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Final report on Texada "goop" used on Gabriola Island.

Nick Doe P.Eng, Hon. Research Assoc. Earth Sciences, Malaspina U-C.

1787 El Verano Drive
Gabriola, BC, V0R 1X6
Phone: (250) 247-7858 FAX: (250) 247-7859
nickdoe@island.net

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Second revision note:

Results of an analysis of pothole water sample TEX-5 looking for arsenic, boron, fluoride, manganese, and iron is included. Levels of all these minor components were acceptably low according to both local and international standards.

The "relative ionization" parameter of the water samples has been replaced by the more conventional "total disssolved solids" measurement. All samples are "normal" if suspended matter (clay) is excluded.

Remarks are included on an observation by Jeremy Baker, a water-quality technologist, of the formation of silica gel when the clay component of the Texada material is washed. The interaction of the clay with the dust-treatment chemicals as well as with the calcite in the limestone increasingly seems to be a significant part of this problem.

A Piper diagram, much favoured by hydrologists, is included to aid intepretation of the results of the water analyses.

Site photographs are included for TEX-5 (Horseshoe Road).

The laboratory has re-calculated the HCO_3^- concentrations after resolving some technical issues. These corrections had been anticipated in the previous draft and do not change my earlier interpretation of their results.

General view of the sampling site TEX-5 on Horseshoe Road, Gabriola
(no, not a NASA planetary flyby photograph).

Taking sample TEX-5 on Horseshoe Road, Gabriola. The yellow instrument is the pH meter.

The brown colour indicates iron, but this is very common of course. The shales on Gabriola particularly contain a lot of it; very little iron is needed to provide colour; and iron is not a health hazard in groundwater. However, this particular sample did appear to be loaded with magnesium, probably from dust control treatment. The combination of calcite, magnesium chloride, and bentonite is a good candidate for being a major part of the “goop” problem.

Scope:

A technical analysis of the material known locally as “Texada goop” or “Texada slime”. This is chipped limestone, as is commonly used on walkways, driveways, and unpaved roads, but in this particular case has an extraordinary high clay content which gives the limestone many objectionable qualities. The clay is probably bentonite, a volcanic ash.

These remarks address only the geology, geochemistry, and mineralogy of the “goop” as it appears on Gabriola Island (www.texadaslime.org). I have made no investigation into its technical specifications for highways use, nor have I had an opportunity to visit the quarry on Texada Island, nor do I have any expertize in highway construction and maintenance.

I apologize to those readers who would prefer to call it “gravel”, but this stuff really does create a horrible mess and one can only carry political correctness so far.

Sampling:

Solids: Horseshoe Way.

Only one solid sample was taken (spooning up material around a pothole). This cannot be taken as being necessarily representative of the whole, though it appeared so to me.

Pothole water: Canso Drive, Horseshoe Road, and McConvey Road.

One sample each on three separate “gooped” roads.
One additional control sample was taken from a puddle in a mature limestone chip pathway, not gooped and not salted in winter. A second control was from a stream in a nearby forest.

Gravel:

Solid sample was washed and dried. Extracted by hand (no sieve used), clasts in the 2–25 mm range (gravel). The rest was discarded. The sand-sized component was seemingly similar to the extracted clasts and the silt component was small.

Total weight dry 687 g.

Components observed:

1. Limestone chips
   Pale greyish, often streaked and blotched with white. Reacts to cold dilute (3%) HCl so likely little Mg (dolomite). No fossils.

   Total weight 416 g. (61%)

2. Calcite

   White crystalline mass, good cleavage, hardness around 3. Vigorous reaction to cold dilute (3%) HCl.

   Total weight 78 g. (11%)

3. Gabbro?

Quartz-like appearance but with good cleavage (pyroxene?). Green (olivine?).

Total weight 61 g. (9%)

4. Intrusives

   Granite and granodiorite. K-feldspar common. Some lightly weathered (limonite stains) but most not. Assume biotite? and hornblende? but wasn't positively identified.

