Rep. Trans. Devon. Ass. Advmt Sci., 150, 137–176

Geological Highlights and Controversies Recorded in Early Volumes of the *Transactions*

Jennifer A. Bennett
Geology Section, Devonshire Association, Unit 10, Chitterley Business Centre, Silverton, Exeter, Devon EX5 4DB

John D. Mather
Dept. of Earth Sciences, Royal Holloway, University of London, Egham, Surrey, TW20 0EX
(corresponding author)

The desire for a forum within which to discuss science, and particularly geology, provided the impetus for the formation of the Devonshire Association in 1862, with William Pengelly as the driving force. In its early years, up to 1914, members were particularly active in geological fieldwork, particularly in the southern part of the County. Along with Pengelly a group of dedicated amateurs, including Arthur Hunt, Alexander Somervail and Richard Nicolls Worth, addressed most of the geological problems of the time. They argued about the age and origin of the schistose rocks of the Start Peninsula, worked out the age of the Dartmoor Granite, speculated on the depositional environment of the Red Sandstones, debated whether Devon had been glaciated and tried to understand the significance of the raised beaches and drowned forests along the coast. They came into conflict with the elite geologists, who ran the national learned societies and the British Association, who accepted Pengelly but regarded the others as amateurs whose field observations were of value but whose opinions were of little merit. This particularly irritated Hunt who, through the pages of the Devonshire Association's Transactions, attacked the influential professors for being obstructive and treating his work with contempt. The exchanges are evidence of the tensions which existed between those who regarded themselves as professionals and those with private means for whom geology was a passion rather than a profession.

INTRODUCTION

One afternoon in October 1861, three friends, Charles Spence Bate (1818–1889), a Plymouth dentist, expert on marine crustacea and Fellow of the Royal Society (FRS), William Harpley (1832–1914), the Headmaster of Plymouth Grammar School and William Pengelly (1812–1894), a Torquay teacher, lecturer and Fellow of the Geological Society of London (FGS), set off along the Hoe in Plymouth to spend the day at a quarry in neighbouring Stonehouse. On the way, encumbered as they were with formidable geological hammers, they attracted attention as they swapped stories heard at recent meetings of the British Association (BA). Suddenly Pengelly suggested it would be good if a similar organisation to the BA could be formed for the County of Devon, a suggestion eagerly supported by his friends. Soundings were taken, and a meeting convened in Plymouth in April 1862, where Pengelly successfully moved a resolution to form the *Devonshire Association for the Advancement of Science, Literature and Art* (Harpley, 1912).

The first meeting was held, in Exeter, in August that same year, at which six papers were read and published subsequently in the first volume of the *Transactions* (Anon, 1863). Three of these papers were on geological topics, two of which were read by Pengelly. The desire for a county-wide forum to discuss science, particularly geology, can be seen as the spark which led to the formation of the Devonshire Association (DA) and Pengelly can rightly be regarded as its 'Founding Father'. Perversely, not one of the three individuals whose geological excursion was to have such an impact was born in Devon; Bate and Pengelly were Cornish and Harpley was a Yorkshireman.

Why had it taken so long for a county-wide organisation to emerge in Devon, compared with neighbouring counties? To the west, the *Cornwall Literary and Philosophical Institution* (later the *Royal Institution of Cornwall*) dates from 1818 and to the east, the *Dorset Natural History and Archaeological Society* was founded in 1846 and a comparable Somerset Society in 1849. In Devon, Societies developed at a local rather than a county level with the *Plymouth Institution* (founded 1812) and the Exeter-based *Devon and Exeter Institution* (founded 1813) comparable in age to the Cornish Society and the *Torquay Natural History Society* (founded 1844) and the *Barnstaple Literary and Scientific Institute* (founded 1845), a similar age to those to the east. A *Devon and Cornwall Natural History Soci-*

ety had been formed in 1838 but had amalgamated with the *Plymouth Institution* in 1851. Perhaps the size of Devon and the consequent travelling distances favoured the formation of locally-focused organisations rather than one which was county-wide.

The delay in founding a county-wide body is particularly surprising as, since early in the nineteenth century, Devon had been at the forefront of developments in the new science of geology. Henry Thomas De la Beche (1796–1855), who had spent his early life in Lyme Regis in neighbouring Dorset, had begun mapping along the coast by 1819, when he read a paper to the Geological Society of London (De la Beche, 1822). Between 1832 and 1835, supported by Government funding, he completed a geological survey of Devon at the scale of one inch to a mile, leading to the establishment, in 1835, of what is now the British Geological Survey. Around the same time, a dispute about the identification and correct sequence of strata in Devon, between De la Beche on the one hand and Roderick Impey Murchison (1792–1871) and Adam Sedgewick (1785–1873) on the other, led to the definition of a new geological period, named the Devonian (Rudwick, 1985). This made Devon the only English county to give its name to a significant slice of geological time – some 60 million years. In south Devon, exploration of caves in Torquay and Brixham had shown that bones of extinct animals and flint tools used by man occurred together, in conflict with interpretations of the biblical story. Thus, by the middle of the nineteenth century, Devon had seen the birth of the Geological Survey and the Devonian System and been instrumental in demonstrating the antiquity of man, without any county-wide society to encourage discussion and wider participation in the field of geology, particularly amongst those amateurs where geology was their recreation not their business.

Pengelly became President of the Devonshire Association in 1867 and since that time some ten Presidents have been Fellows of the Geological Society as have many members of the Association. An attempt was made to form a Geology Section in 1948, with Henry Dewey (1876–1965), a former Assistant to the Director of the Geological Survey who had retired to Newton Abbot, as Chairman, but this was unsuccessful. It was not until 1957 that a Section eventually got off the ground, with Alan Stuart (1895–1983), head of the Geology Department of the University of Exeter as Chairman. The Section has operated continuously since then and its 61st Report was published in the *Transactions* for 2017 (Bennett, 2017), when membership of the Section stood at 244, although only a quarter of these were active in attending lectures and field excursions.

Throughout its 149 volumes, members of the Association have contributed papers on geological topics to the *Transactions*. These have ranged from general reviews of Devon geology, as understood at a particular time (e.g., Pengelly, 1867; Hudleston, 1889; Scrivener, 1994; Hart, 2012) to detailed analyses of Devonshire localities, minerals and fossils. The amateur members have never been afraid to disagree with their professional contemporaries, no matter how distinguished. This paper reviews selected contributions made by members of the Association, through the pages of the *Transactions*, to the geology of Devon, the disagreements which ensued, and the individuals involved. Most of the work discussed was carried out between 1862 and 1914, the period during which members were particularly active in geological fieldwork. The cave deposits, although extremely important in any discussion of the recent geological record, will be excluded from consideration, as they are dealt with in a separate paper in this volume.

GEOLOGY OF DEVON

By the date of the formation of the Devonshire Association, the fundamental geological building blocks of Devon and south-west England had been defined and a geological map and descriptive memoir were available (De la Beche, 1839). A simplified map showing the major rock groupings is reproduced in Figure 1 (from Scrivener, 1994). A short description of these groupings follows, providing a framework within which contributions made by Association members can be reviewed.

1. The north of the County is underlain by Devonian sandstones and slatey mud-rocks, containing thin beds of limestone.
2. The south of the County is again underlain by Devonian slates, with local beds of sandstone. Around Plymouth and Torbay, thick beds of Devonian limestone occur, interbedded with volcanic rocks. In the far south, on the Start Peninsula, schistose rocks are faulted against Devonian slates immediately to the north.
3. Much of the central and western parts of Devon are underlain by interbedded sandstones and shales of the Upper Carboniferous,

known locally as the Culm Measures. Lower Carboniferous rocks, consisting of shales, cherts, mudstones and limestones occur in limited outcrops on the northern edge of Dartmoor and west of Barnstaple.

