlier slide. This slide occurred when frost came out of the ground and drainage opened. Hydrostatic pressure from water build-up was released, enhanced by recent rains. Failure was a "blow-out" with high water flow that undermined the overlying bank causing a 50 foot vertical piece to break-off and move down slope 300 ft., stopping where the gradient was lower.

Another type of slope collapse observed was where springs undermined the slope, but were not associated with frozen ground. This slope collapses, but does not "flow" and material comes to rest on the steeper slope of 3:1. This material can later flow if it become water saturated.

Similar to 1932, the local residents thought the water was coming from leaking City water pipes. This theory was discounted by the report engineering author, Hardy, who thought it was due to a rise in ground water. It was discovered that several of the houses on Crescent Road still had septic tanks, having being built before services were installed this far west in Rosedale. Leaking tanks were a concern, but unlikely to have been a significant contributor to the slides. Electromosis (running a current laterally through mud) was used to try to dry the mud flow. This was the first use of this technology in Canada, hence the Globe and Mail story. It was later concluded to not have been effective.

The engineering consultants came up with a plan to prevent further sliding. They suggested putting down a sand & gravel drainage blanket (in orange in figure below), after first drying-out the silty glacial sediments using shallow wells. At the 1948 site, they planned a horizontal gravel blanket and horizontal wells for water drainage. At the 5th St. N.W. spring, located high on the slope, the plan was to install wells with pumps to depths > 20 feet. They recommended not moving the threatened 9th Ave. N.W. houses, but three years later, the City did just that.

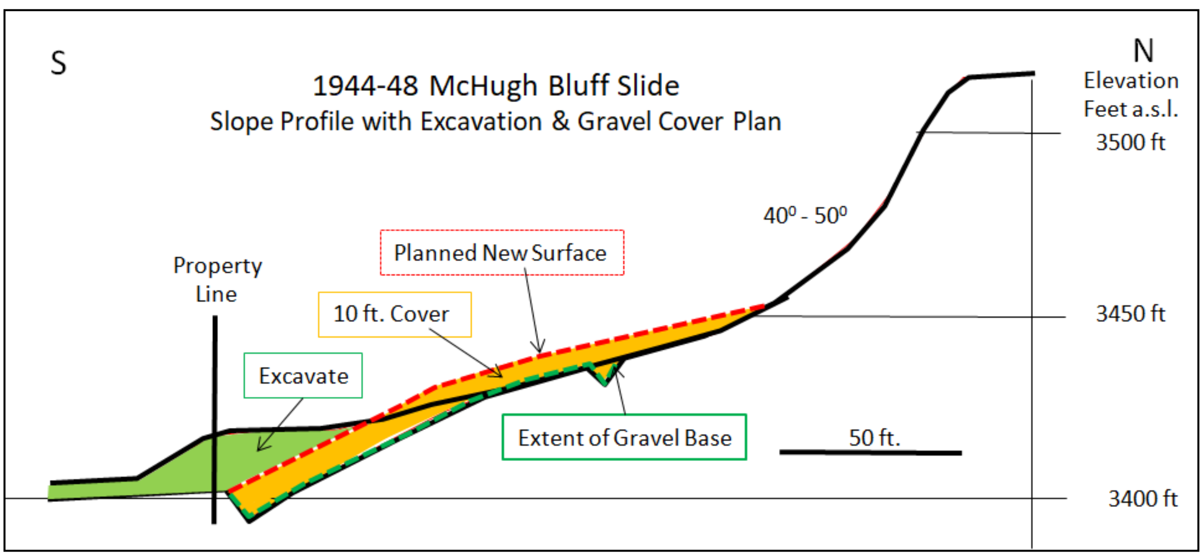


Figure D6. *Slope Profile after 1948 Slide showing plans to excavate and place gravel cover. Wells were also drilled into the slope to monitor water levels.*

1950 & 1952 City Engineering reports on Sunnyside Slope Drainage mention a drainage ditch behind 614 9th Ave. N.W., plank fences to deflect run-off silt at the toe of the slide, cut-off ditches along Crescent Road, grading & grass seeding on the hill, compacted toe of slide behind 540 9th Ave. N.W., filling in hole on the slope between 5th St. N.W. and 5A St. N.W. that was undermining Crescent Road, moving six houses from 500 block of 9th Ave. N.W. & two from north end of 4A St. N.W. Most were moved to 5th St. N.W. onto empty lots by the City. The 1949/50 work cost $80,000 to remove toe of slide that was 400 ft. across (includes moving houses).

Figure D7*. 935 5th St. N.W. Slater house was moved from 540 9th Ave. N.W. in 1952/53. One of eight houses located on the north side of 9th Ave. N.W. and north end of 4A St. N.W. to be moved by City to new lots at City expense. They even poured new sidewalks for those homes that had them at their original location. City supplied the new lots and covered the moving costs.*

From 1953-1956, there was wet weather that led to slope instability to the east of the 1948 slide area all the way to within 100 feet from Centre Street.

1958 - 1960 Slides

Figure D8. *1959 Geotechnical Drilling on Alexander Crescent. The same houses are still there in 2022. The City of Calgary Archives (copyright; cannot be reproduced without obtaining permission of City Archives).*

The February, 1958 slide was massive. It was centered at the top of the slope near 5th St. N.W. and fanned-out east to near 4A St. N.W. in Sunnyside and west to the 600 block above 9th Ave. N.W. In response, another batch of geotechnical wells was drilled in Rosedale & Crescent Heights and also in Mount Pleasant.

The Alberta Research Council Bulletin 8, P. Meyboom, 1961 "Groundwater Resources in the City of Calgary and Vicinity" is principally concerned with aquifer potential of the different near surface glacial and bedrock sediments. The last portion of the bulletin reviews engineering issues related to groundwater - landslides, slope creep, and inundated basements. The 1958 Sunnyside slope slide is described and analysed using the data from the 1959 geotechnical boreholes, including measured water levels in the 1959 wells.

