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SILICA ASSESSMENT OF THE HAWKE BAY FORMATION, HIGHLANDS OF ST. JOHN AREA, GREAT NORTHERN PENINSULA, NEWFOUNDLAND

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ABSTRACT

The quartz arenite, of the Early Cambrian Hawke Bay Formation, Labrador Group, was sampled on the Highlands of St. John's to determine its potential as a source of silica. The Highlands are located about 10 km northeast of the community of Hawkes Bay and form plateaux that have an area of over 250 km^2. The formation, which is estimated to be between 100 and 250 m thick, has reserves of billions of tonnes of silica. The quartz arenites are thick bedded and contain minor amounts of siltstone and conglomerate. Obvious impurities in some of the lower beds include hematite cement and grains, and heavy-mineral laminae. Overall, the formation is clean and well sorted.

INTRODUCTION

The Highlands of St. John (the Highlands) are located along the western side of the Great Northern Peninsula (Figure 1), 13 km northeast of Hawkes Bay (Figure 2). The Highlands are capped by a thick sequence of quartz arenite of the Early to Middle Cambrian Hawke Bay Formation, which is the upper most formation of the Labrador Group. A rock geochemical sampling program was conducted to determine the potential of the formation as a source of silica.

LOCATION AND ACCESS

The silica-assessment project was conducted on the Highlands of St. John and on a newly accessible ridge to the southeast of (Big) East River, which runs along the southern margin of the Highlands (Figure 2). Road access to the northern part of the Highlands is limited to two branch roads from the Squid Cove forest-access road. The southeastern part of the Highlands lies within 3 km of the end of a forest-access road from Hawkes Bay. The ridge southeast of East River is also accessible by two branch roads off the Hawkes Bay access road. Traverses were also carried out using a helicopter for drop-off and pick-up. However, most of the area was grid-sampled by helicopter.

TOPOGRAPHY

The Highlands of St. John is a spectacular composite high plateau with the southern end located about 13 km north of the town of Hawkes Bay on the Great Northern Peninsula. The Highlands cover an area of about 250 km^2 and lie between the (Big) East River (locally termed and

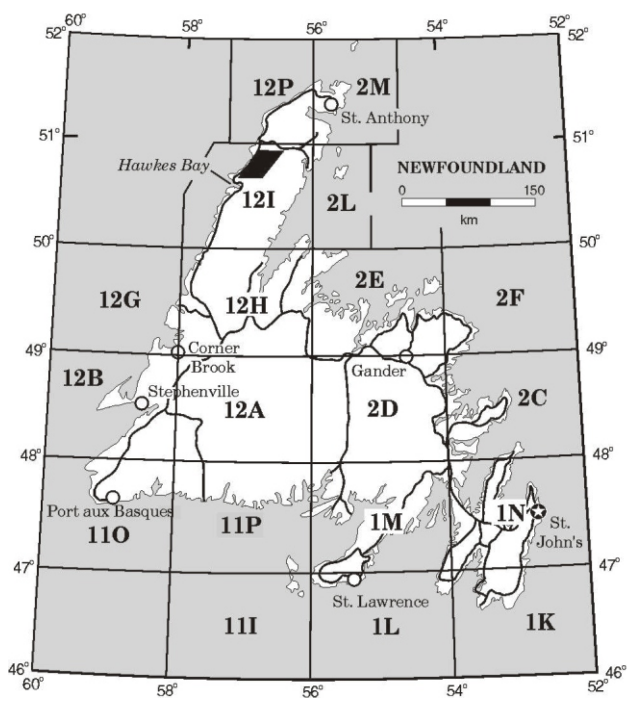

Figure 1. *Location of the Highlands of St. John.*

sign-posted as Big East River) to the south and Castors River to the north. The Cambrian rocks of the Highlands are sandwiched between the Grenvillian basement of the Long Range Mountains to the east and the low-lying Ordovician carbonate platform adjacent to the Gulf of St. Lawrence to the west (Figure 2). The Highlands consist of two high plateaux (> 450 m) to the northeast of Hawkes Bay linked by a lower plateau at the head of Doctors Brook. The "South Summit plateau" (informal name; Plate 1) reaches 500 m

