WILLIAM BUCKLAND (1784-1856) AND HENRY DE LA BECHE (1796-1855): THE EARLY HISTORY OF COPROLITES

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Abstract—The Reverend William Buckland possessed one of the most innovative and fertile minds ever to grace the science of geology. He was also one of its most interesting and eccentric characters. His science can best be described as eclectic, encompassing, among other things, the first scientific study of dinosaur footprints, the first study of coprolites, the first mention of preserved raindrop impressions, and the first study to utilize modern analogs to interpret ancient structures by injecting plaster of Paris into shark and ray intestines. He also pioneered the study of cave paleontology, was an early leading advocate of economic geology, was one of the first to embrace the glacial theory, and was one of the first to recognize the significance of functional morphology. Buckland published the first scientific study of fossilzed feces and coined the term coprolite. He also recognized the beneficial effects of coprolites on agriculture and was instrumental in the establishment of the coprolite mining industry. His works on footprints and coprolites were the first attempts at neo-ichnology and taphonomy, and his work on coprolites led directly to the creation of the engraving Duria Antiquior by Henry De la Beche that represented the first attempt at a paleoecological reconstruction.

INTRODUCTION

Ichnology concerns the study of biogenic sedimentary structures and encompasses a wide array of entities ranging from bioturbation structures to bioerosion structures to biostratification structures. Also included in this classification is another unique group—biodepositional structures—that includes, among other things, fecal pellets, fecal castings, pseudofeces, and coprolites (Pemberton, 2003).

The term coprolite is defined as:

> "The fossilized excrement of vertebrates such as fishes, reptiles, and mammals, larger than a fecal pellet, measuring up to 20 cm in length, characterized by an ovoid to elongate form, a surface marked by annular convolutions, and a brown or black color, and often composed largely of calcium phosphate; petrified excrement. The term is incorrectly used to refer to desiccated or fresh fecal remains... (b) An English term applied commercially and popularly to any phosphatic nodule mined for fertilizer" (Neuendorf et al., 2005, p. 143).

Amstutz (1958, p. 498) indicated that its etymology is Greek and comes from the words *kopros*, which means dung or excrement, and *litos*, which means stone.

In his extensive review of the literature on coporolites, Amstutz (1958, p. 498) incorrectly reported that the first use of the term "coprolite" was by Dekay (1830). In a short but interesting paper, Folk (1965) pointed out this error and stated:

> "The Dekay reference actually occurs in a communication written by Buckland (Phil. Mag., new series, v. 7, p. 321-323, on the discovery of coprolites in North America), who quotes a letter from paleontologist Dekay announcing the identification of coprolites in New Jersey. Dekay had written Buckland that he was able to identify the material after 'a notice of your interesting coprological researches met my eye' and sent Buckland a cast of his coprolite" (Folk, 1965, p. 272; cf. Buckland, 1830).

Folk (1965), as well as Häntzschel et al. (1968), thus correctly gave credit to the Reverend William Buckland for introducing the term "coprolite." Buckland's work on fossil feces was the result of his travels to Lyme Regis in Dorset, the site famous for marine reptile fossils. On 6 February 1829, Buckland gave a paper on fossil feces of *Ichthyosaurus* at the Geological Society of London, but he did not use the term "coprolite" in the published summary (Buckland, 1829a). Later, in May 1829, he read a second paper describing fish bones and scales contained within the same fossil feces and also mentioned black fecal balls indicating consumption of ink bags by these reptiles. In the published summary of this paper (Buckland, 1829b) he stated:

> "The author concludes that he has established generally the curious fact that, in formations of all ages, from the carboniferous limestone to the diluvium, the faeces of terrestrial and aquatic carnivorous animals have been preserved; and proposes to include them all under the generic name of Coprolite" (Buckland, 1829b, p. 143).

Buckland's seminal memoir on coprolites was not published in final form until 1835. This paper still represents one of the most detailed studies ever done on the subject. Details on the history of the origins of the term coprolite can be found in Amustutz (1958), Folk (1965), Duffin (1979), Pemberton and Frey (1991), Hunt et al. (2007), and Duffin (2009).

THE REVEREND WILLIAM BUCKLAND (1784–1856)

The Reverend William Buckland (Fig. 1A) was born in Axminster, England, on 12 March 1784, the eldest son of the Reverend Charles Buckland, a local rector. Details of the life of Buckland were summarized by Portlock (1857), Phillips (1857), Buckland, (1858), Gordon (1894), North (1942), Edmonds (1956), Boylan (1967), Cannon (1970), Rupke (1983), Armstrong (1990), Haile (2004), and Duffin (2006). Buckland was first educated at home by his father, but then entered Axminster School in 1797 and the grammar school at Tiverton. His interest in natural history developed early; speaking as the President of the Geological Section of the British Association at Bristol, he recalled that in the neighborhood of Bristol he had learned a part of his geological alphabet: "The rocks of this city were my geological school. They stared me in the face; they wooed me, and caressed me, saying at every turn 'Pray, pray be a geologist'" (Gordon, 1894, p. 4).

In 1798, Buckland entered St. Mary's College, Winchester to receive better preparation to enter university. With the help of some coaching from his uncle, he obtained a scholarship to Oxford University and

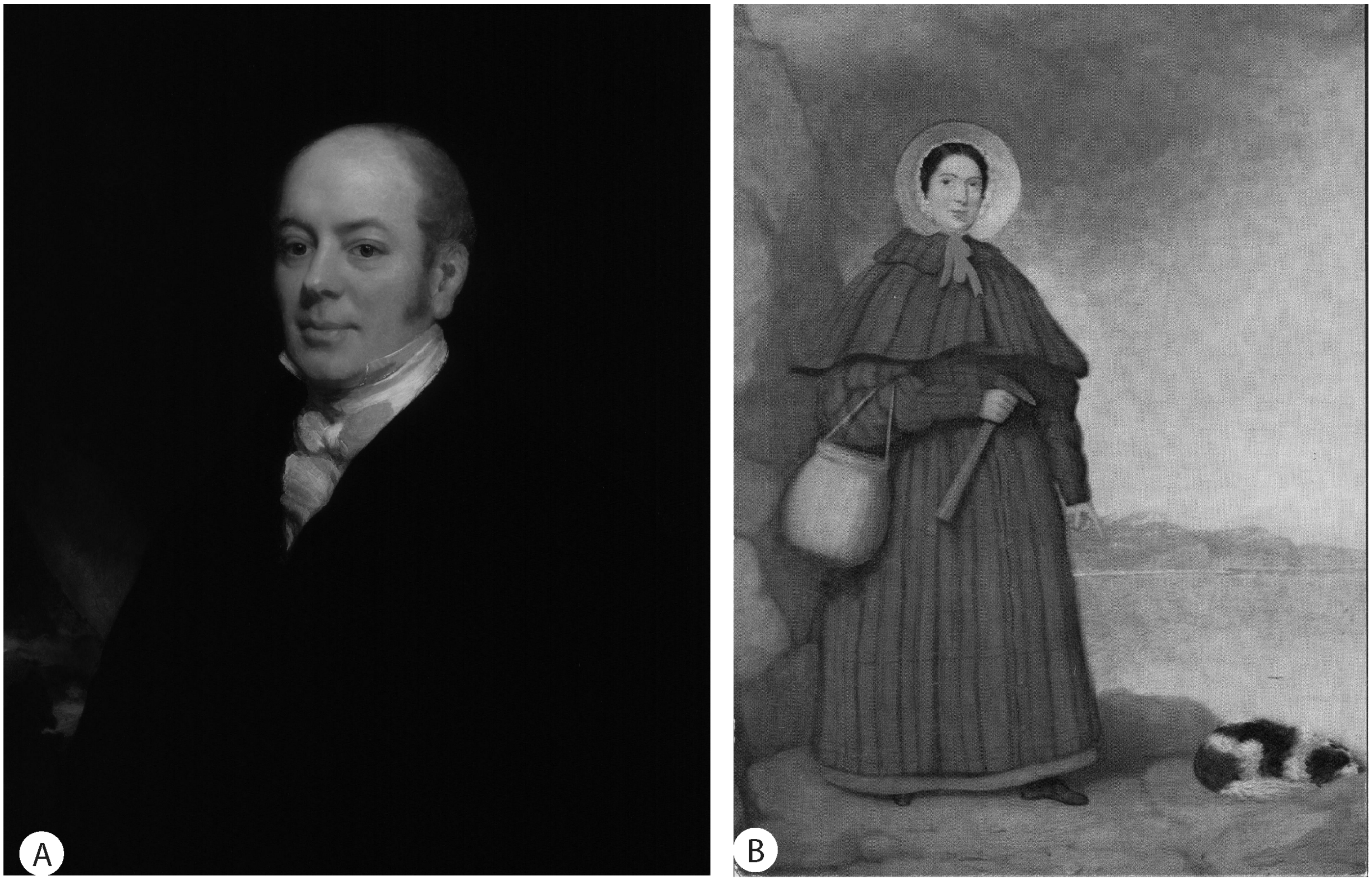


FIGURE 1. Portraits of William Buckland and Mary Anning. A, William Buckland by Thomas Phillips, given to the National Portrait Gallery, London in 1900. B, Mary Anning (1799–1847), original painting by William Gray, probably painted in 1842. The one illustrated is a later version by B.J. M. Donne in 1847 or 1850, and is credited to the Natural History Museum in London.

