Weathering (Part 1)

Weathering is defined as the continuous in-situ breakdown of rock at or near the Earth's surface, and it eventually creates what is called 'regolith', i.e. the weathered skin of the Earth's crust (Fig. 1). Regolith has been described as comprising 'everything between fresh air and fresh rock' (Pillans (2007).

Weathering produces rock fragments from boulder to silt-clay size which form the 'fuel' for the various downslope erosional processes described in my previous articles, e.g. soil creep, solifluction, river erosion, etc. This material formed by weathering, when transported by erosion into rivers, lakes, or the sea becomes sediment, whilst if it remains as a stable cover over the land, it becomes soil.

Any exposed rock at the surface of the Earth, from mountain sides, through buildings, to gravestones or pebbles, will all be subject to the different kinds of weathering, namely:-

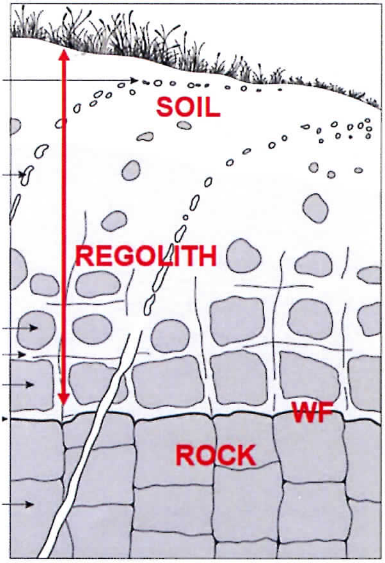

Fig. 1: Sketch of the weathering zone, otherwise known as regolith.
WF = Weathering Front.

1. Mechanical weathering: the physical breakdown of rock, by heating, freezing, or impact.

2. Chemical weathering: dissolution, disaggregation, or corrosion of rock by chemical reactions, usually requiring the presence of water with dissolved CO2 or SO2, (i.e. very dilute carbonic or sulphuric acid, respectively).

Fig. 2: Scree slopes (red arrows) below the Devils Chimney, Leckhampton. A = whilst quarry was still working (~1860, from www.archive-images.co.uk). B = Recent: scree slopes, now mostly vegetated (from www.cotswoldhillsgeopark.net).

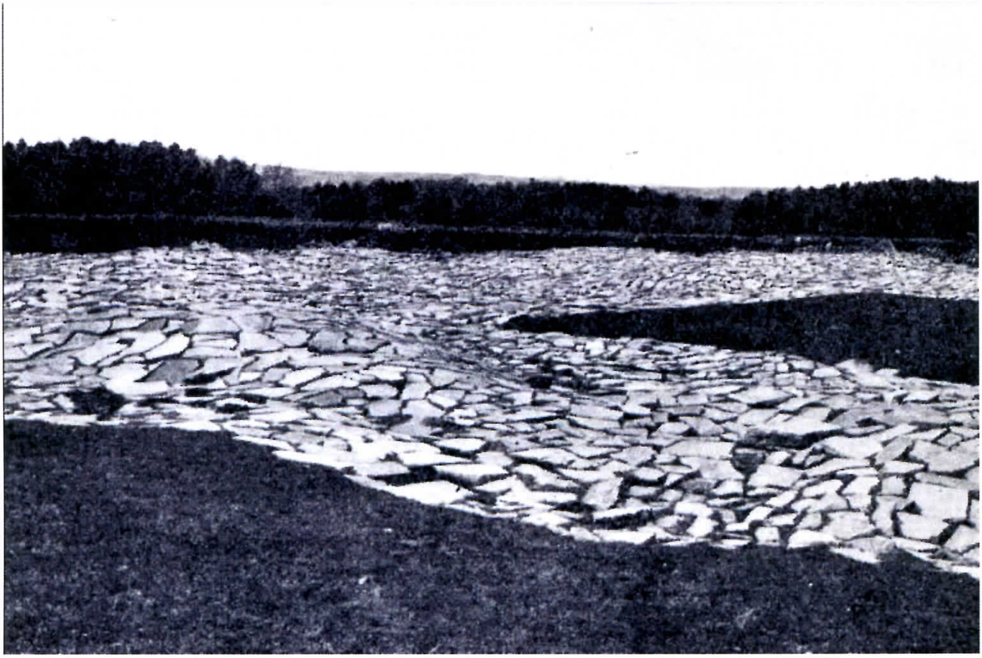

Fig. 3: Slabs of Stonesfield slate laid out in the fields to be split by frost action (from Finberg (1955)).