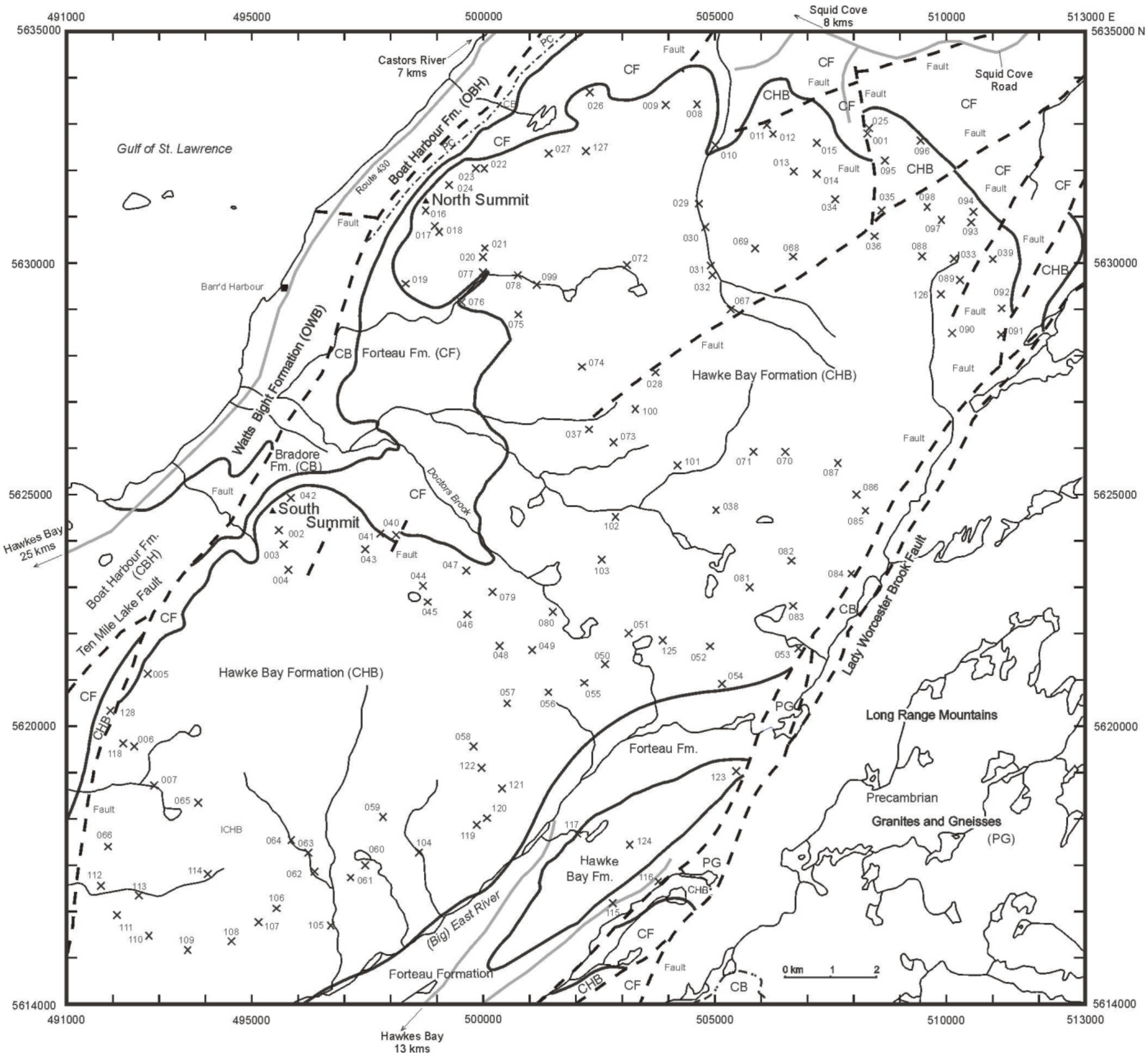

Figure 2. *Geology, and geochemical sample sites in the Highlands of St. John area.*

(1650 feet) and slopes gently eastward to about 230 m (750 feet) before dropping off more steeply along a fault system into the East River valley at an altitude of less than 120 m (400 feet). The "North Summit plateau" (informal name; Plate 2) starts at about 450 m (1500 feet) and reaches a height in excess of 625 m (2050 feet). The western edge of the two plateaux is a fault scarp (Ten Mile Lake Fault; Figure 2) that forms high cliffs that descend to about 230 m (750 feet). Both plateaux are covered by felsenmeer and only rarely is bedrock exposed (Plates 3 and 4).

