Context:
Gabriola ice-age geology

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This is Version 4.2, the final version with 2017 addendum.

Gabriola's sand deposits

Nick Doe

Quadra Sand is the name given to an extraordinary band of well-sorted sand with minor silt and gravel that is common throughout the Georgia Depression and Puget Sound.[1] It pre-dates the peak of the Fraser Glaciation and is underlain by sediments deposited in a non-glacial environment. The consensus is that it dates from a time when glaciers were commencing their advance down and into what is now the Strait of Georgia, and numerous rivers and creeks were pouring glacial sediment into the Georgia Depression, probably seasonally, and creating vast sandy, ice-free lowlands and tidal flats (sandurs).

Map showing the distribution of Quadra Sand (black areas). The inset map shows the maximum extent of the Cordilleran ice sheet during the Fraser Glaciation. [Gabriola is the island below the "g" in Georgia.]

from Clague et al., *Early growth of the last Cordilleran ice sheet deduced from glacio-isostatic depression in southwest British Columbia, Canada*, Quaternary Research 63, pp. 53– 59, 2005.

The combination of Quadra Sand and underlying non-glacial sediment laid down over tens of thousands of years was sufficient to completely fill the Georgia Depression.

It is clear from the map (*right*) that Quadra Sand is, or must have been, present on Gabriola, but it has not been recorded here. However, there is a good chance that much of the island's sand came from Quadra Sand. Some of this sand, Quadra sand[2] was

[1] Clague, J.J., *Quadra Sand: A study of the late Pleistocene geology and geomorphic history of coastal southwest British Columbia*, Geological Survey of Canada, Paper 77-17, 1977.

[2] I use the lower case for "sand" when referring to Quadra Sand that has been re-worked to the point where it is no longer identifiable as such through stratigraphy alone.

probably transported by meltwater at the end of the ice age; however, none of the sites had a deposit underlying the suspected Quadra Sand that would have confirmed this.

Locating Quadra sand on Gabriola would be interesting because of the possibility of finding ice-age fossils in it, but distinguishing late-Pleistocene Quadra sand from the sand that is the product of the weathering of late-Cretaceous Nanaimo Group sandstone will be a challenge, given that their unweathered source materials in the Coast Mountains are likely similar.

Sample notes

The following preliminary notes were made with a reflective light microscope, mostly without sieving samples, and then only with dry sieving. For some samples, clay coating made particle identification difficult. The definitions used are:

very angular: edges and faces unworn, sharp, delicate protuberances
angular: edges and faces unworn
sub-angular: faces unworn, edges worn
sub-rounded: edges and faces worn but clearly distinguishable
rounded: edges and faces worn and barely distinguishable
well-rounded: no edges or faces distinguishable.

No quantitative modal analysis was attempted. In the following, the terms "abundant/minor/rare" applied to quartz and feldspar indicates very approximately 80%/20%/5% and to other minerals very approximately 10%/2%/trace.

"Mafic" usually means amphibole (hornblende) and biotite, very rarely pyroxene (big question mark, augite? or enstatite?), and sometimes mistakenly opaques, usually magnetite rather than pyrite.

"Muscovite" is used only when the mica is unmistakably clear flakes, so it might sometimes be called biotite.

"White feldspar" is, from previous experience with local rocks, plagioclase in the albite-oligoclase-andesine range.

"Lithics" or rock fragments were not analysed. Mostly appeared to be weathering-resistant volcanics, but intrusives could easily go unrecognized in tiny fragments.

Reference samples

Pseudo-sample (0) is from Clague 1977, Table 4, Plutonic provenance. Its characteristics have been averaged from many samples.

Vancouver Island and Puget Sound samples

Three samples (20, 26, 13, 16) from identified deposits on Vancouver Island for reference. A fourth sample (27) is from Puget Sound.

Gabriola Holcene sand samples

Three samples (4, 21, 10) from deposits on Gabriola Island that are, or are very likely to be, post-ice-age and not Quadra Sand.

Gabriola Marine till samples

Two samples (15, 18) from deposits known to be marine, not merely suspected to be marine as is fairly common in the literature.

Gabriola sand samples

Fifteen samples (7, 1, 8/3, 9/12, 19, 24, 11, 17, 2, 14, 5, 25, 6, 23, 22) listed in the order of their elevation above sea level (high to low). Of these 8/3 and 9/12 are the same sample, one being sieved and the other unsieved.

