



# Geological mapping and petrogenesis of carving stone in the Belcher Islands, Nunavut

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## Abstract

Soft stone suitable for carving is a highly sought-after resource in Nunavut. The Qikiqtani Inuit Association (QIA) has developed a program to assess carving stone reserves, site accessibility, and quarry safety, management and development in their jurisdiction. A team of geologists from the QIA, Canada-Nunavut Geoscience Office and University of Manitoba visited four carving stone sites on the Belcher Islands to conduct land surveying, geological mapping and petrogenetic evaluations of the rock being extracted as raw carving stone by local quarriers and carvers.

The carving stone at these sites is interpreted to comprise dolostone in sedimentary strata of the Costello and McLeary formations that have been intruded by diabasic to gabbroic rocks of the Haig suite and are locally contact metamorphosed. Within these areas, the dolostone beds are metamorphosed to a softer, more easily carved rock, likely due to the growth of fine-grained talc and other metamorphic minerals. Other locations in the Belcher Islands where dolomitic sedimentary strata are cut by Haig intrusive rocks also have the potential to host undiscovered carving stone reserves.

## Résumé

La pierre tendre se prêtant à la sculpture est une ressource fort recherchée au Nunavut. La Qikiqtani Inuit Association (QIA) a mis en place un programme d'évaluation des réserves de pierre à sculpter, d'accessibilité aux sites et de pratiques de sécurité, de gestion et de mise en valeur des carrières au sein de leur territoire. Une équipe formée de géologues issus de la QIA, du Bureau géoscientifique Canada-Nunavut et de l'Université du Manitoba a visité quatre emplacements de pierre à sculpter dans les îles Belcher afin d'y mener des travaux de levé, de cartographie géologique et d'évaluation pétrogénétique de la roche extraite sous forme de pierre à sculpter à l'état brut par les exploitants de carrières et les sculpteurs.

Les géologues décrivent la pierre à sculpter à ces endroits comme étant de la dolomie gisant dans des strates sédimentaires des formations de Costello et de McLeary, lesquelles sont pénétrées par des roches de la suite de Haig dont la composition varie de diabasique à gabbroïque et qui ont subi par endroits les effets du métamorphisme de contact. À ces endroits, les couches de dolomie ont été métamorphosées et sont formées de roches plus tendres, et ainsi plus faciles à sculpter; ce phénomène est attribuable à la croissance de talc à grain fin et d'autres minéraux métamorphiques. D'autres endroits dans les îles Belcher où des roches intrusives de la suite de Haig recoupent les couches sédimentaires formées de dolomie pourraient également receler des réserves encore non découvertes de pierre à sculpter.

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## Introduction

Soft stone suitable for decorative carving is a resource of special significance in Nunavut. Under Section 19 of the Nunavut Land Claims Agreement, an almost unrestricted access to carving stone is guaranteed for Inuit peoples, pro-

viding a supply of raw stone to a growing industry of artisan carvers (Government of Canada, 1993). Under the guidance of the Government of Nunavut's Department of Economic Development and Transportation (EDT), an inter-governmental document called *Ukkusiksaqtarvik, The Place Where We Find Stone: Carving Stone Action Plan*

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This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the Canada-Nunavut Geoscience Office website: <http://cngo.ca/summary-of-activities/2016/>.

(Nunavut Department of Economic Development and Transportation, 2007) was created. This document highlights the importance of carving stone as a commodity in the territory, and encourages improvement for access to quality carving stone across Nunavut by strengthening traditional quarrying methods and facilitating intercommunity distribution.

The first step in *Ukkusiksaqtarvik* was to identify, locate and estimate resources at known, traditional and relatively new carving stone localities. This was accomplished during approximately five years of community consultation and site visits by the EDT's Nunavut Carving Stone Deposit Evaluation Project (NCSDEP; Beauregard et al., 2013; Beauregard and Ell, 2014, 2015). Although the NCSDEP identified hundreds of potential sites across the territory and concluded that sufficient good- to excellent-quality carving stone exists to supply the territory's needs for hundreds of years, the challenges associated with co-ordinating the distribution of raw materials to communities and carvers have yet to be addressed.

In recognition of the economic and cultural importance of carving stone in Nunavut and the logistical challenges associated with implementation of the next steps of *Ukkusiksaqtarvik*, the Qikiqtani Inuit Association (QIA) launched their own evaluation project in the summer of 2016. The project targets the largest carving stone deposits on Inuit Owned Lands in the Qikiqtaaluk Region, and provides the necessary expertise to evaluate and assess resources at each site. It builds on the results of the NCSDEP, implementing its recommendations and addressing regional issues with regards to quarry development and the economic feasibility of community-led expansions. The project will include quantifying the lifespan of sites based on surface and subsurface deposits, and evaluating the work required to make deposits accessible and free from dangers such as rock falls, flooding or wall collapse. The conclusion of this work will provide critical information for understanding long-term resource availability in the region, which is necessary for further implementation of the *Ukkusiksaqtarvik*, and will ultimately enable local Inuit to utilize their resources in a commercially viable and responsible manner.