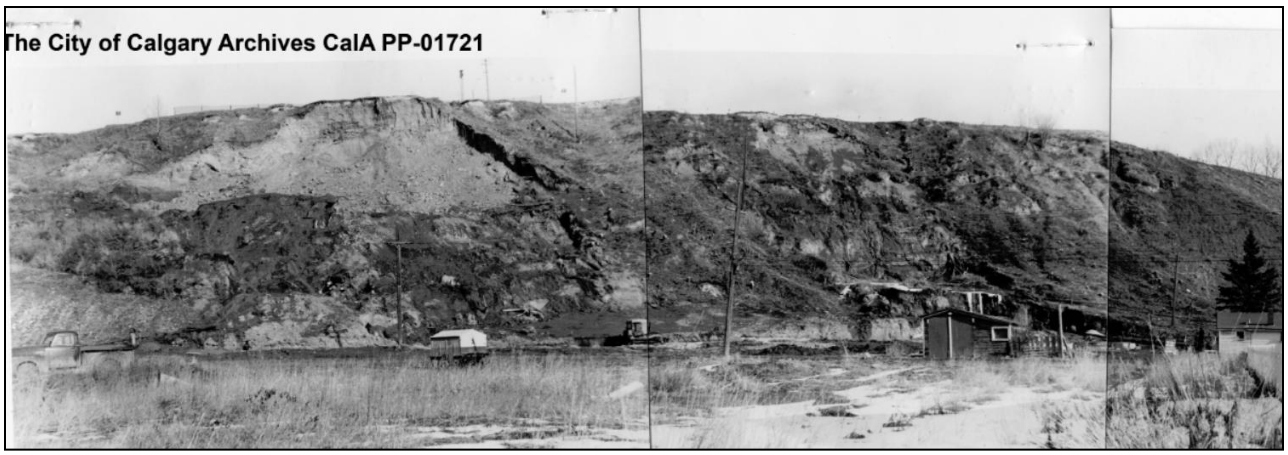


Figure D9. *1958 Slide Photo of McHugh Bluff. The City of Calgary Archives (copyright; cannot be reproduced without obtaining permission of City Archives).*

Meyboom in his paper observed that generally in Spring part of the slope suddenly moves downward, often preceded by the formation of tension cracks along the crest of the danger zone. During the sliding, the upper part of the moving mass subsides, whereas the lower part bulges and the slide-scar becomes a C-curve - a classic landslide. He interpreted the 1958 slide to be due to an increase in hydrostatic pressure in the low permeability glacial lake clays & silts that reduced their shear strength and caused them to fail.

Meyboom noted that boreholes on the slope when first drilled are "moist", but after days or hours, water drains out of the sediments. The sediments are confined or semi-confined, so this water level is higher than the regional water table. He identified the "till" layer filling the bedrock channel as the main aquifer and with recharge during wet periods, there is a corresponding increase in water pressure in the till and the basal glacial lake sediments, decreasing the shearing resistance of the sediments on the slope. Meyboom's hypothesis was that the underlying bedrock channel was leading to enhanced slide risk. See figure 23 in main text and figure B2 in Appendix B for maps and geological cross-sections from Meyboom's paper. Hardy & Associates, in their 1963 engineering review, discounted the significance of the bedrock channel fill as the primary cause of the slides.

The piezometric surface in Rosedale, Figure D10 below, shows the hydrostatic pressure is highest above the deepest part of the bedrock channel. The recharge area shown on the piezometric map is relatively small with a westward boundary located at about 8th St. N.W. Thus, it is the low permeability of the glacial sediments in combination with wet conditions on a steep slope that led to the slides.

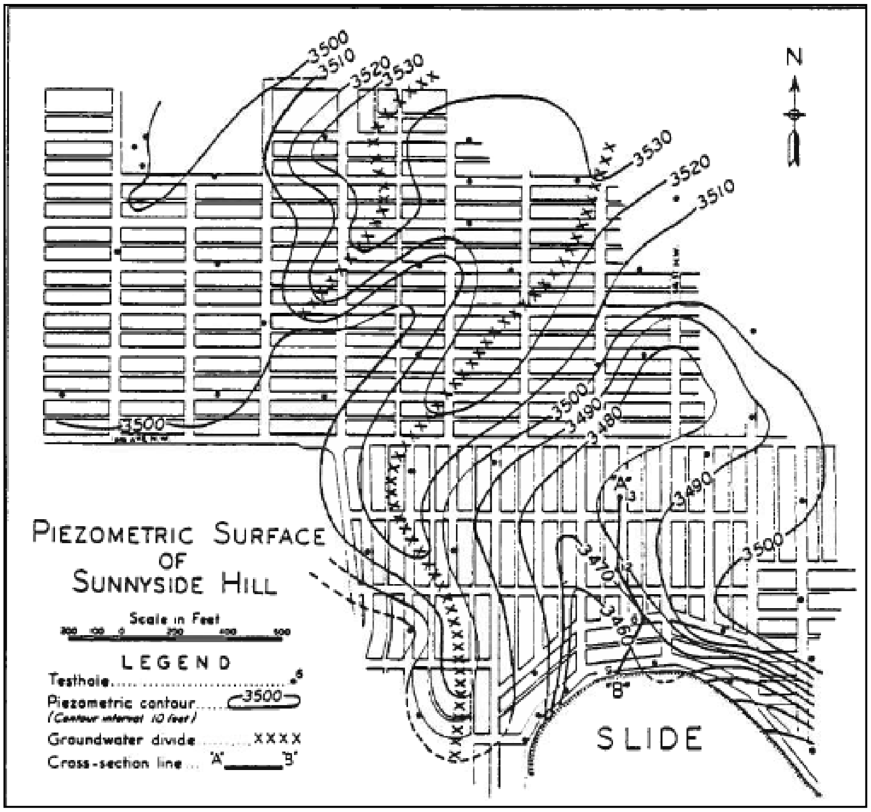
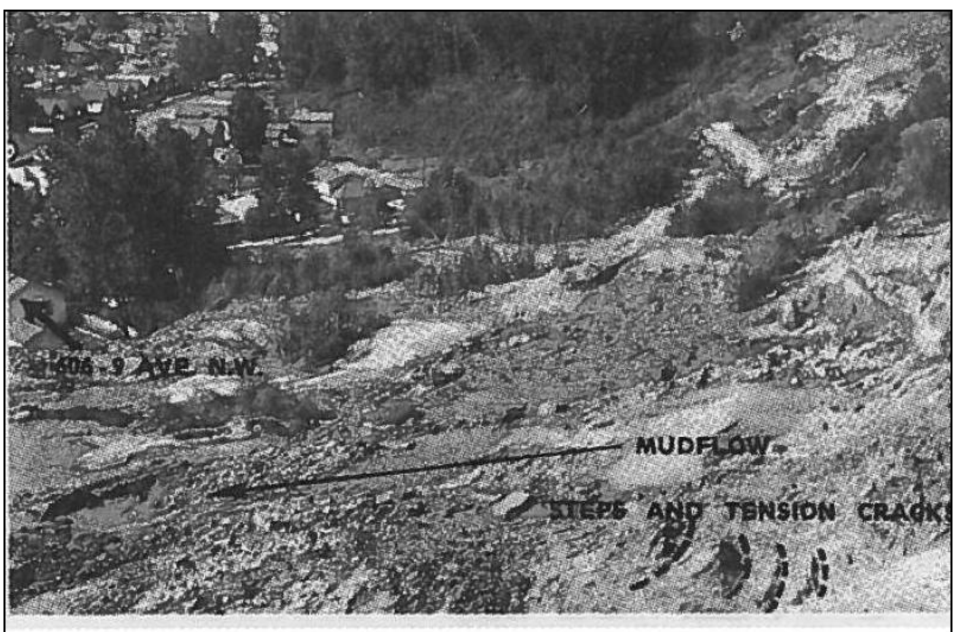


