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Survey of selected tufa forming sites in Staffordshire, UK

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BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT OR/19/054

Survey of selected tufa forming sites in Staffordshire, UK.

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Front cover

Tufa deposits at Trickle Ridge: © BGS

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¹ British Geological Survey

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Foreword

This report is a record of a survey of a small selection of seven tufa forming sites in Staffordshire commissioned by Nick Mott of Staffordshire Wildlife Trust. The survey was undertaken between 17th and 18th of June 2019 by Gareth Farr (hydrogeologist) and Jonathan Graham (bryologist) accompanied by Nick Mott (Staffordshire Wildlife Trust). The aim of the survey was to determine the assess the ‘H7220’ tufa forming springs habitat and make recommendations for future site enhancement.

Acknowledgments: We would like to thank the various landowners who granted access during the survey. We would also like to thank the BGS Inorganic Geochemistry Laboratory for undertaking the water analysis.

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1 Introduction

Tufa sites are not well described for Staffordshire. Calcareous tufa forming springs, seepages and water courses with the mosses *Palustriella commutata*, *Palustriella falcata* qualify as the European habitat ‘H7220 Petrifying springs with tufa formation (*Cratoneurion*)’. Naturally occurring tufa forming springs and seepages are important wildlife habitats, especially for invertebrates, but remain little known in Britain for invertebrates (Boyce, 2002). Several tufa-forming sites are known to occur within existing Sites of Special Scientific Interest (SSSI) but are not directly referenced within the citations. The aim of this survey is to report on a small selection (7) of known tufa sites within Staffordshire determine the presence of H7220 habitat and make recommendations for enhancement. This is not a comprehensive survey of Staffordshire’s tufa forming habitats.

Table 1 Site location, geology and occurrence of tufa and H7220 habitat

Site	Grid Ref	Flow	Site description & geology	Active Tufa	<i>Palustriella</i>	H7220
Stanton Pastures	SK1198 246962	Springhead	Spring head with tufa dome in open field. Carboniferous Bowland Shale.	Yes	<i>P. falcata</i>	Yes
Limestone Hill	SK1381 646140	Seepage	Wooded stream valley (Ordley Brook) with waterfall and adjoining seepages with tufa. Sandstones of the Triassic Chester Formation.	Yes	<i>P. commutata</i>	Yes
Kirksteads Brook	SK0908 056817	Surface water brook	Lightly wooded brook with series of tufa barrages. Carboniferous Ecton Limestone formation.	Yes	No	No
Trickle Ridge	SK0069 248260	Seepage	Tufa seepage in woodland with large tufa block "Trickle Ridge". Carboniferous Woodhead Hill Rock	Yes	<i>P. commutata</i>	Yes
Emerald Cave	SK0050 748425	Seepage	Tufa seepage in woodland with localised tufa domes. Carboniferous Woodhead Hill Rock	Yes	<i>P. commutata</i>	Yes
Booth's Wood	SK0008 848546	Seepage	Wooded seepage with small amounts of tufa. Carboniferous Lower Coal Measures formation.	Yes	<i>P. commutata</i>	Yes
"The Petrifactio ns"	SJ9209 634761	Seepage	Wooded valley with shallow waterfalls, steep rock faces with tufa. Triassic Kibblestone member and Mercia Mudstone Group	Yes	<i>P. commutata</i>	Yes

2 Methodology

2.1 SITE SURVEY

Seven sites were selected by Nick Mott (Staffordshire Wildlife Trust) and surveys were commissioned and undertaken on 17 and 18th June 2019. Site vegetation (flowering plants and bryophytes) was recorded using nomenclature adopted follows Stace (2010) for most flowering plants; Cope & Gray (2009) for grasses; Atherton, Bosanquet & Lawley (2010) for bryophytes.

2.2 WATER ANALYSIS

Water samples were collected from drip water directly below areas of tufa formation that has both active tufa formation and contained the target moss species *P. commutata*. pH, electrical conductivity, temperature and alkalinity were measured in the field. pH and electrical conductivity were measured on a hand held Hanna meter and temperature on a digital thermometer. Field alkalinity was measured using a digital titrator, with three measurements made for each inorganic water sample sent to the laboratory. Each water sample was filtered using a 0.45 µm filter into two separate 35 ml plastic bottles. The water samples were chilled and sent to the UKAS accredited British Geological Survey Inorganic Geochemistry Laboratory (Nottingham) for ICP-MS and IC analysis of major ions, nutrients, alkalinity and trace elements. The same method and laboratories were used for studies in Wales and Gloucestershire (e.g. Farr et al., 2014; Farr & Graham, 2017, Graham et al., 2019). Full chemical analysis of major and minor ions are included in Appendix 3.

3 Results

3.1 SITE SURVEY

Seven sites were surveyed. The details of all sites are provided in Table 1 and the location of sites is shown on Map 1. Photographs are included in Appendix 1; All plant data (flowering plants and bryophytes) is provided in Appendix 2 and water chemistry in Appendix 3.

3.1.1 Stanton Pastures

A small tuferous spring head underlain by Carboniferous Bowland Shales, situated in an open cattle-grazed field that feeds a small area of rushy pasture dominated by hard Rush *Juncus inflexus* and Jointed Rush *Juncus articulatus*. The immediate spring head has a raised tufa dome with the stonewort *Chara vulgaris* and bryophytes *Palustriella falcata*, *Bryum pseudotriquetrum*, *Scorpidium cossonii* all actively associated with tufa formation. Locally the two mosses *Philonotis calcarea*, *Plagiomnium elatum* also occur.

The adjoining spring-fed rushy pasture supports a large number of flush or wetland species including Marsh Marigold *Caltha palustris*, Cuckoo Flower *Cardamine pratense*, Star-sedge *Carex echinata*, Carnation Sedge *Carex panicea*, Marsh Thistle *Cirsium palustre*, Common Spotted Orchid *Dactylorhiza fuchsii*, Slender Spike-rush *Eleocharis uniglumis*, Hoary Willow-herb *Epilobium parviflorum*, Red Fescue *Festuca rubra ssp. rubra*, Yorkshire Fog *Holcus lanatus*, Greater Bird's-foot Trefoil *Lotus pedunculatus*, Water Mint *Mentha aquatica*, Tufted Forget-me-not *Myosotis laxa ssp. caespitosa*, Meadow Buttercup *Ranunculus acris*, Ragged Robin *Silene flos-cuculi*, Marsh Arrow-grass *Triglochin palustre* and the moss *Calliergonella cuspidata*.

Slightly raised areas within the calcareous seepages support small flowering stands of Common Butterwort *Pinguicula vulgaris* with Quaking-grass *Briza media*, Devil's-bit Scabious *Succisa pratensis*, Purging Flax *Linum catharticum*, Common Milkwort *Polygala vulgaris* and the moss *Ctenidium molluscum*. Slightly raised areas within the seepage area, above the influence of the calcareous flush water, are mildly acidic and of interest in supporting small numbers of calcifuge species including Common Cotton-grass *Eriophorum angustifolium*, Heath Louse-wort *Pedicularis sylvestris* and Tormentil *Potentilla erecta*.