obtained a B.A. degree from Corpus Christi College in 1804; in 1808, he obtained his M.A. degree, was elected a Fellow of his College, and was ordained a priest.

From 1808 to 1812, Buckland made frequent geological excursions on horseback to various parts of England, Scotland, Ireland, and Wales. He did so much fieldwork that his horse was trained in a unique way:

> "He rode a favorite old black mare, who was frequently caparisoned all over with heavy bags of fossils and ponderous hammers. The old mare soon learnt her duty, and seemed to take interest in her master's pursuits; for she would remain quiet without anyone to hold her, while he was examining sections and strata, and then patiently submit to be loaded with interesting but weighty specimens. Ultimately she became so accustomed to her work, that she eventually came to a full stop at a stone quarry, and nothing would persuade her to proceed until the rider had got off and examined (or, if a stranger to her, pretended to examine) the quarry." (Buckland, 1858, p. xxix).

In 1813, Buckland was elected reader in mineralogy at Corpus Christi College, succeeding Prof. John Kidd. Because of the success of his lectures, a readership (but not a professorship) in geology was endowed in 1818 and, with the intervention of the Prince Regent, Buckland was elected to this post (Edmonds, 1979). His lectures were very lively events (Buckland, 1858; Gordon, 1894; Edmonds and Douglas, 1976): he used many props, such as maps, diagrams, and fossil specimens. His students were enthralled by his personality and many wrote about their experiences in his lectures (Fig. 2). Sir Henry Acland (later to become Regius Professor of Medicine at Oxford from 1858–1894), one of Buckland's students (Fig. 2), described Buckland's lecturing style:

> "He paced like a Franciscan preacher up and down behind a long showcase, up two steps, in a room in the old Clarendon. He had in his hand a huge hyaena's skull. He suddenly dashed down the steps — rushed skull in hand at the first undergraduate on the front bench and shouted 'What rules the world?' The youth, terrified, threw himself against the next back seat, and answered not a word. He rushed then on to me, pointing the hyaena full in my face - 'What rules the world?' 'Haven't an idea', I said. 'The stomach, sir', he cried (again mounting the rostrum) 'rules the world. The great ones eat the less, the less the lesser still.'" (Gordon, 1894, p. 31).

Buckland was associated with Oxford University, in some capacity, for the rest of his life.

Buckland was perhaps one of the most interesting of the 19th century geologists. He was a true eccentric who delighted in the macabre and unusual. This side of Buckland has been summarized as follows:

> "Buckland had another, if lesser, reputation in Oxford—as an eccentric whose proud boast it was that he had not only housed, but eaten, his way through the animal kingdom. One anecdote (possibly apocryphal) has it that, on being reverently shown the heart of a French king, carefully preserved in a snuff box in a house near Oxford, he promptly picked it up and swallowed it. Tuckwell recalled 'the queer

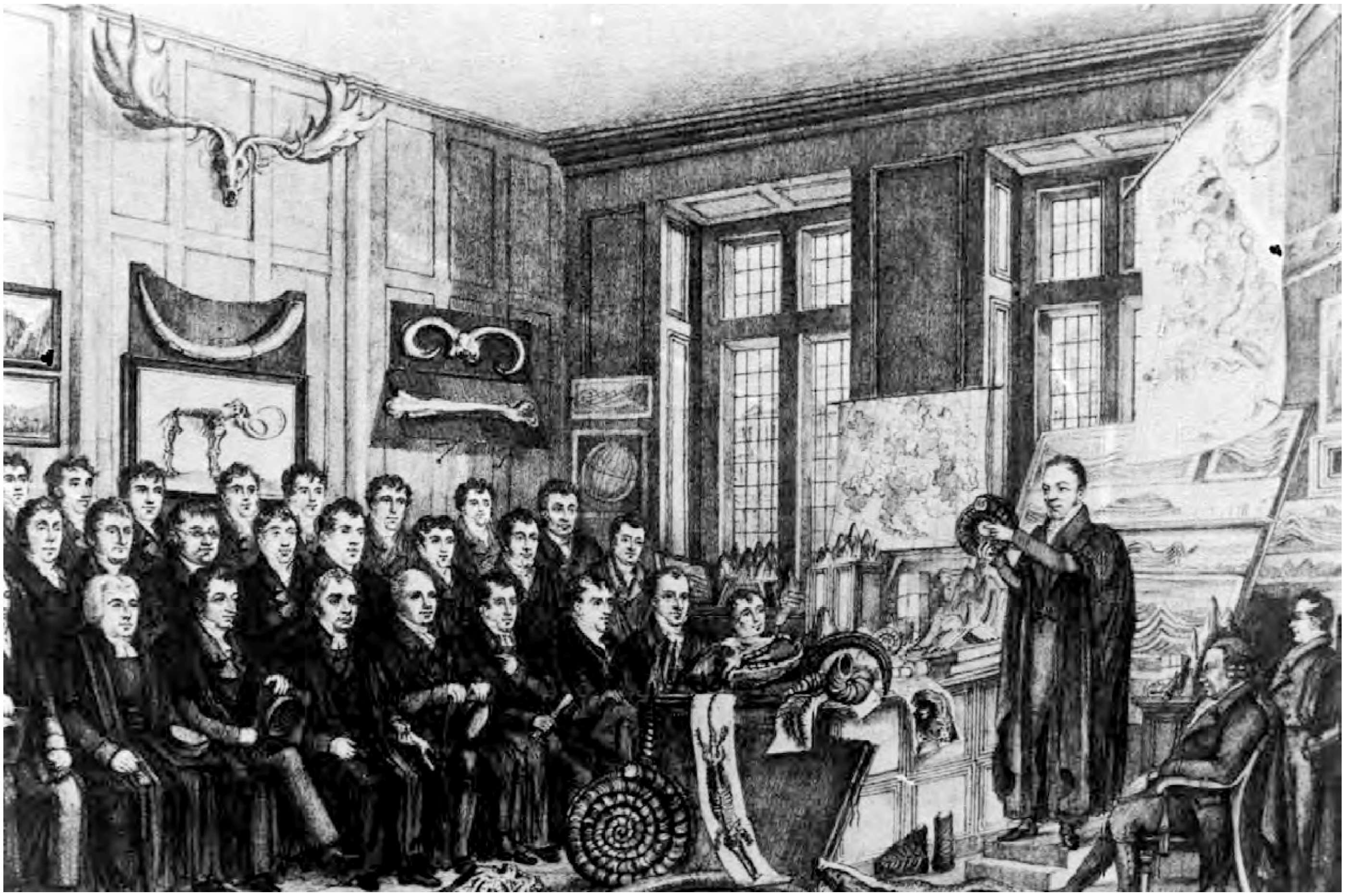


FIGURE 2. William Buckland lecturing in the Ashmolean Museum on February 15, 1823; for details on the members of the audience who represent senior members of the university see Edmonds and Douglas (1976).

dishes garnishing the table—horseflesh I remember more than once, crocodile another day, mice baked in batter on a third day', while Buckland's son, Frank, used to tell of their visit long afterwards to a foreign cathedral, where was exhibited a martyr's blood—dark spots on the pavement ever fresh and ineradicable. The professor dropped on the pavement and touched the stain with his tongue. 'I can tell you what it is—it is bat urine!'" (quoted in Craig and Jones, 1982, p. 54).

