



Teaching Perspective

The Bristol Dinosaur Project

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ABSTRACT

Dinosaurs have been fascinating to the widest public since the 1840s, and that interest has grown step-wise ever since. Public interest has been harnessed over the years especially by museums in blockbuster exhibitions, and in the form of best-selling books and films. Here we describe a major educational initiative, the Bristol Dinosaur Project, which has run for ten years and has reached tens of thousands of children and adults, supported by substantial funding. The Bristol Dinosaur Project focuses on the fourth dinosaur ever named in the world, *Thecodontosaurus*, discovered in Bristol in 1834, and named in 1836. The dinosaur is not in itself spectacular, being only 1–2 m long, but its evolutionary role as one of the first plant-eating dinosaurs in the world justifies our current research, and provides a strong theme for the public presentation. Further, the fact that the dinosaur is found as disarticulated bones in ancient tropical cave systems, allows us to develop numerous key themes with all age groups: the geological time scale, continental drift, reconstruction of ancient environments, modern landscape analogues, the rock cycle, evolution, biomechanics, and critical assessment of geological and palaeontological evidence. These themes are of key importance for socio-economic and intellectual reasons, and yet are often poorly understood.

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1. Introduction

Dinosaurs have always been an excellent means of science engagement for people of all ages, especially children. In the early years of their subject, palaeontologists recognised this, and their books, articles, and public lectures were generally written partly for their fellow academics and partly for the educated public. In Victorian times in England, Richard Owen (1804–1892) and Thomas Henry Huxley (1825–1895) went a step further than their forebears, and made specific efforts to broaden the interested constituency. Owen famously advised on the construction of life-sized concrete models of dinosaurs for the outdoor parts of the Crystal Palace exhibition, and sanctioned imaginative drawings in the *Illustrated London News*, as well as souvenir models of dinosaurs and posters (Fig. 1) for keen children (Torrens, 1995; Gould, 1997; Secord, 2004). This was really the first manifestation of 'dinomania'. Huxley too made particular efforts to engage the public, lecturing to non-professional audiences such as the Working Men's Association.

Since the 1850s, there have been numerous waves of enthusiasm for dinosaurs in the United States, Europe, Japan, and elsewhere, associated with the 'bone wars' from 1870 to 1900

when Edward Cope (1840–1897) and Othniel Marsh (1831–1899) named dozens of new dinosaurs from the American Midwest, and during the early decades of the twentieth century when major museum exhibits were opened in capital cities, from New York to London, and Berlin to Buenos Aires (McIntosh, 1990; Benton, 2000; Brinkman, 2010). Enthusiasm levels seem to have been low from the time of the First World War to the 1950s, and this was associated with a low ebb in the number of professional palaeontologists working on dinosaurs, and in the numbers of new dinosaurian species being named (Benton, 2008).

In the 1950s and 1960s, renewed interest was stimulated by classic dinosaur art, in the paintings of Charles Knight (1874–1953) in the American Museum of Natural History, and by Rudolf Zallinger (1919–1995) in the Peabody Museum of Natural History (Allmon, 2007). Images from both artists formed special features in popular magazines such as *National Geographic* and *Time*, and the new colour printing gave these an impact on the public that had not been seen before. At about this time, Edwin H. Colbert (1905–2001) wrote a number of authoritative popular books on dinosaurs, in fact the first in a genre that now counts thousands of titles written, or co-written, by professional palaeontologists. Further boosts to the public excitement about dinosaurs in the 1950s and 1960s came from early fictional films such as *One million years BC* (1966) – although the excitement may have been stimulated more by Raquel Welch's flimsy costume made from three small rabbit skins. Certainly the stunning computer-generated imagery of

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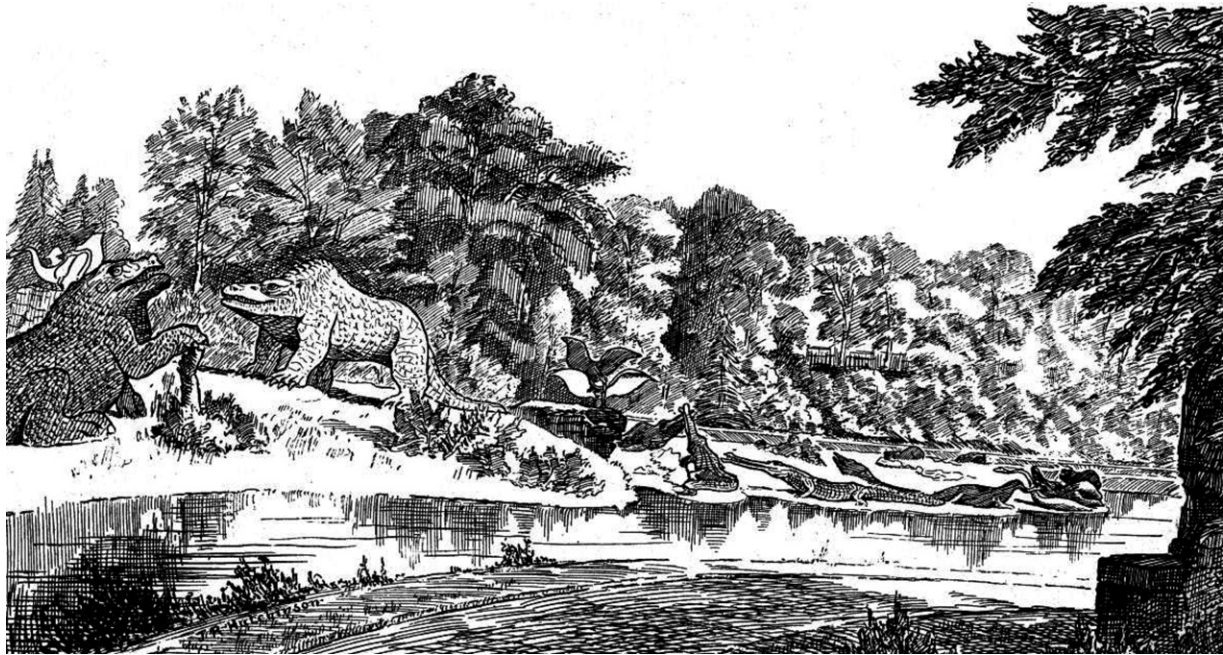


Fig. 1. An early example of 'dinomania', a drawing of the life-sized concrete dinosaurs constructed by the sculptor Waterhouse Hawkins, under the direction of Sir Richard Owen, for the outdoor exhibition at Crystal Palace which opened in early 1854.

Jurassic Park (1993) and *Walking with dinosaurs* (1999), and their sequels, brought enormously heightened interest (Campbell, 2009).

In this paper, we present the Bristol Dinosaur Project, a high-profile educational and engagement enterprise, supported by substantial funding, and reaching out to many thousands of people of all ages. This is based on one of the first dinosaurs to be found, *Thecodontosaurus*, whose bones were excavated in Bristol in 1834. In true British style, it was neither large nor showy, but was a modest-sized herbivore, indeed one of the first herbivorous dinosaurs to evolve. Nonetheless, it has proved to be a successful ambassador for science, engaging the interest of people in and around Bristol. We use our experience over twenty years to explore how dinosaurs can unlock understanding and enthusiasm for science.

2. Dinomania phase 5 (1969->)

It may be worthwhile to place the Bristol Dinosaur Project (BDP) in the wider context of where we are now in terms of dinomania. Here, we use the term 'dinomania' to mean 'the popular excessive enthusiasm for anything to do with dinosaurs'. As noted, the first three phases of dinomania were discrete and focused by country: phase 1 was from 1830–1860 in England (Owen, Huxley), phase 2 from 1870 to 1900 in the United States (Cope, Marsh), phase 3 from 1900 to 1910 in the United States and Canada, and phase 4 from 1950 to 1970 in North America first, and then more widely. These earlier phases all apparently fizzled out as a result of the deaths of key scientists, reductions in new dinosaur finds, or world wars. The fifth phase of dinomania dates from 1969; unlike previous manifestations, current public interest in dinosaurs seems to be sustained, it is not focused on a single author or a single manifestation or event, and it does not seem to fade. We have to go back to the 1960s to see the beginnings (Benton, 2000).

Oddly, the current phase of dinomania did not stem from the excitement of new discoveries – that came later. Owen and Huxley were taking the new science of palaeontology to the public, and it is true now that much of the current brouhaha about dinosaurs

comes more from science than Hollywood. Press releases about new dinosaurs, and other new professional publications in palaeontology more widely, appear every week and quickly reach every corner of the Earth through a hungry press and media, as well as an even more hungry internet machine of blogs and science reporting websites. But, back in the 1950s and 1960s, very little dinosaur research was published, and very few new dinosaurs were reported. The tipping point came in 1969, when John Ostrom published one of the finest palaeontological monographs ever (Ostrom, 1969), a painstaking, detailed, 165-page account of the new dinosaur he had found in 1963, *Deinonychus*.

Why was this one paper such a crossover hit, impressing the scientists and invigorating a new wave in palaeontological research, as well as taking the latest science to the public at a leap? There are perhaps six reasons: (1) *Deinonychus* was an astonishing dinosaur, something quite new and dynamic, especially with its massive switch-blade slashing toe claw; (2) Ostrom's work in words and illustrations of the bones, was superb, an example of excellence in science and monographic palaeontology for professors to show their students; (3) *Deinonychus* was not just any old dinosaur, but it was, argued Ostrom, a close relative of birds; (4) Ostrom justified a new, dynamic kind of dinosaur – *Deinonychus* just could not be conceived of as a slow, lumbering creature, but it had to have been able to balance on one leg, swing its foot-claw, and leap aside to avoid damage from its larger prey; (5) further, the model for the lifestyle of *Deinonychus* involved pack hunting and cooperation, in other words, a large brain and keen senses; and finally (6) this was all fleshed out with one of the most iconic palaeontological drawings ever, Bob Bakker's pencil sketch of a dynamic running *Deinonychus*, backbone horizontal and tail stretched back (Fig. 2). In this one drawing was synthesized the wow factor of an astonishing new dinosaur, a small, active predator, but also a new model for dinosaur posture and life, and a very convincing one too. The old 'kangaroo posture', where bipedal dinosaurs rocked back and stood with their torso vertical, now looked ridiculous and improbable. With the body balanced over the hips, dinosaurs ran with their backbones horizontal, the tail acting as counterbalance to the torso and head.