Dashwood drift (Sample 20)

Chef Creek, Vancouver Island, 49°26.857'N, 123°45.190'W, 28m AMSL. Pebbly sand (till). Overlain with Quadra Sand. sample # is 6mm high

Sand, well sorted. Sub-angular quartz with rare feldspar. Abundant lithics. No mafics. Small clay-sized particles. Rare magnetite.

Quadra Sand (Sample 26)

Quadra Island, 50°3.333'N, 125°11.267'W, 59m AMSL. White sand with 2m, brown, clayey silt overlay. sample # is 6mm high

Coarse sand, well sorted. Angular to sub-angular white feldspar and clear quartz. Some lithics, mostly grey. Minor hornblende. No clay-sized particles, very clean. Rare magnetite.

Quadra Sand (Sample 13)

Chef Creek, Vancouver Island, 49°26.857'N, 123°45.190'W, 28m AMSL. Overlain with Vashon till. Sample 13 is from the middle of the 3-m thick deposit;

sample # are 6mm high

Ref: Fyles, J.G., *Surficial geology of Horne Lake and Parksville Map-areas, Vancouver Island, British Columbia*, p. 27, GSC Memoir 318, 1962.

Fine to coarse sand. Mainly clear quartz with only minor white feldspar. Minor hornblende and muscovite. Minor to rare angular lithics, but more common than in most samples. Rare colourful small particles (red and green), volcanics, rutile, chlorite, epidote, hematite? Some iron-stained clay-sized particles.

Quadra Sand (Sample 16)

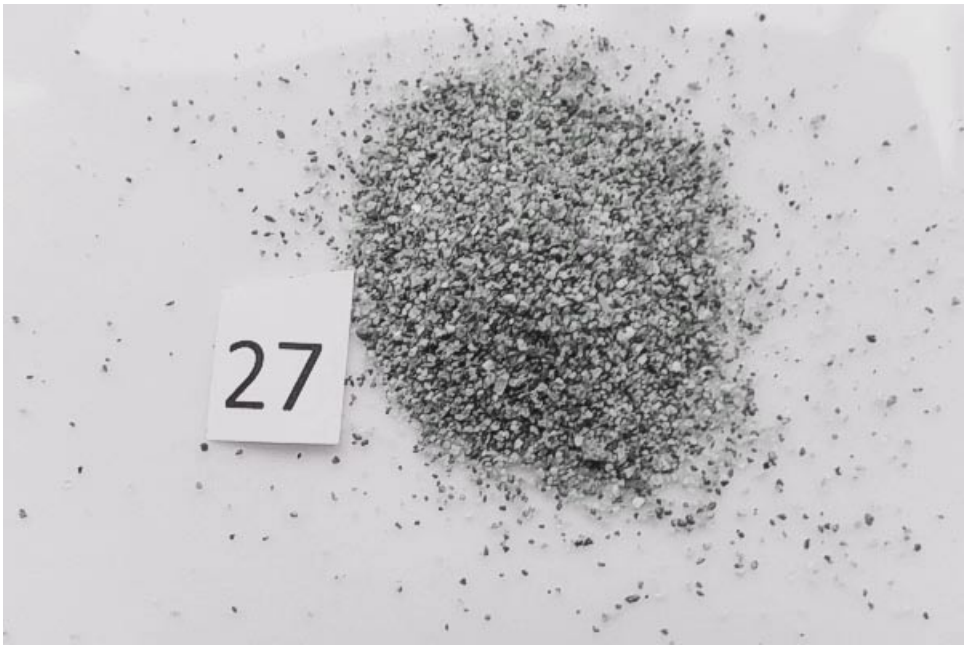
Chef Creek, Vancouver Island, 49°26.857'N, 123°45.190'W, 28m AMSL. Overlain with Vashon till. Sample 16 is from near the bottom of the 3-m thick deposit.

sample # are 6mm high

Ref: Fyles, J.G., *Surficial geology of Horne Lake and Parksville Map-areas, Vancouver Island, British Columbia*, p. 27, GSC Memoir 318, 1962.