Sites targeted by the QIA for resource and development assessment require geological mapping and interpretation, land surveying and site-accessibility evaluations. Geophysical surveys (i.e., magnetic-anomaly mapping), prospecting and/or satellite-imagery analysis may also aid in the full evaluation of resource viability at these sites. The top-priority sites include Kangiqsukutaaq (Korok Inlet, near Cape Dorset), Tatsituya and Tatsitui Tiniiniya (Aberdeen Bay, near Kimmirut), Opingivik Island (near Pangnirtung), Qullisajaniavvik (near Sanikiluaq) and the Koonark deposit at Mary River (near Pond Inlet). Detailed geological mapping has already been conducted at the

Kangiqsukutaaq (Steenkamp et al., 2014) and Opingivik (Steenkamp et al., 2015) sites.

On September 11–14, the Canada-Nunavut Geoscience Office, the QIA and a research student from the University of Manitoba visited four carving stone localities near Sanikiluaq (Figure 1a; Beauregard and Ell, 2015) to conduct detailed geological mapping and further the QIA's carving stone resource assessment project. This paper provides a detailed geological description and map for the Qullisajaniavvik carving stone site, herein referred to as the community quarry (CQ in Figure 1b), as well as an abandoned quarry site (Aqituniavvik; AQ in Figure 1b) and two other carving stone occurrences near Salty Bill Hill, referred to as SBH1 and SBH2 (Figure 1b), on Tukarak Island. The authors present a geological interpretation for the petrogenesis of soft, easily carved stone at these sites, and highlight the geological elements required for future prospecting of similar carving stone resources.

## Geological background and site histories

The geology of the Belcher Islands was mapped at a 1:125 000 scale and described in detail by Jackson (2013). The islands are underlain by the Proterozoic (ca. 1.96–1.87 Ga) Belcher Group, comprising dominantly shallow-marine carbonate and siliciclastic strata interrupted by volcanic flows and associated volcanoclastic rocks. Jackson (2013) summarized the depositional history of the Belcher Group in three major stages:

- 1) Steady, dominantly carbonate sedimentation occurred in a stable continental-shelf environment during marine transgression.
- 2) Abrupt emplacement of volcanic flows and minor associated volcanoclastic and fluvial sedimentary rocks was followed by a return to marine sedimentation in a less stable continental-shelf environment. Sedimentation included local iron formation, greywacke, mudstone, siltstone and carbonate rocks.
- 3) A second phase of abrupt volcanism included emplacement of regionally extensive basalt flows and intrusion of diabase–gabbro sills in pre-existing strata. Volcanism was followed by a thick succession of mostly deep-water turbidites that shallowed upward into more proximal, coarse-grained, nearshore-marine and terrestrial strata.

The Belcher Group was regionally folded and weakly metamorphosed (sub-greenschist facies), likely due to continental-collision events associated with the 1.85–1.83 Ga Trans-Hudson orogeny (Hoffman, 1989; Corrigan et al., 2009). The islands are included in the Reindeer Zone, in the upper-plate Churchill Province north of the orogenic front. The impact of the Trans-Hudson deformation is highlighted by the uniquely folded and interconnected geography of the Belcher Islands.

During the Pleistocene, the Belcher Islands were completely covered by ice, and they are still rebounding at a rate of a few centimetres per year. It is likely that the islands were completely inundated by the sea when the ice retreated, based on the presence of beach deposits atop the highest hills on Tukarak Island (Jackson, 2013).

The four carving stone sites visited during this study (Figure 1b) were previously visited by Beauregard and Ell (2015), who completed carving stone quality assessments and preliminary resource-reserve calculations. The community quarry, established in the 1970s, provides good- to excellent-quality, grey, dark green and black carving stone that can be extracted as blocks up to 1 m across and 40 cm thick and is soft enough to carve by hand. The stone is traditionally quarried using the plugger-and-feather method, and excavated with a hammer and chisel or pry bar before being transported approximately 50 km by snowmobile or motorboat to the hamlet of Sanikiluaq. The community quarry contains an estimated 30 000 tonnes of carving stone reserves, making it the second largest deposit in Nunavut (Beauregard and Ell, 2015).

The abandoned quarry yields a desirable light green stone, yet this is viewed by traditional carvers as lower quality than the stone from the community quarry. An area within this site was abandoned in the late 1990s when rocks from the outcrop above the quarry slid down to partially cover the quarry access, raising concerns about the integrity of the remaining overhanging outcrop. The abandoned quarry site is estimated to have 1000 tonnes of carving stone reserves, as the desired horizon of carving stone continues along strike to the north of the blocked quarry access (Beauregard and Ell, 2015).

