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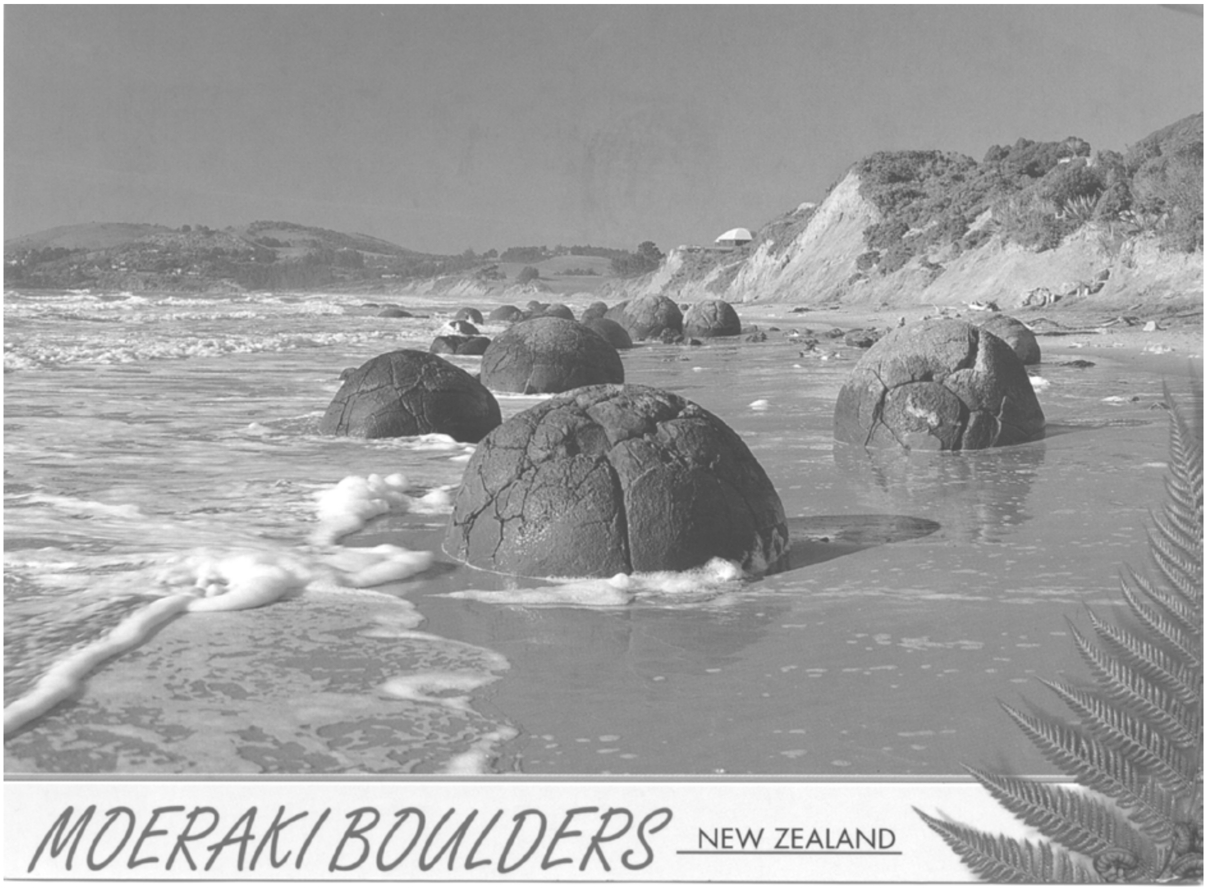
Great balls of stone—concretions

by Nick Doe



On Gabriola and the surrounding islands, concretions are most commonly recognized as "cannon-balls". They sit on our beaches, quietly weathering away; or they protrude from sandstone cliffs as if momentos of salvoes fired in battles of long ago; or they stand guard at garden gates because, fascinating though they are, nobody knows what else to do with them.

