

Context:

Petroglyphs, age, lichen, weathering, geographic orientation

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SHALE 17 was a special issue on petroglyphs. See the *SHALE* Index.

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Observations for the curious at sites DgRw 193, -198, and -201

by Nick Doe

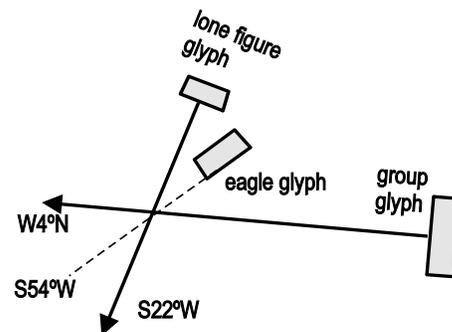
I have looked at a few other petroglyph sites in the same area as those reported on in this issue of *SHALE* for unusual alignments and geometry with mixed results. Also, at one site, DgRw 198, a short study was made of spalls, and of the growth of lichen as revealed by old photographs. Lichen growth has been used to date archaeological sites.

thing noticed there was that the face of the boulder carved with one of the glyphs (the group of females) runs very close to north-south though this would not have been under the carver's control because the boulder is so large.² The orientations of the faces of other glyphs at the site are interesting, but of doubtful significance.

DgRw 193

DgRw 193 (Boulton) is, I'm sure, a site where alignments and orientations are significant features of the designs; however, it is a difficult site to survey and research progress is slow. Many glyphs are faint—virtually invisible in summer—and in winter, quickly obscured by fresh moss.

Two of the largest glyphs there are well known.¹ One has obviously been aligned with a fracture in the rock, and the vertical axis of the other lies exactly east-west. The conjugate fractures at the site run at N68°E (248°) and N35°E (215°). The largest “sea-wolf” glyph faces along one fracture at 248°, and 215° is the bearing of it from the second glyph, as measured between well-defined eyes. Like the Church site, understanding this site will demand more resources than I can muster.



The “group” looks west, W4°N; the “lone figure”³ looks *roughly* south, S22°W; and the “eagle”⁴ looks *roughly* southeast (S36°E) so that its face runs midway between the other two at S54°W (exactly midway between is S58°W).

DgRw 198

Orientations and geometry

DgRw 198 (Stokes Road) is another hillside site. The faces of two of the large carved boulders about thirty-six metres apart were

DgRw 201

DgRw 201 (Lobo Springs) is a hillside site with petroglyphs standing upright. The only

¹ Mary & Ted Bentley, *Gabriola: Petroglyph Island*, pp.73–4 & 75, 1998 ed., Sono Nis Press. Spalling is bad and recent at this site. The well-defined pits likely have positional significance.

² Bentleys, *ibid*, pp.96–8.

³ Bentleys, *ibid*, p.101.

⁴ Bentleys, *ibid*, pp.94–5.



Three pictures of the larger panel at DgRw 198. All three show “the spall” which has left only the beak of the second glyph on the downhill side.

The first picture was taken by Phil Hobler (1936–2006), professor of archaeology at SFU, probably in the summer of 1987.

The second is from the 1998 edition of the Bentleys’ book and probably dates from their visit in 1997.

The third I took in July 2005.



Historical pictures like these are useful because they reveal the growth rates of the lichens, which can then be used for dating. Unfortunately, using flash is the best way to photograph lichen, but it is also a poor way to photograph glyphs, so many a useful photo has probably been ditched.

Note in the third picture how the lichen is concentrated on the spall. The relatively unweathered rock is maybe more nutritious, or else somebody has cleaned the glyph off, not bothering with the spall.



Lichen protects surfaces against rain drops and absorbs harmful chemicals in the air, but it can also accelerate weathering of the rock. I suspect, overall, glyphs benefit from being covered, and any damage the lichen does is minor compared with that done by salt.

oriented roughly the same way (N35°E, to be viewed facing SE). The boulders are far too heavy to have been moved, so not much significance can be attached to this observation.

While I see no geometry in the larger glyph panel,⁵ the smaller glyph,⁶ which currently leans to the observer's right by about 8°, has unmistakable signs of being a geometric design. It includes a "pit" that, together with a deeply-carved finger, defines a direction at right angles to the edge of the boulder and to the vertical axis of the glyph. However, without further work it is not easy to say what the horizontal horizon was when it was carved. Arguably, the spans of the fingers indicate the altitude of the sun at noon in midsummer; or could it be that the span is $\tan^{-1}(2)$ because the designer was using a square grid for his layout; or could they possibly be just fingers? The "I'm a geometrician" lines on its left cheek may be 45° to the (modern) horizontal, but they are too short to be sure. It's easy to see geometry everywhere once you get started on this, but I'm sure there is some here.