This gastronomical tradition was carried on by Frank, who was a proverbial chip off the old block and just as interesting as his famous father. The Buckland household at Oxford was rather bizarre; Brightwell (1941) and Burgess (1967) present interesting accounts of it.

Buckland, because of his eccentric behavior, was either well liked or viewed with suspicion by his scientific colleagues. Many of the most prominent geologists of the time, such as the great French paleontologist Georges Cuvier, Henry De la Beche, Louis Agassiz, John Phillips, William Conybeare, George Greenhough, and Richard Owen, were great admirers of Buckland and visited him often. Others, such as Charles Lyell, Roderick Murchison, Adam Sedgwick, and Charles Darwin, however, felt that Buckland treated science with far too much levity. This view was summed up by Darwin, who wrote in his autobiography:

"All the leading geologists were more or less known by me, at the time that geology was advancing with triumphant steps. I liked most of them, with the exception of Buckland, who though very good humoured and good natured seemed to me a vulgar and almost coarse man. He was incited more by a craving for notoriety, which sometimes made him act like a buffoon, than by a love of science" (Darwin, 1958, p. 60).

From a scientific viewpoint, Buckland was also a man of extremes, and his opinions were highly unpredictable. Most of his early work (e.g., Buckland, 1820) was an attempt to show how geology confirmed the evidence of theology and the scriptures (Boylan, 1967). Buckland is perhaps best known as the champion of the diluvialists, who believed in the "Universal Deluge" or the "Noachian Flood." His research on caves and their associated fossil remains (e.g., Buckland, 1823) formed the cornerstone to the theory and ensured Buckland international fame (Rupke, 1983). This phase of Buckland's career culminated in the preparation of his work for the Bridgewater Treatise (Buckland, 1836), a series of works to justify to man the ways of God as laid out in the will of the Earl of Bridgewater.

In 1840, Buckland abruptly reversed his position and, along with Louis Agassiz, became a leading advocate of the view that many of the features attributed to the Deluge were, in fact, results of glaciation. Buckland was one of the early converts to the glaciation theory, and he became the early British spokesman for Agassiz. As pointed out by Boylan (1967), "In this episode Buckland displayed one of his greatest qualities: that of freely admitting that his previous judgment or opinion was wrong. Buckland, who had been one of the most vigorous defenders of the Flood until 1838, now led the opposition" (Boylan, 1967, p. 239).

Buckland's changing views led one of his friends, Philip Shuttleworth, the Bishop of Chichester, to write: "Some doubts were once expressed about the Flood Buckland arose, and all was clear—as mud!" (Burgess, 1967, p. 10). This ability of scientists publicly to abandon committed positions on major issues was and is indeed rare, not only in Buckland's day but also today. Hallam (1989, p. 216) pointed out how remarkable it was for Buckland to drop, in successive stages, his diluvial theory, and become Britain's leading supporter of Agassiz. This change in position led to some of the dissention among the clergy when Buckland was named Dean of Westminster in 1845.

Buckland's work was generally held in high regard, and during his career he was awarded the Copley Medal by the Royal Society, was President of the Geological Society of London (on two separate occasions, 1824–1825 and 1840–1841), was awarded the Wollaston Medal by the Geological Society of London, was a member of the Royal Society Council (1827–1849), and was President of the British Association for the Advancement of Science (1832). He also played a prominent role in establishing the Geological Survey of Great Britain (now the British Geological Survey), the Royal School of Mines, the Museum of Practical Geology (now the Geological Museum, part of the Natural History Museum of London), and the Mining Records Office. In addition to his scientific accomplishments, Buckland was also a social reformer and led the fight for instituting gas lighting and sanitation reforms.

In 1845, Sir Robert Peel, then Prime Minister of Great Britain, appointed Buckland Dean of Westminster. Peel was a great admirer of Buckland, yet his appointment was controversial because orthodox churchmen were suspicious of Buckland's anti-diluvial interpretation of the Bible (Boylan, 1967). Buckland, however, did an admirable job and was responsible for vastly improving both Westminster Abbey and the prestigious Westminster School. Buckland also held the rectory of Islip, seven miles from Oxford, where he eventually retired due to illness.

In 1849, Buckland contracted a mysterious illness that was characterized by apathy and depression; he died seven years later. The autopsy showed that damage to the base of his skull, caused by a carriage accident in Germany thirty years before, had developed into an advanced state of decay (Cannon, 1970). This illness left Buckland unable to pursue his scientific interests, and John Philips, Buckland's successor at Oxford, aptly summed up the tragedy of his last seven years: "…that apparently indefatigable mind ceased from its labours, and only the form of Buckland survived till the 15th of August, 1856" (Philips, 1857, p. 268). He was buried in St. Nicholas Churchyard, Islip, Oxfordshire, a small village outside Oxford where he and his family lived at the time of his death (Fig. 3A).

Perhaps the final irony belongs to Buckland: it was only when the grave-digger came to excavate the reserved plot in the local graveyard that Buckland's final geological jest was revealed. The chosen spot was, as he must have known, on an outcrop of solid, Jurassic limestone just a few inches below the ground (Gordon, 1894). In the end, explosives had to be used to excavate the grave (Fig. 3B).

BUCKLAND'S WORK ON COPROLITES

Duffin (2009) presented an excellent summary of the early history of coprolite research, including the works of Woodward (1729), Parkinson (1804), and Mantell (1822). Buckland's interest in animal feces was kindled by his work on cave deposits and their organic remains. One of his most famous studies was conducted in 1821, when he visited the Kirkdale Cave in Yorkshire (North, 1942; Boylan, 1967). The cave floor was littered with the bones and teeth of a diverse suite of animals, including hyena, elephant, rhinoceros, hippopotamus, horse, bear, fox, deer, water rat, ox, and various birds. Such deposits, in the past, had been used as evidence for the Universal Deluge, but Buckland was able to offer an alternate hypothesis. He developed an ecological theory that suggested that the cave was actually the den of antediluvial hyenas. Buckland concluded "from the comminuted state and apparently gnawed condition of bones, that the cave at Kirkdale was, during a long succession of years inhabited by hyenas, and that they dragged into its recesses the other animal bodies whose remains are found mixed indiscriminantly with their own" (Buckland, 1823, p. 19–20).

This interpretation generated considerable controversy because Buckland did not advocate the Flood as the causative agent for emplacing the bones: "To the horror of conventional geological and theological thought the Reverend Mr. Buckland convicted the Cave Hyena of the massacre of the animals found in the cave, and relegated Noah's Flood to the minor role of covering the bones with a layer of mud" (Boylan, 1967, p. 241).

Buckland used essentially two lines of evidence for his hyena-den hypothesis: the absence of complete bones and the presence of what he interpreted to be fecal remains. The bones in the cave were nearly all damaged, and Buckland stated "Scarcely a single bone had escaped fracture, with the exception of the astruglus [sic], and other hard solid bones of the tarsus and carpus joints, and those of the feet... On some of the bones, marks may be traced, which, on applying one to the other, appear exactly to fit the form of the canine teeth of the hyena that occur in the cave. The hyena's bones have been broken, and apparently gnawed equally with those of the other animals" (Buckland, 1823, p. 16). Buckland was also puzzled by abundant, white deposits on the cave floor that he concluded were the fecal remains of the hyenas. He called the material "album graecum" because of its white color, which he felt was the result of the hyenas eating bone.

In order to test the hypothesis, Buckland employed rather novel techniques. Boylan (1967) reported that when a travelling menageria came to Oxford, Buckland fed a spotted hyena a meal of the shin bone of an ox, and after collecting its remains the next morning, he concluded "I preserve all the portions of this one for the sake of comparison by the side of those I have from the antediluvian den in Yorkshire: there is absolutely no difference in them except in point of age" (Buckland, 1823, p. 38). This was confirmed by William Wollaston, who did a chemical analysis of the cave album graecum. This study led Wollaston to sarcastically caution Buckland by writing "…though such matters may be instructive and therefore to a certain degree interesting, it may as well for you and me not to have the reputation of too frequently and too minutely examining faecal products" (quoted in Rupke, 1983, p. 33).

