The submarine portion of the tunnel would be 22 miles, with four miles of approaches on either side, the English approach starting from the western end of Abbott's Cliff tunnel, from which half a mile of heading has been driven.

The gradient would be 1 in 80 towards Dover and the centre of the Channel until a depth of 150 feet below the bottom of the sea is reached, after which it would be driven approximately level, rising slightly towards the centre to throw off the water on either side should it be met with. The tunnel would be lined with cement made with grey chalk derived from the tunnel itself, mixed with pebbles from Dungeness.

The new heading in the chalk at Shakespeare's Cliff for the proposed Channel tunnel has now been carried a quarter of a mile, and is being carried on at an average of 36 feet per day, 80 men being in all employed in two shifts, and a third more will shortly be employed. The excavations are now many yards under the sea in the direction of the Admiralty Pier at Dover; the workings are quite dry, the springs which caused so much delay in the former experimental heading at Abbot's Cliff being absent. The present rate of working, if carried on at both ends, would give eight years for completion of the tunnel and connection with the railway systems of France, which would be reduced by working 24 hours a day.

2. DESCRIPTION OF A SECTION ACROSS THE RIVER SEVERN BASED UPON THE BORINGS AND EXCAVATIONS MADE FOR THE SEVERN TUNNEL.

BY EVAN D. JONES,* of Severn Flint Works.

The portion of the Severn Basin here described is entirely hidden beneath a considerable depth of Alluvium at one end, and forms the bed of the Estuary at the other. Until the borings and excavations for a tunnel underneath the river were recently carried out, but little was known of it.

The new section by which this is illustrated is seven miles in length, between Almondsbury Hill, in Gloucestershire, and the banks of the river, in Monmouthshire. At its western extremity it lies beneath the river, which is here $2\frac{1}{4}$ miles wide, and at its

* I am indebted to Charles Richardson, Esq., C.E., Engineer of the Severn Tunnel Works, for his kind permission to use the information contained in the documents and sections in his office.

eastern end beneath the alluvial flats, which have here a width of $3\frac{1}{2}$ miles.

The tunnel now being constructed runs under the river and a portion of the alluvium along the line of section. Its position is indicated in Figs. 2 and 3. A great many borings were put down along its whole length, several shafts sunk and headings driven all the way under the river, with the exception of about 130 yards near the English shore. Other headings have also been driven along the land portion of the tunnel from each of the shafts, affording information from which a geological section across the whole width of the Severn Basin can be constructed.

At high water the whole of the $2\frac{1}{4}$ miles forming the bed of the river here are covered, there being a depth of water at the shallowest place of 24 feet at spring tides, and of 13 feet at neap tides; but at low water the rocks over the greater part of this distance are exposed, those on the English side stretching out for $1\frac{1}{2}$ miles, with the exception of a narrow strip of water left by the tide, about 150 yards wide, immediately adjoining the English shore. These rocks are called the English Stones, and are composed of New Red Sandstone. On the Welsh side also the rocks of the bed of the river are exposed at low water, and have, as on the English side, a strip of water separating them from the shore. The low water rocks on this side are called the Lady Bench and the Lower Bench. Between these rocks and the English stones is the actual river channel, called the "Shoots," through which the whole of the water runs at low tide. This channel is 450 yards wide at the top, and 280 at the bottom, with a depth of from 50 to 55 feet, and the slopes of its sides are very steep, that nearest the Welsh shore, where the curve is convex, being almost perpendicular. The course of the river is shown on the map (Fig. 2), where it will be seen that after leaving the "Shoots" the deep water channel runs towards the English shore, forming at Avonmouth the deep water anchorage of Kingroad. The "Shoots" and the rocks on either side are shown in section in Fig. 3, and it will be observed how deep and narrow the "Shoots" are when compared with the whole bed of the river.

From some thousands of soundings which were taken near this section and in other places, under the direction of Mr. Richardson, the deeper parts of the floor were found to be comparatively level, and a boring put down on its eastern edge proves that very nearly the whole of the rock through which it passes is Pennant Grit

Fig. 2. MAP OF SEVERN BASIN & ADJOINING COUNTRY.
Scale 2 Miles = 1 inch.

