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Gabriola's glacial drift—counting stones on the beaches

Nick Doe

> For there are some who weary themselves out in learning and proving things that, after they are known and proved, are not worth a farthing to the understanding or memory. Don Quixote

Most of the stones on Gabriola's beaches are volcanic, intrusive, and metamorphic rocks brought here by glaciers. Stones that you may find that are sedimentary rocks include channery fragments of sandstone; friable, greenish-grey or dark-grey fragments of shale; rounded quartzite cobbles from conglomerate; and rusty calcareous nodules from shale. These are from Gabriola's Nanaimo Gp. bedrock. Shale quickly weathers to coarse angular grains of dark-grey sand, and sandstone boulders on the beach often haven't travelled very far and their origin is obvious,[1] so for the purpose of glacial studies, they can be discounted.

Left: basalt from the Englishman River on Vancouver Island (Triassic, Karmutsen Fm.).

Right: andesite from Howe Sound on the mainland (early-Cretaceous, Gambier Gp.).

Basalt

Many of the pebbles and cobbles on the beach are smooth and uniformly dark, slightly-bluish grey, and black when wet. Most of these are basalt. Basalt is a very common rock. How common is concealed on the beach because basalt pebbles often have a thin weathering-rind containing iron oxides, *plagioclase*, or, more rarely, *calcite*. These rinds can be jet-black, red, brown, orange, purple, or even white.[2]

Basalt also sometimes has large whitish crystals[3] embedded in its fine-grained matrix creating "flowerstones", or it has former gas vacuoles that are now filled with a whitish mineral of some kind (amygdules). Basalt is also sometimes greenish-grey or olive-green due to the presence of *olivine*, or in metamorphic and metasomatic forms, *chlorite*. Basalt is

[1] There are however occasional sedimentary "erratics" that are Nanaimo Group rocks, but may not be from the island. Geoffrey Fm. conglomerate on Gabriola contains very rounded *quartzite* cobbles with a very recognizable mottled rosy weathering rind (patchy Munsell 10R 4/6 to 10R 7/2). Some conglomerate erratics do not match this description.

[2] N.A. Doe, *So what colour is basalt?—stones on Gabriola Island's beaches*, *SILT* 3, 2012, <www.nickdoe.ca/pdfs/Webp510.pdf>. Accessed 2012 Mar 12.

[3] I assume these phenocrysts are feldspar. None of the few I have tested reacted to acid.

what makes up most of the floors of the world's oceans. Mount Benson and neighbouring mountains on Vancouver Island are mostly basaltic rock (Karmutsen Fm.).[4]

Basalt "flowerstone" with white phenocrysts

Basalt with white amygdules

Andesite

Another rock that may closely resemble basalt is andesite. This is not a common rock on those parts of Vancouver Island that could have contributed to our till, but it is plentiful along the shores of Howe Sound (Gambier Gp.). It is most often a lighter grey than basalt, and its weathering rind is less colourful and duller, often just a lighter shade of grey. Sometimes the rind is much thicker than the usual weathering-rind; if this is whitish, it is usually a result of metasomatic (hydrothermal) changes of plagioclase feldspars to *albite*.

Andesite, like basalt, is a hard rock, and pebbles of it are not easily cracked open. Andesite from the Coast Mountains is more often porphorific than basalt from Vancouver Island and commonly has white, very-well-weathered phenocrysts that basalt usually lacks. It is however sometimes impossible to distinguish basalt and andesite without laboratory tests.

Intrusive rocks

Other common pebbles and cobbles on the beaches are shiny white and crystalline with black speckles that are usually dull, but that may sometimes sparkle in the sun (*hornblende* and *biotite*)—"salt-and-pepper" rock. These are granitic (intrusive, plutonic, felsic) rocks, rocks that come from magma that never reached the surface as lava. Granodiorite is the most common of these. Granodiorite differs from granite in that it is sodium rich (with *plagioclase*, especially *albite* or *andesine*) and lacks potassium (*orthoclase, K-feldspar*), which makes it white rather than white intermixed with pink.