Figure D10. Piezometric Surface Map of Rosedale from Meyboom, 1961.



B: Detail of mud flow, showing steps and tension cracks

Figure D11. *From Meyboom, 1961. The 1958 slide advanced to back yards of houses on 600 block of 9th Ave. N.W. All the houses on north side were removed. Previously, houses in the 500 block were removed in 1952/53, after the 1944-1948 slides*

Figure D11 shows the mud flow that encroached onto the back yards of 600 block 9th Ave. N.W. houses. The houses were deemed at risk and were removed. The north side of 9th Ave. S.W. sidewalk is still there, located at the edge of the encroaching brush. What is interesting is this sidewalk is 3 metres higher than the road and houses on the south side of 9th Ave. N.W. Were these houses built on the toe of a much older slide?

A 1963 Engineering Report, again by Hardy & Associates, on stabilization of Sunnyside Hill concluded that the 1948 horizontal drains were not successful. They concluded that the bedrock channel is filled with heterogeneous types of material resulting in a greater incidence of seepage layers. Aquifer recharge is thought to be from surface waters. They note perched water tables at 25 feet and 130 feet below surface. They observed fissures in boreholes - this is potentially significant as it would allow for vertical connectivity. They concluded that the gravel cover put on slopes after 1948 slides helped with stabilization.

The 1963 recommended plan for slide mitigation was to install large diameter vertical drainage wells: 5 x 12" wells to 40 feet depth spaced at 25 - 50 feet and connected by a 10 foot deep trench filled with gravel. The wells were designed to capture excess pressure build-up in clay rich sediments. It was considered too expensive to drill deep wells to bedrock north of the base of slope and pump the water that built-up. They considered the critical portion of the slope for slides to be where slope angle changes from an upper slope at 25^0 to 8^0 on the lower slope. The plan was to cover the near vertical faces near the top of slope with gravel.

Figure D12. *Glenbow Archives 1967 aerial photo of McHugh Bluff. The remnants of the 1958 slide are still obvious as white coloured area on bluff. As is the area of the 1932 slide - you can see where it covered the low angle tramline path that ran up to Centre Street.*

Recent Slides

A July, 1998 mudslide occurred that uprooted poplar trees. The mudslide was 50 metres long and 10 metres wide. It caused a temporary closure of the bike path - below 7A St. N.W. promontory (Rosedale Stories).

An October, 2021 slide occurred on the steep slopes on the east side of the 7A St. N.W. promontory. This slide occurred after a prolonged dry spell, contrary to the established models for slide initiation. Cracks on the slopes parallel to the bike path below were observed as early as March, 2021 (Peter Hews, personal communication). The top of the slide is near the top of the slope and extends down slope to cover the bike path. Engineers have studied the slide, drilling a borehole on the bike path, and made recommendations to the City for an initial mitigation plan. Their report has not yet been released.

