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Spheroidal weathering

by Nick Doe

Weathering of rock that results in spheroids is common everywhere and there's lots of it on Gabriola. You pass some good examples on the way up the hill from the ferry.

The explanation for most of it is simple. The rock (sandstone) was initially fractured into square-ish blocks, and the subsequent weathering is rounding off the corners of the blocks. Each corner is being abraded from three directions, but the rock in the middle of a face is being abraded from only one. Cubes of sugar dissolve that way.

In the photograph on the next page, the rounded sandstone blocks in the middle have been shaped by groundwater seeping down vertical joints, and along the (near-horizontal) mudrock interbeds.

Not nearly so easy to explain however, is the *spheroidal weathering* you see in the faces of mudrock (shale) cliffs. Mudrock is just like sandstone except that the grains are a lot smaller, but there is no sign of the cubic fracturing of the mudrock that could initiate the spheroidal weathering that you see.

In a previous article (*SHALE* 9, p.48), I floated the idea that spheroidal weathering in mudrock was due to "density variations" in the mudrock and that these density variations caused the rock to weather differentially in the way that it does. The density variations had been caused, I went on to say, waving my arms about, by shrinkage into clumps of the silt before it was turned into rock.

Now while the first notion—density variations—may be "sort of" true, the second—three-dimensional shrinkage (3D)—I've discovered, most certainly isn't (sorry about that).

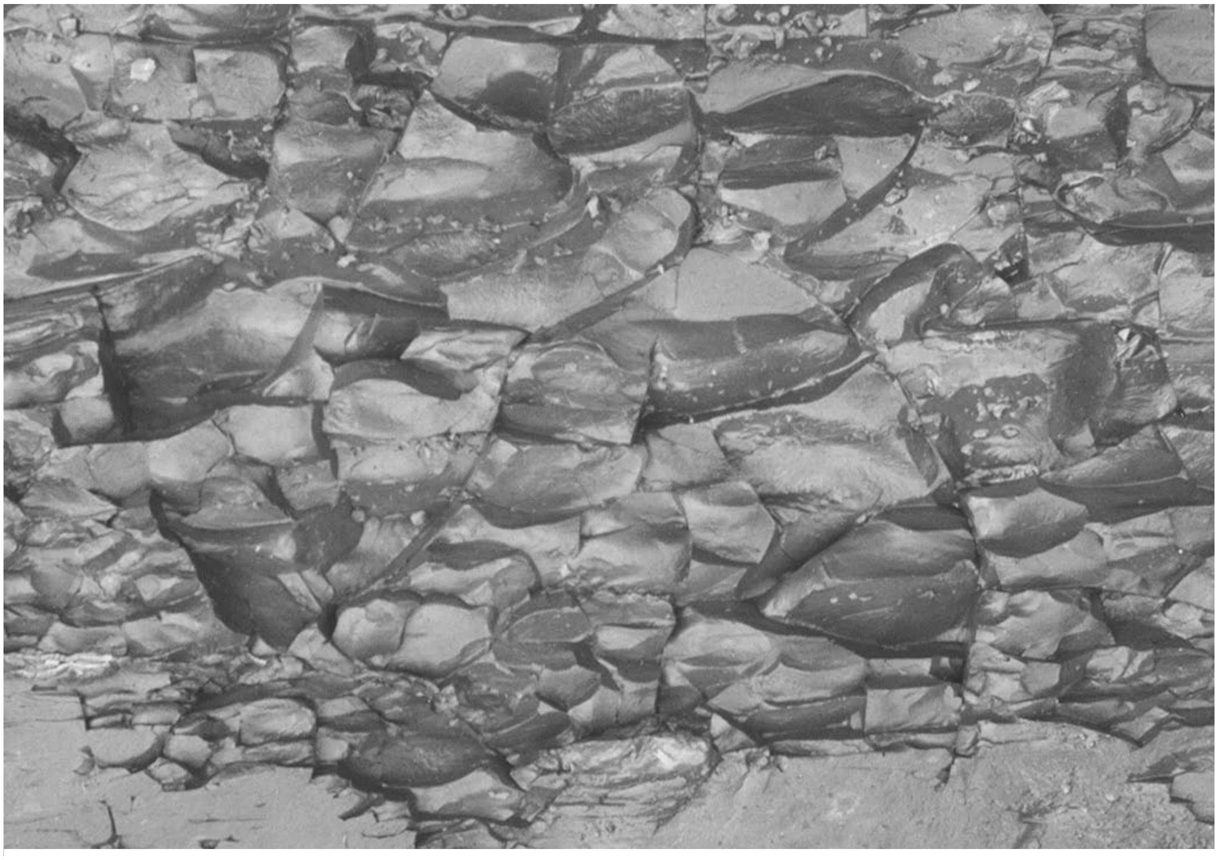
The notion of 3D shrinkage into clumps came to me from the once-popular idea that stars are created by the spontaneous gravitational collapse of giant dust clouds. When computers became available in the 1960s and the behaviour of a dust cloud could be simulated on a particle-by-particle basis, this idea was shown to be wrong—dust clouds do not simply collapse into "clumps" to form solar systems, even though each particle in the cloud attracts all the others. The motion of the particles is too disordered for that and it requires an external stimulus, such as, in our solar system's case, a near-by supernova, to trigger a collapse. I should have known that the 3D-shrinkage idea was a bad one.