4. The high ground of Dartmoor is underlain by granite, intruded into the Devonian and Carboniferous rocks.
5. Much of east Devon is underlain by a sequence of red-coloured breccias, sandstones and mudstones, formed in a continental environment during the Permian and Triassic periods.
6. These Permo-Triassic rocks are capped, in places, by the Upper Greensand and Chalk, of Cretaceous age.
7. Tertiary (Cenozoic) sands, clays and lignites occur in two basins, Bovey in the south and Petrockstow in the north, both associated with the Sticklepath Fault.
8. The bedrock is overlain by a range of more recent deposits. These include those associated with freeze/thaw conditions and glaciation, as well as river terraces, raised beaches and drowned forests, associated with changes in sea level.

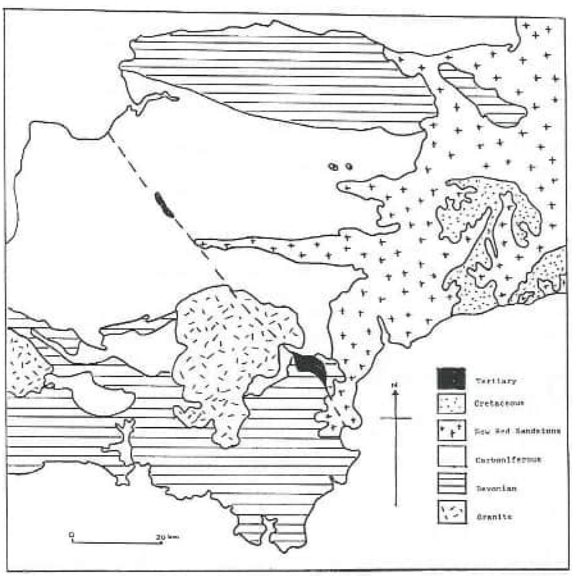

Figure 1 *Geological sketch map of Devon (from Scrivener, 1994).*

Both the Devonian and Carboniferous rocks have been deformed by north/south compression during the Variscan Orogeny, which resulted in faulting and fracturing, and the spectacular exposures found along the north and south coasts of the County.

HIGHLIGHTS AND CONTROVERSIES

Five topics have been selected, where discussions in the *Transactions* either made a significant contribution to understanding the geology of Devon, resulted in disputes amongst individual Association members or generated debates, which were often extremely acrimonious, between Association members and geologists based elsewhere. These are the age and origin of the schists which crop out in the extreme south of the County; the age and form of the Dartmoor Granite; the source of the vast amount of sediment within the red beds of the Permo-Triassic; the possible glaciation of the Dartmoor uplands; and the significance of raised beaches and drowned forests which occur in many coastal locations. Although modern research has clarified some of the problems which concerned early workers others, such as the form of the Dartmoor Granite and the possible glaciation of Dartmoor, are still controversial.

The slates and schists of south Devon

Most early workers in Devon recognised that the quartz-mica and hornblende-chlorite schists, which form the most southerly part of the County (Fig. 2), were metamorphic rocks (Sedgwick and Murchison, 1840; Sedgwick, 1852). The exception was De la Beche who rejected a metamorphic origin, considering that the schists were more ancient than the rocks which adjoined them to the north (De la Beche, 1839). In subsequent years Joseph Beete Jukes (1811–1869), the Geological Survey's Local Director in Ireland, suggested that the schists and the non-metamorphosed slates were not two separate formations, but one, of which part had been altered and partially converted into mica schist. He surmised that a boss of granite may approach the surface in this region, perhaps reaching this surface under the sea in adjacent parts of the English Channel (Jukes, 1871). His view was shared by Harvey Buchanan Holl (1820–1886), a surgeon who in his youth had accompanied De la Beche during his reconnaissance of Devon and Cornwall, who thought it probable that the schists were altered rocks of Devonian age, mantled over a granite mass, like that of Dartmoor, but more deeply seated (Holl, 1868).

Figure 2 *The slates and schists of South Devon.* ***(a)*** *Slatey mudstones at Hope Cove (SX 675402); (b) Hornblende/chlorite schists at North Sands, Salcombe (SX 732382). The ruler length is 30 cm. Images © J.D. Mather.*

Figure 3 *Portrait of Alfred Roope Hunt MA, FLS, FGS (1843–1914), President of Torquay Natural History Society (1879–1881) by an unknown artist. Image © Torquay Museum, accession number PCF3 (https://artuk.org/discover/artworks).*

It was in 1879 that members of the DA became involved with the schists of south Devon, addressing two questions, how were they formed and what was their age? Interest was initiated by a paper from Arthur Roope Hunt (1843–1914) on a block of granite dredged from offshore fishing grounds in the English Channel (Hunt, 1879). Hunt was a gentleman of independent means, born in Oporto, Portugal, where his father was a partner in a firm of wine merchants (Fig. 3). The family settled in Torquay in 1852, and Hunt became interested in geology and was elected FGS in 1870. As early as 1872 he had been told, by local fishermen, that they often picked up large blocks of granite in their trawls, about 20 miles (32 km) off the coast of the Start Peninsula. Wishing to confirm or otherwise the presence of such boulders, in October 1878, Hunt acquired a large sub-angular boulder landed by a trawler at Brixham. He was able to confirm that the block was granite, with a weight of some 9¼ cwt (470 kg). He was informed that there were many such boulders on the sea bed, that they were not all granite and that, unlike the landed boulder, some were well-rounded. He discovered that blocks landed previously had been incorporated into local buildings, where they were known as 'Old Noll's Stones', because of a supposed association with Oliver Cromwell (Old Noll). Hunt concluded that:

> "the large detached stones in the sea off Salcombe are really granite, and that the ground on which they lie is granite too" (Hunt, 1879, p. 316).

Hunt's fellow Association member, William Pengelly, had at various times noted granite pebbles on the beaches of the Start Peninsula, which he thought had been cast up by the sea rather than carried down by the rivers from Dartmoor (Pengelly, 1879). Inspecting the boulder acquired by Hunt, which had been transferred to the Museum of the Torquay Natural History Society, he felt that the block was too big for ballast and that there were only three other tenable hypotheses; that the block was part of the cargo of a floundered ship, that it had been carried to the site by ice, or that it was part of a granite formation cropping out on the floor of the Channel. He favoured the latter suggesting the presence of:

> "a submarine granitoid formation, occupying wholly, or probably at intervals, the bottom of the English Channel, from

> beyond the thirty-fathoms line to the near neighbourhood of the coast of South-Western Devon, and extending thence as a subterranean formation, but in places at considerable depths, to the similar rocks of Dartmoor" (Pengelly, 1879, p. 342).

This granitoid formation was thought to account for the metamorphism of Devonian sediments to form the schists.

Over the next decade, through his contacts at Brixham, Hunt acquired more large boulders, dredged from the floor of the English Channel, describing them in a series of papers in the *Transactions* (Hunt, 1880, 1881b, 1883, 1885, 1889b). Thin sections were made and examined by Edward Bernard Tawney (1840–1882), Assistant to the Woodwardian Professor at Cambridge and, following his death, by Thomas George Bonney (1833–1923), Professor of Geology and Mineralogy at University College, London. In Bonney, Hunt could not have picked a more influential collaborator, as he was a Secretary of the Geological Society from1878 to 1884, its President from 1884 to 1886, and the recipient of its highest award, the Wollaston Medal in 1889.Thirty-three crystalline and 11 non-crystalline rock specimens were listed in Hunt (1889b), including 18 granites as well as 7 gneisses, 3 gabbros and a range of other igneous rocks. One fragment of granite appeared to have been ripped off an *in-situ* outcrop on the sea bottom, in Hunt's eyes confirming the presence of granite outcrops off-shore (Hunt, 1881b). The rocks differed mineralogically from those of Dartmoor and were thought by Tawney to be older and possibly Archæan [Precambrian] (Hunt, 1881b). If this was the case, Hunt noted that it was impossible for them to be responsible for the metamorphism of the Devonian sediments to form the schists.