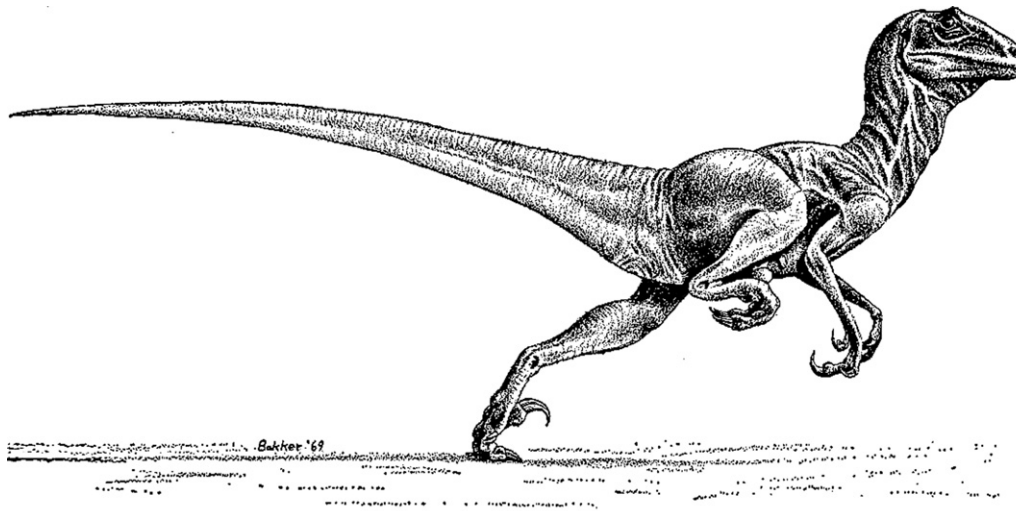


Fig. 2. Reconstruction drawing of *Deinonychus* by Bob Bakker, published first in Ostrom (1969), and identified as the single image that revolutionized scientific and public perceptions of dinosaurs. © Bob Bakker/Yale Peabody Museum.

The reawakening of interest in dinosaurs for both children and, importantly, adults, led to an explosion in publication of books and magazine articles. Notable among the books is Norman (1985), a massively important publication both in terms of the volume of advanced detail and concepts about current palaeontological research, but also for the iconic painted reconstructions of dinosaurs by the celebrated artist John Sibbick.

The earlier suggestion that dinosaurs had been warm-blooded (endothermic), just like birds and mammals, was perhaps overplayed by Bakker (1986), but the discovery that most or all theropods bore feathers (Norell and Xu, 1995), and coloured feathers at that (Li et al., 2010; Zhang et al., 2010), confirmed the new, active kind of dinosaur. Perhaps it is this dynamic dinosaur, as opposed to the tail-dragging miseries seen in previous phases of dino-mania, that triggered the beginning of the last forty years of dino-fanaticism. On top of this, the enthusiasm has then been fanned and fuelled by continuing spectacular discoveries, especially from previously only partly explored and 'exotic' areas such as China, Mongolia, and Argentina.

3. The Bristol dinosaur

The Bristol dinosaur, *Thecodontosaurus antiquus*, was found in 1834, and the genus named in 1836, the species in 1843 (Benton et al., 2000). The first reports of bones were published as short accounts in 1834 in several local newspapers and journals – quarrymen had found isolated 'crocodile' bones in a series of quarries located in the northern part of Clifton, in an area sometimes called 'Durdham Down', along the north side of Worrall Road. In the 1830s, there were several deep quarries that were being worked for building stone, and they were driven northwards from the level of Worrall Road towards the Downs, which stood much higher, so creating a high south-facing active quarry wall. Indeed, quarrying had to stop about 1840 because the north and east faces of the quarries were beginning to undermine houses built on top.

The quarrymen took their mystery bones to Samuel Stutchbury, curator of the museum of the Bristol Institution for the Advancement of Science, Literature and the Arts, a body founded in 1823 (Taylor, 1994), and housed in a grand building at the foot of Park Street, now the home of Bristol's freemasons. Stutchbury recognised the importance of these bones, and he called on Henry Riley, a renowned local surgeon, who was able to provide the

anatomical expertise required to describe and interpret the bones. Other locally based geologists became involved at the time, and were severely warned off by Stutchbury, who clearly wanted all the isolated bones for the museum.

Samuel Stutchbury (1798–1859) began his professional career as an assistant at the Hunterian Museum of the Royal College of Surgeons in London, and he made an adventurous collecting trip to the Pacific and became an expert on the corals and shells he encountered (Crane, 1983). Stutchbury was then hired as curator of the Bristol Institution in 1831, and served there until 1850 when he left, probably because museum funds were running out and his salary had barely advanced. He went to Australia as mineral surveyor for New South Wales, but returned to Bristol and died in 1859, the year of Darwin's *Origin of Species*. He is buried in Bristol's Arnos Vale Cemetery.

Henry Riley (1797–1848) was a local surgeon and medical teacher who had been trained in Paris. He gave a successful series of lectures in Bristol, emphasising the works of the fashionable French anatomists, Lamarck, Cuvier, and Geoffroy, and he was a member of the important group of gentleman naturalists who founded the Bristol Institution in the 1820s. Riley was involved in a body snatching scandal in the late 1820s, and was renowned for his yellow waistcoats, worn in the daring Parisian fashion.

The gentleman surgeon and naturalist Dr. Riley, and the hired hand Mr. Stutchbury, read a paper about the new reptile finds to the Geological Society of London in March, 1836, and to the British Association for the Advancement of Science, which met in Bristol later that year. The 1836 account (Riley and Stutchbury, 1836) is not illustrated, but it gives a full-page of description of the new genus *Thecodontosaurus*, and indicates the repository of the jawbone and other elements, in the Museum of the Bristol Institution, and can hence be regarded as an adequate characterization of the genus. In the same summary paper, Riley and Stutchbury also announced their new genus *Palaeosaurus*, but here the characterization of the genus is minimal and, of the species, non-existent. The second paper (Riley and Stutchbury, 1837), concentrates mainly on the geology of the bone-bearing sediments, and adds nothing to the description or interpretation of the bones. The full descriptive memoir (Riley and Stutchbury, 1840) was published three years later. This confirms that *Thecodontosaurus* was named from a right dentary with 21 teeth, and further information was given on the two species of *Palaeosaurus*. The 1840 paper gives a full description of the key fossils, and presents

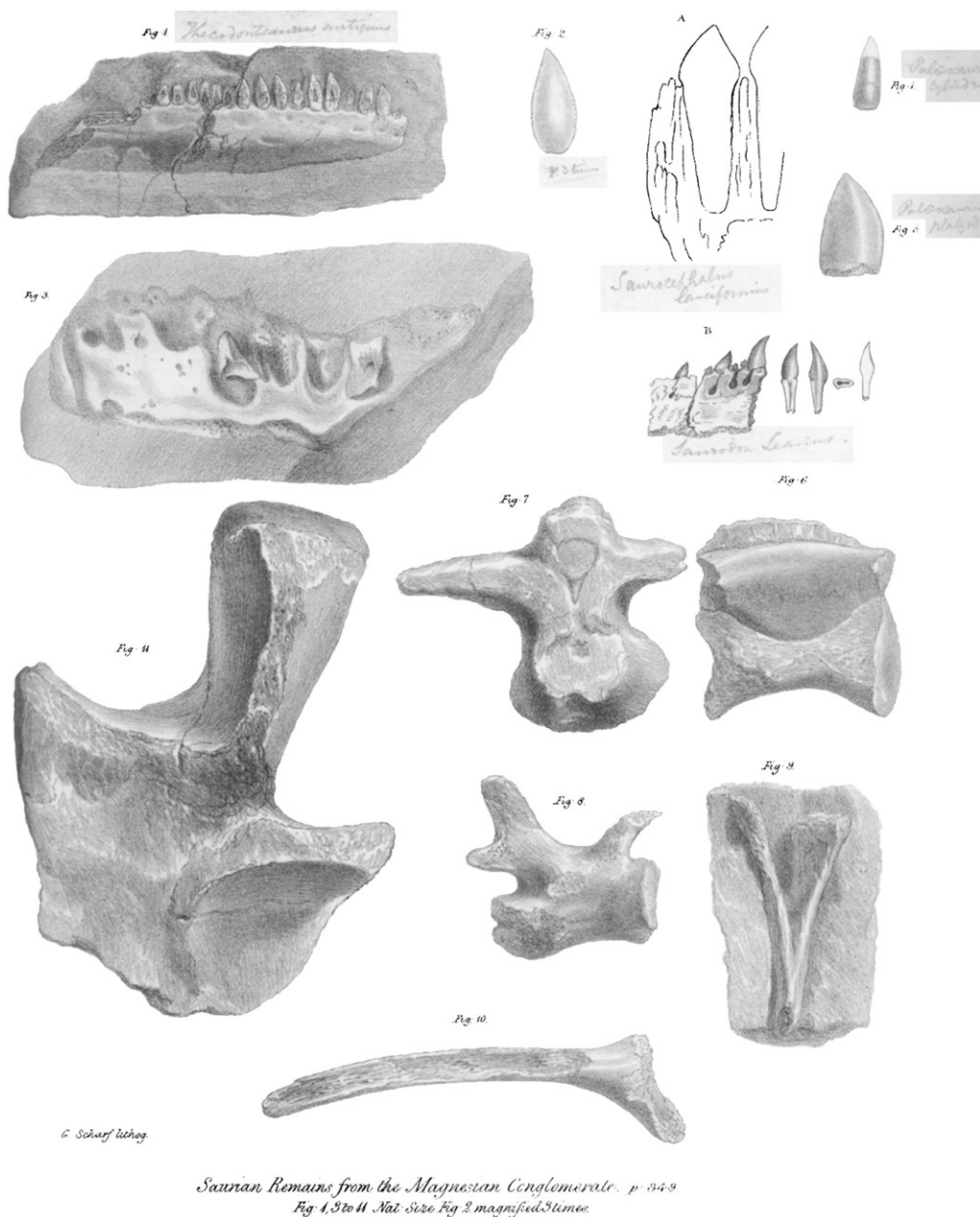


Fig. 3. One of the two original plates from Riley and Stutchbury's (1840) description of *Thecodontosaurus*, showing the type lower jaw (top left), teeth (top right), a partial ilium (lower left), vertebrae (lower right), and a rib (bottom).

two plates illustrating the remains (Fig. 3). As a genus named without a species epithet, and this was a common enough habit at that time, *Thecodontosaurus* remained in limbo until Morris (1843) rectified the omission in a catalogue of British fossils, naming the species as *antiquus*.

