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**XXVI.—On the Upper Formations of the New Red Sandstone System in Gloucestershire, Worcestershire, and Warwickshire; showing that the Red or Saliferous Marls, including a peculiar Zone of Sandstone, represent the “Keuper” or “Marnes Irisées;” with some account of the underlying Sandstone of Ombersley, Bromsgrove, and Warwick, proving that it is the “Bunter Sandstein” or “Grès Bigarré” of Foreign Geologists.**

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[Read June 14, 1837.]

PREFACE.

IN former communications to the Geological Society\*, the System of the New Red Sandstone of Gloucestershire, Worcestershire, and Shropshire was subdivided by Mr. Murchison in the following manner:

Foreign Equivalents.

- 1. Marls with salt, gypsum, and a thin course of sandstone .. *Keuper—Marnes Irisées.*
- 2. Quartzose, red sandstone, and conglomerate..... *Bunter Sandstein—Grès Bigarré.*
- 3. Calcareous conglomerate=magnesian limestone ..... *Zechstein.*
- 4. Lower new red sandstone ..... *Rothe-Todte-Liegende.*

The objects of this Memoir are to describe with greater precision than had been previously attempted, the two superior members of this group, by showing that they are both fossiliferous, and that they can be separated from each other by their zoological and lithological characters, as well as by geological position. The communication is the result of a joint examination of the district, and of other observations made independently by the authors. In it, they propose to describe the prominent characters of the two superior formations of the New Red System as exhibited in Gloucestershire and Worcestershire, and to extend their remarks concerning those beds into Warwickshire. The strata will be considered in descending order.

\* See Proceedings, vol. i. p. 471. March 27th, 1838; vol. ii. p. 115. January 21st, 1835; and “The Silurian System,” p. 27 *et seq.*

§ 1. *Saliferous Marls and Sandstone (For. Syn. Keuper—Marnes Irisées).*

Having examined the junction-beds between the lias and the new red sandstone from the southern extremity of Gloucestershire through Worcestershire into Warwickshire, we have only to repeat what was adduced by one of us on previous occasions, that in many positions the lowest calcareous band or "limestone of the lower lias shale" is also underlaid by shale, which passes into the new red system by alternations of whitish sandy marlstone, black shivery schist, and greenish marls, with occasional courses of very thinly laminated, flag-like sandstone. The uppermost zone of the new red system, beneath these junction beds, is composed of whitish-green marl, and is succeeded by red marl, which passes downwards, alternating frequently with party-coloured marls, though red for the most part predominates. As the country, occupied by these marls, presents few steep acclivities or neatly cut escarpments, it is not often easy to estimate, with precision, the depth beneath the junction lias beds at which a change of mineral character is first perceived; but we may state, that a zone of sandstone rises, at many places, from beneath the upper portion of these marls. This Keuper sandstone we have detected at intervals, and we have laid it down on the accompanying Map (See Plate XXVII.). It lies at a distance varying generally from half a mile to three miles, from the lowest edge of the lias, the distance changing with the angle of inclination of the strata; its relative position being also dependent on dislocations along the boundary line. There are, however, localities where this sandstone is covered by a considerable thickness of red marl; and by prolonging the course of the strata beneath adjoining platforms of lias, we have been enabled to estimate, that this sandstone is separated from the lias by at least 200 feet of red and green marls. It was stated, on former occasions, that this rock appears in Gloucestershire, at Tibberton, in the form of sandy marlstone, and that it re-appears at Burgehill\* quarries, near Eldersfield, at the southern extremity of Worcestershire. (See S.W. corner of the Map, Pl. XXVII.). The section of these quarries is,

1. Red marl about .....	4 Feet.
2. Greenish grey marl .....	5 —
3. Thinly laminated marl, with white gritty sandstone.....	2 —
4. Soft white sandstone .....	6 —
5. Greenish and grey marly sandstone .....	8 —
	— 16
	—
Dip 10° towards the south.	25

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\* This place, though spelt Burg-hill on the Ordnance Map, is invariably pronounced with the soft g.

The sandstone beds thin out; and their surface often presents ripple marks. The marls in the bed No. 3 were much cracked at the time of their deposition, for the crevices are filled with whitish sandstone, in the same manner as septaria are occupied by calcareous spar. Sometimes the marl is more broken up, and detached angular fragments are imbedded in the sandstone. The general relations of the Burge-hill sandstone to the surrounding formations is shown in Section, Pl. XXVII., fig. 1.

This sandstone rock, as before stated, is also exposed distinctly at Ripple, three miles north of Tewkesbury. To the north of Ripple it appears gradually to thin out; and in a section at Old House Farm, south of Spetchley, near Worcester, it is represented by only about twelve feet of grey shivery marls with thin courses of sandstone, the whole reposing on red marl. It is also seen half a mile east of Spetchley at the junction of the Alcester and Evesham roads. It is not discernible further north, being lost or obscured amidst the great mass of red marl in which it is enclosed. We, therefore, proceed to describe the characters of the rock at Inkberrow, about twelve miles east and by north of Worcester, in which neighbourhood it has long been quarried, and is so clearly exposed, that it appears to us to afford the best lithological type of the subdivision in Worcestershire.

The sandstone of Inkberrow occupies a prominent part of a distinct ridge about three miles in length, and varying in height from 210 to 320 feet (above the sea), and it extends from the quarry pits, north-west of Radford, in a low hummock, one mile west of Inkberrow by Penhills to Morton Hill, as a culminating point, whence the ground lowers to Feckenham on the north. The same stone re-appears, at intervals, in an attenuated form to the north of Feckenham, ranging by Lower Berrow, and wrapping round a bay of lias, from beneath which, it rises at Wallhouse Farm, at an angle of  $20^{\circ}$  to  $25^{\circ}$ . (See Section, fig. 2.)\* Near Inkberrow the sandstone is quarried at three chief localities, viz. the Quarry Pits, Stone-Pits, and Mucklow's Grave. It is also clearly exposed on the sides of any of the lands, descending from the ridge of red ground on the east to the vale of lias on the west†. The following section exhibits the whole of the strata here exposed. (See Pl. XXVII., Section, fig. 3.)

1. Red and green marls occupying the crown of the ridge, estimated thickness 100 to 120 Feet.

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\* Owing to the undulations of the red marl in which it is contained, the same rock is again brought out at Love Lane, about two miles to the east.

† This plain of lias, bounded on the east by hills of red marl, indicates a line of fault which is traceable from Bredon Hill on the south towards Bromsgrove Lickey, and has been described by Mr. Strickland, Geol. Proc. vol. ii. p. 5, and Analyst, vol. ii. p. 1.

2. Sandstone, consisting in detail of
  - a. A cover of finely laminated flag-like marly sandstone, of delicate greenish and light drab colours, alternating with marls. . . . . 20 to 30 Feet.
  - b. Thick-bedded, finely laminated, soft, siliceous sandstone, of various colours, the prevailing one being a white or pinkish white, with occasional tints of green, purple, &c. . . . . 15 to 30 —
  - c. Finely laminated flag-like sandstones, similar to a. . . .
3. Red and green marls similar to No. 1.

These sandstones, though usually of a white or lightish colour, exhibit so many lithological varieties, that their characters can, with difficulty, be rigorously defined.