Over Easter 1883, about a month after agreeing to help Hunt, Bonney spent a few days looking at the schists and, on 7th November of that year, gave a paper on the subject to the Geological Society in London (Bonney, 1884). His work, for the first time, used microscopic examination of thin sections to investigate the relationship between the schists and the Devonian slates to the north. Bonney concluded that the two rock types were quite distinct, with a faulted contact between them, and that the schists were older and of Archæan age. Some three years later, Catherine Alice Raisin (1855–1945), a student of Bonney's, and destined to become a role-model for women in geology (Burek, 2007), generally supported her Professor's conclusions (Raisin, 1887).

In the same year in which Raisin's paper was published, another member of the Devonshire Association became interested in the schists, with three papers in the *Transactions* in succeeding years (Somervail, 1887, 1888, 1889). Alexander Somervail (1841–1910) was a retired master stationer from Edinburgh, who had moved to Torquay in the early 1880s and was to become Honorary Secretary of the Torquay Natural History Society, a post he occupied for some twenty years, between 1890 and 1910. He opposed the idea that the schists and slates were separated by a fault, pointing out the similarity in composition of the rocks to the north and south and maintaining that the chlorite-rich rocks to the south were the metamorphic equivalents of the sheets of dolerite interbedded with the slates to the north. It followed that the schists were not Archæan in age as claimed by Bonney, but Devonian. Bonney briefly acknowledged Somervail's conclusions, but dismissed his work as he had not looked at the rocks in thin-section, commenting that microscopic:

> "methods are essential in order to distinguish real differences, and avoid being misled by superficial resemblances, I cannot admit that he is qualified to investigate the subject, or waste time by discussing it with him" (Bonney, quoted in Hunt ,1895, p. 8).

Clearly Bonney was becoming irritated!

Wilfrid Hudleston Hudleston (1828–1909) addressed the age of the schists in his presidential address to the Association in 1889, commenting that Somervail's argument, that the chlorite schists are the metamorphic equivalents of interbedded sheets of igneous rock in the slates, "though ingenious, is scarcely convincing" (Hudleston, 1889, p. 46). Hudleston was a gentleman, whose private resources enabled him to indulge varied scientific interests, particularly geology. As a Secretary of the Geological Society from 1886 to 1890 and its President from 1892 to 1894, he was a man with equal status to that of Bonney and the amateurs of the Association, Hunt and Somervail, were faced with formidable opponents.

The question of the schists lay dormant for a few years, until the Survey geologist, William Augustus Edmond Ussher (1849–1920), began working in the area in 1890. Hunt accompanied him on three occasions: "to learn a little of the details of field-work with map and hammer" (Hunt, 1895, p. 9). In answer to an enquiry from Hunt, asking how the work was going, Ussher wrote to him in May 1891:

> "As far as my investigations of the Start and Prawle areas have gone, I have been unable to obtain a shred of evidence from the stratigraphical side in favour of the Archæan age of the mica schists and so-called chloritic rocks" (Hunt, 1895, p.10).

Examination of the rocks Hunt had collected also demonstrated affinities between the schists and the slates to the north, through the occurrence in both of detrital tourmaline. During 1891/1892, armed with this information, Hunt went into action, with a presentation to the British Association and a paper in the *Geological Magazine*. The latter he sent to Bonney who replied that:

> "he did not mean to enter into any controversy on the subject [of the schists] until his shield was struck by a knight of equal experience" (Hunt, 1895, p.11)

An exchange of views followed, during 1892/1893 in the *Geological Magazine*, culminating in a letter from Bonney, charging Hunt with "misrepresentation by selective quotation and with general ignorance" (Hunt, 1895, p.12). Hunt's response was that the first charge was untrue, and the second, though true, was not one for Bonney to make! Within a few weeks of the publication of Bonney's letter, Hunt was asked to allow himself to be proposed as President of the Devonshire Association. This he rejected being:

> "strongly of the opinion that a worker who has been treated with contempt by officers of the Geological Society, and of the British Association, is not morally eligible to be the representative of a great county Society" (Hunt, 1895, p.12)

Hunt did not give up and in 1893 had a detailed criticism of Bonney's ideas printed privately and sent to leading Fellows of the Geological Society, in both the United Kingdom and overseas! Hunt felt that a *prima facie* case for the Devonian age of the schists had been established and there was an exchange of letters in the journal *Nature*. Bonney was unmoved, observing that:

> "In regard to [Mr. Hunt's] letter, I content myself with repeating what I have already said, either that I have wasted a good many years in study bearing on this question……or his 'evidence' is of little value, and his knives of the wrong temper for the dissection which he has essayed. He will not succeed in drawing me into a controversy with him on this question. Life is short" (Hunt, 1895, p.13)

Perhaps not surprisingly, Hunt's reply was suppressed by *Nature*. Hunt summarised his dispute with Bonney in further papers published in the *Transactions* in 1895 and 1896, both containing long rants about Bonney and his perceived contempt for amateur workers. To Hunt it was a matter of principle: facts should be dealt with on their own merits, not on the merits of the messenger who announces them (Hunt, 1896). There is no doubt of Bonney's arrogance, but Hunt's valid arguments were nullified by the rambling and poisonous nature of his attacks and his attempt to include the whole geological establishment in his criticisms.

A few years later, Harford John Lowe (1852–1934), a Torquay schoolteacher and a Fellow of the Geological Society, reviewed the work of his fellow Association members, suggesting an alternative hypothesis which he felt accounted for what he observed in the field (Lowe, 1901). He assumed that, before deposition of the slates, a similar formation, which could have been Archæan or younger, was deposited in the area, in which mud deposits were interbedded with volcanic ash and lava. At considerable depth, these rocks were subjected to high temperature and pressure, converting the mud into mica schist and the volcanic rocks to chlorite schist. Subsequently these were brought into contact with the slates by faulting. This followed closely the hypotheses of those such as Bonney, supporting the two-formation theory.

The publication of the Geological Memoir for the Kingsbridge and Salcombe area (Ussher, 1904) might have been expected to provide a definitive answer to the age of the south Devon schists. However, Ussher sat on the fence and, to quote the Survey's Director in the Preface:

> "The age of the schists is left undecided......Although Mr. Ussher has not been able to settle the question of the age of the metamorphic rocks by stratigraphical evidence, his detailed mapping of the green schists and his careful description of the line which separates the altered from the unaltered rocks will be found of value to all future workers in the district" (Teall in Ussher, 1904, p. iii)

The age of the schists remained an enigma until they and the slates to the north were dated radiometrically in the early 1970s. Using the potassium-argon method, both appeared to have undergone a metamorphism at about 300 Ma (late Carboniferous) which was probably accompanied by folding. The continuity between schists and slates, has led to the conclusion that both were formed in Devonian times, with the precursors of the schists deposited in a rapidly subsiding zone where, due to the depth of burial, metamorphism reached a higher grade. Hunt and Somervail would have been delighted that their one-formation concept had finally prevailed over the two-formation theory of Bonney and his allies. The granite boulders, that Hunt thought were evidence of an offshore granite which had caused the metamorphism of slates to schists, are now thought to be ice-rafted erratics put into position during the Quaternary (Cullingford *in* Durrance and Laming, 1982, p. 259).