Figure D13. *2021 Slide on east side of 7A St. N.W. Promontory*

Appendix E
Historical Documents

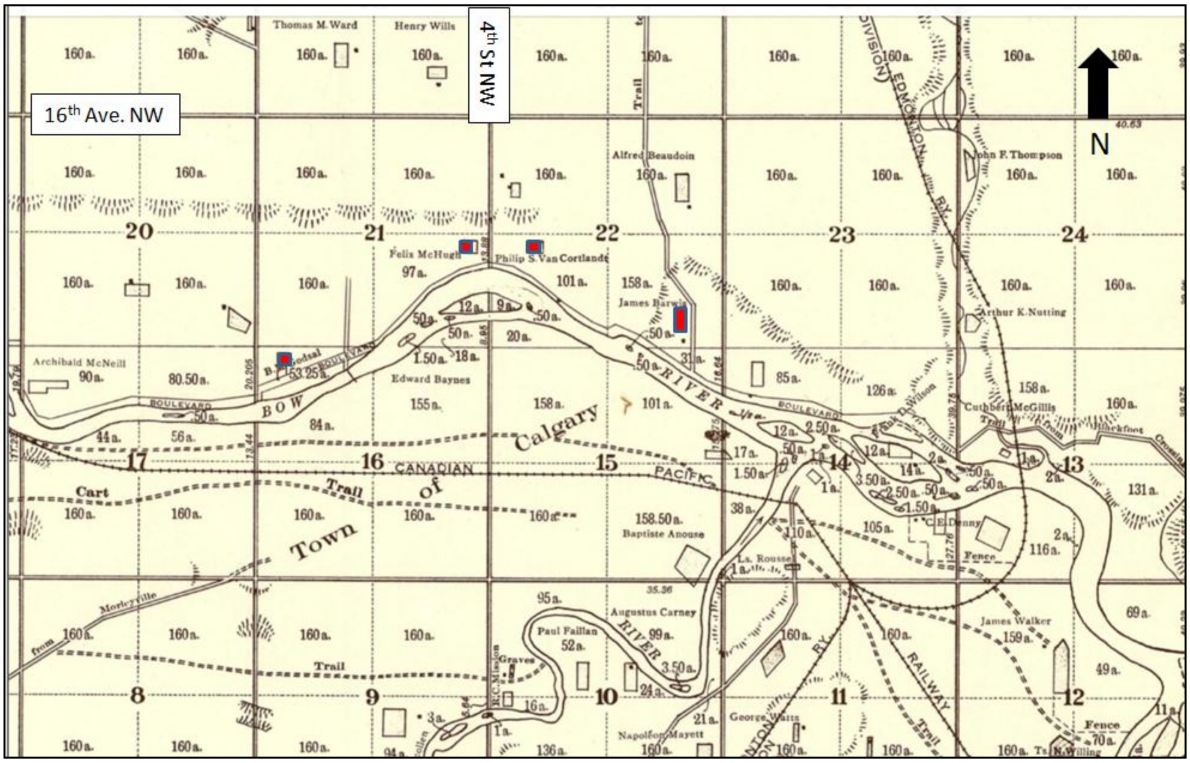
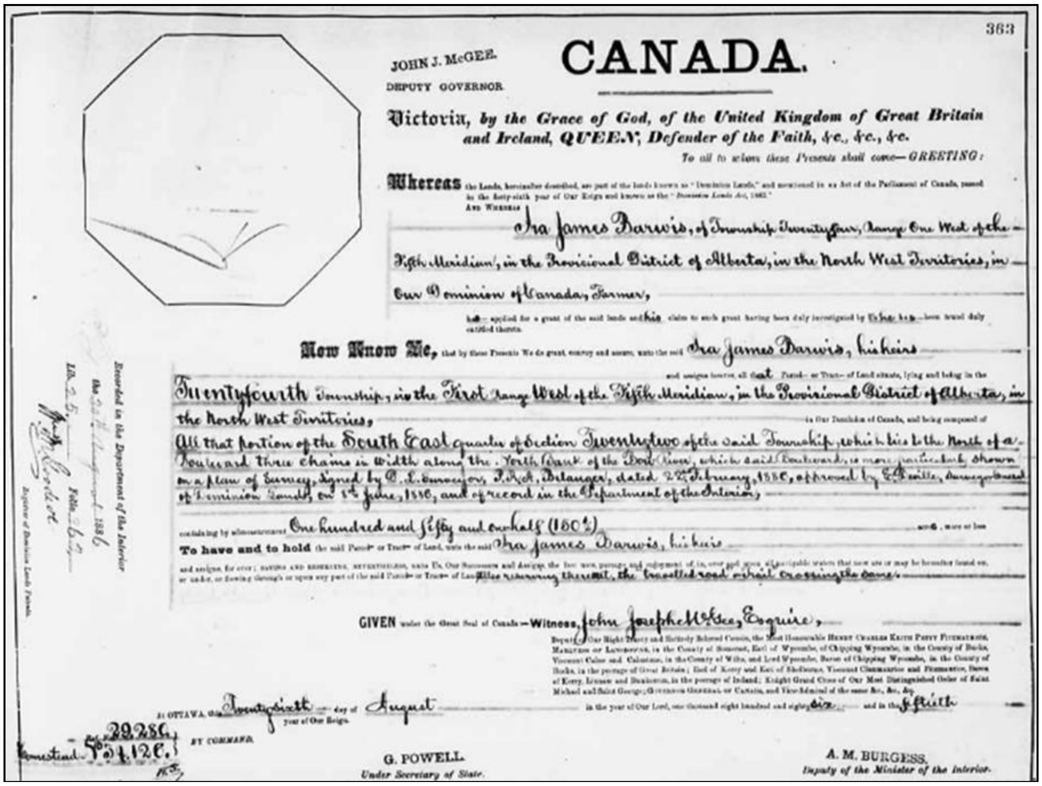


Figure E1. *A replica 1883 Survey Map of Calgary Area. The Van Cortlandt and McHugh homesteads of 97 acres and 101 acres, respectively, suggests proximity to the town, not agricultural endeavors was the prime reason for choosing these lands. The Barwis land seems the better choice as it is nearly a full quarter section and it is traversed by the Morley Trail. North-South railways that were built much later are shown on map, but in 1883 the mainline C.P.R. had just arrived in Calgary. The C.P.R. was entitled to all the odd numbered sections on this map and chose to build their station in section 15 instead of paying the high asking prices for land in section 14, the original settlement location. McHugh lost his homestead to the C.P.R. because he had staked an odd numbered section.*


363

JOHN J. McGEE.
DEPUTY GOVERNOR.

CANADA.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland, QUEEN, Defender of the Faith, &c., &c., &c.

To all to whom these Presents shall come—GREETING:

Whereas ...

Ira James Barwis, of Township Twentyfour, Range One West of the Fifth Meridian, in the Provisional District of Alberta, in the North West Territories, in Our Dominion of Canada, Farmer,

Now Know Ye, ... Ira James Barwis, his heirs ... Twentyfourth Township, in the First Range West of the Fifth Meridian, in the Provisional District of Alberta, in the North West Territories, ... All that portion of the South East quarter of Section Twentytwo of the said Township, which lies to the North of a Boulevard three chains in width along the North Bank of the Bow River, ... dated 22nd February, 1886, ... of record in the Department of the Interior,

containing by admeasurement One hundred and fifty and one half (150½) acres, more or less

To have and to hold ... Ira James Barwis, his heirs

GIVEN under the Great Seal of Canada—Witness, John Joseph McGee, Esquire, ...

