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1873.—38. Address to the Geological Section of the British Association, Brighton. Rept. Brit. Assoc. for 1872, Trans. of Sections, pp. 90-96. (Also printed in Nature, August 29th, 1872.)
1877.—39. On the Geological Significance of the Boring at Messrs. Meux's Brewery, London. GEOL. MAG. Dec. II. Vol. IV. pp. 474-475.
1877.—40. On some further Evidence as to the Range of the Palæozoic Rocks beneath the South-East of England. Rept. Brit. Assoc. for 1877 (Coloured Geological Map).

II.—IGUANODON MANTELLI, Meyer.[1]

By HENRY WOODWARD, LL.D., F.R.S.

(PLATE I.)

IN 1822, just sixty-three years ago, Mrs. Mantell found the first tooth of a new and remarkable reptile (afterwards known as *Iguanodon*), imbedded in a mass of coarse conglomerate, which had been brought as 'road-metal' from one of the quarries in the Wealden formation of Tilgate Forest.

This tooth, with others subsequently found in the same rock, was submitted to Baron Cuvier, who pronounced them to belong to a large terrestrial herbivorous reptile hitherto quite unknown.

Various other detached and fragmentary remains were subsequently collected in the Wealden strata, and in 1825 the discovery was communicated by Dr. Mantell to the Royal Society,[2] when the name of *Iguanodon* was proposed for the fossil reptile, from the resemblance which its teeth presented to those of the living *Iguana*, a large vegetable-feeding lizard common in the West Indies and Central America.

In 1834 the first important connected series of bones of *Iguanodon* was discovered by Mr. W. H. Bensted in the "Kentish Rag" quarries of the Lower Greensand formation at Maidstone.

This specimen (which is preserved in the Geological Gallery of the British Museum of Natural History) consists of a large number of the bones of the skeleton of a young individual imbedded in stone in a very confused manner and all more or less flattened and distorted. Amongst them are two long and very slender bones which in the original description are referred to as "two clavicles," and they continued to be so called in Owen's British Fossil Reptiles.[3]

The true nature of these long and slender bones was pointed out by Prof. Huxley in a paper entitled "Further Evidence of the Affinity between the Dinosaurian Reptiles and Birds."[4] They are in fact the ischia, and occupy in Bensted's *Iguanodon* a position near to the ilium, to which they were once united.

Another specimen, embracing the chief part of the vertebral column with some of the bones of the extremities of a supposed young *Igua-*

[1] "Palæologica," by Hermann von Meyer, 1832, 8vo. (Frankfort).
[2] See Phil. Trans. vol. 115, p. 179.
[3] Pal. Soc. 1851, pp. 111-113, tab. xxxiv.
[4] Quart. Journ. Geol. Soc. 1869, vol. xxvi. pp. 12-50.

nodon (since referred to *Hypsilophodon*) from the Wealden of Cowleaze Chine, Isle of Wight,[1] shows the remains of the ilium, with the ischium and rod-like post-pubis attached to it, lying side by side. But the anatomical importance of this specimen was not discovered[2] until Huxley redescribed it in 1869.[3]

In estimating the value of such comparative anatomical studies, we must not, however, omit to take into account the circumstances under which that work was performed, and when we look at the enormous labour accomplished by Sir Richard Owen in describing and figuring the vast number of detached bones and parts of skeletons of new and remarkable Dinosauria in the Palæontographical Society's volumes, we cannot fail to admire his untiring energy and wonderful skill in deciphering so many difficult remains, and are no longer astonished that he fell into some erroneous determinations, but rather marvel that he made so few.

More latèly[4] Mr. J. W. Hulke, F.R.S., described a new species of *Iguanodon* (*I. Prestwichii*), from the Kimmeridge Clay, Cumnor Hurst, near Oxford; distinguished from *I. Mantelli* of the Wealden by the shape of the vertebral centra, by fewer than five sacral vertebræ, and by the simpler character of its tooth-serrature.