The age and form of the Dartmoor Granite.

The area of high ground in mid to south Devon, known as Dartmoor, is underlain by a large mass of granite and its metamorphic aureole (Fig. 1). It is the largest of a chain of intrusions which form the Cornubian Batholith, extending south westwards to Land's End, the Isles of Scilly and Haig Fras. De la Beche described the granite as:

> "a coarse-grained mixture of quartz, feldspar and mica, the latter sometimes white, at others black, the two micas occasionally occurring in the same mass" (De la Beche, 1839, p.157)

The frequent presence of large crystals of feldspar and widely disseminated tourmaline was also highlighted. This porphyritic granite was used as a building and paving stone throughout Devon, although no quarries operate currently (Fig. 4).

Figure 4 *Pavement slabs of porphyritic granite in Cathedral Close, Exeter. Image © J.D. Mather.*

Of the two papers given by Pengelly, at the first annual meeting of the Association in 1862, one dealt with the age of the Dartmoor granite (Pengelly, 1863) and he addressed this subject again in his Presidential Address, five years later (Pengelly, 1867a). Previous workers had divided the granite into three distinct varieties based on their perceived field relationships: a schorlaceous (tourmaline) granite was thought to be the earliest, followed by a porphyritic granite (containing large feldspar crystals), and finally cross-cutting bodies of elvan or felsite (a fine-grained acid rock, dominantly quartz and feldspar, often hard and flint-like). The schorlaceous granite was more recent than the Carboniferous rocks in contact with it, since it passed into them in the form of veins. However, it was not as easy to assign an upper limit to the age of the granite as, although red sandstones and conglomerates could be seen to unconformably overlie the Devonian and Carboniferous rocks, their contact with the granite was nowhere visible. If the granite was older than the red rocks, granite clasts should occur within them and, as no granite pebbles had been identified, the conclusion was that, when the red rocks were being deposited, the granite was not exposed. At this time the red rocks were all considered to be Triassic in age and only later were some assigned to the Permian. Although the coarser lithologies were described as conglomerates, the angular clasts mean that they would now be recognised as breccias.

It was with this background that the local knowledge of Association members came into its own. Pengelly records that, on a visit to North Tawton, he had mentioned the absence of granite pebbles to a fellow Association member, William Vicary (1811–1908), who ran a local tannery business. Vicary had immediately taken him to a local site, extracting two or three pebbles, which both of them regarded as originating from Dartmoor (Pengelly, 1863). In August 1861, they again met up and Vicary reported that he had recently found unmistakable fragments of Dartmoor granite in the red rocks, south of Exeter. Later a joint search yielded several specimens, amongst them representatives of each of the three types of granite recognised by earlier workers. Pengelly concluded that the Dartmoor granites were not in existence when the Carboniferous Culm Measures, of north and central Devon were deposited, but did exist, and were exposed at the surface during the deposition of the red rocks (Pengelly, 1863).

A few years later, Vicary drew attention to pebbles and boulders containing a type of feldspar known as murchisonite which were scattered over parts of the red sandstone outcrop (Vicary, 1867). Previous workers, such as De la Beche, had not considered them to be related to the granite. Following detailed optical and chemical analyses, Vicary concluded that the red colour, of the murchisonite and the boulders which contained them, was the result of iron oxidation and that the boulders were merely altered lumps of the Dartmoor granite. He surmised that a large component of the red rocks had been furnished by the granite, which was a far more important constituent of the red rocks than geologists had supposed (Vicary, 1867). In retrospect it is difficult to see why there was ever doubt about the presence of granite pebbles in the red rocks. The breccias were widely used as a building stone in medieval Exeter, where granite clasts are readily identifiable (Fig. 5).

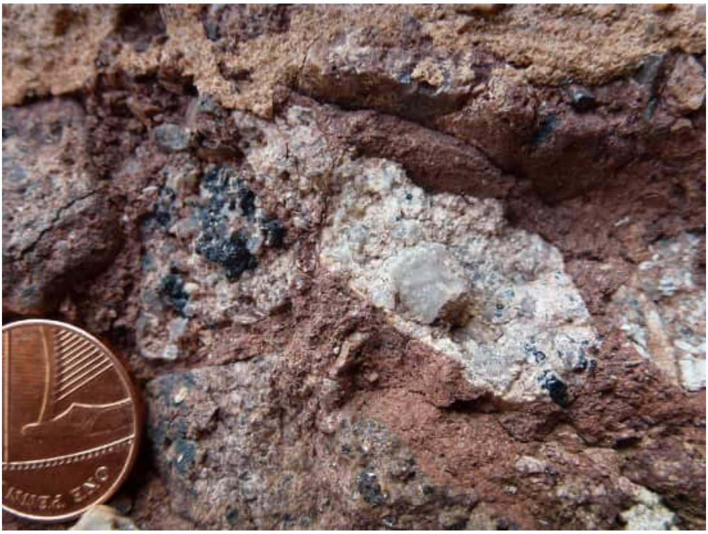

Figure 5 *Granite clasts within a block of breccia in the wall of St Stephen's Church, High Street, Exeter. Image © J.D. Mather.*

The establishment of the age of the granite as Pre-Triassic/Post-Carboniferous owes much to the efforts of early DA members and it was two others Richard Nicholls Worth (1837–1896) and William Ussher who continued their work to examine the mode of origin and form of the granite body. Worth, a Plymouth journalist and publisher, was elected FGS in 1875 and Ussher, although an officer with the Geological Survey, was an Association member from 1875 to 1895, when he gave up his membership, perhaps following the death of his friend Pengelly. Worth noted that schorlaceous rock is found all around the edge of Dartmoor and that the evidence seemed conclusive that it was produced by alteration of the original granite, rather than an earlier phase (Worth, 1887). This conclusion was emphasised in a further paper in which he described the range of variation in the granites and felsites of the County, concluding that there were two events, rather than three; the formation of the granite and the formation of the elvans or felsites which were clearly more recent than the mass of the granite (Worth, 1892).

The form of the granite intrusion was the subject of a presentation by Ussher to the DA's 1888 annual meeting. He noted that:

> "it was generally supposed that the granite now at the surface communicated directly and, on all sides, downward with the primordial mass below" (Ussher, 1888, p. 142)

But, he asked, what had happened to the strata which originally occupied the space, now occupied by the granite, was it pushed up like a saddler's punch, pushing the mass of stratified rocks up into the air, or was the heat evolved:

> "so great as to boil up and amalgamate indistinguishably the stratified rocks and granite" (Ussher, 1888, p. 142)

After careful analysis he concluded that there was no field evidence to support either of these theories. As an alternative, he suggested that the form of the granite was that of a laccolite [laccolith], a mass of igneous rock thrust up a pipe or fissure but discharging, not at the surface but flowing

> "out laterally along such lines of weakness in the encompassing strata as it can find" (Ussher, 1888, p. 154)

The main evidence for this was the apparent conformity of the Carboniferous sediments with the granite boundary, around its northern edge. He compared his laccolite to the familiar mushroom, the stem occupying the place of the feeder pipe and the ground from which it springs being the reservoir furnishing it with material

An alternative theory was put forward by Worth (1888), in a paper to the Plymouth Institution, which suggested that the granite was the eroded base of a giant volcano, which had been surmounted by vents that had thrown out lava and ash of a composition similar to that of the granite. This was the origin of the material previously described by Vicary. Not to be outdone by his colleagues, Arthur Hunt came forward with another suggestion (Hunt, 1889a). He proposed that the granite was an anciently consolidated rock, probably of Archæan age, which in post-Carboniferous times had again been subjected to heat and moisture, the latter being supplied by a superincumbent ocean. The intrusive elvans were the product of this later period. Ussher (1892) later revised his view, suggesting that the granite had resulted from the metamorphism in situ of pre-existing rocks of pre-

Devonian age, which accounted better for the deflections in strike observed in the country rocks, adjacent to the granite. This mechanism was closely aligned to that suggested by Hunt.