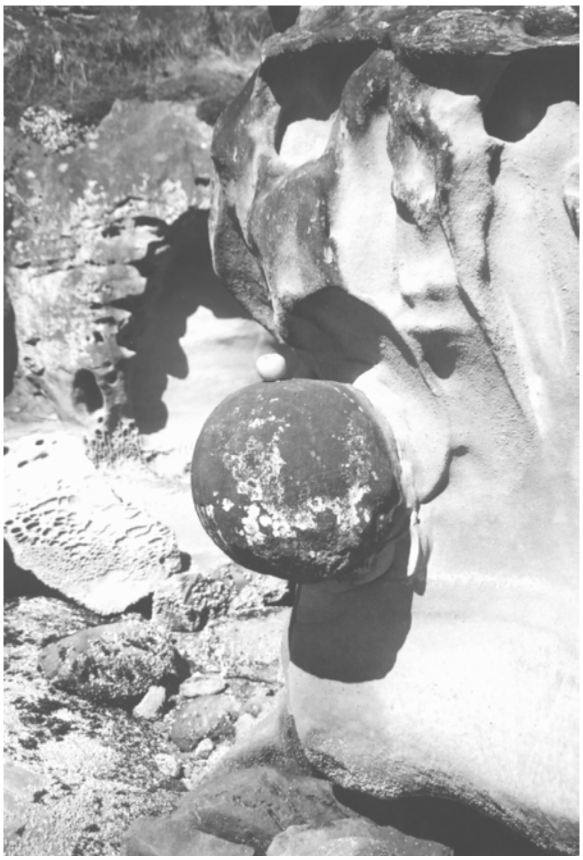
Concretions are common in sedimentary rocks the world over. They consist of exactly the same material as the host rock—in our case, sandstone—but the grains of sand have been cemented (concreted) together more firmly than they are in the host rock, making them more resistant to weathering.

The cement in the sandstone we have here in the Gulf Islands is normally clay, but in concretions, this is augmented, or replaced, by *calcite* (calcium carbonate). Some, not all, concretions, darker in appearance, have a "case-hardened" shell. This shell is relatively *calcite*-free, and the cement contains oxides of iron.

The most conspicuous concretions are spherical, but others are not so round. The most extreme "oblate" forms are pale, small, and plate-like; and they don't have a shell.

The usual explanation for concretions is that they formed, while the sandstone was still sand, around a nucleus of organic material—a buried plant or animal. As the organic material decayed, it enriched the water around it with carbon dioxide and organic acids, thereby increasing the amount of dissolved carbonate it contained. Eventually, carbonate precipitated from the concentrate, which cemented the grains of sand more firmly than those of the host rock.

Concretions tend to be spherical because diffusion of the organic chemicals through the uncompacted sand was driven by capillary forces, not gravity. If you want a two-dimensional demonstration of this, put a drop of water on a paper towel and then put the towel in the freezer. After it's frozen, you'll find you have a surprisingly well-defined disk of ice.



A "cannon-ball" concretion emerges from an eroding sandstone boulder in Descanso Bay. Gabriola Formation. That's an apple perched on top.

The cement in these sandstone concretions is *calcite*, but in the cannon-ball variety, the outer crust of sandstone has been "case hardened" by iron oxides.

The origin of concretions is actually problematic. While there is undoubtedly a lot of truth in the standard explanation—fossils are indeed occasionally found at the centre of Gulf Island concretions—the theory fails to explain how the concretions retained their spherical shape in relatively unconsolidated sand when they are so heavy (Mozley, 1996). The answer is not known, but my guess would be that the formation of Gabriola's concretions was a two-step process involving first, carbonate cementation light enough to hold the sand together, but not enough to make it overly dense, and then, in a subsequent step, chemical weathering and infilling of the remaining pores with closely-packed clay.

Many concretions are fractured in a way that indicates that they have been around for a very long time—40 million years or more. Some fractures are not closely matched by fractures in the host sandstone, probably because the fractures in the host rock have been "healed" by an infilling of sand or mud, which has now been lithified.

Calcite is chemically the same as limestone, which is slightly soluble in fresh water,[1] so it's not surprising that some of our concretions show erosion patterns not dissimilar to those you see in karst (limestone) country. Fractures become very

[1] Rainwater is more acidic (lower pH) than seawater and is nowhere near being as saturated in carbonate as seawater is. If seawater dissolved *calcite* readily, we wouldn't have shellfish.

Concretions without a “case-hardened” shell in the De Courcy Formation, west side of De Courcy Island, and yes, those nipple-like appendages are also concretions, and they are pale pink.

Concretions contain lots of *calcite* (calcium carbonate). The calcium came from the weathering of *feldspar*, and the *carbonate* probably from the microbial decomposition of organic material that acted as a nucleus for the formation of the concretion. Note the “visor” *top-left centre*. This is “case hardened” sandstone similar to that in the shells of cannon-ball concretions.

Concretions in sandstone: hand-sized globules in the Gabriola Formation at Pilot Bay (*left*). Like spherical concretions, these are rich in *calcite*. Black dots among small disc concretions (*right*) are periwinkles (*Littorina scutulata*), which are common on Gabriola’s beaches. It’s sad to relate, but it’s they that make the crunchy noise when you walk on a sandstone beach in summer.