At the Great Quarries or Inkberrow Stone Pits, there are several excavations exposing surfaces of the rock from 30 to 40 feet in depth. The chief or central beds are brownish red, brownish yellow, rusty pink, delicate pale green and white, the same tint being seldom persistent for more than a few yards in horizontal extension. The quality of the stone also varies very much, in short distances. A sandstone of a fine grain and good quality sometimes thins out and terminates in soft marly beds, whilst wedge-shaped masses of marl are dove-tailed with the sandstone. The very great variety of the rock is well seen in the tombstones, piled up for sale. From these the purchaser may select slabs of five or six distinct tints, varying from nearly a pure white to a deep purple; each slab being for the most part of one colour. This uniformity, however, extending only to the length of a large tombstone and to the depth of four or five inches, is due to the fine lamination of the beds, and the effect, though evident to the depth of a few inches, disappears where the rock is quarried for troughs or building purposes, when various tints and zones occur in the *same* block. It is, however, essential to remark, that although blotches of marl appear at intervals to certain depths, the rock is never spotted red and green like many of the inferior sandstones, whether of the new or of the old red systems. In the quarry at Mucklow's Grave, the upper flag-like beds are underlaid by sandstone, which weathers to brownish yellow colours with dark ferruginous stripes, marking the laminæ of deposition, the edges of the stone being sometimes worn into cavities. The thin way-boards are of green and deep red colours, and they sometimes cover rippled surfaces of the rock, on which are often raised, serpentine strings of sandy marl. Occasionally, these assume the forms of *Septaria*, the fine sand penetrating irregularly in minute and sinuous courses through the marly way-boards. In some instances, these layers of clay appear to have been cracked before the sand was accu-

mulated ; in which respect, they precisely coincide with the beds at Pyle in Glamorganshire, recently described by Dr. Buckland as Keuper sandstone. At this spot, the best building material is a white sandstone, composed of rounded grains of quartz with specks of whitish decomposed felspar, having in some parts a delicate pink tinge. The mass cuts into blocks two feet thick.

The same sandstone, subordinate to the marls, is seen near Harvington, south of Inkberrow, where it was formerly worked ; also between Ragley and Alcester, and at numerous localities in the western part of Warwickshire. At Oversley Lower Lodge, near Alcester, it caps a platform about one mile and a half from the lias escarpment. The quarry there presents the following section :

- |   |         |
|---|---------|
| 1. Red marl .....   | 4 Feet. |
| 2. Grey marl .....  | 4 —     |
| 3. White sandstone with laminæ and fragments of greenish marl . | 6 —     |
| 4. White sand with veins of gypsum.                             |         |
| 5. Red marl to the foot of the hill.                            |         |

A similar sandstone also caps the great Alne Hills, ranging parallel to a narrow outlier of lias, which extends north-west from the main body of that formation. There are here indications of an upcast of the red marl, ranging from near Stratford-on-Avon towards the north-west\*. On the north of this line of fault near Knowle, (North boundary of the Map, and Section, fig. 4.) distant full eleven miles from the chief escarpment of lias on the south, is a kind of basin of red marl, with a small outlier of lias in its centre. On the east this basin is bounded by a fault which appears to strike northwards from Warwick, while its northern margin is obscured by the great prevalence of quartzose gravel in that direction. The stratum of sandstone above described occurs within this area at the following points:—Mousehill, near Tanworth ; Lapworth, Knowle, Rowington, Shrewley Common, Barnmoor near Claverdon ; and Wolverton. At these localities its mineral character and geological position distinguish it from the sandstone of Warwick, which underlies the marls, and identify it with the sandstone of Inkberrow, Ripple, and Burge-hill. One of its most distinguishing lithological characters, is the abundance of greenish marl, which separates the sandstone into finely laminated beds, rarely fifteen inches thick and commonly much less. The marl is often intersected by the thin sinuous veins of sandstone resembling septaria, before alluded to, a character which, both in Warwickshire and

\* We may hereafter endeavour to show that this as well as several other lines of dislocation terminate in the Lickey Hills.

Worcestershire, seems to distinguish this upper bed of sandstone from the lower one which occurs at Warwick. This sandstone is also more variable in its texture than that of Warwick, for though *hand* specimens may be found much resembling the latter in appearance, yet in some of the beds a coarse grit prevails, similar to that of Burge-hill.

The best place for studying this sandstone in Warwickshire, is at Shrewley Common, about four miles north-west of Warwick, where it occurs near the summit of an extensive platform of red marl. The great thickness of this underlying marl, is evident at Hatton Hill, which is wholly composed of it. At Shrewley Common, the sandstone is exposed by a tunnel, on the Birmingham and Warwick canal, and in some adjacent quarries. The following section is visible :

Red marl.....	30 to 40 Feet.
Sandstone and green marl.....	20 —
Red marl.....	10 —
	<hr style="width: 10%; margin: 0 auto;"/>
	70

The stratification is very nearly horizontal.

The sandstone is obtained in large slabs and removed to Warwick, where it is used for tombstones and other purposes. It is whiter than the Warwick sandstone, and considerably harder, thinner-bedded, and closer grained. Small nodules of ironstone occasionally occur in it, and their great hardness gives much trouble to the stonemason. Ripple marks and septaria-like veins of sandstone are very abundant; and this locality is further distinguished by the occurrence of footsteps of animals, bivalve shells, and teeth of fishes, which will be described in the sequel.

The same beds are repeated at Rowington, where a deep cut on the canal exposes the following strata :

White sandstone and green marl.....	20 Feet.
Red marl .....	40 —
	<hr style="width: 10%; margin: 0 auto;"/>
	60

The stratification horizontal.

At the foot of the hill south-east of Knowle, the same stratum of sandstone appears, and, though not exposed by quarries, may be seen in one of the locks on the canal. It is surmounted by red marl, which dips beneath lias, about a mile further north\*.

\* The outlier of lias, at Knowle, is about a mile and a half in length by half a mile broad. It was worked for limestone a few years ago at Waterfield Farm and Copt Heath, and the shafts of the workings still remain. The discovery of this outlier is due to Dr. Lloyd, of Leamington, to whom we are indebted for much valuable information on the geology of Warwickshire.

To the south-east of Warwick, the red marls are so denuded, that there is little hope of finding this band of sandstone clearly developed, though the sandy character of the ground at Radford, about two miles from the lias escarpment, seemed to us to indicate the range of the sandstone (see Section, Pl. XXVII., fig. 4.). The undulations and faults, near Warwick, by which the younger beds are reproduced as outliers on the north-west, are, therefore, very important for our present purpose. Having traced this peculiar sandstone through so wide an area, there was no difficulty in identifying it, when discovered near Knowle and in the adjacent hills, between that place and Warwick, as represented in Section, Pl. XXVII., fig. 4. Besides a precise mineralogical resemblance with the sandstones of Burge-hill, Ripple, and Inkberrow, the rock in Warwickshire contains the *same* peculiar little bivalve shell (*Posidonomya minuta*, Pl. XXVIII., fig. 4.) which occurs at the southern extremity of Worcestershire, and thus throughout a course of not less than forty miles, we are enabled to mark the position of this thin band of sandstone, and to distinguish it from other sandstones, which not only underlie it, but are separated from it, by a great thickness of marl.