Fine sand. Mainly clear quartz with only minor white feldspar. Minor mafics (biotite and hornblende). Minor lithics. Occasional light-green coloured particles, epidote/chlorite? Relatively free of iron-stained clay-sized particles.

Quadra Sand (Sample 27)



Between Tulalip (Port Susan) and Priest Point, Puget Sound, 48°2.594'N, 122°15.777'W, 10m AMSL. A very thick (30 m), finely bedded, glaciofluvial (glaciolacustrine?) deposit of sorted sand, becoming sharply gritty only at the very bottom, overlain at the surface with a thin, patchy layer of Vashon till. Underlain by a layer of similar glaciofluvial sand but deposited in a strong turbulent flow, in turn, underlain by a thin dark grey, clay-rich layer. No fossils, but search was perfunctory. Sample 27 is from near the bottom of the upper sand deposit just above the gravel.

sample # are 6mm high

Identified as pre-Vashon by: Bretz, J.Harlen, *Glaciation of the Puget Sound Region*, p. 167, Washington Geological Survey, Bulletin 8, 1913.

Coarse sand. Clear quartz (unusually large breakage surfaces resembling cleavage) with abundant sub-rounded white feldspar. No hornblende or recognizable biotite, but some mica or a clay mineral. Minor to plentiful lithics, a few colourful (green most common, but some red), most grey/black (pyroxene?). Mostly free of iron-stained clay-sized particles. Probably specks of rutile.

Quadra Sand (Sample 0)

Clague 1977 Type A

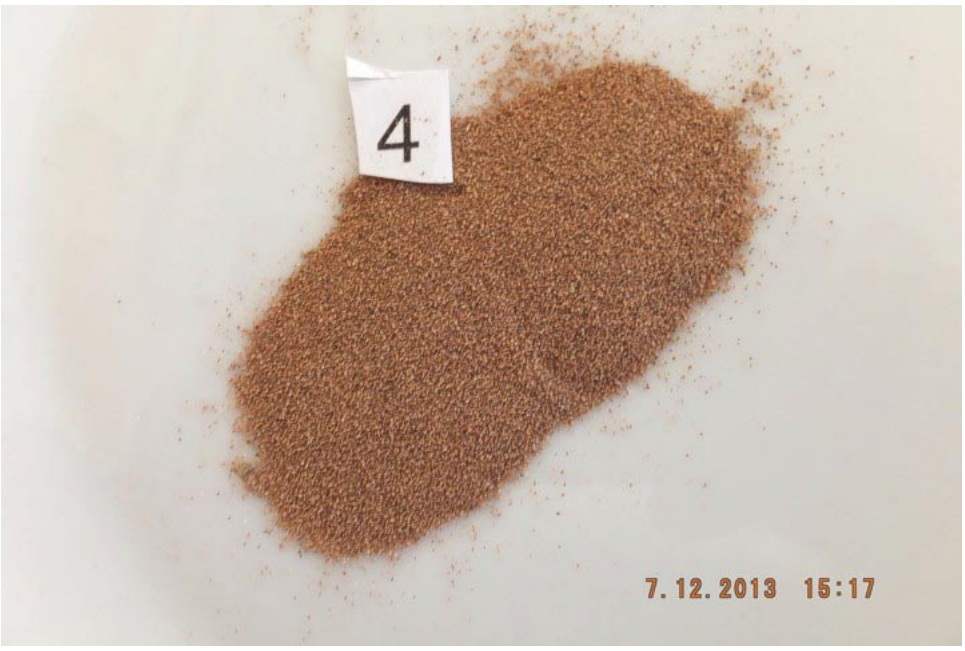
feldspar	>42.5%
quartz	17–47.5%
lithic	0.9–9.5%
amphibole (hornblende)	2.5–7.5%
pyroxene	0.1–1.5%
epidote	0.1–1.5%
mica (biotite, chlorite, muscovite)	0.1–1.5%
opaque (magnetite, hematite)	0.1–1.5%

Mineral concentrations approximate quartz diorite.

Angular to sub-angular grains.

Well-sorted sand. White feldspar with lesser clear quartz with angular to sub-angular grains. Minor hornblende and trace biotite. Minor lithics. Trace pyroxene, (epidote, chlorite?) and magnetite. Free of iron-stained clay-sized particles.