   Total weight 47 g. (7%)

5. Mafics

   Most with a greenish tinge. Hardness >5. Some very-fine-grained basalt.

   Total weight 31 g. (5%)

6. Quartz

   Some with accessory minerals epidote and rutile. From a vein? Not numerous enough to be from arenite.

   Total weight 25 g. (4%)

7. Volcanics.

   Fine-grained, small, mostly dark but some whitish, colour when present dark earthy browns and reds. Some white phenocrysts (mainly andesite?).
   Total weight 17 g. (2%, though possibly includes metamorphics)

8. Magnetite with some ilvaite

   One clast with crystal aggregate, small, mainly lemon-yellowish, abundant perfect cleavage with pearly faces, not micaceous. (dolomite?).
   Total weight 12 g. (2%)

9. Obsidian

   One clast - conchoidal fracture.

10. No sedimentary lithic fragments were seen.

Summary:

Around 72% carbonate (by weight); mafics 11%; felsics 15%.
Quartz arenites and other sedimentary rock components apparently absent.

The non-carbonate component is probably local to Texada, possibly, surficial. Mix doesn't have the signature of glacial till from the Coast Mountains - too little granodiorite, biotite, and amphibole (hornblende).

Clay:

Clay was separated out by reducing a suspension in water. Some browness in suspension, but not a lot.

Powder, white. Appears to be translucent crystals, shiny faces, a micron or two or less (minimum microscope FOV 400 microns). Slippery. Conspicuous, but rare, red rutile. Some black specks (magnetite?). No green tinges indicating chlorite. Illite also unlikely because no muscovite seen.

Its swelling properties were assessed by putting two equal size drops of water with suspended clay on a glass slide and allowing them to dry. A drop of water was then added to one of the circular, dome-shaped spots and the effect observed under the microscope. The surface of the spot, which was lightly crusted, immediately broke into Y-shaped tension fractures as the underlying material swelled, but the effect was not dramatic; the clay did not disperse. After re-drying the diameter of the spot had increased from 8 to 9 mm, but some of that might be a surface tension effect. Conclusion? the clay does swell somewhat, which suggests it is not kaolinite or illite, but not vigourously, so it's probably not vermiculite. Possibly a smectite.

So, impossible to identify for sure but could be montmorillonite.

Source is a puzzle. No obvious candidate for a weathered parent material. Only a little granite/granodiorite present, very little limonite in spite of the magnetite, and very few to no micaceous minerals other than the clay itself.

Summary:

My guess the clay material is bentonite containing a fair amount of montmorillonite. Would be consistent with almost complete lack of other non-carbonate sediment and late-Triassic environment of the Vancouver Group (Quatsino over Karmutsen).

Water analysis:

Five samples in all. Three from potholes in "goop" covered roads filled with rainwater (very murky and not at all hard to find) and two controls. It was fairly cold the day they were collected (5ºC or so) which will have influenced the on-the-spot pH measurements. It was not raining at the time. All samples were filtered through a 0.45 micron filter before testing

I looked for: pH, alkalinity as $CaCO_3$, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, and Cl^{-}.

Field-meter calibration (demineralized H_2O = 7.0; seawater = 8.3).

The lab results indicate CO_2 partial pressures approximately 10 times atmospheric, while the field results indicate undersaturation of CO_2.

In the following results, the first table for each sample shows the results as reported by the lab. using a flame atomic absorption spectrometer. The following two tables shows my interpretation of these results. It shows total dissolved solids as calculated from the chemical analyses; and the percentages of the various cations and anions by number of ions (not weight). A Piper diagram for all samples is shown at the end of the section.

Gabriola wells

The quality of well water varies widely, but the following is provided as a rough indication of “normal” values.