Again, the exact geological position of this sandstone, which we consider to be the equivalent of the Keuper sandstone of Suabia and Alsace, is 200 or 300 feet below the lowest beds of the lias, a position, which coincides well with that of the principal mass of this sandstone in Wurtemberg, where one of the authors has examined it. In Germany, however, the Keuper formation contains several courses of sandstone and grit, but always subordinate to thick masses of marl. In England, we have one well-defined band only, which, occurring from 200 to 300 feet below the lias, is completely and distinctly separated from the great red sandstone of the central counties, by a vast thickness of red and green marls, which in certain tracts are saliferous. Independently of natural sections, the great thickness of the red marls, or the depth to which they extend beneath the Keuper sandstone, is established by the shafts and borings made at the saltworks of Stoke Prior, near Droitwich, where the gypseous marls with masses of rock salt, were penetrated to a depth of nearly 600 feet *without an indication of any bed of sandstone\**.

Combining these facts with the sections exposed in the escarpments of Inkberrow, Knowle, and other places, it appears evident, that the Keuper of England (on the whole quite as largely developed as that of Germany) is, like the "Marnes Irisées" of France, a great marly formation, with one principal band

\* See Dr. Hastings's paper in the Analyst. vol. ii. p. 359.

of sandstone subordinate to it, which sandstone is separated, by at least 600 feet of marls, from the great mass of the underlying new red sandstone.

*Organic Remains of the Keuper.* (Plate XXVIII.)

When our examination of this tract commenced, it was a prevalent belief, that as no fossils had ever been found in the red marl formation, so was it hopeless to look for them. We have now to announce the existence of fishes, shells, and the impressions of footsteps of probably a Batrachian animal. The locality, in which organic remains were first discovered in the Keuper sandstone, is at the Burge-hill quarries, before mentioned. Here, they are by no means plentiful, but after considerable search a long Ichthyodorulite was found\*, (fig. 3.) with numerous casts of small bivalve shells (fig. 4.). This Ichthyodorulite manifestly belongs to an undescribed species of the genus *Hybodus*, (Agassiz,) and it is therefore exceedingly interesting in showing, that the same types of organization, which prevail in the lower lias, existed during the deposition of the upper part of the new red system. The dentated posterior margin of the spine is unfortunately wanting, but sufficient characters remain to warrant us in regarding it as a new species. It is remarkable for the straightness of the anterior margin, which hardly deviates one-eighth of an inch from a straight line. It appears to have been of a remarkably taper form, but from the loss of the hinder margin the diameter from front to back cannot be determined. The transverse diameter at the larger end is about three-eighths of an inch, and the total length is five inches. The longitudinal *costæ* are smooth, rounded, regular, and closely packed; at the larger end six of them cover a quarter of an inch (*i. e.* their diameter is one twenty-fourth of an inch). We propose to name this species *Hybodus keuperinus*.

The bivalve shells, (Plate XXVIII., fig. 4.) appear to be the *Posidonomya minuta* of Bronn (*Lethæa Geognostica*, page 164, Pl. XI., fig. 22.), or the *Posidonia minuta* of Goldfuss (*Petrefacten*, Pl. CXIII., fig. 5.) and of Zieten (*Versteinerungen Württembergs*, Pl. LIV., fig. 5.)†.

In Germany, this shell is stated to pervade the new red system from the "Keuper" to the "Bunter sandstein" inclusive, but in this country, it appears peculiar to that band of sandstone, which we have proved by stratigraphical evidence to represent the upper formation. It is indeed a very characteristic shell, for,

\* By Mr. Strickland.

† Bronn has changed the generic name to *Posidonomya*, the term *Posidonia* being pre-occupied in botany. Capt Portlock has lately detected this shell in the new red sandstone of Roan Hill, near Dungannon, Ireland.



as previously stated, we have detected it at Burge-hill and Inkberrow, in Worcestershire, and at Shrewley Common, in Warwickshire, where it is very abundant in some of the sandstone beds.

*Batrachian.*—Our proofs of the existence of probably a Batrachian in this rock, are similar to those which have been held sufficient to establish the claims of the sandstones of other countries to a similar distinction, *viz.* the impressions of the feet of animals. The slabs which we lay before the Society will, we trust, bear out this inference. (Fig. 1.) We found these interesting relics in the sandstone of Shrewley Common. They afford the same proofs as those which were insisted on in the case of the footsteps of tortoises in Dumfries-shire, *viz.* the same inverted position of the claws—similar raised portions of sandstone behind each impression, caused by the progressive movement of the animal—and similar indentations proving occasional halts in the march of the animal; in short, all the *indicia* by which the Rev. Dr. Duncan was first led to refer the impressions in the red sandstone of Dumfries-shire to the footsteps of animals, and by which Dr. Buckland sustained and established those views. The Warwickshire impressions are further distinguished by a depressed groove, running intermediate between the footsteps, and apparently caused by the tail of the animal dragging in the soft sand. Plate XXVIII., fig. 1, represents a large slab, now in the Warwick Museum, the counterpart of that which we have presented to the Society. These footsteps, which are given of their natural size in fig. 2, bear some resemblance to one of the Hildburghausen species figured in Buckland's "Bridgewater Treatise," Plate XXVI"; and supposed by Mr. Owen, Mr. Broderip, and other zoologists who have examined them, to belong to some genus of crocodilean saurian. Greater accuracy of definition cannot at present be attained; but perhaps, when the science of comparative ichnology shall be more advanced, the nature of the animal, which has left us these faint traces of its existence, may be ascertained with greater precision.

*Teeth of Fishes.*—Two small teeth of squaloid fishes were found at Shrewley.

§ 2. *New Red Sandstone* (For. Syn., "*Bunter Sandstein*" and "*Grès Bigarré.*").

The red sandstone of Gloucestershire (as described on former occasions), is comparatively of small dimensions; but, as the formation advances to the north of Worcester, it expands, and massive strata of sandstone rise from beneath the thick cover of marls above described. The uppermost beds of this great sandstone formation are distinctly exhibited, at various places, between

Omersley and Bell Broughton. At Ombersley, and the adjoining hamlet of Hadley (Plate XXVII., fig. 5.), these beds have been much quarried; and they afford a very beautiful lightish-coloured, fine-grained, slightly micaceous, quartzose sandstone, sometimes tinged with slight shades of pink and green; but a delicate olive colour prevails. At Hadley, the quarries expose from 30 to 40 feet of sandstone, covered by red marl. The sandstone is of greenish white colours, tinged, in parts, with purplish and reddish hues, and it is somewhat micaceous; the upper portion, or that nearest the marls, being a breccia of marl and sandstone. About 8 to 10 feet below the surface, carbonaceous laminæ are very abundant; and on flaking off the beds, their surfaces are found to be covered by numerous impressions of plants, nearly the whole of which have passed into a black powdery charcoal, which readily disintegrates on extraction. Hence, it is very difficult to preserve these fossils with all the freshness of form, which they exhibit when first disinterred; and when the jet-black colour forms a striking contrast to the light buff-coloured matrix. When the black, incoherent matter has fallen out, the impression of the matrix is usually marked by ferruginous colours. The large slabs, which we procured for the Society from this locality, have been examined by Professor Lindley, who thus expresses himself concerning their vegetable contents:—

“The only plant among the specimens, that has been published, is the *Echinostachys*, of which slight traces are visible (Plate XXVIII., fig. 11.). I presume they all belong to the same species; but at all events, one of them is *identical* with that published by Adolphe Brongniart, from the *Grès bigarré* (*E. oblongus*). The remainder of the impressions consist of many narrow, monocotyledonous leaves, resembling those of *grasses*, a portion of a *flabelliform palm-leaf*, some large moulds of stems of a doubtful character, a longitudinal section of a portion of a *dicotyledonous stem* with the bark on, a considerable portion of a broad leaf of some monocotyledon, and a great multitude of fragments wholly indeterminable. I can detect no trace of a *Voltzia*, unless a very imperfect stain upon one of the smaller slabs should be of that nature; the genera *Æthophyllum* and *Paleoxyris* are equally absent; *Convallarites* may be present in the form of some of the broken leaves, but it cannot be identified.”