[4] The Karmutsen Formation (Vancouver Group) is the most likely source of basalt on Vancouver Island, though there is some in the Duck Lake Formation (Sicker Group). The Karmutsen basalt is black, weathering orange-brown, commonly aphyritic [without phenocrysts], variolites rare, volcanic breccia with *chlorite* or *quartz* infillings common, chert rare, felsic material absent. Massey (fn.5).

A certain source of "granodioritic" rock (granodiorite, tonalite, quartz-diorite, leuco-diorite, anorthosite, latite, aplite) is the Coast Mountains on the mainland, but intrusive rocks on Vancouver Island are also plentiful, and they are also very granodioritic.[5] I have never found any granite (with K-feldpar) pebbles or boulders on the east coast lowlands of Vancouver Island, but one or two such stones regularly appear in handful-sized gravel samples from the mainland. To add to the challenges, dacite, which is an extremely fine-grained granodiorite, is also sometimes found on the beaches, and this is not the easiest rock in the world for the casual observer to distinguish from andesite.

Volcanics and metamorphic rocks

Other rocks, and there are lots of different types, are (explosive) extrusive volcanics (andesitic or rhyollitic rather than basaltic), or metamorphics and metasomatics which tend to be light in colour and sometimes colourful, particularly green due to the presence of *chlorite*, *epidote*, or light-green *amphibole* (*actinolite*). Felsic volcanic rocks, mixed-type metamorphic rocks (migmatite), and hydrothermally-altered metasomatic rocks are eye-catching, and, in my experience, it is easy to over-estimate their abundance in gravels.

Left: a typical granodiorite—sodium/calcium feldspar matrix with some *quartz* and speckles of dark (mafic) minerals, usually *hornblende* and *biotite*. Very common in this part of the world. The fraction of dark minerals can vary from none to almost 100%, but 10–20% is usual.

Right: a more granite-like granodiorite with some pinkish-orange potassium feldspar (not rust stains). True granite (more than 35% *K-feldspar*) is rare in this part of the world though there is some at Montizambert Creek in Howe Sound. Granodiorite and granite cobbles with pink potassic feldspar are not numerous on Gabriola beaches, but you can usually find one or two if you look.

[5] N.W.D. Massey, *Geology and mineral resources of the Alberni-Nanaimo Lakes sheet, Vancouver Island, 92F/W, 92F/2E and part of 92F/7E*, Ministry of Energy, Mines, and Petroleum Resources, BC, Paper 1992-2. Vancouver Island Intrusives are older (Jurassic) than those from the mainland (Cretaceous). They tend to be rich in *hornblende* and contain less *biotite* than most mainland intrusives, but the difference is too variable to be a reliable indicator of origin.

Selected (not representative) pebbles and cobbles from on the *left*, False Narrows, and on the *right*, Whalebone Beach. Light-coloured intrusive and felsic volcanic rocks appear more common on the north side of the island facing the Strait of Georgia, but appearances are deceptive. The beach stones in the narrow channel between Gabriola and Mudge Islands (*left*) have a biofilm that dulls their brightness.

North-side and south-side Gabriola

One of the interesting things about Gabriola's beaches is that the pebbles, cobbles, and boulders on Whalebone Beach, on the north side of the island, look more "interesting" and aesthetically pleasing than those on False Narrows, on the south side of the island. There appears to be more variety and colour on Whalebone Beach. When I see them, the stones remind me of the gravel bars in the Fraser River, not in detail, but in overall visual appeal.

A geological difference between the north side and the south side of the island might imply that more than one glacier was involved, or it might simply be due to the tendency of rocky debris being transported by a glacier to remain on whichever side of a valley was its source. For sure, some of the difference is due to the presence of biofilms on the beaches of False Narrows that for some reason seem less prevalent on Whalebone Beach. Biofilms on the surfaces of the stones give them a duller, brownish-green appearance. But is there anything else? A quantitive analysis of the gravels was called for.

Large pebbles and small cobbles (4–10 cm)

My first attempt at analyzing the stones was to count the frequency of the different rock types. To do this, I laid out a 0.8 × 0.8 m wooden frame on the beach and classified and counted all the large pebbles and small cobbles within the frame. This was done at a couple of locations on each of the two beaches (north and south).