3. Fire: breaks down the ties that bind plants (trees, grasses) to the soil or rocks.

4. Biological weathering: the breakdown of rock by biological agents or processes.

The process of weathering has been essential for life on Earth. The physical disintegration and chemical / biological decomposition of rock is the primary source of all the essential elements for life (except water and atmospheric gases) e.g. phosphorous, potassium, carbon, magnesium, and many trace elements, which are released through weathering in a form directly available to all life (Hoffland *et al* (2004)).

The first three weathering processes will be discussed here in turn:-

Mechanical weathering refers to the physical breakdown of rock. The principal processes are:-

- Freeze and thaw: Dominant in high altitude and cold – temperate regions. Frost shattering works due to the volume expansion of water upon freezing, causing rock to split. Mountain peaks and rock outcrops thereby shed

Fig.4: Frost splitting of gravestone, Naunton churchyard.

blocks of rock downslope to form screes, like the classic Wastwater screes of the Lake District, or boulder fields, as found on the Stiperstones Ridge in Shropshire. Scree slopes fed by freeze-thaw are uncommon in the Cotswolds because of the generally benign climate and the lack of high-relief cliffs and peaks, but they can be seen at a small scale below quarry faces, e.g. around the Devil's Chimney, Leckhampton (Fig.2), and face of the Cotswold escarpment, e.g. below Cleeve Cloud.

Freeze and thaw was also essential to the production, until recently, of Stonesfield roofing slates. The slabs of rock were quarried or mined in autumn from a band of fissile limestone at the base of the Great (Upper) Oolite. The slabs were kept damp, and then laid out in the fields when hard frosts were due (Fig. 3). The frost froze the thin films of water along the bedding planes of the stone, weakening them so that a blow from a mallet would be enough to split the slabs into the roofing slates.

Freeze and thaw action can also be seen in churchyards, where it is responsible for the splitting of some gravestones (Fig.4)

Fig. 5: Onion-skin weathering, formed by diurnal heating and cooling (from 'Spread of Geological Knowledge' on Facebook).

- Heating and cooling: not seen in the Cotswolds, but in hot desert climates. The heating of rock surfaces during the day, followed by rapid cooling as the sun sets, causes the outer layer of rock to crack, typically forming 'onion skin' weathering (Fig. 5)

Fig. 6: Honeycomb, or careous, weathering formed by salt crystal growth in the pore spaces of this sandstone (on the coast of Washington State, USA, from zschierlphotography.com).

- Salt crystal growth: in coastal environments, where rock surfaces can be invaded by salt water. The subsequent growth of salt crystals within the pore spaces of the rock can break up or disaggregate the rock. Sandstones are especially prone to this effect, producing 'honeycomb' or careous weathering (Fig. 6).
- Impact: the impact of torrential rain and/or hail can break down soft rock outcrops or displace grains

of sand or rock on the land surface. In addition, the impact of frost-shattered boulders (see above) on the rocks onto which they fall, is sufficient to break them into smaller and smaller pieces.

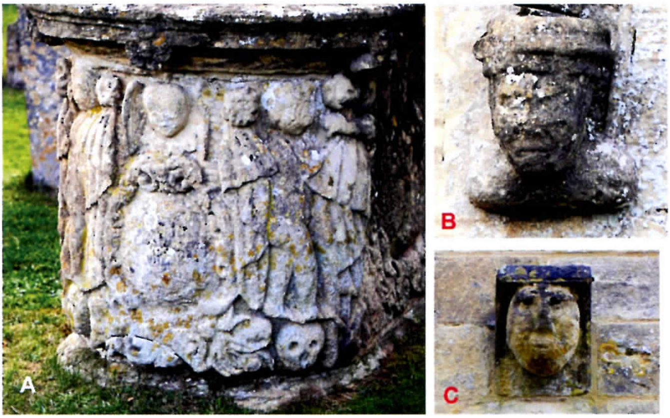

Fig. 7: Chemical weathering of limestone tomb and church fabrics. A and B = Northleach church; C = Naunton church.

