Honeycombing of a gravestone at Tilton on the Hill, Leicestershire, UK

The remarks in this file were originally posted in May 2015. In July 2015, I received more information from a local resident of Tilton on the Hill, and this information completely changed the picture.

According to the new information, the gravestone is not sandstone, it's limestone. The green tint may not be due to algae; it's most probably due to mineral staining.

The weathering is thus not salt-weathering of the kind seen in sandstone. It's also probably not a result of asymmetrical exposure to the sun, but is more likely due to asymmetrical exposure to driving rain; however, limestone weathering is not something I have any detailed practical experience of.

It's an example of how speculation based solely on a photograph can be seriously flawed. The new information is as follows:

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I have examined the
gravestone in question.

There is no honeycombing on
the rear of the stone.

It is one of several in the
churchyard made of the same
stone, which I think is the
high quality oolitic
limestone which comes from
ancient quarries at Barnack
some twenty miles to the
east of here. It's known
locally as Barnack Rag.

The stone has been used
since Roman times and was
used in the building of
several cathedrals
hereabouts and many of the
buildings at Cambridge
University.

All the stones have some
brown and green staining,
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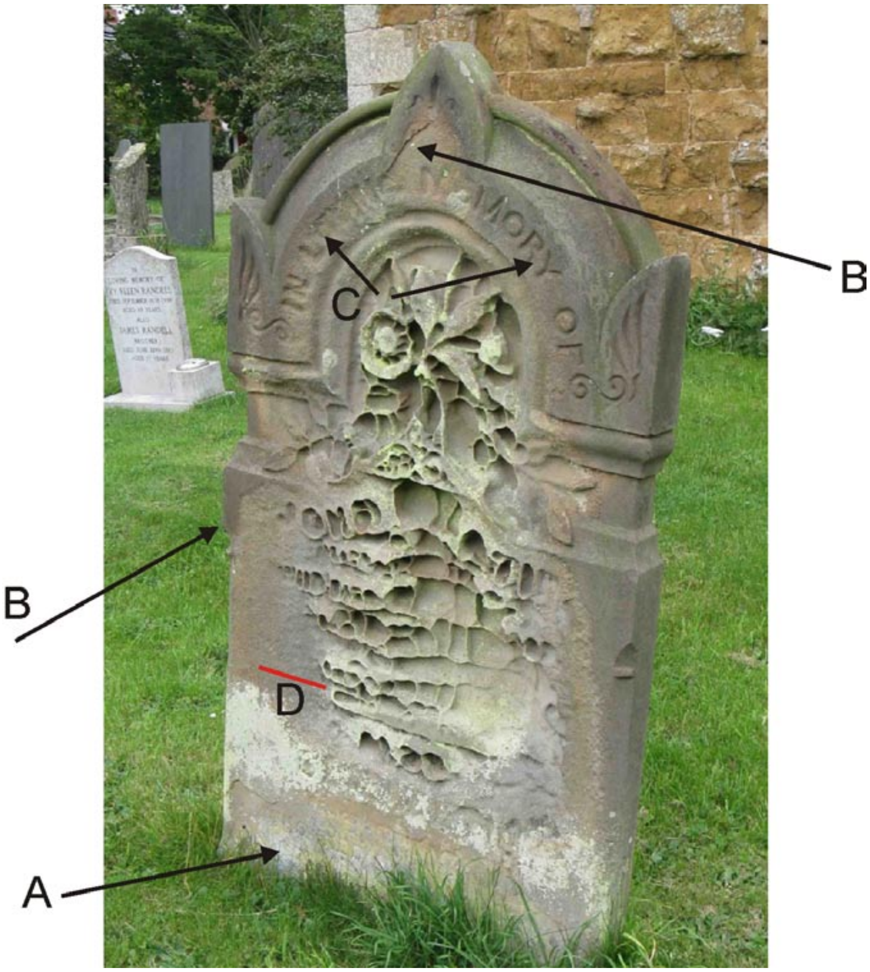
Barnack Church

which is probably due to iron impurities in the original rock being oxidised to ferric (brown) or ferrous (green) salts by long-term weathering.

The stone you picture has rather more green staining, which I believe may be due to its slightly more exposed position in the Churchyard.

JA
July 12, 2015

Honeycombing of a gravestone at Tilton on the Hill, Leicestershire, UK —notes by Nick Doe.



A: efflorescence? white with faint tinges of pink, if it is an evaporite mineral it's probably *calcite* with minor *magnesite* with colour added by traces of *hematite*. Also very possible is that it is just desiccated algae, not a mineral salt;

B: spalling, case-hardening. Case-hardening develops compressive stress at the junction of the weathered surface and underlying unweathered stone and this makes the surface layer prone to spalling;

C: asymmetrical weathering possibly related to orientation;

D: possible bedding plane orientation giving rise to the linear arrays of honeycomb holes.