But interesting and numerous as have been the discoveries of fragmentary remains of *Iguanodon*, in this country, they could only have assisted us to a more or less conjectural notion of the living aspect of this huge Dinosaur, whilst the restoration by Waterhouse Hawkins (1855) was known to be erroneous in several particulars. Two somewhat small Dinosaurs, allied to *Iguanodon*, have, however, been met with in England in a tolerably perfect state. The first of these is from the Lower Lias of Dorset, obtained by the late Mr. Harrison of Charmouth, and is a fairly-complete skeleton of a herbivorous Dinosaur about 12 feet in length, closely allied by its dentition to *Iguanodon*, and described by Sir Richard Owen as *Scelidosaurus Harrisoni*.[5] This reptile was armed with lateral rows of thick bony scutes, and exhibits considerable disparity between the fore- and hind-limbs as well seen in *Iguanodon*, *Compsognathus*, and many other Dinosaurs. There are four functional digits and one rudimentary one in the pes.

The researches of Prof. Huxley and of Mr. J. W. Hulke have also made us acquainted with *Hypsilophodon Foxii*, obtained by the late Rev. W. Fox from the Wealden beds of the Isle of Wight. At first only known from fragmentary remains[6] in 1869, it became possible in 1881 to speak of an almost entire individual about 4 feet in length, preserved in one mass of matrix, besides parts of several others more or less complete. The important remains are figured by the Royal Society in twelve quarto plates, and

[1] Figured by Owen in Pal. Soc. Foss. Rept. Wealden, tab. I. 1855.

[2] The two ischia and the pubes are marked in the original description as the right tibia and fibula.

[3] Quart. Journ. Geo. Soc. vol. xxvi. pp. 3-12, Pl. ii.

[4] Quart. Journ. Geol. Soc., 1880, vol. xxxvi. pp. 433-456, pl. xviii.-xx.

[5] Pal. Soc. Foss. Rept. Oolitic form. 1861, pl. 2, 4, 5, 6; and 1862, pl. 1-11. Preserved in the British Museum (Nat. Hist.).

[6] See Quart. Journ. Geol. Soc. 1870, vol. xxvi. pp. 3-12, pl. 1 and 2.

in the last a complete restoration is given by Mr. Hulke.[1] The animal has four large and powerful digits to the hind-foot[2] and a small rudimentary 5th outer toe; an extremely small manus with four small digits and a 5th rudimentary one. Mr. Hulke thinks that the sharp-pointed and curved ungual phalanges indicate that it was probably arboreal and rock-climbing in its habits. "The sides of the crowns of the teeth are finely serrated and repeat in miniature the lamelliform serration of the crown of *Iguanodon Mantelli*" (*op. cit.*).

Prof. Huxley was the first to draw special attention[3] to one of the most perfect remains known in Europe of a small Jurassic Dinosaur from the Lithographic Stone of Solenhofen, Bavaria, and described some years since by Dr. Andreas Wagner, under the name of *Compsognathus longipes*. "It has a light head with toothed jaws, supported on a very long and slender neck. The ilia are prolonged in front and behind the acetabulum. The pubes (?) seem to have been remarkably long and slender. . . . . The fore-limb is very small; the hind-limb is disposed as in birds, and is very large, with three digits to the manus and pes. The femur, as in birds, is shorter than the tibia." Notwithstanding its small size—not more than two feet in length—it strikingly resembles the figure of *Iguanodon* (Plate I.), but its proportions are more light and slender, and its dentition shows that *Compsognathus* was carnivorous, whilst *Iguanodon* belongs to the herbivorous type.

Amongst the earlier discoveries of large Dinosaurians in North America must be enumerated, *Hadrosaurus Foulkii*, Leidy, from the Cretaceous beds of New Jersey, an herbivorous animal closely resembling *Iguanodon*, and fully twenty-eight feet in length; and *Lælaps aquilunguis*, Cope, twenty-four feet long, of carnivorous type like *Megalosaurus*. Attempted restorations of both these genera were set up some years since, in the Central Park, New York, by that ingenious enthusiast, B. Waterhouse Hawkins, F.G.S. (see GEOL. MAG., 1869, Vol. VI. p. 565), but have been since removed.

