Warwickshire, and at Shepton-Mallet in Somersetshire, an *Isastrœa* occurs. Dr. Wright states that *Isastrœa Murchisoni* has been met with in the next lowest bed of the Lower Lias, namely the White Lias, with *Ammonites Planorbis* at Street in Somerset; and another Coral has been found in the same zone at Whitnash and Itchington in Warwickshire. Lastly, in the "Guinea-bed" or "Guineas" at Binton in Warwickshire another Coral has been met with.

The *Montlivaltie* of the Hippopodium-bed and the *Isastrœa* of the Lima-beds appear to have grown over much larger areas in the Liassic sea than the other Corals here referred to.

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2. *On the SECTIONS of the MALVERN and LEDBURY TUNNELS (WORCESTER and HEREFORD RAILWAY), and the intervening Line of Railroad.* By the Rev. W. S. SYMONDS, F.G.S., and ALAN LAMBERT, Esq. *With a Note on the FOSSILS*; by J. W. SALTER, Esq., F.G.S., of the Geological Survey of Great Britain.

In a paper published in the Edinburgh New Philosophical Journal for April 1857 (p. 257), I described briefly the "Correlation of the Triassic Rocks in the Vale of Worcester and at the Malvern Tunnel." These rocks have the following order on the flanks of the Malverns:—

1. Upper Keuper Marls.
2. Upper Keuper Sandstone.
3. Lower Red or Keuper Marls.
4. Lower Keuper Sandstones (Waterstones).
5. Upper Red Sandstone (Bromesberrow beds).
6. Lower Red Sandstone (Stourport beds).

No. 6. The lowest of these deposits is a dark-red sandstone with black patches, and closely resembles the "Lower Red Sandstone" of the geological surveyors in mineralogical character. It is to be seen at the back of the stables of the Belle Vue Hotel at Great Malvern, dipping from the hill, to the south-east, at an angle of 60°.

A large erratic block, angular and with no sign of subaqueous action, was found imbedded in this dark-red sandstone. This erratic block is different to any rock now exposed in the Malvern district, and appears to me to belong to the Cambrian grits of North Wales, or possibly to that of the Longmynd. It may be seen in the Museum of the Malvern Field-Club at the Messrs. Burrow's, Great Malvern.

No. 5. This Upper Red Sandstone (Bromesberrow beds) may be studied with advantage at the village of Bromesberrow, where it overlies the Haffield or Permian breccia of Prof. Ramsay and the Geological Survey Map, and is covered by the Waterstones of the Newent district.

- No. 4. Lower Keuper Sandstones (Waterstones).

A patch of these sandstones flanks the Chase End Hill of the Southern Malverns, and ranges from a wood at the back of the Hawthorns, in the parish of Berrow, towards Bromesberrow Place,

the seat of Mr. Osman Ricardo, M.P. for Worcester. Again they may be seen covering the Bromesberrow sandstones near the Glynn Brook, and ranging south towards Red Marley D'Abitot, where they are faulted against the Lower Keuper Marls, which should surmount them.

No. 3. Lower Red Marls.

These soft marly beds are well exposed in the lateral valleys in the Malvern district. These are valleys of denudation, and in most instances occur where anticlinals of Keuper Sandstone have been broken and the apices or ridges of the anticlinals removed.

No. 2. Upper Keuper Sandstones.

These fossiliferous sandstones have been generally denuded along the Malvern Vale. Wherever I have studied them, they are mere relics of a series of low anticlinals.

No. 1. Upper Grey and Red Marls.

These rocks are the uppermost Triassic deposits, and at the Berrow Hill, within two miles of the Chase end of the Malvern ridge, pass upwards conformably into the Lower Lias, with the characteristic fossils.

I now refer to the section of the tunnel at Malvern Wells, on the Worcester and Hereford Railway, prepared by Mr. Alan Lambert and myself, and for the admeasurements of which I am indebted to Mr. Lambert, one of the engineers upon the line, who has assisted me throughout this somewhat arduous undertaking with the utmost courtesy and good will. Mr. Lambert has prepared a section (reduced in fig. 1) of the line of railway, from the entrance of the Malvern tunnel to the exit of the Ledbury tunnel on the Hereford line, for the Geological Society of London, at the request of Mr. Liddell, the chief engineer of the railroad.