Spalling at DgRw 198

The largest boulder at DgRw 198 is incised with two carved mythical creatures. The panel has however spalled badly and only the beaked head of the second remains.⁷

The spall sporadically engenders a spike in concern among islanders about the longevity of the glyph and the damage that "loggers" have done to it, but this quickly subsides.

⁵ Bentleys, *ibid*, pp.88–9.

⁶ Bentleys, *ibid*, pp.85–7.

⁷ A report of attempts to salvage the spall by various well-meaning people reads like a comedy of errors. All have now been lost; however, it seems the fragments did not include significant portions of the second glyph. Ian R. Wilson, *False Narrows Bluffs Archaeological Investigations*, Permit 1987-40.

My guess is that the spall is actually much older than people imagine and it is not the result of anything some human did. Similar examples in "unlogged" environments are common on Gabriola.

Spalling is a well understood geological phenomenon and has several causes. The "short" explanation for it in this case is that minerals at the surface of the sandstone have been chemically weathered. This weathering has released oxides of iron, and these have cemented the grains of sand in the sandstone more tightly than usual, creating a tough surface zone—the surface has been "case-hardened". Subsequently, disturbance, probably natural, has broken this zone away from the main bulk of unweathered rock.

The "longer" explanation (which you may want to skip) is a quote from an unpublished paper of mine on the marine weathering of sandstone. It goes like this:

Unweathered sandstone in the upper- Nanaimo Group formations is a bright bluish grey with flecks of black *amphibole*, milky-white *feldspar*, and sparkling *mica*. On exposure, it quickly develops a weathered "surface zone" that has an overall sandy-brown colour.⁸ Sandstone that has weathered for a very long time, including below the surface zone, has lost most of this colour and appears predominantly dull grey often with a brownish or greenish cast, with the surface zone being typically darker.⁹ The surface zone itself may acquire a patchy, eggshell-thin, dark-red or dark-brown rind that eventually turns black.

The surface zone is commonly about 20–30 mm thick, which is the limit of penetration by oxygen-

⁸ When fresh, the colour sometimes includes warm-coloured hues such as pink, orange, rose, buff, dark red, or brown.

⁹ Colour changes have been proposed as a means of measuring the weathering rate of sandstone but old rock surfaces are often made more colourful, or greyer and darker, by a patina of lichens. Ultimately, the feldspars (mostly *plagioclase*) erode leaving only *quartz* but I've only seen this on granitic surfaces.

rich water driven by capillary forces.¹⁰ In freshly weathered rock, the boundary between the surface zone and unweathered rock is razor sharp, even when seen under a microscope. On small boulders, this zone frequently exfoliates. Curiously however, when this happens, the newly-exposed surface below the spall often retains its unweathered grey look for some time and no sign of weathering can be seen in the microscope.

Exfoliation of the surface zone of boulders is due to expansion of the zone relative to the underlying rock. This expansion arises because the products of weathering are more voluminous than the original minerals, and until a spall occurs this creates compression stress in the zone, much like the internal stress in the outer layers of tempered glass. So long as the surface remains intact, it is strong and very resistant to further weathering, but once broken or spalled, it continues to break away.

The breakaway line of a spall is usually the inner boundary of the surface zone, but sometimes it occurs a little deeper and some unweathered rock is left adhering to the piece that breaks away. This indicates that it is the rigidity of the surface zone that concentrates externally applied stress and causes it to spall rather than, say, differential thermal expansion.

Most of these observations can be related to the weathering of iron-rich minerals in the sandstone, principally *biotite* and *hornblende*, but also *magnetite* and *pyrite*, which occur as fine particles in the matrix.

Biotite is a mica that is easily weathered, largely because partial oxidation of the Fe^{2+} to Fe^{3+} alters the balance of charges in the structure and releases the cations held in the interlayers between the sheets of aluminosilicates. The water responsible for the weathering distributes ferrous iron (Fe^{2+}) between the grains of the sandstone as it moves through the rock. The iron only remains in solution so long as conditions are favourable for this, principally so long as the pH is low (acidic) and there's not much oxygen. Any rise in pH to a more neutral value, and increase in the available oxygen, will cause the iron to precipitate as very insoluble ferric iron (Fe^{3+}) oxides, and it is these oxides that coat the grains of the sandstone, cementing them at their points of contact, much as does on the threads of a rusty bolt.