Fig. 4. SECTIONS OF SHAFTS.

Scale 50 Feet = 1 inch.

Fig. 3.

SECTION FROM ALMONDSBURY TO PORTSKEWET.

Horizontal Scale 1000 yds = 1 inch

Vertical " 100 " = 1 "

of the very hardest description, with a few feet of New Red Sandstone on the top.

Two theories have been advanced to account for the formation of this channel. The first, advocated by the late Mr. Stoddart, asserts it to be an ancient fissure which existed here prior to the time when the river commenced to run; the second, advocated by Mr. Richardson, attributes its existence solely to the action of the river itself, which, by the wear and tear of ages, has worn it away to its present dimensions, and is still engaged in widening and deepening it.

If the first theory had been correct, the strata on either side would have been found to incline in opposite directions from the axis of upheaval, and we should have also expected to find the bottom of the fissure filled up with debris; but on the contrary, in driving the heading underneath the channel, solid, compact Pennant Grit occurred, dipping regularly in one direction, without any evidence of dislocation.

In support of the denudation origin of the channel, it may be stated that the current here possesses extraordinary power, having on some occasions a speed exceeding 12 miles an hour. Large quantities of pebbles and gravel are carried backwards and forwards by it during spring tides. The following instances may be cited:—

1. When the piers for the Bristol and South Wales Union Railway were being built excavations had to be made in order to receive the brickwork footings; the excavations had to be made during the low water of one tide, and the brickwork put in during the low water of the next, and it was found that during the one flow which intervened the holes had become full of pebbles and gravel.

2. The fishermen here, who are in the habit of making holes in the rock to receive poles for fastening their nets to, find that if these holes are left for a few tides, before putting the poles in, they become so completely choked with pebbles and gravel, which are jammed in so tight, that they sometimes find it easier to dig new holes than to reopen the old ones.

3. In driving underneath the English Stones, about half-way along, a fissure was met with which can also be traced on the surface of the Stones, and although it was about two feet wide, the pebbles and gravel had so effectually choked it up that not a drop of river water came from above into the heading.

It must be remembered that these effects are to be seen above low water mark, and near the shore, where the current is but weak compared with that in the "Shoots," along the bottom of which the great bulk of the gravel must be rolled.

Owing to the curved form of the channel, the current acts with much greater force upon the Welsh side of the "Shoots," which is consequently worn steeper and deeper than the other, as is clearly shown in section (Fig. 3).*

The fact of the low water channel being so narrow here, and the rock so strong, render this place the best possible for crossing the river by means of a tunnel, as only a quarter of a mile will thus be constantly under water.

Altogether 10 shafts have been sunk for the construction of the works, 3 on the English side and 7 on the Welsh; but it will only be necessary to describe six of these, as the remaining four are sunk respectively alongside of Nos. 3, 4, and 5, one each side of Nos. 3 and 5 and two by the side of No. 4.

The direction of the line in which the headings have been driven is given in plan on Fig. 2, being represented by the thick dotted lines from A to C, which is the total length of the tunnel. It is shown in section by the dotted lines on Fig. 3.

The positions of the shafts are also indicated on these two figures. Fig. 4 shows a section of each of the six shafts driven in the line of the tunnel; they are arranged in order, and at their respective levels above a given datum.

Shaft No. 1 is about two miles in shore on the Welsh side, and is wholly in the New Red Sandstone. It is 75 feet deep. No. 2

* The following extract from a paper read by Mr. Richardson before the British Association at their Bristol meeting in 1875 places this matter in a very clear light:—

"It has only to be conceived that at the time when the Severn first began to run down this way, and before the banks or cliffs on each side had been worn back, the surface of the ground was undulating, as it is elsewhere. The river waters would, of course, follow the lowest natural channel that was to be found, and in this case that channel may have been narrow, and in the place where the "Shoots" are now found. The rise and fall of the tide being then, as now, very great, it would roll up and down this channel large quantities of gravel, and this gravel would gradually and constantly deepen the channel along the deeper parts of the course of the stream, so that, as the river was gradually widened by the action of the water alone on the sides, this original channel would still continue to be the deepest, and consequently the main pathway of the water-driven pebbles. . . . The rate of wear must, however, have been very slow, for the hard rock has only been worn down to a depth of about 70 feet since the time when the river first ran this way; a rate of it may be less than a foot in ten thousand years.'