Owing to a line of dislocation, which runs along the Doverdale valley, the sandstone of Hadley is thrown to the west, and is partly covered by marl; but farther west, it rises with a gentle easterly dip; and in that position forms the low ridge, at the southern end of which is the village of Ombersley\*. By pursuing a transverse section from this little ridge to the Severn, we pass through an unbroken, descending series of sandstones, in the following order. (See Plate XXVII., Section, fig. 5.)

\* The quarries from which the pretty church of Ombersley was built, are about half a mile south of the village, but they are now abandoned. This is the point at which the rock first emerges from beneath the marl; and hence it is overlaid by much rubbish.

- a. Beds of the Keuper or red marl, forming the crest of the Hadley and Ombersley ridge.
- b. Thin-bedded, red sandstone.
- c. Sandstone of a whitish and yellow colour, with plants similar to those of Hadley, 10 feet below its surface.
- d. Thick masses of deep red sandstone. They rise up to the west, and cap the hills on the left bank of the Severn above Holt Bridge. They are underlaid by wayboards of sandy marl.
- e. Alternating thin bands of coarse, concretionary, or rather fragmentary marlstone,—gritty small quartzose conglomerate, and soft, thick-bedded, dull red sandstone, the latter much predominating;—the whole dipping E.S.E. about 12°. The right bank of the river, at Holt Bridge, offers magnificent sections of the massive red sandstone, some quarries exposing faces of 60 feet and upwards.

This transverse section from Hadley and Ombersley to the river Severn, completely establishes the fact, that the light-coloured *sandstone, with plants, is inseparable from the great mass of red sandstone, and lies beneath the whole of the Keuper marls*, by a large portion of which, it is entirely separated from the true Keuper sandstone.

In following the Ombersley ridge upon its strike to Elmley Lovett, the same light-coloured sandstone is found, at intervals, for five or six miles, and is largely quarried at the latter place. Here, indeed, the prevalent tint of the rock is *red*, and the plants are again found in some quantity, generally in layers, which separate the principal masses of sandstone. The line of dislocation which passes by these quarries, will be noticed hereafter. The tract to the east of this ridge is covered by red, saliferous marls, extending by Droitwich to Stoke Prior. But at Bromsgrove, the peculiar sandstone of which we are speaking, rises from beneath the marls, and offers, on the high road from Droitwich, a most instructive section, which confirms, in every respect, the transverse section from Ombersley to the Severn, and proves the light-coloured rock to be an integral part of the great red sandstone formation.

Descending section of Breakback Hill, one mile S.W. of Bromsgrove :

- Red marls crowning the hill.
- a. { Ledge of darkish red sandstone, consisting of  
Thin-bedded earthy sandstone, alternating with marls, and whitish, thick-bedded, soft sandstone. Top beds partially brecciated like those of Ombersley, and inlaid with blotches of greenish marl. It contains fragments of plants and carbonized wood.
  - b. Thick-bedded, greenish white sandstone, full of plants.
  - c. Deep red coloured, solid, massive sandstone, scarcely micaceous, without wayboards; 40 feet are exposed in one quarry. Patches of marl, here and there, inosculate in the form of wedges or irregular concretions.
  - d. Light yellowish and brownish sandstone, with wedge-shaped masses of grit and marly calcareous breccia, occasionally cavernous, with traces of plants.
  - e. Red sandstone, slightly green in some parts.

2 Y 2

These last-mentioned beds lie near the turnpike-gate, west of the town of Bromsgrove, the whole mass dipping westerly. They are succeeded, on the opposite side of the valley in which the town stands, by distinct courses of deep, red, soft sandstone, which in their turn are underlaid by strata, containing irregular concretions of impure limestone or cornstone. The further consideration of these lower beds, in Worcestershire, would carry us beyond the limits of this memoir; and as they have been already described, at some length, by one of the authors, and proved to be the equivalents of the Dolomitic Conglomerate and Lower New Red Sandstone,\* and that the latter passes down conformably into the coal-measures, they are now merely cited to corroborate the inference, that the overlying red sandstone of Bromsgrove, including the light-coloured rock, with plants, constitutes the true equivalent of the Bunter Sandstein †. (Plate XXVII., fig. 5.)

#### *Sandstone of Warwick.*

We now proceed to show, that the sandstone of Warwick occupies the same geological position as that of Ombersley and Bromsgrove. In approaching Warwick from the west or south-west, this peculiar rock rises suddenly from beneath the red marl. It extends for several miles to the north-east, and is quarried at Warwick, Guy's Cliff, Leek Wootton, Blakedon Hill, Leamington, Bubenhall, and other places. Its strike appears to be from north-east to south-west; while its abrupt termination at Warwick may perhaps be due to a fault ranging in a northerly direction to the west of Kenilworth. It is probable that the upcast which has thus raised the sandstone above the marls on the west, has given the more or less dome-shaped structure to the hill on which

\* See The Silurian System, p. 46, *et seq.*

† Passing over these lower rocks, and also those of much higher antiquity, which constitute the Lickey, we again meet with a fine section of whitish sandstone rock at the "Sandhills" near Alvechurch, the dip being reversed, to the N.N.W. The section of these quarries consists, in descending order, of

- a. Red loam and marl. . . . . 6 to 8 feet.
- b. Thin, flag-like sandstone and marl alternating . . . . . 10 to 12
- c. Solid, whitish sandstone, of a delicate green tinge, void of wayboards, soft under the hammer, and working into any form. Lines of bedding partially indicated by flakes of dark mica, so that when cut and smoothed, the undulations of the dark-coloured material appear through the light-coloured ground; thus producing the appearance so well known in the *Cipollino* marble. In other parts, the mass is freckled with small dark spots (manganese?), which, when the stone is rubbed down, give it a warm brown tinge. We could detect no plants or organic remains in this beautiful sandstone. It is perhaps, therefore, not precisely of the same age as that of Bromesgrove and Ombersley, but a repetition of analogous strata rather lower in the series.

Warwick stands. On the south, however, the sandstone rises quite conformably from beneath the red marl; while, on the other side, the stratification, as far as the irregular bedding allows it to be traced, appears, in some places, to dip towards the north-west\*. (See Plate XXVII., fig. 4.)