3.1.2 Limestone Hill

Despite its name, the steeply eroded banks of the Ordley Brook comprised of red coloured Triassic age Sandstones. The wooded upper section of the Ordley Brook supports ancient sycamore, alder, ash, hazel woodland with occasional holly, guelder rose with ivy, bramble on the ground beneath. The brook descends a gradient below a minor road (Stanton Lane) where there are a number of small falls before the brook widens at the point of a larger crescent-shaped waterfall. Below this larger waterfall the brook is bordered on both sides by steep dripping vertical rock faces with tufa and the mosses *Palustriella commutata*, *Eucladium verticillatum* and very occasional Hart's-tongue Fern *Asplenium scolopendrium*. The rock faces on the west side of the brook are more heavily shaded and dominated by *Eucladium* and only have localised stands of *Palustriella*.

Rocky terraces and the lower parts of rock faces (within the flood/splash zone of the brook) have dominant stands of the liverwort *Pellia endiviifolia* with other bryophytes including *Cratoneuron filicinum*, *Conocephalum conicum*, *Rhizomnium punctatum* and occasional stands of Wavy Bitter-cress *Cardamine flexuosa*. Locally, seepages with Opposite-leaved Golden Saxifrage *Chrysosplenium oppositifolium* and the moss *Brachythecium rivulare* also occur. Stones within the brook are dominated by the pleurocarpous moss *Platyhypnidium ripariodes* and localised stands of a tiny non fertile moss likely to be *Fissidens crassipes*.

Rich deep soil is present further up the banks of the wooded brook and supports a relatively rich ground flora including many species considered characteristic of ancient woodland including Wood Anemone *Anemone nemorosa*, Wild Garlic *Allium ursinum*, Bluebell *Hyacinthoides non-scripta*, Yellow Archangel *Lamiastrum galeobdolon*, Dog's Mercury *Mercurialis perennis*, Wood Sanicle *Sanicula europaea*, Greater Stitchwort *Stellaria holostea*, Wood Sorrel *Oxalis acetosella* and Wood Speedwell *Veronica montana*.

3.1.3 Kirksteads Brook

This site comprises a steep section of the Kirksteads Brook complemented with a series of tufa dams bordered by ash, hawthorn, hazel, wych elm scrub woodland just above its outfall to the River Manifold. A series of tufa dams are present dominated by the bryophytes *Pellia endiviifolia* and *Platyhypnidium ripariodes*. The rocky edge of the brook support stands of the moss *Cratoneuron filicinum* with occasional stands of Wavy Bitter-cress *Cardamine flexuosa* and the thalloid liverwort *Lunularia cruciata*. Marginal seepages have Opposite-leaved Golden Saxifrage *Chrysosplenium oppositifolium*, the moss *Brachythecium rivulare* and more open areas support 'tall fen' vegetation with Wild Angelica *Angelica sylvestris*, Common Valerian *Valeriana officinalis*, Greater Willowherb *Epilobium hirsutum*, Meadow-sweet *Filipendula ulmaria*. Shaded banks under scrub woodland support a moderate woodland ground flora including several species considered characteristic of ancient woodland including Sweet Wood-ruff *Galium odoratum*, Dog's Mercury *Mercurialis perennis*, Wood Avens *Geum rivulare* and Greater Stitchwort

Stellaria holostea. The bed of the brook, particularly in the lower section close to its outfall to the River Manifold, has a thick layer of gravel comprised of loose tufa and tufa-encrusted stones.

3.1.4 Trickle Ridge

A remarkable site within a woodland section of the Churnet valley where a series of tuferous seepages converge down a relatively steep slope to form a very large and impressive feature known locally as “trickle ridge”. This site has a history of local people maintaining a grove along the top ridge of the tufa block to concentrate the water flow, in turn, this influences the formation of new tufa and so greatly raise its height. The thickness of the tufa deposit is unknown but it protrudes from the slope of the bank, the underlying geology is reported to be the sandstone dominated Carboniferous Woodhead Hill Rock.

The upper springheads appear within ash, sycamore, alder woodland and are tuferous with Pendulous Sedge *Carex pendula*, Hart’s-tongue Fern *Asplenium scolopendrium*, Wavy Bitter-cress *Cardamine flexuosa* and the bryophytes *Cratoneuron filicinum*, *Brachythecium rivulare*, *Pellia endiviifolia*, *Conocephalum conicum*. Locally there are marginal stands of Opposite-leaved Golden Saxifrage *Chrysosplenium oppositifolium* and Wild Garlic *Allium ursinum*. The pleurocarpous moss *Palustriella commutata* occurs locally at the springheads on stones and tree roots and then becomes the dominant species covering most of the tufa block of “trickle ridge” below along with very occasional strands of the shade tolerant moss *Eucladium verticillatum*.

The shaded banks away from the seepages support a moderate woodland ground flora including several species considered characteristic of ancient woodland including Wood Melick *Melica uniflora* and Wood Sorrell *Oxalis acetosella*. Seepage flow from the bottom of “trickle ridge” descends a steep vertical bank before collecting and outflowing under a footpath to the river. The large thalloid liverwort *Conocephalum salebrosum* occurs in the vicinity of this outfall. It was noticed that *Palustriella* had died back (going brown) in a few places on the top of “trickle ridge” and that this die back most probably relates to the previous hot summer of 2018.

3.1.5 Emerald Cave

A site just to the west of Trickle Ridge where several tuferous springheads converge and have associated small tufa domes. The underlying geology is reported to be the sandstone dominated; Carboniferous Woodhead Hill Rock. One of the springheads has a concrete chamber constructed around it to collect water (see photograph in Appendix), and this has been confirmed as a private water supply. The upper springheads are dominated by the bryophytes *Pellia endiviifolia*, *Brachythecium rivulare*, *Cratoneuron filicinum* with occasional Hart’s-tongue Fern *Asplenium scolopendrium*, Wavy Bitter-cress *Cardamine flexuosa*, Opposite-leaved Golden Saxifrage *Chrysosplenium oppositifolium*, Wild Garlic *Allium ursinum*, Tufted Hair-grass *Deschampsia cespitosa* and the liverwort *Conocephalum conicum* towards the margins. Several tufa domes are present dominated by *Palustriella commutata* of which the largest is raised c30cm above ground level.

Lower down the slope, the seepages converge in more open woodland and are dominated by Pendulous Sedge *Carex pendula* with other taller species in small quantity including Wild Angelica *Angelica sylvestris*, Greater Willowherb *Epilobium hirsutum*, Meadow-sweet *Filipendula ulmaria*, Hoary Willowherb *Epilobium parviflorum*, Hogweed *Heracleum sphondylium* and Woody Nightshade *Solanum dulcamara*.

The shaded banks away from the seepages support a moderate woodland ground flora including several species considered characteristic of ancient woodland including Dog's Mercury *Mercurialis perenni* and Yellow Archangel *Lamiastrum galeobdolon*. Significant stands of the tall invasive Himalayan Balsam *Impatiens glandulifera* were noted in several places. Seepages combine to one main channel before outflowing via an old stone structure under a public footpath to the Caldon Canal.

3.1.6 Booth's Wood

RSPB Booth's Wood and SCC Dale Spring SSSI. A small shaded seepage with some tufa within a swampy area of alder, grey willow woodland, within an area of Carboniferous Lower Coal Measures. The swampy ground flora includes Marsh Marigold *Caltha palustris*, Opposite-leaved Golden Saxifrage *Chrysosplenium oppositifolium* as well as small stands of the non-native species Pink Purslane *Claytonia siberica*, Himalayan Balsam *Impatiens glandulifera*. However, a seepage channel has the mosses *Brachythecium rivulare*, *Cratoneuron filicinum* (mostly growing on stones) and the *Cratoneuron* is associated locally with active tufa deposition.