is sunk through the Marshland at Caldicott, one mile in shore from the Welsh Bank; one half of it is in Severn Alluvium, consisting of Blue Clay, and the other half in the New Red Sandstone. This shaft is 100 feet deep.* Shafts Nos. 3 and 4 will be fully dealt with further on. No. 5 is sunk immediately behind the Sea Wall on the English Bank of the river. It is 70 feet deep; the first 15 feet are in Alluvium, consisting of 12 feet of Blue Clay and 3 feet of gravel. The remaining 55 feet are in the New Red Sandstone. No. 6 is half a mile in shore from No. 5, and is entirely in Severn Alluvium. It is 45 feet deep, and the top of the New Red is immediately underneath. The first 30 feet of this shaft are in Blue Clay, containing two layers of Peat, each about two feet thick. A bed of gravel, 15 feet thick, formed the remainder of the shaft. It is stated by some of the inhabitants of this Marsh that the land is slowly sinking. If such is the case, it is probably due to the existence of these two layers of peat, which, under the weight of the overlying Clay, are gradually being compressed.

The high water of spring tides rises above the level of these Flat Marshlands, which has rendered it necessary to protect them by means of a sea-wall. Before this wall was built, some 45 years ago, the land was continually being flooded, but since its erection, which enabled the land to be properly drained and cultivated, the soil is considered to be one of the richest in the district.

Returning to Shaft No. 4, sunk at Sudbrook Point, on the Welsh Bank of the river, and 200 feet deep, the order of the strata is as follows:—Under the top soil was a thin bed of gravel, then a six feet bed of fine sand, and the remainder, to a depth of 85 feet, was New Red Sandstone, consisting of 13 feet of Yellow Sandstone, and 65 feet of very hard Marl. Three springs of water, yielding about 12,000, 27,000, and 15,000 gallons an hour respectively, were tapped in sinking through the Marl. Under the Marl came a bed of Dolomitic Conglomerate, four feet thick, of

* Several fresh water and marine shells were found in this Alluvium. The following is a list of those obtained at a depth of 39 feet below the surface, named by Professor Sollas, of University College, Bristol:—

<i>Scrobicularia piperata</i>	<i>Cardium edule</i> (not distorted)
<i>Lyneea peregra</i>	<i>Planorbis glaber</i>
" <i>auricularia</i>	<i>Hydrobia marginata</i> ?

Specimens of some of these are preserved in the Bristol Museum.

Prof. Sollas also kindly examined a specimen of the Alluvium itself, which was found to contain—

Diatoms; grains of quartz; entomostraca (cypris, &c.); seeds and leaves of plants, especially of chara; sponge spicules (spongilla).

the same character as a thick bed of Conglomerate on the beach by the Portskewet Pier of the Bristol and South Wales Union Railway, and known locally as the "black rock."

This Conglomerate is also exposed for a distance of 300 feet at low water on the western edge of the "Shoots." From the frequency with which it has been met with in sinking in various places, and the number of places in which it is exposed along the beach, and at low water on the bed of the river, it appears to extend over a considerable area in this district, and possesses such prominent characters that it deserves to be particularly noticed. Its thickness varies considerably, being in some places as much as 28 feet, whilst in others it thins out to a mere strip, disappearing in some places altogether.

In sinking two shafts (represented by No. 3 in section, Fig. 4) about a quarter of a mile in shore from the one under notice, and which are only 45 feet apart from centre to centre, it was also met with, being in the one shaft 28 feet thick, and in the other 24 feet. In the latter it was divided through its whole depth by a joint about six inches wide, through which a large quantity of water kept constantly gushing in, whilst in the adjoining shaft it was perfectly compact and dry, and was so hard that the rate of sinking through it averaged only $1\frac{1}{2}$ feet per day. The bed consists of limestone pebbles imbedded in a very hard reddish matrix, and in situ presents a very massive and solid appearance. Many of the pebbles are two feet in diameter, others not more than half an inch, and there are all sizes between. They vary considerably in form, some being more or less spherical, some oval, a few conical or egg-shaped; some have two flattened faces, others only one. One was nearly a perfect cone, rounded almost as regularly and smoothly as if by the hands of a lapidary, its length being 18 inches, and its greatest breadth nine inches. A portion of one of these pebbles, on being treated with dilute nitric acid, dissolved very slowly, and yielded a residue of microscopic crystals of dolomite, hæmatite, tourmaline, and quartz.