The various theories put forward by Association members came up at a discussion, at the Geological Society of London, of a paper by Charles Alexander McMahon (1830–1904), a retired officer in the Indian Service, who, following retirement, had devoted himself to geology (McMahon, 1893). Hunt (1897) later reported that Ussher was treated with a little humorous banter, Worth with calm indifference and himself chastised for a ridiculous hypothesis. This was yet more evidence for Hunt that the views of amateurs were treated with disrespect.

After his death, Worth's interest in the Dartmoor granite was continued by his son Richard Hansford Worth (1868–1950), a Plymouth consulting engineer, who was a member of the Institution of Civil Engineers and a Fellow of the Geological Society. In a series of papers in the *Transactions*, Worth (1902, 1903, 1912, 1937) continued his father's petrographical work, looking in particular at a felsite, which occurred as a sheet lying between the granite and the surrounding country rocks. It was designated by Worth as Felsite A, and he considered it to be one of the clues to the geology of Dartmoor. Typically, it was a rich India red in colour, weathering eventually to a pure white rock. It was subvitreous in character and Worth considered it to be a chilled marginal phase of the granite which was contemporaneous with the intrusion of the main mass. Its characteristics were unaltered at its various exposures and Worth (1902, p. 527) noted:

> "It points......to an original uniformity of the magma from which the Dartmoor Granite has consolidated, which will, perhaps, prove to have been unsuspected by most observers".

An exposure of Felsite A, some three miles (5 km) from the granite margin, confirmed to him that the present land surface was close to the original granite surface (Worth, 1937).

The Geological Survey accepted many of the ideas put forward by Worth and his colleagues, concluding that:

> "This granite probably forms a giant laccolite or intruded lake of molten rock of which the upper surface was no great height above the present surface of the Moor... (Reid *et al.*, 1912, p. 27)

They considered that the granite was of one main type, as previously postulated by Worth (1892), a coarse-grained biotite granite with a variable content of megacrysts. The granite has also interested more recent members of the Association. A review of the geology of the granite by William Robert Dearman (1921–2009), then Lecturer in Geology at the University of Newcastle, was included in a volume of "*Dartmoor Essays*" published by the Association in 1964 (Dearman, 1964) and Richard C. Scrivener, an officer of the Geological Survey based in Exeter, highlighted work on the granite in his Presidential address thirty years later (Scrivener, 1994). Using geophysical techniques and radiometric dating, the age and form of the granite is now better understood. These methods have demonstrated that Worth's concept of a Dartmoor volcano was perhaps not as far-fetched as envisaged in 1888 and the fragments identified by Worth, as originating from the volcano, and found in the red rocks, have been shown to be genetically related to the granite (Scrivener, 1994).

The source of the red rocks

At the first annual meeting of the Devonshire Association, Pengelly had discussed the Dartmoor granite; at the second it was the turn of the red rocks, which he referred to as New Red Sandstone. He pointed out that these rocks occupied the whole of the county east of a line extending from the centre of Torbay to Porlock, on the north coast in west Somerset, although they were frequently concealed by more modern deposits (Pengelly, 1864a). There were some widely separated outliers to the west, which indicated to him that these red rocks formally covered a much larger area from which they had been stripped by erosion (Pengelly, 1864a, 1866a). He described them as conglomerates, sandstones and marls, belonging to the Lower or Upper Trias. He calculated that, in south Devon, they were at least 4 miles (6.4 km) in thickness, and contained a vast volume of rock debris, which must have come from somewhere! The conglomerates were composed of a mixture of unsorted coarse and fine materials deposited together, but distinctly stratified, as if they had been thrown up on an open beach (Fig. 6). He was certain that the sands and marls, replete with fossil ripple marks, sun cracks and raindrop impressions, were formed on a tidal strand. He concluded that the area where the red rocks were deposited was one of continuous slow subsidence; a littoral environment in which, despite the enormous aggregate thickness the water was shallow from first to last (Pengelly, 1864a). He also noted that joints in the underlying Devonian rocks were filled with sand, forming sandstone dykes which were a feature of the coastal section between Brixham and Berry Head on the south coast of the County (Fig. 7). He speculated that the sand filling the earliest set of joints might represent the "very commencement of the Devonshire Trias" (Pengelly, 1864a, p. 41).

Figure 6 *Breccia-conglomerates towards the base of the Permian succession at Watcombe Head, Torbay (SX 927675). The clast marked by the star is 18 cm in length. Image © J.D. Mather.*

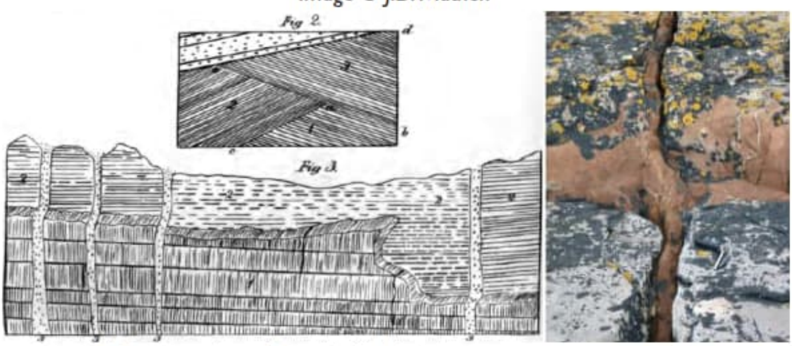

Figure 7 Diagram from Pengelly (1864a) showing on his Figure 2 a 17 ft (5.2 m) bed of sandstone, with what Pengelly called diagonal stratification, exposed in a cliff at Goodrington and, on his Figure 3, a vertical section on the shore near Brixham, showing sandstone dykes. On his Figure 3, stratum (1) is Devonian limestone, (2) is a vertical dyke of sandstone orientated east/west and (3) are vertical dykes of sandstone with a north/south orientation, which intersect both the limestone and the east/west dykes.

A very different conglomerate occurred in Triassic rocks at Budleigh Salterton on the south Devon coast, where a bed, about 100 ft (30 m) in thickness, rose from the beach diagonally in the cliff. It was formed of quartzite pebbles, from the size of a hazel nut to that of a man's head and was valued locally for road making. These pebbles contained fossils, which had been collected by Association member William Vicary, and identified as Lower Silurian forms, well known as occurring in quartzites in Normandy, but having no exact equivalents in Britain (Pengelly, 1864b). These pebble beds were described in more detail by Ussher (1877) who outlined several hypotheses for their origin, favouring a source in France.

Over the next decade there were several papers on the red rocks at annual meetings, which were mainly descriptions of sections and exposures. At the Paignton annual meeting in 1878, Ussher discussed the geology of the town, dividing the red rocks into breccio-conglomerates, breccias and rock-sands (Ussher, 1878). Following this meeting the term breccia, rather than conglomerate, was used widely in descriptions of these rocks. Ussher noted the occurrence of the peculiar form of chalcedony, called beekite, supposedly first noted by a Dr Beeke, Dean of Bristol, found in the local breccias. Limestone clasts were dissolved away, leaving the hard chalcedonic coating which had formed around them as a hollow shell.

