III.—THE NEW RED (PERMIAN) GRAVELS OF THE TIVERTON DISTRICT.

By EDGAR C. MARTIN, B.Sc., A.I.C.

INTRODUCTION.

AMONGST the Lower New Red deposits of the Tiverton area are loose rubbly aggregations of angular and subangular fragments of grit and sandstone of all sizes in a loose earthy or sandy matrix.¹ These deposits, which seem best described by the term gravel, rest unconformably on the grits and shales of the Culm-measures, from which they appear to have been largely derived. In the deeper areas of deposit, further from the Culm margin, they pass into finer breccias and sand.² These gravels were formerly regarded as superficial deposits, and it has been suggested that they may be Boulder-clays.³ Detailed mapping, however, proved their distinct connection with the Lower New Red Sandstones and breccias, and they have been found in places, as at Washfield and Silvertown, underlying the trap, which corresponds to the German Permian Melaphyre (Middle Sötern); hence they are now regarded as deposits of Permian age.

About forty years ago Mr. J. T. Underhill found amongst the fragments in the Exeter Hill gravel-pit, Tiverton, some with an assemblage of Upper Devonian fossils. These were placed in the Exeter Museum, where, some time later, they attracted the attention of the Rev. W. Downes. On the occasion of the construction of the Exe Valley Railway he examined the cuttings between Tiverton and Bolham and noticed fragments of grit with *Spirifer Verneuli*, Murch., *Stropholonia productoides*, Murch., sp., and other Pilton fossils.⁴ These fragments were associated with pieces of trap, and having regard to the proximity of the Washfield trap, Downes was led to the conclusion that the Devonian fragments were ejected during the volcanic outbursts.

The present investigation was undertaken at the suggestion of Mr. Underhill with the object of examining the whole area where the gravels occur in order to find how far Devonian fragments could be traced, and in the hope of throwing light on the source from which these fragments have been derived.

In the following account the area has been divided into districts, in order that the places mentioned may be more easily found on the map.

1. District north-west of Tiverton.
2. District north-east of Tiverton.
3. Butterleigh District.
4. Silvertown and Bradninch District.
5. Thorverton District.

The first three districts are included in Sheet 310 of the Ordnance Survey (1 inch scale), and the last two districts in Sheet 325 of the Geological Survey.

¹ Quart. Journ. Geol. Soc., 1876, pp. 387–389.

² Memoirs of the Geol. Survey, Exeter District, 1902, pp. 29, 33.

³ GEOL. MAG., 1872, p. 574: "Boulder-clay in Devonshire."

⁴ Rev. W. Downes, B.A., F.G.S., "On the occurrence of Upper Devonian Fossils in the component fragments of the Trias near Tiverton": Transactions of the Devonshire Association, 1881.

MAP OF THE TIVERTON DISTRICT.

Places where Upper Devonian fragments have been found in the New Red Gravels are marked thus $\oplus$. Scale, 4 miles to an inch.

1. DISTRICT NORTH-WEST OF TIVERTON.

The valley between Washfield and Calverleigh is filled with the gravels as far west as Holmead. Two outlying patches of gravel occur north-west of Stoodleigh.

In a section about a quarter of a mile north-west of Washfield Church, on the Stoodleigh Road, the gravels are seen underlying the trap. Fragments of soft red sandstone containing crinoid joints, *Spirifer Verneuli*, Murch., and *Rhynchonella Partridgei*, Whidborne,¹ were found about three feet below the trap. Fossiliferous fragments were also detected in the gravel-pits on Hensleigh Hill and behind the Roman Catholic Chapel, Tiverton, and in the road section at Leigh Barton, near Loxbear.

In a small gravel-pit on the Templeton Road, three-quarters of a mile west of Calverleigh, at an elevation of 800 feet, the following fossils were found in pieces of dark red sandstone and grit:—

<i>Phacops latifrons</i> , Bronn (two heads and one tail).	<i>Orthis interlineata</i> , Sow.
<i>Spirifer Verneuli</i> , Murch.	<i>Tentaculites conicus</i> , F. A. Römer.
<i>Rhynchonella Partridgei</i> , Whidb.	<i>Strophalosia productoides</i> , Murch., sp.
	Crinoid joints.

