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The Geology of the Thames Valley near Goring.

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Some apology is due for addressing an Archaeological Society on a geological subject. Yet the story of the development of the hills, coombes and rivers with which our excursions have made us familiar is one of much interest. Goring occupies a central position in the range of chalk-hills which extends from Yorkshire to Devon. Whether as Wolds in Yorkshire and Lincolnshire, as the Chiltern Hills in Buckinghamshire and Oxfordshire, as Downs in Berkshire, or again as the great cliffs of Flamborough and Beer Heads, this chalk makes a dominant feature in the landscape, and throughout its range forms high ground overlooking a low undulating plain to the west. To anyone ignorant of the river-system of England, it would seem obvious that the rain falling on this plain would find its easiest exit to the sea along the low ground. So far from this being the case, the rivers all flow from the low ground directly at and across the chalk-range, crossing it by deeply-cut defiles. Thus the Ouse, Aire and Trent, combining to form the Humber, cross it at Hull. The Witham, Welland and Great Ouse make their exit by the broad gap in it known as the Wash. The Thames traverses it by the defile, so well known to us, between Goring and Reading. The stream of the Vale of Wardour, the Avon and the Stour make their way down to Christchurch. The same apparent perversity is observable in the Medway, Mole and

Wey in relation to the North Downs, and by the Ouse, Adur and Arun in their passage of the South Downs.

In seeking for an explanation of this behaviour, we must enquire more closely into the geological structure and history of the chalk-range. If we ascend it where its features are characteristically developed, we find that it presents its steeper face towards the West. Broad gently undulating slopes lead up to bolder shoulders, and these again are succeeded by a still steeper, more or less continuous brow. These features are easily seen to be due to the fact that the range is, in fact, the outcropping edge of a great sheet of chalk dipping gently eastwards, consisting in its lower part of soft marly chalk (the Lower Chalk), in its middle part of more massive chalk (the Middle Chalk), and its upper part of the tougher and more resistent Upper Chalk with flints, forming the brow. Continuing our traverse we descend long gentle slopes, intersected by numerous coombes, and gradually merging into the low ground east of the chalk-range. Our downs therefore present the characteristic features of a chalk-escarpment facing generally westwards and with long dip-slopes leading down eastwards. The total thickness of chalk in this neighbourhood ranges from about 600 to 800 feet.

Closer examination of the dip-slopes shows the existence here and there of patches of sand. These patches become larger and more frequent until they merge into a continuous outcrop near Reading. The sands, easily recognised by the fact that they are associated with clays of crimson and other bright colours, are known as the Woolwich and Reading Beds. They are about 80 feet thick, and pass eastwards under the London Clay, a watertight formation about 200 feet thick, which has proved so eminently suited for the making of tube railways under London. Upon the London Clay rests the Bagshot Sands, of which we have an example in Bucklebury Common. These three sub-divisions form the lower part of the Tertiary Beds. The chalk-floor upon which they rest descends from a height of about 550 feet above the sea near Streatley to the level of the river (about 110 feet above the sea) near Reading, indicating a general slope of about 1 in 68 or rather less than 1°.

So much for the form of the escarpment. Every feature in it reflects the character of the outcropping strata so faithfully that a trained observer would be rarely at a loss to say upon what subdivision of the chalk he was standing at any point. Owing to the gentle angle at which the chalk rises we have to travel some miles westwards before the base comes up to the surface. At Wittenham Clumps the base rises above the level of the river and the strata below the chalk come into sight.

The chalk itself is obviously a deposit which has been laid down in a sea. It contains an abundance of fossils all of purely marine shells, and is partly made up of microscopic marine organisms, but largely of amorphous calcareous sediment with segregations of silica (flints). The chalk-sea, therefore, though not necessarily deep, must have been clear and free from mud, sand and pebbles. The chalk presents these characters, not only throughout its range across England, but in the face of the escarpment itself. We find in it no indications of the neighbourhood of a shore. Evidently the limits of the chalk as they exist now are not the original limits of the deposit. Indeed, we have to travel far westwards and northwards into Ireland and the western isles of Scotland before we get evidence of a shore-line of the chalk-sea. We may, then, confidently assume that the chalk once extended continuously many miles westwards of the present chalk-escarpment, that is, over the area drained by the rivers we are considering.