Holocene sand (Sample 4)



Fawn Place, Gabriola Island, 49°9.5'N, 123°47.92'W, 126m AMSL. Gabriola Fm. Small stone-free deposit at surface (modern? erratics but no till). sample # is 6mm high

Fine sand/silt. Angular to sub-rounded quartz with lesser amounts of white feldspar. Minor biotite and (mostly) hornblende. Minor sub-angular and sub-rounded lithics. Abundant very small iron-stained clay-sized particles. No clumping.

Holocene sand (Sample 21)

Bluff overlooking Lock Bay, Gabriola Island, 49°10.835'N, 123°50.21'W, 97m AMSL.
Gabriola Fm. surface rainwater rill, (modern, no till). sample # is 6mm high

Fine sand. Roughly equal amounts of angular quartz and white feldspar. Unweathered flakes of biotite common. Rare hornblende. Almost no lithics. Relatively free of iron-stained clay-sized particles. Rutile.

Holocene sand (Sample 10)

Bluff overlooking Lock Bay, Gabriola Island, 49°10.89'N, 123°50.2'W, 85m AMSL.
Gabriola Fm. from boulder surface, (undoubtedly modern). sample # is 6mm high

Fine sand/silt. Angular quartz with sub-angular white feldspar. Biotite flakes with much lesser hornblende. Rare lithics. Many clay-sized particles. Iron staining localized.

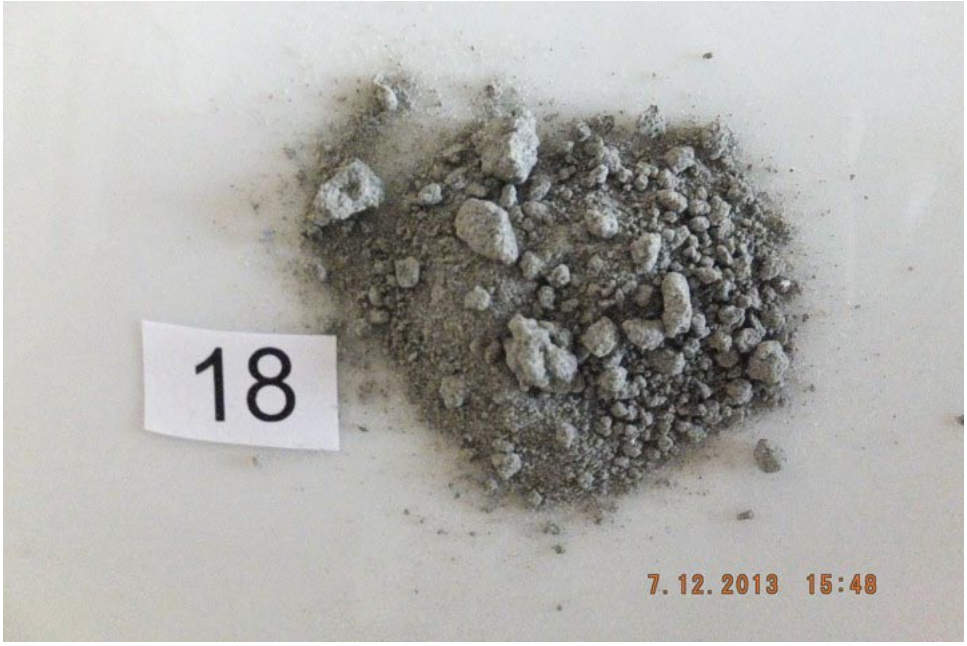
Gabriola Island marine till (Sample 15)

Tait Road Pond, Gabriola Island, 49°9.12'N, 123°49.8'W, 109m AMSL. Marine w. shells. Small stone-free deposit. Not concreted when collected. (File: GD-533 Site 4). In contact with Sample 19.

sample # is 6mm high

Silt. Mainly clear angular quartz, a few grains brightly coloured (iron). No lithics. Tiny specks of black minerals, probably hornblende (not magnetite). No general iron staining.

Gabriola Island marine till (Sample 18)



Somerset Pit, Gabriola Island, 49°8.575'N, 123°44.56'W, 46m AMSL. Upper pit. Marine w. shells. Working pit. Clumps are clayballs. (File: GD-533 Site 12, GD-527 Site E). In contact with Sample 14.

sample # is 6mm high

Silt. Mainly quartz with rare feldspar. No lithics. Tiny fragments of black minerals (not magnetite). No iron staining.