It was not practical or possible to stop and unequivocally identify each rock type, so a crude classification scheme was used that required on a quick glance at the rock. Basically, this was is it fine- or coarse-grained (volcanic or intrusive?), and was it light- or dark-coloured (felsic or mafic?). Minor refinements to this scheme are explained in the following table.

			A	included in A
igneous	intrusive	felsic	granodiorite	granite, tonalite, coarse gabbro, anorthosite
		intermediate, mafic, & ultra-mafic	diorite	dark monzonite, dark tonalite, dark quartz-diorite, & amphibolite (despite being meta-)
	volcanic	felsic	rhyolite	quartz porphyry, pumice, rhyodacite, felsite, latite
		intermediate mafic, mafic, & ultra-mafic	basalt	andesite, dacite
			"basalt" w. phenocrysts	basalt, andesite, porphyritic w. grey, fine-grained matrix
		dykes, veins, pyroclastics		dallasite, tuff, *quartz*, aplite, lamprophyre
sedimentary	clastic		sandstone	
			mudrock	argillite
			conglomerate	breccia, volcanic breccia, agglomerate, quartzite (despite being meta-)
	siliceous		chemical	chert, *jasper*
metamorphic			orthogneiss migmatite	anything w.*epidote*, greenstone (not basalt), granulite, meta-sediments

Notes: Only igneous stones were included and were counted as in the top half of column A. Mostly this classifies rock fragments by grain size (coarse = intrusive/plutonic; fine = extrusive/volcanic) and colour (light = felsic or leucocratic, dark = mafic or melanocratic).

Sedimentary stones were counted but not included in the analysis. Quartzite is not a sedimentary rock but it occurs widely in Geoffrey Fm. conglomerate which is. Shale from the Northumberland Fm. weathers extremely quickly, but on Whalebone and False Narrows beaches rusty calcareous nodules from shale persist.

Metamorphic rock fragments were often hard for me to recognize and probably more common than counted. *Amphibolite* was taken to be xenolithic in a felsic intrusive.

"Basalt with phenocrysts" was any rock with a fine-grained grey or greenish-grey matrix and large (porphyritic) crystals. I did not bother to differentiate between phenocrysts and mineral-filled vacuoles.

Conglomerates of various kinds are only recognizable as such in large cobbles and boulders.

Argillite was only recognized as such when its hardness was less than 5. It is sometimes close to being slate or mudstone (meta-sediments).

The results of the observations are shown in the following table:

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Large pebbles and small cobbles (4–10 cm) % frequency							
		intrusive	basalt	w. phenocrysts	other volcanic	sediment	other
north side (567 stones)	site 1	6	52	10	3	26	3
	site 2	18	52	13	3	13	1
	site 1	8	71	14	4	–	3
	site 2	20	60	15	3	–	2
	all	16	64	15	3	–	2
south side (549 stones)	site 3	12	60	12	4	7	5
	site 4	7	55	10	2	20	6
	site 3	13	66	14	4	–	3
	site 4	9	70	13	3	–	5
	all	12	67	13	3	–	5

A "dash" indicates not included. Site 1 was Bell's Landing; Site 2 was east end of Whalebone Beach; Site 3 was Spring Beach; Site 4 was False Narrows.

My conclusion is that there is no statistically-significant difference between the composition of the stones on the north and south sides of the island. The count for basalt and basaltic rocks is very high, about 80%.[6]

Big boulders

A large proportion of the erratic boulders one sees on Gabriola are granodiorite. Since this observation is at odds with the counts described above, I re-visited the beaches and counted the different types of large boulders at the top of the beach. Sandstone, which was very common, was ignored.

Large erratic boulders % frequency					
		intrusive	mafic	ultra-mafic	migmatite & other volcanic
north side (157)	sites 1&2	41	39	5	15
south side (453)	sites 3&4	49	31	10	10

[6] 64%+15% and 67%+13%. I have a suspicion that these stones are older than just the last ice age.