At Leamington, the same sandstone rises very gradually from beneath the red marl on the south. The uppermost beds consist of very soft sandstone and white sand, with alternations of marl. The following section was lately exposed in cutting a large drain on the south side of the Leam:—

- a. Gravel with flints ..... 6 to 8 feet.
- b. Light-coloured sand with an irregularly denuded surface, containing concretionary masses of sandstone ..... 3 to 5
- c. Red marl..... 4

The concretionary masses in the sand contain numerous fragments of bone, in a better state of preservation than is usual in the Warwick sandstone. They appear, however, to have undergone much attrition; and it is rare to find any traces of their original form. A small tooth of a fish, probably that of a shark, was also found in these sandy concretions.

Below these rubbly beds, the sandstone assumes a degree of compactness, which adapts it for masonry; and many houses in the new town of Leamington, are built with the stone which has been extracted from their cellars. Indeed, in beauty of tint, facility of working, and durability, the light-coloured sandstone of Warwickshire and Worcestershire, like that of Grinshill, near Shrewsbury, with which we shall presently compare it, is probably surpassed by no other rock in the British isles.

To the north of Leamington, the same variety of the red sandstone is quarried at Blakedon Hill, where fragments of bones have also occurred in it. At the northern foot of this hill, the subjacent sandstone, of a deep red tint, commences; but the junction of the two rocks is not exposed.

The quarry, which has been most productive in the remains of *Vertebrata*,

\* About one mile north of Warwick, and half a mile north of the canal, is a singular knoll of sandstone, partly removed by quarrying, which must be very near the line of this fault; for at the canal bridge, on the south-west, a section of red marl is exposed, and no traces of the subjacent sandstone are visible. This fault, as it passes Kenilworth, is much obscured by the abundance of gravel; but its presence is proved by the fact, that there is no intervention of the buff-coloured or Warwick sandstone, between the red sandstone of Kenilworth and the red marl, which appears to abut against it on the west. To the south-east of Warwick, the hill of red marl called Highdown Hill; with a strip of lias at its eastern base, not improbably indicates the continuation of the fault, above described.

is at Coton End, on the south-east side of Warwick, where the following section is exposed:—

a. Soft, white sandstone and thin beds of marl .....	8 feet.
b. Whitish sandstone, thick-bedded.....	12
c. Very soft sandstone, coloured brown by manganese, called "Dirt-bed" by the workmen .....	1
d. Hard sandstone, called "Rag," about.....	2
	23

The dip about 3° to the S.

The bones are principally found in the so-called "Dirt-bed." They are in the same rolled and fragmentary condition as at Leamington, but in a state of much greater decomposition. When first taken from the quarry, they resemble stiff jelly, with singular hues of blue and red. It is necessary to remove them with great care from the quarry, and when dry, to saturate them with a solution of gum arabic, as the best means of preserving them. The only specimens which exhibit any distinct zoological characters, are some teeth obtained by Dr. Lloyd, to whose kindness we are indebted for the figures given of them in Plate XXVIII., figs. 6, 7, 8.

The light-coloured sandstone extends from Warwick, by Guy's Cliff, to Wooton Grange; beyond which it is succeeded by the underlying redder sandstone of Kenilworth. In a quarry in the grounds at Guy's Cliff, is the following section:—

Sandstone and beds of marl .....	8 feet.
Solid sandstone, whitish or grey, occasionally of a reddish tint.....	12
Red, micaceous marl, with wedges of sandstone .....	8
Solid, light-coloured, reddish tinted sandstone, about .....	20
	48

The bedding very irregular. Ripple marks occur on some of the beds.

We have now to speak of the redder sandstone which underlies the light-coloured strata. The upper part of this red rock consists of flaggy beds, with marly wayboards. In a quarry, south-east of Ashow, on the left bank of the Avon, is the following section:—

a. Thin, flaggy beds of red sandstone .....	6 feet.
b. Thick-bedded red sandstone .....	8

Calcareous matter pervades the thin beds *a*, in concretionary patches; and where that is the case, the sandstone is intensely hard.

One of the best sections of the red sandstone is in a quarry on the north-west of Kenilworth Castle :—

a. Laminated, marly red sandstone .....	5 feet.
b. Thick-bedded, reddish brown sandstone, sometimes discoloured by manganese, with occasional fragments of red marl, and a few rolled pebbles of altered sandstone and porphyry .....	20
	25

The bedding irregular. The general dip about 5° S.E.

It is needless to give further details respecting this great red sandstone deposit, for its general features are very uniform. We therefore proceed to make a few concluding observations.

The section fig. 4, proves that the light-coloured sandstone of Warwick agrees completely with the rocks of Ombersley and Bromsgrove, (fig. 5.) in rising from beneath the marls, and in passing downwards into solid red sandstone. Although this rock has been recently described by Dr. Buckland, it is essential to our purpose to state, that, from geological and other evidences, we consider that it cannot be, as he conceives, the equivalent of the German Keuper. The true position of that rock is, fortunately, indicated in natural sections near Warwick, as well as in many parts of Worcestershire, where it is demonstrated that the *thin-bedded* sandstone, or true Keuper, is separated from the *thick-bedded* sandstone of Ombersley, Bromsgrove, and Warwick, by a vast thickness of red and green marl. Obedient, however, to geological principles, based on zoological evidences, we should not pretend to set up the classification here suggested, in opposition to the views of so distinguished a geologist as Dr. Buckland, if founded only on the relative geological position of these rocks. On the contrary, if it could have been shown, that the fossils which we have now pointed out as characterizing the upper sandstone, occurred also in the lower,—that the plants in the lower sandstone were similar to the well-known plants of the German *Keuper*,—and that the fragments of Saurians found in the sandstones of Guy's Cliff and Warwick really belonged to the *species* peculiar to the Keuper,—then, indeed, we should willingly allow that the lower sandstone *also* must be grouped with that formation. Seeing, however, that the animal remains of the one sandstone are, as far as we can judge, entirely different from those of the other, and that the plants, so abundant in the lower rock, have none of the characters of the Flora of the Keuper, but, on the contrary, contain one remarkable plant, the *Echinostachys*, a genus considered by Adolphe Brongniart as peculiarly characteristic of the *Grès bigarré*,—we are compelled to adhere to our opinion, and to contend that the peculiar sandstone of Burge-hill, Ripple, Inkberrow, Alcester, Shrewley Com-

mon, &c., which we have been the first to describe, is the true equivalent of the *Keuper Sandstein*; and that the sandstone of Ombersley, Bromsgrove, and Warwick, is not the *Keuper*, but a portion of the *Bunter Sandstein*. In respect to the Saurian of Guy's Cliff, which we have had no opportunity of examining, it is sufficient to state, that Dr. Buckland himself does not contend that it is either of the species of the *Phytosaurus* (*Jäger*) of the German Keuper; and he hesitates even to refer it to that genus. Now the mere existence of a Saurian in the Warwick sandstone proves nothing; for geologists are well aware, that various species of the family occur in all the formations, from the lias down to the magnesian limestone inclusive. Indeed, as these animals are not unfrequent in the Bunter Sandstein of Germany, we cannot avoid suspecting that the animal remains of Guy's Cliff may, if ever accurately determined, be assigned to some of those species, mentioned by M. Voltz and others, as occurring in the Bunter Sandstein, or German deposits, which, from the other proofs adduced, we consider to be of the same age.