Gabriola Island sand (Sample 7)

Pit (nr. Gun Club), Gabriola Island, 49°8.99'N, 123°46.67'W, 120m AMSL. No marine layer. Abandoned pit. Clumps are clayballs. (File: GD-527 Site H). sample # is 6mm high

Fine sand/silt. Mainly clear quartz with only very minor white feldspar. Iron-stained clay-sized particles abundant, sometimes in small clusters with heavy orange staining. Rare muscovite. No biotite or hornblende. No lithics. Occasional red particles, rutile? and rare light-green coloured particles, epidote/chlorite?

Gabriola Island sand (Sample 1)

Stoneyridge Pit, Gabriola Island, 49°8.59'N, 123°47.395'W, 112m AMSL. No marine layer, below till. Clumps are clayballs. Working pit. Stockpile 1—grey coloured. (File: GD-533 Site 3, GD-527 Site I).

sample # is 6mm high

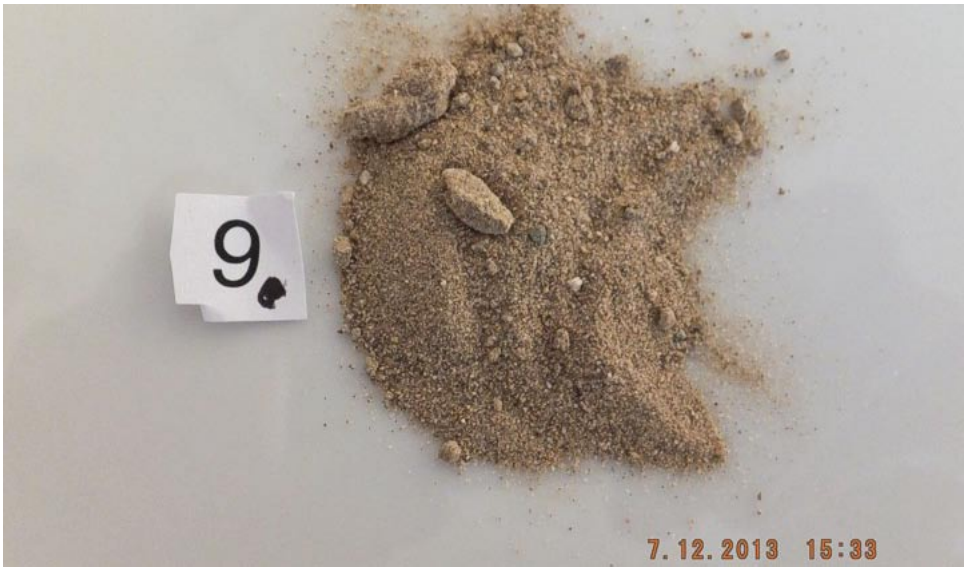
Fine sand. Mainly clear sub-angular quartz with white feldspar. No lithics. Possibly tiny fragments of mafics. Minor unstained clay-sized particles. Minor magnetite.

Gabriola Island sand (Sample 8/3)

Stoneyridge Pit, Gabriola Island, 49°8.59'N, 123°47.395'W, 112m AMSL. No marine layer, below till. Sample 3 is after #230 sieving. Clumps are clayballs. Working pit. Stockpile 2—sandy coloured. (File: GD-533 Site 3, GD-527 Site I). sample # is 6mm high

Fine sand/silt. Mainly clear angular quartz with some sub-rounded white feldspar. Minor mafics (hornblende, biotite), small particles but apparently unweathered. Moderate iron-stained clay-sized particles. Occasional light-green coloured particles, chlorite/epidote? Rare lithics.

Gabriola Island sand (Sample 9/12)



Stoneyridge Pit, Gabriola Island, 49°8.59'N, 123°47.395'W, 112m AMSL. No marine layer, below till. Sample 12 is after #230 sieving. Clumps are clayballs. Working pit. Pit face. (File: GD-533 Site 3, GD-527 Site I). sample # is 6mm high

Fine sand/silt. Angular quartz with relatively unweathered sub-angular white feldspar. Rare biotite, minor hornblende. Minor lithics of several types. Abundant very small iron-stained clay-sized particles. Rare magnetite.