Thecodontosaurus was only the fourth dinosaur to be named from Britain, and indeed from anywhere in the world (Benton, 2000; Benton et al., 2000), after *Megalosaurus* (1824), *Iguanodon* (1825), and *Hylaeosaurus* (1833). *Thecodontosaurus* and *Palaeosaurus*, also named in the 1836 paper, were the first reptiles to be described from the Triassic (Riley and Stutchbury, 1836, 1837, 1840), and *Thecodontosaurus* was the first Triassic dinosaur to be named. *Plateosaurus* from the Late Triassic of Germany was named a year later, in 1837.

When Richard Owen christened the Dinosauria (Owen, 1842), he did not identify *Thecodontosaurus* as a member of this new group. He included only *Megalosaurus*, *Iguanodon*, and *Hylaeosaurus*, and noted that they were all very large and were characterized by having more than the primitive two sacral vertebrae. Perhaps he thought that *Thecodontosaurus*, with its smallish jaw, could not possibly be a dinosaur; he classed it as an 'inferior or squamate saurian', with some resemblances to crocodylians, lizards, rhynchosaurs, and dinosaurs. It was only later that Thomas Huxley (Huxley, 1870) finally recognized that *Thecodontosaurus* was a dinosaur, and so it has been recognized ever since.

What none of the Victorian palaeontologists had done was to provide a full description of the *Thecodontosaurus* material. This

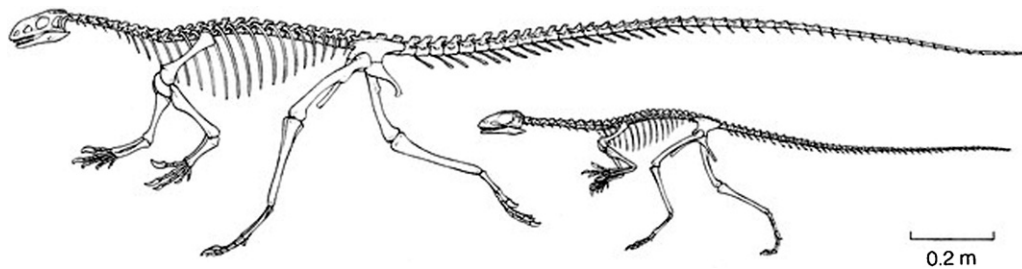


Fig. 4. Whole-body reconstruction of *Thecodontosaurus*, the Bristol dinosaur, with *Pantydraco*, then thought to have been a juvenile of the same genus. Drawing by John Sibbick, first published in Benton et al. (2000).

was rectified by the enthusiastic German palaeontologist Friedrich von Huene, who described and illustrated the entire *Thecodontosaurus* collection from the 1840s, some 300–400 bones (Huene, 1902, 1908a,b, 1914). This record is invaluable because Bristol City Museum was famously bombed in 1940, and nearly everything on show was destroyed, including all the best *Thecodontosaurus* bones, most notably, several classic specimens of marine reptiles purchased in the 1820s and 1830s from Mary Anning of Lyme Regis. It had then been assumed that essentially everything was lost, but in fact the bulk of the non-exhibit collections of fossils had been stored in an old railway tunnel in Avon Gorge, and these were retrieved after the war, including 184 specimens of *Thecodontosaurus* (Benton et al., 2000). Together with specimens in other museums, 245 specimens of the 1830s collection remain.

The classic *Thecodontosaurus* materials were unpacked in the late 1950s, and they were seen by Beverly Halstead (1933–1991), then beginning his studies on the Bristol fissure fossils. The whole collection was borrowed by John Attridge, then at Birkbeck College in London, and he intended to restudy the materials. Nothing came of this, however, and it was not until rather later that the whole collection was redescribed and included in a novel cladistic analysis of basal sauropodomorphs (Benton et al., 2000). In this paper, a careful reconstruction of *Thecodontosaurus* based on the original materials is presented (Fig. 4), which has led to a variety of life restorations (Fig. 5). More recently, Galton (2007) has queried the validity of the type material of the original taxon, *Thecodontosaurus antiquus*, and has suggested that the 1834 collection includes remains of several sauropodomorph taxa.

Currently, there is a display case with some *Thecodontosaurus* specimens, including one remarkable specimen that shows smoke damage from the bombing of 1940, in the Bristol City Museum. An

associated diorama shows a full-sized model of *Thecodontosaurus* in life, together with *Diphydontosaurus* and appropriate Late Triassic plants, constructed by local sculptor Arril Johnson about 1990. Further, in mid-2011 the new 'M Shed' museum opened at Bristol docks, and this includes a permanent case dedicated to *Thecodontosaurus* and exhibiting some of the original specimens.

4. Occurrence and significance of the Bristol dinosaur

In relaying the Bristol dinosaur to the public, two aspects are of key interest, its preservation in ancient cave systems formed in a dry, tropical landscape in the Late Triassic, and the fact that it is one of the first herbivorous dinosaurs, close to the base of the great clade Sauropodomorpha that later included the massive sauropods such as *Diplodocus* and *Apatosaurus* (Benton et al., 2000; Yates, 2003b; Langer and Benton, 2006). These two observations open up a broad array of geological, palaeontological, and evolutionary themes, as well as providing opportunities to explore with the audiences how scientists can discover these facts.

The original *Thecodontosaurus* remains came from limestone quarries that showed an unconformable contact between the Carboniferous and the Triassic (Savage, 1993; Benton et al., 2000; Whiteside and Marshall, 2008). The bones occurred in breccia pipes within the Carboniferous limestone, and in fact this particular rock was often considered inferior for building purposes. It is sometimes used in garden walls, but not houses, around Clifton, and a harder variety from Draycott near Cheddar in the Mendip Hills, was used in building Brunel's original Temple Meads station. Victorian geologists struggled to explain the breccia and the occurrence of reptile bones, and they realized that they were looking at an ancient cave system, and the breccia was formed

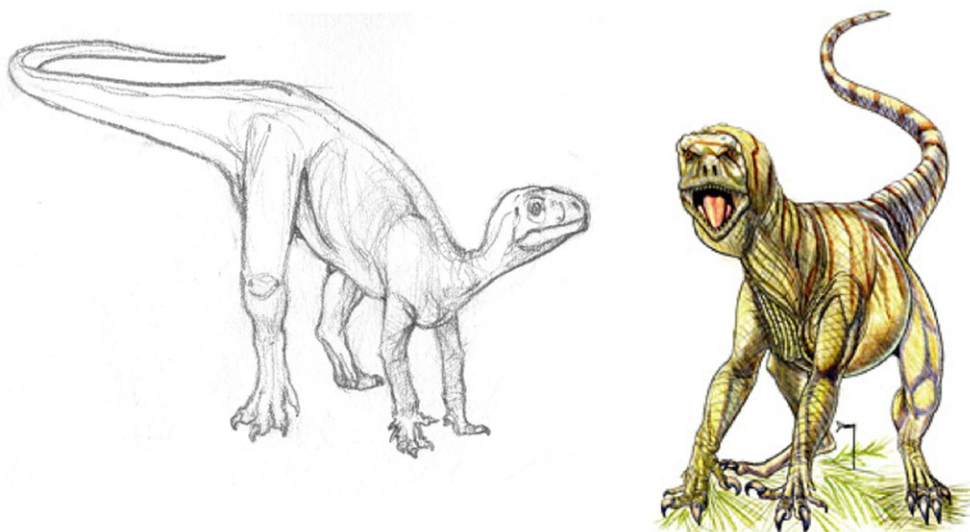


Fig. 5. Restorations of the possible life appearance of *Thecodontosaurus* by Ben Jones (left) and Richard Deasey (right).

from blocks of the cave walls, mixed with reddish soils and bones, presumably washed in from above. So, this occurrence encapsulates some key facts about the geology of the Bristol area: that much of the bed rock is Carboniferous limestone, deposited in shallow seas some 350 Ma, and containing abundant marine fossils such as corals, crinoids, and brachiopods; that this marine limestone was subsequently folded and modified by the Variscan Orogeny, and uplifted to form hills that were islands in a Triassic shallow sea/plain; that iron-rich tropical soils formed over these limestones, which in fact formed fissured karst surfaces; and then that the former tropical archipelago has become a series of low hills with today's lower sea levels (Fig. 6A). Reminding the citizens of Bristol on a cold, damp day that the topography of their area has not changed much in the past 200 myr, but that their native city looked rather like the limestone coast of the Bahamas in the

Triassic, is an excellent introduction to understanding what geologists can do.

Most of the *Thecodontosaurus* bones were not found in articulation and many seem to show signs of transport, perhaps as a result of having been washed by flood waters into the cave (Fig. 6B). Other specimens, however, are articulated - most notably a nearly complete forelimb in the Peabody Museum, Yale University, USA. Many individuals are represented: Huene (1908a) counted 20 femurs and fragments, indicating the presence of at least ten individuals.