The gravels are well exposed at Washfield Weir, by the Exe, and contain fossiliferous fragments. In the pebble bed in the Exe below the weir (the pebbles composing which seem to have been washed out of the cliff or gravel above the weir) fragments of hard grit with the following fossils were found:—

<i>Spirifer Verneuli</i> , Murch.	<i>Orthis interlineata</i> , Sow.
<i>S. Urii</i> , Fleming.	? <i>Ctenodonta lirata</i> , Phil., sp.
<i>Productus prælongus</i> , Sow.	? <i>Sanguinolites minus</i> , Whidb.
<i>Rhynchonella Partridgei</i> , Whidb.	<i>Adelocrinus hystrix</i> , Phil.

The Stoodleigh Outliers.

Two outliers of the New Red gravels occur in Stoodleigh parish. The first caps the hill north of Stoodleigh village, and can be examined in a large gravel-pit about half a mile north-west of Stoodleigh Church, 936 feet above sea-level. The deposit in this pit is very coarse, and no fossiliferous pieces were detected there. The second outlier covers a much larger area in the north-west part of Stoodleigh parish. It is interesting as being the last as well as the highest patch of the gravels in this direction. It can be examined in a gravel-pit at Stoodleigh Beacon, 980 feet above sea-level. Fragments of yellowish-red grit found in this pit contained *Spirifer Verneuli*, Murch., *Fenestella plebeia*, McCoy, *Loxonema* (?) sp., and Crinoids.

In the lane east of Stoodleigh Beacon trap occurs, and a fragment containing *Naticopsis Hallii*, Whidb., was found.

¹ Phillips, in his "Palæozoic Fossils of Devon, Cornwall, and West Somerset," refers this very common '*Rhynchonella*' to his Carboniferous species *Rhynchonella pleurodon*. Whidborne ("Devonian Fauna of the South of England," vol. iii) thinks that the Devonian species is specifically distinct, and has named it *Rhynchonella (Camarotochia) Partridgei*, Whidb.

In the lane section west of Warbightsleigh Barton pieces of soft reddish micaceous sandstone were found with *Rhynchonella Partridgei*, Whidb., *Fenestella plebeia*, M'Coy, and Crinoids. This section is very close to the outcrop of the Culm-measures, which are quarried in a field to the north. The deposit at Warbightsleigh is much finer and more consolidated than that occurring at Stoodleigh Beacon.

2. DISTRICT NORTH-EAST OF TIVERTON.

In the gravel-pit at Bolham about 30 feet of a very coarse earthy gravel are exposed. Pieces of dark red 'rotten' sandstone containing *Orthis interlineata*, Sow., and other fossils are common.

At Uplowman the gravels are exposed in a road section north of the Church. A piece of soft red sandstone found here contained *Aviculopecten transversus*, Sow., sp. Another piece was crowded with small Gasteropods and other fossils, including the following species:—

<i>Euomphalus vermis</i> , Whidb.	<i>Aviculopecten nezilis</i> , Sow., sp.
<i>Bellerophon subglobatus</i> , M'Coy.	? <i>Spiriferina cristata</i> , var. <i>octoplicata</i> , Sow.
? <i>Macrochilina</i> sp.	<i>Spirifer Urii</i> , Flem.
<i>Tentaculites tentaculare</i> , Phil., sp.	Crinoid stems.

Similar fragments with the same species were found at Coombe, near Uplowman, and at Pit, north-east of Sampford Peverell.

Three Gates Outlier.

A large outlying patch of gravel caps the hill between Huntsham and Cove. It can be examined in three gravel-pits on the Upper Tiverton—Bampton Road, north of Landrake. In two of these pits fossiliferous fragments were found. In the most northerly pit a piece of crinoidal sandstone measuring $6 \times 2\frac{1}{2} \times 3\frac{1}{4}$ inches was noticed.

Further east the gravels are exposed in a pit by Three Gates Farm. In this pit fossiliferous pieces of grit and sandstone are abundant, and contain the following species:—

<i>Phacops latifrons</i> , Bronn.	<i>Spirifer Verneuili</i> , Murch.
<i>Fenestella plebeia</i> , M'Coy.	<i>S. Urii</i> , Flem.
<i>Penniretipora bipinnata</i> , Phil., sp.	<i>Rhynchonella Partridgei</i> , Whidb.
<i>Seminula oblonga</i> , Sow., sp.	Crinoid stems.

Chimney Down Outlier.

This is the last patch of gravel to the north-east, and the fossiliferous fragments are much more plentiful here than elsewhere. This fact is significant, since Chimney Down is only about two miles distant from the outcrop of the Pilton Beds, where the same species of fossils can be found *in situ*.