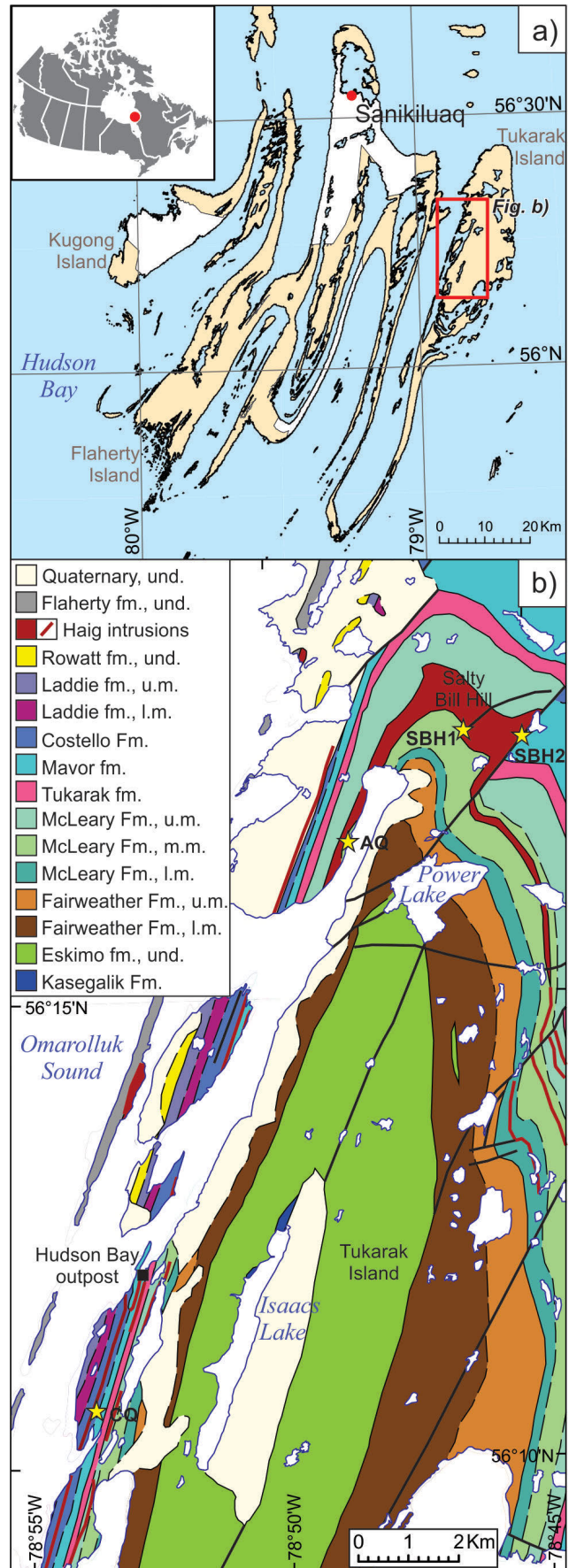
The two occurrences of carving stone near Salty Bill Hill have not been traditionally quarried, as they are farther inland and would require development of an ATV route to transport stone to the shore. However, they are estimated to each hold <100 tonnes of good-quality carving stone (Beauregard and Ell, 2015).

## Field observations

### Community quarry (*Qullisajaniavvik*)

The community quarry area is underlain by steeply west-dipping sedimentary rocks of the Costello Formation that

**Figure 1:** a) Location of the Belcher Islands in eastern Hudson Bay (Inuit-owned land in yellow) and location of study area (red box) in relation to Sanikiluaq. b) Geology of the study area (adapted after Jackson, 2013) and locations of the community quarry (CQ), abandoned quarry (AQ) and carving stone occurrences near Salty Bill Hill (SBH1 and SBH2), indicated by yellow stars. Thick black lines represent minor faults. Thin, continuous black lines represent observed geological contacts, and thin, dashed black lines represent interpreted geological contacts. Abbreviations: Fm./fm., Formation/formation; l.m., lower member; m.m., middle member; u.m., upper member; und., undivided.