The entrance of the tunnel (see Section, fig. 1, and the Explanation) commences with the Upper Keuper Marls (10 m. 330 yds.), overlain by a considerable thickness of subangular drift, which has furnished the bones and teeth of *Bos primigenius*, of *Elephas primigenius*, and of *Rhinoceros tichorhinus*. The site where these mammalian relics were discovered is near the Station at Malvern Wells. Some of these fossils are in my possession, and some are at Worcester Museum. The Upper Keuper Marls at the tunnel's mouth have been much denuded. In the tunnel they pass into the Keuper Sandstones and Marls with the *Estheria* and fragments of teeth and spines of *Lophodus* (formerly *Acrodus*).

These deposits are much broken and contorted, and pass into a series of red marls, which, I do not doubt, are the representatives of the Lower Keuper Marls (10 m. 550 yds. to 704 yds.).

The Lower Keuper Marls dip away from a syenitic and brecciated rock, against which they rest conformably at an angle of 50°.

It is worthy of observation that the Lower Keuper Sandstones (Waterstones) and the Red Sandstones of Bromesberrow are *entirely wanting* in the tunnel. I was puzzled, at first, whether or not to rank the brecciated syenite as an equivalent of the Haffield Permian breccia, as there is evidence of stratification. The stratifi-

Fig. 1.—Section on the Worcester and Hereford Railway, beginning at 10 miles 380 yards from Worcester, and ending at 15 miles 1463 yards: including the Malvern and Lodbury Tunnels.

Explanation of the Geological Section on the Worcester and Hereford Railroad, from 10 miles 330 yards from Worcester to 15 miles 1463 yards.—See Fig. 1.

	Miles.	yds.	
At	10	330.	Keuper Marls, red with grey bands.
	"	550.	Tunnel commences.
From	"	550.	to 10 m. 704 yds. Keuper marls and sandstone, twisted and broken; sometimes nearly horizontal, and sometimes with a dip of 50°.
At	"	704.	Syenitic breccia and thin band of black schist: dipping at an angle of 58° towards the hill.
	"	711.	Syenite.
	"	792.	Thin band of chlorite, with black schist in contact.
	"	836.	Chlorite, with syenite caught up.
	"	858.	Syenite.
	"	909.	Greenstone.
	"	925.	Syenite.
	"	946.	Greenstone.
	"	1012.	Black hornblendic rock, with highly crystallized felspar, with overlying greenstone.
	"	1037.	Syenite.
	"	1159.	Two thin bands of Llandovery limestone, about 6 in. thick, with 2 ft. of marl.
	"	1160.	Syenite.
	"	1254.	Llandovery shales and limestone in thin bands, pressed against syenite; syenite overhanging.
	"	1320.	Woolhope shales.
	"	1436.	Woolhope limestone.
	"	1449.	Wenlock shales and thin bands of sandstone.
At about	11	260.	Wenlock limestone (thickness uncertain).
Up to	"	440.	Lower Ludlow shales.
At	"	440.	Old Red marls, with thin bands of grey and red sandstones.
From	"	1012	to about 13 m. Local drift and red marls.
At about	13	0.	Ludlow rock.
	"	44.	Old Red, lying unconformably against Ludlow rock.
From	"	44	to 14 m. 352 yds. Local drift and red marls.
At	14	352.	Upper Ludlow rock.
	"	880.	Old Red marls.
	"	1144.	Upper Ludlow rock.
	"	1298.	Aymestry rock.
	"	1342.	Lower Ludlow rock.
	"	1430.	Local drift, 40 ft. thick, overlying drift derived from Old Red Marl: Lower Ludlow rock beneath.
	"	1518.	Upper Ludlow rock.
	"	1600.	Aymestry rock.
From	"	1600	to 15 m. 406 yds. Ludlow and Wenlock shales.
At	15	406.	Wenlock limestone, horizontal.
	"	572.	Lower Ludlow rock, angle 12°, north, passing at about 886 yards to 75°, south.
	"	957.	Aymestry rock, angle 75°, south.
	"	1029.	Upper Ludlow shales, angle 75°.
	"	1087.	Downton sandstone, angle 75°.
	"	1091.	Passage-beds into the Old Red Sandstone, angle 75°; thin bands of grey and red sandstones.
	"	1186.	Tunnel's mouth.
	"	1463.	Section ends.

cation, however, is but partial, and I am inclined to look upon the brecciated rock as a portion of an ancient beach or talus derived from the syenitic ridge. We observed a thin band of black hornblendic schist in contact with the syenitic breccia; and both these rocks have undergone so much derangement as to dip at an angle of 58° into the hill.