Alexander Somervail, addressing the annual meeting at Seaton in 1885, considered that the breccias at the base of the Trias in south Devon, could be explained satisfactorily only on the basis of contemporaneous volcanic activity. He envisaged that their formation commenced by the blasting of the upper covering of surface rocks, shattering them into angular fragments, which were immediately or very shortly afterwards deposited, along with other ejected finer materials, before any great amount of abrasion had taken place (Somervail, 1885a).

The origin of this vast thickness of red rocks continued to trouble members of the Association and Thomas Andrew (1831–1902), an accountant and former Mayor of Exeter, speculated if sands in quarries at Heavitree, near Exeter, might be æolian in origin (Andrew, 1888). Somervail returned to the red rocks in 1903 at the Sidmouth annual meeting, where he spoke about the difficulties in their classification and correlation, reviewing recent work whilst including some views of his own (Somervail, 1903). He noted that the red rocks had been deposited under multiple conditions so that in one locality breccia may have formed whilst sandstones were being formed elsewhere. Claims had been made that the succession was representative of both the Permian and Triassic periods and that the red rocks in the southern coastal section, from their base in Torbay, up to but not including the Pebble Beds at Budleigh Salterton, were Permian and those to the east of Budleigh, Triassic. This division was accepted by Somervail, who noted that, although there was no distinct unconformity, there was a major lithological break at this level. He viewed the Permian succession, as what would now be regarded as a fining-upward sequence, going from very coarse breccias in the Torbay area, marking shallow water and in-shore conditions, to sandstones and fine breccias between Teignmouth and Exmouth, marking deeper water, to marls between Exmouth and Budleigh Salterton, indicating yet deeper conditions. In the Triassic there was a comparable sequence in which the Pebble Beds were overlain by sandstones and then by marls with beds of gypsum. He felt that the Permian rocks were lacustrine rather than open sea deposits, perhaps great salt lakes or lagoons to which the sea had periodic access. In the Trias, lacustrine conditions were even more pronounced, and the sea had less access to the lake system. The brackish or salt water lakes appeared to have been shallow and contained few living organisms, in his mind, perhaps comparable with the Dead Sea (Somervail, 1903).

The shallow nature of the Permian deposits around Exeter was confirmed by Arthur William Clayden (1855–1944), the Principal of University College Exeter, who was to become Devonshire Association President in 1915. Clayden was a Fellow of the Geological, Royal Astronomical and Royal Meteorological societies, and author of a classic book on clouds (Clayden, 1905). The re-opening of a sandstone quarry outside Exeter, prompted him to arrange a visit by his College Field Club, during which numerous animal tracks were discovered, made by a small animal as it descended from the surrounding hills, formed of Culm Measures and walked across the sandy shoreline in Permian times. His short paper contains excellent photographs of the tracks (Clayden, 1908) which, subsequently, were referred to the ichnogenus *Chelichnus*, associated with aeolian dune deposits (see Warrington, 2017 for a review).

Questions which interested early members of the Association have been addressed subsequently by local geologists. Deryck James Colson

Laming (1931–2017), worked on the red rocks for his PhD at Imperial College (London University) and later made his home in Devon, becoming an active Association member. He noted that pebbles in the breccias at the base of the Permian were mostly derived from local rocks and considered that they had been laid down in a desert area, as alluvial fans in intermontane basins where infrequent floods surged down canyons laying down gravel sheets on the flat unvegetated plains (Laming, 1969). Sands were deposited by streams, and sometimes worked by the wind forming dunes, and muds formed in ponds left by the floods. The sediments were derived from an east-west trending mountain range, where Dartmoor lies today, probably with a height of about 1 to 1.5 km (Hart, 2012), and the depositional environment was comparable to that currently seen in some countries of the Middle East. The Permian/Triassic boundary is now thought to be absent from the rock succession in Devon, with an hiatus of about 4 My occurring between late-Permian mudstones and the early-Triassic Budleigh Salterton Pebble Beds (Warrington, 2017).

Glaciation

The possible influence of ice on the Devon landscape, and the raised beaches and drowned forests which occur around the Devon coastline, are topics that have long intrigued Association members, and are still controversial at the present day. The subject of glaciation, and its possible impact in Devon, was first raised by Edward Vivian (1808–1893), a Torquay resident of independent means, who was the third President of the Devonshire Association in 1864 and subsequently served as General Treasurer from 1866 until his death. He looked at the formation of the Torwood Valley in Torquay, and the loam in Kent's Cavern, noting that there was evidence of frost to a depth of about 2 m over the whole surface of the district. He thought that the valley was filled:

> "with a glacier which from its limited extent and the angular character of the valley was stationary and left no traces" (Vivian, 1868, p. 359)

A reference to 'compact snow' also suggests that he was visualising the snow/ice as static rather than mobile.

Also close to the south Devon coast, George Pycroft (1819–1894), a surgeon, practising at Kenton, near Exeter, and a founder member of the Devonshire Association, suggested that the landforms and large boulders seen in valleys in and around Dawlish must have been formed by glacial processes (Pycroft, 1872). He recorded "many thousands of erratic boulders of trap and limestone weighing from one to six tons" (Pycroft, 1872, p. 80) and noted that the trap boulders were full of quartz and feldspar, which had been interpreted by Vicary (1865, 1867) as coming from the granite. Pycroft rejected water as the transport mechanism, as the blocks were widely distributed, not stratified and with no sandy material present, just clay. He concluded that:

> "they might have been brought hither and thither by ice, and this I suggest is probably the solution to the difficulty" (Pycroft, 1872, p. 81).

R. N. Worth, writing on glacial conditions in Devon, noted that there was:

> "general agreement that neither in Devon nor in Cornwall are the more pronounced marks of the glacial era to be found" (Worth, 1881, p. 351)

However, he felt that, although there were no roches moutonées, moraines or boulder clays, there were other features that indicated glacial conditions. He rejected the idea of the total submergence of Devon during the Quaternary, which had often been suggested as a mechanism for transporting erratic blocks, as the latter were found mainly in coastal situations. He was particularly impressed by the many examples of 'terminal curvature' around the county (Fig. 8). This feature occurred where slates, in particular, were bent over in the opposite direction to their dip with:

> "edges turned forward as if by the action of the force which was exerted down the slope… so slow and steady in its operation… that the laminae were simply curved, rarely broken… and left pretty much in situ" (Worth, 1881, p. 352)

Worth suggested that this curvature formed in response to the melting of winter snows and related them to the widely found 'head' deposits. He concluded that it was possible, but unlikely, that the 'snow-cap' might have developed, in certain favourable locations, into small local glaciers.

Figure 8 *Terminal curvature as discussed by Worth (1881), near Landacre Bridge, Exmoor. Image © J.A. Bennett.*

The issue was discussed widely in the geological literature and Pengelly (1886) became involved when he responded to a paper by Alexander Somervail published in the *Transactions of the Edinburgh Geological Society* (Somervail, 1885b). Somervail was dismissive of the possibility of glaciation on Dartmoor, concluding that there were no features in Devon or Cornwall which could be legitimately ascribed to glacial action. Somervail had only recently moved to live in Devon and Pengelly clearly felt that it was presumptive of him to come to such a conclusion. He went through the apparent absence of such indicators as boulder clay, moraines, erratic boulders and striated surfaces in detail, refusing to accept that small glaciers could not have existed on the great uplands of Dartmoor and Exmoor (Pengelly, 1886). In a subsequent paper, Somervail (1897) argued that the absence of small tarns on Dartmoor provided further evidence against glaciation. Although, Pengelly was no longer alive to respond, further arguments in support of glaciation were put forward by R. H. Worth who had:

> "been driven to the conclusion that ice action has had a great if not preponderating influence on the formation of Devonshire scenery" (Worth, 1898, p. 379)

He described the formation of U- and V-shaped valleys, considering parts of many south Devon valleys to be U-shaped and thus formed by ice. He referred the granitic material found in gravels to glacial detritus and noted occurrences of a yellow clay, with no water borne characteristics, in the Rivers Dart and the Tamar, comparing these to the boulder clays of Merseyside and Wales. He appears as a more committed advocate of glaciation in Devon than his father.