3.1.7 The Petrifications

This site comprises a wooded section of a stream "Cotwalton Drumble". The stream descends eastwards via several small waterfalls to the valley bottom where it joins the "Mill Lades" water courses. The stream widens and drops over a significant water fall below which a long series of vertical, dripping rock outcrops occur with tufa along the north bank. These tuferous outcrops are well known locally and referred to as "The Petrifications". The steep banks of the stream cut down sharply in places into the red coloured Triassic bedrock, including strata of the Mercia Mudstone Group and the Kibblestone member.

The woodland is ash-dominated with hazel, occasional guelder rose, oak, beech, holly, wych elm, ivy, bramble, dog rose, honeysuckle and alder on the immediate banks of the stream. The main area of dripping rock outcrops with tufa along the north bank are dominated by the bryophytes *Palustriella commutata*, *Pellia endiviifolia*, *Eucladium verticillatum*, *Conocephalum salebrosum* although most of the *Palustriella* stands appear stunted due to the heavy shading. Seepages below the rock outcrops and elsewhere on the south bank have Opposite-leaved Golden Saxifrage *Chrysosplenium oppositifolium*, Wavy Bitter-cress *Cardamine flexuosa* and the bryophytes *Cratoneuron filicinum*, *Conocephalum conicum*, *Brachythecium rivulare*. The rocky terraces that adjoin many parts of the stream have a broad number of river-edge or emergent species including Wild Angelica *Angelica sylvestris*, Fool's Water-cress *Apium nodiflorum*, Meadow-sweet *Filipendula ulmaria*, Water-cress *Nasturtium officinale sensu lato*, Butterbur *Petasites hybridus*, Common Valerian *Valeriana officinalis*, Brooklime *Veronica beccabunga*, meadow Buttercup *Ranunculus acris*, Creeping Buttercup *Ranunculus repens* and bryophytes *Rhizomnium punctatum*, *Lunularia cruciata*.

The shaded banks away from the seepages support a broad number of common woodland ground species including Garlic Mustard *Alliaria petiolata*, Wild Garlic *Allium ursinum*, Hart's-tongue Fern *Asplenium scolopendrium*, Lady Fern *Athyrium filix-femina*, Remote Sedge *Carex remota*, Wood Sedge *Carex sylvatica*, Enchanters Nightshade *Circaea lutetiana*, Tufted hair-grass *Deschampsia cespitosa*, Scaly Male-fern *Dryopteris borneri*, Broad Buckler-fern *Dryopteris dilatata*, Male-fern *Dryopteris filix-mas*, Cleavers *Galium aparine*, Herb Robert *Geranium robertianum*, Herb Bennet *Geum urbanum*, Rough-leaved Meadow-grass *Poa trivialis*, Soft Shield-fern *Polystichum setiferum*, Wood Dock *Rumex sanguineus*, Red Campion *Silene dioica*,

Nettle *Urtica dioica* and bryophytes *Atrichum undulatum*, *Eurhynchium striatum*, *Fissidens taxifolius*, *Kindbergia praelonga*, *Lophocolea bidentata*, *Oxyrrhynchium hians*. A number of species considered characteristic of ancient woodland are also present locally including Bluebell *Hyacinthoides non-scripta*, Sweet Woodruff *Galium odoratum*, Wood Anemone *Anemone nemorosa*, Yellow Archangel *Lamiastrum galeobdolon*, Wood Melick *Melica uniflora*, Dog's Mercury *Mercurialis perennis*, Greater Stitchwort *Stellaria holostea*, Wood Speedwell *Veronica montana*, Three-nerved Sandwort *Moehringia trinervia*, Primrose *Primula vulgaris*, Wood Sorrell *Oxalis acetosella*, Greater Woodrush *Luzula sylvatica*, the large leafy liverwort *Plagiochila asplenoides* and beside a strong seepage (SJ 9204834781) a stand of Hard Shield-fern *Polystichum aculeatum*. Vertical mildly acidic soil stream banks locally support other bryophytes including *Dicranella heteromalla*, *Mnium hornum*, *Pseudotaxiphyllum elegans* and *Plagiochila porelloides*.

The trunks and roots of larger trees have a number of common bryophytes including *Amblystegium serpens*, *Hypnum cupressiforme*, *Isothecium myosuroides*, *Lophocolea heterophylla*, *Rhynchostegium confertum*, *Brachythecium rutabulum* while upper branches and twigs of trees in the most humid areas support other epiphytic bryophytes including *Metzgeria fruticulosa*, *Metzgeria furcata*, *Ulota bruchii*, *Orthotrichum affine* and locally Common Polypody fern *Polypodium vulgare*. The moss *Plagiomnium rostratum* was noted in several places adjoining waterfalls while submerged rock terraces and stones of the stream are dominated by the robust aquatic moss *Platyhypnidium ripariodes*.

3.2 RARE OR NOTEWORTHY PLANT SPECIES

Table 2 lists 4 plant species recorded during the brief survey that are considered rare or noteworthy (*) in a county (Staffordshire) context. The national threat status of flowering plants, included in brackets, is based on Stroh *et al.* (2014). All four of these noteworthy plants were recorded from the same site, Stanton Pastures (Stanton Pastures & Cuckoocliff SSSI).

Table 2 Rare or noteworthy plants

Common name	Latin name	status
Common Butterwort	<i>Pinguicula vulgaris</i>	* (Vulnerable)
Claw-leaved Hook-moss	<i>Palustriella falcata</i>	*
Intermediate Hook-moss	<i>Scorpidium cossonii</i>	*
Thick-nerved Apple-moss	<i>Philonotis calcarea</i>	*

3.3 WATER CHEMISTRY

3.3.1 Description of data

Six water samples were collected and analysed, the field measurements, cations, anions nitrate and phosphate are summarised in Table 3. Field measurements including temperature 9.1-10.9°C, pH 7.1 – 8.4, electrical conductivity 420-810 $\mu\text{S cm}^{-1}$ and HCO_3^- 196-407 mg/l are all indicative of groundwater chemistry (springs, seepages or baseflow dominated surface waters). The dominant cation is Ca and dominant anion HCO_3^- and the waters can generally be considered to be of ‘calcium-bicarbonate’ type which is expected for groundwater and some surface waters that have originated or interacted with calcareous bedrock (or quaternary deposits). Nitrate (N) is below the UK Threshold Value (UKTAG, 2014) of 4.5 mg/l for low altitude petrifying springs in all sites except ‘The Petrifications’ where nitrate may be derived from the local catchment and associated land use. There is no equivalent threshold value for phosphate, however all samples are below the limit of detection of <0.03mg/l. The full water analysis is included in Appendix 3, however, a detailed discussion of the data is outside of the scope of this project.