¹⁰ I have seen similar weathering in layers of waterlogged sand.

Case-hardening of the surface of the sandstone in this way forms the visors of galleries; the shells of "cannon-ball" concretions and hollowed-out boulders; the "thick-lips" of fractures; and many other interesting weathered-sandstone features commonly seen on Gabriola's shoreline.

Many of the changes in colour observed in the surface zone are attributable to changes in the nature of the iron oxides present as the zone moves toward thermodynamic stability. The iron ions will likely precipitate as *ferrihydrate*, $5\text{Fe}_2\text{O}_3 \cdot 9\text{H}_2\text{O}$ or $5\text{Fe}_2\text{O}_3 \cdot 10\text{FeO}(\text{OH}) \cdot 13\text{H}_2\text{O}$, which has a reddish-brown colour and a poorly ordered structure. *Ferrihydrate* is typically formed in conditions of rapid oxidation and is a "young" oxide. It



Spalling on the downhill side of the large carved boulder at DgRw 198. The surface zone is even more visible in real life because of its reddish colour. Some spall remnants have a dark-brown rind.

This side would have originally been a cross-bedding joint, and the similarity of its weathering with that of the carved front face and the bedding-plane top indicates that the weathering occurred after the rock had fallen from the cliff face.

gradually transforms to the most stable oxide, which is *goethite*, α -FeO(OH), either directly, or by first forming *hematite*, α -Fe₂O₃. *Goethite*, which is named after the German poet, is usually very dark brown, which, when old, appears black. *Hematite*, the possible intermediary between *ferrihydrate* and *goethite*, is dull to bright red (seen in Gabriolan-made bricks and the sites of bonfires on the beach).

Some of the other colours that are observed in the surface zone of weathering may also be due to *goethite*, which does have a yellowish-brown form (a major component of *limonite*) as well as the very-dark-brown form; and to the rarer *lepidocrocite*, γ -FeO(OH), which is bright orange.

The rind observed is likely either the very-dark-brown *goethite*, or *hematite* (when markedly red) on its way to becoming *goethite*. Most of the sandstone is slightly magnetic indicating the presence of minor amounts of *magnetite*, Fe₃O₄. *Magnetite* rather slowly oxidizes to reddish-brown *maghemite*, γ -Fe₂O₃, and then to *ferrihydrate* and eventually, as do all the other oxides, to *goethite*.

That the large glyph panel at DgRw 198 has been carved on case-hardened sandstone, which weathers only slowly, opens up the possibility that the glyph may be very old—“many hundreds”, perhaps a thousand years, as opposed to the “few hundred” of other glyphs in the area—but I emphasize strongly the “may be” as the age of the case-hardening is clearly not necessarily the age of the carving. On the coast, case-hardening develops in just a few years on freshly exposed sandstone boulders.¹¹ Judging by its distinctly reddish colour on all sides, and the dark-brown, not black, rind, I would say that in fact the surface zone in this case is “not ancient” and that its development has occurred since the rock fell. That the boulder is only shallowly buried in litter and

¹¹ In my limited experience, there’s not a lot of difference in effort required to punch a small pit in weathered and unweathered sandstone. Partially spalled sandstone also requires far more force than one might expect to dislodge more of it. It can quite easily be hammered with no effect, so I don’t know if one can tell which came first, surface-zone weathering or carving.

diff suggests also that this fall was “recent”. It also seems to me that the carving was done with the rock in its present situation. Tipping it so as to level the bedding planes would give the glyph a distinctly “head-down” look.