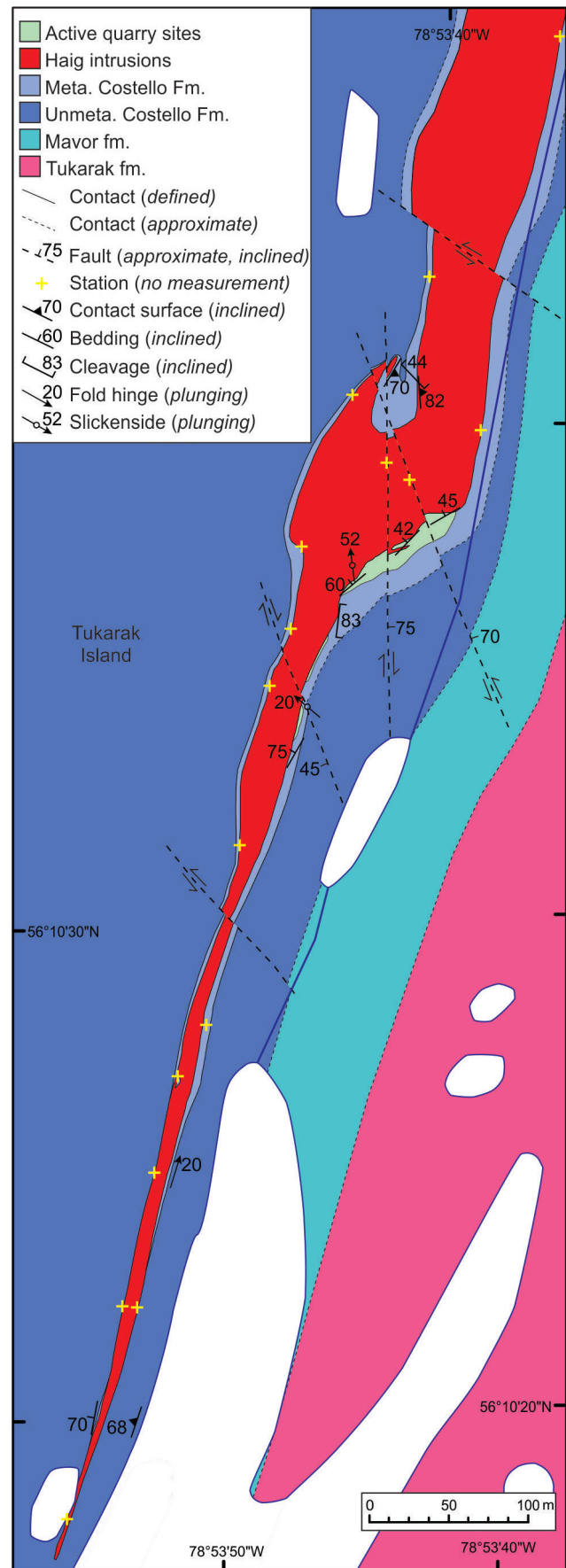
are injected by a diabasic to porphyritic gabbro of the Haig intrusive suite (Figure 2). Along the tideline of the small bay in the southern part of the map area, the basal member of the Costello Formation is well exposed and contains thinly laminated, dark grey shale. This is in conformable contact with interbedded orange-weathering, fine-grained dolostone and grey-weathering, thin (<4 cm) mudstone (Figure 3a) that dominate the Costello Formation in this area. The dolostone exhibits wavy and low-angle crosslamination, and is medium grey on fresh surfaces. The mudstone exhibits low-relief, asymmetric ripple crosslamination and is dark grey to black on fresh surfaces. Dolostone beds are locally boudinaged, likely an effect of dewatering processes operating during regional compaction and diagenesis.