In concluding this sketch of the structure and contents of the two upper formations of the New Red System, in the central counties of England, we may observe, that in Shropshire and the adjacent parts of Staffordshire, where these deposits have been described at length by one of the authors, the upper marls, or Keuper, have been so much denuded, particularly near their junction with the lias, that the peculiar band of Keuper sandstein which we have found persistent in Gloucestershire, Worcestershire, and Warwickshire, has not yet been met with. But, rising from beneath the whole of the marls, and apparently separating them from the underlying massive sandstones, there does exist a thin course of impure limestone, which, it is presumed, may represent the *Muschelkalk*, and of which an account is given in Mr. Murchison's work\*. If this should really prove to be the equivalent of the *Muschelkalk*, the age of the formation which underlies it, will be still more clearly established; for the sandstones of Cheshire and Shropshire, which there rise from beneath the saliferous marls, as in Worcestershire and Warwickshire, correspond in mineral structure with those which we have been describing, particularly in containing, near their upper limits, courses of a stratum (sometimes 70 to 80 feet thick) of whitish or light-coloured sandstone, of which the celebrated quarries of Grinshill, near Shrewsbury, and the picturesque rocks of Hawkstone, are good examples†. These rocks are indeed identical with the sand-

\* The Silurian System, p. 36.

† At Grinshill, eight miles north of Shrewsbury, where the rock is identical with the best building-stone of Leamington and Warwick, the mass of whitish coloured sandstone (80 feet thick) is exposed, between a cap of red marly sandstone and a deep red sandstone of vast thickness, on



stone of Ombersley, Bromsgrove and Warwick; and like those we have here described, they pass into, and are inseparable from, the great mass of the New Red Sandstone of England, which, from geological and zoological proofs, we consider to be the equivalent of the Bunter Sandstein.

In thus identifying the red and green marls, and an included band of sandstone with the Keuper, and separating this marlous formation from the underlying sandstones, we have the direct authority and example of the best French geologists; for M. Elie de Beaumont, in a memoir on the Vosges, has shown that the formation of *Marnes Irisées*, which he places on a parallel with our English red marl, is the true representative of the Keuper; and in the south-western parts of France, M. Dufrenoy has shown us, that these marls and the underlying sandstones, are brought together precisely in the same manner as in England, the Muschelkalk, or subdividing limestone, having thinned out\*.

In a subsequent memoir, we may offer some explanation of the lines of dislocation, by which these deposits have been affected.

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POSTSCRIPT.

Dr. Buckland has described in the Geol. Proc. v. ii. p. 439, the silicified stems of trees, which occur at Allesley near Coventry, but has not determined the age of the rock in which they are imbedded. Having visited that spot, we have no doubt that these trees occur in that part of the series, which we have shown to be the equivalent of the Bunter Sandstein. The red sandstone of Kenilworth may be traced without interruption from that place to Coventry and Allesley, where it is interstratified with beds of quartzose and trappean conglomerate, which are identical with those of North Worcestershire, Staffordshire, &c. (See Mr. Murchison on The Silurian System, p. 42.) The fossil trees of Allesley are found in a stratum of this conglomerate, containing manganese, and lying between strata of ordinary red sandstone.

The same red sandstone occurs in thick beds at a quarry, lately opened, about three quarters of a mile N.W. of Coventry. It differs in no respect

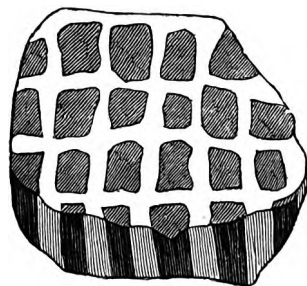
which it rests; thus perfectly resembling the section at Bromsgrove. The Hawkstone Hills are chiefly composed of the same light-coloured variety of the Red Sandstone. It is indeed remarkable that a mere lithological distinction of colour should be so very persistent.

\* See Dufrenoy and Elie de Beaumont *Mémoires pour servir à une description géologique de la France*, vol. i. p. 313, *et seq.*

from the sandstone of Kenilworth, and the only remarkable circumstance connected with this quarry, is the discovery of a fossil jaw, represented at Plate XXVIII., fig. 5. The teeth of this jaw are very irregular both in form and position, and appear to have lost much of their destructive character by trituration. The teeth are not inserted in alveoli, but are united with the maxillary bone like the teeth of fishes.

This specimen, the only example known of an animal relic in this part of the New Red Sandstone of central England, is deposited in the Warwick Museum.

At the railway station near Coventry, the cuttings have laid bare the upper or light-coloured beds of variegated sandstone, spotted with manganese, dipping to the E.S.E., and covered by the red marl or Keuper, which, on the line to London, is seen to graduate into and pass under the lias. In following the rail-road from Coventry towards Birmingham, the underlying or deep red sandstone is traversed; and in the adjoining hill of Meriden, it is again capped by the same light-coloured rock as at Coventry. The red sandstone continues as far as Berkswell, where it is succeeded by the upper marls of the Knowle basin, which extend to within a mile of Birmingham. At Berkswell a singular variety of this sandstone occurs, exhibiting the appearance of a pavement of bricks, 2 or 3 inches square, separated by bands of a whitish cement. The stone splits into thin flags, and the division in the colours extends through each layer. No change of texture is visible in the white bands from the red portions which they inclose; but along the centre of each is a fine raised line, apparently due to a cast in an extremely narrow crack. The following wood-cut represents a fragment of this stone.



A similar sandstone is stated by Dr. Macculloch to occur in the coal-measures of Arran. Description of the Western Islands, vol. ii. p. 374.

## EXPLANATION OF THE PLATES AND WOOD-CUTS.

### PLATES XXVII. and XXVIII.

To illustrate Mr. Murchison and Mr. Strickland's Memoir on the Upper Formations of the New Red Sandstone System in Gloucestershire, &c. : p. 331.

#### PLATE XXVII.

Map and Sections : p. 331. et seq.

#### PLATE XXVIII.

(Fossils from the Keuper Sandstein, p. 338.)

*Fig. 1.* Ripple marks and impressions of footsteps on a slab of sandstone from Shrewley Common, Warwickshire, one-third the natural size. The impressions are in relief. The slab is preserved in the Warwick Museum ; but a portion of the counterpart is in the Museum of the Geological Society : p. 339.

The footsteps were formed by an animal which was probably allied to the Batrachians. The toes appear to have been destitute of claws, and the larger or posterior foot exhibits faint traces of having been webbed. In these respects and in their general form they have some resemblance to the feet of frogs, but differ from them in having the outer toe of both the hind and fore feet longest, while in frogs the second toe is the longest. It is moreover evident, that this animal possessed a tail, which dragging in the soft sand, has caused a groove, about  $\frac{5}{8}$  of an inch wide, intermediate between the alternate footsteps. This groove meanders slightly from side to side, approaching each pair of footsteps alternately.