	$Na^+ + K^+$	Mg^{2+}	Ca^{2+}
% cations:	85	4	11

	Cl^-	SO_4^{2-}	$HCO_3^- + CO_3^{2-}$
% anions:	15	4	81

The $Mg^{2+}/(Ca^{2+}+Mg^{2+})$ ratio is 0.27.

Sample # TEX-4:

Clear, stream. No leaf litter. Descanso Park (glacial till over sandstone bedrock not exposed).

Field pH: 7.1 Lab pH: 6.44 Alkalinity: 19 mg/L TDS = 58 mg/L TYPE: Na-Cl

	Na^+	K^+	Ca^{2+}	Mg^{2+}	$HCO3^-$	Cl^-	S
mg / L	9	0.3	5.6	1.8	23	14	1.51

	$Na^+ + K^+$	Mg^{2+}	Ca^{2+}
% cations:	65	12	23

	Cl^-	SO_4^{2-}	HCO_3^- (CO_3^{2-})
% anions:	48	6	46 (0)

The intent of selecting this stream for sampling was to provide a “pristine” baseline. In fact, the stream shows contamination by chloride, presumably carried in run-off from the roads. The $Mg^{2+}/(Ca^{2+}+Mg^{2+})$ ratio is 0.35.

Sample # TEX-3:

Pool. on walkway in Descanso Park. Clear. Lined with limestone chips common on driveways. Mature. Some leaf litter and abundant organic matter. Not salted but fairly close to the sea..

Field pH: 6.8 Lab pH: 5.95 Alkalinity: 8 mg/L TDS = 19 mg/L TYPE: Ca-Cl

	Na^+	K^+	Ca^{2+}	Mg^{2+}	$HCO3^-$	Cl^-	S
mg / L	2	1.2	2.8	0.4	10	2.3	0.16

	$Na^+ + K^+$	Mg^{2+}	Ca^{2+}
% cations:	58	8	34

	Cl^-	SO_4^{2-}	HCO_3^- (CO_3^{2-})
% anions:	28	2	70 (0)

This sample was intended to be representative of a pathway made using chipped limestone, but not “goop”. The chloride level is high in spite of the lack of salting (from the sea?) and, as expected, the calcium level is higher than “normal”. The $Mg^{2+}/(Ca^{2+}+Mg^{2+})$ ratio is 0.19.

Sample # TEX-1:

Pothole. Canso Drive/Easthom Road. Murky.

Field pH: 8.9 Lab pH: 7.67 Alkalinity: 80 mg/L TDS = 140 mg/L TYPE: Mg-HCO_3

	Na^+	K^+	Ca^{2+}	Mg^{2+}	$HCO3^-$	Cl^-	S
mg / L	4	1.2	16	10.1	97	8.79	0.7

	$Na^+ + K^+$	Mg^{2+}	Ca^{2+}
% cations:	20	41	39

	Cl^-	SO_4^{2-}	HCO_3^- (CO_3^{2-})
% anions:	13	1	85 (0)

This pothole sample shows expected alkalinity due to the limestone. The $Mg^{2+}/(Ca^{2+}+Mg^{2+})$ ratio is 0.51 suggesting the “goop” is a significant source of magnesium, i.e. the limestone is dolomitic. The chloride level is normal.

Sample # TEX-2:

Pothole. McConvey Road, near Taylor Bay Road. Murky. TYPE: Ca-HCO_3

Field pH: 8.4 Lab pH: 7.51 Alkalinity: 92 mg/L TDS = 190 mg/L

	Na^+	K^+	Ca^{2+}	Mg^{2+}	$HCO3^-$	Cl^-	S
mg / L	13	3	23.9	8.9	112	24.25	1.69

	$Na^+ + K^+$	Mg^{2+}	Ca^{2+}
% cations:	40	23	37

	Cl^-	SO_4^{2-}	HCO_3^- (CO_3^{2-})
% anions:	27	2	71 (0)

This pothole sample again shows expected alkalinity due to the limestone. “Salt” level is high. The $Mg^{2+}/(Ca^{2+}+Mg^{2+})$ ratio is 0.38.