A notable contribution to the debate was made in the 1943 Presidential address of Colonel Ransom Pickard (1867–1953). Ex-military, a prominent ophthalmologist and Exeter's Mayor in 1926, Pickard was a keen amateur geologist. He made a compelling case for glaciation setting out the evidence with photographs and an extensive list of sites (Pickard, 1943). He compared his observations on Dartmoor with those made on visits to Norway and argued that the lack of boulder clay seen on Dartmoor was due to the rock type, as clays derived from granite were formed by chemical weathering, rather than by physical weathering such as abrasion.

The concept of periglaciation, that is of very cold conditions with frozen ground, peripheral to ice sheets and glaciers, was introduced in 1909 by a Polish geologist, Walery von Lozinski (French, 2007). At the time of the papers reviewed above, this concept was not generally understood, and discussions were polarised around whether ground was glaciated or not. '*Dartmoor Essays*', published by the Devonshire Association in 1964, includes a paper on the geomorphology of Dartmoor (Waters, 1964) which focuses on tor formation and periglaciation. Waters was firmly of the opinion that Dartmoor was never glaciated, citing calculations that the permanent snow line would have cleared the highest Dartmoor summits by about 30 m. He described the granite and the effects of freeze/thaw processes, which he saw in landscape features such as the shape of tors, patterned ground and solifluction debris.

Whilst it is now accepted that most of Devon was subject to at least periglacial conditions during the cold stages of the Pleistocene, the issue of glaciation is still divisive, with a series of fierce discussions within the wider geological literature (Harrison, 2001; Evans *et al.*, 2012) on the possibility of small ice caps on Exmoor and Dartmoor, as envisaged by Pengelly over 130 years ago (Pengelly, 1886).

Raised beaches and drowned forests

Raised beaches (Fig. 9), at elevations much higher than present day sea level, and drowned forests (Fig. 10) are found on both the north and south coasts of Devon and are well represented around Torbay, where they were described in the *Transactions* by William Pengelly (1865). He followed this up by describing similar occurrences of raised beaches and/or drowned forests at Bigbury Bay (Pengelly, 1866b), Barnstaple Bay (Pengelly, 1867b; 1868) and Blackpool, near Dartmouth (Pengelly, 1869). He discussed the differing sea levels shown by the raised beaches and the drowned forests, and commented that, in Torbay, the area of drowned forest appeared to have been submarine before the forests grew, indicating a long history (Pengelly, 1865). He concluded that:

> "enough has been stated to show how utterly fallacious must be any conclusions based on the assumption that our country has stood still ever since the ancient beaches were first raised' (Pengelly, 1868, p.422)

His colleague Arthur Hunt was also interested and visited Paignton and Blackpool, after the storms of 1881 to record the temporary exposures of clays and organic material (Hunt, 1881a). Other Association members, including Henry Samuel Ellis (1826–1878), an Exeter businessman and mayor in 1869, and Peter Orlando Hutchinson (1810–1897), a Sidmouth antiquary, described bones, teeth (Fig. 11) and flints found in the submerged forest deposits of north Devon (Ellis, 1866, 1867) and south Devon (Hutchinson, 1873).

Figure 9 *The raised beach at Hope's Nose, Torquay. A photograph taken by Hunt in 1891, with Thatcher's Rock in the background. Image from British Geological Survey, P 232131 (http://geoscenic.bgs.ac.uk) and an image taken in 2009 by J.A. Bennett.*

Figure 10 *The drowned forest at Goodrington Sands, exposed in April 2009 following severe storms. Inset is a tree root, taken from the exposure. Images © J.A. Bennett.*

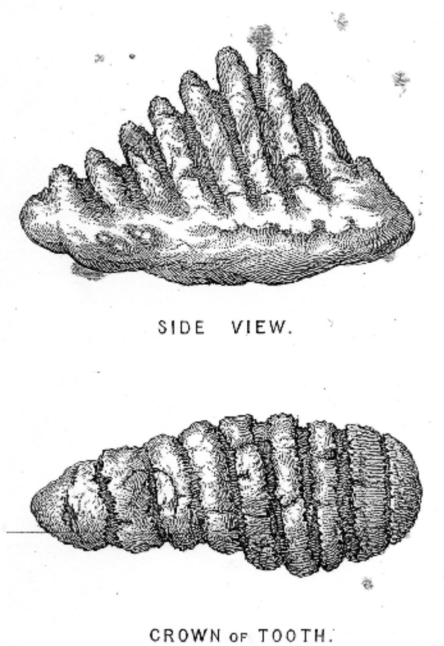

Figure 11 *Fossil tooth found on Sidmouth beach by a visitor from Manchester, drawn by Peter Orlando Hutchinson and reproduced in Hutchinson (1871).*

Hunt owned a small yacht, *The Gannet*, and became well acquainted with the Torbay coastline and the local fauna and geology, investigating raised beaches at Hopes Nose, Thatcher Rock and Sharkham Point. He catalogued the shells found on the raised beaches, particularly on Thatcher Rock (Hunt, 1888), using experts to help with identification and making comparisons between assemblages currently found on beaches in the area and those of the raised beaches. One of the experts consulted suggested that the shells could be storm deposits thrown up onto ledges during extreme weather (Pidgeon, 1890). Hunt refuted this robustly, on the basis that many delicate shells were still intact, particularly those from Thatcher Rock (Hunt, 1903). Hunt made deductions on the past shape of the coastline, arguing that the softer rocks along the coast are likely to have been worn back preferentially. He had previously considered that the present coastline between Hope's Nose and Portland had "no intermediate points in common with the old" (Hunt, 1888, p. 230) which was why beach remnants were preserved at so few locations. He also dissented from the view that the English Channel was formed by faulting (Austen, 1850), regarding it as an erosional feature.

The past physical geography of Torbay was important in the interpretation of the emplacement of the raised beaches and was a theme explored by Jukes-Browne (1912). Alfred John Jukes-Browne (1851-1914) had been appointed a Temporary Assistant Geologist with the Geological Survey in 1874 and, perhaps because of ill-health, seems never to have advanced to a permanent position. He had retired from the Survey in 1902, on health grounds, moving to Torquay, although he does not appear to have become a member of the Association. Although he authored papers in the *Transactions*, they were presented by others and he did not attend annual meetings. His obituary in *Nature* records that he continued his work as a geological surveyor for twenty years after the almost complete loss of his powers of locomotion (Anon, 1914), so field work must have imposed severe problems.

Jukes-Browne discussed past drainage patterns in the Torbay area, stating categorically that Torbay could not be one drowned valley as:

> "its square-cut outline does not represent the appearance of a drowned valley, and no wide valley opens into it" (Jukes-Browne, 1912, p.718)

Instead he deduced the existence of a drowned valley north of Berry Head, using submarine contours, arguing that the Goodrington and Torre valleys were tributaries of a continuation of the River Exe that then emptied into the Seine system. He produced a map of the physical geography during the early Pleistocene, with a sandstone plateau to the south, the existence of which was demonstrated by the sandstone dykes described by Pengelly (1864a). The lack of surviving raised beaches on the western side of Tor Bay was because the bay did not exist when the beaches were being formed. He also considered that the raised beaches were all contemporaneous, but older than the drowned forests (Jukes-Browne, 1912).