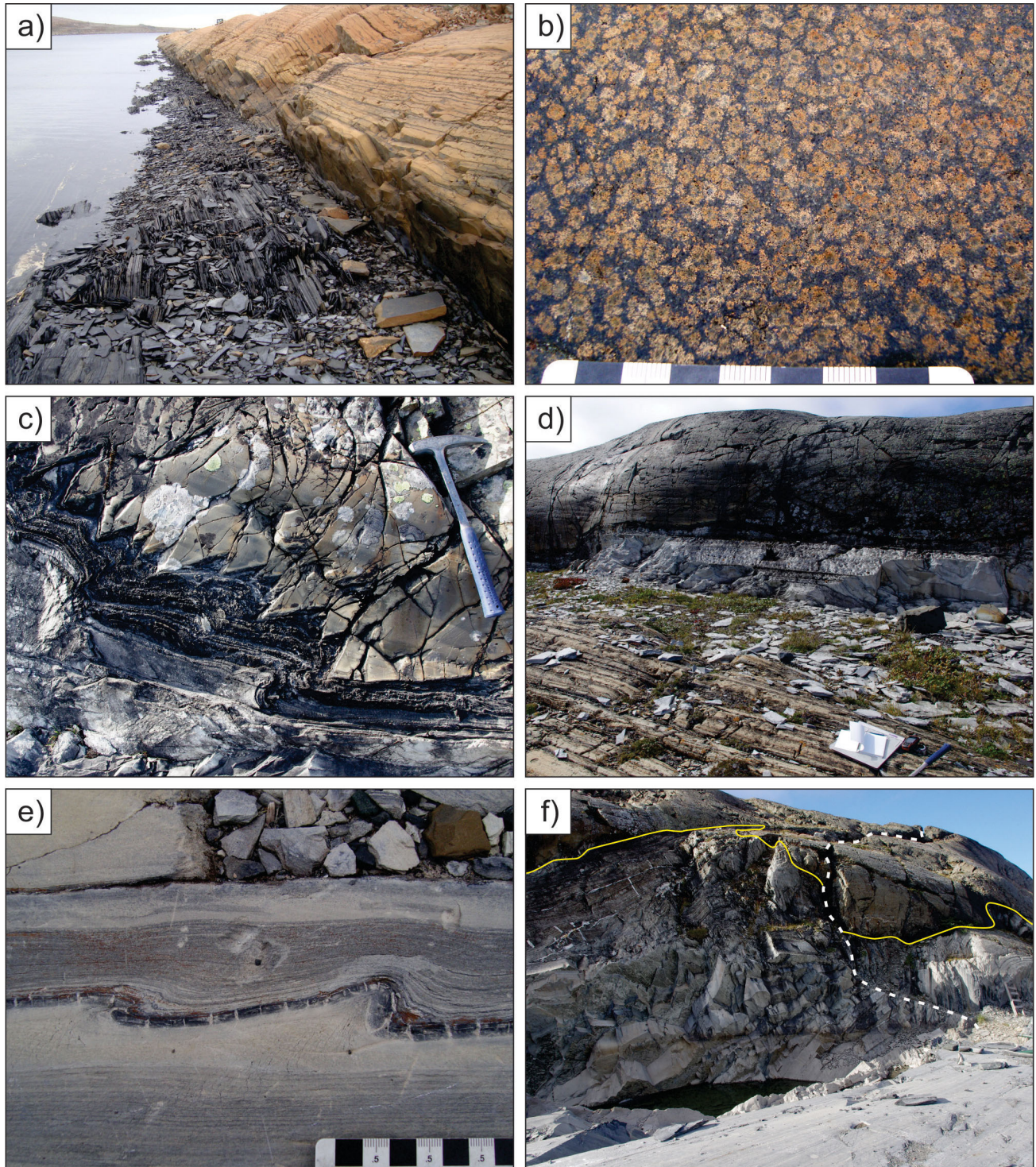
At the southern end of the map area, the Haig gabbro intrudes the Costello Formation parallel to bedding as a sill. The sill thickens to the north, near the active quarry sites, and locally crosscuts the sedimentary bedding at oblique angles. The interior parts of the Haig intrusion have a porphyritic texture, with individual phenocrysts and agglomerations of plagioclase in a black aphanitic matrix. West of the active quarry area, where the sill is thickest, plagioclase grains appear to have dark cores (Figure 3b), which could be due to compositional zoning (suggesting two-stage crystallization from compositionally different magmas) or be a different mineral phase (possibly clinopyroxene) that acted as nucleation sites for later plagioclase crystallization.

Along the intrusive contact, the gabbro has 10–20 cm thick, aphanitic chilled margins that are regularly fractured perpendicular to the contact. The fractured margin segments appear to be subsequently rotated 10–20°, possibly by continued internal flow of magma during injection. Locally, the rotated margin segments of the gabbro have been slightly offset. Where this occurs, the dolostone and mudstone layers are ductilely deformed and appear to infill the offset spaces (Figure 3c), suggesting that the displacement may have occurred during later regional deformation. The interlayered dolostone and mudstone of the Costello Formation, both stratigraphically below and above the Haig intrusion (to the east and west, respectively), is contact metamorphosed adjacent to the contact surface. The width of the contact aureole appears to correlate with the thickness of the intrusion, ranging from 20–50 cm where the sill is 3–5 m thick in the southern part of the map area, up to 30 m in the community quarry area where the sill is thickest.

The contact-metamorphosed dolostone and mudstone have a bleached grey-white appearance on weathered surfaces

**Figure 2:** Geology of the community quarry area on Tukarak Island, Belcher Islands. Abbreviations: Fm./fm., Formation/formation; meta., metamorphosed; unmeta., unmetamorphosed.





**Figure 3:** Photographs from the community quarry area on Tukarak Island, Belcher Islands: **a)** contact between the lower, grey shale member (exposed for 1.2 m above the waterline in the foreground) and predominant orange-weathering dolostone with mudstone interbeds of the Costello Formation; **b)** porphyritic texture in the centre of the Haig intrusion west of the active quarry, showing plagioclase phenocrysts with dark cores; **c)** fractured, rotated and displaced blocks of aphanitic gabbro along the chilled margin of the Haig sill, and contact-metamorphosed dolostone that has ductilely deformed around the Haig margin; **d)** white-grey weathering of contact-metamorphosed dolostone adjacent to the black, glacially polished gabbro sill; clipboard, GPS and hammer for scale; **e)** thin black mudstone layer with regular z-folds and concentrations of brown-weathering sulphides within the dolostone and close to the contact with the mudstone layer; **f)** view of the active quarry looking northwest from within the contact aureole (grey polished outcrop in the foreground), showing a minor brittle fault (traced by the white dashed line) that displaces the intrusive contact (yellow lines), and typical white calcite-quartz veins (left) in the contact-metamorphosed Costello Formation; small ladder for scale is approximately 1.2 m tall.

