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OLUF BORCH AT WOOKEY HOLE IN 1663 AND HIS IDEAS ON SPELEOTHEM FORMATION

by

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ABSTRACT

Oluf Borch, the Danish scientist, visited Wookey Hole in 1663. He described the speleothems there and also noted that the villagers were not specially susceptible to developing stones in the kidney, etc., although they drank water from the cave. This led him to suppose that speleothems were not due to impurities but were formed from pure water. He explained the process by saying that the particles of water, if left totally undisturbed, would bind together because they were so similar (rather as ice forms when molecular movement is reduced by low temperature).

By the middle of the 17th century, Wookey Hole (or Wokey, Okey or Ochy Hole as it was then called) was already well known, nationally and internationally. Although William of Worcester's account of his visit about 1478 remained unpublished until 1778, and therefore did not contribute to this knowledge at the time, at least ten printed books, some of them running to many editions, gave it prominence.

This is not the place to record these early visits in any detail. Suffice it to say that in the decades immediately before Borch's visit the cave was recorded, sometimes with quite lengthy descriptions, by Hammond (unpublished until 1834), Jacob (1652), Leigh (1659), Childrey (1660) and Hermannides (1661). It has been argued (Shaw, 1972, p. 107) that the 'Cheddar Hole' described by Henry of Huntingdon about 1135 was in fact Wookey Hole, confusion arising because the town of Cheddar was itself known as Chedarhol at that time. The index in the 1495 edition of Higden's *Policronicon* gives Wokihole as a synonym for Chedderhole.

Of much more widespread influence than any of these were a brief mention by Harrison (1577) in Holinshed's *Chronicle*, a slightly longer account in Camden's *Britannia* (1586 and thirteen other editions before 1663), and the poetical description in Drayton's *Poly-Olbion* (1612 and two other editions before 1663).

It is perhaps significant that Wookey Hole was only two miles from the main coach road from Bath to Exeter and conveniently close to the coaching inns of Wells (Ogilby, 1675). The cave entrance itself was shown on the county maps of Saxton (1577 and 1607), Speed (1610), Blaeu (1645) and Jansson (1646).

There were already many local tales of the cave, but it was the printed books and maps that enabled those at a distance to become aware of it. Thus Lodewijck Huyghens, the younger brother of Christiaan Huyghens the physicist and astronomer, included a visit to Wookey Hole in his English tour of 1652 (Huyghens, 1982).

Of particular importance, in view of Borch's geological interests, was the fact that Archdeacon Hakewill (1635) adduced the growth of flowstone in Wookey Hole as evidence that the world was not universally decaying and being worn away. This passage was given further prominence by being reprinted in Fuller's widely read *Worthies of England* (1662).

Many of these books would certainly have been in the University Library at Copenhagen and hence accessible to Borch. The information they contain would have been supplemented by correspondence with scientific friends in England and by advice given once he had arrived there.

FIG. 1—OLUF BORCH. A PAINTING BY JOHAN JEPSEN IN THE UNIVERSITY CONSISTORIUM, COPENHAGEN
Reproduced by courtesy of the Rektor, University of Copenhagen

Oluf Borch, his name sometimes written as the latinized version Olaus Borrichius, was born in 1626. He was best known as a botanist and chemist and was the first person to make oxygen by heating saltpetre (Weeks, 1956, p. 211). In addition he was an anatomist and physician and one of the best Latin scholars of his time (Scherz, 1969). From 1660 until his death in 1690 he was professor of philology, botany and chemistry in the University of Copenhagen, and in 1681 he became the university librarian as well (Meissen, 1932). He was interested also in poetry and the occult, and he corresponded with friends in the Royal Society (Seaton, 1935). His portrait by Jepsen is reproduced in FIG. 1.

It was in 1663 that Borch came to England, accompanied by his two pupils, the sons of the Danish statesman Gerstorff. He went into Wookey Hole on 21 July 1663 in the course of a West Country tour, from Oxford to Gloucester, Salisbury, Wilton, Stonehenge, Bristol, Bath and Wells. The account in his manuscript diary (Borch, 1663–65) (FIG. 2) is as follows in the original Latin:

> 21 Jul: Ad milliarem unum ab urbe Vellensi ingressi sumus naturalem cavernam (Uki-hole que Ugartiloch incolae appellant) horridam, ad tres vel 4 telor iactam in longitudinem patebat, via inter aspera saxa et aquas difficiles; destillabant ex superiori caverna formitae guttae aqueae, que sensim in lapidos coalescebant, pendebantque stiriacos*; que ubi incidebant in terram subjectam, sur gebant iterum in varias figuras, cum pillis leonini virginis etc: saxa ipsa quod ex aqua illa nascebatur erat aemulae marmoris; alibi instar nitri, alibi instar crystallorum; praesertim non procul a cavernae ostio, saxa figurabantur. Fluvius inferiora cavernae perlabebat, in quales omnes se guttae que no statim in saxa abeunt se exonerant, bibiturque ille fluvius ab incolis nullo valetudinis damno, que nemo illorum calculis tentatur.
>
> * hijeme in caverna calet evidenter