Gabriola Island sand (Sample 19)

Tait Road Pond, Gabriola Island, 49°9.12'N, 123°49.8'W, 109m AMSL. Above marine layer (15). Small stone-free deposit with thin till overlay. (File: GD-533 Site 4). In contact with Sample 15.

sample # is 6mm high

Fine sand/silt. Angular quartz with some white feldspar. Rare biotite and hornblende. Rare lithics. Abundant iron-stained clay-sized particles, some staining very intense locally.

Gabriola Island sand (Sample 24)

MoTI Pit, Gabriola Island, 49°8.27'N, 123°44.98'W, 100m AMSL. Above marine layer. Clumps are clayballs. Worked pit for gravelly sand but now exhausted. (File: GD-533 Site 7, GD-527 Site F).

sample # is 6mm high

Fine sand. Mainly clear sub-angular quartz with traces of sub-rounded white feldspar. Minor lithics (usually volcanics but one substantial intrusive). Possibly tiny fragments of mafics (amphibole, pyroxene?). Occasional red (hematite?) and light-green coloured particles (epidote/chlorite?). Not many clay-sized particles.

Gabriola Island sand (Sample 11)

Somerset Pit, Gabriola Island, 49°8.51'N, 123°44.567'W, 75m AMSL. Up the gulley from upper pit; no marine layer at this location. Clumps are clayballs. Working pit. (File: GD-533 Site 12, GD-527 Site E). sample # is 6mm high

Silt with clay cement. Quartz with only minor deeply-weathered feldspar. Iron-stained clay-sized particles abundant. No biotite or hornblende. Minor to rare lithics. Some magnetite.

Gabriola Island sand (Sample 17)

North Road, Gabriola Island, 49°9.335'N, 123°44.67'W, 54m AMSL. Beddis soil, no marine layer. Unworked stone-free deposit. (File: GD-527 Site C) .sample # is 6mm high

Ref: *Soils of the Gulf Islands of British Columbia—Volume 1, Soils of Saltspring Island, Appendix: Profile descriptions and analytical data of the soils*, p 118, Report 43, British Columbia Soil Survey, 1987.

Very-fine sorted sand. Clear angular quartz with some sub-rounded white feldspar. Minor hornblende and rare biotite. Minor, mostly volcanic, sub-rounded lithics. Iron stained clay-sized particles are small. Minor magnetite.

Gabriola Island sand (Sample 2)

Ferne Road, Gabriola Island, 49°8.38'N, 123°46.69'W, 48m AMSL. No marine layer. Clumps are clayballs. Unworked deposit. (File: GD-527 Site G). sample # is 6mm high

Fine moderately-sorted sand. Mainly clear angular quartz with some more rounded white feldspar. Only trace biotite (if that) and rare hornblende. Rare lithic. Moderate amounts of small iron stained clay-sized particles.

Gabriola Island sand (Sample 14)

Somerset Pit, Gabriola Island, 49°8.575'N, 123°44.56'W, 47m AMSL. Upper pit. Above marine layer (18). Clumps are clayballs. Working pit. (File: GD-533 Site 12, GD-527 Site E). In contact with Sample 18. sample # is 6mm high

Fine sand/silt. Sub-angular quartz and white feldspar. Fairly rare, rounded lithics of different varieties. Rare biotite with slightly more hornblende. Minor magnetite. Many small iron-stained particles, clumping common.

Gabriola Island sand (Sample 5)

Somerset Pit, Gabriola Island, 49°8.585'N, 123°44.54'W, 44m AMSL. Upper pit. Interleaved with marine layer (18). Fossil wood (dated). Clumps are clayballs. Working pit. (File: GD-533 Site 12, GD-527 Site E). sample # is 6mm high

Fine to medium sand. Mix of quartz and quite angular white feldspar. No biotite or hornblende. Coarse lithics common. Minor amounts of very small iron stained clay-sized particles. Organic fragments that radiocarbon dating shows to be post-Vashon.

Gabriola Island sand (Sample 25)

Wharf Road, Gabriola Island, 49°8.5'N, 123°47.67'W, 32m AMSL. Upper site. Clumps are gravel. Small unworked deposit, thin till cover. (File: GD-533 Site 14, GD-527 Site J).

sample # is 6mm high

Fine sand/silt. Sub-rounded quartz and lesser feldspar. Rounded lithics more common than usual. Black specks, might be hornblende. Only minor very small iron-stained particles. Trace of magnetite.