The impressions of the feet are repeated twelve times, at equal intervals of about  $9\frac{1}{4}$  inches. To this, however, there are two exceptions,—the distance from *a* to *b* in *fig. 1.* being only 6 inches, and from *c* to *d* 7 inches. We may conjecture that the animal stopped for a time at this point, and then proceeded, an opinion which is confirmed by the semicircular ridge of sand marked *e*, which may have been formed by the under side of the animal, or by the impulse necessary for the resumption of his motion. Several smaller impressions of similar footsteps may be detected on the surface of the slab ; four of them marked *f, g, h, i*, are in regular alternate succession ; the others, marked *k*, are in no regular order, the impressions corresponding to them being too faint to be detected.

A considerable resemblance exists between these impressions and some which have since been discovered (in company with those of the Cheirotherium) in the Bunter Sandstein at Storeton Hill, near Liverpool ; also at Grinshill near Shrewsbury, specimens of which latter are in the Museum of that town.

*Fig. 2.* A pair of footsteps of the natural size marked with a star on *fig. 1.*

*Fig. 3.* An Ichthyodorulite of *Hybodus Keuperi* (Murch. and Strick.) from Burgehill, now in the Museum of the Geological Society.

This Ichthyodorulite was nearly perfect when the description at p. 338 was written, but having been since unfortunately injured, we are able to show only the fibrous structure of the interior in *fig. 3*, the external costæ on the lower side

## EXPLANATION OF THE PLATES AND WOOD-CUTS.

being concealed by the matrix. The costæ are however seen on the fragment fig. 3*a*. natural size, and the fibrous internal structure is shown, magnified twice, at fig. 3*b*. p. 338.

*Fig. 3\**. A small tooth, probably of a species of *Hybodus*, from Shrewley Common, natural size and magnified twice. In the Museum of the Geological Society.

*Fig. 4.* A fragment of sandstone with casts of *Posidonomya minuta*, Bronn, from Shrewley Common. In the Museum of the Geological Society: p. 338.

### *Fossils from the Bunter Sandstein.*

*Fig. 5.* Maxillary bone of a fish in the Warwick Museum, from a quarry 1 mile N.W. of Coventry. The left-hand end of the figure seems to be the anterior extremity. The bone, which is here thickened and rounded, gradually becomes thin and flat towards the other end. Much of the thinner portion is wanting, but the impression of the lower surface remains in the sandstone, as shown by the dark shade in the figure. The specimen seems to have been considerably worn, and to have lost several of the teeth, before it became imbedded in the sandstone.

*Fig. 6.* Tooth of *Megalosaurus*? (*a*) natural size, (*b*) magnified twice. From Coton End near Warwick: p. 344.

*Fig. 7.* A smaller tooth of the same animal from Coton End. Warwick Museum: p. 344.

*Fig. 7a.* A small tooth from Leamington. Museum of the Geological Society.

*Fig. 8.* Tooth of a Saurian? from Coton End. Warwick Museum: p. 344.

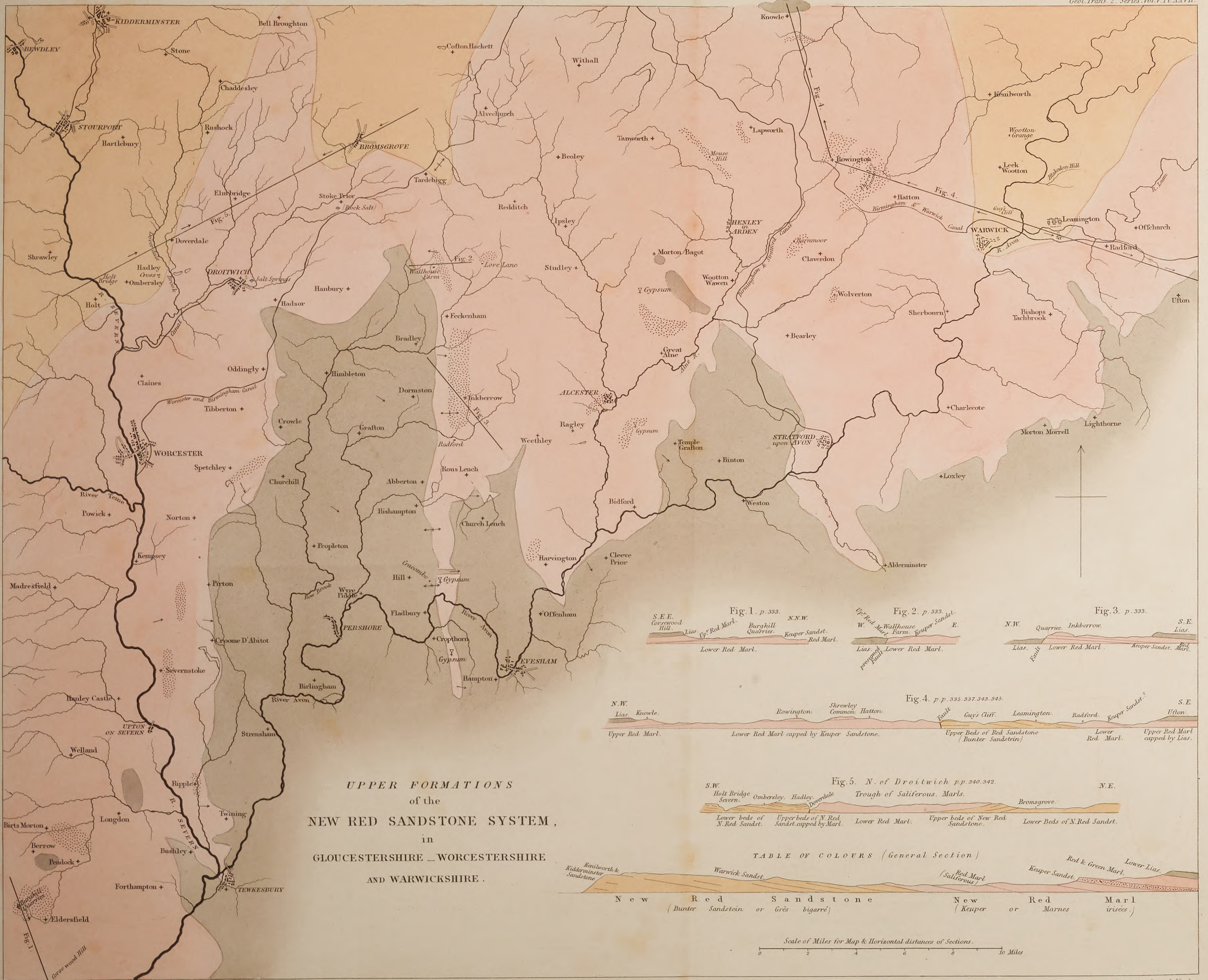
*Fig. 9.* A smooth curved tooth, flattened on one side, from Leamington. Warwick Museum.

*Fig. 10.* A vertebra from Coton End. Warwick Museum: p. 344.