Being an avid collector of marine reptiles, Buckland frequently went to Lyme Regis, a famous fossil site in the Lias, along the southern Dorset coast. In the company of the famous amateur collector Mary Anning (Fig. 1B), Buckland found what locally had been called "Bezoar stones" (Fig. 4A), referring to their supposed superficial similarity to the concretions developed in the stomach of the oriental Bezoar goat (*Capra aegagrus*) that were used extensively in 16th- and 17th-century medicine as a universal antidote to poisons (Torrens, 1995). Buckland, however, recognized them as something else:

> "It has long been known to collectors of fossils at Lyme Regis, that among the many curious remains in the Lias of that shore; there are numerous bodies which have been called Bezoar stones, from their external resemblance to the concretions in the gall-bladder of the Bezoar goat once so celebrated in medicine: I used to imagine them to be recent concretions of clay, such as are continually formed by the waves from clay on the present beach; but I have now before me sufficient evidence to show that they are coëval with the lias, and afford another exmaple of the same curious and unexpected class of fossils with the album graecum, which I first discovered in 1822 in the cave of Kirkdale, being the petrified faeces of Saurian animals, whose bones are so numerous in the same strata with themselves" (Buckland, 1835, p. 223).

Buckland went on to suggest that "The certainty of the origin I am now assigning to these Coprolites, is established by their frequent presence in the abdominal region of numerous small skeletons of Ichthysosauri" (Buckland, 1835, p. 224). This interpretation was later questioned by Woodward (1917), who believed that the spiral folds in some of the coprolites were more likely to have been made by sharks than by reptiles (Fig. 5). However, a re-examination of Buckland's material by Pollard (1968) reaffirmed the ichthyosaur interpretation.

FIGURE 3. The burial site of William Buckland. A, St. Nicholas Churchyard, Islip, Oxfordshire, United Kingdom. B, Grave of William Buckland in the St. Nicholas Churchyard Cemetary, Islip.

Torrens (1995) reported that Mary Anning had already identified these dark gray structures, typically up to 10 cm long and resembling “elongate pebbles, or kidney-potatoes,”as “faeces” as early as 1824, and she played a vital role in finding specimens that showed the association of such coprolites with the fossil animals from which they were derived. In particular, she was key in finding specimens that showed coprolites preserved inside the fossils concerned. Mary Anning had noticed that the purported "bezoar stones" were often found in the abdominal regions of Liassic ichthyosaur skeletons at Lyme Regis (Fig. 6A). Buckland credited Anning with two key observations about certain odd fossils: that they were sometimes found in the abdominal regions of ichthyosaur skeletons, and that they often contained fossilized fish scales and bones (and sometimes the bones of small ichthyosaurs) (Fig. 6B). These observations were what led Buckland (1829b) to propose a fecal origin for the nodules for which he coined the term “coprolite.” Since then, the term has become the general name for all fossilized feces. Buckland (1829b) also concluded that the spiral markings on the fossils indicated that ichthyosaurs had spiral ridges in their intestines similar to those of modern sharks, and that some of the coprolites were black because the ichthyosaurs had ingested ink sacs from belemnites. Thus, marine reptile coprolites were described in the inaugural publication of coprolites alongside the fossilized hyena dung he had found in Kirkdale Cave and other, similar objects from other formations.

Because of his earlier cave work, Buckland was acutely aware of the rather unique information that could be garnered from the Lyme Regis material, writing:

> "Dispersed irregularly and abundantly throughout these petrified faeces are the scales, and occasionally the teeth and bones, of fishes, that seem to have passed undigested through the bodies of the Saurians, just as the enamel of teeth and sometimes fragments of bone are found undigested both in the recent and fossil album graecum of hyaenas. These scales are the hard bright scales of the Dapedium politum, and other fishes which abound in the Lias, and which thus appear to have formed no small portion of the food of the Saurians. The bones are chiefly vertebrae of fishes, and of small Ichthyosauri; the latter are less frequent than the bones of fishes, but still are sufficiently numerous to show that these monsters of the ancient deep, like many of their successors in our modern oceans, may have devoured the small and weaker individuals of their own species" (Buckland, 1835, p. 225).

This idea of seeing organisms as interacting entities was one of the first attempts at interpreting paleoecology.

Buckland was also well aware of the magnitude that coprolitic deposits can have in the rock record and reported:

> "This remarkable phenomena of a stratum of stone many miles in extent and many inches in thickness, and in which

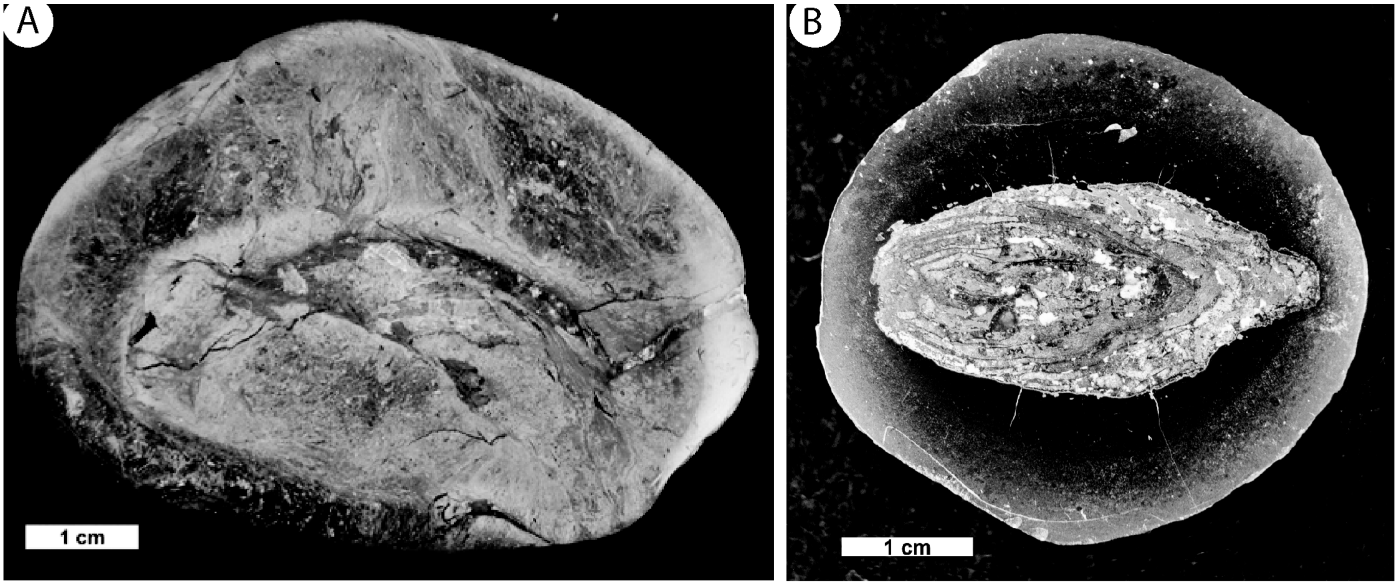


FIGURE 4. Cut and polished coprolites. **A**, Coprolite from the Jurassic Black Ven of Lyme Regis, attributed to an ichthyosaur showing fish scales and bone fragments (author's collection). **B**, Carboniferous shark coprolite, Carboniferous Sandstone, Wardie Shales, Wardie, Midlothian, Scotland (author's collection).

> sometimes one fourth part of the whole substance is made up of balls of Coprolites, seems explicable only by its position in the lowest region of the great formation of the lias, a position which must for a long time have been the bottom of an ancient sea, and the receptacle of the faeces and bones of its inhabitants, the cloaca maxima, as it were of primaeval Gloustershire" (Buckland, 1835, p. 229).