Chemical weathering, where chemical reactions attack individual mineral grains in the rock, causing dissolution and/or disaggregation. These reactions include:-

- Acid attack: is seen in the corrosion of rock by rain water containing dissolved carbon dioxide (from the atmosphere) or sulphur dioxide (acid rain - from industrial pollution), which effectively turns the water into very dilute carbonic or sulphuric acid, respectively. Limestones are especially prone to such attack, as seen in the gravestones of many Cotswold churchyards, and on the fabric of many old churches and cathedrals (Fig. 7).

  Recent comparative studies of marble gravestones found that weathering rates in rural areas were ~5 times lower than those in urban, industrial sites (where acid rain was far more common and concentrated).

  Pooling of water in hollows on the surface of limestone outcrops (or standing stones) slowly dissolves the limestone to create circular or irregular depressions called weathering pits (Fig. 8), which may be subsequently occupied, and deepened, by grass or mosses.

- Hydrolysis and Oxidation: these processes basically convert minerals which are unstable at near-surface conditions (because they formed at high temperatures and pressures, namely as igneous and metamorphic rocks) into minerals which are stable at low temperatures and pressures. A classic example is provided by the china clay deposits of Cornwall, formed by the rotting of feldspars of the Cornish granites into kaolinite (a soft clay mineral).


Fig. 8: Weathering pit, with floral offering (Rollright Stones, Oxfordshire).

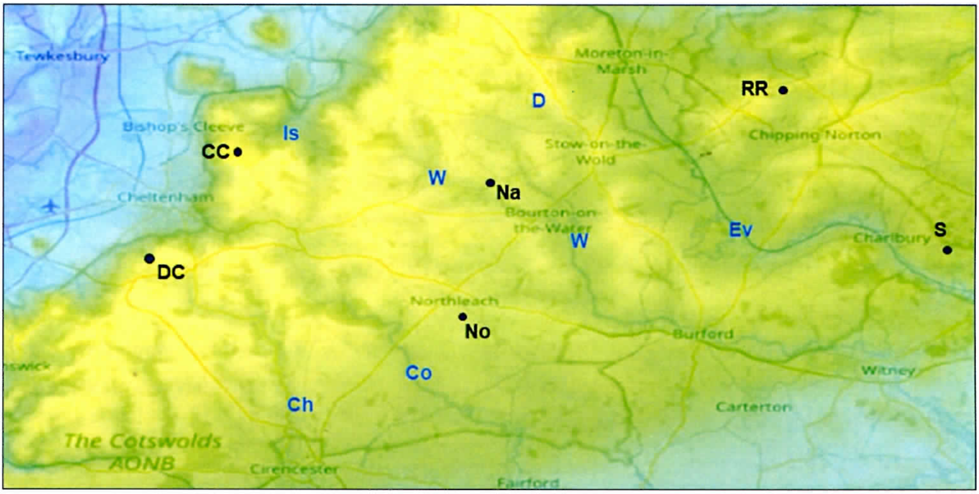

Fig 9: Map showing the location of local places mentioned in the text (in black):- DC = Devil's Chimney, Leckhampton; CC = Cleeve Cloud; Na = Naunton; No = Northleach; RR = Rollright Stones; S = Stonesfield. Rivers (in blue):- Ch = Churn; Co = Coln; D = Dikler; Ev = Evenlode; Is = Isbourne; W = Windrush.

In the weathering profile (regolith – see Fig. 1) the circulation of water, air, acids, and organic compounds causes the conversion of rock fragments into clay minerals and fine sand, which then bind together with humus and other organic material to form soil.

The presence of oxygen in pore waters attacks iron-rich minerals, especially in sandstones. The oxygen causes ferrous ($Fe2+$) iron compounds to convert into ferric ($Fe3+$) iron oxides or hydroxides (rust: red-coloured) which can cause disaggregation of the sandstone.

Fire: Roughly 3% of the Earth's surface burns every year (Archibald *et al* (2018). These fires range from slow, smouldering peat fires to intense crown fires, depending on vegetation type, moisture levels, and prevailing weather conditions. The North Cotswolds is fortunate that it is not subject to wildfires, but at a global level, fire is a very efficient source of material for the erosive processes of rain, slopewash, and stream flow that follow the fire, because it breaks down the ties that bind plants (trees, grasses) to the regolith. As a result, ash, soot, and charred vegetation and soil can clog up streams, dams, and beaches and degrade water quality.

For the local localities mentioned in the above text, see Fig. 9.

Biological weathering: this will be discussed in the following article.

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