To Prof. O. C. Marsh, M.A., F.G.S., of Yale College, Newhaven, belongs the honour of making known perhaps the largest number of American Dinosaurs, some of which as, *e.g.*, *Brontosaurus excelsus*,[4] Marsh, from the Jurassic formation of Colorado, *Diplodocus longus*,[5] Marsh, *Ceratosaurus nasicornis*,[6] Marsh, and *Allosaurus fragilis*,[7] Marsh, have been illustrated in these pages. Altogether more than thirty genera of Dinosauria have been described from North America alone.

It is remarkable, that after more than sixty years, since the first

[1] See Phil. Trans. Roy. Soc. 1883, vol. 173, part iii. pp. 1035–61 and pl. 71–82.

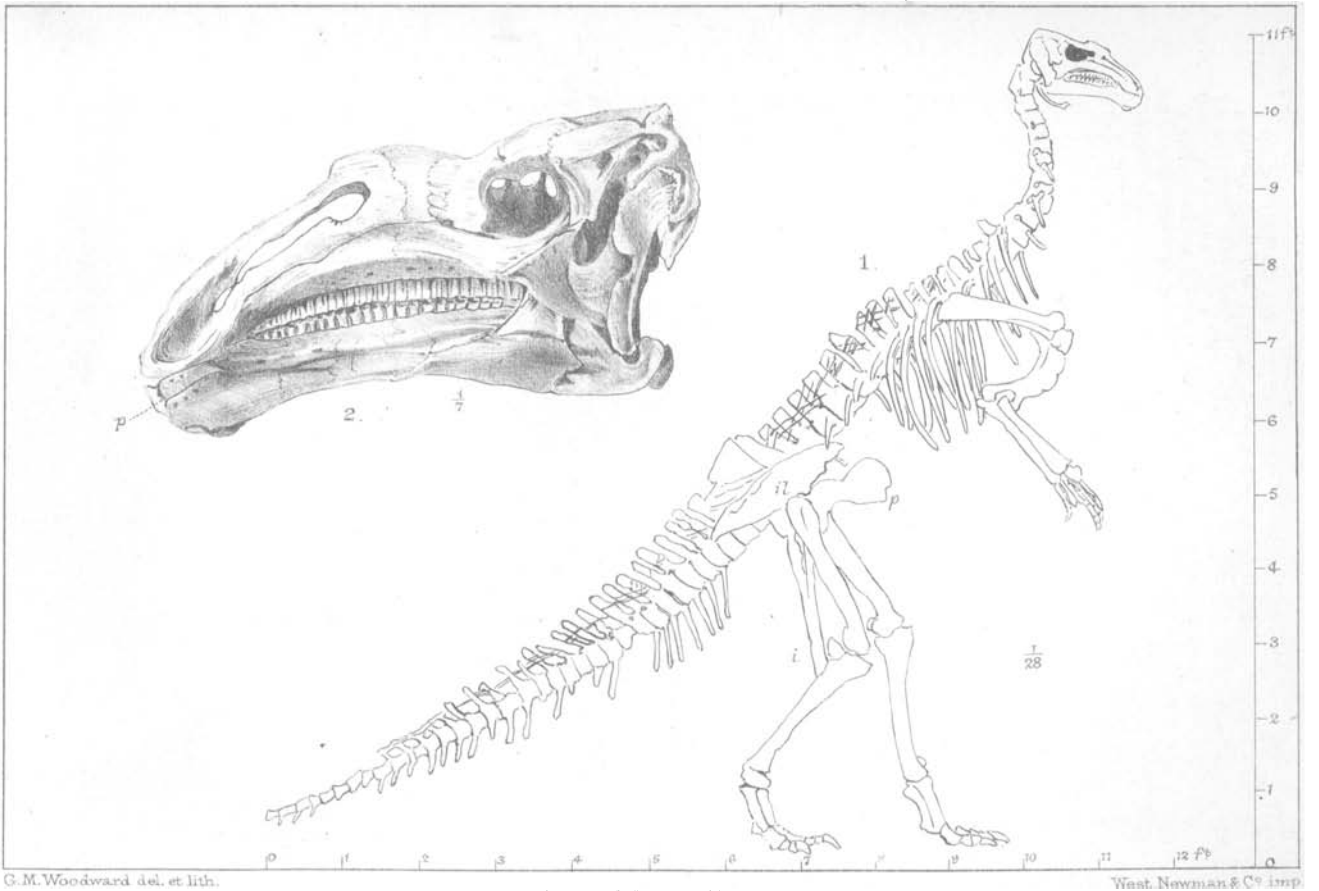
[2] In this point it agrees with *Scelidosaurus Harrisoni*; but that Dinosaur was furnished with rows of bony scutes, whereas *Hypsilophodon* has none. (See the original specimens in the British Museum (Nat. Hist.))