This marked the first real understanding of the concept of biodeposition and its stratigraphic significance in the generation of fine-grained sediment. The significance of the origin of coprolites as feces also was instrumental in their recognition as a source of phosphorous and, therefore, fertilizer (Henslow, 1846; O'Connor, 2001). Ford and O'Connor (2009) indicated that phosphatic nodules (coprolites) occur mainly in the Cretaceous clay formations that outcrop in a SW-NE belt from Norfolk to Oxfordshire with outlying patches in Yorkshire and Kent, and in the early Pleistocene of Suffolk. They were exploited commercially in Victorian times as a source of phosphate for fertilizer that was then called "chemical manure." This resource made a substantial contribution to British agriculture in the 19th century (O'Connor, 2001; Ford and O'Connor, 2009).

Not all the specimens Buckland found could be assigned to reptiles, and Buckland attributed them to sharks and rays. In order to verify this, he made plaster casts of the intestines of modern sharks and compared them to the fossil specimens. On this topic, Buckland reported:

> "An examination of the form and composition of the faeces of living fishes, particularly of the shark and ray and sturgeon tribes, throws much light on the present inquiry. I have recently dissected some rays and log?-fishes, and found in them a short spiral intestine coiled around internally like a screw-pump or winding staircase; injecting these intestines with Roman cement, I have made artificial Coprolites that in form are exactly similiar to many of our fossil specimens" (Buckland, 1835, p. 234).

Buckland thus once more demonstrated his ability to attack a problem in an imaginative and unique way. He pioneered the use of plaster casting techniques of recent structures to compare with ancient ones. Such techniques are now commonplace in many neoichnological studies.

Buckland concluded his coprolite paper with a most insightful analysis:

> "Thus, in formations of all ages, from the first creation of vertebral animals to the comparatively recent period in which hyaenas accumulated album graecum in their antediluvian dens, we find that the faeces of aquatic or terrestrial carnivorous animals have been preserved. In all these various formations our Coprolites form records of warefare, waged by successive generations of inhabitants of our planet on one another: the imperishable phosphate of lime, derived from their digested skeletons, has become embalmed in the substance and foundations of the everlasting hills; and the general law of Nature which bids all to eat and be eaten in their turn, is shown to have been co-extensive with animal existence upon our globe; the Carnivora in each period of the world's history fulfilling their destined office to check excess in the progress of life, and maintain the balance of creation" (Buckland, 1835, p. 235).

On the subject of coprolites, his son Frank Buckland wrote:

> "Some of these coprolites have been turned to purposes of art, under the name of 'Beetle-stones'. Dr. Buckland had a table in his drawing-room that was made entirely with these coprolites, and which was often much admired by persons who had not the least idea of what they were looking at. I have seen in actual use ear-rings made of polished portions of coprolites; and while admiring the beauty of the wearer, have made out distinctly the scales and bones of the fish which once formed the dinner of a hideous lizard, but now hung pendulous from the ears of an unconscious belle, who had evidently never read or heard of such things as coprolites" (Buckland, 1883, p. 8).

The table in the junior Buckland's reference (Fig. 7) has recently been documented in the collections of the Philpot Museum in Lyme Regis (Accession Number LYPH 38/42). Sharpe (2004), Duffin (2009), and Bull (2010) give details about both the description and the provenance of the table, which is probably composed of coprolite specimens not from Lyme Regis, but from the Wardie Shales near Edinburgh, Scot-

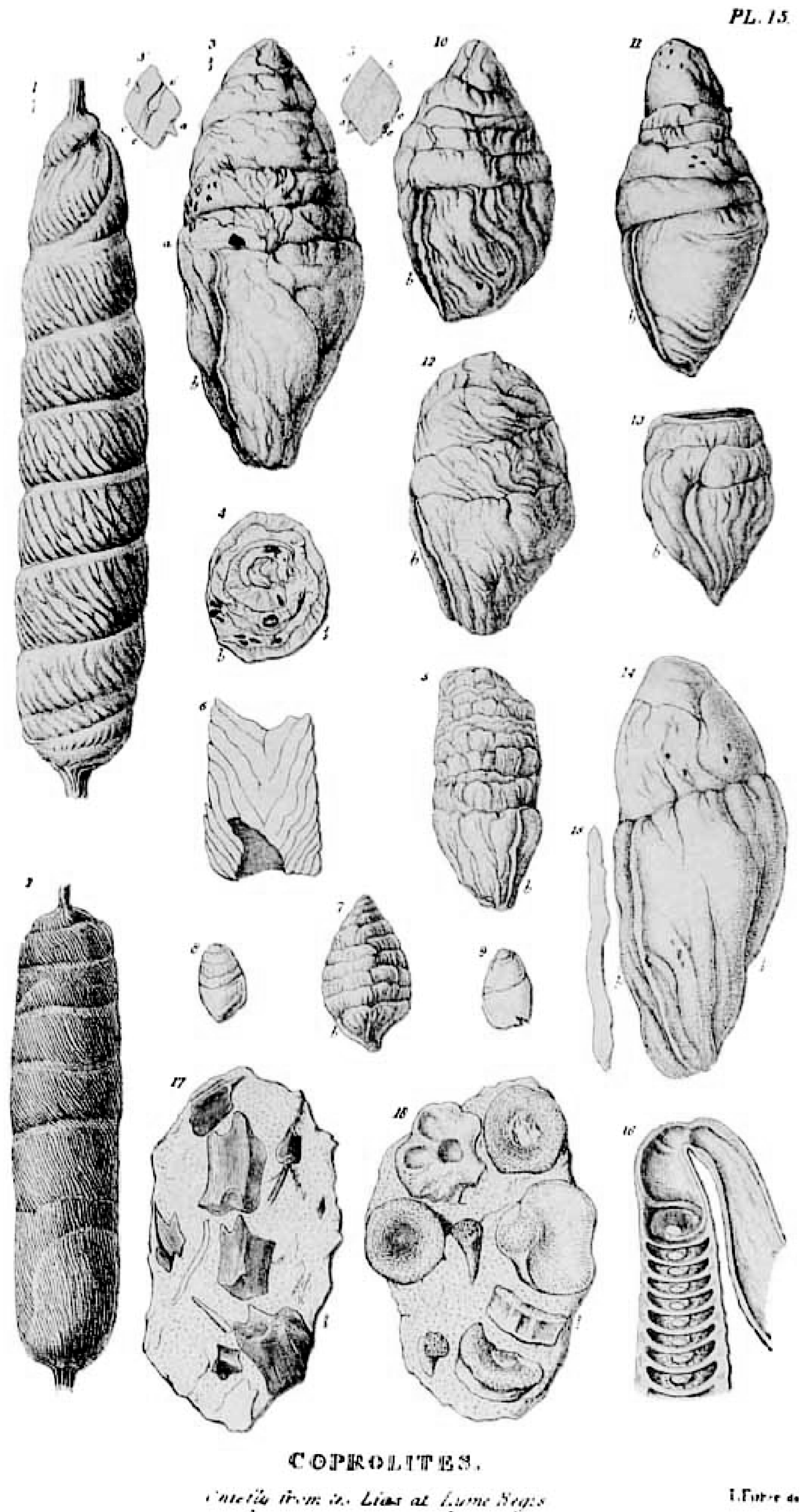
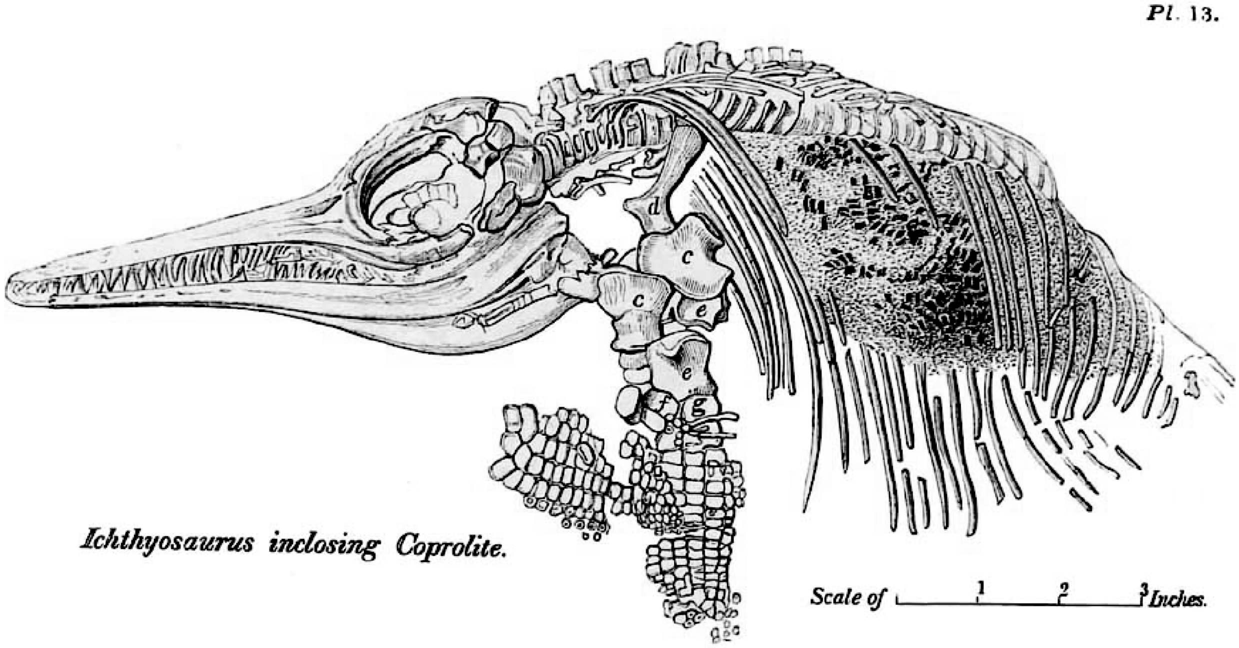