The gravel-pit on Chimney Down, 878 feet above sea-level, exhibits a very coarse unstratified gravel composed of angular and subangular fragments of grit and sandstone of all sizes up to over two feet in length in a red earthy matrix. The surfaces of the pebbles are very often smooth and somewhat polished. One large fragment of grit ($23 \times 18 \times 15$ inches) contained a fossiliferous layer two inches thick.

Pieces of soft red sandstone, crowded with fossils, are very common. A single piece, about two feet long, yielded the following species:—

<i>Phacops latifrons</i> , Bronn (at least twenty heads, but only one tail).	<i>Spirifer Urii</i> , Flem.
<i>Bellerophon subglobatus</i> , M'Coy (very common).	<i>Rhynchonella Partridgei</i> , Whidb. (very common).
<i>Euomphalus vermis</i> , Whidb. (very common).	<i>Productus prælongus</i> , Sow. (very common).
<i>Pleuronomaria aspera</i> , Sow.	<i>Strophalosia productoides</i> , Murch., sp.
<i>Tentaculites tentaculare</i> , Phil., sp.	<i>Seminula oblonga</i> , Sow., sp.
? <i>Macrochilina turbineæ</i> , Whidb.	<i>Athyris (Cleiothyris) Royssii</i> , Leveillé.
? <i>Naticopsis Hallii</i> , Whidb.	<i>Orthoceras Barumense</i> , Whidb.
? <i>Murchisonia</i> sp.	<i>Aviculopecten transversus</i> , Sow., sp.
<i>Spirifer Verneuli</i> , Murch. (very common).	Several undetermined Lamellibranchs.
	Crinoid joints.

Another piece of sandstone was crowded with casts of *Cucullæa* similar to those occurring in the Marwood Beds of North Devon.

Spalsbury Outlier.

A small patch of gravel between Chimney Down and Uplozman is exposed in a gravel-pit near Spalsbury. Crinoidal fragments of grit were found here.

3. BUTTERLEIGH DISTRICT.

This includes the district south-east of Tiverton embraced in the Ordnance Survey one-inch map, Sheet 310.

The Exeter Hill gravel-pit, near Tiverton, is mentioned in a letter by H. B. Woodward, F.G.S., to the GEOL. MAG. (1872, p. 574), calling attention to the resemblance between the New Red deposit exposed there and the Boulder-clays. Here, as elsewhere, fragments with Upper Devonian fossils occur. One piece of grit contained numerous casts of the small Gasteropod *Bellerophon subglobatus*, M'Coy. Another contained a Lamellibranch similar to *Pleuronectites Piltonensis*, Whidb.

Similar gravel-pits occur at Road Farm and south of Butterleigh, and in both fossiliferous fragments have been detected. They have also been found in the road sections near Ford, and on the Tiverton road $1\frac{1}{2}$ miles north-west of Cullompton. On the common above Trinity a piece of grit with *Strophalosia productoides*, Murch., sp., was found.

Between Tiverton and Butterleigh the fragments of grit are gathered off the fields and used for road-mending. In these fragments the following species have been found:—

<i>Phacops latifrons</i> , Bronn.	<i>Strophalosia productoides</i> , Murch., sp.
<i>Spirifer Verneuli</i> , Murch.	<i>Finestella plebeia</i> , M'Coy.
<i>S. Urii</i> , Flem.	? <i>Fistulipora</i> sp.
<i>Orthis interlineata</i> , Sow.	? <i>Ctenodonta lirata</i> , Phil., sp.
<i>Rhynchonella Partridgei</i> , Whidb.	Crinoid joints.

4. SILVERTON AND BRADNINCH DISTRICT.

A full account of the geology of this district will be found in the Memoirs of the Geological Survey, Exeter district, by W. A. E. Ussher. In the Silvertown and Bradninch district the

gravels occupy the higher grounds (400 to 850 feet) and are replaced by breccias in the lower grounds. Fossiliferous fragments occur, but are not so common as further north. They have been detected at Christ Cross, near Silverton (847 feet), and in the lane sections north-west of Bradninch. The species found included :—

Spirifer Verneuili, Murch.

Tentaculites conicus, F. A. Römer.

Rhynchonella Partridgiae, Whidb.

Crinoid remains.

A fragment of grit with *Spirifer Verneuili* was found in the section by the Tiverton-Exeter Road, south of Jenny's Portion.

The last patch of gravel mantles the slopes of the large Culm inlier at White Down Copse, in the parish of Broad Clyst; and here, 15 miles in a straight line from the outcrop of the Pilton Beds, fragments of grit with Pilton fossils occur. They were found in the lane section east of Frogmore, and in another section still further to the east. The species found included *Rhynchonella Partridgiae*, Whidb., *Otenodonta lirata*, Phil., sp., and Crinoids.