It was observed by Prof. Sollas* that most of the pebbles are marked by very characteristic striæ. These striæ are mostly about half an inch in length, commencing with a mere scratch, gradually deepening into a rut, and terminating in a little round pit, giving them much the form of a comet; they occur generally only on one

* "Geol. Mag.," February, 1882.

face of the pebble, and have their deeper ends all pointing in the same direction. Judging from the large quantity of quartz which the matrix has been found to contain, there must have been a considerable quantity of this mineral near at hand, and its crystals may probably have been the instruments employed in scratching the pebbles. But whether this be so or not, it is evident from the form of the markings, the gradual deepening of the ruts, and the character of their terminations, that the action took place when the pebbles were in motion, and that this motion was one which took place under great pressure. Further evidence of pressure is afforded by some of the larger pebbles, on which smaller ones adhere so firmly without any obvious cementing matter that it requires a hard blow from a hammer to separate them, and it is then found that they had penetrated in some cases about $\frac{1}{16}$ inch into the larger pebbles, leaving, when removed, a very decided impression of their form.*

The Coal Measures were entered under the Triassic Conglomerate, and the information on this point, afforded by the excavations for the Severn Tunnel, is that to which the greatest interest attaches. The Pennant Grit passed through, under the Conglomerate in this Shaft, had a vertical thickness of 19 feet, dipping towards the centre of the river, or a few degrees S. of E. at about 1 in 12, its upper surface here forming the plain of denudation upon which the Trias has been deposited. Beneath the Grit were 35 feet of the Lower Coal Measures, dipping in the same direction, 25 feet consisting of Clay Shales, and 10 feet of Coal Shales, separated by a 2-inch seam of coal. These rested on Millstone Grit, 11 feet thick, under which were interlaminated beds of Firestone and Shale, about six feet thick. Under the Shale came a remarkable bed made up of lumps of Mountain Limestone, with angular corners, imbedded in Shale, 14 feet in thickness; the lumps varied in size from small pieces to blocks as large as a wheelbarrow. The remaining 26 feet of the shaft penetrated a very hard, close-grained red firestone, or ironstone (as it was called by the miners), occurring in regular beds from 6 to 12 inches thick, separated by layers of hard fireclay about an inch in thickness.

From this Shaft two headings have been driven under the river,

* Prof. Hughes, in a paper read before the Geol. and Polytechnic Soc. of the W. Riding, Yorks (July 17th, 1867), has suggested that the striæ on the pebbles of Old Red Sandstone may have been formed in a similar way to that described by Prof. Sollas in the case of these Triassic Stones, and not, as Prof. Ramsay suggested, by glacial action.

a lower one commencing at the bottom of the Shaft, and an upper one 40 feet from the bottom, the former being continuous, and nearly two miles long.

The upper heading begins in the Millstone Grit, and the floor of the heading continues in it for 50 yards, but the roof passes into the Coal Shales at a distance of 10 yards. The length of Coal Shales passed through was 20 yards, and it was followed by the Shales for a length of 110 yards, when the Pennant was entered.

In the lower heading the same kind of rock that occurred at the bottom of the shaft was found for a distance of 40 yards, when the limestone blocks in shale were reached. The limestone was here continued for 90 yards, occurring first in strips about three feet thick (of which there were six interlaminated with shales), but becoming more massive towards the end, where a block about 12 yards thick at the bottom and tapering away to a point at the top was met with, which appeared to be but a projection of the limestone underneath into the overlying shales.