Table 3 Selected Water Chemistry Data

	Temp °C	pH	HCO_3^- mg l ⁻¹	Conductivity $\mu\text{S cm}^{-1}$	Ca mg l ⁻¹	Mg mg l ⁻¹	Na mg l ⁻¹
Limit of Detection					0.3	0.003	0.4
Stanton Pastures	9.1	7.10	196	590	101	5.07	5.0
Limestone Hill	10.2	8.00	295	500	66.2	4.15	14.1
Kirksteads Brook	10.9	8.40	252	420	74.6	2.80	3.9
Trickle Ridge	9.8	8.00	405	810	82.7	37.6	6.0
Booths Wood/Emerald Cave	10.1	7.20	407	730	80.5	35.3	5.3
The Petrifications	10.7	7.40	280	630	63.8	29.3	6.4

	K mg l ⁻¹	Cl ⁻ mg l ⁻¹	SO_4^{2-} mg l ⁻¹	N mg l ⁻¹	Total P mg l ⁻¹	Mn $\mu\text{g l}^{-1}$	Total Fe $\mu\text{g l}^{-1}$
Limit of Detection	0.04				0.03	0.2	0.4
Stanton Pastures	1.14	6.65	12.3	0.54	<0.03	794	185
Limestone Hill	6.11	27.2	14.3	1.75	<0.03	0.7	1.1
Kirksteads Brook	1.73	5.99	10.4	0.81	<0.03	2.4	25.1
Trickle Ridge	4.62	9.95	74.1	2.12	<0.03	0.4	4.1
Booths Wood/Emerald Cove	4.22	8.28	58.7	0.68	<0.03	<0.2	1.1
The Petrifications	2.97	13.4	33.4	14.60	<0.03	0.4	0.8

3.3.2 Nitrate

To date only nitrate has been considered in Water Framework Directive assessments for tufa forming springs (H7220) (e.g. UKTAG, 2014). Nitrate can be expressed as NO_3 or N and in this report we have converted NO_3 to N, which for this habitat has a threshold value of 4.5 mg/l N (UKTAG, 2014). It is important to stress that threshold values are simply a guide to where favourable or unfavourable condition may occur and that with time as more evidence is collected these threshold values may change. We are able to compare measured nitrate concentrations from this selected survey to the UKTAG threshold value of 4.5mg/l and also to other studies carried out around the UK by the authors (Farr et al., 2014; Graham & Farr, 2017) using a box plot (Figure 1). The graph shows that the median value (red line) is below the threshold value, however the upper part of the box is possibly heavily influenced by the one high nitrate concentration measured from water at ‘The Petrifications’.

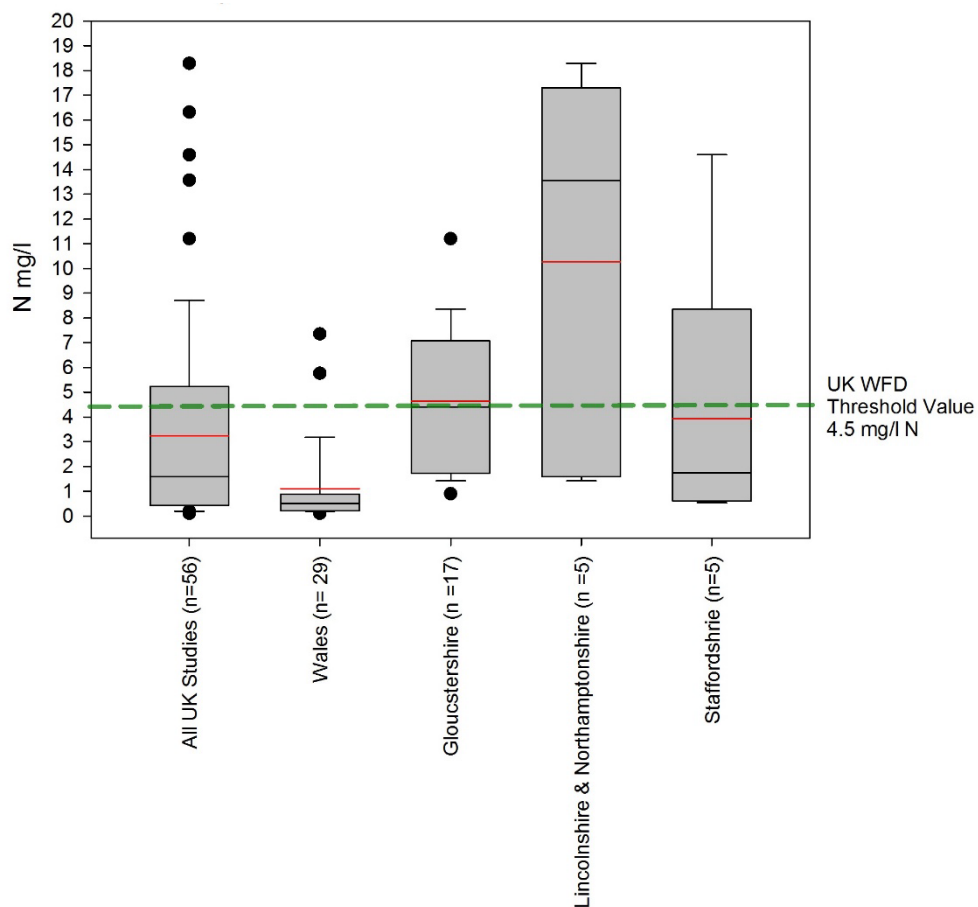


Figure 1 Box Plot of nitrate concentrations - comparison with other UK studies

(Data from Farr et al., 2014; Graham & Farr, 2017 and this report ©BGS UKRI)

4 Recommendations

Practical Recommendations

- Trickle Ridge (RSPB Booth's Wood & SCC Dale Sprink SSSI) consider erosion protection, fencing bank at base of Trickle Ridge adjoining public footpath.
- "The Petrifications", Cotwalton Drumble - consider selective removal of sycamore and holly from above the dripping rock outcrops with tufa along the north bank to rejuvenate stands of *Palustriella commutata* which currently appear to be stunted due to heavy shading. Historic photos of these outcrops c1915/16 suggest the site was once more open.
- Emerald Cave and Dale Sprink (RSPB Booth's Wood & SCC Dale Sprink SSSI) - control of invasive Himalayan Balsam *Impatiens glandulifera*.
- Emerald Cave (RSPB Booth's Wood & SCC Dale Sprink SSSI) – liaise with the private landowner(s) to promote the restoration of seepages associated with their water supply. Its location as a source of potable water may also have implications for how or when Himalayan Balsam is treated in the area, especially around the spring head and associated pipe work.

Research and survey recommendations

- This small survey highlights the potential for varied and good condition H7220 sites in Staffordshire and an expanded survey could identify and help protect other tufa forming sites in Staffordshire.

5 Conclusions

This survey undertaken over just two days has shown that there are varied and good condition H7220 tufa forming spring sites in Staffordshire. The survey is not a comprehensive account of tufa forming sites in Staffordshire. 'Trickle Ridge' where the direction of water flow and morphology of tufa formation has been altered by humans for aesthetic reasons, illustrates an important interaction with the local community. Water chemistry provides evidence that 5 out of 6 sites samples are below the UK threshold value for nitrate. Simple actions including fencing, removal of sycamore, holly and Himalayan Balsam and the investigation of a water supply pipe work could result in improvements to the condition of these sites. Further survey work could identify and help protect more tufa forming springs that could add to the known 'H7220' habitat within Staffordshire.

Appendix 1 Site Photographs

Stanton Pastures



Main open springhead with tufa dome surrounded by rushy vegetation



Measuring water chemistry at top and base of tufa dome

Limestone Hill



Upper part of main waterfall with marginal stands of wild garlic (foreground left and distance right)



More heavily shaded rock outcrop (west side of stream) below main waterfall (right) with tufa, *Eucladium* and localised stands of *Palustriella commutata*.