5. THORVERTON DISTRICT.

The following note appears in the Geological Memoir of the Exeter District (p. 7):—"South of Cadbury, between the streamlets near Kidlake (West Bowley on the old series map), amongst numerous fragments of brown grit scattered over the surface one containing casts resembling *Strophomena* was picked up. The stones, although unworn, may be mixed with débris resulting from the denudation of lower New Red rocks."

Fragments with Upper Devonian fossils are fairly common in the road sections and ploughed fields north of Thorverton. They contain the usual fossils, *Spirifer Verneuili*, Murch., and *Rhynchonella Partridgiae*, Whidb., being the most common. Further west, between Thorverton and Crediton, the gravels are replaced by breccias composed largely of trap. No fossiliferous pieces have been detected in this direction.

SUMMARY AND CONCLUSIONS.

The New Red gravels of the Tiverton type extend from Warbrights-leigh and Chimney Down on the north to Thorverton and White Down Copse on the south. Further south they are replaced by breccias and sandstones or covered by the higher beds of the New Red series. Throughout the whole of this area of nearly 100 square miles the gravels contain fragments of sandstone and grit with Upper Devonian fossils. These Devonian fragments are most common in the north-east of the district, and are comparatively rare further south. They are found at the entrance of the Crediton valley, but do not appear to be present further west.

All the fossils that have been identified are known to occur in the Pilton and Marwood Beds of North Devon. The only Trilobite found (*Phacops latifrons*, Bronn) is practically the only Trilobite occurring in the Pilton Beds, where it is very common. *Spirifer Verneuili*, Murch., *Spirifer Urii*, Flem., *Rhynchonella* (*Camarotoechia*) *Partridgiae*, Whidb., and *Productus praelongus*, Sowerby, are the commonest Brachiopods both in the gravels and in the Pilton Beds. The little

Gastropod *Euomphalus vermis*, Whidd., is also common in the gravels and Pilton Beds. *Bellerophon subglobatus*, M'Coy, is a characteristic fossil in the Marwood Beds of the Barnstaple district; it is also common in the grits that occur further east near Wiveliscombe, and in the grit fragments found in the gravels.

At Chimney Down, in the north-east of the district, fossiliferous fragments of Upper Devonian sandstone and grit are extremely common, whilst trap fragments appear to be absent. This fact, as well as the wide distribution of the fossiliferous fragments, completely disposes of the Rev. W. Downes' theory of volcanic ejection. The facts tend, rather, to prove a drift from the north-east during the period of deposition of the gravels. The grit and sandstone matrices suggest a derivation from the Wiveliscombe end of the Pilton Beds rather than from the more slaty beds found further west. The Devonian fragments in the gravels may even have been derived from a still more easterly extension of the Pilton Beds, now buried under Triassic deposits.

The angular and subangular nature of the fragments composing the gravels, as well as the non-separation of coarse and fine material, gives the impression that the component fragments have not travelled far, and yet at White Down Copse they are found at least 15 miles from the outcrop of the Pilton Beds. The fossiliferous pebbles found at White Down Copse were all subangular. These New Red deposits certainly bear a considerable resemblance to the Boulder-clays, but in the absence of striated pebbles (and none have yet been found) the theory that they are glacial deposits is hardly admissible.

Mr. Ussher regards the gravels as the result of torrential action periodically operating on the margin of an area of depression attended by periodic dessication and wind-drift. This supposition is in accordance with our present views of the climate of England in Permian and Triassic times, and would explain the coarse unstratified nature of the deposits. The derivation from the north-east is natural on this supposition, but difficult to explain on any other theory such as that of marine agency. For the New Red rocks are overlapped on the margin of the Middle Devonian rocks near Williton, and thence to Porlock Triassic rocks alone represent the series. Hence, on the marine derivation theory a drift from the north is highly improbable, and we would have to suppose drift from the east where the extension of Devonian rocks may be expected to occur beneath the New Red rocks. The theory of torrential derivation from the north-east is therefore most probable and is consistent with the appearance of the deposits. These torrents carried the fragments as far as the entrance of the Crediton valley, where they were met by other torrents bringing down fragments of trap from the upper parts of this valley. The fact that the Devonian fragments are apparently absent to the west of Thorverton and that the gravels are replaced by a breccia composed largely of trap is thus explained.

The author's best thanks are due to Mr. J. T. Underhill for proposing the investigation and to Mr. W. A. E. Ussher for some of the above suggestions.