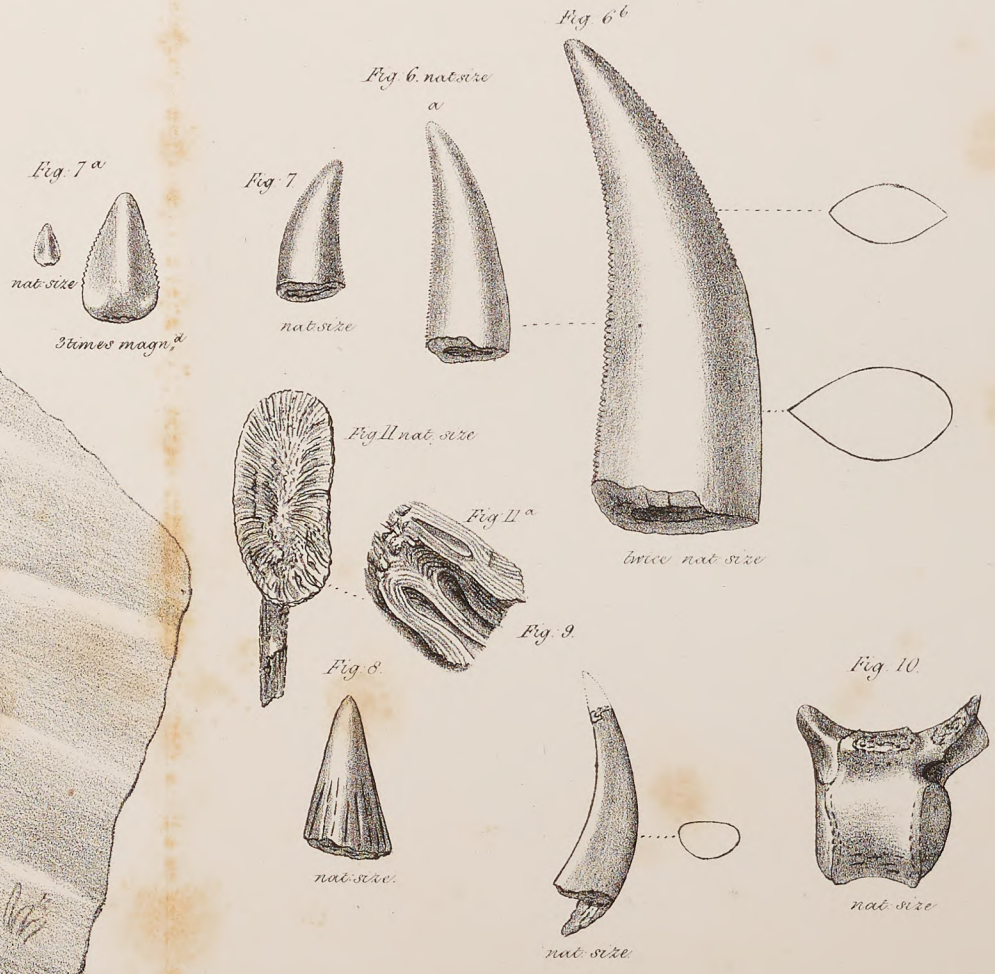
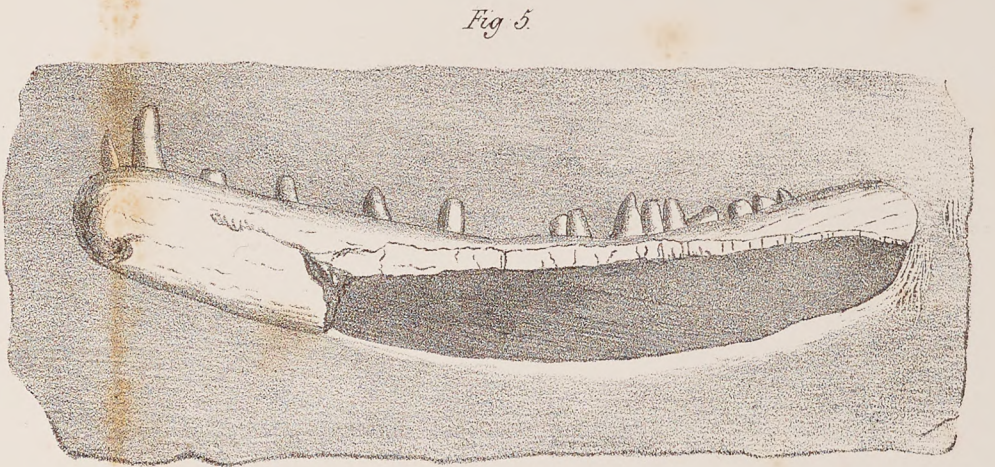
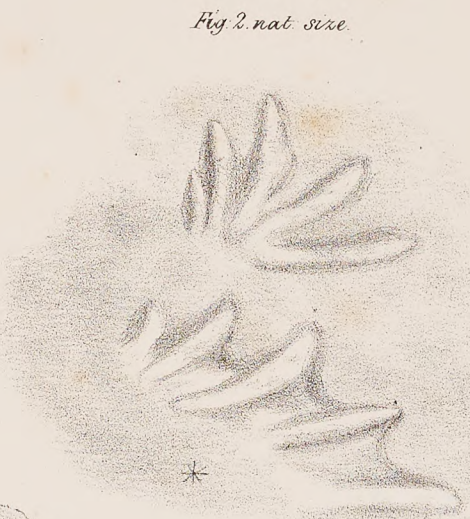
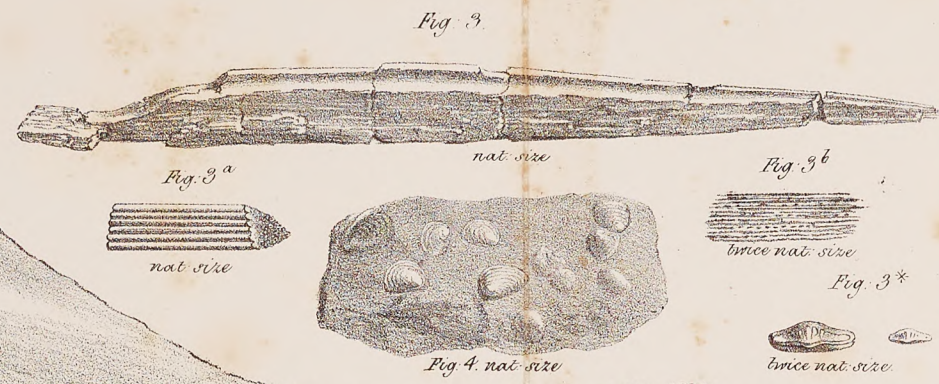
*Fig. 11.* *Echinostachys oblongus* from Hadley near Ombersley, Museum of the Geological Society: p. 340.

WOOD-CUT: p. 348.

Fragment of sandstone from Berkswell.



Engraved by J. Gardner, Regent St. London.



H. Schuchert del. G. Scharf lithog.

Fossils of the Keuper Sandstone p. 328

Fig 1. Slab of Sandstone with ripple marks and impressions of footsteps. Fig 2. The footsteps. Fig 3. Ichthyodermite of *Hybodus Keuperi*. Fig 3 a. Fragment of the ribbed surface. Fig 3 b. Portion of interior. Fig 3\*. Tooth of an *Hybodus*. Fig 4. *Pesidonomya minuta*.

Fossils of the Bunter Sandstone. p. 340 a seq.

Fig 5. Portion of the lower jaw of a Fish. Fig 6-7. Teeth of *Megalosaurus*. Fig 7 a. A Tooth from Leanington. Fig 8. Tooth of a Saurian? Fig 9. A tooth found at Leanington. Fig 10. Vertebra of a Saurian. Fig 11. *Echinostachys oblongus* p. 340.