Sample # TEX-5:

Pothole. Horseshoe Road. Murky.

Field pH: 9.1 Lab pH: 7.46 Alkalinity: 56 mg/L TDS = 158 mg/L TYPE: Mg-Cl

[Technical note: The theoretical pH at $10^{-3.5}$ atm. partial pressure CO_2 (normal atmosphere) is 8.3 so the sample may have acquired some CO_2 en route to the lab possibly as the result of organic activity, but this is not a complete explanation for the pH readings. The effect on the results of pH uncertainty is however negligible.]

	Na^+	K^+	Ca^{2+}	Mg^{2+}	$HCO3^-$	Cl^-	S
mg / L	5	1.4	17.4	18.3	68	40.27	2.58

	$Na^+ + K^+$	Mg^{2+}	Ca^{2+}
% cations:	18	52	30

	Cl^-	SO_4^{2-}	HCO_3^- (CO_3^{2-})
% anions:	49	3	48 (0)

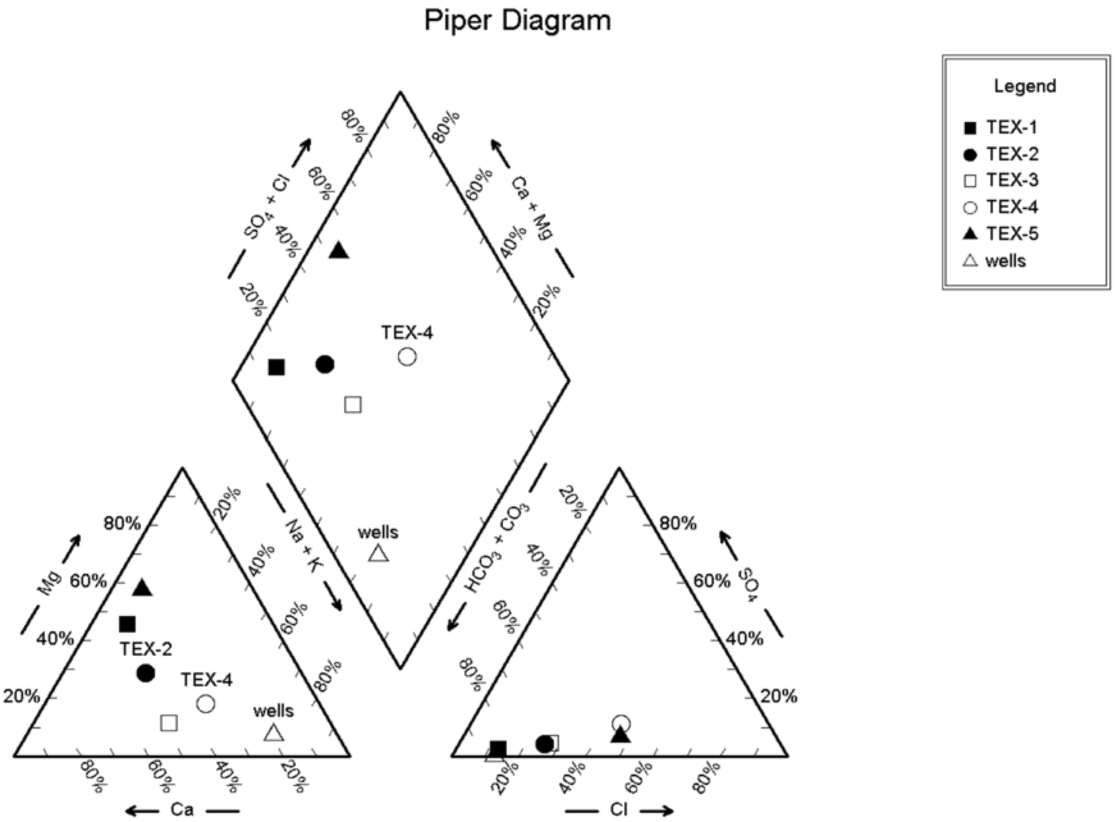
Trace elements by flame atomic absorption spectroscopy (with hydride generation for arsenic) :