Other fossils from the Durdham Down site are rare. There is the phytosaur *Paleosaurus platyodon*, based on a tooth (Huene, 1908b), as well as other similar teeth in the Natural History Museum, London. In addition, two specimens of the sphenodontid *Diphydontosaurus avonis* were noted as the partial skeleton of a 'lizard'

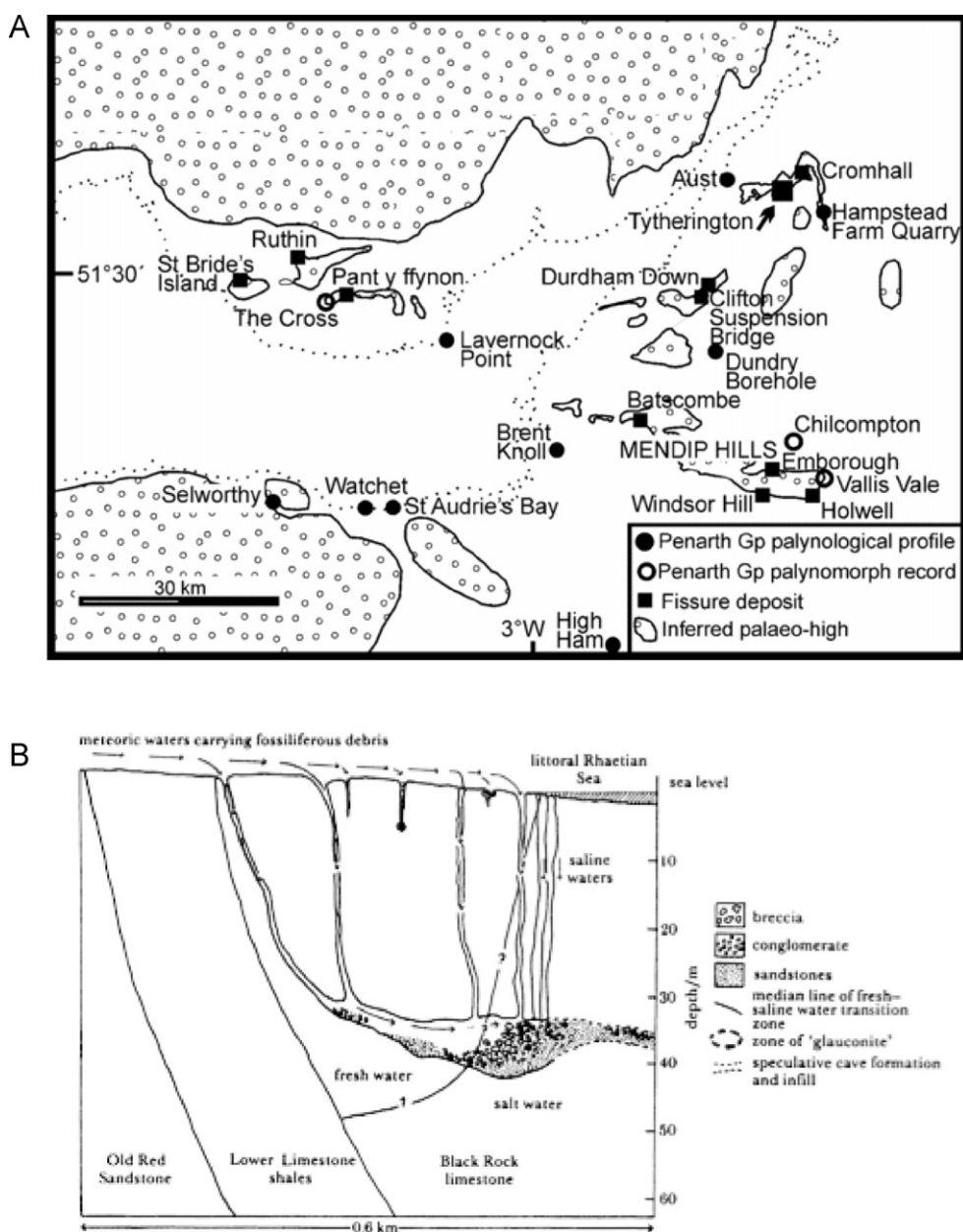


Fig. 6. Geology of the Bristol fissures. (A) Palaeogeographic map of the Bristol Channel area some 200 Ma, showing land (stippled) and sea (blank), and an archipelago of some 20 small islands, most of them bearing fissures with fossil remains (named by quarries). (B) Cross-section of the Tytherington fissures, showing cave formation and water courses that captured and transported the bones.

Modified from Whiteside (1983) and Whiteside and Marshall (2008)

and a small jaw of the sphenodontid *Diphydontosaurus* – both specimens are in the collections of Bristol City Museum (Whiteside, 1983).

The Durdham Down fissure site is only one of many such locations around Bristol, partly in the Mendip hills, and in South Wales, collectively known as the 'Bristol fissures' (Savage, 1993; Benton and Spencer, 1995; Whiteside and Marshall, 2008). These caves (Fig. 6A) date from Late Triassic to Early Jurassic, from 210 to 190 myr, and there appear to be at least two age ranges: latest Triassic (Rhaetian) fissures with reptile fossils and some spores indicative of their age; and a suite of Early Jurassic fissures, largely in South Wales, and with reptile and mammal fossils, as well as a flora including the conifer *Hirmeriella*. The Triassic reptile-bearing fissures have been suggested to range in age from Carnian to Rhaetian (e.g. Benton and Spencer, 1995), but there is no positive evidence for ages older than Rhaetian (Whiteside and Marshall, 2008) other than the general resemblance of some of the reptiles to late Carnian/early Norian forms.

In 1975, additional remains of *Thecodontosaurus* came to light in the working stone quarry at Tytherington (ST 660890), 15 km NE of Bristol. The discovery was made by two amateur collectors, Mike Curtis and Tom Ralph, who alerted David L. Dineley, then Head of the Department of Geology at the University of Bristol. Dineley referred the find to Robert J.G. (Bob) Savage (1927–1998; Benton, 1994), then Professor of Vertebrate Palaeontology. An additional twist is that the University was contacted before the quarry itself was notified of the find, as Curtis (pers. comm. to RS) feared that the fossiliferous material might not be made available for research because of possible interference with quarrying operations. Savage organised a visit to the quarry, and persuaded the operators not only to delay operations in order to secure the material, but also to provide and pay for the transport of the 5 tonnes of fissure rock to the University of Bristol.

This new material formed the basis of the PhD thesis work of David Whiteside (1983). In his fieldwork, he identified 16 fissures at Tytherington, and was able to recover some age-significant fossils, including pollen and spores, from the sediment, including the sediment containing the *Thecodontosaurus* bones, which indicated a Rhaetian age (Marshall and Whiteside, 1980; Whiteside and Marshall, 2008).

Mike T. Curtis (1950–2008) continued to be involved in advising various academics on his find and also continued his own tireless research and documentation on the bonebeds of Aust Cliff and Manor Farm. Additionally, Maurice White deserves a mention as he prepared some of the material as a fossil preparator, under supervision of Bob Savage.

Thecodontosaurus is one of the earliest herbivorous dinosaurs in the world. The older palaeontologists who studied the jaws and teeth noted its relatively small head, its narrow jaw, and its delicate little leaf-shaped teeth (Fig. 3) – all characters of a plant-eater rather than a carnivore. Cladistic analyses (e.g. Benton et al., 2000; Yates, 2003b; Langer and Benton, 2006; Upchurch et al., 2007) have consistently shown that *Thecodontosaurus* falls near the base of the clade Sauropodomorpha, below such well known 'prosauropods' as *Plateosaurus* and *Massospondylus*, and it is only shown as less basal than the South American forms *Guaibasaurus*, *Chromigosauros*, *Panphagia*, and *Saturnalia* (Langer and Benton, 2006; Ezcurra, 2010; Martinez et al., 2011). All of these were relatively small animals, and they are all known from relatively few specimens. It seems that, after an initial time of differentiation, restricted geographically to what is now South America, these early herbivores spread slowly across the world, reaching Europe before they eventually expanded into North America, China, Africa, and other regions.

The fact that the palaeogeography of the Bristol-South Wales area in the Triassic-Jurassic consisted of an archipelago of small

islands emerging from the surrounding shallow sea (Fig. 6A), led Whiteside (1983; Whiteside and Marshall, 2008) to investigate whether *Thecodontosaurus* was an island dwarf. They referred to the well-known phenomenon of 'island dwarfing', in which mammals in particular, but also birds and reptiles, on islands today may be smaller than their close relatives on the mainland. The argument has been that large and medium-sized animals that find themselves by chance on an island have to restrict their home ranges or go extinct. The classic example of recently extinct dwarf elephants on several Mediterranean islands appears to be strong evidence of the phenomenon. Island dwarfing has been reported in dinosaurs (reviewed, Benton et al., 2010), and this phenomenon might also be seen in *Thecodontosaurus*. Whiteside and Marshall (2008) note that the largest animals preserved in the fissure deposits are smaller than 3 m in length, which could be a physical sorting effect perhaps determined by the size of the cave entrances and the underwater streams, or might simply indicate the absence of such large animals from the islands (Whiteside and Marshall, 2008). But, in addition, *Thecodontosaurus* is smaller than near-contemporaries such as the 5–10-m long *Plateosaurus* in Germany. An argument against dwarfing could be that *Thecodontosaurus* is a basal sauropodomorph, closely related to other basal forms from South America, most of which are also similarly small (Benton et al., 2000; Yates, 2003a,b).

It is important to stress the role of amateur collectors Mike Curtis and Tom Ralph, without whom the Tytherington materials would not have been identified and made available to the research community. Over the years, Mike Curtis continued collecting with exquisite care in the Late Triassic and Early Jurassic of the Bristol-Gloucester area, and was always keen to work with professional palaeontologists and students. This kind of friendly cross-over between amateurs (=unsalaried enthusiasts) and professionals has often been crucial in the history of palaeontology.