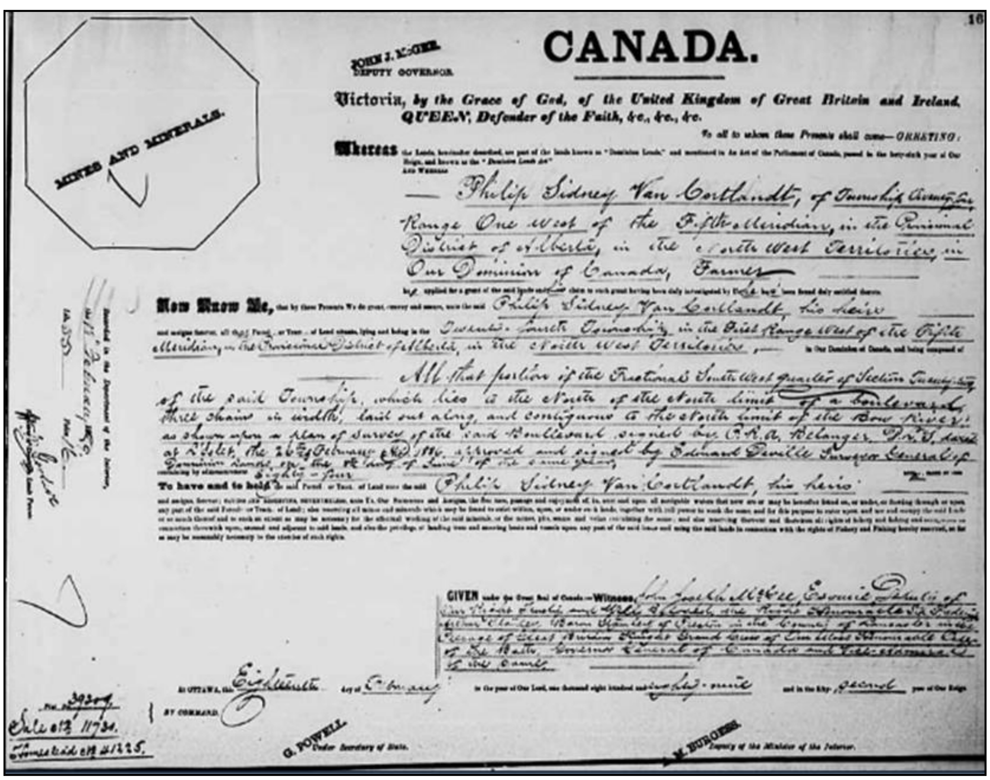
At OTTAWA, this Twentysixth day of August ... eightysix ... fiftieth

BY COMMAND,

G. POWELL.
Under Secretary of State.

A. M. BURGESS.
Deputy of the Minister of the Interior.

Figure E2. *James Barwis Land Title to SE-22-24-1 W5M dated 26th Aug. 1886. No mention of mineral rights exclusion.*


JOHN J. McGEE.
DEPUTY GOVERNOR.

CANADA.

MINES AND MINERALS.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland, QUEEN, Defender of the Faith, &c., &c., &c.

To all to whom these Presents shall come—GREETING:

Whereas ...

— Philip Sidney Van Cortlandt, of Township ..., Range One West of the Fifth Meridian, in the Provisional District of Alberta, in the North West Territories, in Our Dominion of Canada, Farmer

Now Know Ye, ... Philip Sidney Van Cortlandt, his heirs ... Twenty-fourth Township, in the First Range West of the Fifth Meridian, in the Provisional District of Alberta, in the North West Territories, ...

All that portion of the Fractional South West quarter of Section Twenty-two of the said Township, which lies to the North of the North limit of a boulevard three chains in width, laid out along, and contiguous to the North limit of the Bow River, as shown upon a plan of survey of the said Boulevard signed by C.R.A. Belanger, ... 1886, approved and signed by Edouard Deville, Surveyor General ...

containing by admeasurement Eighty-four ...

To have and to hold ... Philip Sidney Van Cortlandt, his heirs

GIVEN under the Great Seal of Canada—Witness, John Joseph McGee, Esquire, ...

At OTTAWA, this Eighteenth day of February ... eighty-nine ... second

BY COMMAND,

G. POWELL.
Under Secretary of State.

A. M. BURGESS.
Deputy of the Minister of the Interior.

*Figure **E3.** Van Cortlandt Land Grant for SW-22-24-1 W5M that reserves mineral rights for the Crown. Dated 18th February, 1889.*

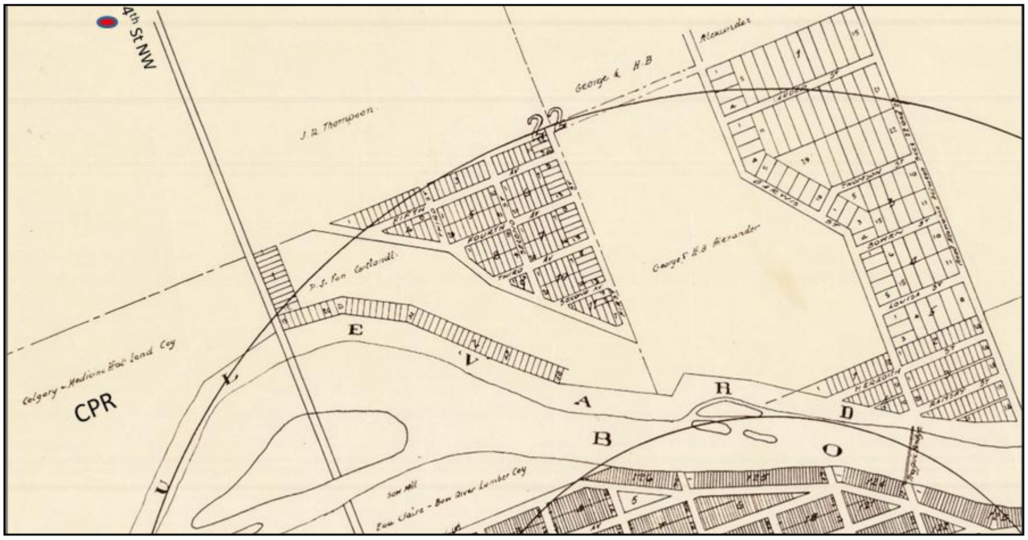


Figure E4. *1891 Map of Calgary and north bank of Bow River. No marking to indicate quarry locations. Land title searches also did not reveal any reference to quarries.*