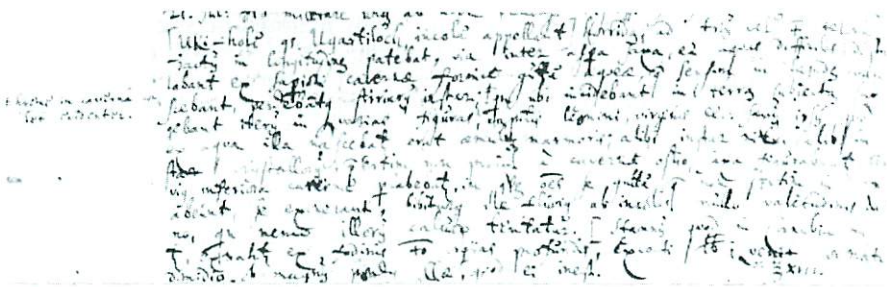

FIG. 2—BORCH'S DIARY ACCOUNT OF HIS VISIT TO UKI-HOLE [WOOKEY HOLE] ON 21 JULY 1663. TRANSCRIBED ABOVE

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Translated into English, it reads:

> 21 July; One mile from the city of Wells we entered a natural cave (Uki-hole—the inhabitants call it Ugartiloch) [which was] awe-inspiring, it lay open as far as the third or fourth chamber, by a path between the jagged rocks and difficult waters; drops of water formed at the top of the cave were dropping down, and gradually were building up on the stones and were hanging like frozen drops*; and where they fell on the ground below, they were rising up again in various shapes, with stones like a lion, a girl, etc: the stones themselves which were produced from that water were like marble; in one place like nitre in another like crystals; not far from the entrance to the cave the rocks had particular formations. All those drops of water which do not immediately disappear into the stones, empty themselves into a river flowing through the lower parts of the cave, and that river is drunk by the local people with no damage to their health, and none of them is affected by calculus.
>
> *Apparently it is warm in the cave in winter

The diary (Borch, 1663–65) is still unpublished, but a considerably modified version was included in a journal-letter written by him to his friend Thomas Bartholinus in August 1663 and subsequently printed (Borch, 1667, pp. 532–534):

> Near the town of Wells we entered a cavern, forbidding but formed by nature (the inhabitants call it the Ukis-hole . . .); we saw pure water without any taste dripping down and little by little turning into rock, and stone concretions (of which I have kept several) hung down just like icicles over almost all the cracks of the rough rock. Terror

> of the place caused the hair to rise on the head of some of my companions, while others broke out into a sweat all over their bodies, although it was all generally fairly cold there; the inhabitants however said the cave is warm in the midst of cold weather. Asked whether people living near suffer from calculus, because the stream passing through the midst of the rock supplies drinking water to the inhabitants, they replied that they suffer much less from calculus than any other people in England. They even venture to claim that if the actual water from that Trophonian cave is drunk, it will to a large extent drive out calculi, especially the smaller stones . . .

No doubt it was the ability of the cave water to form speleothems that put this idea in his mind. It is ironic that Borch himself died after an operation for stone in the bladder (Garboe, 1958, p. 48).

It was evidently this 1663 visit to Wookey Hole that inspired Borch's subsequent interest in speleothem formation. His letter to Bartholinus quoted above states that it was 'pure water' that was 'dripping down and little by little turning into rock'. And yet his question as to whether the local people suffered from internal stones indicates that he realized that it might be some property of the water itself after travelling 'through the midst of the rock' that caused it to form deposits, i.e. that it was not necessarily the cave environment alone that caused this. In the days before the process of solution was properly understood, 'pure water' normally denoted no more than clear water without sediment or visible suspension, but the observer no doubt believed it to be really pure. Borch's belief in the purity of the cave water must have been encouraged by the reply he received to his question: that the inhabitants of the village 'suffer much less from calculus than any other people in England.'

This was still his belief many years later when he wrote his treatise (Borch, 1680) on the formation of stone in cavities in rocks and in living organisms. By that time he had also seen 'two caves in France and many more in Italy and the Alps; I have not just glanced at them cursorily but examined them in great detail'. He also recalled seeing one of the mines in the oolitic limestone at Bath, 'in which slowly trickling water is turned into a yellowish marble'; but Wookey Hole:

> is more beautiful, having a much wilder appearance and seeming to be entirely natural in origin. Its white walls glisten as if they were covered with diamonds. Elsewhere are large stone stalactites growing the whole time by the continuous trickling of water; if they are broken off, short new ones soon grow. Thick masses of white stone on the floor of the cave are formed by the water dripping from the roof which is continuously increasing them.