5. The Bristol dinosaur takes its first bow

The current major educational project is based around the historic collections of bones from the 1830s, but mainly around the new collection made at Tytherington in 1975. Whiteside had started his PhD (Whiteside, 1983) with the ambitious idea of completing the studies during three or four years. Preparation work, however, proved harder than had been assumed (Fig. 7). Attempts to release the bones by a controlled acid-treatment method were successful to a point, but the disadvantage is that the method involves time-consuming monitoring and rinsing. Mechanical methods, using aircsribes of various sizes as well as

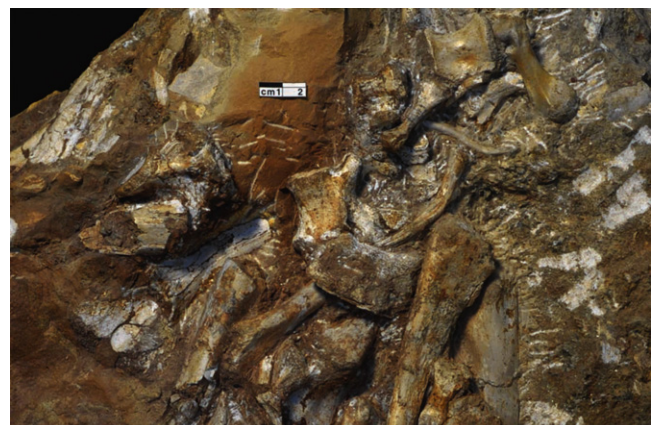


Fig. 7. One of the Tytherington fissure fill blocks, containing numerous limb bones and vertebrae of *Thecodontosaurus*, partly physically prepared.

hammer and chisel, work well for the larger bones, yet also have disadvantages in being time-consuming and also risking damage to fine detail and the loss of very small specimens. Further, because much of the limestone has been dolomitised, chisels rapidly become blunted and have to be retempered. Close attention to the rock matrix around the bones has yielded insights into bone preservation and aspects of the environment of deposition. Most bones show clear signs of sun bleaching, indicating that the animals died long before their remain ended up in the fissure. Also, in the spongy extremities of the bones, calcite crystals have formed and actually pushed apart the more fragile bone structure. This is evidence of waterlogging and makes the bones hard to prepare by both chemical and mechanical means. In any case, the acid method has the advantage of producing a multitude of micro-remains, which can be sieved out, and both methods are used in combination.

David Whiteside took the blocks to local stonemasons to have them reduced in size, and he prepared some 200 bones out of the matrix. After he left Bristol, the blocks of rock remained in storage, first in a substantial building that had been a cinema and then a garage, at the junction of Park Row and Woodland Road. Bob Savage had all his collections, including tusks of fossil elephants and other collections from Libya and Kenya, skeletons of modern animals, fossils from the Bristol area, and an embryo giraffe in a freezer, housed in this cavernous structure on metal shelving. Savage handed the collection over to MJB, when he moved to Bristol in September, 1989, and one of his first tasks, in 1990, was to arrange for the entire collection to be moved because the building was to be demolished (and it was rebuilt as the Merchant Venturers' Building by the University of Bristol). Bob Savage's entire collection was moved to alternative storage in a lock-up shed built from corrugated iron on the farm adjoining the Veterinary School of the University of Bristol, at Langford. Here the motley collection remained until May 1998, when Bob Savage died of pancreatic cancer. At this point, the bulk of the African fossil mammals collection was sent to the Natural History Museum in London, other parts were incorporated into the main collection of the Department of Earth Sciences in Bristol, and the Tytherington blocks were brought back to the Palaeontology Laboratory to begin the current phase in their existence.

Substantial funding of £100k was received from the Leverhulme Trust in 1999 to begin a project on the *Thecodontosaurus* specimens. The funding paid for intensive physical preparation of the blocks, a task done by RS, who oversaw the return of the blocks to the laboratory, their further breaking into more manageable pieces, and the beginning of the second phase of active preparation in 2000. In addition, the core of the funding was for a postdoctoral research fellow, a post taken by Dr Adam Yates, who moved to Bristol from Australia, completed excellent work on basal sauropodomorph dinosaurs (e.g. Yates, 2003a,b) before heading for an academic position at the Witwatersrand University in Johannesburg, South Africa. As Whiteside had found before, the intractable rock made preparation time-consuming, and the initial intention to free all the bones from the rock in two years was not achieved.

After 2003, and the end of the Leverhulme-funded project, bone preparation continued also as an educational initiative. MJB began giving talks in schools and other venues to remind the citizens of Bristol about their very own dinosaur. RS changed post to become Palaeontology Teaching Technician, and latterly Palaeontology Laboratory Manager, paid by the University of Bristol. He continued to prepare *Thecodontosaurus* bones from the rock, and took an active role in their educational use in two ways, first in encouraging students attending the Masters in Palaeobiology degree programme to get involved, and second in showing the laboratory work to school parties.

The Masters in Palaeobiology degree was launched by MJB in Bristol in 1996, and by 2000 it had expanded and attracted some 15–20 students each year. These students came from Britain primarily, but about one-third each year came from other countries in Europe and worldwide. One theme that attracted them was undoubtedly dinosaurs, and they were all taught basic palaeontological laboratory skills by RS, and given a chance to handle and prepare *Thecodontosaurus* bones. The enthusiasts among these MSc students gave additional time working as volunteer laboratory preparators, often devoting hours to extracting single bones, under the direction of RS. These practical experiences were doubtless important in the future careers of many of the graduates of the Bristol Palaeobiology MSc programme. Since those early days, the MSc has been running for 15 years, and over 200 students have graduated (<http://palaeo.gly-bris.ac.uk/MSc/index.html>).

The second educational use of the Bristol dinosaur was in outreach to local schools. In presenting talks, MJB, RS, and others would often take blocks of the bone-rich rock or bones that had been extracted, and pass these round. In an age of videos, and realistic-looking dinosaur movies and documentaries, there is still nothing like the thrill of handling the real thing: a bone that was fossilised 200 million years ago and still looks fresh and tells a story about ancient life and ancient environments.

6. Taking the Bristol dinosaur further

The conundrum of how to complete the scientific work on *Thecodontosaurus* without additional scientific funding remained. Having received a 3-year grant from the Leverhulme Trust, it was not reasonable to seek further scientific funding for a project that evidently could not be completed promptly: the laborious nature of the fossil preparation work meant that any proposal would have to indicate a very long span of time and a large sum of money for the technical work. In an intensely competitive funding environment, it would be essentially impossible to secure such research funding. But, perhaps the Bristol dinosaur could earn its keep as a science engagement ambassador. Thus was born the 'Bristol Dinosaur Project' (BDP).

Palaeontology undergraduates, Masters, and PhD students in Bristol have always been supporters of community and engagement activities, and school visits and presentations continued at a modest level throughout. Other efforts produced an excellent web site (<http://www.bristoldinosaur.com/>), initially by Sarda Sahney, a PhD student with professional expertise in web design (Fig. 8), and relaunched in a new form in 2011, redesigned by local web designer Neil Connelly. The website incorporates historical and scientific accounts by Sarda Sahney and RS, and it acts as a strong promotional tool to inform schools and others of the project and the educational opportunities.

The second substantial outcome of the Leverhulme funding was that we were able to begin to seek funding for the BDP on a new basis – its value in public engagement rather than simply its scientific merits. The first funding of this kind came from hypothecated funds received by the University of Bristol to foster widening participation, the long-standing endeavour to encourage children from low-participation backgrounds to aspire to go to university. We secured £20k from University of Bristol Widening Participation funds to hire Caroline Milner to act as the 'Bristol Dinosaur Education Officer' (BDEO), from 2002 to 2003. She set up a gruelling programme of school visits, and took our story to over 15,000 school children in the course of nine months. In the following year, we secured further funding from HEFCE Teaching Quality Enhancement Funds to develop schools engagement further, and we extended the BDEO post into a second year, 2003 to 2004, when Tom Challands was employed, Caroline Milner

THE BRISTOL DINOSAUR PROJECT

Spotted: The Bristol Dinosaur Team

An amazing team of volunteers visit schools, science centres, festivals and other venues around Bristol to tell you more about our very own dinosaur! Most recently they were spotted at Science Alive where visitors had the opportunity to learn about the Bristol Dinosaur, touch real dinosaur bones, watch videos, and they even made replica bones to take home! [Read more about the exciting event...](#)

New Photo Galleries

Due to popular demand the Bristol Dinosaur website has launched two new photo galleries. Check out [pictures of community events](#) as the Bristol Dinosaur team tours the city. And see where science meets art as you browse through a [gallery of artist's impressions](#) of what they think the Bristol Dinosaur looked like. Come take a peek inside...

Heritage Lottery Fund Awards £294,000 to BDP

In November 2009, the Heritage Lottery Fund awarded £294,300 to the Bristol Dinosaur Project to fund an Education Officer and a Preparator for three years. This will allow us to process the remaining 3.5 tonnes of bone-bearing rock, and to take the project to thousands of people in the Bristol area. More information will appear shortly. Read more about the painstaking task of removing the bones from the rock [here](#). The current state of the project is outlined here, as a [pdf document](#). The University of Bristol press release is [here](#), and some of the many press reports are [here](#).

Heritage LOTTERY FUNDED

Heritage LOTTERY FUNDED

NEWS THE DINOSAUR ENGAGEMENT RESOURCES GALLERY KIDS CONTRIBUTORS LINKS CONTACT US

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Fig. 8. Home page of the BDP web site at <http://www.bristoldinosaur.com/>, as designed by Sarda Sahney in 2006.

(now Caroline John) having moved to a permanent science engagement position at the discovery centre, Thinktank, Birmingham Science Museum.

The BDEO post was based on an integrated programme of four activities: managing the contacts list, arranging bookings, developing teaching materials, and delivering the engagement sessions.

The first task, *compiling and managing the contacts list* was time-consuming and is a step often done badly in such school engagement programmes. We had found that normal methods of mail shots do not work – hard-pressed school heads tend to throw such unsolicited mail into the recycling bin. So, the BDEO made sure to gather names of science teachers and heads of primary and junior schools from the local education authority, and then wrote to each personally. She followed up soon after with a telephone call, and made sure she had identified the appropriate person in each school. The conversation then allowed her to confirm a booking. If there was no suitable time when pupils could be available, she would call back some months later to arrange a visit.