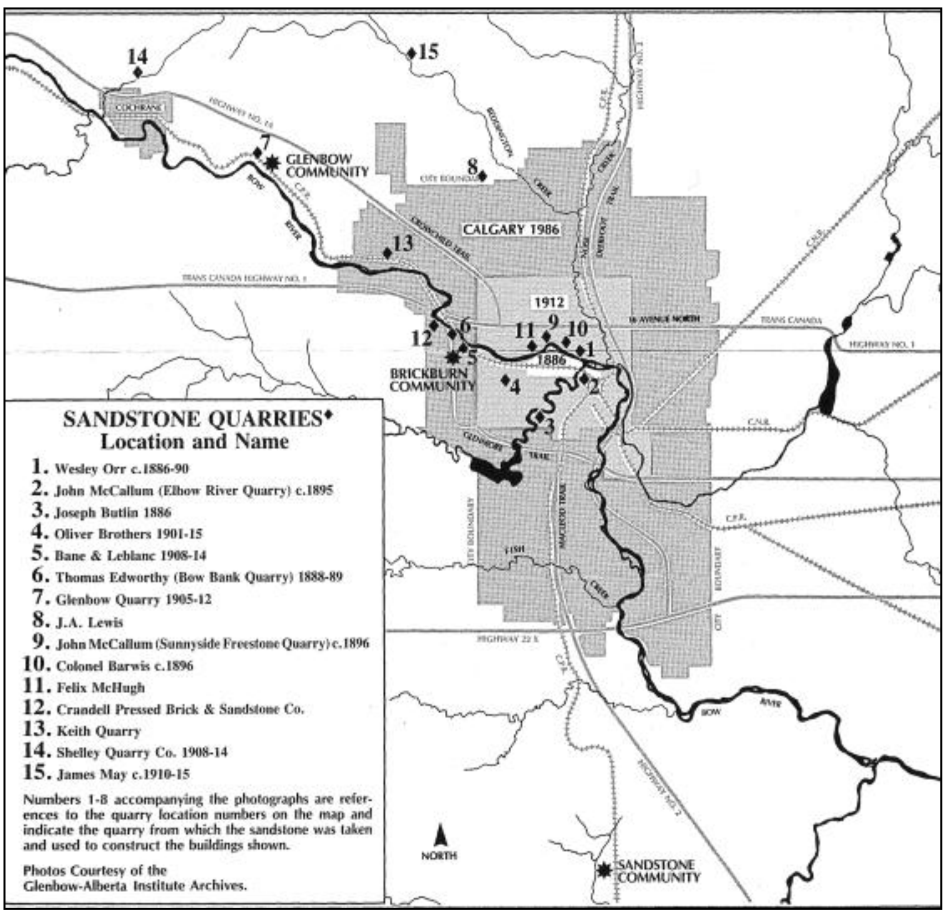


Figure E5. *Four sandstone quarries shown on the north bank of Bow River. From east to west: Orr (1886 - 1890), Barwis (1896), Sunnyside Freestone Quarry (1896), & McHugh. Locations should not be taken as exact, as Sunnyside Freestone Quarry for example is shown where there is no bedrock outcrop. The 1896 date for the Sunnyside Freestone Quarry is unlikely; we know sandstone was quarried as early as the winter of 1888/89 until at least 1892.*

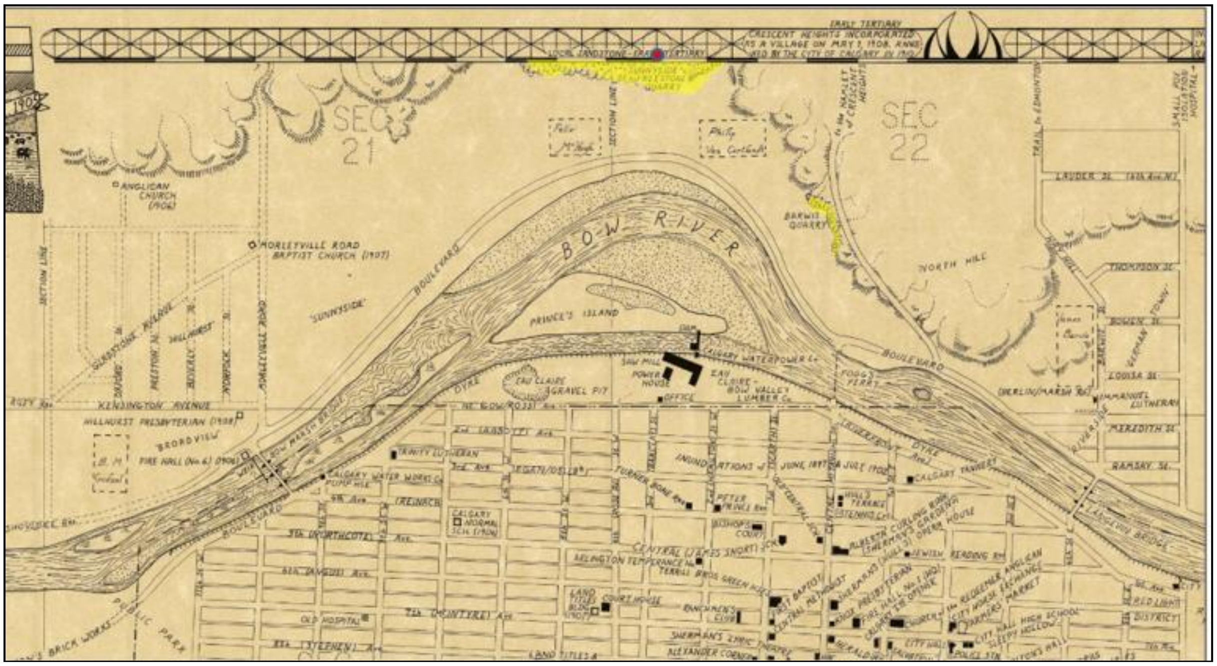


Figure E6. *A recently drafted replica map of 1905 Calgary and the north side of Bow River. The Sunnyside Freestone Quarry is shown at top of the map, located on either side of 4th St. N.W. -scaling the map, places the quarry on top of the escarpment. We now know from geology that the furthest west this quarry could have been located was 3rd St. N.W. The Barwis Quarry is placed on trend with Centre St. - this is on Van Cortlandt land. It is also placed on top of the escarpment, not the base when scaled. It is unlikely either of these quarries was still quarrying sandstone in 1905. Claystone quarrying was possible as there was a brick factory in Bridgeland at the time and there were clay mineral leases over the quarry sites.*