[3] Proceedings of the Royal Institution of Great Britain, Feb. 7, 1868. See also GEOL. MAG. 1868, Vol. V. pp. 357–365.

[4] See GEOL. MAG. 1883, Dec. II. Vol. X. pp. 385–388, Pl. IX.

[5] *Op. cit.* 1884, Dec. III. Vol. I. pp. 99–107 (10 Woodcuts).

[6] *Op. cit.* 1884, pp. 252–262 (Figs. 1–5). [7] *Op. cit.* 1884, *loc. cit.* (Figs. 6–8).



G. M. Woodward del. et lith. West, Newman & Co. imp.

Iguanodon Mantelli, Owen.
Restored by M. L. F. de Pauw, in the Brussels Museum.

discovery of *Iguanodon* remains was made in the Wealden—during which time similar reptilia, more or less complete, have been exhumed on the Continent, in England, and in North America, in strata varying in age from the Trias to the Chalk,—numerous perfect specimens should have lately been met with in their original *gisement*, the Wealden formation, from which the first was obtained; not however in Sussex, but in Belgium. Their preservation is due to a very singular circumstance. In the colliery of Bernissart[1]—between Mons and Tournai near the French frontier—the Coal-measures (which are overlain by the Chalk-formation and by thick Quaternary deposits) are fissured in many places by deep valleys or chasms more than 200 metres deep.[2] These must have been formed by denudation and dislocation of the strata in post-Carboniferous times, and were *open gorges* in the old land-surface in the Wealden period.[3] Into this vast abyss were precipitated, by some Cretaceous débacle, twenty-three huge *Iguanodons*, numbers of fish of the genera *Lepidotus*, *Ophiopsis*, and *Microdon*; a Batrachian; several species of Chelonians; and Crocodilians—equally perfect with the Iguanodons;—and numerous ferns of the genus *Lonchopteris*, *Pecopteris*, *Alethopteris*, *Sphenopteris*, *Gleichenites* and *Gleichenia*; agreeing with those described by Dunker from the Wealden of Hanover, and by Mantell from that of the south-east of England.[4]

The ossiferous deposit is separated from the steep walls of coal-shale bounding the chasm by a talus 10 metres thick, composed of *débris* of the coal-formation. The layers are composed of finely laminated blackish clay, interstratified with veins of grey sand and fragments of coal.

The skeletons are imbedded in concretionary masses in the fine clay-sediment with fishes and plants, and indicate a repetition of ossiferous deposits at different levels, more or less widely separated by beds of unfossiliferous clay. The beds themselves are inclined at 70° against the sloping talus, but their inclination diminishes rapidly and is reduced to only 5° at a distance of 12 to 15 metres from the sides of the chasm. The discovery was first made known in 1878, and three years were subsequently spent by M. de Pauw in extracting the great series of fossil-remains from the pit-shaft, the bones being brought up from a depth of 322 metres.[5] It must have been no small inconvenience and loss to the owners of the Sainte-Barbe coal-pit, to allow M. Dupont, the Director of the Brussels Museum and his Assistants, to carry on their researches for so long a period, and bring to bank with care so large and bulky a collection.