The second task, *arranging schools bookings*, depended on the school, and especially the exact age groups and numbers of pupils who would be available. We focused on two age cohorts, ages 7–8 and ages 14–15. In junior schools, it was relatively easy to identify an afternoon when we could visit and present our ‘Bristol dinosaur show’. In many cases, this would be integrated with ongoing project work organised by the classroom teachers in advance of our visit, and then, when we came in, the pupils were already well informed about dinosaurs, and had perhaps painted pictures, made models, or written projects. This ensured the visit from the University of Bristol team made maximum impact. In support of such input of effort by the school teachers, the BDEO produced problem sheets, colouring sheets, and teachers’ packs with basic information. This ‘topping and tailing’ of the core show can occupy one or two weeks of a junior school curriculum and make sure the

whole exercise has maximum impact and benefit. With older pupils in secondary school, the presentation is entirely different, and is aimed at exploring core science themes in the context of scientific discovery (e.g. geological time, plate tectonics, mass extinction, biomechanics, evolution vs. creationism) and directed towards careers in science and engineering (A-level choices, how science can be applied to fascinating problems, jobs available and qualifications required).

For the third task, *developing teaching materials*, the BDEO used her experiences in the classroom to develop slide shows (now Powerpoint presentations) suitable for different age groups, and different lengths of show, whether 40 min or 2 h, say, with intervening practical exercises. These teaching materials were distributed during sessions, or sent in advance so teachers could set their classes to exploring dinosaur-themed topics before the visit. The purpose of the teaching materials was twofold. Some were designed as documents that covered key topics in geology, palaeontology, and evolution (all parts of the National Curriculum), as suggestions of ways to address these themes and as introductions to other resources for teachers. Other teaching materials were aimed at the children themselves, whether dinosaur colouring sheets for younger children, or careers guidance leaflets for older pupils.

The fourth step, *delivering the engagement sessions*, was developed by experience: it soon becomes clear when facing fifty 7-year-olds whether their attention is engaged or not (Fig. 9). We would refer to something currently happening, like a new dinosaur discovery just reported in the news, or a new film or television series about dinosaurs that they might have seen. This could provide the ‘hook’ to begin the session, and the presenter would then move on to show that the children do not have to go to Mongolia or Patagonia to find dinosaurs, but that these behemoths can actually be found right on their doorsteps. The presentation would then explore questions such as:



Fig. 9. Children at a school in Bristol handle specimens of bone-bearing matrix, and measure up the reconstruction of *Thecodontosaurus* and fit bone casts to the skeleton. Simple practical exercises like this can make a deep impression and teach them something about basic palaeontological techniques.

1. How do we know Bristol was near the Equator and had a dry, tropical climate?
2. How do we know this dinosaur lived 200 million years ago?
3. How could dinosaurs end up in a cave?
4. How do we know *Thecodontosaurus* ate plants?
5. How can we work out the running speed of a dinosaur?
6. How can we tell whether *Thecodontosaurus* ran about on all fours or on its hind legs?
7. Why was not the Bristol dinosaur huge and bloodthirsty?

Each of these questions addresses a fundamental broad-scale science question, and the answers involve physics (radiometric dating, geophysics, biomechanics), chemistry (identifying the rocks, preservation of the bone), biology (evolution, biodiversity, function), and geology (continental drift, geological time, mass extinctions). These issues are directly applicable to the 'How Science Works' programme in the current National Curriculum for schools in England and Wales, and equivalent initiatives elsewhere.

In addition to these four initial tasks, we have added two more to the repertoire of the current BDEO: monitoring effectiveness, and fund raising.

It is essential to *monitor the effectiveness of engagement activities*. This is done regularly by the BDEO by examining what the pupils knew before the workshop and what they learned afterwards. Observation of workshops to see how children and young people use the sessions, and post-visit enquiries to find out what the children can recall at a later date are other forms of evaluation that can illustrate how we are meeting the learning outcomes for the workshop. Such data can be collected by the presenters, but can be even more effective if gathered by a third party, especially a person or team skilled in monitoring feedback and outcomes. The presenters are regularly monitored and given feedback to improve their performance, which in turn helps trainers to advise students and others who are new to schools-based engagement. Some presentations have been accompanied by radio or TV teams, or local newspaper reporters, and they ask the children questions such as 'What did you learn today?' Such evidence of the effectiveness of the sessions is required of course in reporting to

funding agencies, and it is helpful also in demonstrating success and value for money to future funders. As a rough estimate, a stripped-down BDEO position, funded at a reasonable salary, delivers presentations to 10,000 people in a year, so at a cost of £3–5 (€4–6) per person for a one- or two-h session.

The sixth role for the BDEO is to *seek additional funding* to expand the programme and to ensure continuity. It is relatively easy to secure small grants in the range of £500–10,000 (€600–12,000) because many government agencies and charities run schemes for single events and small programmes. Indeed, ironically, the funding for single events can be quite lavish. However, much more problematic is to find sources that can contribute basic salary costs for the core BDEO position. So, whereas dozens of agencies see engagement and outreach, and especially STEM activity, as a highly attractive area to fund, few will assume responsibility for the core funding that is needed to ensure efficiency and a high return in terms of continuity and large numbers of people engaged. The funders expect someone else – perhaps the university, museum, or local education authority – to make the learning officer's role part of their salary bill, and yet that is difficult because such a role is often peripheral to the core activity of the institution, and it cannot readily generate revenue.

In addition to the school visits, the BDEOs and other members of the team welcome parties of children and adults to the Palaeontology Laboratory to see the work in progress (Fig. 10). Such laboratory visits are harder to arrange than a school visit because the laboratory can accommodate only ten or twelve visitors at a time, and safety issues are more serious than in a school hall. Further, the BDEO has built teams of keen students who were and are given basic training, and sometimes accompany school trips, but more often help at exhibitions, such as the Rocky Road Show, held each year in Bristol City Museum, events at the science exploration centre At-Bristol, and the annual Science Week exhibitions in the Galleries Shopping Centre in central Bristol. The BDP presence consists of posters and hands-on demonstrations in which, for example, children can handle real dinosaur bones, search for bones 'buried' in sand pits, or look for smaller bones and teeth under the microscope. These events are typically attended by hundreds or thousands of children and adults, and the dinosaur



Fig. 10. Remmert Schouten instructs some trainees in safe ways to use a dental drill on one of the Tytherington Quarry blocks containing *Thecodontosaurus* bones.

booth always attracts a great deal of attention. Each year, we participate in five such hands-on events, and encounter about 10,000 people throughout each year.

7. The importance of engagement in the geosciences

The earth sciences are of key importance for three major socio-economic reasons, and at least one fundamental intellectual reason, and these together form a *manifesto for the broadest engagement by all citizens in key geosciences themes*. The key economic reason is of course that human beings depend ever more on diminishing resources of minerals and fossil fuels, and geologists and environmental earth scientists will be needed in multitudes in the future to find those resources and to help mitigate the environmental impacts of human activity. The other two socio-economic impacts of the earth sciences are in the broader care of the natural environment and in natural hazards such as earthquakes, volcanoes, and tsunamis. The key linked intellectual themes in the earth sciences are deep time and evolution – humans have always been concerned about origins, whether the origin of life, the origin of humans, the origin of the Earth, and the origin of the universe. These are all reasons that every citizen in the world should understand such topics in some way so that they have a basic grounding in the key themes of human knowledge, and can make political decisions about the socio-economic issues of resources, environment, and hazards.

These elements of the manifesto for understanding and engagement in key geoscience themes might be thought to line up with standard expectations and outcomes of the educational systems in advanced countries. Not so. Numerous educational surveys show how poor is the teaching and understanding of the deep time-evolution intellectual area in schools in North America and Europe at least. Other reports suggest that key socio-economic themes are also poorly construed and poorly conveyed.

Some concepts, such as geological time or 'deep time', are particularly important, but challenging to teach. For example, Catley and Novick (2009), in a study of biology students at an American university, found poor understanding of relative and absolute dating of key events in the history of the Earth and of life, such as the age of the Earth, the emergence of life, and the appearance of early humans. The students reported startlingly large time ranges for all questions, ranging over several orders of

magnitude (e.g. from 1000 to 600 billion years ago for when most dinosaurs became extinct). Generally, they substantially underestimated the absolute dates of such events in deep, geological time. Cotner et al. (2010) reported a similarly disturbing survey of knowledge about geological time among first-year undergraduates. These difficulties are probably compounded in the United States by active and loud campaigning against evolution and geology by creationists of various stripes, many of whom have hardened their attitudes to campaign for a 'young earth' model of geology, where everything happened within 7000 years. However, the creationists cannot be blamed for all the problems students have in grasping the rudiments of geological time and evolution, because such confusion exists in countries where creationists are not so active.

Geological time is not the only problem area in geoscience education. Many other themes are poorly taught and poorly understood in schools, perhaps in part because they fall between core subjects such as chemistry, physics, and geography (King, 2008). This is despite the fact that basic geoscience themes are compulsory parts of the national curriculum in many countries, and nearly always taught by qualified science teachers, whether chemists, biologists, or physicists by initial training. King (2008) highlighted five themes that underpin adequate geoscience understanding, namely: the particular methodologies of geoscience thinking; the holistic systems perspective; geoscientific spatial abilities; the understanding of geological time; and the methodologies and attributes of geoscientific fieldwork. These are the hardest elements of the education process, to go beyond facts and ideas to thinking in three dimensions, linking observations in the field to theoretical concepts, conceiving of vast time scales, and linking themes from many different sciences into a single model. Stringent efforts can be made (e.g. Oldershaw, 2004) to rectify misconceptions and to roll out training programmes for teachers, who should then pass on the information to their pupils.