Photograph by Maurice Rogers

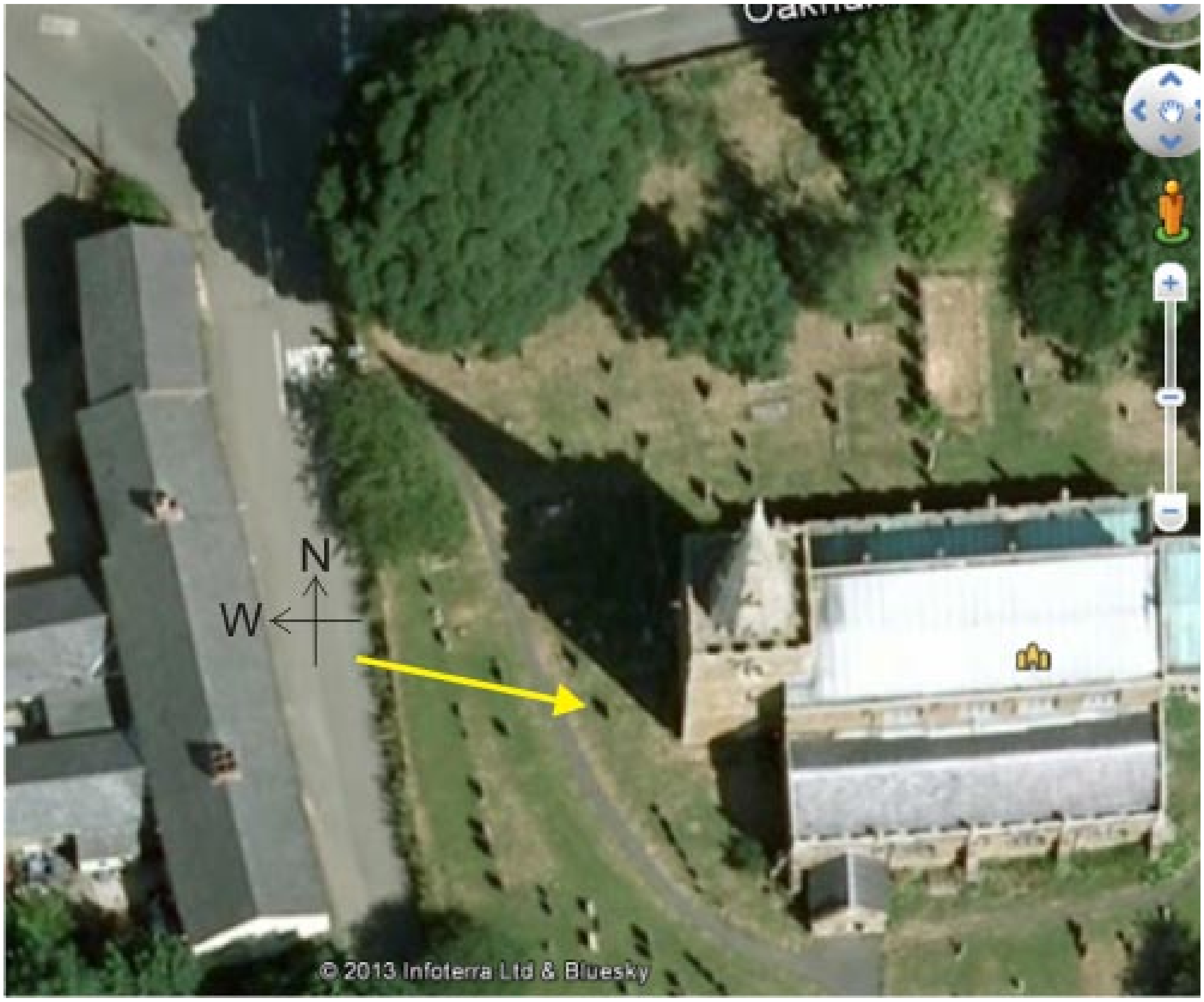
Photograph kindly provided by Maurice Rogers of Rugby, Warwickshire, UK.

The stone is on the west side of St. Peters Parish Church, (52° 38.610' N, 0° 54.167' W) and is presumably sandstone, but I have no petrographic information other than what can be gleaned from the photograph, the stone being a very long way from where I live in Canada. [More local information very welcome]

Judging by what appears to be efflorescence [A] at the ground level, the sandstone is quite porous. The presence of efflorescence would indicate a fairly high probability of there being subflorescence present also, and, if so, this could be weakening the cementation of the sandstone.

There are traces of spalling[1] [B] so the sandstone does retain some mafic mineralization [*biotite*, *amphibole*?]. The weathering, judging

[1] Very noticeable on the headstone of John Lorimer.

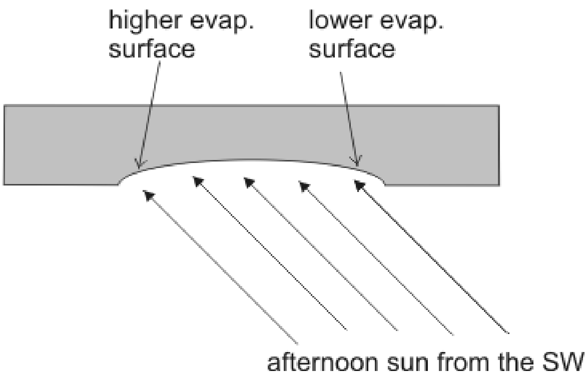


The location and N-S orientation of the stone means neither side faces the sun at noon; however, the front face facing west receives uninterrupted illumination during the afternoon and evening; while the back face is in the shadow of the church throughout the morning. Sun absorbed on the front face during the day keeps the stone warm in the evening and increases evaporation from the holes as the outer air cools. This does not happen on the back side of the stone so evaporation remains low there.