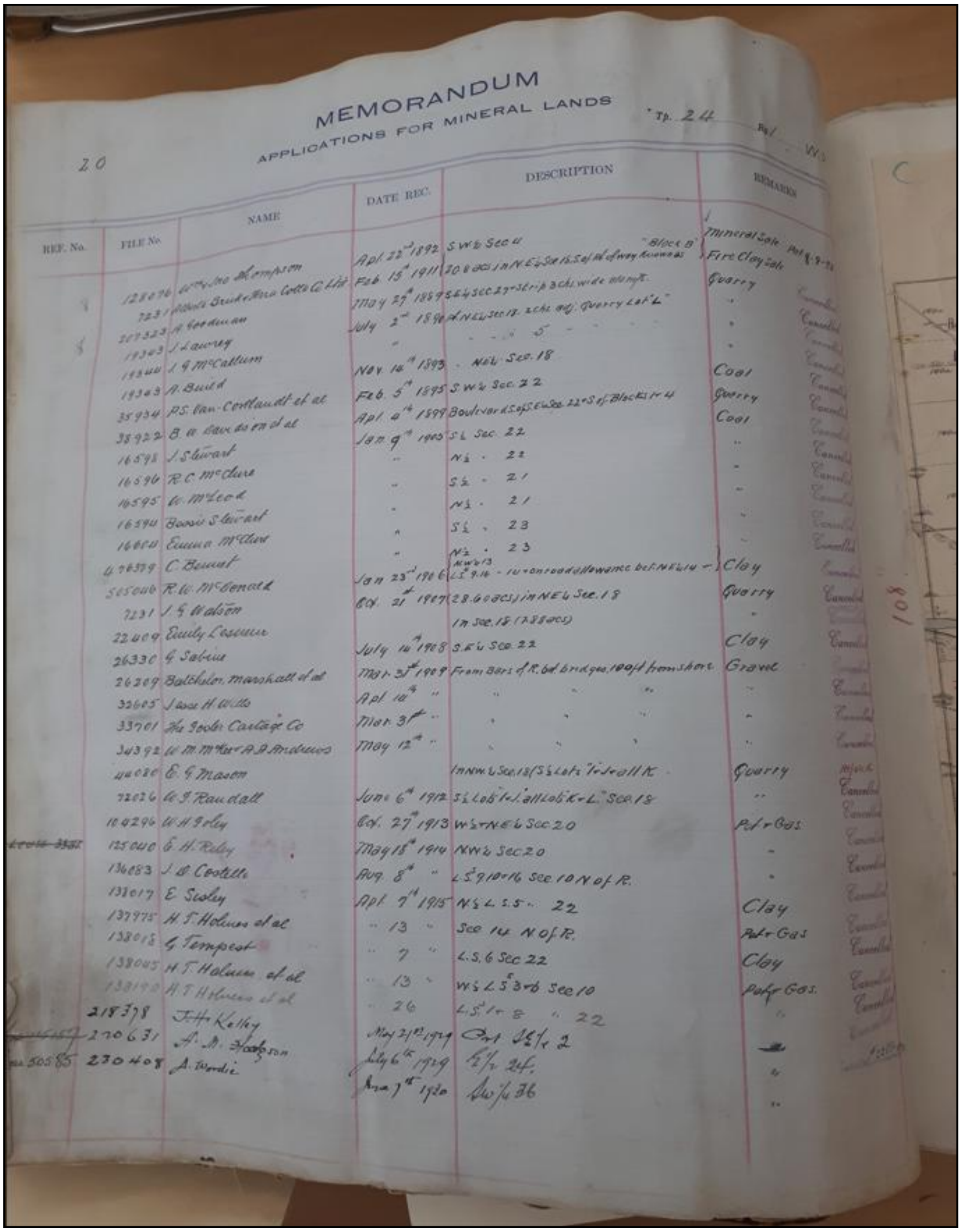


Figure E7. *N.W. Territories Mineral Lease Record for Twp. 24 Rge. 1 W5M. Earliest entry is 1889. Entries are not in chronological order. This is earliest record in Provincial Archives for this township. Perhaps listing of pre-1889 leases was destroyed or lost. The non-chronological order of entries suggests that some entries on above page may have been copied from an earlier source. No entry for Sunnyside Freestone Quarry - a site where the Crown held mineral rights.*