Facts and ideas are important too, and King (2010) also identified some serious problems in that area. One key obstacle to improving the current woeful situation in geoscience teaching is that the core science textbooks on the market are riddled with errors. King (2010) surveyed 51 science texts used in British schools, and found poor coverage of National Curriculum earth sciences topics, with on average one error or misconception per page. The areas of the earth science curriculum most prone to

misconception are sedimentary processes and sedimentary rocks, earthquakes, Earth's structure, and plate tectonics. The text books can be rewritten, but can the complex ideas and ways of thinking and conceiving be transmitted also to all our citizens? Dinosaurs may at least open the door.

8. The impact of dinosaurs in public engagement

In themselves, dinosaurs do not address any pressing societal problems. Far better perhaps to take out a road show focused on global warming, conservation, food supply, or natural hazards. However, for children in particular, dinosaurs are a much more appealing way to open the door to science, critical thinking, the scientific method, and other themes encompassed under the 'How Science Works' element of the English National Curriculum. Young children are already familiar (from the age of two or three, it seems) with the names of the top hundred popular dinosaurs, and the basics of the Mesozoic time scale. Therefore, it is a small step to harness that fanatical and widespread interest to formulating how and why questions.

The ethos behind all the engagement work from the School of Earth Sciences in Bristol is that the basic how and why questions that a child asks are identical to the questions a researcher may ask, and this allows us to use dinosaurs as a vehicle to open doors to the scientific method. The BDP presentations are never dogmatic: 'we know this, and this, and this', but they focus on looking at the evidence that lies behind the things scientists say.

This then points to a classic engagement tool: the startling fact. To begin a presentation with a remarkable observation, such as (especially on a rainy day) 'Bristol once had a climate like the Bahamas', or (on any kind of day) 'the dinosaurs died out in June, 65 million years ago' can engage even a bored teenager. The answer need not come right away, but this allows the presenter then to open up the scientific toolkit. Younger children can be led through the basics of most of the science involved in studying dinosaurs, and teenagers can be given some of the harder facts. For example, it is difficult to introduce radioactive decay series, isotopes, half lives, and the like to young children, but these concepts, as part of an explanation of the geological time scale, are ideal for pupils who are already studying these topics in chemistry and physics classes.

What of the two startling facts noted above?

The claim that 'Bristol once had a climate like the Bahamas' is answered of course by taking the pupils back through time, through the times of the Romans, the Neolithic hunters, the last ice age, down through the times of Cenozoic mammals, and back into the Mesozoic. The rock record, fossils, geological dating, and clues to ancient environments are explored. Evidence from the sedimentary rocks (e.g. evaporite beds, mudcracks), the fossils (e.g. tropical plants and reptiles), and geochemistry (oxygen and carbon isotopes) tell us that the Bristol Triassic was a time of dry, tropical conditions. If time permits, examples of the relevant rocks and fossils are passed round. Calculations from geophysics and other sources allow us to reconstruct continental positions in the past, and this reveals that in the Triassic, all continents were fused as one great supercontinent, Pangaea, and that North America and Europe lay much further south, with northern Europe just north of the Equator and in the equatorial belt. Q.E.D.

How on Earth could we know that the dinosaurs died out in June? Especially how could we know this, when we cannot determine whether the extinction crisis lasted for a year or a thousand years? This deduction refers to a classic piece of detective work, presented in a modest paper in *Nature* by the palaeobotanist Jack Wolfe. Wolfe (1991) investigated the sediments deposited in a small lake at Teapot Dome in Wyoming that was dated at exactly the Cretaceous-Tertiary boundary, 65 million years ago. The Teapot Dome lake contained abundant fossil leaves of lilies, belonging to

the fossil genus *Paranymphaea*, a close relative of the living water lily *Nuphar*, and they had all been frozen, as shown by study under the microscope which showed how the sap-bearing plant cells had been burst open by growing spiky ice crystals (water expands as it turns to ice). The freezing was caused presumably by the flash cooling event that afflicted at least the northern hemisphere after the impact of the Chicxulub meteorite. The impact threw up clouds of fine dust that remained high in the stratosphere and blocked out the rays of the Sun, so creating darkness and freezing conditions for a short time. Why June? Well, the fossil *Paranymphaea* plants were frozen with leaves and flowers in the state they achieve every June today, and so these ancient close relatives presumably showed the same annual cycle of leaf growth and flowering.

The younger age group (7–8 years) require no more: their natural sense of wonder and amazement means such engagement sessions always work well (Figs. 9 and 10). The teenage audiences can be more challenging: the simple wonder at dinosaurs is no longer there, the pupils may be cynical about the motives of people who come in and speak to them, and they may be concerned with more pressing issues such as their love lives and earning a living. With such teenage audiences, however, it is often good to compare a palaeontologist (or indeed any natural scientist) to a forensic scientist, using CSI (crime scene investigation) techniques to read subtle clues. Rock types, fossil specimens, chemical analyses, microscopic investigation and other techniques can be applied to extract information. Further, we try to use the BDP story with the teenage audiences to explore their career aspirations. The message is simple: 'if you want to have choices in your life, stick with education and get those qualifications'. Further, it is also a chance to answer any questions they might have about university entry, suitable choices of subjects to study at school for different universities and university courses, and likely career prospects. All of these issues (hard work, appropriate subject choices at school, the need for good grades, university aspiration, inclusion in tertiary-level education for all social classes and backgrounds) line up with common government and university objectives.

9. Heritage Lottery Funding (2010–2013)

Fund-raising attempts from 2004 to 2009 were generally unsuccessful. The University Development Office produced attractive materials to send to potential sponsors. Toshiba had generously provided a laptop and data projector for the BDEO to use in 2002–2004, but other sponsors, commercial or individual, failed to take an interest. After an initial unsuccessful attempt, we were successful with a bid led by RS and MJB in securing substantial funding (£295k) from the Heritage Lottery Fund (HLF) in 2009, for a three-year project entitled 'Hands on our Ancient Heritage', running from 2010 to 2013. This funds two full-time posts for the duration of the award, a laboratory preparatory position (PV) and a learning officer (ED), both posts analogous to the fossil preparator post funded by the Leverhulme Trust (RS) and the BDEO post funded earlier from WP and other sources.

The HLF proposal highlighted four broad project objectives:

1. To raise awareness of the Bristol dinosaur.
2. To continue preparing bones out of the rock for conservation and learning, and of course to fulfil the long-term scientific objective of providing a complete anatomical description of the dinosaur, to supplement accounts of the older materials (Huene, 1908a; Benton et al., 2000).
3. To reflect best practice in engaging the public in science and heritage themes.
4. To provide the infrastructural resources, and engage with internal and external partners and service providers to deliver all project aims and activities.

It was argued that these objectives fall under the University of Bristol's overarching aims concerning public engagement as defined formally, but presumably common to all universities: (1) to play a leading role in setting the national agenda on public engagement in higher education; (2) to respond positively to community needs; (3) to play a positive role in the affairs of the city, region and nation; (4) to nurture relationships with alumni and other friends of the University; and (5) to behave responsibly as an institution

The key components of the HLF funding are:

1. Infrastructural changes to the Palaeontology Laboratory required to deliver the project's ambitions (i.e. new staff, disabled access to the laboratory, expanded laboratory space and equipment for volunteers).
2. Strengthening collaborations with internal and external partners to deliver aspects of the programme (Centre for Public Engagement, University of Bristol; Widening Participation, University of Bristol; Bristol's Museums, Galleries & Archives; At-Bristol; STEMNET (Science, Technology, Engineering and Maths); Bristol Natural History Consortium; Avon Gorge & Downs Wildlife Project; Young Bristol).
3. Proof of concept, in that previous BDP engagement activities were successful (i.e. school visits, outreach events, learning resources generation).
4. Evidence that current, largely unfunded, activities, although restricted, are successful but could be increased (i.e. school visits, outreach events, volunteer engagement).
5. Proposals that new activities should be developed to bring the Bristol Dinosaur to new audiences (e.g. creative and innovative ways to engage people from diverse backgrounds, volunteer recruitment and training opportunities, new displays and updated communications).

The main activities have so far been to rebuild the programme of schools visits, following principles established earlier, but with the added component of more formal, and recognised, *training for the student volunteers*. The offer to schools is based on established good practice that works well in museums where objects and artefacts are pivotal in providing a quality learning experience (Graham, 2006; Hooper-Greenhill, 2006). In a call at the beginning of October, about half of the new cohorts of MSci, MSc, and PhD students expressed an interest in being trained in public engagement, and they received training from the STEMNET centres. Those who then put their skills into practice are identified as Science Ambassadors in Schools, and they receive additional recognition from the University of Bristol. The students respond strongly for a mix of generous reasons (they actually want to do it) and selfish reasons (such activities enhance their careers in that the various STEM qualifications are regarded highly by many employers). Those students who are interested in palaeontology have received additional training for BDP road shows from our local STEMNET representatives, and they in turn can pass on their training after they have had some experience of leading their own presentations. The project has also led to some science cafes in schools and day trips to the Jurassic Coast for STEM-related after school clubs. The latter enables young people to learn how to look for and find their own fossils as well as meet other young people from other schools in the region.

The second strand of the HLF funding supports PV as fossil preparator, and he has a challenging 3-year programme to extract all the remaining bones from the rock, and to lead laboratory-based programmes of training and engagement. He continues to involve palaeontology Masters students in laboratory work, and there are MSc research projects, on the smaller fossils associated with the *Thecodontosaurus* bones from Tytherington (remains of procolo-

phonids, sphenodontids, possible crocodylomorphs and unknown archosaurs) and on the *Thecodontosaurus* relative *Pantydraco* (Yates, 2003b; Galton et al., 2007) from South Wales. These continuing laboratory-based preparation and research activities provide a strong narrative for any school or laboratory visits, to show the continuing scientific activity: it is important that the whole BDP does not just become a fossilised educational project with no real scientific purpose!