Top: Spheroidal weathering in sandstone. The cliff along South Road opposite the Gabriola Greenhouse farm. The blocks of sandstone in the middle bed are being rounded by groundwater that seeps from thin horizontal mudrock interbeds and down vertical joints

Bottom: Spheroidal weathering in shale.

What then could be causing the spheroidal weathering seen in the mudrock?

A number of simple observations provide the answer:

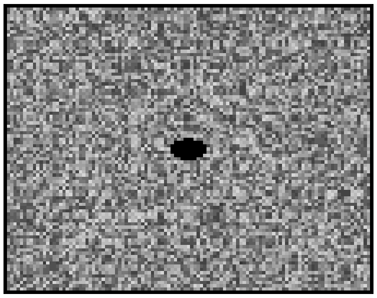


Spheroidal weathering in shale is hard to photograph in black-and-white—it's easier to spot in real life and is very common. Sizes of the spheroids vary from 10–250 mm and more. The spheroids are very friable and weather in concentric shells.

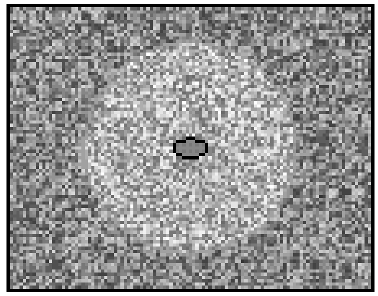
- the spheroids are actually not spheroids at all. Spheres have three equal axes (up-down, left-right, and forward-back), while spheroids have two equal axes (as does a football, for example, with the left-right axis longer than the other two, and as does the earth with its equatorial bulge and an up-down axis shorter than the other two). The "spheroids" in the mudrock are actually *asymmetric ellipsoids*, which have three unequal axes. In the cliffs at the Pioneer Cemetery, these are roughly in the proportion 6:4:3
- the asymmetric ellipsoids all tend to have their axes pointing in the same direction
- if you peel off the weathering shells of an ellipsoid, you often end up with a hard core, about the size of a thumbnail. This core is difficult to break with your fingers
- inside very large ellipsoids, you commonly find smaller ones.

These ellipsoids must therefore be weakly-cemented concretions;[1] I can't see that they could have formed any other way.

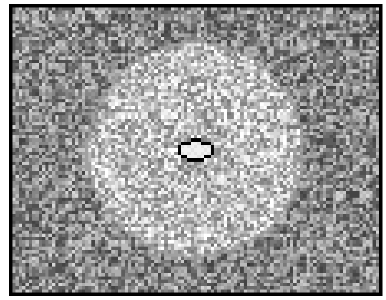
[1] If you never knew what these are see *SHALE* 9, pp.6–11. If you've forgotten, see next two pages.



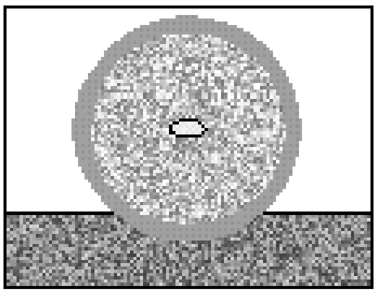
Concretion formation 1



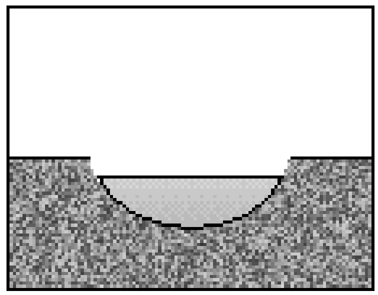
Concretion formation 2:



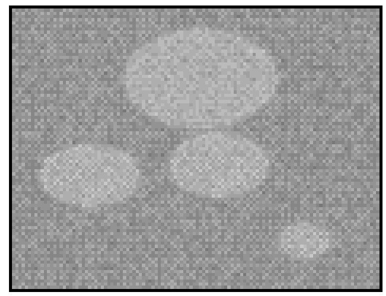
Concretion formation 3:



Concretion formation 4:



Concretion formation 5:



Concretion formation 6:

Concretion formation 1: Concretions begin with organic material, often a shell or piece of wood (the black speck in the middle), buried in the sand at the bottom of the ocean.