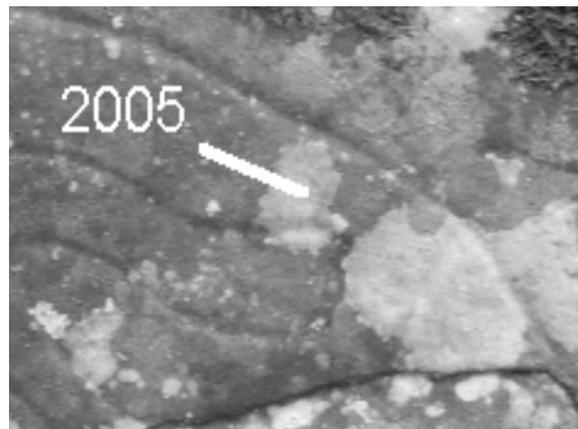
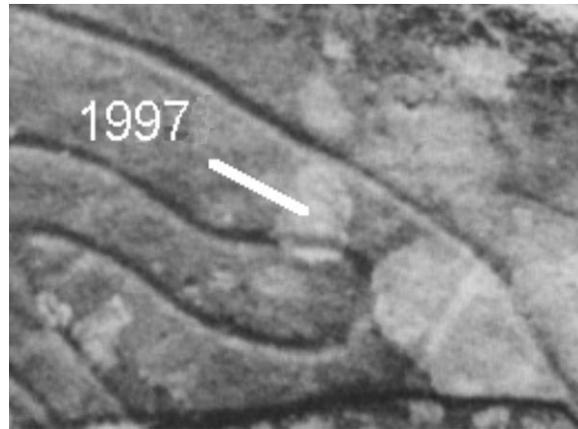
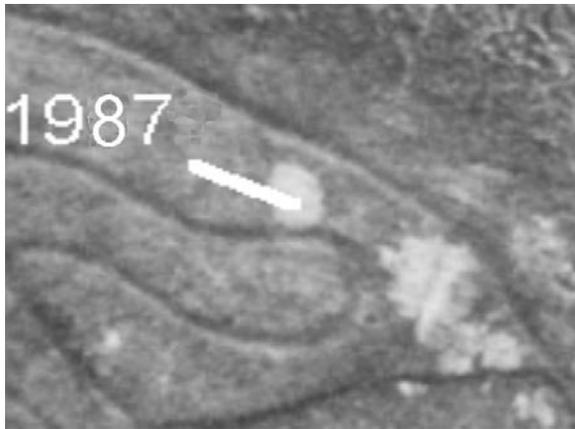
Lichen growth at DgRw 198

The dating of the petroglyphs is an interest of many people, but this is difficult to do. Any hope of doing this scientifically will rely on micro or colour analyses of various sorts, and this requires the glyphs to be pristine, something that is very rare these days. Tampering with the grooves, or introducing foreign material, runs the risk of destroying any evidence of their age that might still be there.

As far as I know, nobody has attempted to use lichenometric techniques to date the petroglyphs on Gabriola, so here are some initial thoughts on the subject.

The photographs on the next page illustrate the growth of a lichen on the petroglyph at DgRw 198 (its position is marked in the larger photographs). The diameter of a mature lichen is said in the literature to increase linearly with age (mm/yr. is constant), and the photographs seem, on first sighting, to support this. There is though an initial growth spurt (again according to the literature) and hence any date arrived at by backward regression will slightly over-estimate the lichen’s age.¹²

¹² Dave H. Lewis & Dan Smith, *Little Ice Age glacial activity in Strathcona Provincial Park...*, Can. J. Earth Sci. 41: pp.285–97, 2004. Daniel P. McCarthy, *Estimating lichenometric ages by direct and indirect measurement of radial growth...* Arctic, Antarctic, and Alpine Research, 35 (2): pp.203–13, 2003.

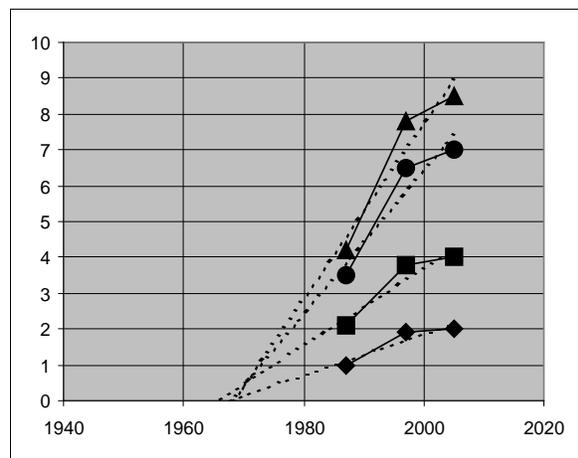


According to the lichenometric literature, the diameter of a lichen increases linearly with age, perhaps after an initial growth spurt. The growth of this and three similar lichens on the unspalled surface appears to support this (but see text). A “proper” analysis however would require identification of this and other species present on the rock surface, which is not within my present skill-set.* Three samples of a different species of lichen on the spalled part of the surface give different results.

* The bright grey lichen is possibly *Acarospora* sp., but this is not an expert opinion.