At the close of the chalk period the area now occupied by the south and east of England was slightly tilted in the west, and in that direction the recently deposited chalk was raised above sea-level and, of course, subjected to erosion by rain, rivers, &c. (subaerial denudation). It was thus removed from this westernmost area before the Tertiary sea overspread it, and it is in this that we find an explanation of the fact that the Tertiary Beds in their westernmost extensions begin to contain fragments of rocks which lie far below the chalk in geological sequence. In technical language they overstepped the chalk. How far they extended is not known, but it is observable that towards their present westerly limits the Woolwich and Reading Beds and the London Clay contain shingle-beds in increasing abundance, with other indications of the immediate neighbourhood of a coast. Eventually the whole region received a fresh tilt in the west, and the physical features of the south and east of England, as we know them, began to take shape, for upon the slope of Tertiary Beds the river-system, with its general tendency to take an eastward direction, was initiated. The first step was the removal of the Tertiary blanket in the more elevated western regions. This revealed the soft strata below the chalk and the truncated edge of the chalk which the Tertiary Beds had overstepped and buried. For the rest the story is one of ordinary river-erosion. As the rivers deepened their valleys the development of their upper tributaries and the degradation of the soft strata upon which they flowed proceeded *pari passu,* and as this degradation proceeded the chalk-escarpment came more and more into relief, each part of the valleys presenting the features characteristic of the geological formations through which it has been cut. Herein, then, lies an explanation of the course pursued by the Thames in gathering its upper waters in the low-lying Oxford plain and in traversing the chalk-escarpment by the defile at Goring.

This theory receives confirmation from some further details in the river-system of south-eastern England. The inclined plane of Tertiary Beds was diversified during its uplift by some minor folds. Thus it sagged into a trough (or syncline) extending from Newbury past London and known as the London Basin. South of this it was raised into an arch (or anticline) which traverses Kent and Sussex, and is known as the Wealden anticline. South of this, again, it sagged into the trough known as the Hampshire Basin, and lastly it rose into an arch which traverses the Isle of Purbeck and part of which survives in the south of the Isle of Wight. We have, then, two troughs and two arches, produced by unequal elevation, in our inclined plane of Tertiary Beds. By the theory of the origin of the river-system which I have outlined, these folds should have affected the courses taken by the rivers. A glance at the map shows that they completely controlled them. Thus the London trough is followed from end to end by the Kennet and by the Thames below the junction of the two. The Hampshire trough is followed similarly by the Frome. Into each of these rivers flowed tributaries from the intervening arched up areas, and in every case the same story of the developmnt of a chalk-escarpment is manifested. Thus the North Downs and South Downs were brought into relief by the erosion of the soft strata which rise from beneath the chalk in the Wealden anticline. This erosion was rendered possible by the deepening of defiles through the chalk escarpment, by the Medway, Mole and Wey through the North Downs; by the Ouse, Adur and Arun through the South Downs.

Of the anticline which traverses the southern part of the Isle of Wight and the Isle of Purbeck, a part only has survived the inroads of the sea. The original course pursued by the Frome along the Solent and Spithead has been converted into an arm of the sea. Two tributaries, rising on the Isle of Wight anticline, have been decapitated by erosion of the southern coast of the island, but their headwaters are still clearly recognisable. The lower parts of their courses survive in the two strips of low alluvial ground which threaten to divide the Isle of Wight into three, namely, the Eastern and Western Yar, broad valleys which now serve no purpose. Presumably the gap of sea between the Isles of Wight and Purbeck marks the site of other tributaries. Lastly, in the Isle of Purbeck we find the prettiest example of all, of the development of a breached escarpment. Two streams rising in the anticlinal area (now, of course, reduced to a low undulating tract) traverse the bold ridge of the chalk by two steep-sided defiles, having between them the hillock of chalk on which Corfe Castle was built. The complete indifference shown by these streams to the physical features of the ground as now presented to us brings home some conception of the vast changes which have been effected by denudation since those streams began to flow.

Returning to Goring and the Thames, it is interesting to find that the extra hard work that the river encountered in deepening its valley through the chalk can be detected by a close study of the gradients of the stream. A profile of the channel showing the diminishing gradient from source to tidal water, if drawn on a sufficiently exaggerated vertical scale, enables us to see that the gradient becomes rather too low as the river enters the chalk defile, and steepens again below the defile. I fancy that I can recognise in the character of the bed the effects of the change, though they are partly masked by the canalisation of the river. Certainly the punt-pole encounters a harder and more gravelly bottom below Goring Lock than above it, and it appears to be just where this harder part begins that the Icknield Way crossed and the Romans made a ford.