The results again show no statistically-significant difference between the composition on the north and south sides of the island, but they do confirm that boulders (ones you cannot easily lift) are more frequently intrusive than are stones on the beach.

Out of interest, I dug out some lithographic analyses of rocks that I helped compile in my student days at Malaspina University College, now Vancouver Island University, in which we gathered statistics on both gravels and large boulders in the Nanaimo River watershed. The results were as follows:

	site 1		site 2		site 3		site 4		mean	
	gravel	boulders	gravel	boulders	gravel	boulders	gravel	boulders	gravel	boulders
intr.	6	17	27	42	18	33	13	35	16	32
volc.	92	80	71	58	82	67	81	61	81	67
sed.	2	1	2	0	0	0	2	4	1	1
meta	0	1	0	0	0	0	5	0	1	0

"volc." includes basalt. Site 1 North Nanaimo River (Jurassic granodiorite bedrock); Site 2 Wolf Creek (mixed Jurassic granodiorite Karmutsen basalt bedrock) ; Site 3 Nanaimo River-Southfork Bridge (Karmutsen basalt bedrock); Site 4 Nanaimo River-Steelhead Trail (Nanaimo Group bedrock). All the intrusive rocks were granodioritic (no granite). There is not much correlation between the lithology of the stones in the river and the local bedrock.

In every case, boulders are more frequently intrusive than are stones along the river. Intrusive rocks may just weather faster so that the total volume of gravel-or-larger-sized particles produced by equal-sized boulders becomes less for intrusive rock than it does for basalt as time passes, or perhaps, each time a boulder or cobble shatters, intrusive rock produces a higher proportion of smaller-than-gravel-sized particles than does basalt.

Intrusive rocks

Not being content with the answer that there is actually little or no difference between the gravels on the north and south sides, I looked more closely at just the intrusive stones.

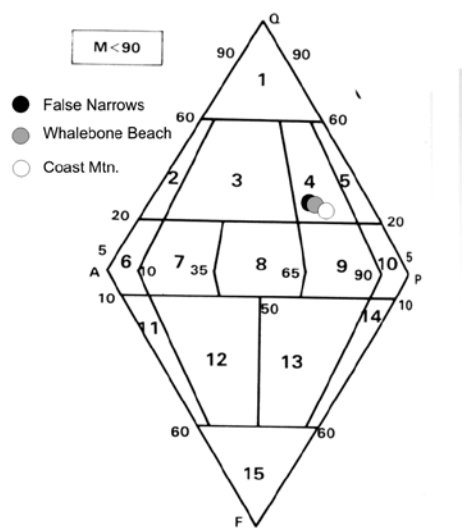
Large erratic boulders % frequency						
	north side		south side		Coast Mountains	
quartz-rich granitoid [1]	0	0	0	0	4	4
granite or granite-like [3]	8		12		8	
syenite [7]	6		4		0	
monzonite [8]	2	16	8	24	0	8
granodiorite [4]	55		48		21	
tonalite [5]	0		6		25	
quartz-diorite [10]	23		22		38	
anorthosite & diorite [10]	6	84	0	76	4	88

Numbers in [] indicate International Union of Geological Sciences (IUGS) classifications; these are often modified by geologists. Quartz-diorite here is diorite with 5–20% *quartz*. Coast Mountain numbers are from *SHALE* 25, p.32 and are derived from thin-section analysis and therefore far more accurate identifications—I'm probably not very good at distinguishing granodiorite from tonalite at a glance. On the south side, there were a couple of orthogneiss (*gneissic* granodiorite?) boulders with pure *aplite* veins. Their *biotite*, seen under a microscope, was mainly in the form of clusters of bright golden-yellow particles.

Again, the analysis showed no real difference between the north and south side of the island. The similarity becomes even more obvious if we plot the weighted composition of the intrusive rocks on a QAP diagram.[7]

Right: The average composition of intrusive rocks gathered at False Narrows and Whalebone Beach.

The triangular top half of the diamond applies to intrusive (coarse-grained) rocks, and the bottom half to volcanic (fine-grained) rocks. The point Q at the top corresponds to 100% *quartz,* the point A on the left to 100% *alkali feldspar* (K-feldspar, not *albite*); and the point P on the right to 100% *plagioclase* (Na/Ca-feldspar).