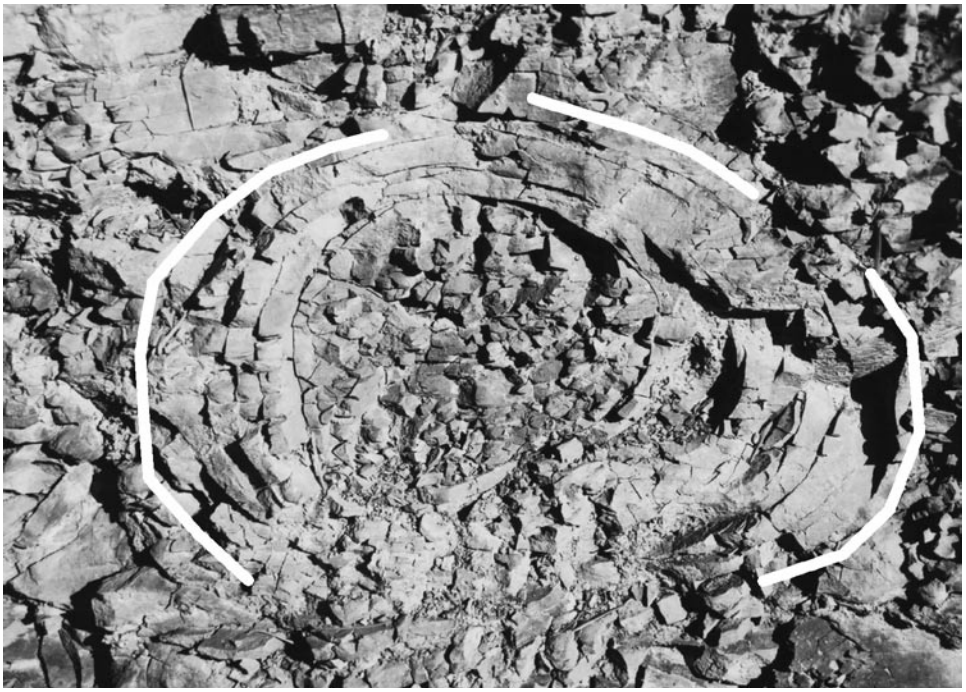
Concretion formation 2: As the buried object decays, it creates a halo of water rich in dissolved carbon dioxide and carbonic acid. The pressure of the carbon dioxide in the halo increases as the nucleus is buried deeper and deeper in the sand, and this increases the strength of the carbonic acid, which in turn hastens the decay. Shells can also start to dissolve as a result of acidification of the halo of water by microbes consuming soft tissue in the nucleus.

Concretion formation 3: Water eventually begins to be squeezed out of the sand. The minerals and clay (mostly clay) left behind cement the grains together to form sandstone. The same process occurs in the halo except that the cement there is enriched with carbonates (mainly *calcite*) and this forms a more effective cement. The nucleus (the white speck in the middle) has now become a fossil.

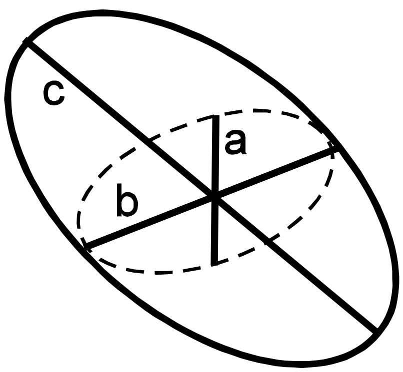
Concretion formation 4 (*top photograph opposite*): Millions of years later, the concretion is exposed at the surface. Because *calcite* forms good cement, the sphere that was originally the halo erodes more slowly than the host sandstone. Concretions often acquire a weathering rind or crust containing oxides of iron (*hematite*) that further protect them from erosion. The sea does not erode them because the sea is alkaline, but rainwater, which is often acidic, does.

Concretion formation 5 (*bottom photograph opposite*): In forests, the groundwater is often so acidic that it dissolves the *calcite* cement of the concretion leaving behind only a circular depression in the sandstone, often filled with water in winter. These hollows are sometimes associated with petroglyphs.

Concretion formation 6: Concretions in mudrock form the same way except that the initial organic material is very much tinier, often only a microscopic fragment of shell. The cementation by *calcite* is consequently much weaker than in sandstone and the concretions readily fall apart when exposed to modern weathering. Because mud is more easily compressed than sand, concretions in mudrock are less likely to retain their original spherical shape.



Although there are rarely any fossils in the asymmetric ellipsoids, and they show little reaction to hydrochloric acid (which they would do if they were rich in *calcite*), you can find right at the centre of some of them, a tiny speck of something that does react vigorously to the acid (it fizzes). These specks are probably tiny fragments of shell—too tiny to have provided enough *calcite* to concrete the mudrock firmly, as in the (illustrated) sandstone "cannon-ball" and "dinosaur-egg" concretions, but enough to cause the differential weathering patterns we see today. At least, that's my theory, and until the next *SHALE*, I'm sticking to it. ◊



Originally, the concretions in the mudrock would all have been perfect spheres, but as the rock lithified and the rock was stressed during burial and subsequent earth movements, the ellipsoids all took on their current shape. This shape captures the strain in the host rock, and is therefore common to all of them.[2]

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[2] I didn't do an extensive statistical survey to come up with ratios of the axes, but they're roughly right. The longest axis "c" (least stress) is roughly parallel to the cliff face and the shortest axis "a" (most stress) is roughly vertical. This is entirely consistent with the pattern of normal faulting in the area.