(Figure 3d) and are light to medium grey on fresh surfaces. Although a grain-size change is not visibly apparent, fresh surfaces of the contact-metamorphosed dolostone exhibit a sugary texture, as opposed to the flat, homogeneous fresh face of an unmetamorphosed equivalent. The site where most of the quarrying for soft stone has so far been done is where the contact-metamorphic aureole in the dolostone and mudstone is the broadest in the map area. The sedimentary rocks in this area likely experienced more consistent, prolonged heating due to the large volume of gabbroic magma stratigraphically above, resulting in localized growth of fine-grained metamorphic minerals, possibly including talc, serpentine, brucite, sericite or calcite. Due to the fine-grained nature of these rocks, petrographic analysis is underway to ascertain their precise mineralogy.

A moderately to steeply northeast-dipping cleavage can be observed where contact-metamorphosed beds are highly frost fractured. This fabric is associated with small, north-plunging z-folds that are most easily seen in the glacially polished mudstone layers near the active quarry (Figure 3e). Locally, clusters of sulphide minerals concentrate at the margin between dolostone and mudstone layers, particularly where the mudstone has been folded. These features likely developed during regional deformation of the Belcher Group rocks associated with the Trans-Hudson Orogen.

The Costello Formation and Haig intrusion both preserve relatively late minor veining and brittle faulting. Veins are common along the intrusive contact in pre-existing fractures, cut vertically and horizontally through the contact-metamorphosed sedimentary rocks (Figure 3f), and occur as a narrow concentrated network that follows bedding in the dolostone west of the intrusion and contact-metamorphic aureole. The veins typically contain varying proportions of quartz and calcite, as well as local dolomite and fine-grained talc. The quartz is massive and white in the unmetamorphosed dolostone and occurs as isolated clusters of crystals that are translucent to white, euhedral to subhedral and surrounded by calcite in the contact-metamorphosed areas. In one locality along the intrusive contact margin, thin veins are rimmed by fine-grained talc crystals and infilled by elongated quartz, both being oriented perpendicular to the vein walls and therefore suggesting that crystallization was synchronous with progressive vein opening.

Several late brittle faults are present in the map area, based on minor offsets in the intrusive contact margin and elongate, aligned concentrations of highly fractured gabbro that is more easily traced where the faults intersect the walls of the quarry (Figure 3f). Displacement along any of these faults was likely no more than 5 m in an oblique-slip motion, as indicated by moderately plunging slickensides of recrystallized calcite and rare actinolite.