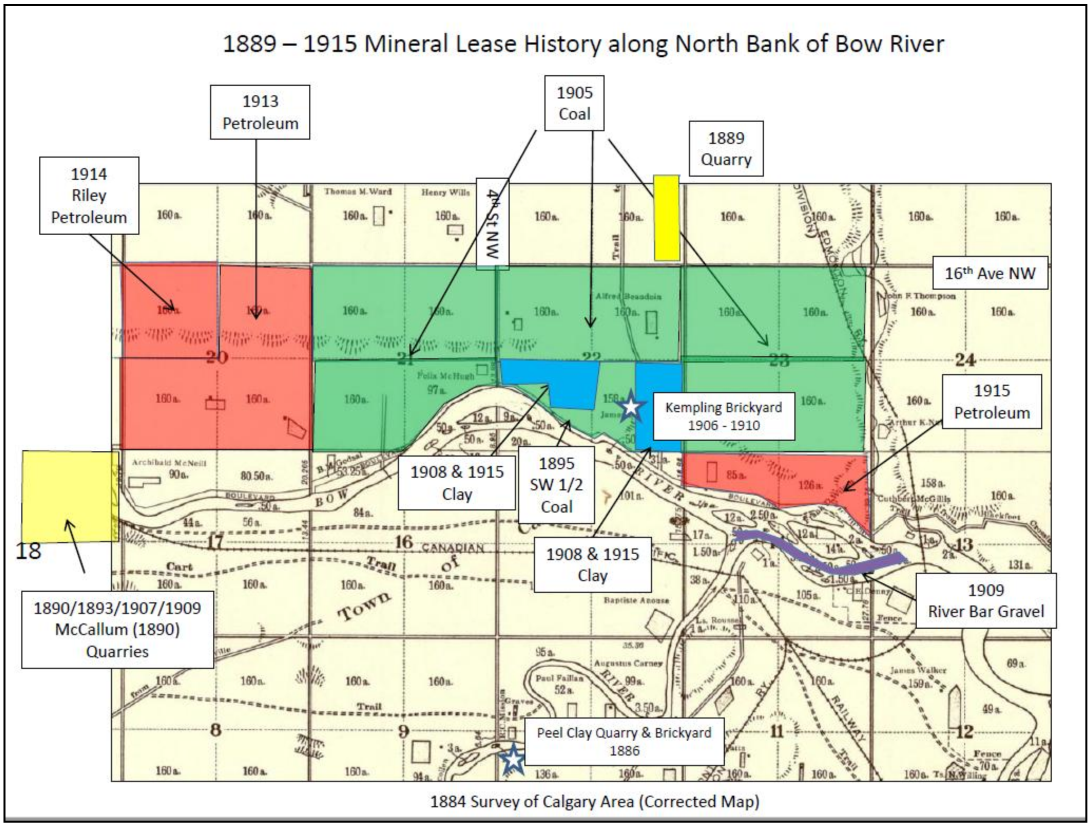


Figure E8. *Mineral Leases 1889 - 1915 on North Bank of Bow River. Note the two clay leases coloured blue on map.*

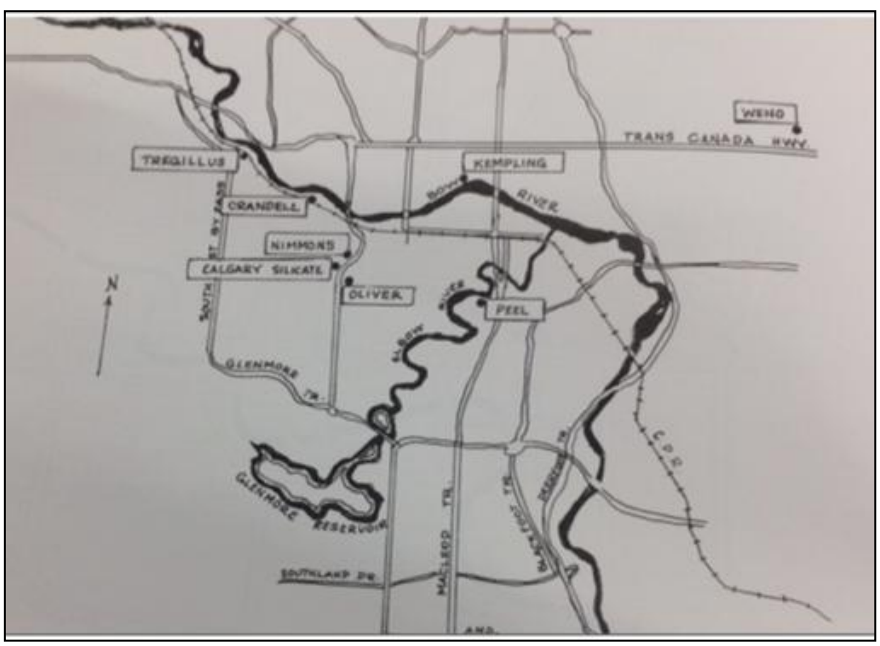


Figure E9. *Map of early Calgary Brickyards from Mason. On map, Kempling brickyard is placed in Sunnyside, approximately where buildings at base McHugh Bluff are seen in 1908 photo. In text, brickyards are described as being located near 4th St. N.E. Which is correct?*

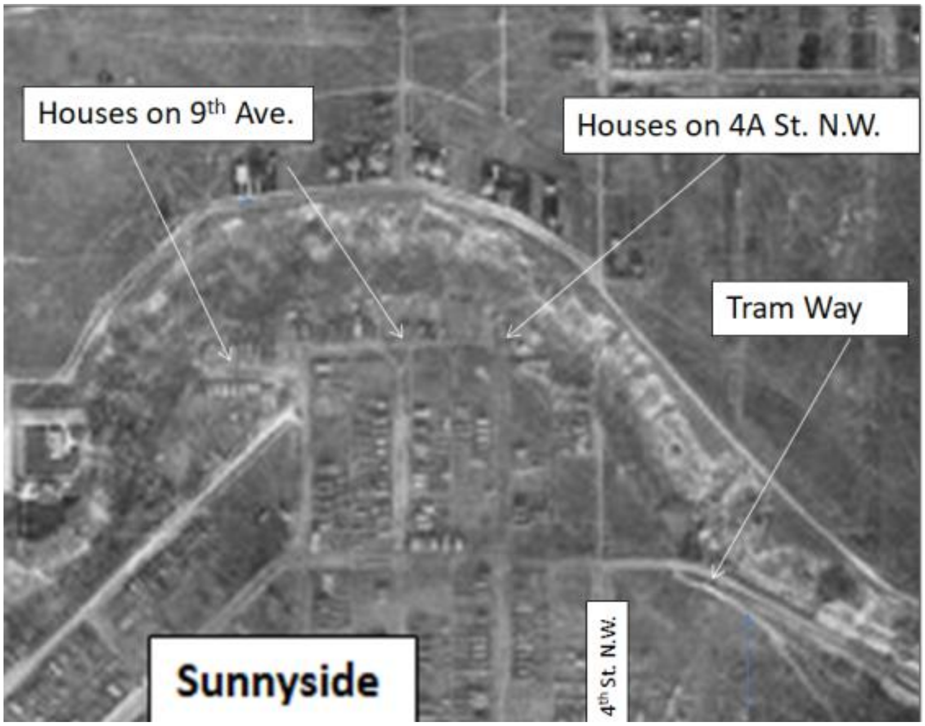


Figure E8. *1924 Aerial Photo of Sunnyside showing development of housing on north side of 9th Ave. N.W. & north end of 4A St. N.W., later removed because of slides in 1944 and 1958.*