Many "cannon-ball" concretions look flawless, but others (*above left*) in the Gabriola Formation in Pilot Bay are a bit chewed up. Probably part of the weathering here is due to rainwater collecting in holes and dissolving the *calcite*, just as it does in forming underground caves in limestone. Another contributor to weathering is salt from seawater wicked up from summer high tides at night, and evaporated in the summer sun by day.

Grooves (grikes), *left*, are fractures that have been widened by dissolution of the *calcite* cement.

wide; holes that hold rainwater are deepened; and concretions embedded in the beach frequently have a rim around them where fresh water gathers and further dissolves the *calcite* cement.

Concretions certainly make an interesting contribution to the geological landscape of Gabriola.

I've attached some endnotes on them for the more technically minded reader. Just skip them if that's not you.

ENDNOTES

Just to make sure I've got my story on concretions straight, I had some thin sections[2] of concretions made and analyzed. The following petrographic reports are almost entirely the work of Craig Leitch, Saltspring Island. Craig, who was very helpful, is the petrologist for Vancouver Petrographics Ltd., Langley, BC.

[2] "Thin sections" are slices of rock that have been ground down so thin that they transmit light. They are mounted on glass slides so that they can be examined under a microscope. This is such a routine procedure for geologists that it can be done by specialized laboratories very cheaply.

In these reports, a questions mark, as in, ?hornblende, indicates an educated guess rather than a firm identification.

[1]. Unweathered sandstone

The sample was grey, homogeneous, fine-grained sandstone with almost no bedding, freshly exposed at a quarry on Lockwood Drive (Sample 03, Gabriola I., ?Gabriola Fm. close to suspected Spray Fm. contact).[3] The sample was weakly magnetic and showed no reaction to cold dilute HCl (it didn't fizz, and so likely contains no calcium or other carbonates).

This particular sample proved, for a sandstone, to be extraordinarily rich in feldspars and poor in quartz—it was a "dirty" sandstone, or what used to be called "graywacke", but known these days as a feldspathic wacke (***plagioclase*** 45%, ***quartz*** 25%, ***K-feldspar*** 10%).

Feldspars, particular Na-Ca feldspar (***plagioclase***), are easily weathered chemically and their high concentration in this sample indicate that the sediment was young when it was deposited. Most likely it was brought to the depositional site more or less directly by fast-moving creeks and rivers.

Minor constituents (5% each) of the sample were ***biotite*** (locally partly-chloritized), an Fe-rich mica; and ***amphibole*** (*?hornblende*), which is a common in intrusive (*granodiorite*) rock. There was also some ***muscovite*** (1%), and traces (<1%) of ***magnetite*** (Fe_3O_4) and ***pyrite*** (FeS_2).

The matrix of the wacke was difficult to determine due to its fine-grained and intimately intermixed nature. However, it appeared to be composed mainly of finely comminuted minerals listed above (feldspars, quartz, biotite, amphibole)—this was the silt component—set in very-fine-grained ***sericite*** with **?clay-*chlorite*** and minor (1-2%) ***limonite*** and ***leucoxene***.

Sericite is fine-grained *muscovite*, an Al-rich mica. Its presence in the matrix of this sample was probably due to the partial decomposition of *feldspars*. The nature of the **?clay** was impossible to determine optically,[4] but ***chlorite*** was present. *Chlorite* is a green, complex, iron-containing silicate that is closely associated with the micas.

Leucoxene is a titanium-oxide rich mineral. ***Limonite*** is a mix of brown or yellowish-brown ferric (iron) oxides. Its presence indicated that this rock sample was partially weathered.

As to the cement, it appears that it is mainly ***clay*** that holds unweathered sandstone together.

A prominent 1-2 mm veinlet was composed of ***zeolite*** crystals (type not possible to determine) with subordinate amounts of carbonate, likely ***calcite***. Plagioclase crystals locally in the sample showed minor microfracturing replaced by zeolite.

[2]. Concretion without case-hardening

The sample was a concretion that showed no sign of a case-hardened shell, from Pilot Bay, (Sample 19, Gabriola I., Gabriola Fm.). The sample was weakly magnetic and reacted vigorously to cold dilute HCl.

In thin section, the sample clearly contained abundant carbonate, likely mostly ***calcite*** in the matrix. Locally there was also minor ***sericite***. There were minor amounts of ***chlorite*** in the matrix, likely as a result of weathering of the ***biotite***.