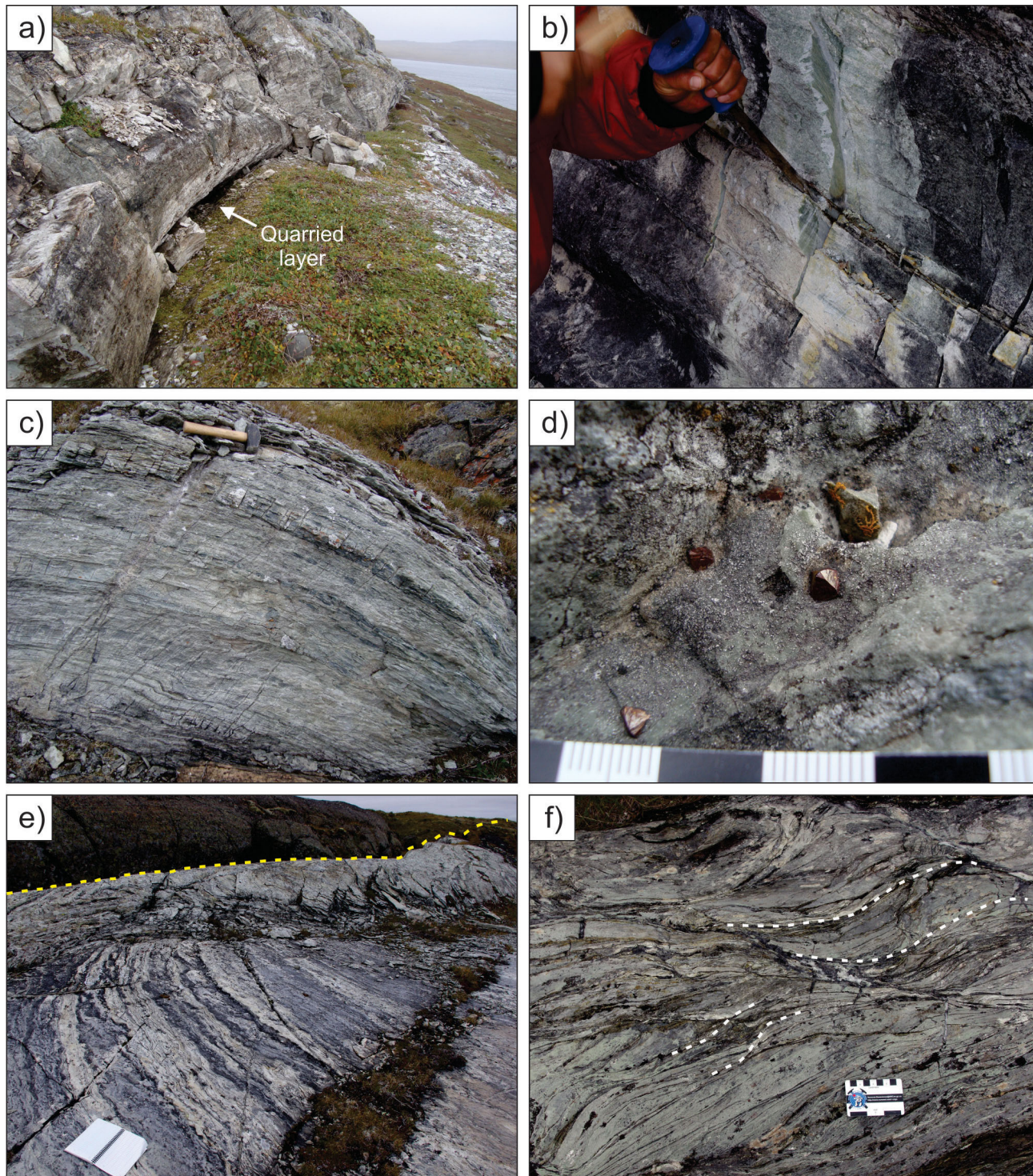
### *Other carving stone sites*

North of the community quarry, three other carving stone localities were visited to evaluate their geological relationships and petrogenesis, as well as their potential for holding additional carving stone reserves for the territory. These sites are the abandoned quarry, which was used as a carving stone source prior to increased use of the community quarry, and two carving stone showings near Salty Bill Hill (Figure 1b). Based on their locations, all three sites appear to involve sedimentary rocks from the middle member of the McLeary Formation that are closely associated with Haig intrusions (Jackson, 2013).

The abandoned quarry site is located approximately 50 m up a steep, grassy hill from the tideline. The lowest outcrop exposure consists of steeply west-dipping, interbedded dolostone and thinly laminated argillite. A 1.5–2 m thick, pink and grey, crossbedded sandstone layer interrupts the interbedded dolostone and argillite about 4 m up the outcrop. The sedimentary rocks are intruded by a thick Haig sill approximately 6 m up from the sandstone bed. Similar to the community quarry site, it appears as though the heat from the intrusion has contact metamorphosed the outcropping sedimentary rocks below it, and possibly farther down the stratigraphy. Common calcite- and quartz-bearing veins, concentrated mostly in the dolostone and argillite, are also similar to those seen at the community quarry. The dolostone is a light greenish grey and the argillite laminae are buff, grey, dark grey and black.

Carving stone has been harvested primarily from a discrete, 30–40 cm thick layer of contact-metamorphosed, light green dolostone that runs along the base of the outcrop. The extraction of this particular layer has resulted in an 8–10 m deep and 20 m long gap that dips down into the outcrop (Figure 4a). Rusted pry bars and other tools can still be seen at the bottom of the worked layer. Boulders of dolostone have fallen over parts of the gap and, because of this, people no longer attempt to quarry from within it. The desired layer of dolostone continues along strike and reappears at ground level farther to the north, where there is ample evidence of past and recent carving stone harvesting (Figure 4b).

The two carving stone showings near Salty Bill Hill were previously described by Beauregard and Ell (2014), and were visited only briefly this year to conduct a follow-up evaluation of the potential for new carving stone reserves. The first site visited, SBH1 (Figure 1b), comprises two relatively small outcrops (measuring roughly 2 by 2 by 3 m each; Figure 4c) of laminated dolostone adjacent to a north-trending, 4 m wide diabase dyke. The bedding appears to fold with proximity to the dyke, and the outcrop becomes less competent and more frost fractured with distance from the dyke. These two outcrops are the only surface exposures of potential carving stone in the vicinity of the dyke,



**Figure 4:** Photographs from other carving stone localities on Tukarak Island, Belcher Islands: **a)** surface opening of the quarried dolostone layer (about 30 cm wide at arrow) at the abandoned quarry site; **b)** the highly desired dolostone layer in photo (a) is well exposed north of the abandoned quarry area along the same outcrop; samples from this site were collected where cuts had already been made with a gas-powered saw; **c)** one of the two exposures of contact-metamorphosed dolostone at SBH1, showing minor folding near the contact with the gabbro dyke just to the right of the image; hammer for scale is 30 cm long; **d)** euhedral sulphide crystals set in pale green dolostone at SBH1; **e)** well-exposed interbedded dolostone and silty dolostone that is broadly folded and lies below the contact (yellow dashed line) with a thick Haig sill (the black rock in the background); spiral binding on the notebook is 22 cm long; **f)** thin beds of dolostone with a weakly developed crenulation cleavage, traced by the white dashed lines.