Gabriola Island sand (Sample 6)

Degnen Bay, Gabriola Island, 49°8.325'N, 123°42.58'W, 17m AMSL. No marine layer. Clumps are hard clayballs. Very minor deposit. (File: GD-527 Site D).

sample # is 6mm high

Fine sand/silt. Angular quartz with only minor feldspar. Iron-stained small clay-sized particles abundant. No biotite or hornblende. Minor or no lithics.

Gabriola Island sand (Sample 23)

Wharf Road, Gabriola Island, 49°8.48'N, 123°47.77'W, 16m AMSL. Lower site. Clumps are clayballs. Small deposit, worked for fill. (File: GD-533 Site 14, GD-527 Site J).

sample # is 6mm high

Silt. Rounded abundant quartz and lesser feldspar. Black specks, might be hornblende or biotite. Rare muscovite flakes. Abundant very small iron-stained particles.

Gabriola Island sand (Sample 22)

Twin Beaches (Taylor Bay), Gabriola Island, 49°11.6'N, 123°51.6'W, 4m AMSL. Exhausted deposit (Gabriola Sands). (File: GD-527 Site A). sample # is 6mm high

Fine sand. Nearly all clear angular quartz, any white feldspar more angular than usual. Rare mafics, likely mostly biotite, traces of hornblende. Minor to rare lithics. No iron-stained clay-sized particles.

Quadra sand?

The top five Gabriola sand samples most likely to be Quadra Sand based on a numerical (but nevertheless subjective) cross-correlation of the reflected-light microscope characteristics are listed as follows. A score of 1.00 would indicate the samples are identical in all respects.[3]

1.	Sample 24	Score 0.81	MoTI Pit
2.	Sample 25	Score 0.79	Wharf Road (upper)
3.	Sample 22	Score 0.76	Twin Beaches
4.	Sample 17	Score 0.75	North Road, Beddis soil
5.	Sample 1	Score 0.71	Stoneyridge Pit: Stockpile 1 (grey coloured)

The top three Gabriola sand samples most likely to be Holocene sand from Nanaimo Group sandstone weathering based on a quantitive cross-correlation of the reflected-light microscope characteristics were:

1.	Sample 8/3	Score 0.85	Stoneyridge Pit: Stockpile 2 (sandy coloured)
2.	Sample 9/12	Score 0.74	Stoneyridge Pit: Pit face
3.	Sample 19	Score 0.73	Tait Road Pond (upper unit)

Quadra Sand samples scored 0.82, 0.85, 0.78 compared to the mean for Quadra Sand; and 0.50, 0.56, 0.65 compared to the mean for Holocene samples.

The Holocene samples scored 0.79, 0.84, 0.82 compared to the mean for Holocene samples; and 0.61, 0.56, 0.50 compared to the mean for Quadra Sand samples.

Discussion

As anticipated, the difficulty of distinguishing Quadra Sand from more recent weathering debris by modal analysis is that both Gabriola Fm. sandstone and Quadra Sand were sourced from the Coast Mountains. All samples contain quartz, feldspar, hornblende, and often biotite, and their weathering products.

One odd characteristic is that John Clague in his famous 1977 paper characterizes the mineralogy of Plutonic provenance (Type A) Quadra Sand as containing more feldspar (a) than quartz (b); yet, it is relatively easy to find sand samples locally that are almost entirely quartz, implying even deeper weathering than Quadra Sand. I think this is because the Nanaimo-area sand (at least) has been weathered in relatively low pH conditions, and this has accelerated the weathering of the feldspar. A clue that this is the case is that in some

[3] The Puget Sound sample (27) was not included, but the Clague "pseudo-sample" (0) was, and was given a weight of one sample and scored 0.78 for Quadra Sand and 0.43 for Holocene sand.

samples, what feldspar there is, is in the form of small well-rounded spheres, a sure indication that acidic weathering is responsible.