FIGURE 5. Copy of original plate (plate 15) illustrating coprolites, from Buckland (1836). Most specimens are from the Lias of Lyme Regis and are housed at the Oxford University Museum.



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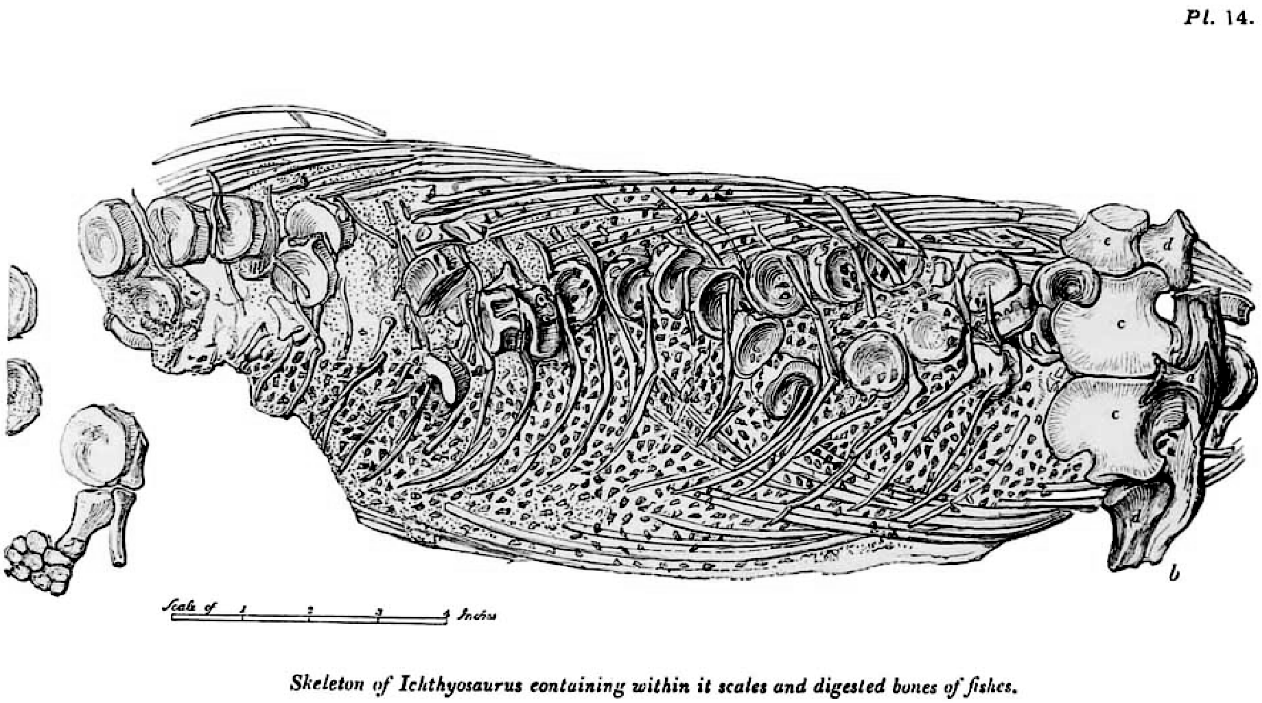

B

FIGURE 6. Skeletons of *Icthyosaurus* containing coprolitic material in the body cavity. **A**, Copy of original plate from Buckland (1836, pl. 13) illustrating the skeleton of a small *Ichthyosaurus*, from the Lias at Lyme Regis, presented to the Oxford Museum by Viscount Cole, enclosing within its ribs scales and digested bones of fishes as coprolites. This coprolitic mass seems nearly to retain the form of the stomach of the animal. c, Coracoid bone. d, Scapula. e, Humerus. f, Radius. g, Ulna. **B**, Copy of original plate from Buckland (1836, pl. 14) illustrating the skeleton of the trunk of a small *Ichthyosaurus* in the Oxford Museum, from the Lias at Lyme Regis, containing within the ribs, a coprolitic mass of digested bones, interspersed with scales of fishes. a, Furcula. b, Clavicle. c, Coracoid bone. d, Scapula. e, Humerus.

FIGURE 7. The Buckland Coprolite Table, Accession Number LYPH 38/42 in Lyme Regis Museum; photo supplied by Mr. Richard Bull of the Friends of the Lyme Regis Museum.

land (Fig. 4B). In his Bridgewater Treatise, Buckland (1836) stated that:

> "Mr W C Trevelyan recognised Coprolites in the centre of nodules of clay ironstone, that he found in a low cliff composed of shale, belonging to the coal formation at Newhaven, near Leith. I visited the spot, with this gentleman and Lord Greenock, in September 1834 and found these nodules stewed so thickly upon the shore, that a few minutes allowed me to collect more specimens than I could carry. Many of these contained a fossil fish, or a fragment of a plant, but the greater number had at their nucleus, a Coprolite, exhibiting an internal spiral structure: they were probably derived from voracious fishes, whose bones are found in the same stratum. These nodules take a beautiful polish, and have been applied by the lapidaries of Edinburgh to make tables, letter presses, and ladies ornaments under the name of Beetle stones from their supposed insect origin". (Buckland, 1836, pp. 198–199).

HENRY DE LA BECHE AND HIS GEOLOGICAL CARICATURES BASED ON COPROLITES

Introduction

Buckland's vivid sense of humor and the fact that he enjoyed working on rather strange subjects, such as coprolites and fossil footsteps, provoked a great deal of light-hearted jesting from both his friends and his students (North, 1942; Boylan, 1967; Rupke, 1983; Pemberton, 2010). Buckland seemed to enjoy, and even encourage, these activities and never seemed to be at a loss for words about anything. This trait was shared by his son Frank, who wrote a series of amusing books on the curiosities of natural history.

A somewhat amusing sidelight to Buckland's work on coprolites was provided by his friend Sir Henry Thomas De la Beche, who was a talented amateur artist. De la Beche also held the distinction of being the first director-general of the Geological Survey of Great Britain. Thereby, he became the first field geologist to be in a permanent, full-time position paid by the state (McCartney, 1977). Rudwick (1975) stated that De la Beche used his artistic abilities to develop a visual language of geology using maps and geological landscape views. He also embellished his scientific correspondence with caricatures, some of which he drew on stone and distributed as lithographs to his close friends (Rudwick, 1975; McCartney, 1977).