DRAINAGE AND VEGETATION

Drainage of the plateaux in summer is commonly below a veneer of angular blocks that cover the stream channels; dry stream beds are common. During the summer, the more incised valleys have visible streams only at their lower levels (Plate 3). The deeply incised canyons within the North Summit plateau indicate that heavy run-off must occur in the spring as the snow pack melts. The few ponds on the plateaux are not drained by surface streams during the sum-

Plate 1. *West side of the South Summit plateau of the Highlands of St. John. The cliffs are Forteau Formation limestone, and the rounded top is the Lower Cambrian Hawke Bay Formation quartz arenite.*

Plate 2. *View of the south side of the North Summit plateau showing the gently inclined beds of Hawke Bay Formation quartz arenite, at the top of the plateau overlying the Forteau Formation on the lower slopes. The area in the foreground is till-covered quartz arenite.*

Plate 3. *Deep gully through the Hawke Bay Formation quartz arenite. The gully is 20 to 50 m deep and the stream is below the debris on the valley floor. The plateau is covered in felsenmeer and valley sides and floor are covered in talus.*

Plate 4. *South side of the South Summit plateau of the Highlands of St. John showing a terrace of felsenmeer composed of blocks of Hawke Bay Formation quartz arenite and gently dipping quartz arenite bedrock.*

mer. The Doctors Brook drainage basin is the only extensive areas of ponds, swamps and streams. Vegetation on the Highlands is sparse and comprises mainly low shrubs such as blueberry, blackberry (black crowberry), partridgeberry (mountain cranberry), (black) bearberry and red bearberry, various low grasses, and crackerberry (bunchberry). The only trees are isolated, stunted and gnarled black spruce up to 2 m tall. Vegetation is much more extensive in the valleys and the lower slopes of the Highlands. The areas around the perimeter of the Highlands support commercially viable forests and are currently being harvested.

GLACIAL AND POSTGLACIAL FEATURES

Glacial erratics of all sizes are scattered throughout the Highlands (including the highest elevations) and include massive granites (Plate 5), granite gneiss, schist and amphibolite, all probably derived from the Long Range Mountains to the east, and transported local blocks of distinctly coloured quartz arenite and sandstone from the Hawke Bay Formation. Some terraces are virtually clear of blocks probably as a result of glacial removal (Plate 6). Three sites were noted to contain glacial striae. On the northern slope of the

Plate 5. *The Hawke Bay Formation on the north side of the North Summit plateau at an altitude of 418 m. A 2-m-long glacial erratic of pink massive granite sits on white quartz arenite.*

Plate 6. *North side of the North Summit plateau showing flat-lying terrace of quartz arenite of the Hawke Bay Formation. Note that the terrace is virtually devoid of talus or loose blocks. Barry Wheaton (1.82 m) for scale.*

Highlands, a striation direction of 030° was obtained on a horizontal terrace at an altitude of 420 m; on the south side of the Highlands the striae directions were 233° at an altitude of 304 m. Small U-shaped valleys are found just east and south of the South Summit. The Doctors Brook valley and the headwaters of (Big) East River are major glacial valleys. Glacial till partially covers small parts of the lower plateau (Plate 2) and is extensive in the Doctors Brook drainage basin. The till contains abundant granite boulders. Till is absent on the high plateaus.