The next 40 yards were in the bed of shale which was found under the Millstone Grit in the shaft, and were followed by 40 yards of Millstone Grit, 30 yards of Coal Shales, and 70 yards of Clay Shales, the two latter representing the Lower Coal Measures. Resting upon these, the Pennant was again entered. It extended in one solid mass (with the exception of a few beds of interlaminated clay shales) for nearly a mile, carrying the heading about 500 yards beyond the Shoots channel. A considerable quantity of water was met with in various places in driving through it, about 150,000 gallons an hour altogether. The Upper Coal Measures were next entered, and were found to consist mainly of hard Clay Shales. In the portion immediately overlying the Pennant two seams of good hard coal were struck, one 15 inches and the other 10 inches in thickness. Some thin beds of Pennant were also found in this shale. The heading continued in these Upper Coal Measures for about 400 yards, when a sudden change took place, and the New Red Sandstone, which is here faulted down against the Coal Measures, was entered. Near to the fault, which is about half-way across the river, the strata were very much distorted, and no regular bedding was found for some distance. The rock contained veins of iron ore, and was perforated here and there by small pot-holes.

About 50 yards from the fault in the New Red Sandstone, a fissure was met with just large enough to admit of a man pushing

himself in. It can be traced at low water on the bed of the river immediately above, having a S.W. direction. The whole of the remainder of the heading driven in this direction, as well as that driven to meet it from the English side, is in the New Red Sandstone; and with the exception of that driven East from No. 3, which is in the Lower Coal Measures and Millstone Grit, all the headings which have been driven East and West from the other shafts, are in the same formation, and possess no features worthy of notice.

Shaft No. 3 is 150 feet deep, and goes down to the Lower Coal Measures only; the strata passed through correspond in order to No. 4, but, as stated above, the Conglomerate is here 28 feet thick, whilst the vertical thickness of the Pennant is only four feet.

Appended is a tabular list of the strata passed through in Shafts Nos. 3 and 4, and the heading from the latter driven East, which are the most important parts of the work geologically considered:—

SHAFT No. 3.				FT.
Trias.	{	Fine Sand and Gravel		18
		Yellow Sandstone		12
		Red Marl (very hard)		68
		Dolomitic Conglomerate		28
Carboniferous.	{	Pennant Grit		4
		Lower Coal Measures (Clay and Coal-		
		Shales Mixed)		20
				150
SHAFT No. 4.				FT.
Trias.	{	Fine Sand and Gravel		7
		Yellow Sandstone		13
		Red Marl (very hard)		65
		Dolomitic Conglomerate		4
Carboniferous.	{	Pennant Grit		19
		Lower Coal Measures	{ Clay-Shales 25 } { Coal-Shales 10 }	35
		Millstone Grit		11
		Shales (very hard)		6
		Limestone and Shales		14
		Red Sandstone (hard and close-grained)		26
				200

BOTTOM HEADING (from Shaft No. 4).

		YDS.
Carboniferous.	Red Sandstone (same as in bottom of Shafts)	40
	Limestone and Shales	90
	Shales	40
	Millstone Grit	40
	YDS.	
Trias.	Lower Coal Measures { Coal-Shales 30 } { Clay-Shales 70 }	100
	Pennant Grit	1,600
	Upper Coal Measures (broken by Fault)...	400
(all beyond the Fault)		

The first feature to be noticed in connection with these excavations is the great variety of strata which have been met with, and their perfect geological sequence. This is shown in a striking manner in Shaft No. 4. This Shaft is only 200 feet deep; nevertheless, in sinking through that distance, the New Red Sandstone, Dolomitic Conglomerate, Pennant Grit, Lower Coal Measures, and Millstone Grit occurred within a vertical depth of 154 feet.

The vertical thickness of the Pennant Grit here is 19 feet, as stated, its dip averaging 4.75° , and its horizontal length 1,600 yards. Calculating from these data, its actual thickness may be stated as 400 feet, or less than a fourth of its average thickness in the Bristol Coal Fields; but the greatest anomaly is in the thickness of the Lower Coal Measures and the Millstone Grit, which here have an actual thickness of only 35 feet and 11 feet respectively, as against 2,000 and 1,000 feet in the Bristol Coal Fields.