[3] The transition from the Geoffrey Fm. up to the Gabriola Fm. is not well exposed in this area, but there is a sharp mudrock/sandstone contact at the bottom of the rockface from which the sample was taken. The contact was in a ditch and there was surface water present even though it was August in a very dry summer, suggesting that the mudrock is more than just a thin interbed and therefore likely the top of the Spray Fm.

[4] Two X-ray diffraction analyses of clay from the Nanaimo Group sandstones by Global Discovery Labs in Vancouver showed in both samples ***quartz*** and ***albite.*** Sample 18 (Gab.Fm. GDL:V03-0666R) showed also ***muscovite***, ***gypsum***, ***kaolinite***, ***?chlorite,*** and ***?montmorillonite***. Sample 23 (Geof.Fm. GDL:V04-0042R) showed also ***montmorillonite*** and ***?kaolinite***.

Some clasts that may have been ***plagioclase*** were partly, or in places completely, replaced by carbonate and sericite beginning along microfractures.

[3]. Concretion case-hardened shell

Two samples:

The first sample was "case-hardened" sandstone from the shell of a cannon-ball concretion, from Pilot Bay, (Sample 20, Gabriola I., Gabriola Fm.). The sample was weakly magnetic, but showed no reaction to cold dilute HCl.

In thin section, there was no evidence of any carbonate whatsoever in the matrix. Instead, the matrix showed what appeared to be an increased abundance of fine-grained, brownish to greenish brown ***hydrobiotite*** (possibly an Fe-rich chlorite, or clay mineral). Also, there was what might be an increased abundance of fine-grained red-brown ***limonite*** in the matrix, loosely associated with the hydrobiotite.

The second sample was case-hardened sandstone from a patch of the "visor" of a gallery that showed an unexpected mild reaction to cold dilute HCl. It was dark in colour, and weakly magnetic. The sample was taken from within the surface zone of weathering, but deeper than the exposed surface, (Sample 11, De Courcy I., De Courcy Fm.).

In thin section, abundant fine-grained carbonate, likely ***calcite***, formed the matrix (but not everywhere). Carbonate and minor ***sericite*** were as also present in microfractures in quartz and feldspar clasts.

The carbonate was faintly, but distinctly Fe-stained, suggesting that the iron (***limonite***) derived from oxidation of Fe-bearing minerals, and possibly causing (or at least contributing to) case-hardening, is sometimes to be found in the carbonate cement.

References

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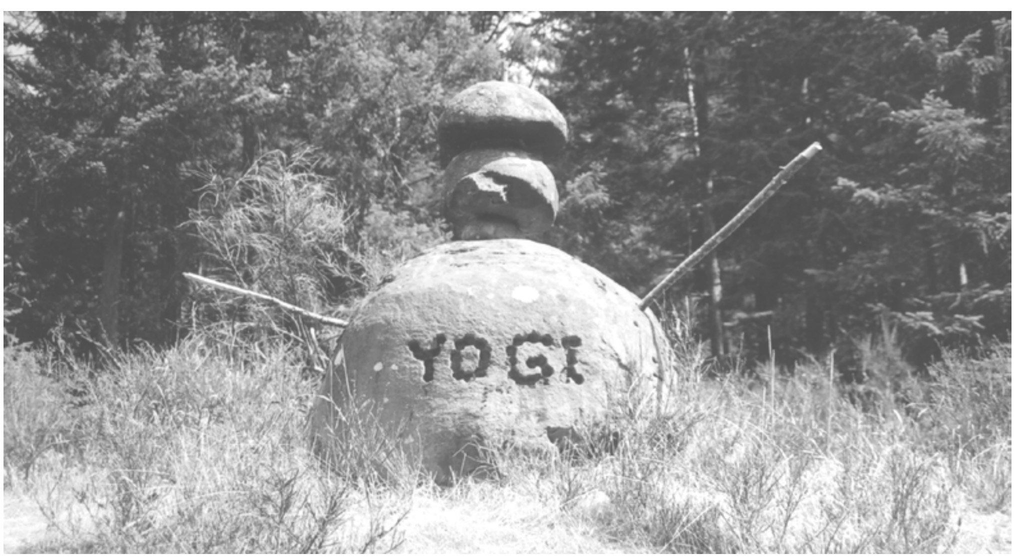

One use for concretions. A well-known Gabriolan landmark just outside Descanso Park. Put there by, who else, the Youth of Gabriola Island—YOGI.