mg/L (ppm)	B, boron	F^-, fluoride	As, arsenic	$Fe^{2+, 3+}$, iron	Mn^{2+}, manganese
Road sample TEX-5	0.13	0.1	<0.001	0.06	0.01
Canadian standard	5.0	1.5	0.025	0.3	0.05
WHO standard	0.5 [1]	1.5 [2]	0.01 [3]	- [4]	0.4 [4]

Notes:

1. Gabriola groundwater with a boron content above the WHO limit is not uncommon; however, it is rarely above the Canadian limit.
2. Gabriola groundwater occasionally exceeds the fluoride limit, usually in sandstone wells within the Gabriola Formation. Naturally occurring fluoride is a health concern on the Gulf Islands.
3. There is no known example of the Canadian arsenic limit being exceeded on Gabriola, though one well has exceeded the US and WHO levels. Arsenic, along with copper and chromium, is a contaminant in wood ash arising from the use of wood preservative.
4. Limits for iron and manganese are usually for aesthetic reasons; there are no health concerns.

This pothole sample again shows expected alkalinity due to the limestone. Chloride level is high, but the sodium is not. The $Mg^{2+}/(Ca^{2+}+Mg^{2+})$ ratio is 0.63; more magnesium than calcium.



Piper diagram (all samples + well-water)

The pothole samples are TEX-1, -2, and –5 (filled symbols). TEX-3, -4, and “wells” (open symbols) are natural surface- or groundwater samples. All from Gabriola.

Note the unusually high content of magnesium in TEX-5 (the black triangle), implying application of MgCl..

Comments:

All five samples passed the Health Canada Potable Water Standards (2004) for drinking water, except for pH. The allowed range for pH is 6.5–8.5; however this is an aesthetic standard and readings outside this range pose no health risk.

It is ironic that of the lab tests, the only samples to fail both the Health Canada and Islands Trust Standards (because they were too acidic) were those NOT from the potholes.

The two ”natural” waters were types Na-Cl and Ca-Cl.
The three ”pothole” waters were (all different) types Mg-HCO_3, Ca-HCO_3, and Mg-Cl.

All samples except TEX-1 showed evidence of chloride contamination. The “goop” shows evidence of being dolomitic—magnesium levels are high. Both observations may however be due to application of magnesium chloride as a dust palliative in the summer. Gravel roads are not normally salted in winter. Although magnesium chloride is not a health hazard, it may be contributing to the cementing problem.

Total dissolved solids (inorganic), not including fine suspended matter, was higher for the pothole water than that from the two “natural” sources, but was well below the potable water standard upper limit of 500 mg/L in all five samples.

The trace element arsenic was virtually absent from the sample, and the other trace elements tested for (boron, fluoride, iron, manganese))were all well within acceptable limits for potable water and concentrations that occur naturally in Gabriola groundwater.

Jeremy Baker, who has professional water-quality expertize and who lives on Gabriola, tells me he has observed the formation of a silica gel when attempting to dry out a sample of the clay component of the goop. My surmise is that a rapid lowering of the pH during washing has brought $H_3SiO_4^-$ and $H_2SiO_4^{2-}$ out of solution. Amorphous silica is quite soluble at pH’s above 9. This might even be a factor in the cementation process that is so objectionable. The material in combination with magnesium chloride and the high pH’s observed in the field might be producing magnesium silicate during drying out and this is a well-known problematic scaling problem compound in water treatment processes. This aspect is however for an expert to comment on.