In the Cutting near Portskewet station on the South Wales Railway, nearly half a mile to the North West of the shaft, the Mountain Limestone is exposed, coming very nearly to the surface, dipping E.S.E., or nearly in the direction of the Shaft, at an angle of about 5° . From this it would appear that the Limestone ought to be found at the Shaft at a depth of about 200 feet from the surface. Very nearly at this depth the peculiar lumps of Limestone in shale, and the interlaminated beds of Limestone and Shale, were found, which show that in all probability we are there on top of the Mountain Limestone.

NOTE.—The average dip of the Carboniferous beds, ascertained by observations taken in the Shafts and Headings, and by comparisons of the relative positions of the beds in the Shaft with those in the headings, is about 4.75° , corresponding to a fall of 1 in 12.

It may be mentioned, with regard to the bed of Millstone Grit, that the distinctive character of the rock would leave no doubt as to its identity, even if this could not be established independently by its position.

From the distinctive character of the rocks, together with the regular sequence in which they occur, and the proximity of the outcrop of the Mountain Limestone in the vicinity, we are led to believe that the Lower Coal Measures and Millstone Grit thin out in this district to a mere strip, notwithstanding that they attain greater thickness in the Bristol Coal Fields.

We know precisely where the bottom of the Pennant is; we have every reason to believe that 50 feet lower down we are on the top of the Mountain Limestone, so that the Lower Coal Measures and Millstone Grit must be wholly contained in the intervening space.

The mixed beds of Shale, Limestone, and Sandstone which occur at the bottom of Shaft No. 4, and probably also for a short distance lower down, might be added to the Millstone Grit, thus increasing the thickness of the series to that extent, but as thin beds of Millstone Grit are usually found among the top beds of the Upper Limestone Shales, I have included this portion of the shaft in the Limestone series.

As far as can be ascertained, the actual thicknesses of the strata on the Western Side of the River Severn are as follows:—

	FT.
Trias 	85
Upper Coal Measures (unknown) ...	—
Pennant Grit 	400
Lower Coal Measures 	35
Millstone Grit 	11

These excavations give a considerable amount of information concerning the Coal Field known to exist under the Severn and adjoining Flats. The existence of this Coal Field was first proved by Mr. Richardson, C.E., 20 years ago, when constructing the Bristol and South Wales Union Railway. At that time about 50 tons of coal were obtained immediately beneath the surface from the excavations for the Calybrook Brick Works, and when tested the coal was found to be of exceedingly good quality, considering it was found so near the surface. It had many of

the qualities of the best coal, and was remarkably free from dust.

The width of the Coal Field in the district under notice is $5\frac{1}{2}$ miles, but it probably widens out considerably further south, passing under the alluvium around Avonmouth and Portishead, and terminating somewhere near the latter place ; but nothing definite can be stated as to its actual limits at either this or at its northern end.

About two or three miles north of a line drawn from Portskewet to Almondsbury the Old Red Sandstone crops up on both sides at some little distance from the banks of the river, but gradually gets nearer further North, until, at a point 12 miles up, it completely hems in this portion of the Severn Basin, the river channel being there cut entirely through the Old Red. It is evident then that it cannot extend to the north much beyond Aust Cliff, where the masses of Mountain Limestone on both sides of the river must nearly approach each other.

VISIT TO THE BRITISH MUSEUM (SOUTH KENSINGTON).

SATURDAY, MARCH 11TH.

Director—T. FLETCHER, Esq., M.A., F.G.S., Keeper of the Mineralogical Collection.

DEMONSTRATION ON THE COLLECTION OF METEORITES.

The Director, before proceeding to indicate any particular specimens of Meteorites, gave a short sketch of the history of the subject, dwelling especially upon the reluctance even of scientific men, down to the latter part of the last century, to admit that these bodies had an extra terrestrial origin. The connection between "sky stones" and "fire balls" was ultimately established about the end of the last, or commencement of the present century. Since then many falls have been observed, and the phenomena carefully investigated. Meteorites fall at all times of the day and night, at all seasons of the year, and favour no particular latitudes ; moreover, they are quite independent of the weather. The origin of these foreign bodies is not yet clear, and many speculations have been hazarded, such as that they come from the volcanoes of the moon,