[1] "Sur la decouverte d'ossements d'*Iguanodon*, de poissons, et de vegetaux dans la fosse Sainte-Barbe du charbonnage de Bernissart:" par M. Ed. Dupont, Membre de l'Académie, Directeur du Musée Royal d'Histoire Naturelle de Belgique. (Bulletins de l'Académie Royale des Sci. etc. de Belgique, 2e Serie, Tome 46, Bruxelles, 1878, pp. 387-408.)

[2] 650 feet.

[3] These old land surface-contours are now quite obliterated by deposits of later date which fill up and conceal them, and, save in these deep gorges, the Wealden formation has been completely destroyed and removed by subsequent denudation.

[4] Mantell's Geology of the South-east of England, 8vo. 1833, and Mantell's Wonders of Geology, 8vo. 1838–1858 (7 editions).

[5] Over 1000 feet.

M. Fagès, the Director of the Bernissart Coal-mining Company, deserves the thanks of all scientific men for his liberality in aiding in so generous a manner this important undertaking.

After seven years' labour, two huge entire skeletons adorn the great glass case in the Court-yard of the Museum in Brussels. That of *Iguanodon Bernissartensis* cannot be less than 15 feet in height, and measured along the dorsal line is rather over 30 feet in length, covering nearly 24 feet of ground in its erect position. That of *Iguanodon Mantelli* (see Plate I.) is less in size, and its bones are more slender generally. Its height is rather over 10 feet; its total length, measured along the back, is about 20 feet, and it covers in its erect position (as represented in our Plate) 12 feet of ground.

These magnificent specimens, which I have had the good fortune to visit and study repeatedly, during the past five years of their development, are unrivalled, and their reconstruction reflects the highest credit on M. L. F. De Pauw, the accomplished controller of the workshops in the Royal Museum of Natural History, Brussels, of whose ability as a modeller and reconstructive anatomist I had occasion to speak in high praise, in reference to his reconstruction of the Mammoth's skeleton noticed in 1871 (see GEOL. MAG. Vol. VIII. pp. 193–8, Pl. IV.), also set up in the Royal Museum, Brussels. The task of working out these fossils, originally begun by M. G. A. Boulenger, was subsequently undertaken by M. M. L. Dollo, on M. Boulenger leaving the Brussels Museum to join the Zoological Staff of the British Museum, London, in 1882.

M. Dollo has already published five Memoirs on "*Iguanodon*";[1] one on the Batrachians;[2] one on the Chelonians;[3] and one on the Crocodiles[4] of Bernissart.

A complete figure of *Iguanodon Bernissartensis* was published in 1883, and reproduced in "Nature" (Sept. 6, pp. 439–43) by Prof. H. N. Moseley, F.R.S., who gives an excellent account of the Brussels *Iguanodon*.

In the present year the reconstruction of *Iguanodon Mantelli* has been completed and the figure of the skeleton published. From this our reproduction on Plate I. is derived.

It is hardly possible to over-estimate the importance of the Bernissart discoveries, or the flood of light which they throw upon

[1] See M. L. Dollo, "Première Note sur les Dinosauriens de Bernissart," "Bulletin du Musée Royal d'Histoire Naturelle de Belgique," tome i.—1882. Pl. ix. Fore- and hind-limbs of *Iguanodon Bernissartensis* and *I. Mantelli*. "Deuxième Note," *ibid. op. cit.* Pl. xii. The *sternum*. "Troisième Note," *ibid. op. cit.* tome ii. 1883, Pl. iii. iv. and v. Tibia and fibula and tarso-metartarsal bones compared with Birds and Reptiles. Bones of Pelvis compared. Complete figure of *I. Bernissartensis* ($\frac{1}{25}$th nat. size). "Quatrième Note," *ib. op. cit.* 1883, t. ii. p. 223. "Cinquième Note," *ibid. op. cit.* tome iii. 1884, pp. 129-46, pl. vi. and vii. Crania of Dinosauria compared, and Restoration of *Iguanodon Mantelli*.