On reference to the section, we find a mass of syenite (at 10 m. 711 yds.) constituting the *external walls* of a nucleus which forms the centre of the Malvern range, and which nucleus is of great interest to the geologist and mineralogist. The thickness of the syenitic crust on the *eastern* side of the Malverns is 125 yards. It is much broken, and will require bricking and roofing in the tunnel.

Traversing the syenite, we found a bed of chloritic rock (at 10 m. 792 yds.) with a vein of shining, coal-black, graphite-looking schist in contact, see fig. 2. Another wall of syenite is succeeded by a

Fig. 2.—Section in the Malvern Tunnel, showing veins of Quartz and Graphite in the band of Chlorite in the Syenite, at 10 m. 792 yds. By Capt. Selwyn.

Fig. 3.—Section in the Malvern Tunnel, showing veins of Felspar in the Greenstone overlying black hornblendic or dioritic rock, at 10 m. 1012 yards. By Capt. Selwyn.

vein of chlorite with highly crystallized bands of syenite. Here the syenite again sets in in a solid mass, and we pass onwards to a mass of greenstone (10 m. 909 yds.) of the hardest material, and 160 yards thick. The greenstone appeared to me to have been injected when fluid into a fissure in the syenite, the syenite being fissured in a line with the range of the Malverns. It is worthy of remark that the syenitic rock is much crystallized where it is in contact with greenstone.

Leaving this mass of greenstone, we find a remarkable black and greenish rock (hornblendic), containing many veins of red felspar. It has greenstone on both sides. This great amount of change in mineral structure in so narrow a compass could hardly have been imagined, had not the interior of the Malverns been laid open to our investigation. See fig. 3.

We pass next into a strong rock of syenite (10 m. 1037 yds.), 147 yards in thickness, and which we may consider as the external

western crust of the Malvern plutonic range. We were astonished to find, almost in the centre of this solid syenite (for the syenite on the western side is not nearly so much shattered as that on the eastern flank), two thin bands of Llandovery limestone, with strata of marly shales 2 feet thick lying in a *fissure* of the syenite. Fig. 4.

Fig. 4.—Section in the Malvern Tunnel, showing a seam of Llandovery rock in the Syenite, at 10 m. 1254 yds. By Capt. Selwyn.

Fig. 5.—Section in the Malvern Tunnel, showing the Junction of the Silurian rock and the Syenite, at 10 m. 1254 yds. By Capt. Selwyn.

This Llandovery limestone (formerly "Caradoc" of Murchison) contains some characteristic fossils; and the shales have furnished a *Pentamerus*. Neither the limestone nor shales are in the slightest degree metamorphosed. The fissure runs from north to south, and becomes smaller towards the south. These sedimentary deposits were evidently deposited in a fissure in the syenite during that far distant epoch when the waves of the Upper Llandovery seas washed above the syenitic ridge of the Malverns, and when this interesting and instructive range of hills was a low submarine ridge, of plutonic origin, and of which the *syenitic crust* was, even in the Upper Llandovery epoch, as much cooled, consolidated, and mineralized as at present.