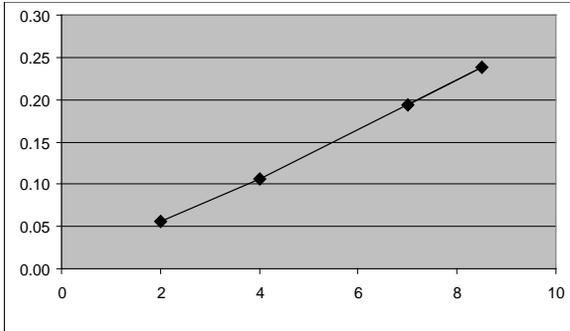
A plot (shown opposite) of the sizes, as seen in the photographs, of four lichen patches on the unspalled surface over time produced a surprise. Backward linear regressions all converge on an unlikely date of 1967 ± 0.8 .

Now there is something seriously wrong with this. First, although one can dream up scenarios which would explain why all four lichens were exactly the same age, it is less easy to explain why their growth rates, as indicated by the slopes of the curves and present sizes, are different. Most lichenometric analyses seem to depend on growth rates being constant (the older the lichen, the larger it is). If this were true, the four curves in the plot would have identical



slopes, which they clearly don't.¹³ At this point, we have to think for ourselves.

¹³ The actual rates are between 0.75 and 3.2 mm/yr. The units on the first two graphs are arbitrary and are as measured on photographs.



The rate of growth of the lichen is linearly dependent on its size. Units are arbitrary (as measured from photographs).

The plot above gives the clue as to what is going on. It shows the rate of growth as function of size. Unmistakably, the bigger the lichen the greater its rate of growth. And I think there is a plausible explanation for this, and that is that the growth of this particular lichen is limited by the quantity of nutrients it can extract from the rock. If we measure this quantity by the area of the rock covered by the lichen then we get the simple mathematical (first-order differential) relationship between growth rate and size:

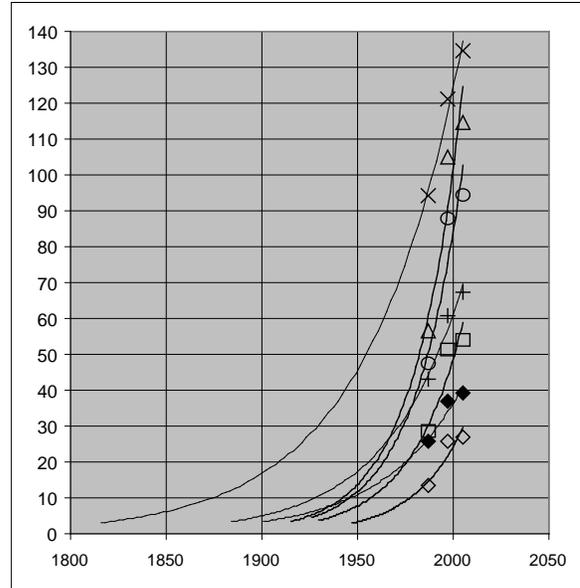
$$\frac{dA}{dT} = kA$$

where A is the area, k is an arbitrary constant related to nutrient supply (probably calcium and potassium), and T is time.

For a circular patch of radius R, $A = \pi R^2$, this becomes:

$$\frac{dR}{dT} = \frac{kR}{2}, \quad \text{and hence } R = R_0 \exp\left(\frac{kT}{2}\right)$$

where R_0 is an arbitrary constant related to the starting conditions. In other words (or symbols), the increase in radius of the lichen is exponential, not linear. The more it grows, the more nutrients become available for growth.



Exponential regression shows the lichens to date from before 1950. The three oldest are from the spalled patch of rock, suggesting perhaps that the unspalled surface was “cleaned off” sometime in the early-20th century and the spall occurred in the 19th century.

The units of the vertical scale are millimetres as they would be if measured on the glyph.

Now if we go back to the original plot and perform a backward exponential (not linear) regression analysis, we get something entirely different. Thankfully, two problems have been resolved. The lichen patches are not the same age, and they date from sometime before 1950. This doesn't provide much information, I agree, but it's a start.

There is always a faint chance that the boulders were dislodged during one of the megathrust earthquakes in the last thousand years; however, boulders can come down at any time. That they came down “recently” (a few hundred years ago) would nicely fit with my gut feeling about the age of other glyphs in this area, but research goes on, and there will doubtlessly be more surprises along the way. \diamond