The effect of canalisation has been to divide the river into a series of reaches of very low gradient, and, as it might be supposed, to put a stop to erosion. This is far from being the case, for in times of flood the water is apt to ignore artificial restrictions. The middle of the main stream originally formed the County Boundary, but it no longer does so. The channel has shifted in many places since the boundary was fixed, and, as a fact, at Goring a piece of Oxfordshire lies now on the Berkshire side of the river. The shifting of the channel is partly due to the tendency of all rivers to meander. Meanders depend upon the gradient and size of the river. The lower the gradient the more will the stream meander, and the larger the volume of water the greater will be the amplitude of the meanders. At Goring the Thames hugs the right bank of its valley, but at Hart's Wood the left bank. At Pangbourne it has come back to the right side, but at Mapledurham it runs under the left bank. At Tilehurst it is once more on the right side, but at Caversham it returns to the left bank of the valley. Thus there are six meanders in a distance of about ten miles. In every case an accentuation of the slope of the side of the valley where the channel approaches it furnishes proof of the power of the river to transport material and widen its valley in recent geological times. I have frequently heard it remarked that the width of the flat bottom of the valley shows that the river was once far larger than it is now. But it will be seen that the width of the flat depends upon the amplitude of the meanders. The stream undercuts the convex bank of each curve, and deposits flood material on the concave side, with the result that the meanders travel down stream, much as undulations may be made to travel along a rope fixed at the far end. The flat bottom of the valley represents the strip along which meanders have travelled.

The cutting of the defile through the chalk range by the Thames has led to some interesting phenomena in the underground water. Practically all the rain that falls upon the chalk sinks into it. Coombes presenting the appearance of stream-eroded valleys are familiar features of our downs, but they contain no streams. The water sinks until it reaches a level at which the chalk is saturated, a level technicallly known as the 'Water Table.' All wells must be sunk into the water-table before they will yield a permanent supply. There is a great number of such wells on our downs, and observations on the permanent water-level in them makes it possible to determine the form of the water-table. The table, though ignoring coombes and minor undulations, shows a general tendency to rise under the highest parts of the downs. Thus it reaches a height above sea-level of more than 300 feet north of Nettlebed, where the downs reach a height of more than 700 feet. Again, north of Hampstead Norris it reaches 350 feet where the downs are 400 feet and upwards in height.

From these elevations the table slopes down towards the nearest points at which the water can escape in the form of springs. We will take first the great springs which break out in the banks of the Thames, such as those at Mongewell and North Stoke, and the smaller so-called medicinal spring at the Leather Bottel which once had a reputation as a cure for sore eyes. It is obvious that if the water-table kept at an elevation of 350 feet from Nettlebed to Hampstead Norris we should find the sides of the valley streaming with water, for wherever the surface of the ground and the water-table meet water must issue. As a fact, the water-table slopes gently from this elevation to the level of the river with a fairly steady gradient of about 30 to 40 feet in the mile. The Thames, in the process of excavating its valley, has provided exits at a level of about 130 feet above the sea, and thus led to a lowering of the water-table in its neighbourhood. Clearly, then, part of the rain that falls on the downs travels underground to escape by the springs along the Thames.

As a type of another class of spring we may take the copious issue at Blewbury which forms the Mill Brook running to Wallingford. This water is thrown out close to the base of the chalk. The impervious strata which lie below the chalk here rise to the surface, and the water from the chalk overflows their outcropping edges, as water overflows the edge of a tilted basin. The level of the water-table is here controlled by the level of the lowest points in the edge of the basin.

But if we transfer our attention to the other side of the downs we find quite a different state of affairs. The chalk here passes under a water-tight blanket of Tertiary Beds. No matter, therefore, how low the ground may fall and how much the theoretical position of the water-table may rise above it, the water cannot escape. These are the conditions necessary for artesian wells, and as a fact, borings through the Tertiary blanket into the chalk have tapped water which rises many feet above the surface. The same conditions prevail under London, where, however, the blanket is thicker. Some of the earliest borings tapped water in the chalk which rose with inconvenient violence, though long-continued pumping has greatly reduced this source. It will be seen that we have now found a third exit for the water in our downs, namely, up the pumps in London.

Lastly, we come to the bournes, a well-known phenomenon of chalk districts. A bourne is a chalk spring which begins to flow after prolonged wet weather, continues to flow for some weeks after the rain has ceased, and then dries up. The 'breaking' of a bourne generally attracts much popular attention. It is due to the general rise of the level of the water-table, through the underground channels of the springs being called upon to carry more water than they can accommodate. Of the many coombes in our downs, some are deep enough nearly to touch the water-table. Only a slight rise in the table therefore is necessary to bring it up to the surface and to cause an issue. Thus the uppermost reaches of the Pang valley are generally dry, but after a wet season becomes temporarily occupied by a running stream.