The plateau is covered by very extensive, thick felsenmeer composed of angular blocks of locally derived quartz arenite and by areas of thin peat and low shrubs above felsenmeer. Frost-heaving is clearly a very active process throughout the area. Along with the formation of felsenmeer, the exposed edges of beds have been frost-heaved along the vertical joints and tilted toward the valleys and depressions (Plate 7). Locally, flat-lying beds have been heaved into small-scale domes and anticlines (Plate 8). A possible large-scale example of doming is located about 10 km east of North Summit, where two circular features having diameters of over 100 m may represent collapsed frost-heaved bedrock domes.

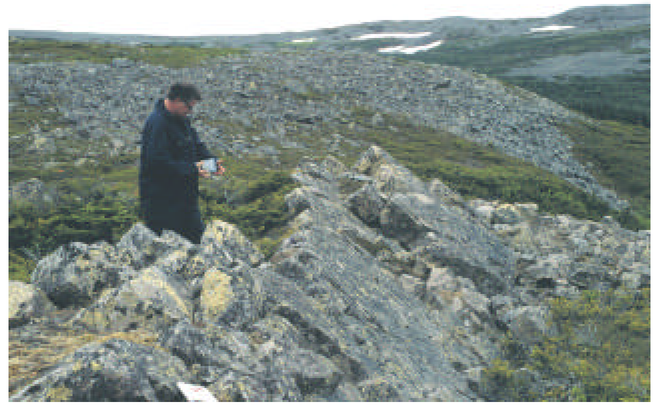

Plate 7. *Frost-tilted beds of quartz arenite of the Hawke Bay Formation. Beds are tilted to 30° from the regional dip of about 2°. This location is near the northern margin of the Highlands of St. John, 2 km south of the Squid Cove forest-access road.*

Plate 8. *Two-metre-diameter dome formed by frost heaving in flat-lying, well-jointed, quartz arenite beds of the Hawke Bay Formation. Rounded granite glacial erratics are scattered among the felsenmeer blocks. East side of North Summit plateau.*

PREVIOUS WORK

The earliest published work on the bedrock geology of the Highlands of St. John area was done by Logan (1863). Subsequently, the area was included in a memoir by

Schuchert and Dunbar (1934) who introduced the Bradore, Forteau and Hawke Bay formations of their Early Cambrian Labrador Series. The first maps were produced by Nelson (1955) and Woodard (1957) who introduced the term Labrador Group. More recent work has been carried out by Bostock *et al*. (1983) and Knight (1991). Schuchert and Dunbar (1934) and Nelson (1955) included a sequence of dolostones and shales in the upper part of the Hawke Bay Formation. Knight (1977, 1978) removed this sequence from the Hawke Bay Formation and it is not present in the Highlands of St. John area. The Highlands of St. John have not been mapped in detail and no detailed stratigraphic sequences and thicknesses have been determined for the area. Published bedrock maps by Bostock *et al.* (1983) and Knight (1991) are based on reconnaissance work. The Quaternary geology of the Highlands of St. John is included in Grant (1992) who proposes a long glacial history for the area.

The silica potential of the quartz arenites of the Hawke Bay Formation of the Labrador Group in the Hawkes Bay area has been assessed by Fong (1968) and by Butler and Greene (1976). Fong (*op. cit.*) assessed the potential of the formation along Hawkes Bay and reported average silica values of 97.2 percent for the north shore, and 98.6 percent for the south shore. Butler and Greene (1976) reported on samples collected from the lower, eastern parts of the Highlands of St. John and from West Lake, about 7 km south of the Highlands. Silica values for the samples obtained from the Highlands averaged 92 percent and for the West Lake area they averaged 93.8 percent.

REGIONAL GEOLOGY

The Highlands are underlain by the Early Cambrian Labrador Group comprising the Bradore Formation (Unit CB) at the base, conformably overlain by the Forteau Formation (Unit CF) and the Hawke Bay Formation (Unit CHB) that forms the upper unit (Knight, 1991; Bostock *et al.,* 1983; Plates 1 and 2). To the east, the Labrador Group is in structural contact with Precambrian Grenvillian rocks (Unit PG) of the Long Range Mountains along the Lady Worcester Brook Fault (Knight, 1991). Outliers of the Bradore Formation unconformably overlie Grenvillian rocks locally to the east of the fault system in the Long Range Mountains. The western margin of the Highlands is bounded by the Ten Mile Lake Fault (Knight, 1991), which juxtaposes the Labrador Group against carbonate rocks of the Early to Middle Ordovician St. George Group. The Grenvillian rocks form small but prominent hills at the base of the cliffs below the Highlands.