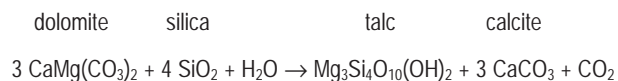
but there may be additional contact-metamorphosed stone beneath the overburden along the dyke margins.

The contact-metamorphosed dolostone is light green to pale grey and locally contains euhedral sulphide crystals (Figure 4d). Calcite and quartz veins in the dolostone are <1 cm wide and cut the bedding obliquely; in the diabase dyke, they are up to 10 cm wide and also contain sulphide minerals, together with minor malachite and azurite.

The second site visited, SBH2 (Figure 1b), consists of several pavement-style outcrops of interbedded dolostone and silty dolostone directly below the base of a large, extensively exposed Haig sill (Figure 4e) that forms the top of Salty Bill Hill. The dolostone bedding is 10–25 cm thick and broadly folded. A locally developed, weak crenulation cleavage (Figure 4f) is a reflection of this outcrop's position at the hinge of the Tukarak antiform (Jackson, 2013). Dolostone beds are light green on fresh surfaces and locally contain rare, euhedral sulphide minerals. The thin, silty dolostone interbeds are light grey to white and contain laminae with elongate mats of fine-grained talc.

## Geological interpretations

The four carving stone sites visited during this study have common geological relationships that have allowed for the genesis of soft, easily carved stone. Each site consists of dolostone beds that have been contact metamorphosed by the Haig intrusive complex. Dolostone within the contact aureoles appears to contain new metamorphic minerals that soften the rock, making it easier to carve. One of many metamorphic reactions that likely occurred in the sedimentary rocks during the intrusion and cooling of the Haig sills is



where the silica may have been sourced partly from the intrusion and partly from the original sedimentary rocks.

Also common to all sites is the relationship between the thickness of the intrusive sill and the resultant thickness of the contact aureole. As documented in the community quarry map area, the extent of the contact-metamorphic aureole also expands where the Haig sill thickens. At the other sites, the tops of the Haig sills are partly eroded, but outcrops still expose a thickness of at least 50 m in places. Also notable is that, where both a top and a bottom contact aureole can be observed (i.e., around the community quarry map area), the aureole below the sill tends to be thicker than that above the sill. It is possible that, after intrusion, the sills may have acted as insulating layers while still progressively cooling. Therefore, rocks below the intrusions may have experienced prolonged heating, allowing more time and energy for the growth of new metamorphic minerals.

Given these observations and interpretations, the petrogenesis of the soft, easily carved stone preferred by local carvers required the intrusion of a thick sill or dyke of gabbroic Haig magma through dolostone beds in the Belcher Group sedimentary strata, followed by persistent, slow cooling of the host strata to allow for the growth of metamorphic minerals. Further prospecting for new carving stone deposits should apply these geological elements and focus particularly around the basal contact surfaces of sills.

## Economic considerations

There are numerous locations where the key geological elements identified above exist in the Belcher Islands. Thus, the potential for finding new sites that contain good- to excellent-quality carving stone derived from contact-metamorphosed dolostone is considerable. In terms of access, the Belcher Islands are unique in Nunavut: the land is relatively low-lying, nearly completely accessible with an ATV or boat in the summer and fully accessible by snowmobile in the winter, and bedrock outcrop is extensive. The community quarry and abandoned quarry sites are very close to tidewater, but the Salty Bill Hill sites would require transportation of harvested carving stone for a distance of 2–4 km over uneven tundra to reach a section of the shoreline that is accessible by boat.

Aside from carving stone resources, the Belcher Islands have potential for base metals, such as copper and iron. Many of the sedimentary formations naturally contain disseminated metals, and these appear to be concentrated and recrystallized where associated with the Haig intrusive rocks, and in calcite-quartz veins such as those observed at the SBH1 site.

Finally, the Belcher Islands host a wide variety of Proterozoic sedimentary and volcanic igneous rocks, and preserve many remarkable geological features such as pillow basalts, volcanoclastic-flow deposits, stromatolite reefs and banded iron formations, to name a few. Other examples of these features from the same geological timeframe that are so minimally deformed or metamorphosed are rare throughout the rest of the world. The Belcher Islands could prove to be a significant location for future discoveries regarding Earth's geological history, and is an excellent location for geotourism and geological field schools.

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