Drinking water concerns:

The “goop” appears to be a perfectly natural substance, so barring the unlikely possibility that it contains highly toxic trace elements, it is likely mostly to add quantitatively to existing water-quality problems on the island, rather than create new ones. Calcite, kaolinite, illite, and montmorillonite (if that’s what the goop clay is) are very common in upper-Nanaimo Group sandstones and shales. Middens also contain a lot of seashell. Having suspended clay in the water is a great nuisance to individuals and can (I’m told) damage pumps, but it is not a problem uniquely associated with goop.

On Gabriola, high pH groundwater is usually found in deep sandstone wells where there has been an increase in sodium ion concentration at the expense of calcium and magnesium ions, promulgated by cation exchange on the surfaces of the clay component of the rock. High pH groundwater on the island is also high in fluorine and boron, which is a concern. It is possible that the combination of "goop" and "salt" *might* raise fluorine and boron in aquifers that are recharged in part from road run-off, but this is speculation and unlikely to be a widespread concern. "Salt" here could be sodium chloride or magnesium chloride, because both the corresponding carbonates are more soluble than calcium carbonate.

Clay does readily adsorb contaminants so its presence in suspension needs to be monitored in shallow wells.

Conclusions

There is nothing in the "goop" which would make it an undesirable or unusual road surface material apart from its high clay content. The clay is likely montmorillonite, a component of bentonite (volcanic ash). It's presence is largely responsible for creating the "goop" problem.

Calcite-rich clay forms a natural hydraulic cement that can seal in moisture and thereby accelerate corrosion. The fineness of the clay when dry means it can cause damage to moving parts by entering through the narrowest of gaps (sub-micron). It likely has a high silica content and is therefore abrasive in such situations. The technical qualities of the material substantiate most if not all of the non-health related complaints against it.

The clay problem may be exacerbated by salting or dusting with magnesium or calcium chloride. This raises the pH, which may be harmful to some types of roadside vegetation in a minor way in the long term, but is not a health concern. Both calcium and magnesium chloride, if formed by cation exchange on the clay surfaces when halite is added, or spread to keep down dust, are hygoscopic, or perhaps even deliquescent, which would cause the material to be very slow to dry out, and the clay has indeed been observed to remain sticky on Gabriola for more than three years. Many unpaved roads on Gabriola are shaded by tall trees which may add to the problem by keeping the sun from drying it out.

A second hazard of mixing magnesium-rich dust control agents with silica-rich bentonite is that it may promote the precipitation in confined spaces of magnesium silicate. This is a compound that is abrasive and forms scales on steel surfaces and is notoriously difficult to remove.

In much drier areas, limestone is deliberately treated with bentonite to control dust, and according to one report is generally not harmful to the environment. See:

http://www.usroads.com/journals/rmej/9803/rm980303.htm

I see nothing that is toxic or in itself chemically corrosive in the material apart from as mentioned. I have not done a whole rock analysis, but I would expect heavy-metal content to be low—there is relatively little quartz in the material and no iron-bearing minerals including the clay, which would suggest that the material is not from the locale of a skarn deposit. Skarn deposits contain valuable mineral ores that are also health hazards, and are common on

Texada, so assurances should exist that mining borrow is not getting into the road gravel. In the single sample I looked at, there was not the slightest evidence that it is.

The effect on drinking water quality (mineral content only) is likely to be negligible for most wells.

OPINION

The material should only be used after being washed clean of clay, or being allowed to weather in the rain (for at least a year?) before application. The clay is clearly a seriously and reasonably objectionable component. It is transported away from the road surface by rain only very slowly.

Alum flocculates the clay, but I've no idea if its application would be useful or feasible in cleaning up the road surfaces.

The chemical interaction of dust control and de-icing agents on the road surface with the clay-rich limestone is something that likely has been overlooked. The use of these compounds should be discontinued until this aspect of the problem has been examined.

My initial conclusion was, and remains after several days familiarizing myself with the problem, that it's use should be immediately halted until the problems are addressed.

END