I mentioned that the Lower Keuper sandstones, the Bromesberrow sandstones, and the Haffield Permian breccia (?), which are all to be seen at the southern extremity of the Malverns, are wanting in the tunnel on the eastern or Worcester side of the Malverns. It is somewhat remarkable, also, to find that the Cambrian (Holly-Bush) sandstones and *Lingula*-flags (black shales) of the Chase End, Ragged Stone, and Midsummer Hills (South Malverns) should be altogether absent on the western flank of the hills of the Wells. The syenite passed, we find limestones and shales, of the Upper Llandovery epoch, full of fossils, resting perpendicularly against the external wall of syenite. Fig. 5. We have evidences of great pressure and crushing, but not a symptom of *metamorphism*; and I exhibit a portion of shale, containing the *Pentamerus levis*, which was obtained by Captain Peyton close to the line of junction. The Rev. Reginald Hill, of Bromesberrow, Hon. Secretary to the Malvern Field-Club, was the first to disinter these fossils of the Llandovery

rock from their long resting-place; and to him, to Captain Peyton, of the Bartons, Ledbury, and to Captain Selwyn, I would express my kind acknowledgments for their assistance in unravelling the secrets of the Malvern tunnel.

It is difficult to ascertain the thickness of the Upper Llandovery rocks here (10 m. 1254 yds.), or to determine any line between them and the overlying shales; they are conformable, and pass one into the other without any perceptible change, excepting in their colour, as, from a purplish grey, they change into a blue mass of shales with thin bands of limestone and grey and brown sandstones. I have thought it necessary, however, to draw a distinction between the Llandovery rocks which rest against the syenite and contain purplish shales with *Pentameri*, and the shales that underlie the Woolhope limestone, because at a certain point I found the *Pentamerus*-shales were overlain by a sandstone also containing Llandovery fossils, but which is the rock formerly known as the "Caradoc sandstone of the Malverns," underlying the Eastnor Obelisk and cropping out along Howler's Heath. At this point of the section, therefore, I have drawn a somewhat arbitrary line, and have designated the shales above this sandstone as Woolhope shales (10 m. 1320 yds.). Dr. Grindrod, of Malvern, has a fine collection of fossils from these Woolhope shales, and also some splendid slabs with *Pentameri* from the Llandovery shales.

The Woolhope limestone (10 m. 1436 yds.) is quarried in the tunnel within a short distance of the shaft No. 2; and we then pass on into the well-known Wenlock shales (10 m. 1449 yds.). The distance from the Woolhope limestone to the point where the Llandovery rocks rest against the syenitic ridge is nearly 200 yards; and it is therefore evident that the sedimentary rocks were deposited at this particular point of the Malverns in a little bay, or coomb, in the syenite. This peculiarity was pointed out to me several years since by my late friend Mr. Hugh Strickland.

From shaft No. 2 to the mouth of the tunnel on the Ledbury or western side of the Malverns, the railroad passes through Wenlock shales, and strikes the Wenlock limestone (11 m. 260 yds.) at the distance of about 260 yards from shaft No. 2. Here we have evidences of a considerable fault: near the tunnel-mouth (11 m. 352 yds.) the Wenlock limestone is thrown down horizontally, the greater part of the Lower Ludlow rock is wanting, the whole of the Aymestry limestone and the Upper Ludlow shales are deficient, and some sandstones and marls of the Old Red series (and these certainly not the lowest Old Red deposits) are faulted against a regular "scrunch" (to use a miners' phrase) of the Lower Ludlow clays. The Malvern greenstone was not so difficult to work (as I have been assured by Mr. Ballard, the contractor) as this "jammed and scrunched clay" (11 m. 440 yds.).

From hence the railroad passes, for a considerable distance, over red clays and marls covered with local drift; and there is nothing worthy of attention until we reach the road that leads from Colwall to Ledbury. In the lane ascending towards The Bartons, the seat

of Mrs. Peyton, we see the Upper Ludlow shales dipping towards the vale in which the railroad runs. At the base of the hill is a bridge constructed for railroad-purposes, and at this spot the workmen quarried the Auchenaspis-grits of the Lower Old Red Sandstone, placed, at an angle of seventy degrees, on the clays of the Upper Ludlow, and reversed*. On reference to the Ledbury section, it will be seen that there is a great thickness of rock between the Auchenaspis-grits and the Upper Ludlow shales.

For some distance the railroad cuts through local drift, until, a short distance after crossing the highroad from Worcester to Ledbury, we pass through a section of Upper Ludlow rock, with abundance of characteristic fossils (13 m. 352 yds.).

We have next a small basin in which, besides the local Silurian drift, there is a mass of red and grey clays, evidently derived from the denudation of the Old Red Sandstone (13 m. 880 yds.).