Knight (1991) describes the Bradore Formation as a fluviatile to shallow-marine unit consisting of red and brown sandstone, granule to small pebble conglomerate, grey to pink glauconitic sandstone and minor grey shale. This formation outcrops around the western margins of the Highlands of St. John.

The Bradore Formation is conformably overlain by the Forteau Formation, which is described by Knight (1991) as a succession of interbedded shale, limestone and lesser sandstone. The Forteau Formation forms the middle portion of the cliffs of the Highlands (Plate 1) and the limestones form the vertical faces on the cliffs. The formation, which is very gently tilted and folded, underlies the Hawke Bay Formation in the Highlands. Southeast of (Big) East River, a ridge shown to be mostly underlain by Hawke Bay Formation as shown by Knight (1991), consists mostly of fossiliferous limestone, siltstone and sandstone of the Forteau Formation that outcrop along a woods road constructed since 1991 along the eastern side of the ridge. The Hawke Bay Formation outcrops only above the edge of the forested area. The area of the Highlands underlain by the Hawke Bay Formation is estimated, from the mapping by Knight, to be 210 km^2.

The Hawke Bay Formation is best exposed around the margins of the plateaux and along some of the steep-sided river valleys. In the type area on Hawkes Bay, the Hawke Bay Formation is composed of mainly white-weathering, buff, white and light pink quartz arenites that are interbedded with minor red and grey argillaceous sandstones. Knight (1991) described the quartz arenites of Hawke Bay Formation as a blanket sandstone deposit formed in a high-energy, shallow-marine, tidal environment. Siltstone and grey glauconitic sandstone, which occur in the lower part of the formation, are interpreted to have formed in a lower energy subtidal environment. The sand was determined by Knight (*op. cit.*) to have been derived from the west.

ROCK TYPES WITHIN THE HAWKE BAY FORMATION

Over 90 percent of the exposed Hawke Bay Formation on the Highlands comprises extensive, thick to very thick beds (>1 m) of undeformed, white-weathering, pink- or buff-, fine- to medium-grained, uniform or laminated or crosslaminated, well-sorted quartz arenite (Plates 4 to 9). Larger 2- to 4-mm diameter, rounded quartz clasts are common, and locally form 1-cm-thick laminae of coarse sandstone and granule conglomerate in the quartz arenites. Trace amounts of magnetite and white feldspar are commonly conspicuous. Heavy-mineral laminae occur in some beds (Plate 9). The lower part of the succession, particularly within the North Summit plateau, is lithologically more variable and includes several interbeds of thin-bedded red siltstone and sandstone (Plate 10) within a sequence of buff quartz

Plate 9. *Thick-bedded quartz arenite of the Hawke Bay Formation containing heavy-mineral laminae. Outcrop is located along a forest-access road, 500 m southeast of (Big) East River, east of Hawkes Bay.*

Plate 10. *White, thick-bedded quartz arenite overlying red, thin-bedded siltstone and sandstone in the Hawke Bay Formation. The siltstones are commonly located at waterfalls along the south side of the North Summit plateau.*

arenites. Throughout the Highlands, within the lower 100 m of the formation, beds contain abundant, conspicuous 2 to 5 mm in diameter, scattered hematite spots and spotted hematite laminae (Plate 11). Red, thick-bedded, hematite-stained and cemented quartz arenites outcrop in the lower parts of the formation and may form a marker horizon about 30 m above the base of the formation. Minor components include feldspar-rich, very thick-bedded, siliceous arenite, and an isolated pebbly sandstone associated with buff quartz arenite. Near the base of the formation, about 2 km to the southeast of North Summit, glauconite-bearing sandstone was discovered.