The third strand of HLF funding is to *take the BDP to wider community groups other than schools*. To achieve this, the team has spent time producing a range of posters and leaflets aimed at different cohorts (Fig. 12), and available widely through the web site. Throughout the year there are opportunities to take part in public festivals such as the Bristol Festival of Nature (Fig. 11) and the Fossil Festival, Lyme Regis. By working with Young Bristol, the project has also visited youth clubs where young people go during the day as an alternative to school. We have worked with a group of young people from across Bristol to make their own 'Bristolian' dinosaur model by collaborating with local street artists Luke Palmer and Andy Council, Young Bristol and Bristol's City Museum & Art Gallery (Fig. 13). We have been involved with a toddler day at At-Bristol and developed with the City Museum a suite of dinosaur-related activities – these included three 'dinonites' and family activity days. The dinonites provided opportunities for visitors to learn more about the Bristol dinosaur and handle real fossils during special late-night openings of the museum.

The fourth and final strand is to *develop volunteering*, not only among the university students, who are a predictable and captive audience, but also to engage any others who express an interest

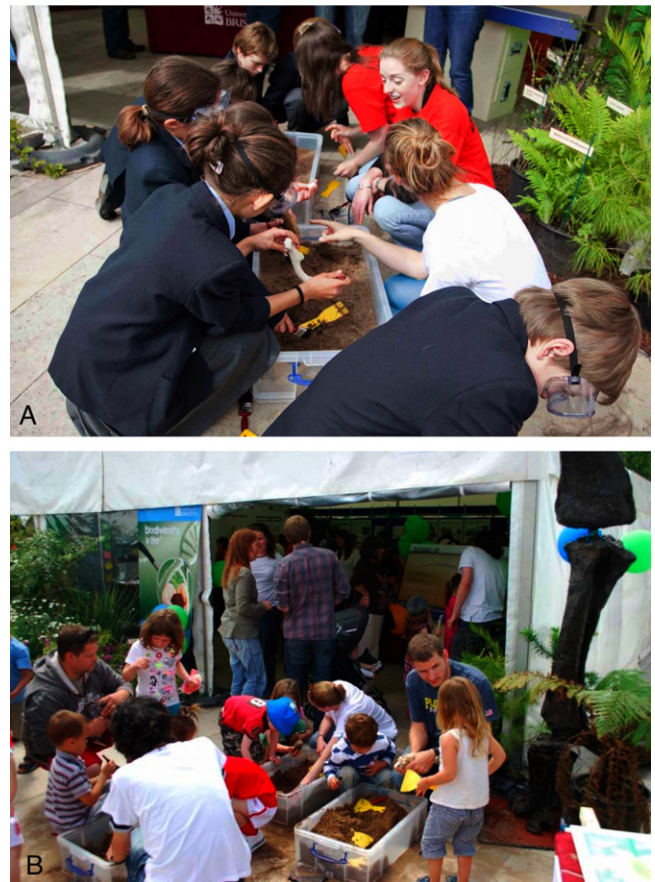


Fig. 11. Public appearance of the BDP at the Bristol Festival of Nature in 2010. (A) Bristol Masters students show some enthusiastic young palaeontologists how to hunt for bones. (B) Outdoor fossil hunting.

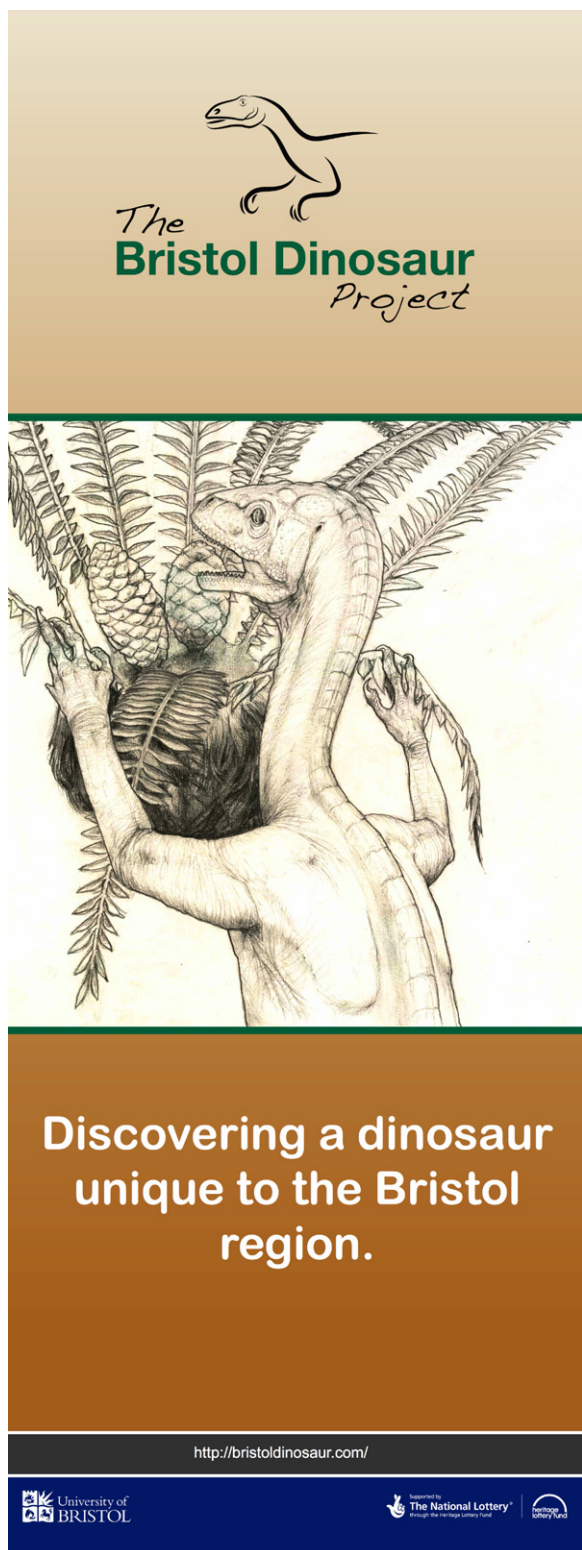


Fig. 12. Example of a poster produced for the BDP, with the new logo. Designed and executed by Simon Powell.

and have aptitude. RS and PV already have a number of keen volunteers from outside the University who are being trained in laboratory techniques. Other volunteers are becoming involved in writing and illustrating work, in web site development, and in educational and engagement aspects of the project. The aim here is not to provide formal training that will guarantee to provide jobs

for the volunteers, but to open doors and engage people in a professional activity that might not otherwise be available to them. PV and ED have also been taking on young people as part of their formal work experience during year 10 when they take a week or perhaps a few days out of school. This provides an opportunity for the young people to immerse themselves in something they are interested in and find out more about the working environment. Additionally, the Prince's Trust provided, and paid for, through the Future Jobs Fund, one young person, Simon Colston to assist in administrative tasks and deal with school bookings.

Simon took this role between October 2010 and March 2011.

10. The future: how to be effective at PES

We have learned that public engagement in science (PES) is easy and fun. Presumably PES based around dinosaurs will always be easier than a focus on some other themes in STEM subjects. Most academics are happy to respond to requests to speak in schools or to amateur science groups. Importantly, most students are especially keen to develop their skills in PES, and they see it as a real benefit to their future careers, especially if they receive semi-formal training and some qualification or recognition that can be cited when they later seek jobs in industry or education fields. Practice in PES provides students with skills as good communicators and good team players, and to be more aware of the commercial and public interest in science. Further, the practice of engaging with school pupils with a range of abilities teaches students a great deal about training, mentoring, and managing people, all core skills that are required for any post in management, as well as in education. The engagement with schools is a two-way process, and the schools acquire new learning resources and ideas from our visits.

Clearly, such PES activities can have a profound impact on some of the individuals in the schools that are visited, and these impacts may assist some young people in focusing their career aspirations, so lining up perfectly with the political will to develop agendas in widening participation (WP) and fair access (FA) to tertiary-level education, as well as the Every Child Matters programme of the UK government, for all children and young people.

We have also learned, importantly, that PES does not just happen. It requires thought and planning and, to be effective and sustainable, it requires funding for coordination. Whereas academics and students are happy to respond to requests, and may be immensely effective in enthusing school children, these same academics and students do not have the time or inclination to market to schools and take bookings. Until institutions find ways to fund posts equivalent to the BDEO, all grand schemes are likely to founder. There has perhaps been a misunderstanding among some of the promoters of PES and STEM engagement that academics must be persuaded to go out to schools and community groups. No; or at least not any more. Therefore, spending money on back-room cheerleaders is not required; as working academics, we do not require persuasion or urging. We simply lack the time to secure and manage the bookings.

The BDEO model suggests a clear and effective way to spend government money for WP and FA – on enthusiastic young scientists who know their subject areas and can give presentations themselves, who are seated within the academic departments they represent, and who manage and organise the staff and students, contact the local schools, make bookings, collect feedback, and strive to maintain and raise standards in their fields throughout. Each university could do this very effectively with 5–10 such people, not sitting in a back room collecting statistics and writing newsletters, but on the front line, driving the programmes.

This is a good time to be involved in science and public engagement. The established scientists, the students, and the



Fig. 13. An art event, focused on the Bristol Dinosaur, in which children paint and decorate parts of a slot-together dinosaur (A), which is then put together at the end of the day as an installation. This event is based on the art of Andy Council, and was run by Bristol-based street artist Luke Palmer.

public all want to see the same things happening. Despite the rapid advance of digital imaging technology, children and adults alike enormously relish seeing and handling real specimens, and hearing live interactive presentations by real people – in this regard, nothing much has changed since the times of Victorian dinomania. Added to this natural enthusiasm are three political agendas, (1) to use PES as a tool for social mobility and wider engagement in advanced education, (2) to increase the number of children entering science and engineering careers, and (3) to require scientists to demonstrate the ‘impact’ of their work, whether financial or societal impact. This is a requirement to a greater or lesser extent of the funding councils in the UK and the USA, and effective public engagement is presumably one way to demonstrate the impact of a research programme. Maintaining the correct balance will be an interesting debate in coming years.

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