[2] "Sur les Batraciens de Bernissart," par M. L. Dollo: *op. cit.* 1884, tome iii. pp. 85-93, pl. iii. *Hylæobatrachus Croyii*, Dollo.

[3] "Première Note sur les Cheloniens de Bernissart," *op. cit. ibid.* pl. i. and ii. pp. 63–79. *Chitracephalus Dumonii*, Dollo, and *Peltochelys Duchastelii*, Dollo.

[4] "Première note sur les Crocodiliens de Bernissart," *op. cit.* tome ii. 1883, pp. 309–338, pl. xii. *Bernissartia Fagesii*, Dollo, and *Goniopholis simus*, Owen.

the structure of the Dinosaurian skeleton. In a subsequent paper we propose to give a notice of some of the more important points which M. Dollo's researches have helped to elucidate. In the meantime we cannot but recall with feelings of the warmest gratitude and admiration those earlier palæontological labourers, who, with exceedingly imperfect materials at their command, succeeded in demonstrating the existence of this great Sub-Class of Animals, which Prof. Huxley has clearly shown occupy a position between Birds and Reptiles, and help us most materially to complete the grand chain by which the Animal Kingdom is linked together.

EXPLANATION OF PLATE I.

FIG. 1. *Iguanodon Mantelli*, Meyer; reproduction on a reduced scale of M. Dollo's beautiful plate, already referred to (Bull. Mus. Roy. d'Hist. Nat. de Belg. 1884, t. iii. pl. vii.) *i*, the ischium: *il.* the ilium: *p*, the pubis.

,, 2. Skull of *I. Mantelli* (seen in profile) $\frac{1}{7}$th nat. size. *p*, the præsymphisial bone (see observations on this remarkable bone by Mr. J. W. Hulke, F.R.S. (Pres. G. Soc. 1884), in his Anniversary Address, Quart. Journ. Geol. Soc. 1884, vol. xl. pp. 47–51.)

III.—The Cause of Slaty Cleavage: Compression *v.* Shearing.

By Alfred Harker, B.A., F.G.S.,
of St. John's College, and Demonstrator in Petrology in the Woodwardian Museum, Cambridge.

THE received theory of Slaty Cleavage has generally been held to afford a complete explanation of the observed phenomena. The proximate cause of the structure was shown by Dr. Sorby to be a superinduced arrangement of the flat and long-shaped fragments constituting the rock, in virtue of which they tend to lie in, or nearly in, the planes of cleavage; this arrangement being assisted, as Mr. D. Sharpe advocated, by a flattening of those particles themselves. These changes were ascribed to great lateral compression of the rock in the direction perpendicular to the cleavage-planes, together with some expansion along those planes in the line of their dip; and a great mass of evidence was brought forward to support this theory.

In papers recently published in the Geological Magazine (1884, pp. 268, 396, etc.) the Rev. O. Fisher rejects this compression and would substitute *shearing*, *i.e.* a creeping motion such as would distort a cube into an oblique parallelepiped without change of volume (see Fig. 3, p. 399). He indeed admits a certain compression in addition, but it is so slight that for simplicity we may disregard it.

Mr. Fisher contends that the kind of distortion presented by the fossils of cleaved rocks is such as would be produced by a shearing motion, and he seems to imply that these appearances could not be brought about by compression and expansion. But it is easy to see that a shear of given amount is precisely equivalent, so far as distortion is concerned, to a compression of proper amount in a certain direction with a corresponding expansion in a direction perpendicular to it. For the distorting effect of any strain or system of strains can be fully represented by the 'ellipsoid of distortion,' *i.e.* the ellipsoid into which a sphere would be distorted by the