Kirksteads Brook



Tufa barrages with *Pellia endiviifolia* (submerged green patches) – wooded section in lower part of brook.



Gravel from bed comprised of loose tufa and tufa-encrusted stones.

Trickle Ridge



Looking down slope along the back of the impressive tufa dome (known locally as “trickle ridge”) towards the river below. Dominant stands of *Palustriella commutata*.



Upper ridge of “trickle ridge” showing the groove that has been cut by local people to accelerate the rate of tufa deposition at the top of the ridge.



Seepages below “trickle ridge” (adjoining public footpath of river bank) with Hart’s-tongue Fern and stands of *Palustriella commutata*.



Upper spring head with Wild Garlic and Pendulous Sedge.

Emerald Cave



One of several upper springheads with Pendulous Sedge, tufa and stands of *Palustriella commutata*.



Main tufa dome with *Palustriella commutata* (right).



Possible private water supply, although use and ownership is not known.

Booth's Wood



The moss *Cratoneuron filicinum* actively associated with tufa formation on a stone within the channel.

The Petrifications



Shaded rock outcrops (left) with tufa, *Eucladium* and *Palustriella commutata* looking west (upstream) towards main waterfall (in distance).



Strong seepage (SJ9204834781) with adjoining stands of Opposite-leaved Golden-saxifrage and Hard Shield-fern

Appendix 2 Plant Data

17/06/2019 – 18/06/2019

Stanton Pastures (Stanton Pastures & Cuckooclipf SSSI), NW of Stanton	
SK1198246962 tuferous spring head in open field	
<i>Briza media</i>	
<i>Bryum pseudotriquetrum</i>	
<i>Calliergonella cuspidata</i>	
<i>Caltha palustris</i>	
<i>Cardamine pratense</i>	
<i>Carex echinata</i>	
<i>Carex panicea</i>	
<i>Chara vulgaris</i>	small plants on top of domed tufa spring head
<i>Cirsium palustre</i>	
<i>Ctenidium molluscum</i>	
<i>Dactylorhiza fuchsii</i>	
<i>Eleocharis uniglumis</i>	
<i>Epilobium parviflorum</i>	
<i>Eriophorum angustifolium</i>	
<i>Festuca rubra ssp. rubra</i>	
<i>Holcus lanatus</i>	
<i>Juncus articulatus</i>	
<i>Juncus inflexus</i>	
<i>Linum catharticum</i>	
<i>Lotus pedunculatus</i>	
<i>Mentha aquatica</i>	
<i>Myosotis laxa ssp. caespitosa</i>	
<i>Palustriella falcata</i>	
<i>Pedicularis sylvestris</i>	
<i>Philonotis calcarea</i>	lvs to 2.5mm long, moderately to strongly falcate
<i>Pinguicula vulgaris</i>	flowering
<i>Plagiomnium elatum</i>	lvs strongly decurrent, cells 20-30um wide
<i>Polygala vulgaris</i>	
<i>Potentilla erecta</i>	
<i>Ranunculus acris</i>	
<i>Scorpidium cossonii</i>	cells 60-80um long, cell ends shortly tapered
<i>Silene flos-cuculi</i>	
<i>Succisa pratensis</i>	
<i>Triglochin palustre</i>	

Limestone Hill area, E of Stanton	
SK1381646140 wooded valley with waterfall and adjoining seepages with tufa (Ordley Brook)	
<i>Acer pseudoplatanus</i>	
<i>Argemone nemorosa</i>	
<i>Ajuga reptans</i>	flowering
<i>Allium ursinum</i>	
<i>Alnus glutinosa</i>	
<i>Amblystegium serpens</i>	
<i>Anthriscus sylvestris</i>	
<i>Asplenium scolopendrium</i>	surprisingly local
<i>Atrichum undulatum</i>	
<i>Brachythecium rivulare</i>	seepages and stones at margins of Ordley Brook
<i>Brachythecium rutabulum</i>	
<i>Cardamine flexuosa</i>	margins of Ordley Brook
<i>Carex sylvatica</i>	
<i>Chrysosplenium oppositifolium</i>	
<i>Circaea lutetiana</i>	local
<i>Conocephalum conicum</i>	
<i>Conopodium majus</i>	
<i>Corylus avellana</i>	
<i>Cratoneuron filicinum</i>	seepages and stones at margins of Ordley Brook
<i>Deschampsia cespitosa</i>	
<i>Dichodontium cf pellucidum</i>	localised non fertile stands on stones in Ordley Brook
<i>Dryopteris dilatata</i>	
<i>Dryopteris filix-mas</i>	
<i>Eucladium verticillatum</i>	forming dominant stands on shaded rock faces below waterfall with tufa
<i>Filipendula ulmaria</i>	
<i>Fissidens bryoides</i>	steep soil banks
<i>Fissidens cf crassipes</i>	localised non fertile plants on stones in Ordley Brook with <i>Platyhypnidium riparioides</i> (If cells average 12um)
<i>Fissidens taxifolius</i>	steep soil banks
<i>Fraxinus excelsior</i>	
<i>Galium aparine</i>	
<i>Geum urbanum</i>	
<i>Hedera helix ssp. helix</i>	
<i>Hyacinthoides non-scripta</i>	steep soil banks and base of older alders
<i>Hypnum cupressiforme</i>	epiphyte
<i>Ilex aquifolium</i>	
<i>Kindbergia praelonga</i>	
<i>Lamiastrum galeobdolon</i>	flowering
<i>Mercurialis perennis</i>	
<i>Metzgeria furcata</i>	epiphyte on hazel
<i>Mnium hornum</i>	local on steep soil banks above waterfall
<i>Nasturtium officinale sensu lato</i>	margins of Ordley Brook
<i>Oxalis acetosella</i>	
<i>Palustriella commutata</i>	

Limestone Hill cont.	
<i>Pellia endiviifolia</i>	
<i>Plagiochila porelloides</i>	local on steep soil banks above waterfall
<i>Plagiomnium undulatum</i>	
<i>Plagiothecium nemorale</i>	steep soil banks and base of older alder [checked microscopically]
<i>Platyhypnidium ripariodes</i>	stones in Ordley Brook
<i>Pohlia melanodon</i>	local on steep soil banks with seepages
<i>Rhizomnium punctatum</i>	stones Ordley Brook
<i>Rubus fruticosus</i> agg.	
<i>Rumex sanguineus</i>	
<i>Sanicula europaea</i>	
<i>Stellaria holostea</i>	
<i>Taraxacum</i> sp.	
<i>Thamnobryum alopecurum</i>	
<i>Thuidium tamariscinum</i>	
<i>Veronica chamaedrys</i>	flowering
<i>Veronica montana</i>	flowering
<i>Viburnum opulus</i>	
<i>Viola riviniana</i>	plants with capsules