Knight (1991) notes that the accessory minerals in quartz arenites of the Hawke Bay Formation include microcline and orthoclase feldspar, and scattered titanite, zircon

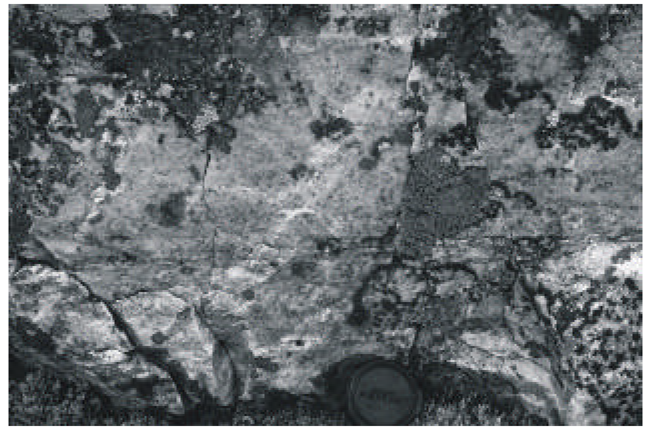

Plate 11. *Quartz arenite of the Hawke Bay Formation containing abundant spots and laminae of hematite. The hematite-bearing sandstones are more common in the lower parts of the formation. The outcrop is located along the south side of the South Summit plateau.*

and magnetite that may form dark-coloured laminae in the arenites. Overall, the Hawke Bay Formation is well sorted quartz arenite.

STRUCTURE

The Hawke Bay Formation generally dips very gently to the southeast and south at around 2 to 10°; at the northeastern margin the formation dips gently to the west at around 10°; in some areas bedding is horizontal. Accurate dip and strike determinations are commonly difficult to obtain in areas of frost-heaved bedrock, (e.g., Plate 7). The thick beds are areally extensive and units can be traced along the hillsides for several kilometres. Felsenmeer-covered terraces in the plateau areas reflect the underlying thick-bedded sandstone units. The quartz arenite is well-jointed with rhombic and rectangular vertical joint patterns and horizontal, bedding-parallel joints. The vertical jointing has produced columns of arenite 30 cm to over 100 cm in width and up to 2 m long in the very thick-bedded arenites. The well-developed jointing has clearly facilitated frost heaving and has also produced a very rugged and permeable surface layer of fractured rock.

SAMPLING AND DATA COLLECTION PROCEDURE

Sampling of bedrock was carried out on a 1 km^2 grid using the 1983 NAD 1 km UTM grid. Other samples were collected within a grid square where large differences in altitude were present. Samples averaging 3 kg and a hand specimen were obtained at each site using a sledge hammer. A total of 128 geochemical samples were collected from 114 grid squares. Some squares that have exposed bedrock were not sampled because of the hazardous location of the outcrop. Sample locations were determined using a Garman GPS 12 with software version 4.57. Felsenmeer and loose blocks were not sampled unless the source of the rock was readily apparent. Rock descriptions, structural and location data were collected at each site. The information collected was entered into a database using Fieldlog v2.83. Sample location maps were produced using AutoCad®. Detailed mapping of the Hawke Bay Formation was not part of this project.

GEOCHEMISTRY

The samples will be analyzed for major elements, loss-on-ignition and 22 trace elements. The initial data indicate that the Hawke Bay quartz arenite samples contain generally less than 0.5 percent iron (measured as Fe) but may contain up to 1 percent iron. The titanium values (measured as Ti) range to about 5000 grams per tonne (g/t) but are commonly less than 1000 g/t. There is an apparent strong correlation between Fe and Ti, which may reflect the presence of the heavy-minerals magnetite, ilmenite and titanite.

THICKNESS AND TONNAGE OF THE HAWKE BAY FORMATION

From a measured section in the Hawkes Bay area, Knight (1991) showed that the formation is 151 m thick. Vertical traverses through the thickest parts of the formation, e.g., in the eastern part of the North Summit plateau and the southern portion of the South Summit plateau, suggest that the formation is at least 200 m thick and averages well over 100 m throughout most of the Highlands. With a minimum surface area of 210 km^2, the amount of quartz arenite available in the Highlands is in the tens of billions of tonnes. The quality of the material and potential uses will be determined by the geochemical analyses.

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