[7] Quartz–Alkali feldspar–Plagioclase. A recommended reference for non-specialists is Simon & Schuster's *Guide to Rocks and Minerals*. It includes an explanation of rock classification schemes. Figures for the Coast Mountains are from Doe, NA, *Non-marine weathering of sandstone and mudrock*, *SHALE* 25, pp..31–48, March 2011, which in turn are calculated using data from Yao Cui, *Geochemistry of Igneous Rocks from the Southern Coast Belt Plutonic Complex, Southwestern British Columbia*, UBC M.Sc. thesis, Oct.1993.

What is striking about the positions of the rocks within the QAP diagram shown on the *right*—the details do not matter here—is that the stones from False Narrows and Whalebone Beach are closer to each other in composition than either are to those of the Coast Mountains, and that the differences between all three are slight. On average, they are all Na/Ca-feldspar-rich granodiorites (bottom of Type 4 in the diagram).

"Interesting" stones

Still not content with the answer that there is no difference between the two groups of stones, I made one last attempt to quantify the difference. I put my watch in stop-watch mode and then searched each of the beaches for exactly ten minutes. During this time, I simply picked up any stone that looked "interesting" using the same criteria as any casual Sunday-afternoon collector of beach stones might—attractive or unusual colour, shape, or texture. Anything out of the ordinary. Not a very objective procedure, but I was getting a little desperate.

In all, I gathered 32 stones from the beach at False Narrows, and 42 from Whalebone Beach, which in itself is an indication that Whalebone is more interesting. The breakdown of the different types was as follows:

	igneous %	felsic %	mafic %	intr. %	volcanic %	volcanic felsic %	volcanic mafic %	intr. contact %
False Narrows	88	50	50	46	54	7	93	14
Whalebone	83	66	34	43	57	23	77	20

And here at last is a difference. Some of the "interesting" stones from Whalebone Beach are granitic volcanics (23% felsic volcanic), that is volcanic rocks from continental volcanic eruptions, whereas False Narrows is comparatively deficient in such rocks (only 7% felsic volcanic) and most are basaltic (mafic) volcanics, that is volcanic rocks from marine volcanic eruptions. The numbers of such types of rock are small, certainly less than 1%, and so they do not show up in analyses that include all types of rocks.

I subsequently went on a search, lasting about an hour or so, for felsic volcanics pebbles.[8] On Whalebone Beach, I came up with specimens of rhyolite, andesite-porphyry, volcanic breccia, dacite, trachyte?, and others, likely metamorphics or metasomatics, I could not identify. At False Narrows, I came up almost empty handed. I found a few ryholite pebbles and one or two of quartz- and andesite-porphyry, but I could find few other volcanics.[9] I should stress however that felsic volcanic, metamorphic, and metasomatic erratic boulders at the top of the beach along False Narrows <u>are</u> common, and so the test was obviously very subjective—what's "interesting" is in the eye of the beholder.

[8] Another approach I didn't try was to classify the rocks that gardeners had selected for their landscaping.

[9] On both beaches, andesite with its common brown or reddish-brown matrix was rare, indicating that the variety that must exist on Whalebone is grey and thus almost indistinguishable in the field from light-grey basalt.

Where from?

As a final step in the analysis of beach stones, I did similar counts of gravels on Vancouver Island and in Howe Sound. One potentially serious problem with this is of course that there is no knowing if gravel samples collected on Vancouver Island are free of "contamination" by ice-borne gravel from the mainland. I just hoped this was not a problem. A summary of the analyses is as follows:

% by number		all intrusive incl. K-	basalt/andesite	other volcanic & metamorphic	sediment	K-intrusive only
Vancouver Island	Nanaimo 2nd Lake	19	73	8	–	0
	Little Qualicum River	21	72	6	–	0
	Englishman River	13	75	12	–	0
	all	18	73	9	–	0
Mainland	Horseshoe Bay	30	56	14	–	2
	Porteau Cove	11	75	14	–	2
	all	24	62	14	–	2
Gabriola	False Narrows	9	83	8	–	0
	Spring Beach	13	80	7	–	0
	Bells Ldg.	8	86	6	–	0
	Whalebone E.	14	81	4	–	0
	all	11	82	7	–	0