Kirksteads Brook, NE of Butterton	
SK0908056817 lightly wooded brook with series of tufa barrages	
<i>Allium ursinum</i>	
<i>Angelica sylvestris</i>	
<i>Anthriscus sylvestris</i>	
<i>Brachythecium rivulare</i>	
<i>Brachythecium rutabulum</i>	tree base
<i>Cardamine flexuosa</i>	
<i>Chrysosplenium oppositifolium</i>	
<i>Corylus avellana</i>	
<i>Crataegus monogyna</i>	
<i>Cratoneuron filicinum</i>	
<i>Deschampsia cespitosa</i>	
<i>Dryopteris filix-mas</i>	
<i>Epilobium hirsutum</i>	
<i>Filipendula ulmaria</i>	
<i>Fraxinus excelsior</i>	
<i>Galium odoratum</i>	
<i>Galium aparine</i>	
<i>Geranium robertianum</i>	
<i>Geum rivulare</i>	flowering
<i>Geum urbanum</i>	
<i>Hypnum cupressiforme</i>	
<i>Lunularia cruciata</i>	
<i>Mercurialis perennis</i>	
<i>Mnium hornum</i>	tree base
<i>Myosotis scorpioides</i>	
<i>Pellia endiviifolia</i>	frequently on tufa barrages
<i>Platyhypnidium ripariodes</i>	frequently on tufa barrages
<i>Poa trivialis</i>	
<i>Ranunculus acris</i>	
<i>Rumex sanguineus</i>	
<i>Stellaria holostea</i>	
<i>Thamnobryum alopecurum</i>	
<i>Thuidium tamariscinum</i>	
<i>Ulmus glabra</i>	
<i>Urtica dioica</i>	
<i>Valeriana officinalis</i>	
<i>Vaucheria sp.</i>	on tufa barrages
<i>Veronica chamaedrys</i>	
<i>Vicia sepium</i>	

Trickle Ridge (RSPB Booth's Wood & SCC Dale Sprink SSSI), NW of Froghall

SK0069248260 tufa seepage in woodland with large tufa block "Trickle Ridge"

<i>Acer pseudoplatanus</i>	
<i>Allium ursinum</i>	
<i>Alnus glutinosa</i>	
<i>Amblystegium serpens</i>	
<i>Asplenium scolopendrium</i>	
<i>Brachythecium rivulare</i>	
<i>Brachythecium rutabulum</i>	
<i>Cardamine flexuosa</i>	
<i>Carex pendula</i>	local
<i>Chrysosplenium oppositifolium</i>	
<i>Conocephalum conicum</i>	
<i>Conocephalum salebrosum</i>	local part of site only by footpath
<i>Crataegus monogyna</i>	
<i>Cratoneuron filicinum</i>	mainly on logs at top of seepage
<i>Deschampsia cespitosa</i>	
<i>Dryopteris dilatata</i>	
<i>Eucladium verticillatum</i>	(localised patches on tufa block
<i>Eurhynchium stratum</i>	
<i>Fissidens cf bryoides</i>	steep soil bank
<i>Fissidens taxifolius</i>	steep soil bank
<i>Fraxinus excelsior</i>	
<i>Geranium robertianum</i>	
<i>Hedera helix ssp. helix</i>	
<i>Ilex aquifolium</i>	
<i>Kindbergia praelonga</i>	
<i>Melica uniflora</i>	local at lower part of site
<i>Mnium hornum</i>	steep soil bank and tree roots
<i>Oxalis acetosella</i>	
<i>Oxyrrhynchium hians</i>	
<i>Palustriella commutata</i>	dominating large part of site
<i>Pellia endiviifolia</i>	
<i>Plagiomnium undulatum</i>	
<i>Plagiothecium nemorale</i>	tree roots
<i>Rhizomnium punctatum</i>	
<i>Ulmus glabra</i>	
<i>Urtica dioica</i>	

Emerald Cave (RSPB Booth's Wood & SCC Dale Sprink SSSI), NW of Froghall	
SK0050748425 tufa seepage in woodland with localised tufa domes	
<i>Acer pseudoplatanus</i>	
<i>Allium ursinum</i>	
<i>Alnus glutinosa</i>	
<i>Angelica sylvestris</i>	
<i>Asplenium scolopendrium</i>	
<i>Brachythecium rivulare</i>	
<i>Cardamine flexuosa</i>	
<i>Carex pendula</i>	locally dominant
<i>Chrysosplenium oppositifolium</i>	
<i>Conocephalum conicum</i>	outflow adjoining footpath
<i>Cratoneuron filicinum</i>	
<i>Deschampsia cespitosa</i>	
<i>Dryopteris dilatata</i>	
<i>Dryopteris filix-mas</i>	
<i>Epilobium hirsutum</i>	lower part of site close to footpath
<i>Epilobium parviflorum</i>	lower part of site close to footpath
<i>Epilobium sp.</i>	lower part of site close to footpath
<i>Filipendula ulmaria</i>	lower part of site close to footpath
<i>Fraxinus excelsior</i>	
<i>Frullania dilatata</i>	epiphyte
<i>Galium aparine</i>	
<i>Geranium robertianum</i>	
<i>Heracleum sphondylium</i>	
<i>Hypnum cupressiforme</i>	epiphyte
<i>Impatiens glandulifera</i>	
<i>Kindbergia praelonga</i>	tree bases
<i>Lamiastrum galeobdolon</i>	
<i>Lophocolea bidentata</i>	
<i>Lophocolea heterophylla</i>	alder trunk
<i>Mercurialis perennis</i>	
<i>Metzgeria fruticulosa</i>	epiphyte
<i>Mnium hornum</i>	tree bases
<i>Orthotrichum affine</i>	epiphyte
<i>Oxyrrhynchium hians</i>	
<i>Palustriella commutata</i>	
<i>Pellia endiviifolia</i>	
<i>Plagiomnium undulatum</i>	
<i>Platyhypnidium riparioides</i>	outflow adjoining footpath
<i>Poa trivialis</i>	
<i>Ranunculus repens</i>	

<i>Emerald Cave cont</i>	
<i>Rumex sanguineus</i>	
<i>Salix cinerea</i>	lower part of site close to footpath
<i>Solanum dulcamara</i>	lower part of site close to footpath
<i>Thamnobryum alopecurum</i>	
<i>Ulota bruchii</i>	epiphyte
<i>Urtica dioica</i>	
<i>Zygodon viridissimus</i>	epiphyte

Dale Sprink (RSPB Booth's Wood & SCC (now RSPB) Dale Sprink SSSI), NW of Froghall

SK0008848546 wooded seepage with small amounts of tufa	
<i>Alnus glutinosa</i>	
<i>Brachythecium rivulare</i>	
<i>Caltha palustris</i>	
<i>Chrysosplenium oppositifolium</i>	
<i>Claytonia siberica</i>	
<i>Cratoneuron filicinum</i>	associated with active tufa formation
<i>Heracleum sphondylium</i>	
<i>Impatiens glandulifera</i>	
<i>Salix cinerea</i>	

"The Petrifications", Cotwalton Drumble, W of Cotwalton

SJ9209634761 steep sided wooded valley with shallow waterfalls & tufa	
<i>Acer pseudoplatanus</i>	
<i>Alliaria petiolata</i>	
<i>Allium ursinum</i>	
<i>Alnus glutinosa</i>	
<i>Amblystegium serpens</i>	
<i>Anemone nemorosa</i>	
<i>Angelica sylvestris</i>	
<i>Apium nodiflorum</i>	local beside stream
<i>Asplenium scolopendrium</i>	
<i>Athyrium filix-femina</i>	
<i>Atrichum undulatum</i>	
<i>Brachythecium rivulare</i>	seepages and on rock at margins of stream)[checked microscopically
<i>Brachythecium rutabulum</i>	(mainly on tree trunks
<i>Cardamine flexuosa</i>	
<i>Carex remota</i>	
<i>Carex sylvatica</i>	
<i>Chrysosplenium oppositifolium</i>	
<i>Circaea lutetiana</i>	
<i>Conocephalum conicum</i>	locally dominant stands on shaded vertical rock faces with tufa beside stream
<i>Conocephalum salebrosum</i>	