Sir Henry De la Beche (1796–1855)

Sir Henry De la Beche (Fig. 8) was born on February 10, 1796 in London to Henry and Elizabeth De la Beche. Details on the life of De la Beche were summarized by Hamilton (1856), Eyles and Eyles (1955), Eyles (1971), McCartney (1977), Reyment (1996), Secord (2004), and Chubb (2010). The family name was originally Beach, but his father changed it to create a fictional connection with the medieval Barons De la Beche of Aldworth, Berkshire (Secord, 2004). His father was a Lieutenant-Colonel in the Norfolk Fencible Cavalry regiment. Having inherited a

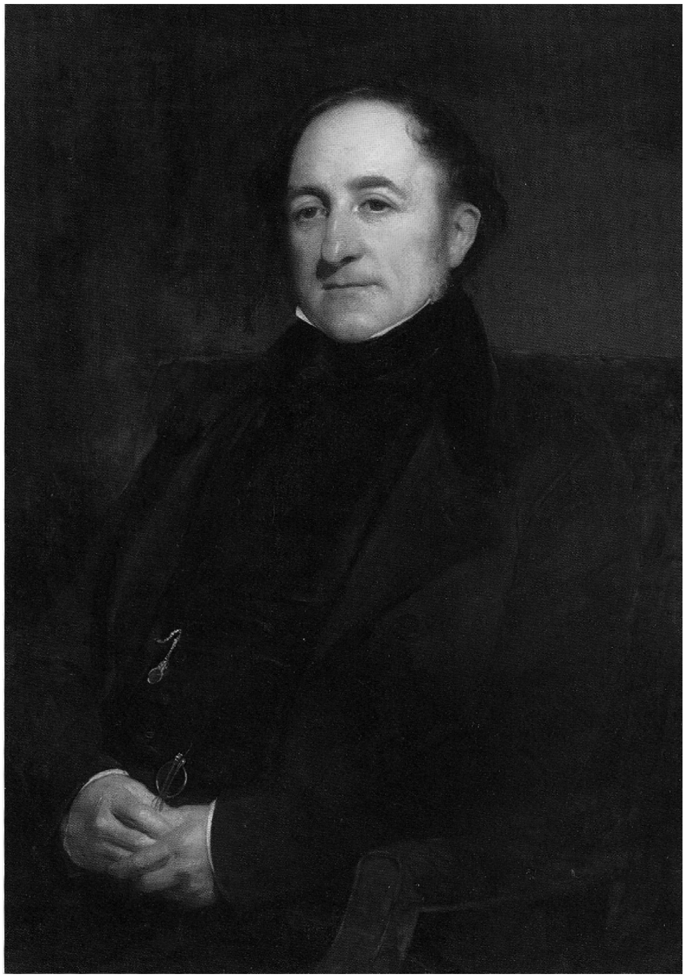

FIGURE 8. Painting of Sir Henry De la Beche (1796–1855) by H.W. Pickersgill (circa 1850). A friend of William Buckland, De la Beche was responsible for the caricatures Coprolitic Vision and Duria Antiquior.

plantation in Jamaica, his father took his family there in 1800, where he died on June 1, 1801. Four months later, Henry returned to England with his mother.

De la Beche was educated first at Mr. Taylor's school in Hammersmith, then in 1805 at Keynsham, Somerset, and then for a year from 1808 at Mr. Holditch's school at Ottery St Mary in Devon. Planning to follow a military career, he entered the Royal Military College at Marlow in 1809, but was expelled in disgrace two years later after encouraging a "dangerous spirit of Jacobinism" (McCartney, 1977) among the cadets. He spent the next few years in towns along the south coast, settling at Lyme Regis in 1812. There he associated with Thomas Coulson Carpenter and George Holland, professional men interested in meteorology and geology. De la Beche travelled with them in Scotland and the north of England in 1816, and joined the Geological Society of London a year later. At Lyme Regis, De la Beche also became acquainted with the Annings, the artisan family that was establishing a business selling fossils, and with the daughter Mary he searched the Lias cliffs for remains of extinct reptiles.

In 1823–1824, De la Beche travelled to Jamaica to inspect his family estate at Halse Hall, and eventually published original research on Jamaican geology, including a detailed geological map of the eastern half of the island (Chubb, 2010). His other notable research was conducted on Jurassic ichthyosaurs and plesiosaurs (Conybeare and De la Beche, 1821). Secord (2004) noted that De la Beche's Jamaican plantation interests supported his early geological pursuits, and within the elite circle of geologists, he developed lasting friendships with several prominent geologists, including William Conybeare and William Buckland.

In the early 1830s, the income from De la Beche's Jamaica holdings failed entirely and he returned to Lyme Regis where he began a detailed investigation of the rocks of Cornwall and Devon. Secord (2004) reported that, for some years, De la Beche had been coloring maps of Devon for the Ordnance Surveys and when his fortunes changed so dramatically, he applied to the government in 1832 for £300 to complete his survey. With support from influential friends in Lord Grey's Whig administration, De la Beche was appointed geologist to the Ordnance Trigonometrical Survey of Great Britain under Colonel Thomas Colby. Further funds were granted in 1835 for a survey of Cornwall, and a tiny Museum of Economic Geology was opened in Craig's Court, Charing Cross. From these small beginnings, De la Beche looked to a transformation of British science: he wanted geology to become part of the state administrative apparatus. De la Beche can be considered, then, as one of the first paid professional geologists. For details on the origins of the Great Britain Geological Survey, see Fleet (1937), Wilson (1985), and Bate (2010).

Aside from being an exceptional geologist, De la Beche was also a talented artist and draugtsman. He did most of his own illustrations for his scientific works, including the many books that he wrote. This talent was most evident in the forty plates of his innovative book Sections and Views Illustrative of Geological Phenomena (De la Beche, 1830), as well as the volumes a Manual of Geology (De la Beche, 1831) and the Geological Observer (De la Beche, 1851). He also produced some biting caricatures that were generally directed at specific people. One of his favourite targets was Charles Lyell (Rudwick, 1975; Clary and Wandersee, 2010), who he preceived as a theoretical geologist. Two of his most famous caricatures were Awful Changes (Fig. 9A) and Preconceived Opinions vs. Facts (Fig. 9B). Awful Changes, which was drawn in 1830, depicted an ichthyosaur professor lecturing on a fossilized human skull: "'You will at once perceive' continued Professor Ichthyosaurus, 'that the skull before us belonged to some of the lower order of animals; the teeth are very insignificant, the power of the jaws trifling, and altogether it seems wonderful how the creature could have procured food.'" Rudwick (1975) presented convincing arguments that suggested that Professor Ichthyosaurus in fact represented Charles Lyell. The caricature Preconceived Opinions vs. Facts, drawn in 1834, lampooned his critics in the debate on the appearance of plant fossils in older geological formations. These critics included Roderick Murchison, Adam Sedgwick, and Charles Lyell; in the caricature, De la Beche's critics are wearing the spectacles of theory. In the caricature, De la Beche opens with the statement "This, Gentlemen, is my Nose" to which his critics respond with "My dear Fellow!—your account of yourself generally may be very well, but as we have classed you, before we saw you, among men without noses, you cannot possibly have a nose." These caricatures illustrate a common theme evidenced even today – the struggle between the field geologist and the model-based geologist.

Henry De la Beche received many honors throughout his career. In 1823, at the very young age of 27, he was elected a Fellow of the Royal Society. He was elected president of the Geological Society in 1847, and, just prior to his death in 1855, was awarded its Wollaston medal. He was knighted in 1842 and made a Companion of the Bath in 1848 (Secord, 2004). However, his greatest triumph came in 1851 when Prince Albert opened the Museum of Practical Geology on Jermyn Street. It was a Museum housing important fossils, rocks, and building stones, and it also housed a government-funded School of Mines modeled on the École des Mines in Paris. Later in the century, the Royal School of Mines emerged as a leading center, especially for training geologists for work in the colonies. In 1907, the school was separated from the survey and the museum to become part of Imperial College, where the student geology society was subsequently called the De la Beche Club. Although other parts of the institutional empire De la Beche created were dismantled in the 20th century, the British Geological Survey and the earth galleries at the Natural History Museum bear witness to the legacy of his belief in state support for the earth sciences.

FIGURE 9. **A**, The De la Beche caricature lithograph Awful Changes drawn in 1830, original in the National Museum of Wales (NMW 84.20G.D 367.1-25). This copy is provided through the courtesy of Dr. Michael Bassett of the National Museum of Wales, who granted permission to reproduce it here. **B**, Pen and ink sketch entitled Preconceived Opinions vs Facts from a letter from De la Beche to Adam Sedgwick, December 11, 1834; original in the Sedgwick papers, Cambridge University Library (Ms. 7652, 1A.125).