One surprise was how unexpectedly common intrusive large and small pebbles are on Vancouver Island given that the bedrock is dominated by the basaltic Karmutsen Fm. Even the Englishman River with its basalt bedrock had significant granodioritic stones in its gravel beds; and correspondingly, the Little Qualicum River with its granodiorite bedrock had significant basaltic stones in its gravels. In the Nanaimo Lakes area, the intrusive bedrock occurs more in the valleys between the high peaks of basalt (Mt. Hooker & Mt. DeCosmos for example) and intrusive bedrock tends to be hidden away below the surface.

Final comments

The low count of intrusive stones on Gabriola beaches leads me to believe that statistical analyses of this kind are of limited value.

The weathering rates of all types of stones on the beach are higher than those of basalt, which leads to other stones being under-represented in the analyses. It is too difficult to accurately identify rock types of all small beach stones without laboratory testing because they are so weathered. They are also derived from a mix of tills from a mix of sources, so there is a tendency for samples to be unhelpfully homogeneous.

In a cursory count of rock types along the trails in the 707CP in the centre of the island, I counted 30% as being intrusive compared with 11% on the beaches, which also suggests that intrusive pebbles weather more quickly on the beaches than elsewhere. One sample of driveway gravel on Gabriola from a quarry near Nanaimo was 22% intrusive, again in contrast to the 11% on the beaches. The evidence that the results of counts of rock types in beach gravel are skewed is very strong.

Another source of error that I overlooked for most of the samples was sorting by the sea. Not only are stones sometimes sorted by size on the beach, they sometimes appear to have been also lightly sorted by density.

Stones on Evans Road Beach have been sorted by size and density—something to watch for when taking samples for a stone-count. I only noticed this toward the end of the project. Pebbles are easy to collect for counting but such counts are not always as informative as to their origin as those of the bigger rocks and boulders.






Top left: Whalebone east, Gabriola

Top right: Drumbeg west, Gabriola

Middle left: Southeast end, Mudge

Middle right: Spring Beach, Gabriola

Bottom left: False Narrows, Gabriola

Bottom right: Taylor Bay, Gabriola

Note: Photographs are not photographs of the samples taken for counting.






Top left: Englishman River, VI

Top right: Little Qualicum River, VI

Middle left: Nanaimo Lake, head of 2nd, VI

Middle right: Porteau Cove, Howe Sound

Bottom left: Horseshoe Bay, Howe Sound

Bottom right: Bowen Island, Howe Sound

Note: Photographs are not photographs of the samples taken for counting.

Gravel on beaches between Nanaimo and Lantzville where the bedrock is Karmutsen Fm. flood basalt.

Bottom lines

The compositions of the stones on the beaches at Whalebone and False Narrows are practically the same, although Whalebone has a quite small, but significant additional component, of felsic volcanic rocks. Some of the stones present on both beaches probably came from Vancouver Island; some probably came from the mainland; and some could easily have come from either place. This is not surprising given that at one time during the last ice age, a glacier moved down from the northwest following the eastern coastline of Vancouver Island, and that, on Whalebone Beach, if you lift your eyes from your feet for a moment, there on the horizon on the other side of the strait are snow-capped mountains, several of which are volcanoes. The lack of differences may in part be due to the fact that these gravels have been moved, sorted, and mixed by more than one major glaciation, not just the last one.

Larger stones than pebbles and small cobbles you find on the beaches are often metamorphic or metasomatic, and these rock types are not well represented in gravel samples where they are difficult to identify. All beaches have several kinds of rocks of this type.

Basaltic rock is more common in pebbles than in erratics everywhere.

In summary though, taking single samples of beach stones and counting just one or two hundred of them is probably not a good way of characterizing the differences between beaches. As can be seen in the photographs, there is more to it than simple stone counts reveal. ◊

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