<i>The Petrifactions cont...</i>	
<i>Corylus avellana</i>	
<i>Cratoneuron filicinum</i>	
<i>Deschampsia cespitosa</i>	
<i>Dicranella heteromalla</i>	vertical soil bank in one place with <i>Pseudotaxiphyllum elegans</i>
<i>Dryopteris borreeri</i>	
<i>Dryopteris dilatata</i>	
<i>Dryopteris filix-mas</i>	
<i>Eucladium verticillatum</i>	dominant stands on shaded vertical rock faces with tufa beside stream
<i>Eurhynchium striatum</i>	
<i>Fagus sylvaticus</i>	local
<i>Filipendula ulmaria</i>	
<i>Fissidens taxifolius</i>	shaded soil bank beside stream
<i>Fraxinus excelsior</i>	
<i>Galium aparine</i>	
<i>Galium odoratum</i>	local beside stream
<i>Geranium robertianum</i>	
<i>Geum urbanum</i>	
<i>Hedera helix ssp. helix</i>	
<i>Hyacinthoides non-scripta</i>	
<i>Hypnum cupressiforme</i>	epiphyte
<i>Ilex aquifolium</i>	
<i>Isoetecium myosuroides</i>	epiphyte on old hazel
<i>Kindbergia praelonga</i>	shaded soil bank beside stream
<i>Lamiastrum galeobdolon</i>	
<i>Lonicera periclymenum</i>	
<i>Lophocolea bidentata</i>	shaded soil bank beside stream
<i>Lophocolea heterophylla</i>	shaded log beside stream
<i>Lunularia cruciata</i>	rocks at margins of stream
<i>Luzula sylvatica</i>	3 plants in one place
<i>Melica uniflora</i>	local beside stream
<i>Mercurialis perennis</i>	
<i>Metzgeria fruticulosa</i>	epiphyte
<i>Metzgeria furcata</i>	epiphyte
<i>Mnium hornum</i>	shaded soil bank beside stream
<i>Moehringia trinervia</i>	local beside stream
<i>Nasturtium officinale sensu lato</i>	local beside stream
<i>Orthotrichum affine</i>	epiphyte on old hazel
<i>Oxalis acetosella</i>	local beside stream
<i>Oxyrrhynchium hians</i>	shaded soil bank beside stream
<i>Palustriella commutata</i>	
<i>Pellia endiviifolia</i>	
<i>Petasites hybridus</i>	
<i>Plagiochila asplenioides</i>	soil bank at base of old alder
<i>Plagiochila porelloides</i>	shaded soil bank beside stream

<i>The Petrifications cont....</i>	
<i>Plagiomnium rostratum</i>	non fertile stands beside small waterfall) [checked microscopically - cells not porose
<i>Platyhypnidium ripariodes</i>	rock bed of stream
<i>Poa trivialis</i>	
<i>Polypodium vulgare</i>	local on fallen trees beside stream)[checked microscopically (annulus cells 16-21)
<i>Polystichum aculeatum</i>	
<i>Polystichum setiferum</i>	
<i>Primula vulgaris</i>	local
<i>Pseudotaxiphyllum elegans</i>	vertical soil bank in one place with <i>Dicranella heteromalla</i>
<i>Quercus robur</i>	
<i>Ranunculus acris</i>	local beside stream
<i>Ranunculus repens</i>	
<i>Rhizomnium punctatum</i>	
<i>Rhynchostegium confertum</i>	on wooden footbridge, fruiting
<i>Rosa canina</i> agg.	
<i>Rubus fruticosus</i> agg.	
<i>Rumex sanguineus</i>	
<i>Silene dioica</i>	
<i>Stellaria holostea</i>	local beside stream
<i>Ulmus glabra</i>	
<i>Ulota bruchii</i>	epiphyte
<i>Urtica dioica</i>	
<i>Valeriana officinalis</i>	local beside stream
<i>Vaucheria</i> sp.	non fertile stands on dripping rock outcrops with tufa
<i>Veronica beccabunga</i>	local beside stream
<i>Veronica montana</i>	flowering
<i>Viburnum opulus</i>	

Appendix 3 Water Chemistry

	Field Temp	Field pH	Field HCO ₃ ⁻	Conductivity	Ca	Mg	Na
	°C		mg l ⁻¹	µS cm ⁻¹	mg l ⁻¹	mg l ⁻¹	mg l ⁻¹
Limit of detection					0.3	0.003	0.4
Stanton Pastures	9.1	7.10	196	590	101	5.07	5.0
Limestone Hill	10.2	8.00	295	500	66.2	4.15	14.1
Kirksteads Brook	10.9	8.40	252	420	74.6	2.80	3.9
Trickle Ridge	9.8	8.00	405	810	82.7	37.6	6.0
Booths Wood/Emerald Cove	10.1	7.20	407	730	80.5	35.3	5.3
The Petrifications	10.7	7.40	280	630	63.8	29.3	6.4

	K	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	Total P	Mn	Total Fe
	mg l ⁻¹	mg l ⁻¹	mg l ⁻¹	mg l ⁻¹	mg l ⁻¹	µg l ⁻¹	µg l ⁻¹
Limit of detection	0.04				0.03	0.2	0.4
Stanton Pastures	1.14	6.65	12.3	2.40	<0.03	794	185
Limestone Hill	6.11	27.2	14.3	7.75	<0.03	0.7	1.1
Kirksteads Brook	1.73	5.99	10.4	3.56	<0.03	2.4	25.1
Trickle Ridge	4.62	9.95	74.1	9.35	<0.03	0.4	4.1
Booths Wood/Emerald Cove	4.22	8.28	58.7	2.99	<0.03	<0.2	1.1
The Petrifications	2.97	13.4	33.4	64.5	<0.03	0.4	0.8

	Br ⁻	NO ₂ ⁻	HPO ₄ ²⁻	F ⁻	Total S	Si	Ba
	mg l ⁻¹	mg l ⁻¹	mg l ⁻¹	mg l ⁻¹	mg l ⁻¹	mg l ⁻¹	µg l ⁻¹
Limit of detection					0.03	0.042	0.05
Stanton Pastures	<0.05	<0.025	<0.05	0.061	6.18	4.05	304
Limestone Hill	0.033	<0.01	<0.02	0.307	4.68	2.28	229
Kirksteads Brook	<0.02	0.041	<0.02	0.093	3.75	2.27	100
Trickle Ridge	<0.1	<0.05	<0.1	0.066	26.4	4.37	28.9
Booths Wood/Emerald Cove	<0.05	<0.025	<0.05	0.077	20.0	3.70	42.8
The Petrifications	<0.05	<0.025	<0.05	0.027	11.2	4.37	75.6

	Sr	Li	Be	B	Al	Ti	V
	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹
Limit of detection	0.2	7	0.08	53	0.7	0.06	0.04
Stanton Pastures	235	11	<0.08	<53	7.8	0.15	0.06
Limestone Hill	66.6	<7	<0.08	<53	<0.7	<0.06	0.15
Kirksteads Brook	194	<7	<0.08	<53	6.1	0.20	0.91
Trickle Ridge	334	53	<0.08	<53	<0.7	<0.06	0.15
Booths Wood/Emerald Cove	297	48	<0.08	<53	<0.7	<0.06	0.08
The Petrifications	47.5	8	<0.08	<53	<0.7	<0.06	0.12