The railroad again strikes the Upper Ludlow shales, rising from a short synclinal, and passes through a section of the Aymestry limestone and a portion of the Lower Ludlow shales, which are overlain, near the eastern entrance to the Ledbury tunnel, by a considerable thickness of red and grey stratified drift derived from Silurian and Old Red deposits (from 13 m. 1144 yds. to 1518 yds.).

This drift appears to me to be one of the most important points with which we have to deal. Bones of *Mammalia* have been detected therein, and amongst them the tooth of *Rhinoceros tichorhinus*. This evidence surely tends to prove that the Old Red Sandstone covered the Upper Silurians of the Ledbury vales as late as the Pleistocene epoch, and that it was removed by the action of Pleistocene waters, which denuded the Old Red Sandstone, and redeposited its débris with the relics of animals that lived on the land.

The tunnel proceeds through the Lower Ludlow shales at 13 m. 1430 yds., and then a fault occurs. The Upper Ludlow shales, with the Aymestry rock, are quarried near Shaft No. 1 of the Ledbury tunnel. The accompanying Section, fig. 6, furnished by Mr. A. Lambert, supplies us with the details of the fault as seen in the tunnel.

Fig. 6.—Section in Ledbury Tunnel, showing the Fault, at 13 m. 1518 yds. By A. Lambert, Esq.

* I have to thank my friend Captain Peyton for directing my attention to this interesting fault.

We descended Shaft No. 2, and examined the tunnel right and left. Shaft No. 2 is in the Wenlock shales; these are seen to pass into the Wenlock limestone (14 m. 406 yds.), which is thrown down, and is horizontal. A glance at the section will explain the extraordinary faulting of the rocks between Shaft No. 2 and the Lower Ludlow rock and the point on the section where the strata incline at an angle of 75° , which dip continues to the western exit of the tunnel, throughout the Lower Ludlow shales, Aymestry rock, Upper Ludlow shales, Downton sandstone, red and mottled marls, grey shales and grits, and purple shales and sandstones, the tunnel ending at the point where the red and grey *Auchenaspis*-beds pass conformably into the underlying strata*.

The following is the ascending order of the beds observed in the section from 14 m. 957 yds. to 1463 yds.:—1. Aymestry rock with *Pentamerus Knightii*, &c. (10 feet). 2. Upper Ludlow rock with *Chonetes lata*, &c. (140 feet). The Ludlow bone-bed seems to be wanting here. 3. Downton bed, thin (9 feet), with *Lingula*. 4 to 8. Red and mottled marls and thin sandstone (210 feet), with *Lingula* and *Pteraspis*. 9. Grey shale and thin grit (8 feet), with *Cephalaspis* and *Pterygotus*. 10 and 11. Purple shales and thin sandstones (34 feet). 12. Grey marl passing into red and grey marl and bluish-grey rock (20 feet), with *Auchenaspis*, *Plectrodus*, *Cephalaspis*, *Onchus*, *Pterygotus Ludensis*, *Lingula*, and a *Lituite* (?). These pass upwards conformably into a series of red marls, with yellowish grey and pink sandstone containing *Pteraspis* and *Cephalaspis*, and undoubtedly forming the base of the Cornstone-series of the Old Red Sandstone.

With the exception of colour, there is no possible means of drawing any line of demarcation here between the Upper Silurian deposits and the lowest rocks of the Old Red Sandstone. Fossils diminish in number in the Old Red, it is true; but it is evident that this is either owing to the change that occurred in the physical conditions of the sea, or because the chemical condition of the deposits was unfavourable to their preservation. As it is, we have a *Lingula* common to the Downton beds and the Lower Old Red; while *Cephalaspis* fishes, beginning in the Silurian (Lower Ludlow), continue upwards into the Old Red.

The section from Malvern to Ledbury is most instructive and most gratifying; for we, who have followed in the wake of Murchison, Strickland, Phillips, and the father of Malvern geology, the present President of the Geological Society (Mr. Leonard Horner), have learned upon how firm and scientific a basis the investigations of these philosophers were founded, and how little we have been enabled to add to the superstructure by later researches.

* See the author's paper on the Ledbury Tunnel, *Quart. Journ. Geol. Soc.* vol. xvi. p. 193.