Borch thought carefully about the phenomenon and believed he had discovered how it was that congelation pure and simple could occur in certain circumstances. According to him, water will solidify into stone if it is left altogether undisturbed so that the particles can settle into fixed position relative to each other. He knew however that much of the water in caves drips or trickles without turning to stone and he explained this by the water moving too fast, or emerging from too large an opening, or being disturbed by strong air currents. It is interesting that this stillness of the molecules leading to solidification is just what is now known to occur in the process of freezing, where the reduced energy in the liquid results in smaller molecular movements.

> The production of stones is explained in various ways by naturalists; I shall not contest their theories but just explain my own ideas on the subject. I believe that ordinary water, such as we use every day, is the only material of which stones are made; if earthy juices or minerals are contained in the water it is they that produce coloured marbles and precious stones of different sorts. As for the actual cause of the formation of stones I consider it to be nothing more than the continuous stillness of particles of water located in places where they are not subject to any disturbance at all from the outside; they are then touching each other on similar faces and, being pressed together by the steady pressure of the atmosphere, they easily bind together because of their homogeneity. . . .

> I will acknowledge, if you like, that cave water may sometimes incidentally contain salts, particles of vitriol or other such mixtures, but one must not draw the conclusion that these materials contribute to the formation of stones. On the contrary a philosopher must reject these foreign matters for he knows that without their aid ordinary water, even though it may not be entirely clear of all salt, can change into stone itself. This is a fact attested by the evidence of our senses. No difference can be detected between the water of the caves I have mentioned and ordinary spring water; the tongue cannot trace any salty taste, the eye cannot detect any colour, it has no grittiness to the touch, no smell of sulphur, it makes no more noise than ordinary water when it flows, and finally when it is evaporated it leaves no different sediment to that of ordinary drinking water; it can be drunk without danger; in the cave near Wells and the one at Chinon* the water that does not have time enough to petrify forms streams supplying the local countryside, the inhabitants of which water their cattle and themselves use the water without suffering from the stone. . . .
>
> It must now be explained how utterly still water is changed into stone. Once this water has soaked into the earth it tends always to sink downwards, partly by its own weight and partly from the pressure of the air. If it comes to a narrow crevice it trickles through drop by drop; the particles of which the drops are composed are pressed together and, all being similar and very smooth-surfaced, they easily bind together. In this way, provided the drops of water are not forced on too rapidly by those behind them and heat has not prevented them coagulating, they pass readily from the fluid to the solid state, rather like the stalactites of ice that hang from our gutters when it freezes, with the difference that the particles of which ice stalactites are composed are not so strongly bound together because of the suddenness of their freezing and so they turn back to liquid easily. It is unnecessary to seek what kind of glue unites the water particles; when two well polished and similar surfaces are held together they cling together more strongly than if glue had been used . . . (Borch, 1680, pp. 185–189)

It will be seen that Borch's explanation of speleothem formation depends on:

(*a*) his observation that the water is clear;

(*b*) the statement that drinking Wookey Hole water does not result in 'the stone' in the villagers;

(*c*) the analogy with freezing.

He notes that when cave water is evaporated it leaves sediment (like that from tap water) but does not appreciate the significance of this.

Borch does admit to some disquiet, though, over the formation of stalactites beneath brick bridges:

> . . . nevertheless this water falling on ancient temple roofs, bridges and gateways gradually percolates into the narrow crevices between the brick and the lime and reaching at last the under surface of the arch where it is no longer disturbed by the air, it condenses and gradually forms stony stalactites. . . . It cannot be argued, without abusing probability, that the supposed lapidifying juices are contained in bricks, that is to say in a substance purified by baking (Borch, 1680, p. 188)

It is strange that he does not allow this logic to suggest the lime mortar as a possible source of the material for these particular stalactites.

Borch's theory of speleothem formation was by no means the only one current at the time. Their vegetative growth (like primitive plants), condensation from vapour, a petrifying influence in the air, and the deposit of material carried in the water: all these ideas were held more or less concurrently in the second half of the 17th century. They and their interrelationship have been discussed in the introduction to a recent book (Shaw, 1986).

Borch's views had some similarity with those of Aristotle, as revived in the 16th century by Buchner (1535) and Gollut (1592), that stalactites were formed by long-continued and hence irreversible freezing. Neither that explanation, nor that of extreme stillness, has been held since, even though some of the other primitive theories survived into the 18th and even (just) the 19th centuries.

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*The cave at Chinon is the Grotte de Savonnières which had earlier been visited by Palissy (1564, f. 22b). The deposition there is particularly rapid.

It is interesting to consider what significance Borch attached to his phrases 'particles of water . . . touching each other on similar faces' and 'the particles . . . all being similar and very smooth-surfaced'. Robert Boyle, who was visited in England by Borch and whose writings Borch must have known (W. A. Smeaton, pers. comm.), believed that particles of all kinds of matter had characteristic shapes (Boyle, 1666). He also believed that water could be transmuted into 'earth' (or stone), though he does not seem to have considered speleothems in particular. Nor did he relate the shape of the particles to the transmutation. It is not clear whether Borch did so or not, but the reference to the similar faces of smooth-surfaced particles suggests that he may have done.

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