	Cr	Co	Ni	Cu	Zn	Ga	As
	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹	µg l ⁻¹
Limit of detection	0.06	0.008	0.02	0.05	0.3	0.06	0.04
Stanton Pastures	0.10	0.048	0.63	0.91	4.2	<0.06	0.18
Limestone Hill	0.10	0.059	0.53	1.15	3.9	<0.06	0.16
Kirksteads Brook	0.25	0.101	3.45	4.55	2.6	<0.06	0.56
Trickle Ridge	0.19	0.019	1.69	0.18	0.5	<0.06	0.11
Booths Wood/Emerald Cove	0.13	0.024	0.49	0.26	<0.3	<0.06	0.06
The Petrifications	0.29	0.020	0.41	0.66	1.4	<0.06	0.46

	Se µg l ⁻¹	Rb µg l ⁻¹	Y µg l ⁻¹	Zr µg l ⁻¹	Nb µg l ⁻¹	Mo µg l ⁻¹	Ag µg l ⁻¹
Limit of detection	0.07	0.05	0.006	0.009	0.01	0.2	0.04
Stanton Pastures	<0.07	1.36	0.061	0.089	<0.01	<0.2	<0.04
Limestone Hill	0.38	0.62	<0.006	0.018	<0.01	<0.2	<0.04
Kirksteads Brook	6.27	1.14	0.063	0.145	<0.01	1.9	<0.04
Trickle Ridge	1.99	5.71	<0.006	0.016	<0.01	<0.2	<0.04
Booths Wood/Emerald Cove	0.80	4.98	<0.006	0.013	<0.01	<0.2	<0.04
The Petrifactions	0.12	2.16	<0.006	<0.009	<0.01	<0.2	<0.04

	Cd µg l ⁻¹	Sn µg l ⁻¹	Sb µg l ⁻¹	Cs µg l ⁻¹	La µg l ⁻¹	Ce µg l ⁻¹	Pr µg l ⁻¹
Limit of detection	0.005	0.08	0.04	0.04	0.003	0.004	0.003
Stanton Pastures	0.028	<0.08	0.09	<0.04	0.026	0.056	0.009
Limestone Hill	0.107	<0.08	0.09	<0.04	<0.003	<0.004	<0.003
Kirksteads Brook	0.117	<0.08	0.52	<0.04	0.019	0.031	0.005
Trickle Ridge	0.006	<0.08	0.28	0.14	<0.003	<0.004	<0.003
Booths Wood/Emerald Cove	<0.005	<0.08	0.08	0.10	<0.003	<0.004	<0.003
The Petrifactions	0.031	<0.08	0.19	<0.04	<0.003	<0.004	<0.003

	Nd µg l ⁻¹	Sm µg l ⁻¹	Eu µg l ⁻¹	Gd µg l ⁻¹	Tb µg l ⁻¹	Dy µg l ⁻¹	Ho µg l ⁻¹
Limit of detection	0.005	0.005	0.003	0.005	0.004	0.003	0.003
Stanton Pastures	0.058	0.018	0.005	0.012	<0.004	0.010	<0.003
Limestone Hill	<0.005	<0.005	<0.003	<0.005	<0.004	<0.003	<0.003
Kirksteads Brook	0.018	0.008	<0.003	0.009	<0.004	0.010	<0.003
Trickle Ridge	<0.005	<0.005	<0.003	<0.005	<0.004	<0.003	<0.003
Booths Wood/Emerald Cove	<0.005	<0.005	<0.003	<0.005	<0.004	<0.003	<0.003
The Petrifactions	<0.005	<0.005	<0.003	<0.005	<0.004	<0.003	<0.003

	Er µg l ⁻¹	Tm µg l ⁻¹	Yb µg l ⁻¹	Lu µg l ⁻¹	Hf µg l ⁻¹	Ta µg l ⁻¹	W µg l ⁻¹
Limit of detection	0.003	0.003	0.004	0.003	0.006	0.006	0.06
Stanton Pastures	0.004	<0.003	0.005	<0.003	<0.006	<0.006	<0.06
Limestone Hill	<0.003	<0.003	<0.004	<0.003	<0.006	<0.006	<0.06
Kirksteads Brook	0.007	<0.003	<0.004	<0.003	<0.006	<0.006	<0.06
Trickle Ridge	<0.003	<0.003	<0.004	<0.003	<0.006	<0.006	<0.06
Booths Wood/Emerald Cove	<0.003	<0.003	<0.004	<0.003	<0.006	<0.006	<0.06
The Petrifactions	<0.003	<0.003	<0.004	<0.003	<0.006	<0.006	<0.06

	Tl µg l ⁻¹	Pb µg l ⁻¹	Bi µg l ⁻¹	Th µg l ⁻¹	U µg l ⁻¹
Limit of detection	0.02	0.02	0.08	0.03	0.009
Stanton Pastures	<0.02	0.43	<0.08	<0.03	0.071
Limestone Hill	<0.02	0.25	<0.08	<0.03	0.398
Kirksteads Brook	0.02	1.47	<0.08	<0.03	1.29
Trickle Ridge	<0.02	6.48	<0.08	<0.03	0.894
Booths Wood/Emerald Cove	<0.02	0.49	<0.08	<0.03	0.557
The Petrifactions	<0.02	3.04	<0.08	<0.03	0.419

Analysis by British Geological Survey, Nottingham

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: <https://envirolib.apps.nerc.ac.uk/olibcgi>.

BOYCE D. C., 2002. *English Nature Research Report Number 452: A review of seepage invertebrates in England.*

COPE, T. AND GRAY, A. 2009. *Grasses of the British Isles (BSBI Handbook No. 13). Botanical Society of Britain and Ireland.*

FARR, G., GRAHAM, J & STRATFORD, C. 2014. Survey, characterisation and condition assessment of *Palustriella* dominated springs 'H7220 petrifying springs with tufa formation (Cratoneurion) in Wales. NERC, 211pp. (Natural Resources Wales Evidence Report No. 136, WL/NEC03832/13_14/T6, OR/14/043) (Unpublished)

FARR, G & GRAHAM, J. 2017. Survey, characterisation and condition assessment of *Palustriella* dominated springs 'H7220 Petrifying springs with tufa formation (Cratoneurion)' in Gloucestershire, England. British Geological Survey, 141pp. (OR/17/020) (Unpublished)

GRAHAM, J., FARR, G., HEDENÄS, L., DEVEZ, A & WATTS, M.J. 2019. Using water chemistry to define ecological preferences within the moss genus *Scorpidium*, from Wales, UK, *Journal of Bryology*, 41:3, 197-204, DOI: [10.1080/03736687.2019.1603416](https://doi.org/10.1080/03736687.2019.1603416)

STACE, C. 2010. *New Flora of the British Isles.* Cambridge: Cambridge University Press.

STROH, P.A., ET AL. 2014. *A Vascular Plant Red List for England.* Botanical Society of the British Isles, Bristol

UKTAG, 2014. Technical report on groundwater dependent terrestrial ecosystems (GWDTE) threshold values. UK Technical advisory group on the Water Framework Directive. Version 9 June 2014. Threshold Values <https://www.wfduk.org>