Just as his ambitious plans came to fruition in 1851, De la Beche began to suffer symptoms of a progressive paralysis. He was able to conduct survey business almost up until his death in London on 13 April 1855; he was buried in Kensal Green cemetery on April 19.

A Coprolitic Vision

One of the most entertaining of De la Beche's caricatures was entitled A Coprolitic Vision (NMW84.20G.D. 432; Fig. 10A), which was De la Beche's way of poking fun at his friend Buckland's latest pastime. McCartney (1977) described the caricature as follows:

> "Although he appreciated the value of his friend's scientific insights, De la Beche could not resist the temptation to caricature this 'Coprolitic Vision'. He produced a lithograph (ca. 1829) showing the 'Reverend Professor of Mineralogy and Geology in the University of Oxford', dressed in gown and mortar-board, and standing on a flat rock at the opening of a long cavern shaped like the nave of a cathedral. The colums supporting the roof were bloated spiral-shaped bezoars, and Buckland, with a geological hammer in his right hand, as it were conducts a service attended by animals—a deer, a bear, hyenas, a leopard, crocodiles, ichthyosaurs, and pterodactyls. Every member of the chair and congregation are shown in that act of defecating. There are even large cylindrical shapes on the rock in the foreground, and one beneath Buckland's own legs" (McCartney, 1977, p. 48).

At first glance, the caricature might indicate that De la Beche and Buckland were not on amiable terms. This was not so, however: they liked each other very much. McCartney (1977) stated that "when De la Beche used his art to poke fun at Buckland, the light-hearted nature of his intention is unmistakable" (McCartney, 1977, p. 50).

Duria Antiquior

Similarly, Buckland provided De la Beche with great paleontological insights for many of his caricatures. For instance, many of the fine paleontological details in one of De la Beche's most famous works, the watercolor Duria Antiquior (or Ancient Dorsetshire; NMW 84.20G.D.368), were provided by Buckland. This lithograph was produced in 1830, a full year after A Coprolitic Vision and illustrates that the two men were still friends after its appearance. The painting (Fig. 10B), an early example of what is now commonly known as paleoart, is a restoration of a scene of prehistoric life based on evidence from fossil reconstructions and is based on fossils found in Lyme Regis mostly by the professional fossil collector Mary Anning. De la Beche had professional artist Georg Scharf produce lithographic prints based on the painting, which he sold to friends to raise money for Mary Anning's benefit. Despite her renown in geologic circles, in 1830 Anning was having financial difficulties because of hard economic times across Britain, and the long and unpredictable intervals between major fossil finds. He then sold copies of the print to friends and colleagues at the price of £2 10s each and donated the proceeds to Mary Anning (Rudwick, 1992).

By 1830, Mary Anning was well known to the leading British geologists and fossil collectors for her ability to spot important fossils in the Jurassic limestone and shale formations around the resort town of Lyme Regis on the Dorset coast, and for her knowledge and skill in collecting, reconstructing, and preparing them (Turner et al., 2010). William Conybeare's scientific descriptions of some of the marine reptile fossils she had found, including the first ichthyosaur skeleton to be recognized for what it was and the first two plesiosaur skeletons ever found, had created a sensation in scientific circles. Anning's observations led Buckland to write a vivid description of the Lias food chain. It was this description that motivated the geologist De la Beche, who had worked with Conybeare describing the marine reptile fossils, to create his pictorial representation of life in ancient Dorset.

Many of the creatures in Duria Antiquior are depicted in violent interaction. The central figures are a large ichthyosaur biting into the long neck of a plesiosaur. Another plesiosaur is seen trying to surprise a crocodile on the shore, and yet another is using its long neck to seize a pterosaur flying above the water. This emphasis on violent interactions in nature was typical of the regency era. Several of the ichthyosaurs are depicted seizing various of the fishes whose scales and bones had been found in coprolites, and a couple are shown excreting the feces that would become the coprolites of the future. In addition to the vertebrates, the restoration depicts several invertebrates, including belemnites, depicted as squid-like, and an ammonite, depicted as a floating creature along the lines of a paper nautilus. There are also more recognizable, empty ammonite shells on the sea bottom, and some stalked crinoids (sea lilies) in the lower right corner, of which some very finely preserved fossils had been found at Lyme Regis. One of the features of the painting that has most struck historians is the split-level view that shows action both above and below the surface of the water. This perspective is known as an aquarium view, and Duria Antiquior is the first known example (Clary and Wandersee, 2005); the style would not become common until the Victorian aquarium craze a couple of decades later. It was the first scene from deep time to see even limited publication. The print proved quite popular, and, at some point, the lithograph was redrawn and a larger run was printed; in some of the later versions, the figures were numbered (Rudwick, 1992). William Buckland kept a supply of the prints on hand and circulated them at his geology lectures. Numerous variations were produced, including a German version done by August Goldfuss (Rudwick, 1992). In the late 1840s, Robert Farron, one of the curators at the Sedgwick Museum of Earth Sciences at Cambridge University, painted a large oil copy of the De la Beche original, and it remains on display at the museum (Clary and Wandersee, 2009).

CONCLUSION

The Reverend Wiliam Buckland possessed one of the most innovative minds ever to grace the science of geology; he was also one of its most eccentric characters. His science can best be described as eclectic, encompassing, among other things the first scientific study of dinosaur footprints, the first study of coprolites, the first mention of preserved raindrop impressions, the first study to utilize modern analogues to interpret ancient structures by injecting plaster of Paris into shark and ray intestines, the pioneering of cave paleontology, early advocacy of economic geology, embracing the glacial theory, and among the first recognitions of the significance of functional morphology. His works on footprints and coprolites were the first attempts at neo-ichnology and taphonomy (Pemberton et al., 1996, 2008; Boylan 1997), and his work on coprolites led directly to the creation of the painting Duria Antiquitor, which is the inaugural paleoecological reconstruction (Rudwick, 1992). Nicolaas Rupke, in his elegant book on Buckland, wrote: "Buckland's cave paleontology became an enduring cornerstone of his subject. It represented the first major ecological study of fossils, examined not just as taxonomic entities, but as members of fossil communities, to be interpreted with the aid of present day analogues" (Rupke, 1983, p. 7).

He went on to stress that "Three geological phenomena in particular formed the basis for Buckland's paleoecology: fossil excrement or coprolites, animal footprints in sandstone, and fossil plants in a soil layer" (Rupke, 1983, p. 139), and he concluded that "[Buckland] rejected the notion that progress is merely a climb up the taxonomic ladder, from a les perfect to a more perfect level of organization, and emphasized that perfection in this context os a relative notion which has little meaning in the abstract, but is a function of adaptation to a particular environment" (Rupke, 1983, p. 158).

With his keen imagination, Buckland saw coprolites not just as somewhat obscure oddities, but as tools to help bring to life long extinct animals. He used coprolites to understand the diets, behaviors, and internal anatomies of the reptiles involved. The final word on coprolites

FIGURE 10. Caricatures by De la Beche. **A**, Copy of the De la Beche caricature Coprolitic Vision. **B**, Copy of the De la Beche caricature Duria Antiquior. Both copies are provided through the courtesy of Dr. Michael Bassett of the National Museum of Wales, who granted permission to reproduce them.

should belong to Buckland, who wrote:

> "The above facts which we have elicited from the coprolitic remains of the Ichthyosauri, afford a new and curious contribution to our knowledge both of the anatomy and habits of the extinct inhabitants of our planet. We have found evidence which enables us to point out the existence of beneficial arrangements and compensations, over in those perishable, yet important parts which formed their organs of digestion. We have ascertained the nature of their food, and the form and structure of their intestinal canal; and have traced the digestive organs through the spiral coils of a compressed ileum, to their termination in a cloaca; from which the coprolites descended into the mud of the nascent lias. In this lias they have been interred during countless ages, until summoned from its deep recess by the labours of the Geologist, to give evidence of events that passed at the bottom of the ancient seas, in ages long preceeding the existence of man" (Buckland, 1836, p. 19).

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Portrait of William Buckland, who coined the term coprolite. Image courtesy of the Wellcome Trust.