Hornblende and biotite appear in roughly equal proportions in the Coast Mountain plutonic rocks,[4] but hornblende appears more often than biotite in the sand samples. A preponderance of hornblende (amphibole) appears to be a fairly good indicator that the sand is relatively old, so long as it is remembered that Vancouver Island intrusives commonly lack biotite. John Clague's paper lists amphiboles in Quadra Sand being 2.5–7.5% of the total, but micas (biotite and muscovite) being 0.05–1.5% of the total. This disparity is not evident in the averages for all of the Gabriola sand samples; however, there is a further complication here in that the weathering rate of amphiboles is sensitive to pH and increases under acidic conditions.

Conclusion

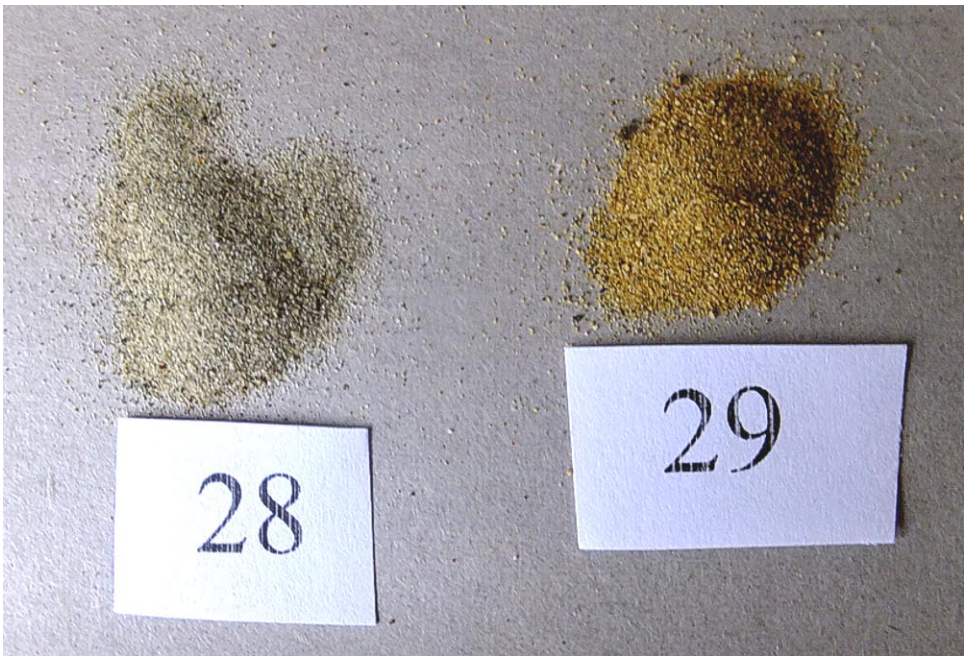
It is highly likely that some of the sand deposits on Gabriola are Quadra Sand. Most likely spots are the MoTI Pit on South Road and Twin Beaches, but I would definitely not rule out Stoneyridge Pit despite the fact that the deposit there is complex and might contain both Quadra Sand and Gabriola Fm. glacial debris. Both the MoTI Pit and the Stoneyridge Pit have an overlay of Vashon ablation till. The sands in the favoured places are certainly more Quadra-Sand-like than the products of modern (Holocene) sandstone weathering. ◊

Articles:

[4] http://www.nickdoe.ca/pdfs/Webp54c.pdf

Addendum November 2017

Gabriola Island sand (Sample 28/29)



Elgie Farm Pond, Gabriola Island, 49°9.34'N, 123°46.80'W, 93m AMSL. Dugout. Massive stone-free sand above marine layer. Sample 28 about 1.5 metres from surface, grey. Sample 29 is from one of the orange-brown mottled areas nearer the surface. (File: GD-533 Site 15).

sample # is 5mm high

28: Fine to very fine sand. Nearly all clear quartz with only very minor rounded white feldspar. Traces of hornblende, very little biotite if any, hornblende clasts bigger than specks, showing good cleavage and being relatively unweathered. No lithics. Assessory light-green coloured particles and iron-staining almost absent. No red particles. No magnetite.

29: Similar in texture. Colour is from silt/clay-sized particles coating the quartz. Mafics weathered, unidentifiable. A few lithics. No magnetite.

Comment

The site is geographically close to Site 4 and sites where samples 7, 15, and 19 were taken. The freshness of the hornblende is striking, but it and the absence of traces of exotics make it difficult to draw conclusions as to the sand's origin. The whole Baynes soil deposit in this area is most likely glaciofluvial (meltwater sediment).