Rainfall (≈700 mm/yr) is not particularly seasonal at Tilton on the Hill and common wind directions are NW, SE, and less often W. The sea to the northwest is about 180 km away.

from the reddish hue, is to *hematite* and by the dark colouration to *goethite*. Brown weathering near the surface may contain manganese.

Weathering of mafic minerals produces an iron oxide/hydroxide *limonite*-cement that case-hardens the surface of the sandstone making it stronger and less permeable, possibly less porous too. It increases the stone's resistance to salt-weathering. Often however, this increased resistance accelerates the weathering of near-by patches of the surface where case-hardening has not occurred or has been breached, which appears to be the case here. This acceleration is due to raised evaporation rates and salt deposition on the unprotected surfaces. Salt-weathering



Very speculative explanation for the asymmetrical weathering pattern C on the front face.

proceeds faster than does case-hardening weathering so once salt-weathering has begun, it doesn't stop, unless there are significant changes in the environment.

The stone faces west, with the church behind it, which makes it a good "salt-pump" position. The sun at noon is edge on, illuminating both faces only obliquely, but the front face seen here (the high-evaporation side) faces the sun in the afternoon and is not shaded by trees or buildings, and is exposed to any wind; while the back face (the low-evaporation side) will be shaded by the tall church in the morning and will be on the backside in the afternoon, making it cooler. There is presumably no honeycombing on the back face as a consequence. [true?]

If the contrast in evaporation rates between the front and back faces is strong enough, and the geometry of the porosity is right, and the stone is not too thick, water will slowly migrate through the stone to the high-evaporation side where it deposits the salt that causes honeycombing. Once a cavity has formed, salt deposition will be higher on its back wall.

Often, the weathering salt is sea-salt (mostly sodium chloride), though sodium sulphate is more damaging, and magnesium sulphate is even worse. The puzzle here is that the stone is not by the sea. A viable speculation might be that the source of the "salt" is actually within the rock. This can happen if the sandstone was immersed in the sea for a long time, during the Pleistocene for example. Here though, it's not likely to be chlorides as these are very soluble and rapidly leached.

My guess is that it is the calcium carbonate that is the "problem". It needs a petrographic analysis to see how the *calcite*, assuming it's there, is distributed within the stone and if there is any evidence of it having been leached leaving microfractures or interstices behind.

Half of a 3D photograph of the stone showing that the honeycombed portion once stood proud of the face. According to the camera taken in January 2011.

Photograph by Matt Neale via Wikimedia Commons

Top left: the subject headstone seen from the road

Bottom left: another headstone a little to the SW but seen from the same vantage point appears to be similar to the subject stone. It also shows efflorescence? near the ground, and there are traces of what I take to be marble (*calcite* and *dolomite*) on the top edge though it might be lichen, and there is algae, but only at the top of the stone.

Calcium carbonate is not very soluble, but it is leached by acid rain thereby increasing the porosity of the sandstone making it more vulnerable to honeycombing.I have limited experience however of sandstone where *calcite* is the main honeycombing agent. We do have lots of calcareous concretions in the local sandstone [Gulf Islands, western Canada].

Most weather more slowly than the clay-cemented host sandstone, I assume because it is less permeable, but there are not infrequent examples where the concretion is weathering faster than the host rock just because the pH of the environment is low, though this kind of weathering is not honeycombing.

Maybe the "salt" is not a carbonate but is a sulphate, perhaps from pollution?....needs mineralogical data to end the speculation.

The greenish tinge to the weathered surface invites the suggestion that the weathering is the result of lithobiontic activity. That the tinge is not due to the clay mineral *chlorite*, which is a common weathering product of feldspars, is evidenced by its presence on many other stones in the graveyard[2] including a stone made of granite.[3]

It looks as though most of the moisture collected by the stone is from rain borne by northwest or west winds rather than being wicked from the ground in an arid environment; however, having enough moisture to support algae on an actively salt-weathering surface is very rare and raises the question as to how this can, at the same time, be a surface where evaporation is high? Usually algae on a surface is an indication that the salt-

[2] For example, headstone of Warren Neall.

[3] Headstone of Peter and Maria Sharpe.

weathering is old and is no longer in progress.

What strikes me about honeycombing is that it generally looks the same no matter where it occurs. I've seen honeycombs in Western Australian deserts that look just the same as here in the Gulf Islands in the Pacific Ocean, and there certainly was far less greenery down there, but just as much salt.

I can see that lithobionts, if present, may be altering the porosity of the outer surface of the rock in a minor way and thereby altering the weathering rate, either positively or negatively, but I don't see that they by themselves could create the damaging Thiessen polygons, as here, without there being salt-weathering present.

This stone and its condition certainly raises a number of interesting questions. ◊

May 20, 2015.