Hunt responded immediately to Jukes-Browne's paper (Hunt, 1913), arguing for the whole bay being a drowned valley, originating from the drowned channel at Goodrington, and was extremely dismissive of the idea of any sandstone plateau. However, what really offended Hunt was that Jukes-Browne had not referred to his previous papers which must have been:

> "either because he did not agree with them, or considered them unworthy of notice" (Hunt, 1913, p. 377)

Additionally, in an exchange in the *Geological Magazine*, described by Hart and Gosling (2017), Jukes-Browne had commenced a letter with the sentence:

> "If Mr, Hunt desires to be an effective critic and not a mere needless fault-finder he should not base an argument on ancient history and ignore modern research" (Hunt, 1913, p. 377)

As a worker on the raised beach question, Hunt felt that it was his business to keep in touch with modern discoveries, and he had done so. He then proceeded to give a detailed breakdown of where he thought Jukes-Browne had misinterpreted and misquoted him (Hunt, 1913). In this he had the advantage of knowing the area well and could call upon this local knowledge to argue against Jukes-Browne. He was particularly scathing about the drowned valley of Goodrington which was well known to local geologists as being at least 70 ft (21 m) deep. Hunt's dispute with Jukes-Browne was reminiscent of his previous acrimonious exchange with Thomas Bonney, which is perhaps apposite as Jukes-Browne had been a student of Bonney's at Cambridge and both were from the same college, St John's.

Many of the arguments over raised beaches and drowned forests had been based on south Devon examples but perhaps the most spectacular exposures were those around Barnstaple (or Bideford) Bay in the north. Those at Westward Ho! were well described by Bideford horologist, Albert Inkerman Rogers (1866–1959) who was a keen amateur geologist and a Fellow of the Royal Astronomical and Geological societies. The forest material was being eroded rapidly, unearthing the trunk of a tree, 18 inches (0.46 m) in diameter and 22 feet (6.7 m) in length (Rogers, 1908). There was proof that man had once lived on the land surface there and the plant assemblage suggested a brackish water marsh environment. He debated how the forest became submerged, concluding that it must have been due to the sinking or subsidence of the whole estuary, a gradual process which he envisaged was continuing (Rogers, 1908).

Further finds in the forest material at Westward Ho!, were described by Jenkyn (1969), but little more appeared in the *Transactions* until the twenty-first century when a detailed review of the buried forest deposits of south Devon was reported by Cove (2007). By this time a framework of oscillations between cold and warm stages, over the past 2.6 Ma, had been derived from long successions of marine sediments and ice cores (Shackleton and Opdyke, 1973; Imbrie and Imbrie, 1986) and it was accepted that there had been related changes in sea level, as ice caps melted and reformed.The raised beaches and drowned forests are now considered to be a consequence of these sea level changes and the Devon buried forests are thought to be the remnants of woodland submerged by a mid-Holocene transgression around 7000 to 6000 years ago (Cove, 2007). The raised beaches, which are present at several levels, are now known to be older than the drowned forests, a conclusion reached previously by both Pengelly (1865) and Jukes-Browne (1912).

DISCUSSION & CONCLUSIONS

When the Devonshire Association was formed in 1862 the title of the new organisation gave precedence to science over literature and art. This was reflected in its objects, which were:

> “to give a stronger impulse, and a more systematic direction, to scientific enquiry, and to promote the intercourse of those who cultivated science, literature and art, in different parts of

Devonshire, with one another and with others" (Anon, 1863, p. 2)

This focus on science was reflected in the papers published in early volumes of the *Transactions* with an emphasis on the flora, fauna, meteorology, and geology of the County. If the Presidential address is excluded, the space devoted to scientific topics, over the first 10 years of the *Transactions,* varied from 84% to 46% per year, with a mean of 66%. This percentage continued throughout the 1880s and many issues of the *Transactions* were dominated by papers on science, particularly geology.

William Pengelly and his colleagues, particularly Arthur Hunt, Alexander Somervail and Richard Nicholls Worth, became involved in most of the major geological issues of the day which affected south west England. They debated the origin of the schists which cropped out in the far south of Devon, sought to understand how the Dartmoor granite had made room for itself and where the vast volume of debris required to form the Permian and Triassic sediments had come from. In this they often came into conflict with academic geologists, many of whom visited Devon for short periods of time and/or were not personally familiar with a locality. From 1874 to 1886, Pengelly produced an annual paper for the *Transactions*, entitled "Notes on recent notices of the geology and palæontology of Devonshire", dropping the word "recent" from 1882. These dealt, critically, with articles on the geology of Devon which had appeared in contemporary literature.

Of the scientific members of the Association who undertook geological work during the Devonshire Association's first 50 years, it was only Pengelly whose expertise was recognised by his professional colleagues with election to the Royal Society. However, even he never reached the ranks of the geological elite, although his opinions and input were sought on a range of issues (Thackray, 1996). The rest were looked upon as amateurs whose work was valued for the factual information it contained but whose opinions were largely ignored. Hunt, in particular, suffered from this attitude and his acrimonious disputes with Bonney over the origin of the South Devon schists and with Jukes-Browne over raised beaches have been described. His argument with both was that they either ignored his work or rejected it without appropriate examination (Hunt, 1895). Bonney was criticised as being actively hostile to the work of amateurs, of treating Devonshire workers with contempt and of using the unprecedented argument that Hunt, and his colleagues, could not be right, because if so he must be wrong! Hunt felt that Papal infallibility was as nothing compared to that assumed by Bonney, as the Pope was only held to be infallible over matters of faith and morals (Hunt, 1895). As far as his work was concerned Hunt considered that:

> "the Royal Society, the Geological, and the British Association have been purely obstructive, making work, already difficult, almost impossible" (Hunt, 1895, p.43)

He thought amateurs, with their local knowledge, had no cause to be ashamed of their status, commenting that:

> "After all what more distinguished title in science can a man desire than that of a "dilettante amateur", a lover of science who delights in it?" (Hunt, 1895, p. 20)

However, the continual rejection of his ideas took its toll and his obituarist records that, on no less than three occasions he was offered the office of president of the Devonshire Association, an honour which he found himself unable to accept (Anon, 1915).

Following the death of Pengelly in 1894, the emphasis on scientific papers in the *Transactions* faded rapidly and the space devoted to such papers averaged just over 10% during the five years from 1899 to 1903. In some fields research took a different path when, from 1876, Committees were established by the Devonshire Association Council to collate information respecting Devon. Detailed reports, listing data on rainfall, temperature and humidity, were collected and tabulated by a Committee on the Climate of Devon, and a Botany Committee produced species lists of Devon flora. Unfortunately, no comparable activity took place relevant to the geology of the County. The 2017 *Transactions* saw the "109^{th} Report on Botany" and the value of the data collected was emphasised when a new county flora was researched and published by the Devonshire Association Botany Section (Smith *et al.*, 2016).

The era of the dilettante amateur, with no need to work and time on his hands, was coming to an end during the early years of the twentieth century, and was extinguished by World War I. Over the 100 years since then, occasional papers on Devon's geology have continued to appear in the *Transactions* (e.g., Dearman, 1966; Hart, 1999) and members have applied their expertise to related fields, such as cliff erosion (Harwood, 1983), hydrothermal energy (Durrance, 1988), ancient wells (Mather, 2013) and building stones (Barr, 2016). The vigorous debates and disputes of the late 19th/early 20th centuries, which involved both local scientists and distinguished national figures, are unlikely to be repeated. However, their record in the pages of the *Transactions*, remains as a source of wonder and disbelief for future generations.

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